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The Effect of Using Snail Shell Ash and Glass Powder in Concrete

Adefisoye S. A.[1, a] Alli P. A[1, b], Adebayo K. J.[1, c], Olaomotito P. A.[1, d], Awos, O. A.[1, e],

[1]*Department of Civil Engineering, Lead City University, Nigeria*

Abstract - *The rising environmental concerns associated with cement production have driven the need for alternative, sustainable materials in construction. One such approach is the partial replacement of Portland Limestone with supplementary materials derived from waste. This study explores the potential of snail shell powder (SSP) and glass powder (GP) as partial replacements for Portland Limestone in concrete. The objective was to evaluate the fresh and hardened properties of concrete produced with these materials to assess their suitability for structural applications. Concrete was prepared using a constant mix ratio of 1:2:4 and a fixed water cement ratio of 0.65 through which four mix compositions were developed, a control mix containing 100% Limestone, and three other mixes with 20% total cement replacement using various proportions of GP and SSP (15% GP + 5% SSP, 10% GP + 10% SSP, and 5% GP + 15% SSP). Material characterization included specific gravity, moisture content, and sieve analysis. Fresh concrete was tested for workability using the slump test, while hardened concrete was evaluated through water absorption and compressive strength at 7, 14, and 28 days of curing. The results showed that incorporating GP and SSP reduced workability but supported gradual strength gain over time. The mix with 15% GP and 5% SSP achieved the highest 28-day compressive strength of 21.60 N/mm², while water absorption decreased across all mixes with curing age. All mixes exhibited acceptable strength and durability performance.*
It is recommended that a moderate inclusion of GP and SSP in concrete production be encouraged for use in non-structural and light structural applications. This promotes environmental sustainability by reducing cement use and encouraging waste recycling without significantly compromising performance.

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I. INTRODUCTION

Concrete is a pivotal material in modern construction, recognized for its exceptional strength, resilience, durability, and versatility, making it a fundamental building material (Jorgene *et al.,* 2023). Concrete feature an important construction binding material which is cement. Cement is a binder and a chemical substance used in construction that sets, hardens and adheres to other materials to bind them together. Its main function is to act as hydraulic binder, which increases the bond between fragmented particles, so it can enable their use in different fields. The evolution of concrete has seen advancements in formulations, such as high-performance concrete and eco-friendly alternatives, which has enhanced sustainability (Mehta and Monteiro, 2006). Innovations like self-healing concrete are also emerging, addressing maintenance challenges and extending lifespan (Zhang *et al.,* 2024). The use of advanced additives and reinforcement techniques has further improved concrete performance in various environments (Bhatt *et al.,* 2023). Additionally, the integration of technology in mixing and curing processes has optimized its application, and concrete itself has continue to adapt to the changing demands of architecture and engineering, highlighting its importance in the built environment (Meraz *et al.,* 2023).

However, the demand for construction materials has surged in many countries worldwide. This increase coincides with rapid growth in construction activities, including housing and other types of buildings, alongside rising production costs and a significant shortage of essential materials. As a result, exploring alternative materials and techniques to enhance the sustainability and efficiency of concrete production has become a pressing concern (Sashidar and Rao, 2010). This shift in perspective stems from the need to improve concrete physical and mechanical properties while considering environmental concerns, such as reducing carbon emissions, minimizing waste, and conserving natural resources (Jorgene *et al.,* 2023). Portland Limestone is associated with several environmental problems, primarily due to its production process, which generates significant carbon dioxide (CO_2) emissions. For every ton of OPC produced, approximately one ton of CO_2 is released into the atmosphere (Jorgene *et al.,* 2023). Additionally, solid and unreinforced cement concrete with a low water-to-cement ratio have been developed in a range of sizes and concrete grades to meet the demands of diverse environmental conditions, such as pavement and buildings applications (Mehta and Monteiro, 2006). To mitigate these environmental impacts, reducing the reliance on Portland limestone by incorporating industrial and agricultural waste materials, such as Glass Powder (GP) and Snail Shell Ash (SSA), can be effective. This substitution not only decreases the amount of cement required but also significantly reduces CO_2 emissions associated with concrete production. The increasing interest in exploring alternative materials and techniques for concrete production has paved the way for developing more sustainable and eco-friendly construction practices. One promising avenue is the incorporation of pulverized apple snail shells, which offer unique characteristics and potential benefits (Jorgene *et al.,* 2023).

Snail Shell is a waste product obtained from the consumption of a small greenish blue marine snail, which rests in a V shaped spiral shell, found in many coastal regions (Zaid *et al.,* 2014). These shells are very strong, hard and brittle material. These snails are found in the lagoons and mudflats of the coastal areas, the people in this area consume the edible part as sea food and dispose the shell as a waste product, but a large amount of these shells are still disposed off as waste. This invariably heightens the nuisance value of the huge deposits of solid waste which dot major towns and cities in this part of the globe (Adeala and Olaoye, 2019). Studies have shown that every year, seafood industry alone generates over 100 million pounds (45.3 million kg) of waste that is strictly from shellfish and crustaceans (Solanski *et al.,* 2009), and most of these are ultimately sent to landfills. Therefore, snail shell being what it is and with all the properties it possess should be useful for something else, if well processed, especially as a partial replacement of cement, as people have being so curious for some time now about finding an alternative to OPC that would be cheaper, readily available and requiring indigenous technology and equipment (Zaid *et al.,* 2014).

