EFFECT OF USING PERIWINKLE SHELL AS A PARTIAL REPLACEMENT FOR COARSE AGGREGATE WITH ADMIXTURES

BY

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PLAGIARISM

This work **EFFECT OF USING PERIWINKLE SHELL AS A PARTAIL REPLACEMENT FOR COARSE AGGGREGATE WITH ADMIXTURES** IN BENIN CITY, EDO STATE, NIGERIA by IGHO, Favour Eguono with number ENG2006182 of the department of Civil Engineering, Faculty of Engineering, University of Benin city, Edo State, Nigeria, has PASSED the PLAGIARISM TEST

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DEDICATION

This work is dedicated to the Almighty God for His Goodness and Protection in my life and to my parents Mr. and Mrs. IGHO for their undying love, care and support in my life.

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ABSTRACT

The increasing demand for sustainable construction materials has prompted the exploration of alternative resources to conventional aggregates. This study investigated the effect of using periwinkle shells as a partial replacement for coarse aggregate in concrete, combined with chemical admixture.

The study utilized the following materials: cement, fine aggregate(sand), coarse aggregate (granite), water, and periwinkle shells. The method involved preparing concrete mixes with varying proportions (0%, 10%, 20%, 30%, and 40%) of granite replaced by periwinkle shells. Standard laboratory tests were carried out, these include: The physical properties of cement (consistency, initial and final setting time), aggregate (fineness modulus, silt content, moisture content, specific gravity, aggregate crushing value, and aggregate impact value test) and mechanical properties of the concrete produced (compressive strength, split tensile strength, flexural strength) at 7, 14 and 28 days curing period. Slump test and water absorption tests, were also assessed to evaluate the suitability of periwinkle shells as coarse aggregate substitutes.

The results showed that compressive strength decreased with increasing replacement but remained satisfactory at lower levels. At 28 days, the control mix achieved 20.85 N/mm^2, while 10% replacement recorded 19.56 N/mm^2, representing a 6% reduction but still retaining over 90% of the control strength. Similarly, split tensile strength reduced from 3.87 N/mm^2 (control) to 3.60 N/mm^2 (10%), and flexural strength decreased from 5.96 N/mm^2 to 4.13 N/mm^2 at 28 days. Water absorption increased slightly from 2.68% (control) to 3.04% at 10% replacement, remaining within acceptable durability limits. Based on these findings, the optimum replacement level is 10%, as it offers improved sustainability while maintaining structural adequacy and durability for practical applications.

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ACRONYMS

NWC - Normal weight concrete

LWC - Lightweight concrete

CTMP - Chemo thermo mechanical pulps

CSA - Coconut shell ash

PKSA - Palm kernel shell ash

OPC - Ordinary Portland cement

SCBA - Sugarcane bagasse ash

BGSA - Bambara groundnut shell ash

GHA - Groundnut husk ash

RHA - Rice husk ash

CHAPTER ONE

INTRODUCTION

1.1 Background of Study

The inflationary trend in Nigeria's economy has led to a significant increase in building material costs, to the point where many of the most popular building materials are no longer suitable for low-cost housing construction (Segun, 2024; Housing Cable, 2024). It is crucial to use locally sourced building materials and basic technologies to create long-lasting and reasonably priced building components. This will save foreign exchange and significantly increase job opportunities (Uwaegbulam, 2024), Researchers have therefore focused on employing naturally occurring elements as alternatives to traditional building materials to help lower construction costs (NBRRI, 2024). However, many engineers and researchers have found it challenging to discover and develop new materials based on renewable resources, given growing concerns over global pollution and the depletion of natural resources (Ahmed and Al Numan, 2023). The use of waste materials and industrial by-products in construction has become a major area of interest. For instance, in the production of lightweight concrete, several of these by-products such as plastic waste, rice husk ash, and wood waste are now being used as aggregates (Olabimtan et al., 2023).

The goal of using local materials to partially or completely replace expensive conventional building materials has been the focus of relentless efforts by materials science and engineering researchers (Olabimtan et al. 2023). Significant progress has been made in this area, and interest continues to grow due to the practical benefits of sustainable development, environmental protection, and reuse of waste materials (Ahmed and Al Numan, 2023). The building industry also benefits from reduced construction costs and the ability to produce a wide range of lightweight, eco-friendly structures (Uwaegbulam, 2024).

Concrete is used extensively in civil engineering practice and construction projects in Nigeria. As one of the primary building materials, concrete can be transported to construction sites in a plastic state and, due to its high workability, can be precast or moulded in-situ into various shapes and forms (Bashir et al., 2020). Its main ingredients include cement, fine aggregate (sand), coarse aggregate (granite), and water used to determine both its quality and production cost. As such, the availability and cost of these raw materials directly affect the overall cost of concrete (NBRRI, 2024). In contrast to normal weight concrete (NWC), which is commonly used for structural elements, lightweight concrete (LWC) is increasingly preferred for non-load bearing walls and non-structural flooring due to its lower cost and environmental advantages (Olabimtan et al., 2023). Consequently, the cost of producing concrete is somewhat decreased. Therefore, the study will use periwinkle shells as a partial substitute for coarse aggregate in order to examine the compressive strength of concrete (NWC).

Periwinkles (Nodilittorina radiata) are marine snails that belong to the Mollusca family. Their shells are typically mottled grey, white, and black, tapering into a rounded cone shape. Periwinkles inhabit the intertidal zone, living between high and low tide levels. Although they require proximity to the ocean and spend some time submerged, they prefer partial atmospheric exposure (Ekong et al., 2019). In the riverine regions of Nigeria, periwinkles are not only consumed as food but also valued for their shells. These shells have been found useful in various applications including soil stabilization, concrete production, poultry feed supplements, and decorative crafts (Alalade and Olafadehan, 2021).

People in coastal locations, like Nigeria's Rivers State, have been using periwinkle shells as a conglomerate in concrete reinforcement for more than 30 years. These shells have been utilised for a variety of projects, including road construction, slabs, soak-away, and dwellings. These shells were more than ten times less expensive than gravel (Neville, 2020).

Periwinkle shell has been investigated as a potential partial granite substitute for concrete projects (Adewuyi & Adegoke, 2018). The physical characteristics of periwinkle shell were examined in this study in relation to the specifications for lightweight concrete and coarse aggregate. Concrete cubes were made with different proportions of coarse aggregate to periwinkle. In order to identify the ideal percentage replacement that would not impact the compressive strength, their compressive strengths were ascertained and the outcomes were assessed. According to the results, concrete mixes containing 35.4% and 42.5% periwinkle still had strength values of 21 N/mm and 15 N/mm, or 1:2:4 and 1:3:6, respectively. Additionally, coarse aggregate containing 50% periwinkle shell can still be considered a normal weight aggregate.

Periwinkle shells are widely utilised as concrete ingredients because they are inexpensive compared to crushed stones (granites), hard, often light, and easily accessible in large quantities. They also mix well with cement and sand. The acceptability and effectiveness of these shells as coarse aggregates in concrete (NWC) have been the subject of relentless efforts both inside and outside of Nigeria. The shells are utilised as coarse aggregates for a single mix design and for varying proportions of periwinkle shells in the concrete, ranging from 0% to 50%. For 0%, 10%, 20%, 40%, and 50% periwinkle shell, six cubes are made each, and their compressive strengths are noted to determine their optimal use.

1.2 Statement of The Problem

Construction costs were extremely expensive due to the global economic downturn and current market inflationary trends in the component materials utilised for concrete constructions. The price of obtaining concrete ingredients has grown to be a significant concern for the average citizen of our country. Despite their easy accessibility, the value attributed to these constituent elements results in their increasing cost. The low-cost housing movement is waning over time because of the extremely rapid inflation of component materials.

Waste management is a major challenge for both developed and developing countries. In Nigeria, raw materials derived from industrial waste, agricultural waste, and other byproducts are among the main sources of waste. People disregard the concept of renewable energy, which is a huge issue in Nigeria, and this type of waste results from their lack of usage for these materials.

According to a case study, periwinkle shells are a major source of waste, particularly in Nigerian markets. Following their consumption as food, the shells are discovered hipped in the marketplace, where they obstruct drainage and cause erosion. Ignoring the fact that periwinkle shells might be a good structural component in concrete, they can become a very unpleasant waste during rainy seasons. Studying the structural role of periwinkle shells as concrete elements is crucial in light of this.

1.3 Aim and Objective of The Study

The aim of this study is to evaluate the effect of using periwinkle shells as a partial replacement for coarse aggregate in concrete with admixtures.

The specific objectives of the study are to:

1. Asses the physical properties of the materials used for the concrete production (i.e. cement, fine and coarse aggregates and periwinkle shell aggregates.

2. Evaluate the mechanical properties of the concrete combine with admixtures (compressive strength, tensile strength, flexural strength and slump test etc.).
3. Assess the durability characteristics of the modified concrete (such as water adsorption).

1.4 Scope of Study

The scope of the study will include:

1. Assessing the physical properties of materials used in the concrete production such as sieve analysis, specific gravity, bulk density, moisture content, aggregate impact value, silt content and setting time. These materials include cement, fine and coarse aggregates and periwinkle shell aggregates. Both processed and unprocessed periwinkle shells, source from Benin City, Edo state, will be used.
2. Evaluating the mechanical properties of the concrete combined with admixtures, including compressive strength, tensile strength, flexural strength and slump test.
3. Assessing the durability characteristics of the modified concrete, such as its water adsorption.

1.5 Justification of Study

The initiative will benefit resident engineers, construction companies, and locals after this study is finished. This study will specifically have a significant impact on the residents' search for more things that are deemed garbage and their use to appreciate nature's treasures. There will be no need to pollute the land in order to market periwinkle vendors because the shells of these periwinkles will be properly packaged and stored for sale.

Due to the impending granite sale, the demand for periwinkle shells will increase dramatically and the cost of creating concrete will decrease if the shells have the same compressive strength as a regular weight concrete made with granite.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

In relation to the project topic, which examines the compressive strength of concrete employing periwinkle shell as a partial replacement for granite, this chapter reviews the study works (including personal research), conclusions, and suggestions of certain researchers. It also highlights the usage of additional agricultural waste as a partial substitute for other concrete ingredients. This chapter also discusses several key points regarding concrete's compressive strength and factors that influence it.

2.2 Previous Work done on the Study

Cement, water, and fine and coarse aggregates are the standard constituents of concrete all around the world. After being let to cure in a mould or formwork, this slurry solidifies into stone-like hardness. The cement and water undergo a chemical reaction that results in hardening. After curing, the cement and fine and coarse particles form a link and become stronger. The mix's characteristics, the characteristics of its constituents, the compaction technique, and further controls during placement, curing, etc., all affect the conglomerate material's strength, durability, and other attributes.

Compared to standard weight concrete, all concretes constructed with lightweight aggregate show a higher moisture mobility (Neville, 2020). The two main types of aggregates typically utilized in the manufacture of concrete are fine and coarse aggregates. Typically composed of natural sand, fine aggregate is sorted from 5 mm particles to the smallest particles, omitting dust. In a typical building, coarse aggregate is defined as natural gravel or crushed stone that is typically greater than 5 mm and less than 16mm (Olufemi et al, 2019).

Large amounts of periwinkle shells have accumulated over time in several regions of the nation, including Bori, Western Ijaw, Burutu, Agoro, Ogalaga, and Lotugbene. The periwinkle is the source of periwinkle shells. Periwinkles are gastropods, or marine mollusks, having thick spiral shells. The growth pattern of gastropod shells is mathematically regular. As a result, they maintain their fundamental shape even as they grow larger. By continuously adding shell to the edge and coiling around a hypothetical axis that passes through the shell directly, the mollusk creates its spiral structure. The mollusk inside the resultant shell has a sturdy, little habitat. The Litorinae family is one of the main periwinkle families. They are abundantly dispersed over the littoral drifts and sand banks of North America and Europe. Tympanostomus spp. and Pachmellania spp. are the two main species found in the lagoon and mudflats of Nigeria's Niger Delta, which stretch from Badagry in the west to Calabar in the east (Dahunsi, 2023). People in coastal locations, like Nigeria's Rivers State, have been using periwinkle shells as a conglomerate in concrete reinforcement for more than 30 years. These shells have been utilized for a variety of projects, including road construction, slabs, soak-away, and dwellings. Compared to gravel, these shells were more than ten times less expensive (Neville, 2020).

Numerous experimental studies have been conducted to enhance the concrete's qualities by incorporating additional components, which could be synthetic, recycled, or natural. A study on the suitability of using periwinkle shell in place of river gravel in concrete was conducted by Olufemi et al. (2019). The study came to the conclusion that periwinkle shells can be utilized in place of certain river gravel in typical construction projects, particularly in areas where periwinkle shells are easily accessible and river gravel is scarce. Although many of these new materials are employed as aggregate in the creation of lightweight concrete, they can also be used as an additive or to replace cement or aggregate (Olufemi et al, 2019).

Natural rounded sands are better than crushed stone fines for all workable concrete, but for high crushing strength or flexural strength, concrete made with angular and rough or crystalline crushed rock, such as granite or carboniferous limestone, may prove advantageous (Murdock et al., 2021). Smooth round gravels are typically preferred for low and medium strength workable concrete.

Periwinkle shell was examined by Olufemi et al. (2019) as a potential partial substitute for river gravel, a coarse aggregate, in concrete. Comparing concrete cubes with periwinkle shells alone as coarse aggregate to those with other periwinkle: gravel qualities, the study found that the former were lighter and had lower compressive strengths. Periwinkle's 28-day density and compressive strength were 13.05N/mm^2 and 1944kg/m, respectively. The more river gravel added to the periwinkle concrete, the higher its density, workability, and compressive strength. According to the study's final findings, periwinkle shells can partially substitute river gravel in typical construction projects, particularly in areas where periwinkle shells are plentiful and river gravel is scarce.

A study on the characteristics of periwinkle-granite concrete was also conducted by Dahunsi (2023). Periwinkle shells have been found to be a suitable partial substitute for granite in typical construction projects, and the strength development of periwinkle-granite concrete is comparable to that of traditional granite concrete. Yang et al. (2021) investigated the effects of using oyster shell in place of fine particles on the properties of concrete. Concrete was made using crushed oyster shells, an industrial byproduct, in place of fine aggregate. According to the investigation, oyster shell did not lower the concrete's 28-day compressive strength. Additionally, it was shown that as the oyster shell substitution rate rose, compressive strength developed more quickly (Yang et al, 2021).

Periwinkle shell has been investigated as a potential partial granite substitute for concrete projects (Adewuyi & Adegoke, 2018). The physical characteristics of periwinkle shell were examined in this study in relation to the specifications for lightweight concrete and coarse aggregate. Concrete cubes with different proportions of coarse aggregate to periwinkle were made. In order to identify the ideal percentage replacement that would not compromise the compressive strength, their compressive strengths were ascertained and the outcomes were assessed. According to the results, concrete mixes containing 35.4% and 42.5% periwinkle still had strength values of $21N/mm^2$ and $15N/mm^2$, or 1:2:4 and 1:3:6, respectively. Additionally, coarse aggregate containing 50% periwinkle shell can still be considered a normal weight aggregate.

