LAUTECH Journal of Engineering and Technology 19 (2) 2025: 83-94

10.36108/laujet/5202.91.0290

Influence of Elastobar and Zycoprime Nanochemicals on Concrete Properties with Coarse Aggregate Partially Replaced by Periwinkle Shell

[1]Obilor K. O., [2]Olaniyan O. S., [3]Jackson D. O.

[1,2,3]*Department of Civil Engineering Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria,*

Article Info

Article history:

Received: Feb 20, 2025
Revised: May 08, 2025
Accepted: May 10, 2025

Keywords:

Concrete strength, Elastobar, Granite, Nano-chemical, Periwinkle shell, Zycoprime

Corresponding Author:
jacksondestiny214@gmail.com,
Tel: +2347060441158

ABSTRACT

Solid waste management, particularly of periwinkle shells, poses a persistent environmental challenge in Nigeria's riverine regions. While past studies have explored the use of periwinkle shells in concrete, limited attention has been given to the potential benefits of nano-chemical additives. This study investigated the properties of concrete mixed with periwinkle shells and nano-chemicals (Elastobar and Zycoprime) enhancing its performance. Periwinkle shells were obtained from Ilaje, Lagos State, and subjected to particle size distribution analysis to determine their coefficient of curvature (Cc) and uniformity coefficient (Cu). Their porosity, permeability, specific gravity, aggregate impact value (AIV), and aggregate crushing value (ACV) were determined according to standard methods. Concrete of grade M30 was prepared with partial periwinkle shell replacement at 0, 20, 40, 60, 80, and 100% aggregate. Tests included slump, bulk density, compressive strength, tensile strength, and water absorption at 28 days. The microstructure of the optimal mix was analyzed using Scanning Electron Microscopy (SEM). The periwinkle shell had Cu (1.31), Cc (1.80), porosity (45%), permeability (1.2 × 10^{-2} cm/s), specific gravity (2.68), AIV (40.2%) and ACV (37.6%). The slump, bulk density, compressive strength for slumps above 20 mm, tensile strength, and water absorption ranged from 51.56 to 76.12 mm, 2345.78 to 2360.25 kg/m³, 10.91 to 42.10 MPa, 1.49 to 4.50 MPa, and 3.6 to 26% respectively. SEM images revealed a denser microstructure with fewer voids in the optimal mix. Incorporating Elastobar and Zycoprime with periwinkle shells in concrete enhances its performance, making it suitable for mass concrete and load-bearing applications.

INTRODUCTION

Nanotechnology involves manipulating materials at the atomic and molecular levels to improve physical and mechanical properties (Gopinath *et al*., 2012). Nanotechnology is not a new science, neither is it a new technology. It is an extension of sciences and technologies that have been developing for many years. It is the logical progression of the work done to examine the nature of our world at the nanoscale (Prince and Jemimah, 2011). Concrete, a heterogeneous composite, benefits from nanotechnology through the addition of nano-particles, for enhancing durability and mechanical behaviour (Luis *et al*., 2021).

One of the proposed benefits of concrete and cement is that it has the potential to reduce permeability. Nanotechnology could greatly increase the life of concrete pavements or structures if a method could be developed to make concrete approach the point of being impermeable (Grove 2010). The use of nanotechnology-based tools and nanomaterials to monitor and modify the permeability of a given concrete system will immediately lead to longer-lasting concrete structures (Birgisson 2010). Nanotechnology can also improve the hardened properties of concrete to improve its compressive strength. Periwinkle shell is an agricultural residue material commonly found in coastal communities. They are relatively non-degradable, and, as such, constitute a great deal of environmental problems. Many of these environmental problems could be solved by using periwinkle shells as primary production materials, especially in concrete making (Ibearugbulem, 2009). Periwinkle shells are a potential alternative to conventional aggregates in concrete. These shells, predominantly found in Nigeria's riverine areas, are often discarded as waste, leading to environmental pollution (Soneye *et al*., 2016). Incorporating nano-chemicals like elastobar and zycoprime could optimize concrete performance, reducing construction costs and promoting sustainability.

Dahunsi and Bamisaye (2002) reported that substantial accumulation of periwinkle shells in many parts of the country such as Warri, Western Ijaw, Burutu, Ogoni, Ogalaga, and Lotughene of the Niger Delta of Nigeria. Thus, this research investigated the properties of concrete mixed with periwinkle shells and nano-chemicals (Elastobar and Zycoprime) enhancing its performance.