Glass is a non-crystalline amorphous transparent solid with a wide range of practical, technological, and decorative applications. Based on the chemical substance silica, which is the main component of sand, "silicate glasses" are the most well-known and historically the oldest varieties of glass (Islam *et al.,* 2024). In common parlance, the word "glass" usually refers only to this kind of substance, which is well-known from its use as window glass and in glass bottle. Among the various silica-based glasses that are available, soda-lime glass is the type that is used to make regular glazing and container glass. It is made up of roughly 75% silicon dioxide (SiO_2), sodium oxide (Na_2O), sodium carbonate (Na_2CO_3), calcium oxide (CaO), also known as lime, and a few small additives. Because of its optical clarity, silicate glasses have several uses, the most common of which is as window panes (Islam *et al.,* 2017). Glass can be cut and polished to create optical lenses, prisms, fine glassware, and optical fibers for high-speed data transmission by light. Glass can be painted or printed using vitreous enamels, or it can be tinted by adding metallic salts. Due to these characteristics, glass is frequently used to create artwork, especially stained-glass windows. Silicate glass is very resilient despite being fragile, and there are several instances of glass fragments from ancient glass-making cultures. Glass has historically been used for vessels, such as bowls, vases, bottles, jars, and drinking glasses, since it can be molded or shaped into any shape. It has also been used to make paper weights, marbles, and beads in its most solid forms (Lad, 2024). It transforms into a thermal insulator when extruded as glass fiber and matted as glass wool in a manner that traps air. These glass fibers are then incorporated into an organic polymer plastic to form a crucial structural reinforcement component of the fiberglass composite material. In the past, silicate glass was used to make some items so frequently that they were only known by that term, such as drinking glasses and eyeglasses. Glass powder functions as a Pozzolan and offers a higher amount of hydration products and a more even distribution. The structure of the cement paste is changed when glass powder is added to a concrete mixture. Compared to regular cement pastes, the resultant paste has a higher concentration of the strong calcium silicate hydrates (C-S-H) and a lower concentration of the weak and readily soluble calcium hydroxides ($Ca(OH)_2$) (Islam *et al.,* 2024). The primary source of concrete strength is the calcium silicate hydrate those forms, which acts as the system's glue or binder. The less potent calcium hydroxide can take up space and doesn't function as a binder. Moreover, the calcium hydroxide and carbon dioxide can react to create a soluble salt that might permeate the concrete and lead to efflorescence. Because glass powder particles are microscopic, they can more easily penetrate and clog concrete's capillary pores, resulting in fewer and smaller pores as well as denser concrete. When comparing concrete with glass powder to ordinary concrete, the micro filler effect significantly lowers permeability and strengthens the paste-to-aggregate bond (Islam *et al.,* 2024). Glass as a partial replacement for cement has garnered significant attention in the construction industry due to its potential to enhance sustainability. Using glass in concrete formulations not only recycles waste material but also improves certain mechanical properties of the concrete. Research has shown that incorporating glass can enhance the workability and durability of concrete mixes (Khaloo *et al.*, 2020). Additionally, studies indicate that the inclusion of glass can lead to improved compressive strength, especially when finely ground (Li *et al.,* 2022). The reduction in cement content through glass replacement also helps lower carbon emissions associated with cement production. Moreover, the pozzolanic properties of glass contribute to increased long-term strength and reduced permeability (Sathiparan and Subramaniam, 2024). The incorporation of glass not only supports the circular economy but also addresses the pressing issue of landfill waste. As the construction industry seeks more sustainable practices, glass as a partial cement replacement presents a viable solution (Khaloo *et al.*, 2020). This innovative approach aligns with global efforts to promote eco-friendly construction materials.

The incorporation of snail shells and glass as partial replacements in concrete not only addresses pressing environmental challenges but also enhances the overall performance and sustainability of construction materials. Utilizing snail shells, which are abundant and often discarded as waste, allows the construction industry to significantly reduce its reliance on traditional cement (Jasni *et al.,* 2024). Similarly, the use of recycled glass, when processed into cullet, offers a dual advantage of enhancing the aesthetic appeal of concrete while promoting sustainability. Integrating glass as a fine aggregate replacement can enhance durability and resistance to chemical degradation, crucial for infrastructure longevity (Mansour *et al.,* 2023). Despite challenges such as density considerations, research indicates that optimizing glass content within concrete can yield favorable mechanical properties and performance outcomes (Zaid *et al.,* 2021; Banerjee *et al.,* 2023). Moreover, the adoption of these materials supports broader sustainability goals within the construction sector, aligning with global efforts to minimize waste and reduce carbon footprints. As building codes increasingly emphasize eco-friendly practices, the integration of snail shells and glass can provide innovative solutions that fulfill regulatory requirements while delivering high-quality construction materials (Jasni *et al.,* 2024). The aim of this study was to determine the properties of concrete produced with varying proportions of snail shell powder and glass powder as partial replacements for cement. The scope of this study focused on evaluating the effect of snail shell powder (SSP) and glass powder (GP) as partial replacements for cement in concrete. It investigates the mechanical properties, durability, and workability of concrete mixes incorporating these materials. The study also assessed the environmental benefits, particularly in terms of reducing CO_2 emissions and promoting waste utilization.

II. METHODOLOGY

Materials Collection

The materials used in this study on the effect of using snail shell and glass powder on concrete included calcined snail shell powder, glass powder, sharp sand (fine aggregate), granite (coarse aggregate), Portland Limestone, kerosene, and clean water as the curing medium.

i. Glass Powder (GP): Recycled glass was collected, thoroughly cleaned, ground into fine powder, and sieved using a 50 µm sieve, similar to the process used for snail shell powder.

ii. Snail Shell Powder (SSP): Snail shells were obtained from Oje Market in Ibadan. The shells were washed, dried, and calcined in a controlled heating environment to produce snail shell powder.

iii. Coarse Aggregate (Granite): 12 mm size granite was sourced from a quarry site in Ibadan. The aggregate was inspected to confirm suitability based on particle shape and cleanliness.

iv. Fine Aggregate (Sand): Sharp sand was purchased from a local supplier and tested for gradation using sieve analysis in accordance with **BS EN 933-1**.

v. Cement : Portland Limestone of 53 grade was used in the study. The cement conformed to the specifications of **BS EN 197-1**.

vi. Water: Clean portable water was used for mixing and curing. The quantity used was based on the required water-cement ratio for each mix batch.

vii. Concrete Cube Mould: A wooden cube mould measuring 150 mm × 150 mm × 150 mm was constructed and used to cast the concrete specimens.

Preparation of Samples

A total of 36 concrete cubes were cast for each set of samples based on partial replacement of cement with a combination of glass powder (GP) and snail shell powder (SSP). All materials used were locally sourced. Portland Limestone was partially replaced with the following mix proportions:

i. 5% SSP + 15% GP
ii. 10% SSP + 10% GP
iii. 15% SSP + 5% GP

The water-cement ratio was maintained at 0.65. Each mix was cured in water for 7, 14, and 28 days. More so, a control mix was prepared using Portland Limestone as the sole binder. Other mixes were prepared by replacing cement with SSP and GP in the specified weight percentages. The required quantities of SSP and GP were weighed and mixed manually with cement, followed by the addition of fine aggregate and then water. All specimens were placed in the laboratory for 24 hours before de-moulding. After de-moulding, they were transferred into water tanks maintained below room temperature for curing. The initial weights of the cubes were recorded before curing, and final weights were measured afterward to determine the water absorption rate of the concrete. The concrete cubes were then tested for compressive strength using a compressive strength testing machine, in accordance with BS EN 12390-3. After the experimental procedures, relevant graphs were plotted to visually present the results obtained.