A byproduct of milling rice is rice husk ash. When paddy is milled, roughly 78% of it is received as bran, broken rice, and rice. The remaining 22% of the paddy's weight is made up of husk. During the fire process, the remaining 25% of the husk's weight is transformed into ash, also referred to as rice husk ash, while the remaining 75% is made up of organic volatile matter (Corotis, 2017). 10% is the ideal amount of rice husk ash to substitute in Portland cement (Bayuaji and Nuruddin, 2019).

Shathiskumar (2023) assessed the viability of palm frond ash and fly ash from rice husks for use in geopolymer cement. The study was split into five parts, which included collecting pertinent data, calculating the proportions of cement slurry, producing geopolymer cement, evaluating the compressive strength of geopolymer cement, and doing a final analysis of the findings. According to the final analysis of the results, increasing the curing time and the proportion of fly ash substitution increased the compressive strength.

In a study conducted by Karim et al. (2022), the strength development of concrete made with a specific amount of rice husk ash replacement was contrasted with that of regular

Portland cement (OPC). They discovered that when RHA was replaced by roughly 20–30%, there was no discernible drop in concrete strength. This study also discovered that sand-cement blocks based on RHA can considerably lower room temperature.

A study was conducted to examine the characteristics, degree of performance, and use of agricultural waste in building construction (Jose et al., 2019). Despite their low durability performance, it was claimed that vegetable fibers are readily available in poorer nations and can be used as reinforcement materials for brittle matrices. The findings demonstrated the suitability of sisal and banana chemo thermo mechanical pulps (CTMP) for the laboratory method of creating cement composites, which is comparable to related procedures widely employed in commercial production.

Oyedepo (2024) conducted study to ascertain the characteristics of concrete in which sand is partially substituted by sawdust. Sawdust is an industrial waste that, if improperly managed, can harm both the environment and human health. The potential of sawdust waste in the creation of inexpensive and lightweight composite constructions was examined in this study. The materials utilized in this study included fine aggregate (4.75mm) and regular Portland cement. sawdust and coarse aggregate (20 mm) in size. After varying the amount of sawdust substituted from 0% to 100%, the mixture was added to 150 x 150 x 50 mm moulds. After 24 hours, the concrete was demolded, and it cured for 7, 14, 21, and 28 days. Following that, tests were conducted to ascertain the density, compressive strength, workability, air entrainment value, aggregate crushing value, and particle size distribution. The findings demonstrated that increasing the amount of sawdust used in place of sand decreased workability. Nevertheless, a 25% substitution of sawdust produced the same compressive strength as the control. We may deduce that replacing 0–25% of the sand will help reduce sawdust waste without adversely influencing the size of the concrete.

The suitability of using coconut shell ash (CSA) and palm kernel shell ash (PKSA) in place of some of the cement in concrete was assessed by Oyedepo et al. (2024). In this study, concrete cubes with different OPC, coconut shell ash, and palm kernel shell ash were made using a mix design ratio of 1:2:4 and a water cement ratio of 0.63. According to the results, concrete that had 20% palm kernel shell ash and 20% coconut shell ash used in place of cement had average optimal values of 15.4N/mm^2 and 17.26N/mm^2, respectively, after 28 days. Thus, it was determined that PKSA and CSA, which partially replace cement, are appropriate for building light-load structures.

It has been determined how well coconut and palm kernel shells work as coarse aggregates in concrete (Olanipekun, 2022). This study compared the costs and strengths of concrete made with crushed coconut shell and palm kernel shell (PKS) as partial replacements for coarse materials. In each instance, two mixes of 1:2:4 and 1:1:2 were utilized at different percentages of 0%, 20%, 50%, 75%, and 100%. According to the study's findings, strength declined as the replacement % rose. In contrast to palm kernel shell, coconut shell had a greater compressive strength. The study found that when utilized as aggregates in the manufacturing of concrete, coconut shells were preferable to palm kernel shells.

Researchers have examined how concrete behaves when coconut shell is added as a coarse aggregate (Subash et al. 2020). Using beam composite, workability, compaction factor value, specific gravity, particle size, aggregate crushing value, and aggregate impact value were determined in order to ascertain the proper mix proportion of concrete containing coconut shell, as well as the mechanical properties of coconut shell and how coconut shell concrete behaved in flexure. According to the impact and crushing value test findings, coconut shell can be utilized for road construction since it has good resistance to impact and gradual loads. It was determined that coconut shell can be utilized for road construction because of its strong resistance to impact and gradual load. It was determined that using coconut shell in concrete is superior to using regular concrete without it.

The properties of sugarcane bagasse ash waste as a Cementous material were examined by Qing et al. (2018). They stated that sugarcane bagasse ash (SCBA) has been used in numerous research and has enhanced the long-term durability and short-term mechanical qualities of mortar, concrete, and other Cementous materials. Additionally, they claimed that comparative studies demonstrated the benefits and drawbacks of various processing techniques that influence the pozzolanic activities of SCBA. It was also mentioned that more technical and environmental studies will be required before SCBA can be used on a broad basis.

Research showed that RHA replaced the least amount of sand, with just 5% success (Nithyambigai, 2019), followed by CNS and SCBA (10%) (Anbazhagan and Gopinath, 2018). According to reports, SDA had a 25% replacement value while WWS had 20%. Additionally, it was noted that the specimen's overall strength measurements were unaffected by the partial substitution of SDA for sand (Bdeir, 2012).

The impact of using sugarcane bagasse ash in place of some of the cement in concrete has been assessed (Kumar et al. 2023). According to the study, silica ash bagasse ash interacts with cement constituents during hydration to affect extra characteristics like corrosion resistance and chloride resistance. The concrete mixes were created by calculating the amounts of bagasse ash for 0%, 5%, 10%, 15%, 20%, and 25%. The cubes were then cast and left in a solution of magnesium sulphate for 7, 28, and 60 days to undergo compression, slump cone, and compaction factor tests. The outcome demonstrated that when it was cured in 5% $MgSO_4$ as opposed to water, the compressive strength was reduced. It was determined that sugar cane bagasse aids in protecting concrete from sulphate damage.

Concrete is appropriate for usage in practically all civil engineering and architectural structures due to its straightforward use and environmental adaptability (Mutallib and Ibrahim, 2019). The advancement of humanity greatly depends on energy conservation and the earning of carbon credits. We employ earth resources like chalk, clay, and limestone to make tonne of cement. An equivalent quantity of carbon dioxide is emitted into the atmosphere throughout the cement making process, which is bad for the environment and people. In the era of growing nations like Egypt, China, India, and Cuba, among others, energy is crucial. Energy and the environment can be preserved by obtaining carbon credits for using groundnut waste from agriculture to make building materials like cement. Cement is essential to the construction heat treatment industry's operations in the building of housing and other infrastructure. The majority of people then find it very difficult to purchase their own homes, and many buildings fall in an effort to cut costs. One solution is to either increase the output of composite cement or lower the energy costs associated with burning clinker. The latter entails substituting other appropriate and unnecessary goods for a portion of the calorie-dense, clinker-containing section.

Pozzolanic cements are Portland cement and pozzolanic material mixtures that offer the following benefits: increased impermeability, reduced evolution of heat of hydration, economy, improved workability, less bleeding, and good resistance to chemical assault. According to Dashan and Kamang (2020), its drawbacks include a slower rate of strength growth and greater shrinking.

The use of agro-waste to partially replace cement has several benefits, including lower capital costs per tonne production than cement, free waste management promotion, less pollution from these wastes, and a larger farmer's income when these wastes are sold, which encourages increased production, limestone deposit conservation, and a decrease in CO_2 emissions (Mbiminah, 2016; Al-Khalaf and Yousif, 2018).

It is evident that using groundnut shell ash lessens environmental issues. The strength and durability of natural pozzolana materials, which are used in place of some cement, have improved recently. There is a wealth of literature and research articles that discuss the many benefits of using pozzolans in the manufacturing of concrete. Utilizing these waste products that are abundant in our environment is now required because environmental conservation issues have gained relevance in recent years. In addition to these materials, a variety of new materials have been used in contemporary construction projects as replacements. Red mud, paper waste, hypo sludge, industrial waste, and so forth are a few of the substitute materials. These substitute materials are also utilized for high-strength concrete. Groundnut shell ash (GNSA) is utilized in this investigation in place of some of the cement. Oil mills and sweet producing facilities use groundnut shell as fuel. The main problem is disposing of the ash produced by groundnut shells after they are used as fuel. This ash can be utilized in place of cement. Consequently, there is less garbage that has to be disposed of and more efficient use of the waste that is produced. In addition to lowering costs, using groundnut shell ash in concrete also conserves energy and lessens environmental damage.

The properties of GSA and OPC combined in Nigerian concrete were detailed by Buari et al. (2019). Over time, GSA's pozzolanic activity rises. GSA is a good pozzolanic substance that forms calcium silicate hydrate when it combines with calcium hydroxide. Since the GSA's specific gravity was lower than that of the OPC it replaced, mass replacement will require a significantly larger volume of cementitious materials (Buari et al, 2023). For the building of masonry walls and mass foundations for affordable housing in Nigeria, the GSA/OPC concrete's compressive strength was deemed satisfactory at a replacement level of 10%. The strength characteristics of GSA blende concrete were published by Raheem et al. (2023). The experiments were set up to include two major mixes with varying ratios of OPC to GSA by weight, as well as modifications in the water/cement ratio. 10% GSA substitution was found to be suitable for both blends.

Alabadan et al. (2015) investigated the partial substitution of Bambara groundnut shell ash (BGSA) for OPC in concrete. Ash was added to the mixture in percentages of 0%, 10%, 20%, 30%, 40%, and 50% in place of cement. As the curing time increased, the strength of cement/ash concrete increased, but as the ash component increased, it dropped. The maximum strength attained after 28 days of curing was 20.68N/mm^2 for 10% and 31.24N/mm^2 for 0%. When making concrete, it was comparatively feasible to substitute ash for cement up to 10% of the time. OPC/BGSA concrete can be utilised for structural parts that handle light loads, despite having a lower compressive strength than 100% cement. (Alabadan & colleagues, 2015).

The strength and durability of GSA mixed cement concrete in sulphate settings were explained by Olutoge et al. (2023). The test's outcome and the analysis that was done led to the following deductions. Concrete mixed with groundnut shell ash has demonstrated resistance to calcium, sodium, and magnesium sulphate media and would function better in soils that contain $MgSO_4$, Na_2SO_4, and $CaSO_4$. As GSA replacement increases, the concrete's slump values decrease. In any sulphate environment, the 10% compressive strength of the GSA/OPC blended concrete provided a significant value that was acceptable and regarded as a favorable development for building mass foundations and masonry walls.

Nwofor and Sule (2022) study focused on the usage of a significant amount of GSA as a partial cement substitute in the manufacturing of concrete. One hundred examples of

GSA/OPC concrete were cast as l00 x l00 x 100 mm cubes and allowed to cure for seven, fourteen, twenty-one, and twenty-eight days. Density and compressive strength were measured. In addition to lowering environmental issues, using GSA results in strong compressive strength at replacement levels between 0% and 40%. 10% replacement is an acceptable percentage for building, particularly for large-scale concrete projects. Sule and Nwofor (2022).

According to Mahmoud et al. (2022), who studied groundnut shell ash as a partial substitute for cement in the manufacturing of sandcrete blocks, GSA offers enough compressive strength at roughly 20% of the binder quantity. Additionally, when the mortar's GSA quantity rises, so does the amount of water need for a given workability.

Sengul et al. (2015) found that replacing cement with ground fly ash reduced compressive strength by up to 40% at 28 days, but at 56 and 120 days, the compressive strength was nearly equal to that of concrete made with no-fly ash, and it was even greater for a year.

A fly ash percentage of 30 to 50% has the best enhancing impact on magnesia phosphate cement, according to another study by Ding and Li (2015). Additionally, Mahmoud et al. (2015) showed that high workability rice husk ash concrete with a 200–250 mm slump and a 28-day strength of 80 MN/m^2 could be generated by substituting 10% of the cement with rice husk ash. They came to the conclusion that rice husk ash may be manufactured at a significantly lower cost than condensed silica fume and is equally effective at making concrete with a grade 80 strength.

Sadaa et al. (March 2023) conducted research into the suitability of groundnut shell as a constituent material in concrete by substituting groundnut shells for fine aggregate (river sand) in volumetric proportions. Fine aggregate was substituted with groundnut shells at replacement levels of 0, 5, 15, 25, 50, and 75%. After 28 days, the concrete cubes' compressive strengths were measured at various % replacement levels, yielding a range of values of 34.37, 40.59, 21.33, 17.78, 12.44, and 7.56 N/mm^2.

Groundnut husk ash was investigated by Ketkukah and Ndububa (2016) as a partial cement substitute in mortar. This essay looks at a few characteristics of mortar made of groundnut husk ash (GHA) and ordinary Portland cement (OPC). OPC was partially replaced with the GHA. The following ash replacement levels were used: 0%, 2%, 4%, 6%, 8%, and 10%. The ash's pozzolanic qualities were determined via a chemical study. The paste's first setting time was 95 minutes, and its total setting time was 11 hours. As the percentage of ash grew, the mortar's density and capacity to absorb water dropped. For the fabrication of sandcrete blocks in hot climates, OPC/GHA mortar is advised.

Okpalla (2018) demonstrated that using rice husk ash (RHA) in place of 40% of cement resulted in concrete that was just as strong as regular Portland cement concrete.

The impact of coarse aggregate on the drying shrinkage and elastic moduli of concrete with OPC partially substituted with RHA was investigated by Kolawole and Mbachu (2023).

The use of groundnut shell ash as a partial substitute for cement in the manufacturing of concrete was investigated by Mujedu et al. (2016). Seventy-two (72) concrete cubes with varying amounts of groundnut shell ash ranging from 0% to 75% at 15% intervalswere created in total. Using a water-to-cement ratio of 0.55 and a mixing ratio of 1:2:4, concrete was batched by weight. According to their findings, the compressive strength rises with the number of curing days and falls with the amount of groundnut shell ash added. They also found that using groundnut shell ash in concrete up to 15% in place of regular Portland cement would be appropriate and may be utilized for light-load bearing constructions.

(Okodugha, 2020) evaluated the compressive strength of concrete pipes by partially substituting cement with lateritic soil and rice husk. During his labor, he used vibrators and a machine mixer to create 288 cubes in total, adhering to the 1:2:4 design mix ratio. He noticed that the concrete cubes created with 20% lateritic soil or 20% rice husk ash reached the necessary strength of $25N/mm^2$ after 28 days of curing. Because of these findings, he suggested that in a concrete pipe mix, rice husk ash might be used to partially substitute cement up to 20% by volume of cement.

The performance of lightweight concrete using palm kernel shell as an aggregate was investigated by Osuji et al. (2018). The palm kernel shell underwent a number of tests and analyses before being analyzed using the American Institute design mix. The palm kernel shell worked well as a lightweight concrete aggregate, according to the results.

Statistical analysis revealed that aggregate properties like shape, surface texture, and modulus of elasticity were the primary causes of strength variations, with surface texture being the most significant property influencing compressive strength. An experiment involving thirteen different types of coarse aggregates revealed that depending on the aggregates, differences of 40% in flexural strength and 29% in compressive strength were obtained for concrete if the same mix ratio was used (Kaplan, 2021).

