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Research Article

EFFECT OF AGGREGATE TYPE ON CONCRETE PROPERTIES: SEASHELL VS. GRANITE

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Abstract

Concrete remains a fundamental material in modern construction due to its durability, versatility, and structural reliability. Its performance is largely governed by compressive strength and density, which determine suitability for load-bearing applications and long-term serviceability. Aggregates, constituting 60–80% of concrete's volume, significantly influence these properties. While crushed granite aggregates are conventionally favored for their high strength, specific gravity, and angular morphology, alternative materials such as seashell aggregates are gaining attention for potential sustainability and cost benefits. This study provides a comparative evaluation of concrete properties using seashell and granite aggregates, examining their effects on compressive strength, density, and overall material behavior. Experimental results highlight differences in mechanical performance attributable to aggregate type, offering insights for sustainable material selection and optimized concrete design in structural applications.

Keywords: Concrete, Compressive Strength, Aggregates, Seashell, Granite

Introduction

Concrete's widespread use in modern construction stems from its durability, adaptability, and capacity to meet diverse structural demands, making it a cornerstone material for infrastructure worldwide. The compressive strength and density of concrete are fundamental parameters that largely determine its suitability for load-bearing applications, serviceability, and long-term performance under varied environmental conditions. These properties are strongly influenced not only by the cementitious binder and water–cement ratio but also by the quality and type of aggregates, which typically occupy 60–80 % of concrete's volume and 70–85 % of its mass. Aggregates therefore play a central role in determining mechanical characteristics and overall material behaviour in hardened concrete (Vaidya et al., 2022; Kaushik et al., 2024). Traditionally, crushed granite aggregates have been widely adopted in structural concrete due to their high inherent strength, relatively high specific gravity, and angular particle morphology, which enhance particle interlock and load transfer within the cement–aggregate matrix. Experimental investigations have illustrated that concrete containing crushed granite usually exhibits competitive compressive strength relative to other aggregate types, with performance often comparable to or exceeding that of conventional gravels and other rock aggregates (Pertiwi et al., 2021). Nevertheless, the extraction and processing of granite and other natural aggregates contribute to environmental degradation, energy consumption, and carbon emissions, and their availability can be limited or costly in certain regions highlighting the need for more sustainable and locally accessible alternatives. In recent years, Gyurkó et al. (2019) posits that waste seashells an abundant by-product of seafood industries in coastal areas have garnered attention as a potential alternative or supplementary aggregate in concrete. Seashells are largely composed of calcium carbonate and exhibit distinct properties such as higher porosity, irregular geometry, and elevated water absorption compared with traditional aggregates, which can influence concrete fresh and hardened properties (Eziefula et al., 2018). Research has explored the use of seashells in concrete in different forms such as crushed seashell aggregates, seashell powder, or combinations thereof reporting varied effects on compressive strength and density (Bamigboye et al., 2021). Zaimy et al. (2023) indicate that low to moderate seashell content may sustain or slightly enhance compressive strength due to improved packing and filler effects, while higher proportions often lead to strength reductions attributed to poor interfacial bonding and increased porosity.

Despite the growing body of research focused on seashell use in concrete, direct comparative studies between concrete made with seashell aggregates and that with conventional crushed granite aggregates remain limited. Most existing investigations examine seashell incorporation in isolation or emphasize particular replacement levels without rigorously benchmarking against a well-established conventional material. This creates a knowledge gap in understanding how seashell aggregate concrete performs in terms of both compressive strength and density, relative to granite aggregate concrete, under standardized mix designs and curing regimes. Moreover, research has often focused narrowly on specific replacement percentages or aggregate types without adequately addressing the broader performance implications across a range of compositions. As a result, there is no clear consensus on the optimal seashell content that balances the environmental and economic benefits of waste reuse with the mechanical requirements of structural concrete. Such comparative evidence is crucial for validating the practical applicability of seashell-based aggregates, especially in contexts where natural aggregate resources are scarce or costly.