Specific Gravity of Coarse and Fine Aggregate

The specific gravity of both the coarse and fine aggregates were determined using a pycnometer bottle. The empty pycnometer bottles were first weighed and recorded as W_1. They were then half-filled with the aggregate's samples, and the combined weights were recorded as W_2. Water was added to the pycnometer containing the

aggregates, and the bottles were shaken thoroughly to eliminate air bubbles. The setups were allowed to stand for approximately 30 minutes to ensure proper settling, and the weight was recorded as W_3.
After emptying the contents, the pycnometer bottles were filled with water alone, and the final weights were recorded as W_4. The specific gravity was calculated using the following formula, after which multiple trials were conducted for each aggregate types, and the average specific gravity was determined to ensure reliability and accuracy of the values used in mix calculations.

$$\text{Specific Gravity} = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)}$$

Specific Gravity of Cement, Snail Shell Powder, and Glass powder
The pycnometer bottles were first weighed empty and recorded as W_1. They were then half-filled with the respective samples, and the combined weights were recorded as W_2. Kerosene was added to the samples in the bottles, and the mixtures were shaken vigorously to remove air bubbles. They were then allowed to settle for 30 minutes, after which the weights were recorded as W_3. Following these, the contents were emptied, and the pycnometer bottles were refilled with kerosene only. The weights of the bottles filled with kerosene were then recorded as W_4.
These values were used to compute the specific gravity (SG) of the binding materials using the appropriate formula, after which multiple samples were tested, and the average specific gravity were determined to ensure accuracy.

$$\text{Specific Gravity} = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)}$$

Moisture Content of Coarse and Fine Aggregates
The moisture content of both the coarse (granite) and fine (sand) aggregates were determined using the oven-dry method in accordance with BS 812-109**.** Clean, dry containers were first weighed and their masses recorded. A representative sample of each aggregate type was placed into the containers, and the initial weight (wet weight) of the container with the sample was recorded. The containers were then placed in an oven maintained at a temperature of 105 ± 5°C for 24 hours. After drying, the containers were cooled in a desiccator to prevent moisture absorption from the air. The final weight (dry weight) of each container with the dried sample was then recorded.
The moisture content (MC) was calculated using the following formula, after which multiple samples were tested, and the average moisture content for each aggregate type was used in adjusting the water content for concrete mixing.

$$Water\ Content\ (\%) = \frac{(W2 - W3)}{W3 - W1} \times 100$$

W_1 = Mass of container, g
W_2 = Mass of container and wet granite, g
W_3 = Mass of container and dry granite, g

Grain Size Analysis of Fine and Coarse Aggregate
Grain size analysis was carried out separately for the fine and coarse aggregates in accordance with BS 812-103.1:1985, Testing Aggregates: Method for Determination of Particle Size Distribution**.** For each aggregate type, representative samples were collected and riffled to obtain uniform sub-samples. Each sample was weighed to determine its wet weight, then placed in an oven at 105 ± 5°C for 12 hours to remove moisture. After drying, the samples were cooled inside a desiccator for 30 minutes, then reweighed to determine the dry weight.
A sieve shaker was prepared for each test, and a stack of sieves was arranged in ascending order of mesh size from bottom to top. The grain size distribution tests for fine and coarse aggregates were performed separately, using different sieve sets appropriate to their grading ranges. For the fine aggregate, the sieve sizes used (from smallest to largest) were; 0.15 mm, 0.3 mm, 0.6 mm, 1.18 mm, 2.36 mm, 5 mm, and 10 mm**,** and for the coarse aggregate, the sieve sizes used (from smallest to largest) were; 2.36 mm, 5.0 mm, 10 mm, 14 mm, 20 mm, 37.5 mm, 63 mm, and 75 mm. Each dry sample was placed on the top sieve of its respective stack and mechanically shaken for approximately 6 minutes using the sieve shaker. After shaking, the material retained on each sieve was weighed sequentially. These values were used to calculate the percentage retained**,** cumulative percentage retained, and percentage passing for each sieve size.

Glass Powder (GP) and Snail Shell Powder (SSP) Manual Sieving
The ground glass and snail shell powders were manually sieved using a 75 µm mesh sieve to obtain only the fine fractions required for concrete production. This was done to ensure that all particles used in the mix were finer than 75 µm, which is critical for achieving good dispersion, improved pozzolanic reactivity, and strong

bonding with the cement matrix. Only the portion of each material that passed through the 75 µm sieve was collected, and used for partial replacement of cement in the concrete mixes.

Concrete Mix Design

A conventional concrete mix design with a ratio of 1:2:4 (Cement : Fine Aggregate : Coarse Aggregate) was adopted, based on the mix design procedure specified in BS 5328-1. The total water-to-cement ratio was fixed at 0.65, and the mixing procedures followed standard practices for concrete preparation to ensure consistency and reliability across all batches.

Experimental Binder Percentage Ratios

The cement in the concrete mixes was partially replaced with varying proportions of glass powder (GP) and snail shell powder (SSP) as follows:

a) 100% Portland Limestone, 0% Glass Powder, and 0% Snail Shell
b) 80% Portland Limestone, 15% Glass powder, and 5% Snail Shell Powder
c) 80% Portland Limestone, 10% Glass powder, and 10% Snail Shell Powder
d) 80% Portland Limestone, 5% Glass powder, and 15% Snail Shell Powder

Workability Test on Fresh Concrete (Slump Test)

Fresh concrete placed and finished without segregation shows the workability of concrete. Slump test was the method used to assess the workability of the fresh concrete mixes by measuring the concrete consistency and flow characteristics immediately after mixing. The test was carried out on each of the pozzolan proportion including the control mix.