When a specific type of sand was divided into different sizes and utilized to make concrete, this observation was observed. It was determined that the strength of concrete built with sands of smaller particle sizes increased with the size of the aggregate of the sharp sand. It was also suggested that the water ratio be kept to a minimum for adequate hydration in order to increase the strength of the concrete (Ajato, 2015).

The possibility of using cockle shell ash as a filler or partial replacement material was examined in a study. Fluorescence X-ray analysis was used in the study to ascertain the chemical makeup of cockle shell ash. The next step was to determine the concrete's properties, including compressive strength, modulus of elasticity, water permeability, and porosity, using a mixture of cockle shell ash at 5%, 10%, 15%, 25%, and 50%. These were compared to regular concrete that was cured in regular water at 7, 28, 90 days, and up to 120 days for the water permeability test. The morphological structure was also observed using SEM analysis. Consequently, the morphological structure appears compacted when 5% and 10% of cockle shell ash are added, which affects the concrete's strength, modulus of elasticity, permeability, and porosity.

Additionally, it has been observed that, under the same conditions and analysis, concrete built using quarry dust as fine aggregate has a better strength than concrete made with sand as aggregate (Abdulimen, 2021).

Ndoke (2016) examined the possibility of using palm kernel shell as a coarse aggregate in road binder courses, focusing on the asphalt concrete's strength as indicated by the flow and Marshall stability values. It has been found that coarse aggregate can be replaced with palm kernel shell up to 30% of the time before a significant reduction is apparent. Therefore, his research suggested that palm kernel shells might be utilised to replace up to 10% of intensively frequented roads and even 100% of moderately trafficked roads in rural areas.

Olutoge (2022) looked into the possibility of using palm kernel shell ash (PKSA) in concrete as a partial substitute for cement. By lowering the amount of cement needed in concrete projects, he hoped to lessen the growing problems of the high cost and scarcity of building materials utilized by the Nigerian and African construction industries. After being dried, the collected PKSA was sieved using a 45um sieve. While the physical and mechanical characteristics of different percentages of PKSA cement concrete and 100% cement concrete of mix 1:2:4 and 0.5 water-cement ratios were investigated and compared, the chemical properties of the ash were also analyzed. a total of 72 150 x 150 x 150 mm concrete cubes with varying PKSA to Portland cement volume percentages in the range of 0:100. 10:90, 30:70, and a 1:2:4 mix ratio was cast, and after 7, 14, 21, and 28 days, their mechanical and physical characteristics were examined. Compressive strength tests revealed that 10% of PKSA in place of cement at 28 days was 22.8N/mm^2, which was quite satisfactory without compromising the compressive strength requirements for concrete mix ratio 1:2:4, even though the compressive strength of PKSA concrete did not surpass that of OPC. According to his research, PKSA can be used in concrete to partially replace cement at a lower volume of replacement. will help lower the amount of cement used in concrete, which will lower the cost of production.

2.3 Concrete

Cement, coarse and fine aggregates (sand), and water are combined to create concrete, a building material that solidifies over time. The most popular kind of cement used to make concrete is Portland cement. Concrete technology is the study of concrete's characteristics and real-world uses.

Concrete is utilized in the construction of slabs, beams, columns, foundations, and other load-bearing components in buildings. In addition to cement, various types of binding materials are employed, such as bitumen for asphalt concrete and lime for lime concrete, which are used in road building. Concrete projects use a variety of cement types, each with unique qualities and uses. Portland Pozzolana Cement (PPC), rapid-hardening cement, sulphate-resistant cement, and other varieties are among the cement varieties.

To achieve the necessary strength, materials are combined in precise ratios. M stands for Mix, and 5, 10, 15, etc. are the strength in KN/m^2 of the mix, which is expressed as M5, MIO, M15, M20, M25, M30, etc. Concrete strength in the US is measured in pounds per square inch, or PSI.

The ratio of water to cement is crucial in determining a number of characteristics, including workability, strength, and durability. To produce workable concrete, a suitable water-to-cement ratio is needed.

Cement and water react when water is added to materials, initiating a hydration reaction. This reaction aids in the formation of a solid matrix that holds the constituents together to create a long-lasting substance that resembles stone.

Any shape can be used to cast concrete. Given that it is a plastic substance in its fresh state, different forms or formworks in a range of sizes are utilized to create diverse shapes, including circular and rectangular ones. Concrete is used to produce a variety of structural components, including beams, slabs, footings, columns, lintels, etc. In the United States, the standard code of practice for concrete construction is ACI 301 Specifications for Structural Concrete and ACI 318 Building Code Requirements for Structural Concrete.

Admixtures come in a variety of forms and are used to impart specific qualities. To enhance the physical characteristics of the wet mix or the final product, additives or mixes like pozzolans or super plasticizers are used. These days, a variety of concrete varieties are produced for use in building construction. These have unique qualities and characteristics that raise the standard of building in accordance with specifications.

2.3.1 Components of Concrete

Cement, sand, aggregates, and water are the ingredients of concrete. Paste is a mixture of Portland cement and water. Thus, concrete can be defined as a blend of aggregates, sand, and paste. Aggregates are occasionally substituted with rocks. When the fine and coarse aggregates are well combined, the cement paste covers their surfaces and binds them together. The hydration reaction, which gives the concrete strength and results in a rock-solid concrete, begins shortly after the components are mixed.

2.3.2 Grade of Concrete

Concrete grade indicates the strength needed for building. For instance, M30 grade indicates that 30 MPa of compressive strength is needed for construction. The mix is represented by the first letter in grade "M," and the necessary strength in MPa is 30. The concrete grade is shown in Mix Proportions based on a variety of laboratory tests. According to the volume or weight of the ingredients, the mix proportion for M30 grade, for instance, might be 1:1:2, where 1 represents the cement ratio, 1 represents the sand ratio, and 2 represents the coarse aggregate ratio.

At the construction site, civil engineers use concrete cubes or cylinders to measure the strength. Cubes or cylinders are formed during the structural member's casting process, and they are cured for 28 days following hardening. The strength is then determined by a compressive strength test. Common concrete grades include Ml5, M20, M25, and so forth. Generally speaking, Ml5 is utilized for basic cement concrete projects. Concrete of at least M20 grade is utilized for reinforced concrete construction.

2.3.3 Compressive Strength of Concrete

The most popular test for hardened concrete is the compression test, in part because it is simple to execute and in part because the majority of the desired characteristics of concrete are qualitatively correlated with its compressive strength. (Dubey and Rakesh, 2014).

The most often used metric to assess the quality of concrete is its compressive strength. The 28-day cube strength, or the crushing strength of typical 150 mm cubes at 28 days after mixing, is the basis for the characteristic strength of concrete in the UK. If the nominal maximum size of the aggregate does not exceed 25 mm, 100 mm cubes may be used. The compression test is used to determine the strength of hardened concrete. The ability of concrete to withstand loads that have the tendency to compress it is measured by its compression strength. Concrete specimens that are cylindrical or cubic are crushed in a compression testing equipment to determine the concrete's compressive strength.

The free water/cement ratio, or the weight ratio of the cement in the mixture to the weight of the free mixing water, is the main factor influencing the strength of concrete. When all else is equal, the concrete's strength increases with a lower w/c ratio.

2.3.4 Applications of High-Strength Concrete

Engineering projects requiring concrete components that can withstand high compressive loads must use high-strength concrete. High-strength concrete is commonly used in the construction of high-rise buildings and has been utilized in foundations, shear walls, columns (particularly on lower floors where the loads will be greatest), and bridge applications on occasion.

Many American cities have successfully used high-strength concrete for high-rise buildings. A high-rise building with more than thirty stories is deemed appropriate for high-strength concrete use. Because of its weight capacity, special concrete has not only made such projects possible, Additionally, it has made it possible to reduce the size of beams and columns. The loads related to foundation design are decreased as a result of lower dead loads. Additionally, owners profit financially because as the area taken up by the columns shrinks, more floor space becomes available for rent, mostly on the lower floors. According to estimates, employing 8000 psi concrete can lower column diameters by roughly 33% for a 50-story building with 4-foot diameter columns made of 4000 psi concrete (Peterman).

Highway bridges are occasionally built with high-strength concrete. Reinforced or prestressed concrete girders can span longer distances than regular strength concrete girders because to high-strength concrete. Additionally, fewer girders may be needed because to the increased individual girder capabilities. Additionally, it can be used to build parking decks, bridges, and other structures that are more likely to be exposed to seawater or de-icers.

2.3.5 Curing of High Strength Concrete

Higher strength concrete exhibits a higher rate of strength gain at early ages compared to normal strength concrete, but the strength difference is not significant at later ages (high strength concrete ranges from 40MPa and above).

A rise in the interior curing temperature of the concrete cubes is what causes high-grade concrete to gain its strength at an earlier age. because high-grade concrete has a higher heat of hydration due to its high cement content. When high-grade concrete is allowed to dry before curing is finished, its strength decreases more than that of regular strength concrete.

2.3.6 Aggregates for Concrete

Any particle matter is referred to as aggregate. It consists of geosynthetic aggregates, recycled concrete, sand, slag, crushed stone, and gravel. Aggregate can be recycled, produced, or natural.

i. About 60–80% of the concrete mix is composed of aggregates. They give concrete bulk and compressive strength.
ii. Any given concrete mix's aggregates are chosen based on their strength, workability, durability, and finish-ability.
iii. A good concrete mix requires aggregates that are strong, clean, and free of coatings of clay and other fine elements that could erode the concrete or absorb chemicals.

iv. There are two types of aggregates: "coarse" and "fine." Particles larger than 4.75 mm are referred to as coarse aggregates. The typical range used is 9.5 mm to 37.5 mm in diameter.

v. Sand or crushed stone with a diameter of less than 9.55 mm are often considered fine aggregates.

vi. Generally speaking, 20mm aggregate is the most widely utilized size in construction. In mass concrete, a bigger dimension of 40mm is more typical.

vii. Cement and water requirements are decreased with larger aggregate sizes.

Common Aggregates

a) Crushed Stone and Manufactured Sand

To create a range of aggregate sizes that satisfy both "coarse" and "fine" requirements, stone is mined, crushed, and ground.

b) Gravel

The rocks that make up gravel are not attached to one another. Gravel is made up of unconsolidated rock pieces with a typical particle size range, ranging in size from granules to boulders, according to the Wikipedia site.

c) Sand

Sand is made up of tiny rock fragments and mineral particles and is found naturally. Depending on the source, its composition can change. It is distinguished by size, being coarser than silt and finer than gravel.

2.4 Compression Test

Amala (2019). defines Concrete's compressive strength as the characteristic strength of concrete cubes measuring 150/100 mm after 28 days of testing. With sand, cement, and coarse aggregate as its micro-ingredients (mix ratio), concrete is a macro-composition that gradually reaches its 100% strength in the cured stage.

Table 2.1: Concrete Strength Gain Days After Casting

Days of casting	Strength Gain
Day 1	16%
Day 3	40%
Day 7	65%
Day 14	90%
Day 28	99%

2.5 Periwinkle Shell

One group of marine snails is called periwinkles. As seen below, their shells are usually speckled in grey, white, and black and taper to a rounded or straight-sided cone with an obtuse point.

The littoral zone, which is the area between low and high tides, is home to periwinkles. They must live close to the ocean and submerge for a portion of the day; however, they would rather be partially exposed to the air. Periwinkles are very helpful in Nigeria's riverine regions. Notwithstanding the fact that snails are eaten, their shells can be used to stabilize soil, make concrete, make beads, feed poultry, make decorations, and more. The following factors support the widespread use of periwinkle shells as concrete materials: in addition to their hardness, the shells are typically light materials appropriate for riverine environments, easily accessible in significant quantities, have good cement and sand bonding qualities, and are less expensive than crushed stones (granites). Investigations into the suitability of these shells as coarse aggregates in concrete have been conducted and are still ongoing both inside and outside of Nigeria. (Soneye et al, 2016). Using several mix designs, design mixes, and altering the quantity of periwinkle shells in the concrete from 0% to 100%, the suitability of the shells as coarse aggregates was investigated. According to their research, the 28-day concrete made with 100% periwinkle shells has a distinctive strength that ranges from 11.77N/mm^2 to 15.65N/mm^2. (Nkem et al, 2016).

The potential use of the shell as coarse aggregate has been the focus of a great deal of research, but the possibility of employing the shell as fine aggregate, either entirely or partially, in structural concrete has received little to no attention. Thus, this study aims to examine the shells' suitability as both fine and coarse aggregates. To this end, a number of tests, including flakiness, Los Angeles abrasion, and periwinkle fine shell (PWFS), are conducted with granite concrete that has varying percentages of periwinkle shell (coarse and fine) ranging from 0% to 100%, respectively.

2.6 Research Gap

While periwinkle shell (PWS) has been studied as partial replacement for coarse aggregate in concrete, most research has been limited to their use without chemical admixtures. The combine influence of periwinkle shell aggregate and admixture such as superplasticizers, accelerators, or pozzolanic materials (fly ash) on concrete performance remains largely underexplored. There is a lack of comprehensive data on how admixtures affect the workability, durability, setting time and mechanical strength of concrete containing periwinkle shell (PWS).

This study will address the identify gaps by conducting experimental investigations incorporating chemical admixtures, evaluating the durability and long-term performance of concrete with periwinkle shell aggregate and optimizing the mix design for improving strength and sustainability.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

The testing, materials, and procedures that were employed in producing the regular-grade concrete cubes were presented in this section of the project. This chapter included the mix proportions, the tests that were carried out, and the methods that were adopted for conducting the testing. The preparation of the normal-grade concrete cubes was undertaken in strict compliance with the requirements of BS 1881.

The experimental programme was executed at the Structural Laboratory of the Department of Civil Engineering, University of Benin. Concrete cubes of regular grade were cast, cured, and tested under controlled laboratory conditions. The testing schedule involved the assessment of compressive strength at three intervals, namely at 7 days, 14 days, and 28 days, in order to evaluate the development of strength with curing age.

3.2 Materials

The materials used for this study include ordinary Portland cement (OPC), fine aggregate, coarse aggregate, water, addictive (Metakaolin) and periwinkle shell.

3.2.1 Portland Cement (OPC)

Portland cement, which is essential for making mortar and concrete, is the most commonly used kind of cement worldwide. For the experiment, ordinary Portland cement with the Dangote brand was purchased from Oluku, Benin City, Edo state. It ensured that it’s attributes were in line with BS 12 (1971).

3.2.2 Fine Aggregate

The fine aggregate that was used for this study was sourced from Oluku. The sand was spread out to dry before being used, after which it was sieved through a succession of sieves arranged from top to bottom, and retained on a sieve with a mesh size of 200 (75 μm). Four different types of sand; river sand, sea sand, crushed stone, and pit sand are commonly employed in the production of concrete bricks. Among these, river sand was the most frequently used type in Nigeria.

3.2.3 Water

Water devoid of contaminants that can compromise the integrity of the final mix was acquired from the structural laboratory of the Department of Civil Engineering, University of Benin, Benin City, Edo state, Nigeria.

3.2.4 Admixture

Material sourcing for concrete admixtures is a complex interplay of industrial chemistry, mineral extraction, and the utilization of by-products, all driven by the need to enhance concrete performance and meet evolving sustainability Examples of concrete admixtures are plasticizers, Fly ash, Metakaolin, superplasticizers, accelerators, retarders etc. Metakaolin was used for this study.