This gap is particularly relevant in coastal regions of developing countries such as Nigeria, where seashell waste is abundant and under-utilized, while quarries for quality granite aggregates may be distant or expensive to exploit. Harnessing seashells as a construction material could contribute to sustainable local resource utilization and reduction of waste disposal impacts provided that their structural performance is rigorously validated against conventional standards. Accordingly, this study aims to systematically investigate and compare the effects of crushed seashell and crushed granite aggregates on the compressive strength and density of concrete, using controlled experimental conditions. By assessing mixes with varying levels of aggregate replacement and measuring key performance indicators at standard curing intervals, the research intends to identify feasible seashell content ranges that meet structural requirements and to provide evidence-based recommendations for sustainable aggregate selection. The outcomes are expected to advance understanding of sustainable concrete alternatives and support more informed material decisions in both research and practice.

Materials and Methods

Materials

Ordinary Portland Cement (OPC) conforming to relevant standards was used as the binding material. Fine aggregate consisted of clean, well-graded natural river sand free from organic impurities. Two types of coarse aggregates were employed: crushed granite and crushed seashells. The seashells were thoroughly washed to remove salts and impurities, air-dried, and crushed to sizes comparable to conventional coarse aggregates. Potable water suitable for concrete production was used throughout the study.

Concrete Mix Design

A nominal mix ratio of 1:2:4 (cement: sand:coarse aggregate) corresponding to Grade 15 concrete was adopted. Concrete cubes of 150 × 150 × 150 mm were cast. The water–cement ratio was maintained at 0.5 for all mixes to ensure uniform workability and comparability. Five concrete mixes were prepared based on the percentage replacement of granite with seashell aggregate by weight:

- Sample A: 100% granite (control)
- Sample B: 80% granite + 20% seashell
- Sample C: 65% granite + 35% seashell
- Sample D: 50% granite + 50% seashell
- Sample E: 100% seashell (control)

All mixes contained identical quantities of cement, sand, and water to isolate the effect of coarse aggregate substitution.

Specimen Preparation and Curing

Concrete constituents were batched by weight using a digital electronic weighing balance and mixed manually until a homogeneous mixture was achieved. The fresh concrete was placed into steel cube molds in layers and compacted using a tamping rod to eliminate entrapped air. After casting, the specimens were left in the molds for 24 hours, after which they were demolded and cured by immersion in clean water at room temperature. Curing durations were 7, 14, and 28 days, with three cubes tested per mix at each curing age.

Compressive Strength Testing

The compressive strength of the concrete cubes was evaluated using a Schmidt rebound hammer, a non-destructive testing method based on surface hardness. For each cube, eight rebound readings were taken at different points, and the average rebound number was recorded. Corresponding compressive strength values were obtained using the calibration chart provided with the hammer. The test was conducted at curing ages of 7, 14, and 28 days.

Density Determination

Concrete cube density was determined by measuring the mass of each specimen and dividing by its volume. Density values were used to assess the influence of seashell aggregate on concrete unit weight.

Data Analysis

Experimental results were analyzed using descriptive statistical tools, including mean values and comparative analysis. Compressive strength and density results of seashell-based concrete were compared with those of conventional granite concrete to evaluate performance trends across curing ages.

Results and Discussion

Compressive Strength Development

The compressive strength results of concrete produced with varying proportions of granite and crushed seashell aggregates at curing ages of 7, 14, and 28 days are summarized in Table 1 and illustrated in Figures 1 and 2. Across all mixtures, compressive strength increased with curing age, reflecting the progressive hydration of cement and continued strength gain over time.