RESEARCH METHODOLOGY

Data Collection

Primary and secondary data were used to achieve the aim of this study. The study was to investigate the effect of elastobar and zycoprime nano chemicals on the properties of concrete with partial replacement of aggregate by periwinkles shell. Primary data were obtained from laboratory tests for materials characterization and determination of properties of fresh and harden concrete. The secondary data was extracted from relevant data and information from texts, journals, and documents on standards, regulations, and specifications.

Materials Selection

The materials used in this study were ordinary Portland cement, sand (fine aggregate), granite, and periwinkles shell (coarse aggregate). The periwinkles shell was added to the concrete by weight of dry concrete. Two nano-chemicals (Elastobar and Zycoprime) were used in this study. They are chosen for their stretchable membrane coating, high strength and ultraviolet stability properties in concrete.

Periwinkles shell used in this study were collected from the Ilaje area of Bariga, Lagos State. They were pre-treated by soaking overnight in detergent, followed by thorough washing and boiling in water to remove impurities such as oil and mud. After washing, they were rinsed thoroughly to ensure that all particles of detergent were removed as these can lower the performance of cement or even be a contaminant in concrete. The shells were finally spread to dry in a shed and then kept in waterproof sacks. Physical properties which include specific gravity, porosity, permeability, particle size distribution, and mechanical properties including aggregate impact value (AIV), and aggregate crushing value (ACV) were conducted on periwinkle shell by ASTM C127, ASTM C136, ASTM D2434, BS 812-110:1990, BS 812-112:1990, and BS 1377-2:1990 standards. The nano chemicals (Elastobar and Zycoprime) were purchased from Zydex Company in Lagos. They are available in liquid form and can be mixed with water to form a solution at different concentrations. The concentration of 0.25 g/L was used in this study as prescribed by the manufacturer.

Materials Characterization and Mixing of the Concrete

The concrete mix of grade M30 was used in this study. The water/cement ratio was calculated to be 0.45. The periwinkle shell was added at various percentages and liters of nanoparticles as shown in Table 2.1. A concrete mould of size 150×150×150 mm was cleaned and oiled, and fresh concrete was poured into it. The fresh concrete poured was tapped at 27 blows per layer of concrete. The concrete cube was de-mould after 24 hours of casting and cured in a curing tank.

Table 2.1: Designed mix proportion of periwinkle shell and nano chemicals

Samples	**% of Periwinkles Shell**	**Granite (%)**	**Elastobar (w/c)**	**Zycoprime (w/c)**
Control	0	100	0	0
A1	20	80	100	0
A2	20	80	85	15
A3	20	80	65	35
A4	20	80	45	55
A5	20	80	25	75
A6	20	80	0	100
B1	40	60	100	0
B2	40	60	85	15
B3	40	60	65	35
B4	40	60	45	55
B5	40	60	25	75
B6	40	60	0	100
C1	80	20	100	0
C2	80	20	85	15
C3	80	20	65	35
C4	80	20	45	55
C5	80	20	25	75
C6	80	20	0	100
D1	100	0	100	0
D2	100	0	85	15
D3	100	0	65	35
D4	100	0	45	55
D5	100	0	25	75
D6	100	0	0	100

Also, the cylindrical concrete specimen was cast for mix proportion at 28 days. Concrete from the cylindrical mould was also cured and crushed after 28 days. In total, about 150 concrete cubes of 10 cylindrical specimens (30×150) mm were produced in this study. The mix proportion of periwinkle shell, granite, and nano chemicals are presented in Table 2.1.

Test on Concrete

Laboratory test was performed on the fresh and hardened concrete. The tests on the fresh concrete were workability and bulk density tests while compressive strength, tensile strength, and water absorption tests were on hardened concrete. The test was carried out as specified in BS 812-103.1 (1985).

RESULTS AND DISCUSSIONS

Physical Properties of Periwinkle Shells

Table 3.1 presents the physical properties of periwinkle shells. The high porosity (45%) suggests a potential for increased water absorption, influencing concrete workability and strength.