3.2.5 Periwinkle Shell

African giant periwinkle shells were sourced from a local market in Benin City, Edo state, Nigeria. Periwinkle shells are dumped as waste at an unapproved dumpsite near the market area in Benin City. The purpose of washing the shells was to get rid of the filth and corpses that were on them.

3.3 Physical Properties

The following physical properties of the concrete produced were analyzed.

i. Sieve Analysis

ii. Specific Gravity

iii. Moisture Content

iv. Setting time for Cement

v. Consistency Test for Cement

vi. Bulk density

3.3.1 Sieve Analysis

Sieve analysis is a commonly used technique in civil engineering and construction materials testing to determine the particle size distribution of a granular material, such as Sand, granite, cement, and water are combined to create concrete concrete cubess, a type of building material. Sieve analysis can be performed on the sand and granite in the concrete mix to ensure that it satisfies the necessary requirements. These include the following: mechanical, manual, dry, and wet sieving techniques. In this investigation, the dry sieving method was utilized.

3.3.1.1 Apparatus

The following apparatus were used for sieve analysis.

i. The British Sieve

ii. Mechanical Sieve Shaker

iii. Weighing balance

iv. Oven

v. Pan

3.3.1.2 Procedure for Sieve Analysis

Sieve analysis uses a set of sieves to determine the soil's particle sieve distribution. The study was conducted using a weighing scale and a set of British Standard (BS) sieves in the following sizes: 1.0mm, 0.85mm, 0.60mm, 0.5mm, 0.30, 0.25, 0.18, and pan. The greatest aperture sieve was placed at the top of the sieve, and the smallest aperture sieve was placed at the bottom.

3.3.2 Specific Gravity

Cement's specific gravity often ranges from 3.1 to 3.16. Accordingly, cement weighs between 3.1 and 3.16 times as much as an equivalent volume of water. The density of a material (in this case, cement) divided by the density of a reference material (often water) is known as specific gravity is epressed according to ASTM C128 as;

$$\text{Specific Gravity (G)} = \frac{\text{Weight of cement}}{V_2 - V_1} \qquad (3.1)$$

Where:

Weight of cement = 64 g

V_2 = Final volume

V_1 = Initial volume

3.3.2.1 Apparatus

The following apparatus were used for specific gravity

i. Thermometer

ii. Weighing balance

iii. Beaker

iv. Glass rod

v. Le chandelier flask

vi. Naphthalene or kerosene

3.3.2.2 Procedure for Specific Gravity

The specific gravity test was conducted following the steps below:

i. Le Chatelier flask was clean and dry.

ii. The flask was fill with kerosene up to the lower calibration mark (usually around 0 ml or a set baseline mark).

iii. The initial volume of kerosene (V_1). was noted.

iv. About 64 g of dry, cool cement was added using a funnel. Avoid sticking or spilling.

v. A glass rod was use to remove air bubbles, that it will not splash

vi. The new reading of the kerosene level (V_2).

3.3.3 Slump Test

The test is widely used method to determine the workability and consistency of fresh concrete. The slump test provides a simple and effective way to assess the workability and consistency of fresh concrete, helping to ensure that the concrete meets the required specifications for a particular project. The slump value indicates the workability of the concrete:

i. Low slump (0-25mm): stiff, dry mix, suitable for road construction or low workability applications.

ii. Medium slump (25-75mm): medium workability, suitable for general construction, such as building foundations, walls and slabs.

iii. High slump (75-125mm): high workability, suitable for applications requiring easy flow, such as pumping or complex formwork.

3.3.3.1 Apparatus for Slump Test

The following apparatus were used for the slump test.

i. Truncated cone shape

ii. Handles

iii. Tamping rod

iv. Scoop

v. Measuring tape/Ruler

vi. Flat surface

3.3.3.2 Procedure for Slump Test

The following procedure was use to carry out the slump test.

i. The slump cone was filled with fresh concrete in three layers, tamping each layer 25 times.

ii. The cone was lifted vertically, allowing the concrete to slump.

iii. The difference in height between the original cone height and the slumped concrete was recorded.

3.3.4 Moisture Content

Moisture content is the amount of water present in a material, usually expressed as a percentage of the dry weight. In construction materials (like soil, sand, or aggregates): It indicates how much water is in the material before mixing with cement. It's crucial for adjusting the water-cement ratio in concrete.

The formula for estimating moisture content is expressed according to ASTM D2216;

$$\text{Moisture Content (\%)} = \frac{(W_1 - W_2)}{W_2} \times 100 \qquad (3.2)$$

Where:

W_1 = Weight of wet sample

W_2 = Weight of dry sample

3.3.4.1 Apparatus for Moisture Content

The following apparatus was used to carry out the moisture content test.

i. Weighing balance (accurate to 0.1 g)

ii. Oven (capable of 105–110°C)

iii. Metal container

3.3.4.2 Procedure for Moisture Content Test

The following procedure was used to carry out the moisture content test.

i. A sample of aggregate was weighed in a clean, dry container (W_1)

ii. The container was placed in an oven at 105–110°C for 24 hours or until constant weight is achieved.

iii. After drying, the sample was casted in a desiccator and weigh it again (W_2)

3.3.5 Setting Time of Cement

The amount of time it takes for cement to attain a specific percentage of its full strength is known as the setting time. This is due to the fact that, unlike sandcrete, concrete is not impacted by variables like temperature and water content when it comes to setting time. It is crucial to remember that the amount of time it takes for cement to set might change based on the type of sand used, water content, and cement quantity.

3.3.5.1 Apparatus for Setting Time of Cement Experiment

The following apparatus was used to conduct the setting time of cement experiment

i. Vicat Apparatus

The Vicat apparatus consists of;

a) A frame and a moveable rod with a platform at one end and the needle which can be attached at the other end

b) Needle.

The needle was used;

a) to determine the initial setting time

b) to determine the final setting time

ii. Plunger for determining the standard consistency

iii. Graduated Scale: length of graduated scale is 40mm and the smallest division is 1

iv. Vicat mould

v. Weighing Balance

vi. Stop Watch

vii. Gauging Trowel

viii. Measuring Cylinder

ix. Tray

3.3.5.2 Procedure for Setting Time of Cement Experiment

Cement weighing 400g was used to make paste. A measuring period was observed, with a maximum of five minutes and a minimum three minutes. The measurement has to be finished before any indication of setting appears. Water was added to the be cement, a stop watch was set in motion. The paste was poured into the Vicat mould, which was set on top of the non-porous plate. The mold's surface was smoothed and leveled with the top of the mold once it has been filled all the way.

a) Initial Setting Time of Cement

The rod that held the needle was placed underneath the mould (needle was used to measure the initial setting time) and was quickly released to allow the needle to puncture the test block after being lowered just enough to touch its surface. Initially, the needle passed through the entire test block. The procedure was repeated until the needle is about 5mm from the bottom of the mould and was unable to get through the block. The time between adding water to the cement and the point at which the needle could not pierce the test block down to a depth of 5mm from the mold's bottom is known as the first setting time.

b) Final Setting Time of Cement

The needle with an annular attachment was used to replace the first needle in order to determine the final setting time. The needle was gently positioned on the surface of the mold until it left an impression. The cement was said to have reached its final set when the attachment could no longer make an impression on the surface of the test block. The period of time between adding water to the cement and the point at which the needle could no longer make an impression on the test block's surface was recorded as the final setting time.

c) Consistency of Cement

Consistency of cement refers to the amount of water required to make a cement paste of standard (normal) workability. It's the minimum water content at which the cement paste allows the Vicat plunger to penetrate 33–35 mm from the top of the Vicat mould. For Ordinary Portland Cement (OPC), standard consistency is usually around 26% to 33%. It's expressed as a percentage of the weight of dry cement.

3.6 Mechanical Test of Concrete

The produced concrete was tested for the following mechanical properties:

i. Compressive Strength test (100 X 100 Cube)

ii. Tensile test (Cylindrical)

iii. Flexural test (Beam)

iv. Slump test

3.6.1 Compressive Strength Test

The quality of a concrete cube's unit and its reaction to curing are assessed using a compressive strength test. This is the ratio of the crushing load a sample can withstand to its net area, or the unit capacity to support an axial load applied to the concrete cubes bed face or edge. According to EN 772-1:2000, concrete cube compressive strength was estimated. The crushing machine should be loaded at a rate of 0.05(N/mm^2)/s when the expected compressive strength is less than 10N/mm^2.

It is expressed mathematically according to BS EN 12390 as;

$$\text{Compressive strength} = \frac{\text{maximum crushing load (N)}}{\text{minimum surface area (mm}^2\text{)}} \qquad (3.3)$$

Concrete hollow blocks have a minimum strength requirement of 2.5 N/mm^2 for 150mm and 3.45 N/mm^2 for 225, according to NIS 87:2007. The following are factors that affect the compressive strength of concrete, which are; water cement ratio, degree of compaction, fine aggregate (grade, texture and shape features), cement type, curing etc.

3.6.2 Tensile Strength Test

Tensile strength test of concrete measures its ability to resist tension (pulling forces). The method that was used for this study is split tensile strength test (ASTM C496). Tensile strength is estimated with the following equation according to ASTM C496.

$$\text{Tensile strength } (f_t) = \frac{(2 \times P)}{(\pi \times L \times D)} \tag{3.4}$$

Where;

P = Maximum load (N)

L = Length of cylinder (mm)

D = Diameter (mm)

3.6.2.1 Apparatus for Tensile Strength

The following apparatus was used for tensile strength.

i. Compression testing machine

ii. Cylindrical concrete specimen (150mm diameter x 300mm height)

iii. Packing strips (thin plywood or rubber)

3.6.2.2 Procedure for Tensile strength Test

The following procedure was use to carry out the tensile strength.

i. Place the cylinder horizontally between the platens of the testing machine

ii. Place packing strip along the length to distribute the load evenly.

iii. Apply load gradually until the specimen spit along its vertical axis.

iv. Record the maximum load applied

3.6.3 Flexural Concrete Test

Flexural test of concrete measures its ability to resist bending often called modulus of rupture. It measures the maximum stress the material can withstand when subjected to a bending load. The formula for estimating flexural strength of concrete according to ASTM C293 is;

$$\delta = \frac{(3 \times F \times L)}{(2 \times B \times D^2)} \tag{3.5}$$

where;

δ = Flexural strength (MPa psi)

F = Maximum load applied (N or Ibf)

L = Span length (mm or in)

b = width of the specimen (mm or in)

d = depth of the specimen (mm or in)

3.6.3.1 Apparatus

The following apparatus was used for flexural test.

i. Flexural testing machine or universal testing machine
ii. Concrete beam specimen (usually 100 x 100 x 500 or 150 x 150 x 700)
iii. Steel rollers/supports
iv. Measuring scale

3.6.3.2 Procedure for Flexural Concrete Test

The following procedure was used to carry out the flexural test.

i. Prepare a beam specimen of the material to be tested
ii. Place the specimen on a testing machine and apply a load until failure occurs.
iii. Calculate the flexural strength using the maximum load and specimen dimensions.

3.7 Durability Test Evaluation on Periwinkle shell Concrete Cubes (PSCC)

The bulk properties identified as likely to have direct bearing with the investigation of the durability of periwinkle shell concrete cubes (PSCC) produced are discussed in the following subsections.

3.7.1 Concrete Cubes Dry Density

The density of a concrete cubes is a valuable indicator of its quality. The determination of the dry density was done carefully in accordance to (BS 6073: Part 2, 1981) by weighing the concrete cubes after they have been oven-dried at 105 ± 5°C for 24 hours and the dimensions of the concrete cubes were taken with an accurate steel tape.

The formula for estimating dry density according to ASTM C140 is;

$$\ell d = \frac{M}{V} \qquad (3.6)$$

where, ℓd = Dry density

m = Mass of dry concrete cubes

v = Volume of concrete cubes

The density obtained in each case is expressed to the nearest kg/m^3

3.7.2 Total Water Absorption Test

Cold immersion method was used in determining the total water absorption (TWA) of the concrete cubes, which was carried out in accordance to BS 3921, 1985. This involves oven drying the concrete cubes samples for 48 hours followed by cold immersion in water. The concrete cubes samples were dried in oven to constant weight, thereafter they were immersed in water for 24 hours. The weights of the wetted concrete cubess were measured. The formula for estimating water absorption according to ASTM C127 is;

$$TWA = \frac{(Mw - Md)}{Md} \qquad (3.7)$$

Where;

TWA = percentage moisture absorption (%),

Mw = mass of wetted sample (g),

1. Md = mass of dry sample (g)

The values obtained from the water absorption test were classified based on Table 3.1.

Table 3.1: Water Absorption Rating

Rating / Classification	Remarks
Low Absorption (<3%) (BS 812-2:1995; ASTM C127-15)	Excellent durability; suitable for structural concrete.
Moderate Absorption (3–4%) (Neville, 2011; Olutoge et al., 2021)	Acceptable for general reinforced concrete applications.
Moderate Absorption (3–4%) (ASTM C127-15; Ejeh & Uche, 2022)	Slightly increased porosity due to shell texture.
High Absorption (≈4%) (BS EN 1097-6:2013)	Suitable for lightweight or non-load-bearing units.
Very High Absorption (>4%) (ASTM C642-13; Shetty, 2013)	Excessive absorption; not suitable for structural use.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the experimental results and discussions on the effect of using periwinkle shells as a partial replacement for coarse aggregate in concrete with admixtures. The findings are organized into three main sections: the physical properties of constituent materials, the mechanical properties of hardened concrete, and the durability characteristics of the modified concrete. The results obtained are presented in the subsequent tables below. Graphs and charts are also provided where necessary to illustrate how each of the percentage replacement aggregates performed relative to another.

The tests carried out include:

(i) Sieve Analysis Test

(ii) Workability Test

(iii) Specific Gravity Test

(iv) Moisture Content Test

(v) Bulk Density Test

(vi) Setting Time and Consistency Test for Cement

(vii) Aggregate Impact Value (AIV) and Aggregate Crushing Value (ACV) Test

(viii) Compressive strength

(ix) Split Tensile Test

(x) Water Absorption Test

(xi) Flexural strength

4.2 Physical Properties of Material Used

The characteristics of the materials used for the study are presented in Table 4.1.

Table 4.1: Physical Properties of Material Used for the Study

MATERIAL	PROPERTY	VALUE	UNIT
Cement (Ordinary Portland Cement)	Initial Setting Time	95	min
	Final Setting Time	238	min
	Consistency	7	mm
Fine Aggregate	Fineness Modulus	4.22	_
	Silt Content	2.05	%
	Moisture Content	2.65	%
Coarse Aggregate	Fineness Modulus	7.79	_
	AIV	10.96	%
	ACV	18.283	%
	Specific Gravity	2.745	_
	Moisture Content	2.72	%
Periwinkle Shell	Fineness Modulus	9.86	_
	AIV	50.44	%
	ACV	29.452	%
	Specific Gravity	2.685	_
	Moisture Content	10.745	%
	Silt Content	2.08	%

From Table 4.1, the initial and final setting times of 95 min and 238 min respectively indicate that the cement used satisfies the requirements of BS EN 196-3 (2016) for Ordinary Portland Cement, ensuring adequate workability time. The coarse aggregate had a fineness modulus of 7.79 and specific gravity of 2.745, which are typical of granite and indicate high density and strength within the limits of (BS EN 12620:2013). Its AIV

(10.96%) and ACV (18.283%) suggest strong resistance to impact and crushing well within the permissible limit of 30% for structural concrete recommended by BS 812-112:1990 and BS 812-110:1990 for structural concrete.