Table 1: Compressive Strength Result

		NUMBERS OF DAYS	
Samples	**Day 7**	**Day 14**	**Day 28**
Sample A	13.83	14.03	18.11
Sample B	12.78	12.65	14.48
Sample C	11.80	11.56	12.61
Sample D	11.85	11.46	12.95
Sample E	11.20	11.46	14.65

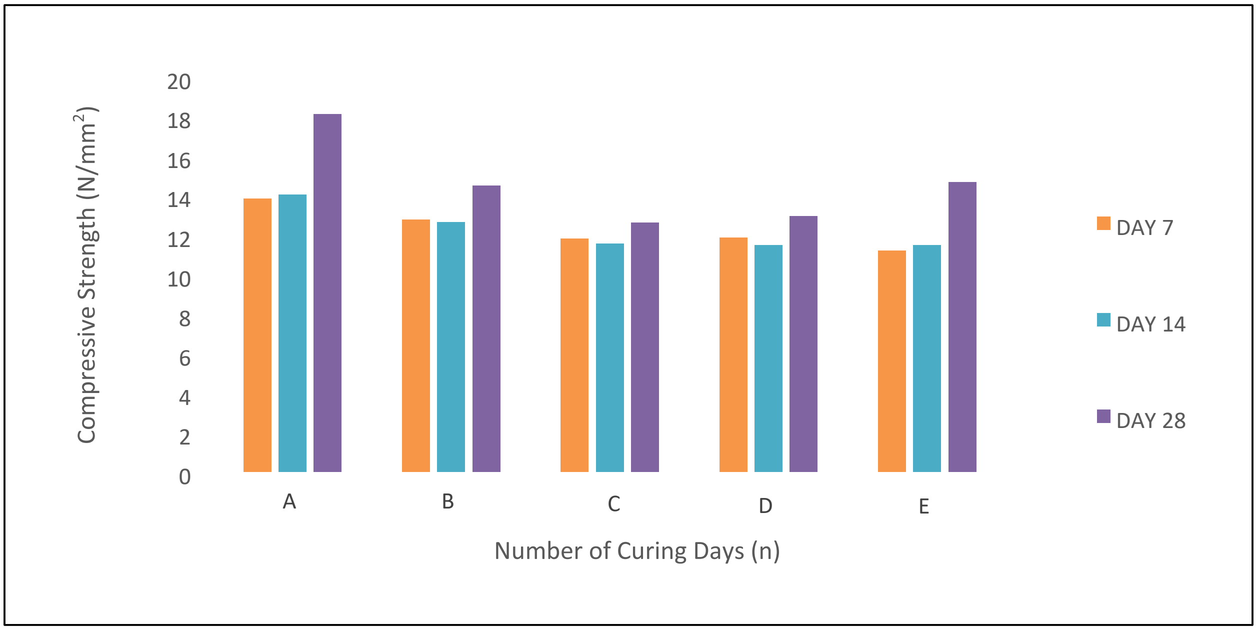

Figure 1: Bar Chat of Compressive Strength against Number of Curing days

The control mix containing 100% granite aggregate (Sample A) consistently exhibited the highest compressive strength at all curing ages, achieving 13.83 MPa, 14.03 MPa, and 18.11 MPa at 7, 14, and 28 days, respectively.