Table 3.1: Physical properties of periwinkle shell

Tests	**Measurement**
Porosity (%)	45.00
Permeability (cm/s)	1.2×10^{-3}
Specific Gravity	2.68

Particle Size Distribution

The particle size distribution of the periwinkle shell aggregate used in this study is presented in Figure 3.1, illustrating the cumulative percentage of particles passing through various sieve sizes. Notably, the curve starts with 100% passing through the 4 mm sieve, indicating that all particles in the sample are smaller than this size. As the sieve size increases, the percentage of material passing decreases, with 85.50% passing through the 10 mm

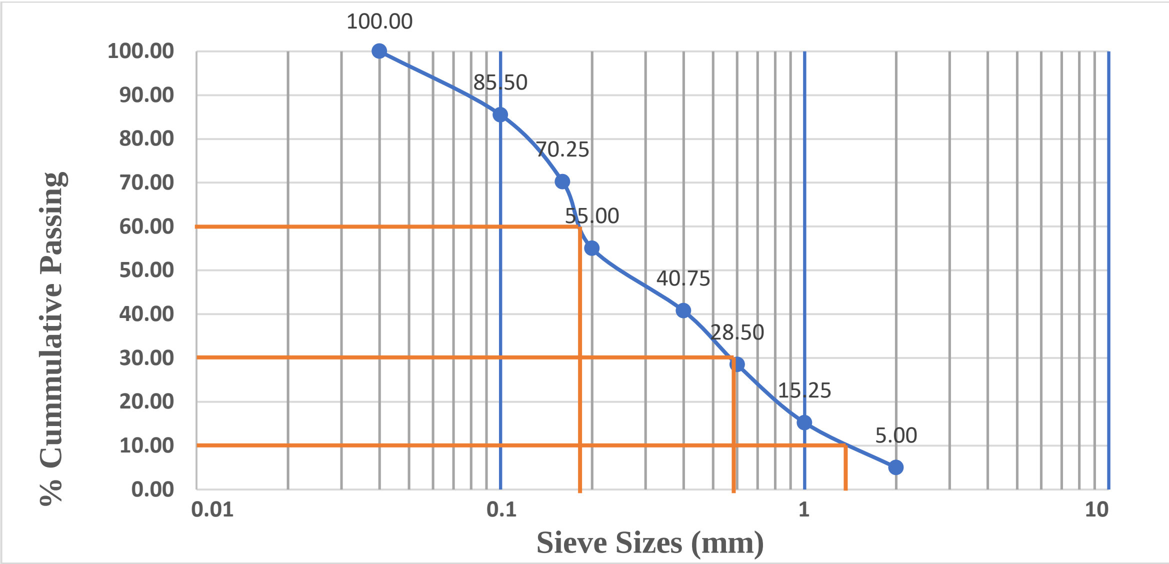

Figure 3.1: Particle Size Distribution of Periwinkle Shell

sieve, 70.25% through the 16 mm sieve, and so forth, until only 0.50% passes through the pan. This distribution suggests that the periwinkle shell aggregates are composed of a wide range of particle sizes, with a significant portion consisting of smaller particles. The shape of the curve, therefore, reflects a gradual reduction in particle size as the sieve size decreases, which is characteristic of poorly graded materials.

Furthermore, to analyze the gradation of the periwinkle shell aggregate, the Uniformity Coefficient (Cu) and the Coefficient of Curvature (Cc) were calculated. The Uniformity Coefficient (Cu) serves as a measure of the range of particle sizes in the sample. In this instance, the Cu value is 1.80, which falls below the threshold of 4, typically indicative of a well-graded material. This value implies that the periwinkle shell aggregate is poorly graded, possessing a relatively narrow range of particle sizes. The results from Table 3.2 provide critical insights into the physical properties of periwinkle shell aggregates when used in concrete, particularly in the context of their influence on concrete properties with coarse aggregate partially replaced by periwinkle shell. The porosity of the periwinkle shell aggregates was 45%, which is relatively high for materials used in concrete. This high porosity suggests that the periwinkle shells have a considerable amount of void space within their structure, which can have a significant impact on the concrete's performance. High porosity typically leads to increased water absorption, potentially affecting the workability, durability, and overall strength of the concrete. This is consistent with the findings of Olutoge (2016), who observed that materials with high porosity tend to reduce the compressive strength of concrete due to the increased water absorption, which can lead to internal voids and weaken the concrete matrix.

Furthermore, permeability, another critical factor, is measured at 1.2×10^{-3} cm/s. This value indicates that the periwinkle shell aggregate has relatively low permeability, meaning it resists the flow of water through its structure. Low permeability is generally advantageous in concrete as it reduces the likelihood of water ingress, which can cause deterioration through processes such as freeze-thaw cycles and sulfate attacks. In comparison, the research by Alawode and Idowu (2018) on the use of seashells as coarse aggregate reported similar low permeability values, which they linked to the shells' dense internal structure. However, the high porosity of the periwinkle shells may pose challenges if not properly managed, potentially leading to conflicting outcomes where the concrete's surface resists water penetration while internal voids retain moisture.