The slump test was carried out according to BS EN 12350-2:2019, using a standard slump cone mould with a height of 300 mm. The mould, which has the shape of a frustum (wider at the base and narrower at the top), was placed on a smooth, horizontal, rigid, and non-absorbent surface. Fresh concrete was filled into the cone in three equal layers, each approximately one-third the height of the mould. Each layer was compacted by rodding 25 times using a 16 mm diameter bullet-nosed tamping rod. This process was repeated for the second and third layers to ensure proper compaction.

Immediately after filling, the mould was carefully lifted vertically and steadily, allowing the concrete to subside under its own weight. The vertical difference between the original height of the mould and the highest point of the subsided concrete was measured and recorded as the slump (Figure 1). This test procedure was applied to all fresh concrete mixes with varying proportions of glass powder and snail shell powder to assess their respective workability.

Figure 1: Slump test of fresh concrete

Test on Hardened Concrete

To evaluate the performance of the hardened concrete, two key tests were conducted, the water absorption test and the compressive strength test. These tests were selected as the primary means of assessing the mechanical and durability-related properties of the concrete produced with partial replacement of cement by glass powder and snail shell powder. The water absorption test was used to assess the permeability and pore structure of the concrete, which relates to its durability. The compressive strength test, carried out in accordance with BS EN 12390-3, served as the principal measure of the concrete's mechanical strength at 7, 14, and 28 days of curing. These two tests provided critical data for evaluating the structural viability and long-term performance of the modified concrete mixes.

Water Absorption Test on Oven dried Concrete

The water absorption test was conducted in accordance with BS 1881-122:2011 to evaluate the permeability and porosity of the hardened concrete. After curing for the designated periods (7, 14, and 28 days), the concrete cube specimens were removed from the curing tank. Each specimen was gently wiped to remove surface moisture and allowed to air dry briefly. The initial weight of the saturated specimen was then recorded as W_1.

Following this, the specimens were placed in a ventilated oven and dried at a constant temperature of 105 ± 5°C for a minimum of 24 hours to ensure complete removal of internal moisture. The specimens were considered fully dried once a constant weight was achieved. After drying, the cubes were allowed to cool to room temperature to prevent moisture uptake from the surrounding air. Once cooled, the final weight of the oven-dried specimen was measured and recorded as W_2. The water absorption of each specimen was calculated using the formula;

$$\text{Water Absorption (\%)} = \frac{Wet\ Weight - Dry\ Weight}{Dry\ Weight}\ x\ 100$$

Compressive Strength Test

Concrete cubes measuring 150 mm × 150 mm × 150 mm were cast and cured for 7, 14, and 28 days, respectively. After each curing period, the dimensions of the cubes were measured accurately, and the specimens were weighed. Each cube was then placed centrally in a compression testing machine, and a compressive load was applied gradually and uniformly until failure occurred. The maximum load sustained by each cube before failure was recorded. The compressive strength was calculated using the formula, after which the test was repeated for multiple specimens in each mix category to ensure consistency and reliability. The average value of the results obtained for each curing age was taken as the representative compressive strength of the mix.

$$\text{Compressive Strength (MPa)} = \frac{Maximum\ Load\ (N)}{Cross-sectional\ Area(mm^2)}$$

III. RESULTS AND DISCUSSION

Preliminary Analysis on Aggregate and Cement

Prior to casting the concrete specimens, preliminary tests were carried out on the key constituent materials, fine and coarse aggregates**,** as well as the pozzolanic materials (glass powder and snail shell powder), to assess their quality and suitability for use in concrete production. The tests conducted included sieve analysis to determine the particle size distribution of the aggregates, specific gravity tests for both aggregates and pozzolans, and moisture content determination for the aggregates. In addition, the glass powder and snail shell powder were manually sieved to ensure only particles passing through a 75 µm mesh were used, which is important for achieving proper fineness and reactivity in the mix. These preliminary evaluations provided insight into the physical characteristics, such as grading, and water content of the concrete materials, all of which play a significant role in workability, and strength development.

Specific Gravity of Coarse and Fine Aggregate

The specific gravity of the coarse and fine aggregates used in this study was determined to be 2.69 and 2.65, respectively as shown in Table 1. These values fall within the expected range for natural aggregates typically used in concrete production, which generally lie between 2.5 and 2.8, depending on mineral composition and source (Jorgene *et al.,* 2023). The coarse aggregate, consisting of 12 mm crushed granite, recorded an average specific gravity of 2.69. This indicates a relatively dense and compact aggregate, suitable for producing concrete with good strength and low porosity. The consistency in values across the two specimens suggests uniformity in the aggregate quality, which contributes positively to concrete strength and durability.

The fine aggregate (sharp sand) had a slightly lower average specific gravity of **2.65**, which is typical for clean, well-graded natural sands. This value indicates that the sand has adequate particle density and is unlikely to contribute excess air voids or segregation in the mix, provided proper batching and compaction are ensured. The results confirm that both the coarse and fine aggregates meet standard requirements for use in structural concrete, which is consistent with Jorgene *et al*., (2023). Their relatively high specific gravities suggest they contribute positively to the concrete's bulk density and compressive strength when combined with the selected binder components (cement, glass powder, and snail shell powder).

Table 1: Specific Gravity of Fine and Coarse Aggregate

Item	Specific Gravity
Coarse Aggregate	2.69
Fine Aggregate	2.65

Specific Gravity of Cement, Glass Powder, and Snail Shell Powder

The specific gravity values obtained for the materials used as binders in this study reflect their intrinsic physical characteristics and their potential influence on the behavior of concrete when blended. In Table 2, the Portland Limestone recorded an average specific gravity of 3.13, which is consistent with established values (typically 3.10–3.15) and confirms the quality and density of the cement used. This high value reflects the dense, fine nature of cement particles, which contributes significantly to concrete strength and mix weight.

The glass powder (GP), derived from finely ground recycled glass and sieved through a 75 µm mesh, had an average specific gravity of 2.57. This lower value compared to cement is expected, given the amorphous and silica-rich nature of glass. While it is less dense than cement, its fine texture and pozzolanic reactivity make it suitable for partial replacement. The reduced specific gravity implies that GP contributes less mass per unit volume, potentially affecting batching by volume and slightly lowering the bulk density of the concrete.