The periwinkle shell, however, exhibited a higher AIV (50.44%) and ACV (29.452%), confirming its lower mechanical strength compared to granite. Its specific gravity (2.685) and fineness modulus (9.86) reveal that the shells are lighter and coarser, contributing to reduced density and increased porosity when used in concrete.

The moisture content (10.745%) and silt content (2.08%) are within acceptable limits ASTM C33/C33M-18 (<5 %), indicating minimal impurities. This confirms that the periwinkle shell can serve as a partial replacement for coarse aggregate, especially for lightweight or non-structural applications.

4.3 Mechanical Properties of the Modified Concrete

The mechanical properties of the concrete produced with the periwinkle shell replacement and without periwinkle shell replacement are presented in Table 4.2.

Table 4.2: Mechanical Properties of the Modified Concrete

Periwinkle Shell Replacement (%)	Coarse Aggregate Replacement (%)	Slump Value (mm)	Compressive Strength (N/mm^2)	Flexural Strength (N/mm^2)	Tensile Strength (N/mm^2)	Curing Days
0	100	23	16.032	5.125	2.581	7 Days
10	90	31	14.289	3.375	2.400	
20	80	35	13.352	2.250	1.957	
30	70	44	11.422	1.750	1.414	
40	60	52	10.639	1.625	1.388	

0	100	23	16.989	5.150	3.060	14 Days
10	90	31	16.470	4.050	2.896	
20	80	35	15.758	2.700	2.322	
30	70	44	14.948	2.100	1.661	
40	60	52	13.148	1.950	1.630	
0	100	23	20.845	5.96	3.873	28 Days
10	90	31	19.558	4.125	3.603	
20	80	35	18.469	4.022	2.935	
30	70	44	17.314	2.625	2.121	
40	60	52	16.077	2.438	2.083	

From Table 4.2, it is observed that the slump value increased progressively with periwinkle shell content, from 23 mm at 0% to 52 mm at 40%, indicating improved workability due to the smooth texture and lower specific gravity of the shells. However, the compressive, flexural, and tensile strengths decreased as replacement level increased.

At 28 days, the control mix (0% replacement) achieved a compressive strength of 20.845 N/mm², while mixes with 10%, 20%, 30%, and 40% replacement recorded 19.558 N/mm², 18.469 N/mm², 17.314 N/mm², and 16.077 N/mm², respectively. This represents a 22.9% overall reduction in compressive strength between the control and the 40% mix. Mixes up to 20% replacement retained over 75% of the control strength, aligning with Okafor (2018) and Adesanya and Raheem (2020), who also observed acceptable strength retention up to 20–25% replacement. Ejeh and Uche (2022) explained that strength reduction arises from the shells' porous and brittle nature, which weakens the interfacial transition zone (ITZ). Adejumo and Adewuyi (2023) noted that optimized mix design and compaction could slightly improve strength retention. Overall, the present results confirm that moderate shell contents (≤20%) maintain adequate compressive performance for light structural use.

Flexural strength followed the same pattern, reducing from 5.96 N/mm² in the control to 2.438 N/mm² at 40% replacement. This decline reflects reduced stiffness and weaker bonding at the ITZ. Olutoge et al. (2021) reported up to 50% reduction in flexural strength at 40% replacement, while Ibrahim et al. (2020) found that mixes with ≤20% shell content retained about 70% of control values. Okorie and Eneh (2019) suggested that proper curing and shell pre-treatment could improve bonding. Thus, the observed trend agrees with established findings that periwinkle shells can be effectively used where moderate strength and high workability are required.

Similarly, tensile strength decreased from 3.873 N/mm² (control) to 2.083 N/mm² at 40% replacement, consistent with Adesanya and Raheem (2020) and Nduka et al. (2019), who reported 25–30% reduction at similar replacement levels. Okafor (2018) also linked this decline to weak bonding between the shell surface and the cement matrix. Despite this, mixes with ≤20% replacement retained adequate tensile strength for non-structural or lightweight concrete applications.

In summary, this study's findings corroborate existing literature: periwinkle shell replacement improves workability but reduces strength as replacement increases. Strength reductions beyond 30% compromise structural integrity, while replacements up to 20% offer a practical balance between strength and workability.

4.3 Durability Characteristics of the Modified Concrete

The durability characteristics of the concrete produced with the periwinkle shell replacement and without periwinkle shell replacement are presented in Table 4.3.

Table 4.3: Water Absorption Test Results for Modified Concrete

Periwinkle Shell Replacement (%)	Coarse Aggregate Replacement (%)	Water Absorption (%)
0	100	2.68
10	90	3.04
20	80	3.50
30	70	3.99
40	60	4.58

The results show that water absorption increased as the percentage of periwinkle shell replacement increased. The control mix recorded the lowest value (2.68%), while the 40% replacement reached the highest (4.58%). This is attributed to the higher porosity and lower density of the periwinkle shell aggregates compared to granite.

Concrete mixes with 10–20% replacement displayed moderate absorption levels (<3.5%), which remain within the acceptable limit of 5% for durable concrete according to ASTM C642-13. According to BS 812-2:1995 and ASTM C127 (2015), water absorption values below 3% are considered low and indicative of dense, durable aggregates suitable for structural concrete. Values between 3–4% represent moderate absorption, while values above 4% indicate high absorption and potential durability concerns in aggressive environments as shown in Table 3.1.

4.4 Summary of Findings

Based on the results obtained, the following key findings were made:

i. The study showed that the use of metakaolin (admixture) helps to improve the workability in concrete.

ii. The compressive, flexural (bending), and tensile strength obtained during this study show sign of reduction as the percentage of periwinkle shells were increased.

iii. The optimum value recorded for the 10% replacement at 28-days curing period for compressive, flexural and split tensile strength are 19.56 N/mm^2, 4.13 N/mm^2, 3.60 N/mm^2.

iv. Water absorption tends to increase as the percentage of periwinkle shells were increased.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This study investigated the effect of using periwinkle shells as a partial replacement for coarse aggregate in concrete with admixtures. A series of experimental tests were conducted to evaluate the physical, mechanical, and durability properties of the resulting concrete mixes. The tests performed include sieve analysis, workability, specific gravity, moisture content, silt content, cement properties, aggregate impact value (AIV), aggregate crushing value (ACV), compressive strength, split tensile strength, flexural strength, and water absorption.

The following conclusions were drawn from the findings:

i. Physical Properties of Aggregates: The sieve analysis confirmed that periwinkle shells met the grading requirements of BS EN 12620 for aggregates but exhibited lower angularity compared to granite. The specific gravity of periwinkle shells (2.685) was slightly lower than that of granite (2.745), indicating that concrete produced with periwinkle shells will have reduced density, leading to lighter-weight concrete. Moisture content tests revealed that periwinkle shells had higher water absorption due to their porous structure, emphasizing the need for careful water–cement ratio adjustment.

ii. Mechanical Properties of Concrete: Compressive strength decreased progressively with higher percentages of periwinkle shell replacement. While the control (0%) achieved an average compressive strength of 20.85 N/mm² at 28 days, the 40% replacement level recorded 16.08 N/mm². This shows that strength reduction is proportional to the replacement level. Split tensile strength followed a similar trend, reducing from 3.87 N/mm² (control) at 28 days to 2.08 N/mm² at 40% replacement.

Flexural strength also declined with increasing replacement, dropping from 5.96 N/mm^2 at 28 days (control) to 2.44 N/mm^2 at 40% replacement.

iii. Durability Properties: The AIV and ACV results indicated that granite aggregates possess excellent resistance to impact and crushing, while periwinkle shells exhibited high AIV (50.44%) and ACV (29.45%), suggesting they are weaker and less suitable for high-load structural applications. Water absorption increased with higher replacement levels, rising from 2.68% at 0% replacement to 4.58% at 40% replacement. All values, however, remained within the acceptable range (< 5%) specified for structural concrete.

iv. Overall Performance: Partial replacement of coarse aggregates with periwinkle shells up to 10% can still yield concrete of acceptable compressive strength and durability for non-load-bearing and lightweight construction applications. Higher replacement levels (20–40%) result in significant reductions in strength and should be limited to non-structural applications such as paving concrete cubes, partition walls, and lightweight panels. The inclusion of admixtures improved workability, as indicated by the slump test results, making periwinkle shell concrete more workable with increasing replacement levels.

In conclusion, while periwinkle shells are not suitable as a full substitute for coarse aggregates in structural concrete, they hold significant potential as a sustainable and eco-friendly alternative for partial replacement (≤ 10% as optimum replacement), especially in lightweight and non-structural applications. Their use also contributes to waste management and the promotion of environmentally friendly construction practices.

5.2 Recommendations

Based on the findings of the study, the following recommendations are made:

1. A comprehensive study on the long-term durability of the modified concrete is necessary, particularly focusing on volume stability (shrinkage/creep) and resistance to chemical attacks (sulphates).
2. Further research should use Scanning Electron Microscopy (SEM) to better understand the poor bonding and porosity within the Interfacial Transition Zone (ITZ) between the smooth shell surface and the cement matrix.
3. Studies should be conducted to evaluate the effect of various pre-treatment methods on the periwinkle shells to improve bonding. Options to explore include surface roughening (light acid etching or sandblasting) and coating the shells with materials like silane or fly ash slurry to reduce water absorption and enhance the ITZ strength.
4. A detailed Life Cycle Assessment (LCA) and cost-benefit analysis should be assessed. This is essential to quantify the environmental impact (reduction in quarrying and waste) and the economic feasibility of using periwinkle shells versus traditional aggregates in local construction markets.

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APPENDIX

A. Physical Properties of the Material Used for the Study

A.1 Particle Size Distribution Test

Table A.1: Fine Aggregate Particle Size Distribution

SIEVE ANALYSIS RESULT OF FINE AGGREGATE				
BS SIEVE SIZE (mm)	**WEIGHT RETAINED (Kg)**	**CUMULATIVE WEIGHT RETAINED (Kg)**	**CUMULATIVE % WT. RETAINED (Kg)**	**CUMULATIVE % WT. PASSING (Kg)**
2.36mm	4.76	4.8	4.8	95.2
2.00mm	8.13	8.1	12.9	87.1
1.18mm	15.24	15.2	28.1	71.9
600µm	19.87	19.9	48.0	52.0
425µm	16.72	16.7	64.7	35.3
300µm	14.16	14.2	78.9	21.1
212µm	9.78	9.8	88.7	11.3
150µm	6.94	6.9	95.6	4.4
75µm	4.40	4.4	100.0	0.0
Lower Than 75µm	-----------------	-----------------	**0**	**0**
TOTAL	**1998.1**		**421.7461**	
HENCE FINENESS MODULUS (F.M.) = 4.22				

Table A.2: Periwinkle Shell Aggregate Particle Size Distribution

SIEVE ANALYSIS RESULT OF PERIWINKLE SHELL AGGREGATE				
BS SIEVE SIZE (mm)	**WEIGHT RETAINED (Kg)**	**CUMULATIVE WEIGHT RETAINED (Kg)**	**CUMULATIVE % WT. RETAINED (Kg)**	**CUMULATIVE % WT. PASSING (Kg)**
20mm	23.4	23.4	1.171112557	98.82888744
19mm	1727	1750.4	87.60322306	12.39677694
13.36mm	228.2	1978.6	99.02407287	0.975927131
10mm	2	1980.6	99.12416796	0.87583204
8mm	0	1980.6	99.12416796	0.87583204
5mm	17.5	1998.1	100	0
2.36mm	-----------------	-----------------	100	0
1.18mm	-----------------	-----------------	100	0
600µm	-----------------	-----------------	100	0
300µm	-----------------	-----------------	100	0
150µm	-----------------	-----------------	100	0
Lower Than 150µm	-----------------	-----------------		0
TOTAL	1998.1		986.0467444	
HENCE FINENESS MODULUS (F.M.) = 9.86				

Table A.3: Coarse Aggregate Particle Size Distribution

SIEVE ANALYSIS OF COARSE AGGREGATE (GRANITE)				
BS SIEVE SIZE (mm)	WEIGHT RETAINED (Kg)	CUMULATIVE WEIGHT RETAINED (Kg)	CUMULATIVE % WT. RETAINED (Kg)	CUMULATIVE % WT. PASSING (Kg)
20mm	0	0	0	100
19mm	0	0	0	100
13.36mm	449.8	449.8	22.50609186	77.49390814
10mm	736	1185.8	59.33242268	40.66757732
8mm	749	1934.8	96.80921859	3.190781409
5mm	63.77	1998.57	100	0
2.36mm	----------------	----------------	100	0
1.18mm	----------------	----------------	100	0
600µm	----------------	----------------	100	0
300µm	----------------	----------------	100	0
150µm	----------------	----------------	100	0
Lower Than 150µm	----------------	----------------		0
TOTAL	1998.57		778.6477331	
HENCE FINENESS MODULUS (F.M.) = 7.79				

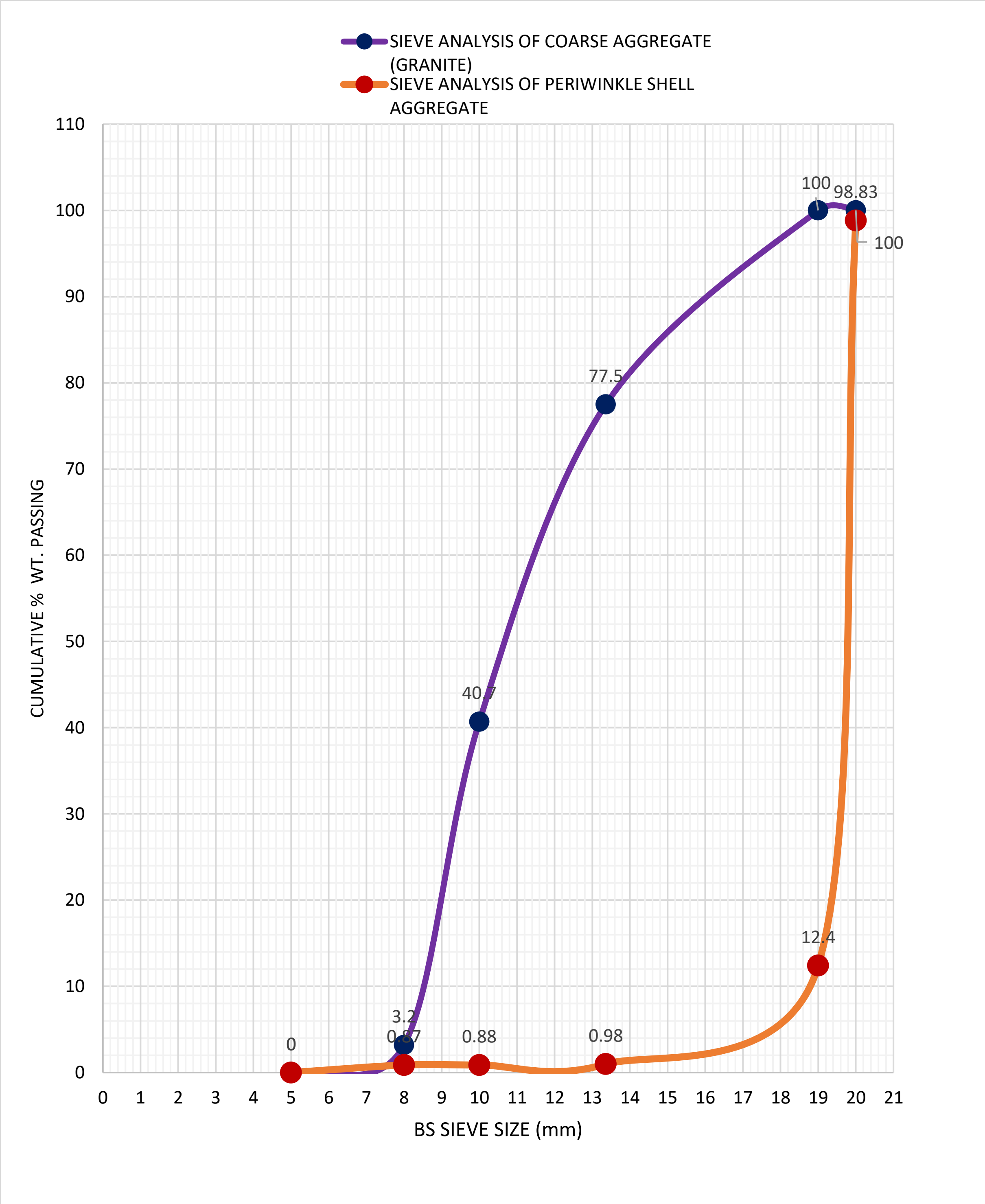

Figure A.1: Particle Size Distribution Periwinkle Shell and Coarse Aggregates.