Additionally, the specific gravity of the periwinkle shell aggregates is found to be 2.68, which is comparable to conventional natural aggregates like granite or gravel, which typically range from 2.6 to 2.8. This suggests that periwinkle shells can be used as a substitute for these traditional aggregates without significantly altering the density of the concrete mix. The specific gravity is a crucial parameter because it influences the overall weight and density of the concrete, affecting its strength and load-bearing capacity.

Mechanical properties

The tests conducted were aimed at assessing the mechanical properties of periwinkle shells, including their resistance to impact and crushing forces.

(a) Aggregate Impact Value (AIV) of periwinkle shell

The Aggregate Impact Value (AIV) test results presented in Table 3.2 provide a comprehensive comparison between granite and periwinkle shells as coarse aggregates in concrete. The AIV is a crucial parameter for assessing the toughness of aggregate materials, which directly influences the concrete's resistance to impact loads. The periwinkle shell demonstrates an average impact value of 40.2%, which is higher than that of granite but still within the acceptable limit of less than 45%. The higher AIV of the periwinkle shell suggests that while it is somewhat less resistant to impact compared to granite, it is still a viable option as a partial replacement for conventional aggregates in concrete.

Table 3.2: Aggregate Impact Value (AIV) of periwinkle shell

Sample	Test	Weight of Aggregate (kg)	Impact Value (%)	Average Impact Value (%)	Remarks
Granite	(a)	0.7	35.7	27.7	<45%
	(b)	0.75	20		
	(c)	0.78	27.4		
Periwinkle Shell	(a)	0.65	42.1	40.2	<45%
	(b)	0.7	39.5		
	(c)	0.68	39		

The relatively higher AIV could be attributed to the organic and porous nature of periwinkle shells, which may lead to slightly reduced toughness compared to granite. However, its AIV still indicates that it can adequately withstand impact loads, particularly in non-structural or low-load-bearing applications.

(b) Aggregate Crushing Value (ACV) of periwinkle shell

The Aggregate Crushing Value (ACV) test results outlined in Table 3.3 provide a detailed comparison between granite and periwinkle shells as potential coarse aggregates in concrete. The ACV is a crucial measure of the aggregate's ability to withstand crushing forces, which is essential in determining its

Table 3.3: Aggregate Crushing Value (ACV) of periwinkle shell

Sample	Test	Weight of Aggregate (kg)	Crushing Value (%)	Average Crushing Value (%)	Remarks
Granite	(a)	2.85	35.26	30.23	<45%
	(b)	2.84	32.44		
	(c)	2.8	23.05		
Periwinkle	(a)	2.6	38.4	37.6	<45%
Shell	(b)	2.55	37.1		
	(c)	2.65	37.5		

suitability for use in load-bearing concrete structures. The average crushing value for granite was 30.23%, which is significantly below the 45% threshold typically recommended for concrete aggregates. This low ACV indicates that granite possesses excellent resistance to crushing forces, corroborating its established reputation as a durable and robust aggregate material widely used in construction.

Properties of Fresh Concrete

This section details the tests conducted on fresh concrete including the slump test, and bulk density test which provide essential insights into its performance characteristics.

Slump

Table 3.4 presents a detailed examination of the workability of concrete mixes as indicated by their slump values. The control sample, composed entirely of granite without any periwinkle shell or nano chemicals, exhibited a slump of 112.37 mm. This control serves as a baseline against which the effects of introducing periwinkle shell, elastobar, and zycoprime can be compared. The data clearly show that the inclusion of these materials alters the slump height, which directly corresponds to the concrete’s workability. As the percentage of periwinkle shell increases, so too does the slump height in most cases, especially when combined with elastobar.

For instance, in sample A1, which contains 20% periwinkle shell and 80% granite, the addition of 100% elastobar increases the slump to 76.12 mm, indicating improved workability compared to the control.