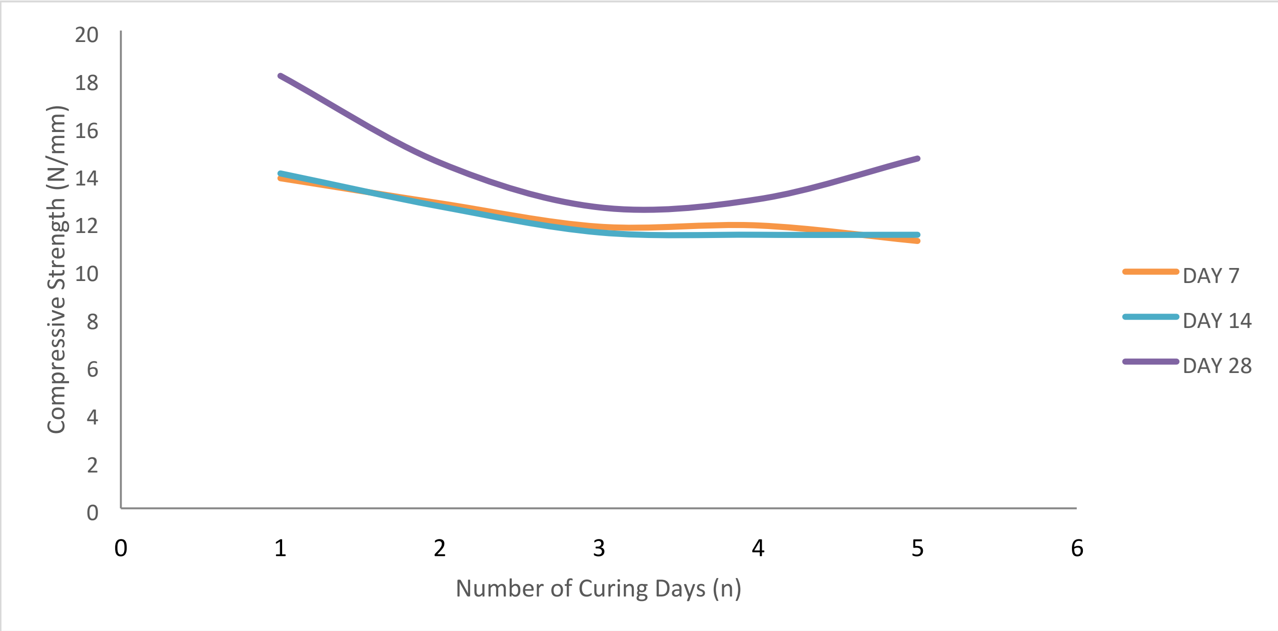

Figure 2: Graph of Compressive Strength against Number of Curing days

This superior performance is attributed to the higher stiffness, angularity, and mechanical interlock characteristics of granite aggregates, which enhance load transfer within the concrete matrix.

Concrete incorporating partial replacement of granite with seashell aggregates showed a gradual reduction in compressive strength as the seashell content increased. Sample B (80% granite, 20% seashell) attained a 28-day compressive strength of 14.48 MPa, representing a moderate reduction relative to the control but still demonstrating acceptable structural performance. This indicates that limited substitution of granite with seashell aggregates can be achieved without significant compromise in strength.

Further increases in seashell content (Samples C and D) resulted in lower compressive strength values at all curing ages. At 28 days, Samples C (65% granite, 35% seashell) and D (50% granite, 50% seashell) recorded compressive strengths of 12.61 MPa and 12.95 MPa, respectively. The observed strength reduction may be attributed to the relatively lower crushing resistance and higher porosity of seashell aggregates, which weaken the interfacial transition zone between aggregate and cement paste.

The concrete made with 100% seashell aggregate (Sample E) exhibited a notable strength increase between 14 and 28 days, reaching 14.65 MPa at 28 days. This late-age strength gain suggests improved bonding and gradual densification of the cement–seashell matrix during extended curing, despite the initially lower early-age strength.

4.2 Effect of Curing Age

For all mixtures, compressive strength increased with curing duration, with the most pronounced gains observed between 14 and 28 days. This trend confirms the importance of adequate curing, particularly for concretes incorporating alternative aggregates such as seashells, which may require longer hydration periods to develop sufficient strength.

The results further indicate that seashell-based concretes exhibit slower early-age strength development compared to granite-based concrete but demonstrate appreciable strength improvement at later ages. This behavior is consistent with materials possessing higher water absorption capacity, which can delay early hydration while supporting prolonged cement hydration.

4.3 Density Characteristics of Concrete

Table 2: Estimation of Concrete cube Density

Cube size: 150 × 150 × 150 mm

Volume (V): 0.003375 m³

Sample	**Mass (kg)**	**Volume (m³)**	**Density (kg/m³)**
A	8.65	0.003375	2561
B	9.05	0.003375	2681
C	8.77	0.003375	2599
D	8.77	0.003375	2599
E	8.10	0.003375	2401
Average	—	—	**2578**

The density results demonstrate a clear influence of seashell aggregate incorporation on the physical characteristics of the concrete. The control mix (Sample A) exhibited a density of 2561 kg/m³, consistent with conventional normal-weight concrete. As the proportion of seashell aggregate increased, a progressive reduction in density was observed, with the fully replaced mix (Sample E) recording the lowest density of 2401 kg/m³. Mixes with partial replacement displayed intermediate densities, ranging from 2599 kg/m³ to 2681 kg/m³, indicating a transitional behavior between conventional and modified concretes.