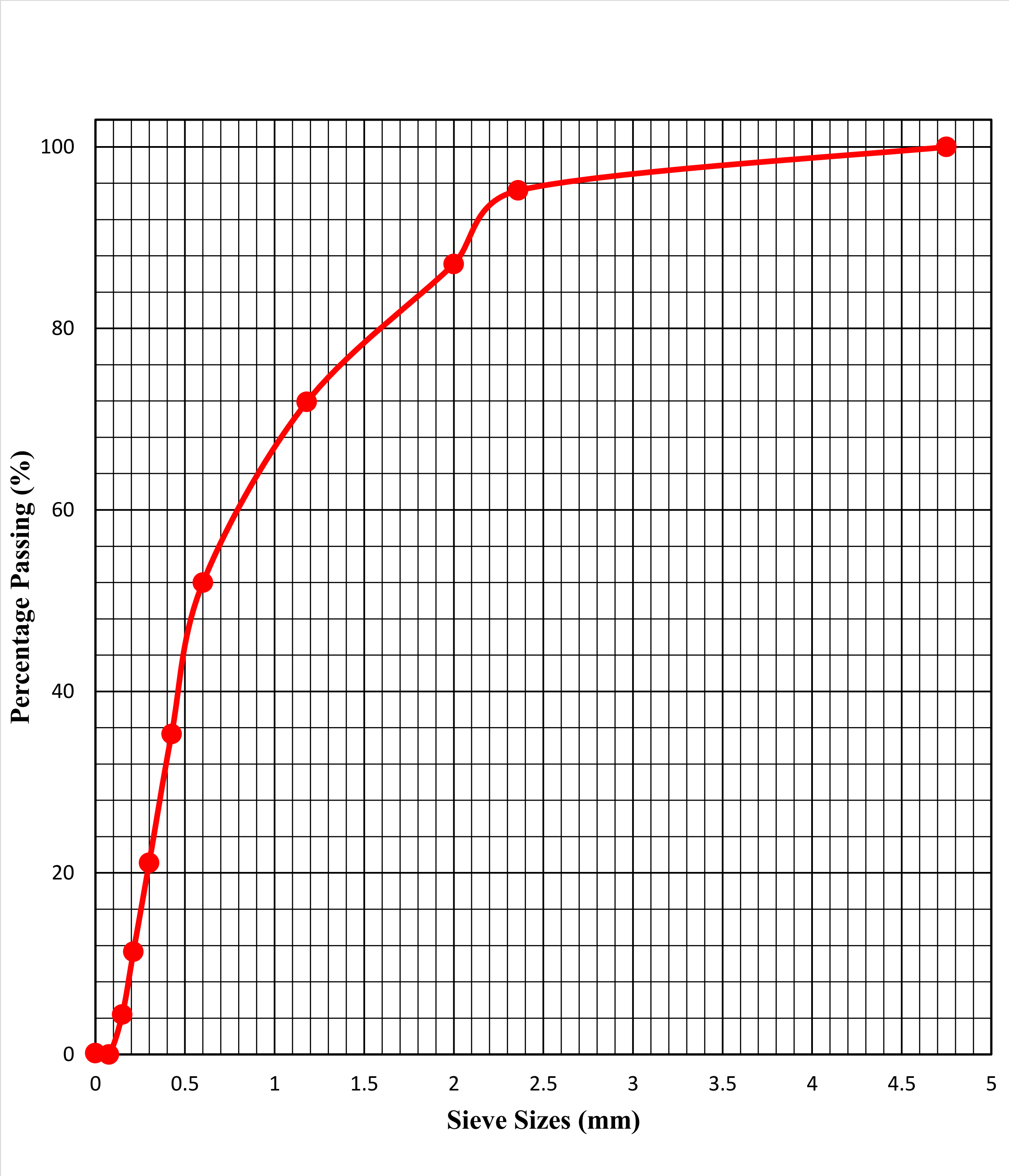

Figure A.2: Particle Size Distribution of Fine Aggregates.

A.2 Specific Gravity Results

Table A.4: Specific gravity for Granite

Bottle No		NO	TZ
Weight of pycnometer(g).	W1	22.72	20.84
Weight of pycnometer + Granite	W2	45.67	44.44
Weight of pycnometer + water + Granite	W3	91.02	90.23
Weight of pycnometer + water.	W4	76.37	75.31
Specific gravity		2.76	2.73
Specific gravity		2.745	

Table A.5: Specific gravity for Periwinkle shell

Bottle No		J2	DK
Weight of pycnometer(g).	W1	28.03	26.88
Weight of pycnometer + Periwinkle	W2	51.22	50.74
Weight of pycnometer + water + Periwinkle	W3	93.41	91.88
Weight of pycnometer + water.	W4	78.95	76.81
Specific gravity		2.656	2.714
Specific gravity		2.685	

A.3 Moisture Content Results

Table A.6: Moisture Content for Periwinkle shell

Can No.		**GB**	**N**
Can Weight + Wet (g).	W1	51.06	54.66
Can Weight + Dry (g).	W2	48.42	51.25
Empty Can Weight (g).	W3	21.32	21.00
Moisture Content (%)		9.81	11.68
Moisture Content (%)		10.745	

A.4 Silt Content Test Results

Table A.7: Silt Content Result for Fine Aggregate

Can No.		**DK**	**P2**	**MR**
Vol. of Sample (mL)	V1	97.8	95.9	95.1
Vol. of Silt after 3hr (mL)	V2	2.0	2.0	1.9
% of Silt		2.04	2.03	2.08
Average % of Silt		2.05		

Table A.8: Silt Content Result for Periwinkle shell

Can No.		DK	P2	MR
Vol. of Sample (mL)	V1	98.0	96.0	94.0
Vol. of Silt after 3hr (mL)	V2	2.0	2.0	2.0
% of Silt		2.04	2.08	2.13
Average % of Silt		2.08		

A.7 Cement Test Results

Table A.9: Properties of OPC cement

Properties	Values
Normal Consistency	7mm
Initial Setting time	95min
Final Setting time	238 min

B. Mechanical Properties of Modified Concrete

B.1 Compressive Test Results

Table B.1-B.3 below shows the results of the compressive strength test at 7, 14, and 28 days respectively.

Table B.1: 7-day Compressive Test Results

Replacement (%)	Sample	Weight (kg)	Density (kg/m³)	Failure Load (kN)	Compressive Strength (N/mm²)	Average compressive strength (N/mm²)
0 (control)	Mix 1	2.594	2594	132.34	13.234	16.032
	Mix 2	2.576	2576	188.49	18.849	
	Mix 3	2.601	2601	160.12	16.012	
10	Mix 1	2.565	2565	136.52	13.652	14.289
	Mix 2	2.547	2547	148.11	14.811	
	Mix 3	2.558	2558	144.03	14.403	
20	Mix 1	2.519	2519	140.01	14.001	13.352
	Mix 2	2.532	2532	141.00	14.100	
	Mix 3	2.510	2510	139.56	13.956	
30	Mix 1	2.478	2478	115.23	11.523	11.422
	Mix 2	2.465	2465	113.02	11.302	
	Mix 3	2.480	2480	114.40	11.440	
40	Mix 1	2.438	2438	106.72	10.672	10.639
	Mix 2	2.423	2423	105.01	10.501	
	Mix 3	2.430	2430	107.45	10.745	

Table B.2: 14-day Compressive Test Results

Replacement %	Sample	Weight (kg)	Density (kg/m³)	Failure Load (kN)	Compressive Strength (N/mm²)	Average compressive strength (N/mm²)
0 (control)	Mix 1	2.621	2.621	2613	168.23	16.989
	Mix 2	2.584	2584	171.56	17.156	
	Mix 3	2.623	2623	169.87	16.987	
10	Mix 1	2.560	2560	165.45	16.545	16.470
	Mix 2	2.551	2551	163.88	16.388	
	Mix 3	2.549	2558	164.77	16.477	
20	Mix 1	2.531	2531	158.34	15.834	15.758
	Mix 2	2.516	2516	156.79	15.679	
	Mix 3	2.522	2522	157.60	15.760	
30	Mix 1	2.480	2480	150.23	15.023	14.948
	Mix 2	2.487	2487	148.67	14.867	
	Mix 3	2.493	2493	149.54	14.954	
40	Mix 1	2.457	2457	132.36	13.236	13.148
	Mix 2	2.451	2451	130.79	13.079	
	Mix 3	2.449	2449	141.28	14.128	

Table B.3: 28-day Compressive Test Results

Replacement %	Sample	Weight (kg)	Density (kg/m³)	Failure Load (kN)	Compressive Strength (N/mm²)	Average compressive strength (N/mm²)
0 (control)	Mix 1	2.613	2613	210.13	21.013	20.845
	Mix 2	2.607	2607	208.45	20.345	
	Mix 3	2.602	2602	211.78	21.178	
10	Mix 1	2.582	2582	193.22	19.322	19.558
	Mix 2	2.567	2567	200.67	20.067	
	Mix 3	2.571	2571	192.85	19.285	
20	Mix 1	2.523	2523	185.40	18.540	18.469
	Mix 2	2.509	2509	183.96	18.396	
	Mix 3	2.516	2516	184.72	18.472	
30	Mix 1	2.482	2482	173.88	17.388	17.314
	Mix 2	2.471	2471	172.45	17.245	
	Mix 3	2.478	2478	173.10	17.310	
40	Mix 1	2.430	2430	162.51	16.251	16.077
	Mix 2	2.418	2418	158.03	15.803	
	Mix 3	2.425	2425	161.78	16.178	

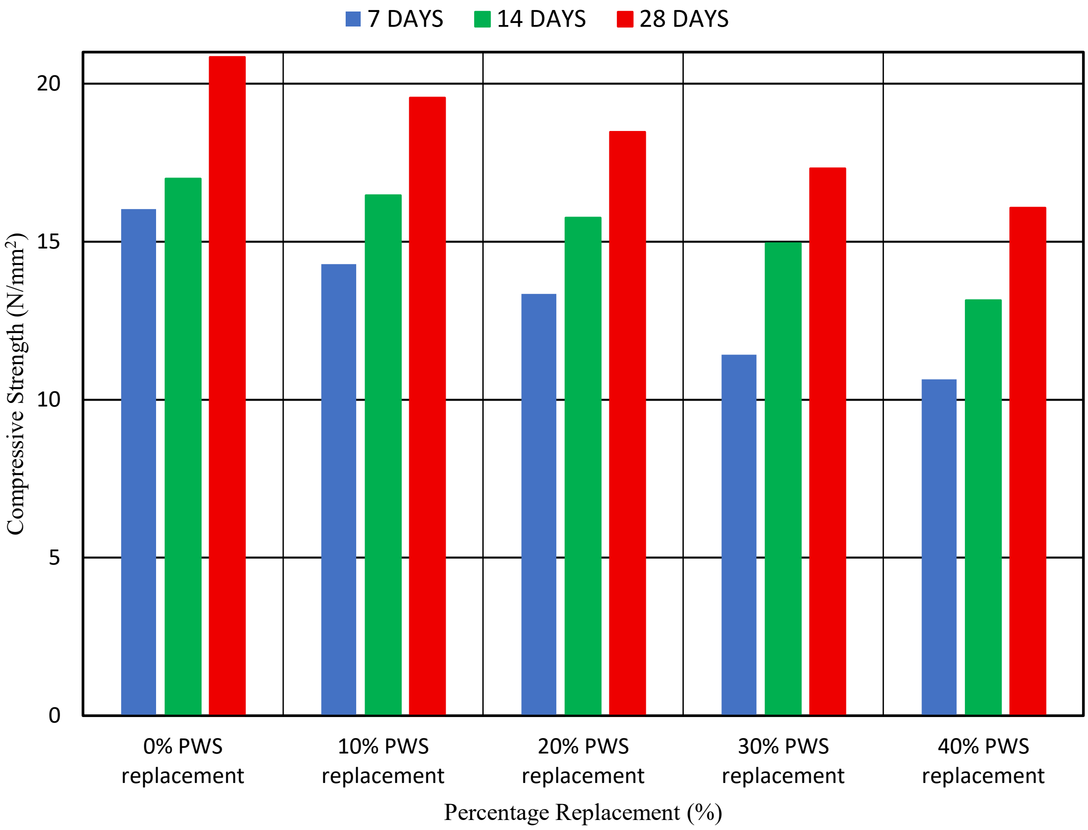

Figure B.1: Compressive Strength Test Result Chart

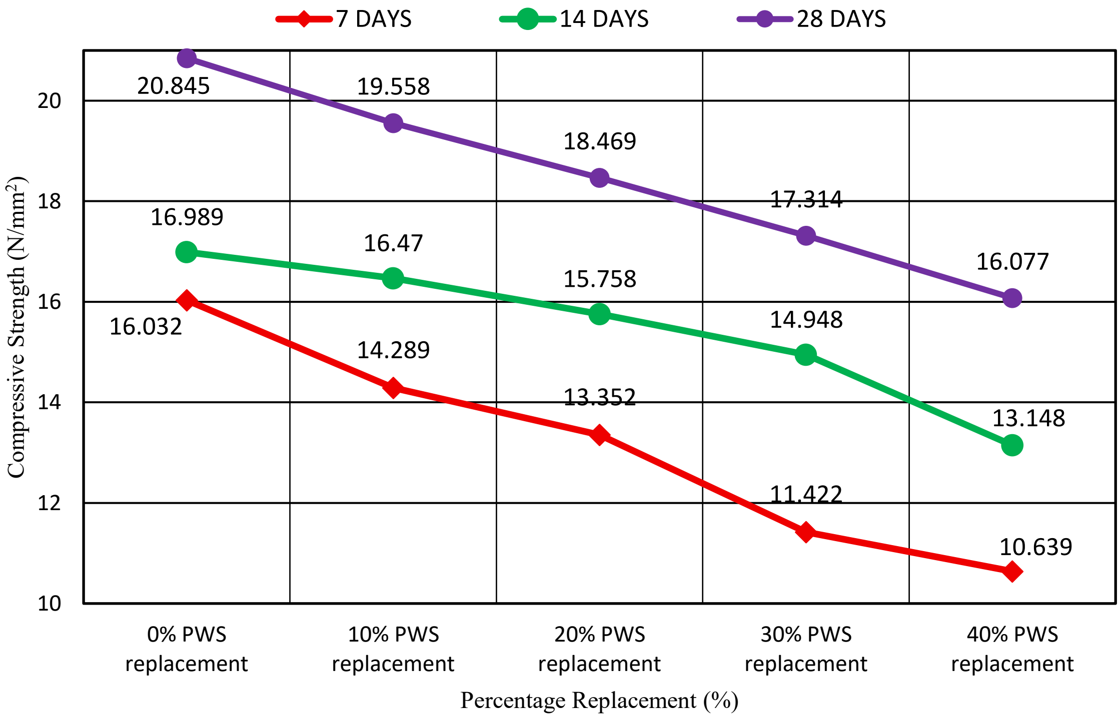

Figure B.2: Compressive Strength Test Result Graph

B.2 Split Tensile Strength Test

The Table B.4-B.6 below shows the results of the split tensile test at 7, 14 and 28 days.