The snail shell powder (SSP), which was calcinated and ground before sieving, had the lowest average specific gravity of 2.45. There is a correlation with Islam *et al*., (2024) confirming attribute in the porous nature and calcium-based composition of the calcined shell, which makes it lighter and less dense than both cement and GP. Although lighter, SSP may still contribute to strength development due to its potential pozzolanic and filler effects, especially when used in small quantities. From a practical standpoint, these values help in adjusting mix designs accurately, especially when replacing cement by mass rather than volume.

Table 2: Specific Gravity of Cement, GP, and SSP

Material	Average Specific Gravity
Portland Limestone (PL)	3.13
Glass Powder (GP)	2.57
Snail Shell Powder (SSP)	2.45

Moisture Content of Coarse and Fine Aggregate

Moisture content refers to the amount of water present in aggregate particles. It is a key factor in concrete mix design, as it affects the effective water-cement ratio**,** workability, and strength of the final concrete. Aggregates can retain surface moisture or internal moisture, which must be considered when batching to avoid excess free water that may weaken the concrete. The moisture content of aggregates is a key factor influencing the water-cement ratio in concrete, especially when working with partial cement replacements like glass and snail shell powders. In this study, the moisture content test was conducted to assess the amount of free water present in the aggregates before mixing, using the oven-dry method in accordance with BS 812-109. The results are being presented in Table 3.

The coarse aggregate recorded an average moisture content of 2.59%**,** while the fine aggregate (sharp sand) had a higher average of 5.18%. These values are higher than typical field values, especially for granite, which usually has low water retention. However, both aggregates used in this study were saturated before testing, and this pre-saturation accounts for the elevated moisture values observed. While higher moisture content in coarse aggregate is uncommon under normal dry storage, it occur due to aggregates exposed to rain. The fine aggregate, with its larger surface area and finer particles, naturally retains more water, explaining its higher moisture content. The implications for mix design are important, without adjusting for the absorbed moisture, there would be excess free water in the mix, potentially leading to reduced strength, higher porosity, and segregation. These values were considered when batching the concrete, ensuring that the effective water-cement ratio of 0.65 was maintained consistently across all mixes.

Table 3: Moisture Content of Coarse and Fine Aggregate

Material	Average Moisture Content (%)
Coarse Aggregate	2.59
Fine Aggregate	5.18

Grain Size Analysis of Coarse Aggregate

Grain size analysis is a fundamental test in assessing the suitability of aggregate for concrete production. It provides insight into the distribution of particle sizes within a sample, which directly influences important concrete properties such as workability, strength, and durability. For coarse aggregates, a balanced mix of various sizes helps minimize voids, reduce paste demand, and improve the strength and economy of concrete. The test for the 12 mm granite used in this study was performed in accordance with BS 812-103.1:1985, using a standard stack of sieves with decreasing aperture sizes.

The sieve analysis result in Table 4 and showed that 100% of the aggregate passed through the 75 mm, 63 mm, and 37.5 mm sieves, indicating that the sample consists entirely of particles much smaller than those sieve sizes. At the 20 mm sieve, 98% of the particles passed, confirming that the material is predominantly below this size. A significant reduction was observed at the 14 mm and 10 mm sieves, with 86% and 60% passing, respectively. This pattern continues with 30% passing the 5 mm sieve and only 8% through the 2.36 mm sieve. No particles were retained in the pan, suggesting minimal to no fine dust content in the aggregate. Based on these results and referencing BS 882:1992, the coarse aggregate can be classified within the 10–20 mm size range, with a nominal maximum size of 12 mm. The distribution indicates that the aggregate is well-graded, featuring a suitable mix of larger and smaller particles. Such grading is ideal for structural concrete as it improves particle interlock, reduces the volume of voids, and helps achieve a denser concrete matrix. This is especially important in this study, where partial cement replacement is being investigated. Well-graded aggregates can reduce the reliance on cement paste to fill voids, which is beneficial when using lower-density pozzolans like glass powder and snail shell powder. Although a small fraction of particles (30%) passed through the 5 mm sieve, which overlaps slightly with the fine aggregate range, the overall distribution remains acceptable. Proper control during batching will ensure that this does not negatively affect the particle packing or result in segregation. The minimal fines also reduce the risk of excessive water demand or shrinkage. Overall, the coarse aggregate used in this research is suitable for concrete production and is expected to contribute positively to both the fresh and hardened properties of the mixes.

Table 4: Grain Size Analysis of Coarse Aggregates

S/N	Sieve Size (mm)	% Passing
1	75.0	100
2	63.0	100
3	37.5	100
4	20.0	98
5	14.0	86
6	10.0	60
7	5.0	30
8	2.36	8
9	Pan	0

Figure 2 presents the particle size distribution curve for the coarse aggregate, illustrating a smooth and progressive reduction in percentage passing with decreasing sieve sizes. The graph confirms a well-graded aggregate profile, with a broad range of particle sizes present and no abrupt gaps, indicating good gradation. The steep drop between the 14 mm and 5 mm sieves reflects a strong concentration of intermediate particles, while the low percentage passing the 2.36 mm sieve confirms minimal fines. This gradation is ideal for concrete production, as it promotes dense packing, reduces void content, and supports adequate workability and strength development when used with partial cement replacements like glass powder and snail shell powder