The observed reduction in density can be attributed to the inherently lower specific gravity and higher porosity of seashell aggregates relative to granite. These characteristics introduce additional voids within the concrete matrix, thereby reducing the overall unit weight. This trend aligns with established findings on lightweight and bio-aggregate concretes, where aggregate microstructure plays a dominant role in governing density. Although the reduction in density may limit the suitability of seashell-based concrete for high-load structural applications, it presents notable advantages for non-load-bearing and lightweight construction. These include reduced dead loads, potential material cost savings, and improved sustainability through the valorization of marine waste. Consequently, seashell aggregates show promise as an alternative material in environmentally responsible concrete production, particularly where reduced selfweight is a desirable design criterion.

4.4 Water Absorption Characteristics

Table 3: Water absorption characteristics of concrete incorporating granite and seashell aggregates

Sample	Coarse Aggregate Type	Replacement Level (%)	Water Absorption (%)
A	Granite (Control)	0	3.6
E	Seashell (Control)	100	5.6

Table 3 presents the water absorption characteristics of concrete produced with conventional granite aggregate (Sample A) and seashell aggregate (Sample E). The control concrete containing 100% granite recorded a water absorption value of 3.6%, which is consistent with typical values reported for normal-weight concrete made with dense, low-porosity natural aggregates. In contrast, the concrete produced with 100% seashell aggregate exhibited significantly higher water absorption of 5.6%.

The increase in water absorption observed in the seashell-based concrete can be attributed to the intrinsic physical properties of seashell aggregates, particularly their higher porosity and rougher surface texture compared to granite. These characteristics promote greater moisture ingress and retention within the concrete matrix, leading to increased overall absorption capacity. Additionally, the lower density and irregular morphology of seashell particles may contribute to the formation of interconnected voids at the aggregate–paste interface, further enhancing water uptake.

From a performance perspective, elevated water absorption may have implications for durability, as it can increase susceptibility to moisture-related deterioration mechanisms. However, the results also highlight the potential of seashell aggregates for applications where lightweight construction and sustainability are prioritized over exposure to aggressive environments. The findings underscore the need for mix optimization or surface treatment of seashell aggregates to mitigate water absorption while harnessing their environmental and economic benefits.

Discussion

The results of this study demonstrate that the mechanical and physical performance of concrete is strongly governed by the type and proportion of coarse aggregate, with clear implications for strength development, density, and durability-related properties. As expected, all mixes exhibited increasing compressive strength with curing age, reflecting progressive cement hydration and microstructural refinement. The control concrete produced with 100% granite aggregate consistently achieved the highest strength at all ages, reaching 18.11 MPa at 28 days. This outcome is consistent with extensive prior research attributing the superior performance of granite-based concrete to the high stiffness, angularity, and crushing resistance of granite aggregates, as well as their ability to form a dense and mechanically efficient interfacial transition zone (ITZ) with the cement paste (Neville, 2011; Zhou et al., 2025).

Partial substitution of granite with seashell aggregates led to a systematic reduction in compressive strength, particularly as the replacement level increased. At 20% replacement, the 28-day strength (14.48 MPa) remained within a range considered acceptable for low- to mediumstrength concrete applications. Similar findings have been reported for concretes incorporating seashells, oyster shells, and other biogenic aggregates, where replacement levels between 10% and 30% resulted in modest strength losses primarily due to differences in aggregate stiffness and surface morphology rather than impaired cement hydration (Yang et al., 2010; Avudaiappan et al., 2026). These studies emphasize that limited replacement can be accommodated without severe degradation of mechanical performance.