However, the trend continues as the proportion of zycoprime is gradually introduced, with a corresponding decrease in slump height. This trend is evident in samples A2 through A6, where the slump height decreases from 71.45 mm in A2 (85% elastobar, 15% zycoprime) to 46.34 mm in A6 (0% elastobar, 100% zycoprime). These findings suggest that while elastobar generally enhances workability by increasing the slump, zycoprime appears to have a stiffening effect, reducing the slump height. In the B series, which contains 40% periwinkle shell, the pattern is consistent with the A series, but with slightly higher slump values. Sample B1, which includes 100% elastobar and no zycoprime, achieves a slump height of 81.54 mm, the highest among the B samples. As zycoprime is incrementally added and elastobar reduced, the slump height decreases, similar to the A series. By sample B6, where zycoprime is at 100%, the slump height has decreased to 52.19 mm. This indicates that the effect of zycoprime on reducing workability is consistent, regardless of the percentage of periwinkle shell present in the mix.

Bulk Density

Figure 3.2 provides results of the bulk density of concrete mixes containing different proportions of periwinkle shell, granite, elastobar, and zycoprime. The control sample, which consists of 100% granite and no additives, has a bulk density of 2360.25 kg/m³. This value serves as a reference point to evaluate the effects of incorporating periwinkle shell, elastobar, and zycoprime on the bulk density of the concrete. As observed, the introduction of the periwinkle shell at 20% replacement (sample A1) slightly reduces the bulk density to 2345.78 kg/m³. This trend continues as the proportion of elastobar decreases and zycoprime increases. By sample A6, where elastobar is entirely replaced by zycoprime, the bulk density has decreased to 2201.54 kg/m³. This reduction indicates that while elastobar contributes to maintaining a higher bulk density, zycoprime, due to its likely lower density and different chemical composition, reduces the overall bulk density of the concrete mix.

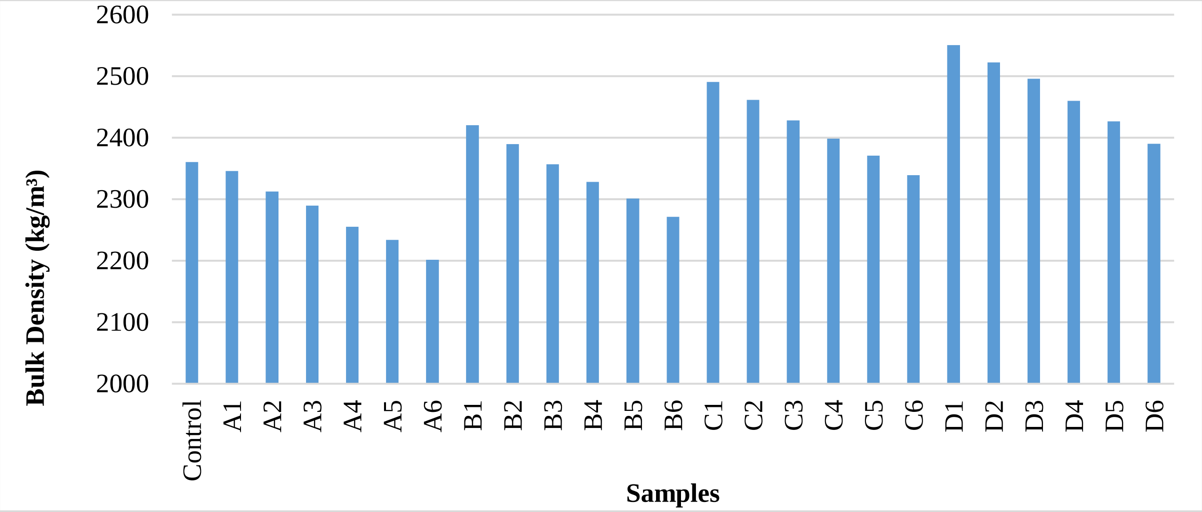

Figure 3.2: Bulk density for concrete with varying percentages of periwinkle shell, granite, elastobar, and zycoprime.

These observations align with existing research that has explored the impact of different aggregate types and chemical additives on the bulk density of concrete. For instance, a study by Li *et al.*, (2019) found that incorporating lightweight aggregates or chemical additives that are less dense can significantly reduce the bulk density of concrete. Li *et al.*, (2019) also observed that while certain additives might enhance other properties, such as durability or strength, they may compromise the bulk density, which is a critical factor for specific applications. The current findings corroborate this understanding, especially in the context of using periwinkle shell and zycoprime as partial replacements for traditional aggregates and additives.

Properties of Hardened Concrete

This section details the tests conducted on the hardened concrete, including compressive strength, splitting tensile test, and water absorption test, which provide essential insights into its performance characteristics.