Table B.4: Split Tensile Strength Test Results at 7days

SPLIT TENSILE STRENGTH (7 DAYS)						
Percentage of replacement	**Compressive Strength (kN)**		**Average Strength (kN)**	**Weight of Cylinder (kg)**		**Strength (N/mm^2)**
	1	2		1	2	
0%(Control)	79.101	83.052	**81.077**	4.693	4.678	**2.581**
10%	77.553	73.268	**75.410**	4.542	4.528	**2.400**
20%	68.876	54.094	**61.485**	4.332	4.240	**1.957**
30%	43.847	45.025	**44.436**	4.043	4.200	**1.414**
40%	50.952	36.277	**43.614**	3.944	3.725	**1.388**

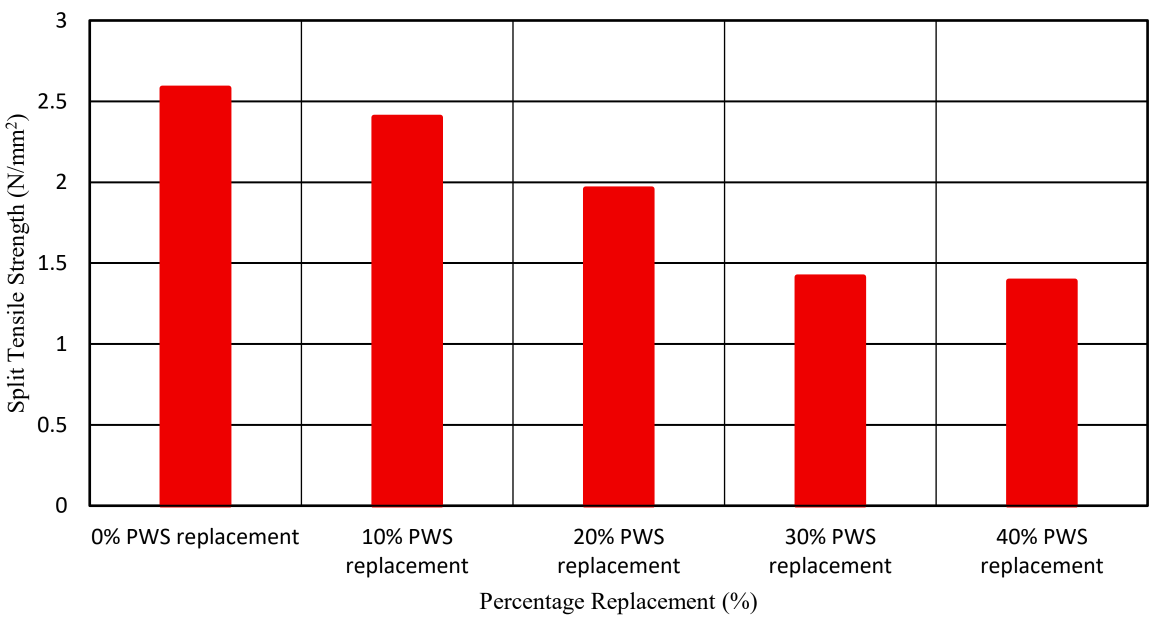

Figure B.3: Split Tensile Strength Test Result Chart

Table B.5: Split Tensile Strength Test Results at 14days

SPLIT TENSILE STRENGTH (14 DAYS)						
Percentage of replacement	**Compressive Strength (kN)**		**Average Strength (kN)**	**Weight of Cylinder (kg)**		**Strength (N/mm^2)**
	1	**2**		**1**	**2**	
0%(Control)	97.922	94.379	96.150	4.715	4.686	3.060
10%	92.604	89.328	90.966	4.565	4.545	2.896
20%	74.580	71.132	72.856	4.355	4.300	2.322
30%	53.186	51.016	52.101	4.060	4.020	1.661
40%	52.232	50.077	51.155	3.965	3.935	1.630

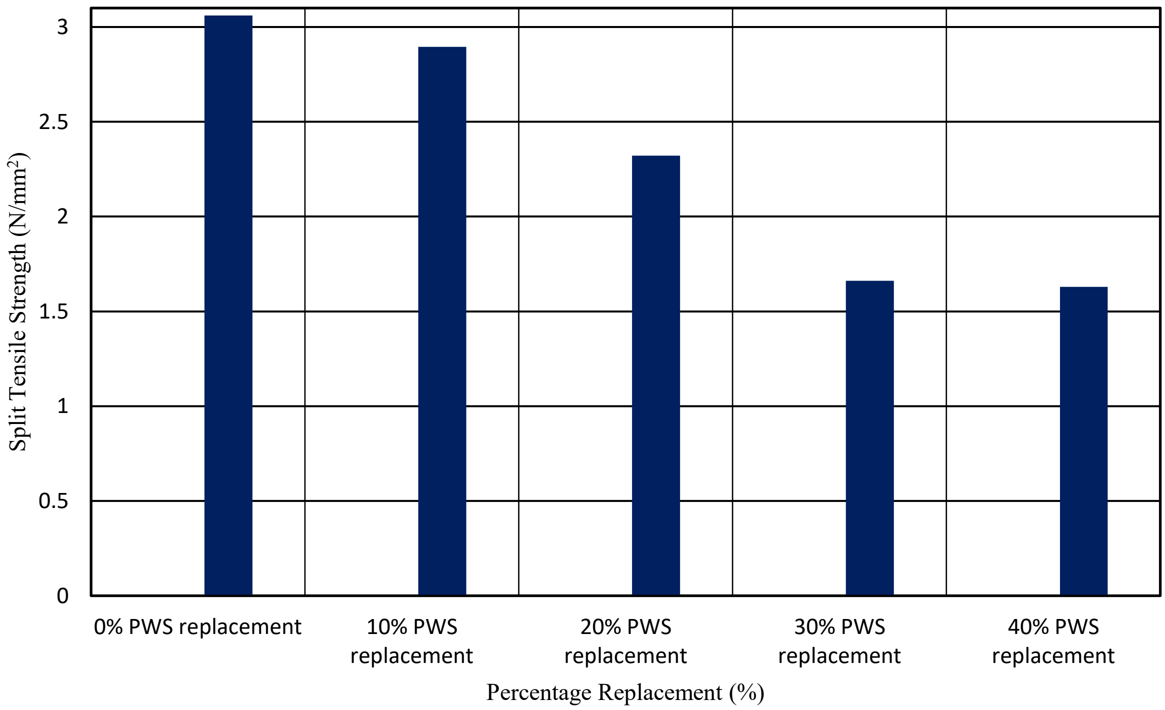

Figure B.4: Split Tensile Strength Test Result Chart

Table B.6: Split Tensile Strength Test Results at 28days

SPLIT TENSILE STRENGTH (28 DAYS)						
Percentage of replacement	**Compressive Strength (kN)**		**Average Strength (kN)**	**Weight of Cylinder (kg)**		**Strength (N/mm^2)**
	1	**2**		**1**	**2**	
0%(Control)	124.048	119.183	121.616	4.740	4.693	3.873
10%	115.377	110.853	113.115	4.587	4.542	3.603
20%	94.072	90.383	92.228	4.375	4.332	2.935
30%	67.987	65.321	66.654	4.083	4.043	2.121
40%	66.729	64.113	65.421	3.983	3.944	2.083

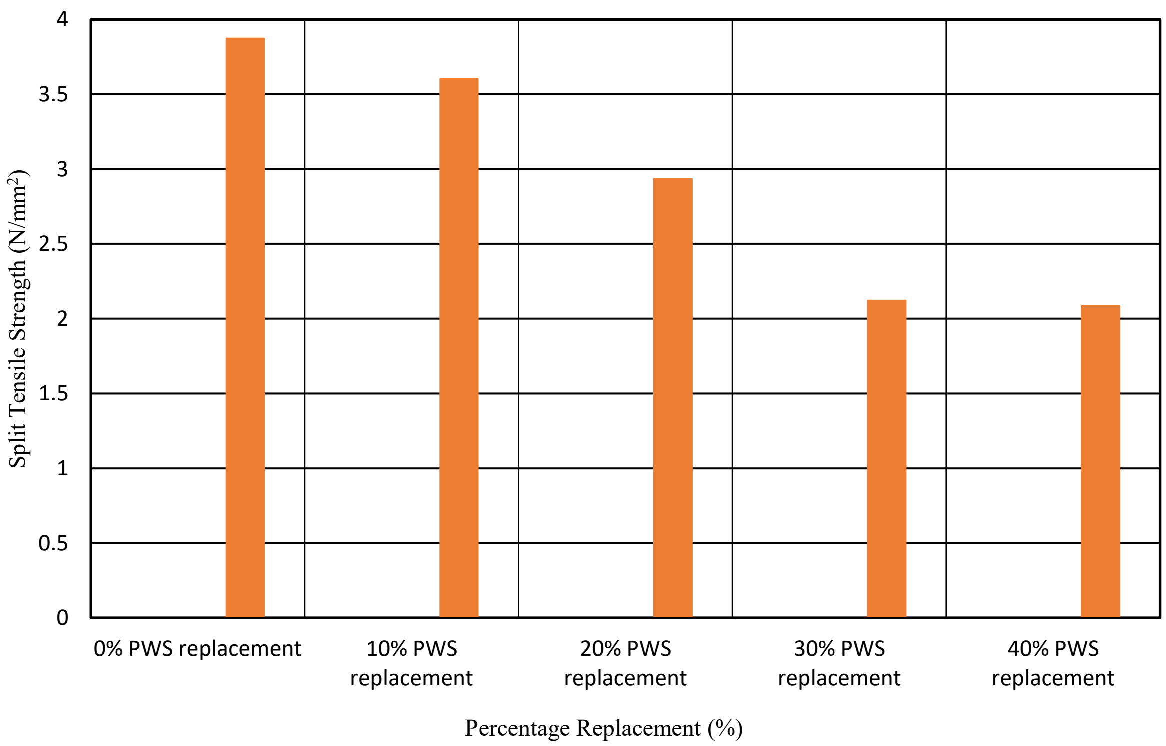

Figure B.5: Split Tensile Strength Test Result Chart

B.3 Flexural Strength Test

The Table B.7-B9 below show the results of the flexural test at 7, 14 and 28 days.

Table B.7: Flexural Strength Test Results at 7 days

FLEXURAL STRENGTH (7 DAYS)						
Percentage of replacement	**Flexural Strength (kN)**		**Average Strength (kN)**	**Weight of Beam (kg)**		**Average Strength (N/mm²)**
	1	**2**		**1**	**2**	
0%(Control)	9.00	11.50	10.25	13.014	12.335	5.125
10%	7.50	6.00	6.75	10.873	11.291	3.375
20%	4.50	4.50	4.50	10.961	11.277	2.250
30%	3.00	4.00	3.50	10.496	10.378	1.750
40%	3.00	3.50	3.25	9.844	8.630	1.625

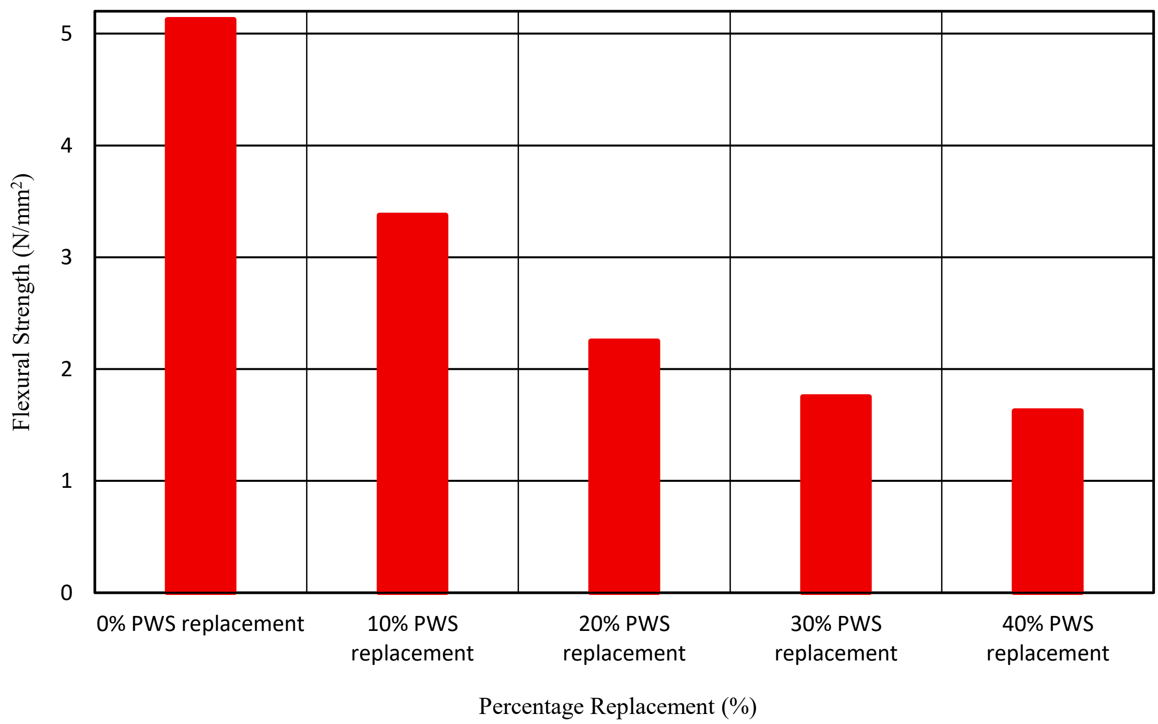

Figure B.6: Flexural Strength Test Result Chart

Table B.8: Flexural Strength Test Results at 14 days

FLEXURAL STRENGTH (14DAYS)						
Percentage of replacement	**Flexural Strength (kN)**		**Average Strength (kN)**	**Weight of Beam (kg)**		**Average Strength (N/mm²)**
	1	**2**		**1**	**2**	
0%(Control)	10.80	12.80	11.30	11.880	11.523	5.150
10%	9.00	7.20	8.10	11.583	10.847	4.050
20%	5.40	5.40	5.40	10.627	10.575	2.700
30%	3.60	4.80	4.20	10.198	10.219	2.100
40%	3.60	4.20	3.90	9.837	9.902	1.950