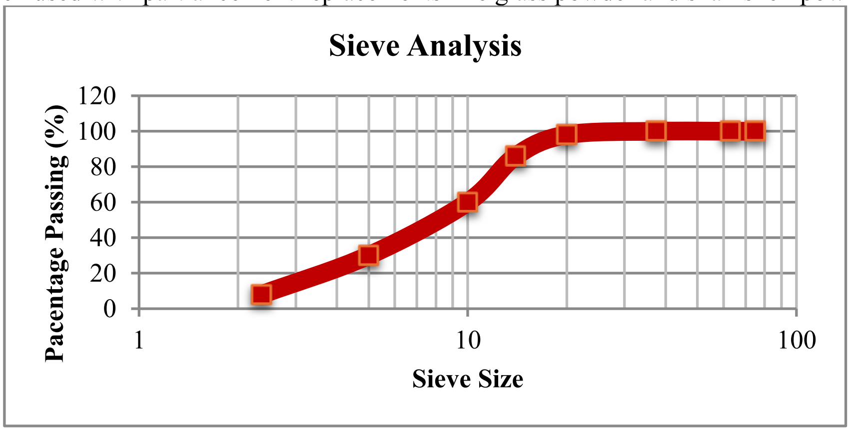

Figure 2: Grain size analysis of coarse aggregate

Grain Size Analysis of Fine Aggregate

The sieve analysis for the fine aggregate was conducted to determine the gradation characteristics of the sharp sand used in the concrete mixes. The test, performed in line with BS 812-103.1:1985, is essential for understanding the proportion of various particle sizes and their likely effect on workability, strength, and finishing quality of the concrete. As shown in Table 5, 100% of the fine aggregate passed through the 9.5 mm sieve and nearly all particles (99.72%) passed the 4.75 mm sieve, confirming that the sample is indeed sand and free from oversized particles. The percentage passing gradually reduced through the finer sieves, with 95.43% passing 2.36 mm, 80.71% passing 1.18 mm, and 57.95% passing 0.60 mm. By the 0.150 mm sieve, only 12.57% of the particles remained, and no fines were observed in the pan.

This distribution suggests that the sand is well-graded, containing a good mix of coarse, medium, and fine particles. According to BS 882:1992, fine aggregates used for concrete should generally fall within Zone 2, which corresponds to a balanced grading suitable for most structural applications. The observed values in this analysis closely align with Zone 2 specifications, meaning the sand is neither too coarse nor too fine. This type of grading is desirable, as it improves workability, reduces segregation, and helps optimize the paste content needed to fill voids between particles. The absence of excessive fines (particles smaller than 150 µm) also suggests a lower risk of shrinkage or high-water demand, making the aggregate suitable for producing quality concrete, especially when combined with supplementary cementitious materials like glass powder and snail shell ash.

Table 5: Grain Size Analysis of Fine Aggregates

S/N	Sieve Opening (mm)	Percentage Passing (%)
1	9.50	100.00
2	4.75	99.72
3	2.36	95.43
4	1.18	80.71
5	0.60	57.95
6	0.300	32.58
7	0.150	12.57
8	Pan	0.00

Figure 3 shows the particle size distribution curve of the fine aggregate, with a smooth and continuous downward slope from the coarser to the finer sieves. The shape of the curve indicates a well-graded sand, with no sharp drops or flat segments that would suggest gaps or excess of any particular size fraction. The curve lies well within the acceptable limits for Zone 2 sands as defined by BS 882, reinforcing the suitability of the material for concrete production in this study. Its balanced grading ensures good packing, reduced voids, and adequate cohesion in both fresh and hardened concrete.

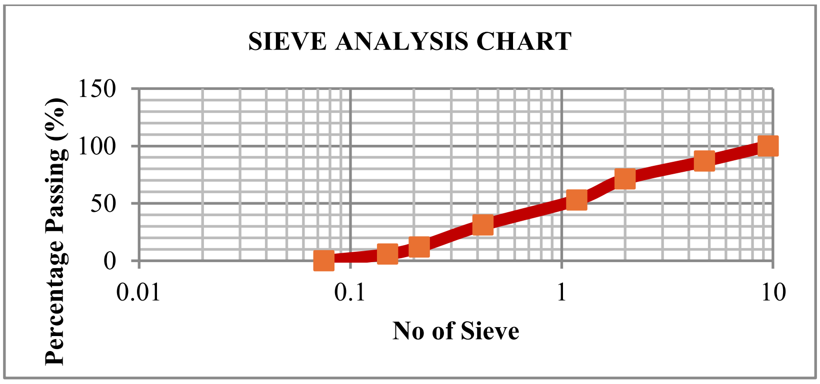

Figure 3: Grain size analysis of fine aggregate

Workability Test on Fresh Concrete (Slump Test)

Workability is a key property of fresh concrete that defines how easily the concrete can be mixed, placed, compacted, and finished without segregation or loss of homogeneity. It reflects the concrete's fluidity and its ability to flow under its own weight or under vibration. In this study, the workability of the concrete mixes was assessed using the slump test.

Table 6 shows the slump values for concrete mixes with varying proportions of glass powder (GP) and snail shell powder (SSP) as partial cement replacements. The control mix, made with 100% Portland Limestone, recorded the highest slump value of 70 mm, indicating the best workability among all samples. As pozzolanic materials were introduced, the slump values progressively declined. The mix with 15% GP and 5% SSP had a slump of 65 mm, still retaining relatively good workability. However, the workability reduced further to 55 mm when the pozzolans were balanced at 10% GP and 10% SSP, and it dropped significantly to 48 mm in the mix with 15% SSP and 5% GP. This trend indicates that snail shell powder has a more pronounced effect on reducing workability compared to glass powder. The reduction in slump with increasing SSP content can be attributed to its finer particle size, higher surface area, and likely higher water absorption capacity, which collectively increase the water demand of the mix. On the other hand, glass powder, with its smooth texture and lower absorption, supports better flowability. Thus, the mix with higher GP content achieved better slump despite having reduced Portland Limestone. The results also suggest that excessive replacement of Portland Limestone with SSP without adjusting the water content or using admixtures may negatively affect the ease of mixing, placing, and finishing. The slump results reflect that while both pozzolans affect fresh concrete behavior, SSP tends to reduce workability more noticeably. Proper mix proportioning or water-reducing agents may be necessary to maintain adequate workability when using higher percentages of SSP in concrete.

Table 6: Slump Test of Fresh Concrete

S/N	Mix Type	Percentage Mix Composition	Slump Values
1	Control	100% Portland Limestone	70
2	Pozzolan Inclusion	80% Portland Limestone + 15%GP + 5% SSP	66
3	Pozzolan Inclusion	80% Portland Limestone + 10%GP + 10% SSP	55
4	Pozzolan Inclusion	80% Portland Limestone + 5%GP + 15% SSP	48

Test on Hardened Concrete

This section presents the results and interpretation of tests conducted on the hardened concrete samples, specifically focusing on water absorption and compressive strength, which are critical indicators of the concrete's durability and structural performance. The water absorption test assesses the porosity and permeability characteristics of the concrete, while the compressive strength test evaluates its load-bearing capacity over curing periods of 7, 14, and 28 days.