Compressive strength

The compressive strength data provided in Figure 3.3 reveal critical insights into the performance of concrete mixes with varying percentages of periwinkle shell, granite, elastobar, and zycoprime. The control sample, which contains 100% granite and no additives, shows a steady increase in compressive strength over time, reaching 35.77 MPa at 28 days. This progression aligns with typical expectations for standard concrete, which tends to gain strength gradually as it cures. For the samples in the A series, where 20% of the granite was replaced by periwinkle shell and varying proportions of elastobar and zycoprime were introduced, the compressive strengths at 28 days generally fell below the control, with A6 recording the lowest at 32.2 MPa. The reduction in strength could be attributed to the introduction of periwinkle shells, which are less dense and have different bonding characteristics compared to traditional aggregates.

Table 3.4: Slump heights for concrete with varying percentages of periwinkle shell, granite, elastobar, and zycoprime.

Samples	% of Periwinkles Shell	Granite (%)	Elastobar (w/c)	Zycoprime (w/c)	Slump (mm)
Control	0	100	0	0	112.37
A1	20	80	100	0	76.12
A2	20	80	85	15	71.45
A3	20	80	65	35	66.78
A4	20	80	45	55	57.22
A5	20	80	25	75	51.56
A6	20	80	0	100	46.34
B1	40	60	100	0	81.54
B2	40	60	85	15	76.33
B3	40	60	65	35	71.12
B4	40	60	45	55	62.47
B5	40	60	25	75	57.64
B6	40	60	0	100	52.19
C1	80	20	100	0	86.48
C2	80	20	85	15	81.59
C3	80	20	65	35	76.87
C4	80	20	45	55	67.23
C5	80	20	25	75	62.89
C6	80	20	0	100	57.13
D1	100	0	100	0	91.76
D2	100	0	85	15	86.52
D3	100	0	65	35	81.21
D4	100	0	45	55	71.4
D5	100	0	25	75	61.33
D6	100	0	0	100	52.87

This trend is consistent with findings from a study by Johnson *et al.*, (2020), which demonstrated that substituting conventional aggregates with organic materials like shells often results in lower compressive strengths due to the materials' lower density and possible interference with the cement matrix. In the B series, where 40% of the granite was replaced by a periwinkle shell, there is a noticeable improvement in compressive strength compared to the A series, with B1 reaching 37 MPa at 28 days. This improvement suggests that a moderate increase in periwinkle shell content, coupled with the presence of elastobar and zycoprime, can enhance the strength characteristics of concrete. This could be due to the improved packing density and better bonding facilitated by the combined effect of the additives. A similar trend was observed by Smith and Lee (2019), who reported that the incorporation of specific chemical additives could counterbalance the reduction in strength caused by alternative aggregates, thereby optimizing the overall concrete performance.

Splitting tensile test

The data presented in Figure 3.4 illustrate the splitting tensile strength of concrete samples with varying proportions of periwinkle shell, granite, elastobar, and zycoprime over 28 days. Initially, the control sample, composed solely of granite, achieved a splitting tensile strength of 4 MPa at 28 days, setting a baseline for the impact of incorporating alternative materials. When periwinkle shell is introduced as a partial replacement for granite, the A series demonstrates a general decrease in tensile strength compared to the control. For instance, sample A1, with 20% periwinkle shell, recorded a tensile strength of 3.8 MPa, while the strength further diminishes in samples with higher periwinkle shell content and varying amounts of elastobar and zycoprime. This trend suggests that while periwinkle shell contributes to a reduction in tensile strength, the inclusion of elastobar and zycoprime may mitigate, but not entirely counterbalance, this effect.

Water absorption test

Figures 3.5 illustrate the water absorption characteristics of concrete samples over various curing periods, with varying percentages of periwinkle shell, granite, elastobar, and zycoprime. The results provide a comprehensive view of how these variables affect the water permeability of the concrete. Initially, the control sample, composed entirely of traditional materials, shows a consistent decrease in water absorption from 4.5% at 3 days to 3.6% at 28 days. This steady decline indicates that conventional concrete achieves lower water absorption as it cures, reflecting the effective hydration and densification of the cement matrix. This finding aligns with previous research, which has shown that traditional concrete mixtures typically exhibit reduced porosity over time (Siddique *et al.*, 2019). In contrast, the samples with varying percentages of periwinkle shell (Series A) display higher water absorption values compared to the control.