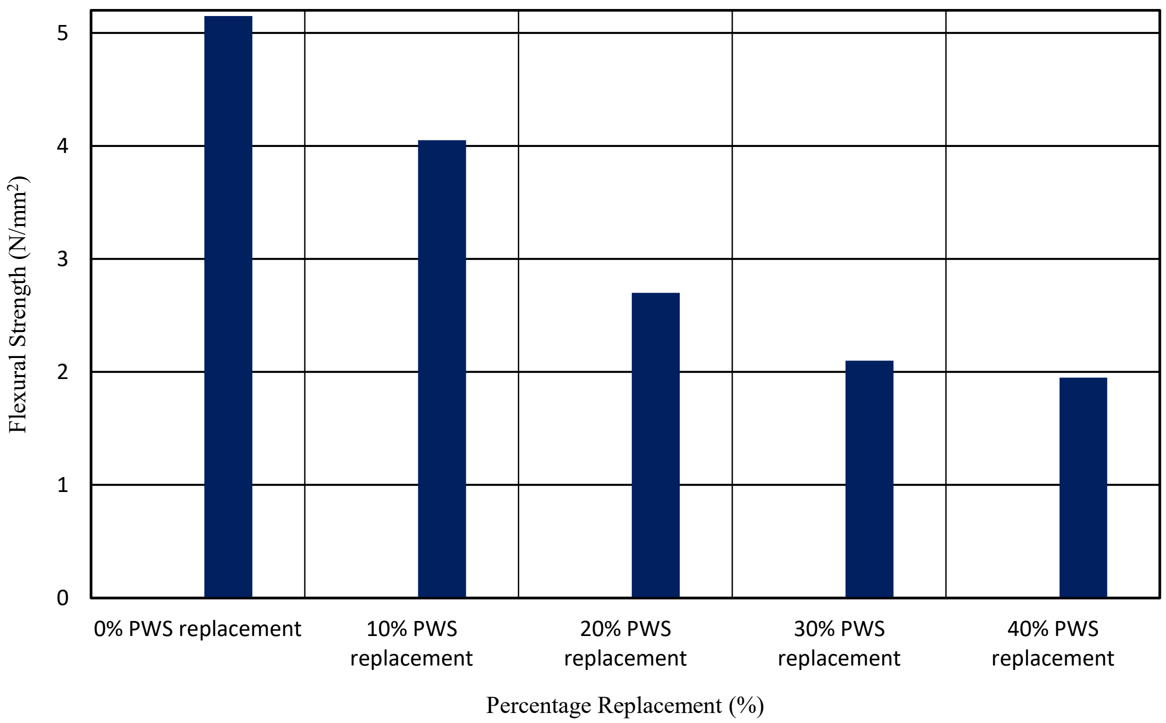

Figure B.7: Flexural Strength Test Result Chart

Table B.9: Flexural Strength Test Results at 28days

FLEXURAL STRENGTH (28 DAYS)						
Percentage of replacement	**Flexural Strength (kN)**		**Average Strength (kN)**	**Weight of Beam (kg)**		**Average Strength (N/mm²)**
	1	**2**		**1**	**2**	
0%(Control)	12.00	12.00	12.00	12.014	12.522	5.96
10%	8.00	8.50	8.25	11.821	12.119	4.125
20%	7.00	9.00	8.00	11.487	11536	4.022
30%	4.50	6.00	5.25	12.043	12.200	2.625
40%	4.50	5.25	4.88	10.385	9.974	2.438

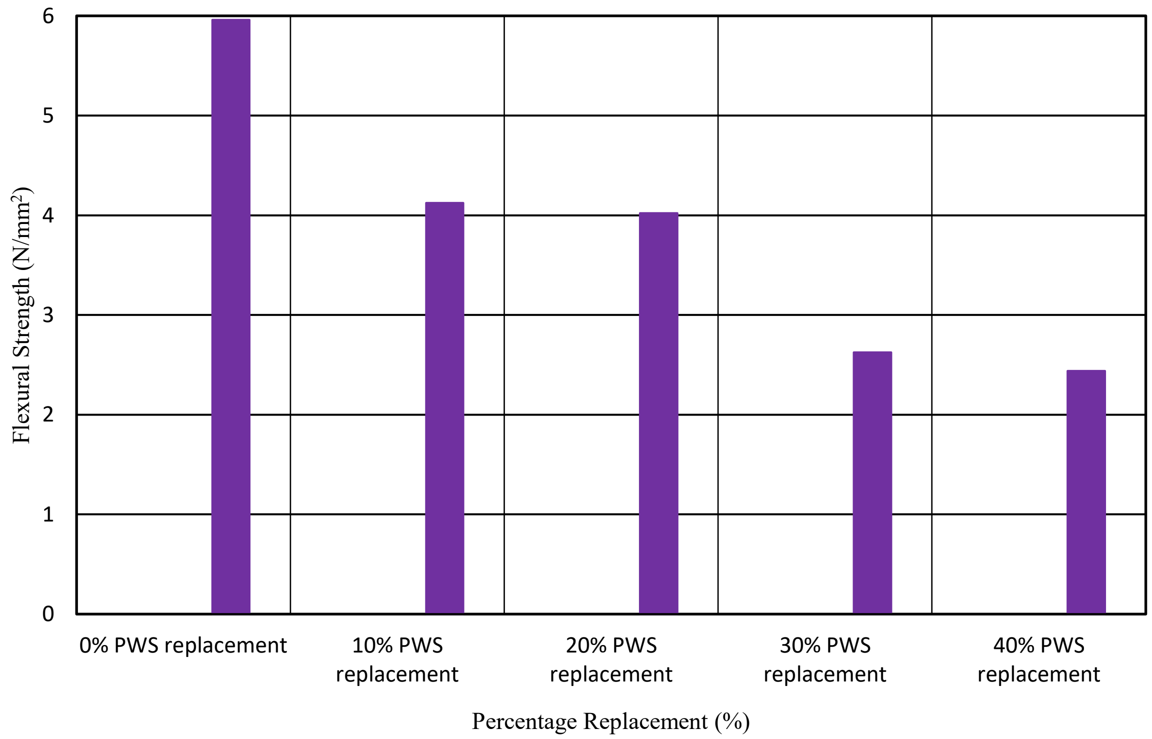

Figure B.8: Flexural Strength Test Result Chart

B.4 Water Absorption Test

The Table B.10 below show the results of the water absorption test at 28 days.

Table B.10: Water Absorption Test Results at 28days

Replacement %	Dry mass (kg) Spec 1	Sat mass (kg) Spec 1	Abs% Spec 1	Dry mass (kg) Spec 2	Sat mass (kg) Spec 2	Abs% Spec 2	Avg Abs%
0% (Control)	2.602	2.671	2.65	2.588	2.658	2.71	2.68
10%	2.556	2.633	3.01	2.542	2.620	3.07	3.04
20%	2.507	2.595	3.51	2.491	2.578	3.49	3.50
30%	2.463	2.561	3.98	2.449	2.547	4.00	3.99
40%	2.426	2.537	4.57	2.414	2.525	4.59	4.58

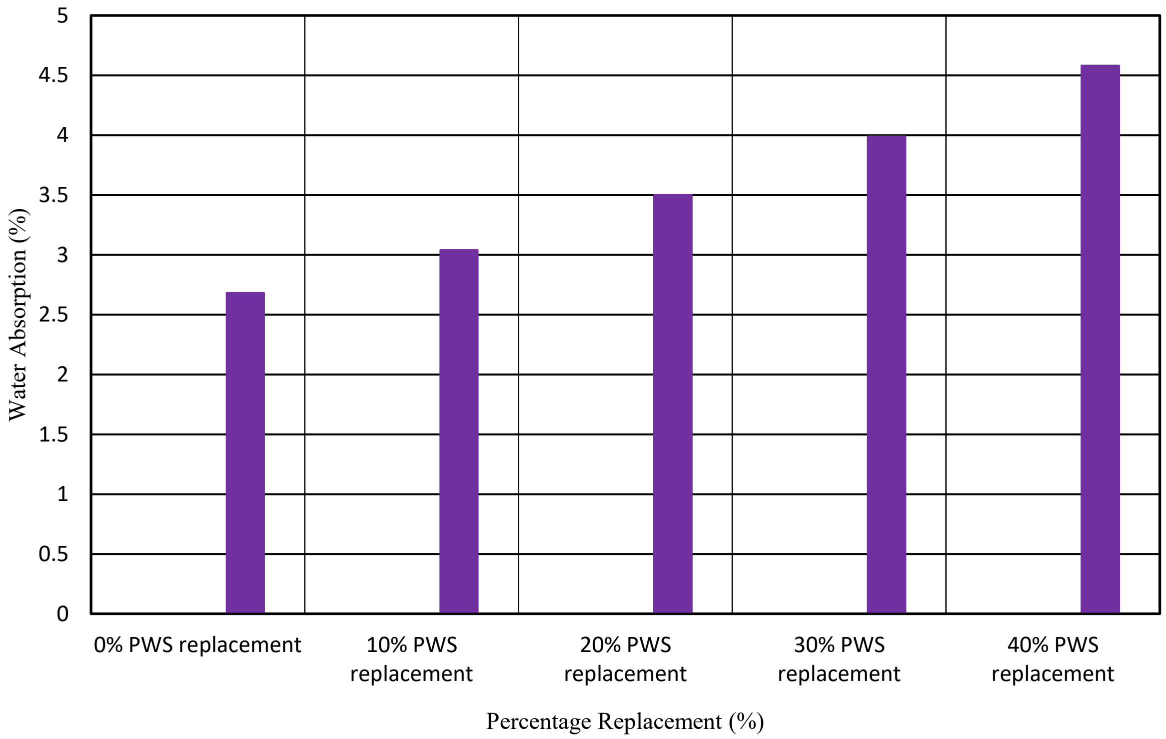

Figure B.9: Water Absorption Test Result Chart

B.5 Workability Test Results

Test results from slump test carried out are as follows

Table B.11: Slump Test Results

REPLACEMENT PERCENTAGE	SLUMP VALUE (mm)
0% Periwinkle Shell replacement	23
10% Periwinkle Shell replacement	31
20% Periwinkle Shell replacement	35
30% Periwinkle Shell replacement	44
40% Periwinkle Shell replacement	52

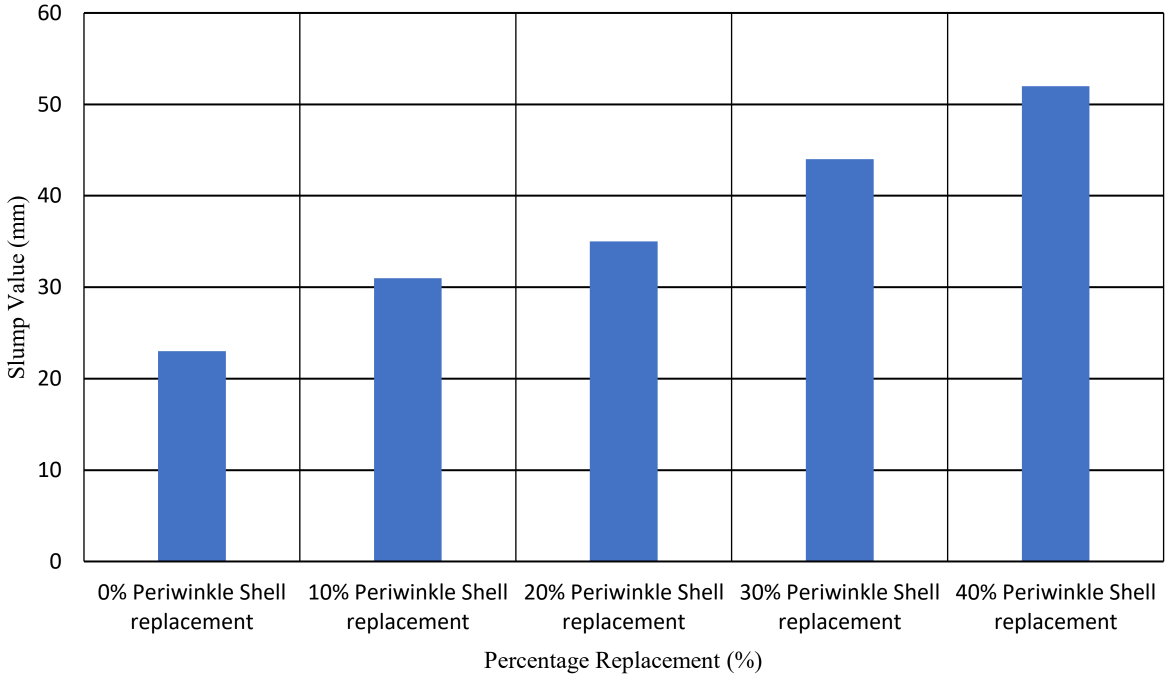

Figure A.3: Chart variation of Slump of Concrete with Periwinkle Shell Replacement

B.6 AIV and ACV Test Results

Table B.12: AIV Test Results for Granite

Mass	TEST A	TEST B	TEST C
M1 (g)	310	310	310
M2 (g)	40	32	30
M3 (g)	280	286	285
M2 + M3 (g)	320	318	315
Loss (g)	1.0	0.8	0.5
AIV	12.9	10.32	9.67

Average AIV =10.96

Table B.13: AIV Result Interpretation

AIV	CLASSIFICATION
< 10%	Exceptionally Strong
10 – 20%	Strong
20- 30%	Satisfactory for road surfacing
>35%	Weak for road surfacing

Table B.14: AIV Test Results for Periwinkle Shell

Mass	TEST A	TEST B	TEST C
M1 (g)	302	302	302
M2 (g)	150	155	152
M3 (g)	151	146	149
M2 + M3 (g)	301	301	301
Loss (g)	1.0	1.0	1.0
AIV	49.67	51.32	50.33

Average AIV =50.44

Table B.15: ACV test results for Granite

Mass	TEST
M1 (g)	2785
M2 (g)	506.9
M3 (g)	1976.3
ACV	18.283

Table B.16: ACV test results for Periwinkle shell

Mass	TEST
M1 (g)	2735
M2 (g)	805.5
M3 (g)	1929
ACV	29.452

Table B.17: ACV result interpretation

ACV Range (%)	Quality Assessment
< 20%	Excellent
20-25%	Good
25-30%	Satisfactory
30-35%	Fair
> 35%	Poor

C. Photographs from the laboratory work

Plate C.1: Sieving of Fine Aggregate for Proper Aggregate Proportioning

Plate C.2: Mixing of Concrete using a Concrete Mixer

Plate C.3: Pouring of Concrete into Molds

Plate C.4: Slump Test being carried out

Plate C.5: Flexural Testing being carried out

Plate C.6: Compressive Testing being carried out

Plate C.7: Fine Aggregate Testing