Water Absorption Test

Table 7 presents the water absorption results of all concrete mixes at 7, 14, and 28 days of curing**.** As expected, the results show a consistent decrease in water absorption across all mix types with increasing curing age. This reflects the ongoing hydration of cement and pozzolanic materials, which reduces pore spaces and enhances the compactness of the concrete over time. The control mix (100% Portland Limestone) recorded the lowest absorption values at all curing ages, beginning with 4.20% at 7 days, reducing to 3.80% at 14 days, and further dropping to 3.40% at 28 days. This trend demonstrates the dense microstructure typically formed in pure L concrete due to rapid hydration and low initial porosity. For the modified mixes containing glass powder (GP) and snail shell powder (SSP), a higher rate of water absorption was observed across all ages, with absorption generally increasing as the percentage of SSP increased. At 7 days, Mix 2 (15% GP + 5% SSP) had 4.60%**,** Mix 3 (10% GP + 10% SSP) had 5.00%**,** and Mix 4 (5% GP + 15% SSP) recorded the highest at 5.40%**.** This pattern was consistent at 14 and 28 days, though the values decreased progressively with age. For instance, at 28 days, Mix 2 reduced to 3.65%**,** Mix 3 to 3.90%**,** and Mix 4 to 4.30%.

The higher absorption in mixes with more SSP can be attributed to the powder's porous and reactive nature, which initially introduces more voids into the concrete matrix. However, as curing progresses, the pozzolanic reaction of SSP with calcium hydroxide contributes to refining the pore structure, thereby reducing absorption. On the other hand, GP, being less porous and more inert in early stages, tends to maintain or slightly improve the mix's compactness when present in higher proportion. The water absorption results show that concrete containing GP and SSP can exhibit higher initial porosity, particularly when SSP is more dominant. However, with adequate curing, the microstructure of the blended mixes improves significantly. The data suggest that a balanced combination of GP and SSP, particularly with GP in higher proportions, helps control water absorption and supports the long-term durability of concrete.

Table 7: Water Absorption of Hardened Concrete

S/N	Percentage Mix Composition	Curing Days		
		7 Days	14 Days	28 Days
1	100% Portland Limestone	4.2	3.80	3.40

S/N	Percentage Mix Composition	Curing Days		
2	80% Portland Limestone + 15% GP + 5% SSP	4.6	4.10	3.65
3	80% Portland Limestone + 10% GP + 10% SSP	5.0	4.45	3.90
4	80% Portland Limestone + 5% GP + 15% SSP	5.4	4.80	4.30

Figure 4 shows the column chart representing the water absorption of hardened concrete across different curing periods visually illustrates the variation in porosity among the four mix types. The chart clearly shows that water absorption values are highest at 7 days for all mixes and gradually decrease at 14 and 28 days, reflecting the expected improvement in concrete density with time. The control mix consistently displays the lowest absorption at each stage, indicating a denser and less porous matrix due to the absence of pozzolanic replacements. Among the modified mixes, those with higher snail shell powder content exhibit noticeably higher absorption, especially at early curing stages, while mixes with a greater proportion of glass powder maintain relatively lower absorption values. The chart highlights the influence of both pozzolans on the concrete's permeability and the importance of proper curing in enhancing the durability of blended cement concretes.

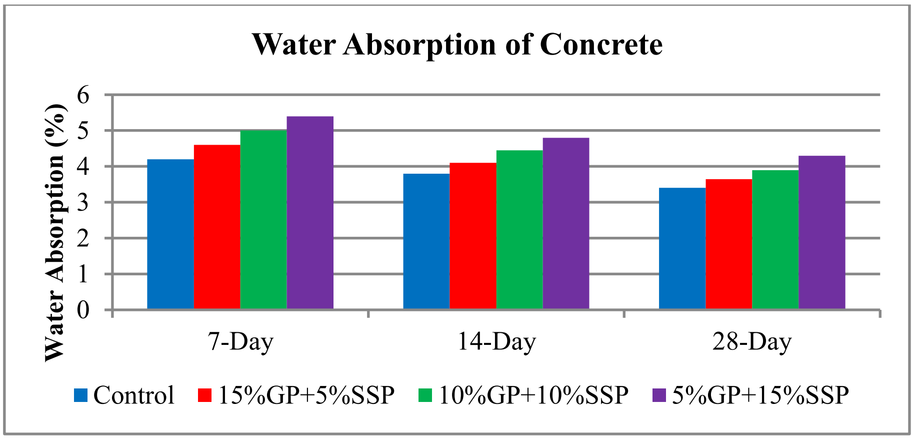

Figure 4: Water absorption of hardened concrete

Compressive Strength Test

Compressive strength is a key indicator of concrete's structural performance and durability. It reflects the ability of the material to withstand axial loads and is influenced by several factors including mix composition and water-cement ratio. According to BS EN 12390-3, compressive strength tests are to be conducted on standard cube specimens after curing for specified durations, typically 7, 14, and 28 days, to monitor strength development over time. In this study, concrete cube specimens were tested at these intervals to evaluate the effect of partially replacing Portland Limestone with Glass Powder (GP) and Snail Shell Powder (SSP). From the results presented in Table 8 and Figure 5, all mixes demonstrated a progressive increase in strength with curing age, which is consistent with the expected hydration and pozzolanic reaction processes. The control mix (100% Portland Limestone) recorded compressive strengths of 12.28 N/mm², 17.21 N/mm², and 20.53 N/mm² at 7, 14, and 28 days respectively. These values fall within the typical range for a 1:2:4 concrete mix with a water-cement ratio of 0.65, indicating moderate strength development suitable for general construction applications.

Among the pozzolan-modified mixes, Mix 2 (80% Portland Limestone + 15% GP + 5% SSP) outperformed the others, recording the highest strength at all curing ages, 11.53 N/mm² at 7 days, 18.71 N/mm² at 14 days, and 21.60 N/mm² at 28 days. This result suggests that a higher proportion of glass powder, which is finely ground and rich in amorphous silica, contributes effectively to the pozzolanic reaction, enhancing the binding properties and densifying the concrete matrix over time. Interestingly, the 28-day strength of Mix 2 slightly surpassed that of the control mix, indicating that GP can be a viable partial replacement for OPC without compromising compressive performance when used in appropriate proportions. Mixes 3 and 4, which had equal or higher proportions of snail shell powder compared to glass powder, recorded lower compressive strengths across all curing periods. Mix 3 (10% GP + 10% SSP) yielded 10.32 N/mm², 16.64 N/mm², and 18.20 N/mm², while Mix 4 (5% GP + 15% SSP) recorded 10.23 N/mm², 16.30 N/mm², and 17.94 N/mm² at 7, 14, and 28 days respectively. The lower strength performance in these mixes may be attributed to the higher content of snail shell powder, which is less reactive compared to GP and tends to act more as an inert filler, especially if not properly calcined or finely ground. Additionally, excessive SSP could disrupt the cementitious matrix, leading to reduced cohesion and increased porosity.