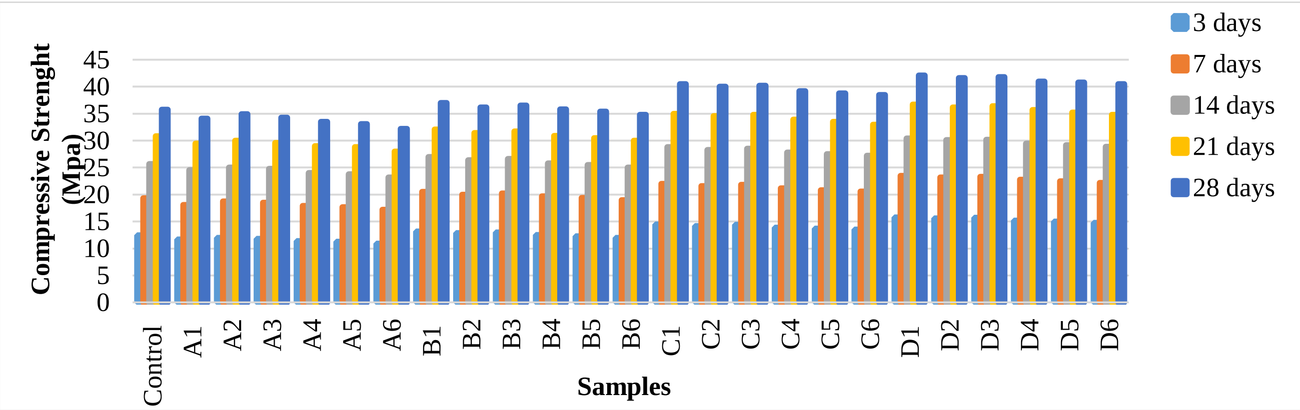

Figure 3.3: Compressive strength of concrete with varying percentages of periwinkle shell, granite, elastobar, and zycoprime.

The samples in Series D, characterized by a complete replacement of granite with a periwinkle shell and maximum levels of elastobar and zycoprime, demonstrate the lowest water absorption values. For example, sample D1 shows a water absorption rate decreasing from 3.5% to 2.7% over 28 days. This significant reduction is indicative of the densification effect contributed by the Nano chemical additives, which enhance the matrix's ability to resist water penetration. This finding is supported by recent studies indicating that the inclusion of nanomaterials in concrete can effectively reduce water absorption and improve the material's permeability due to the formation of pores or voids within the shell (Jang *et al.*, 2021).

Scanning Electron Microscopy (SEM) of Concrete

The cube considered were the control specimen and the optimal concrete mix for 28days curing period. From the observation of tests on concrete, the optimal concrete mix is sample B2 with a percentage of periwinkle shell, granite, elastobar, and zycoprime of 40, 60, 85, and 15% respectively.

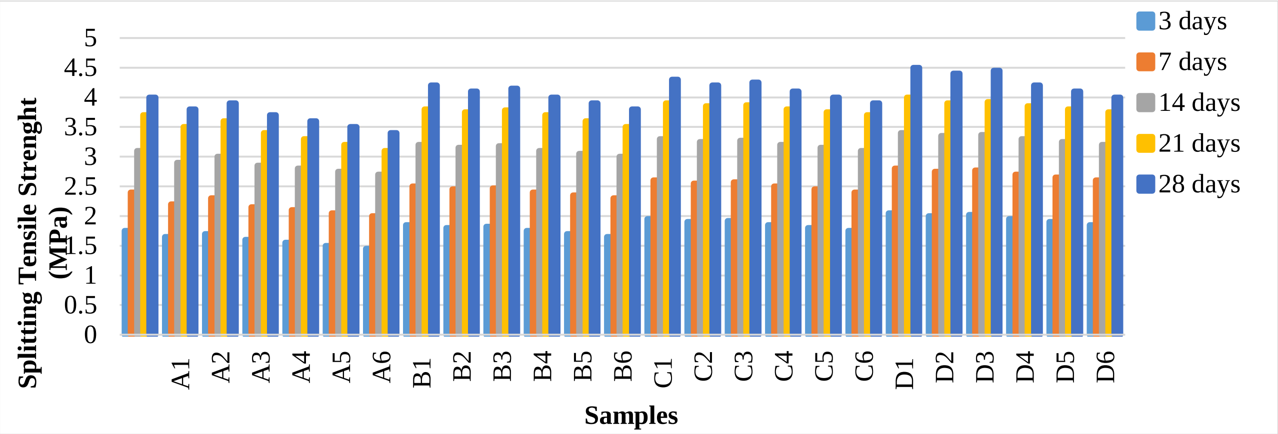

Figure 3.4: Splitting tensile strength of concrete with varying percentages of periwinkle shell, granite, elastobar, and zycoprime

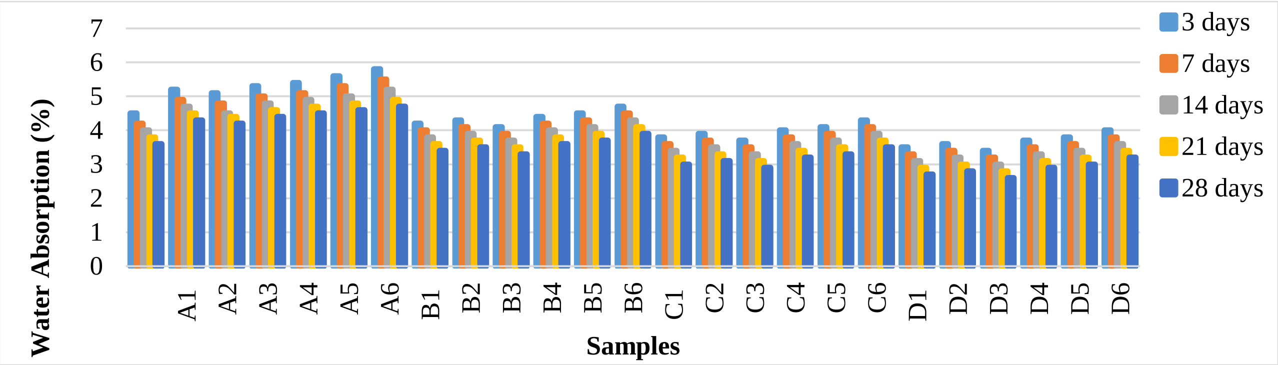

Figure 3.5: Water absorption of concrete with varying percentages of periwinkle shell, granite, elastobar, and zycoprime.

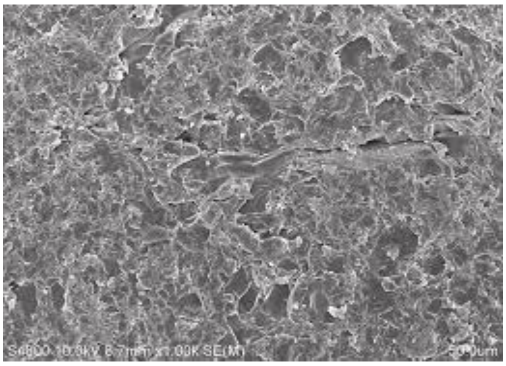

Figure 3.6: SEM image of the control specimen

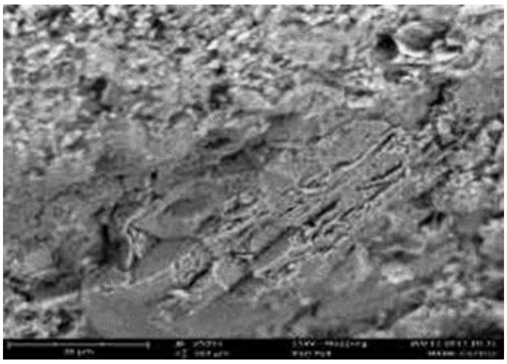

Figure 3.7: SEM image of the optimal concrete mix

In the transition zone of the above concretes, there are large crystals of Ettringite and CH with preferred orientation and porous structure. The porosity of the control specimen concrete was more than that of the optimal concrete mix (Kai et al., 2016).

CONCLUSION AND RECOMMENDATION

The research concluded that periwinkle shell aggregate has poor grading due to its particle size distribution, but its specific gravity is comparable to traditional aggregates, indicating potential benefits if combined with an appropriate mix of design and additives. Additionally, the inclusion of periwinkle shells enhances workability when paired with elastobar, improves concrete toughness, and supports sustainable construction by achieving competitive mechanical properties, particularly when combined with elastobar and zycoprime. The optimal mix exhibited a denser microstructure and reduced permeability, making it suitable for structural applications.

It is recommended to optimize periwinkle shell concrete, incorporating appropriate additives or fine aggregates can improve particle size distribution, while chemical admixtures can mitigate high porosity and enhance bond strength. Additionally, adjusting the proportions of elastobar and zycoprime based on desired properties can enhance workability and tensile strength, supporting the development of durable and sustainable concrete mixes

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