The results align with Akinmoladun *et al.,* (2019) that suggests pozzolans like GP enhance long-term strength through secondary hydration, while natural calcium-rich powders like SSP require controlled incorporation to avoid weakening the mix. The data also confirm that longer curing periods significantly improve strength, emphasizing the importance of proper curing in mixes containing pozzolanic materials. The optimal performance observed in Mix 2 supports the potential of using 15% glass powder and 5% snail shell powder as a sustainable and effective partial replacement for cement in concrete. This combination not only reduces dependency on Portland Limestone but also aligns with environmentally conscious construction practices, provided that strength requirements per relevant standards are met.

Table 8: Compressive Strength of Concrete

S/N	Mix Composition	7 Days (N/mm²)	14 Days (N/mm²)	28 Days (N/mm²)
1	100% Portland Limestone	12.28	17.21	20.53
2	80% Portland Limestone + 15% GP + 5% SSP	11.53	18.71	21.60
3	80% Portland Limestone + 10% GP + 10% SSP	10.32	16.64	18.20
4	80% Portland Limestone + 5% GP + 15% SSP	10.23	16.30	17.94

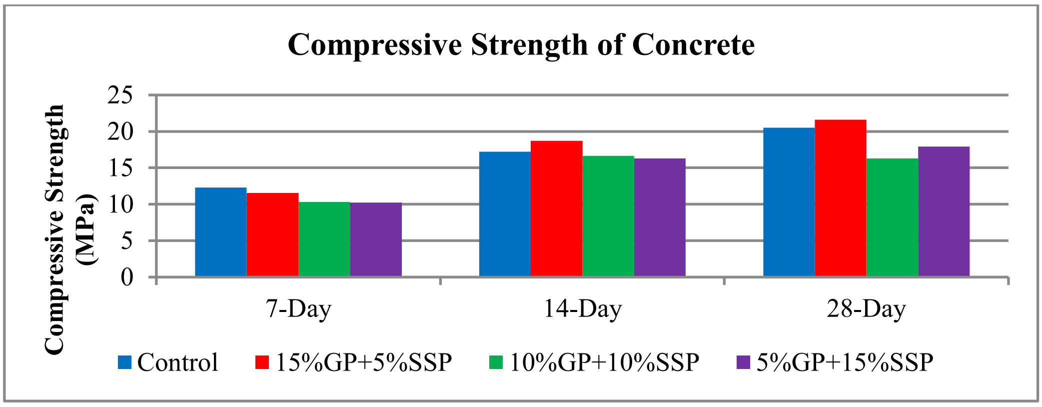

Figure 5: Compressive strength of concrete

IV. CONCLUSION

This study investigated the effects of using Snail Shell Ash (SSA) and Glass Powder (GP) as partial replacements for Portland Limestone in concrete production, with the aim of assessing the strength and durability performance of the resulting concrete. A mix ratio of 1:2:4 and a constant water-cement ratio of 0.65 were adopted throughout the study. The binders were varied in three pozzolanic combinations, (15% GP + 5% SSP), (10% GP + 10% SSP), and (5% GP + 15% SSP), while 100% Limestone mix served as the control. Preliminary tests carried out on the constituent materials, including specific gravity, moisture content, and sieve analysis, established their suitability for concrete production. The pozzolans were manually sieved through 75 µm mesh to ensure proper fineness, enhancing their potential reactivity and bonding with the cement matrix.

Workability of the concrete was assessed through slump tests. Results showed a decline in slump values with increasing snail shell powder content, indicating reduced workability due to the powder's relatively rough texture and high surface area. Mixes with higher GP content showed better workability, confirming the role of glass powder in improving flow-ability due to its finer and smoother particles. Water absorption tests revealed that all mixes exhibited reduced permeability over time, with the control mix having the lowest absorption across all curing days. However, Mix 2 (15% GP + 5% SSP) showed relatively competitive results, indicating the combined contribution of both pozzolans to reducing pore volume over time. Mixes with higher SSP content showed higher water absorption values, likely due to the porous nature of the snail shell ash. The compressive strength results showed that all mixes gained strength with curing age, as expected. The control mix recorded the highest early strength, but at 28 days, Mix 2 slightly outperformed it, indicating the positive contribution of GP in strength development through pozzolanic activity. Mixes with higher SSP content generally had lower strengths, suggesting that excessive inclusion of SSP may impair the cementitious properties of the matrix when not optimally balanced.

The study concludes that a 20% replacement of Limestone with pozzolans can still produce concrete with acceptable strength and durability properties, provided that the mix is properly balanced. The best-performing pozzolan combination was found to be 15% glass powder and 5% snail shell powder, which delivered results that were either comparable to or better than the control in several performance aspects.

V. RECOMMENDATIONS

Based on the results obtained, it is recommended that a maximum of 20% replacement of Portland Limestone with a combination of glass powder and snail shell powder can be adopted in non-structural and light structural concrete works, especially where sustainability and cost reduction are important. Among the tested mixes, the combination of 15% GP and 5% SSP proved most effective, offering improved compressive strength and acceptable water absorption, making it suitable for pavements, block moulding, walkways, and other moderate-load-bearing components. Proper processing of the pozzolans, particularly grinding and sieving through 75 µm mesh, is essential to enhance their reactivity and ensure uniform bonding in the cementitious matrix.

It is also recommended that further studies be conducted on the long-term durability of such concrete, including resistance to sulphate attack, shrinkage behavior, and thermal performance. Additionally, optimizing water-cement ratio and the use of admixtures may help improve workability in mixes with higher SSP content. For large scale adoption, there is a need for awareness creation among builders and regulatory bodies regarding the safe and beneficial use of waste materials in concrete production, as part of broader efforts to promote sustainable and low-carbon construction practices in Nigeria and beyond.

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