At higher replacement levels, the observed reduction in compressive strength aligns closely with earlier investigations reporting that seashell aggregates generally possess lower crushing strength and higher porosity compared to conventional crushed stone aggregates (Do & Kim, 2016). These characteristics weaken the aggregate skeleton and adversely affect the ITZ, thereby reducing load-transfer efficiency. The slight variation in strength between mixes with comparable replacement levels suggests that packing density and mix heterogeneity also play a role, a phenomenon previously observed in concretes incorporating lightweight and recycled aggregates (Poon et al., 2004; Zhu et al., 2019).

Notably, the concrete produced with 100% seashell aggregate exhibited a pronounced late-age strength gain, achieving 14.65 MPa at 28 days and outperforming some partially replaced mixes.

This behavior has been widely reported for concretes containing porous aggregates and is commonly attributed to internal curing effects. Seashell aggregates, owing to their high water absorption capacity, can store and gradually release moisture, sustaining hydration at later ages and promoting continued densification of the cement matrix (Al Saffar et al., 2019). Such delayed strength development is characteristic of lightweight, recycled, and bio-based aggregate concretes.

Curing age exerted a pronounced influence on all mixtures, with the most substantial strength gains occurring between 14 and 28 days. Seashell-based concretes displayed slower early-age strength development compared to granite concrete, but their continued strength gain at later ages highlights the importance of extended curing. This trend corroborates earlier findings that porous aggregates tend to delay early hydration while supporting prolonged cement reactions under adequate moisture conditions (Hossain, 2004; Hamasalh et al., 2020).

The density results further confirm the strong influence of aggregate type. The control mix density of 2561 kg/m³ falls within the range of normal-weight concrete, whereas increasing seashell content led to a progressive reduction in density, reaching 2401 kg/m³ for the 100% seashell mix. Comparable reductions have been consistently reported in the literature for concretes incorporating seashells and other marine bio-aggregates due to their lower specific gravity and internal porosity (Hamada et al., 2025). Such concretes are often classified as transitional materials between normal-weight and lightweight concrete, offering advantages such as reduced dead load and improved handling, albeit with limitations for heavily loaded structural applications.

Water absorption results revealed higher absorption for seashell concrete (5.6%) compared to granite concrete (3.6%), reflecting the porous and irregular nature of seashell aggregates. Similar trends have been widely documented for seashell, recycled, and lightweight aggregate concretes (Poon et al., 2004). Elevated water absorption is commonly linked to increased permeability and potential durability concerns, including susceptibility to chloride ingress, sulfate attack, and freeze–thaw damage. However, previous studies have also demonstrated that such drawbacks can be significantly mitigated through optimized mix design, reduced water–cement ratios, incorporation of supplementary cementitious materials, or surface treatment of seashell aggregates (Nilimaa, 2023).

The present findings are in strong agreement with existing literature and reinforce the growing consensus that seashell aggregates can be effectively utilized as partial or full replacements for conventional aggregates in applications where moderate strength, reduced density, and sustainability are prioritized. While mechanical strength and durability performance remain lower than those of granite-based concrete, the observed properties fall within acceptable limits for non-structural and low-load applications, particularly in coastal regions where seashell waste is readily available. These results contribute to the body of evidence supporting seashell aggregates as a viable component of sustainable and resource-efficient concrete technology, provided that their inherent limitations are addressed through appropriate mix optimization and curing strategies.

Conclusion

The growing reliance on conventional granite aggregates in concrete production poses environmental, economic, and sustainability challenges, particularly in coastal regions where alternative resources are underutilized. This study addressed this problem by comparatively evaluating the mechanical and physical performance of concrete produced with crushed seashell aggregates relative to conventional granite aggregates. The results demonstrate that while granite-based concrete achieved the highest compressive strength and density, partial replacement of granite with seashell aggregates, particularly at low substitution levels, produced concrete with acceptable strength performance for low- to medium-strength applications. All mixtures exhibited progressive strength gain with curing age, and seashell-based concretes showed notable late-age strength development, attributed to their higher porosity and internal curing potential. The reduction in density with increasing seashell content highlights the suitability of seashell aggregates for lightweight and non-structural concrete applications, while increased water absorption indicates potential durability concerns. These findings imply that crushed seashell aggregates can contribute to more sustainable concrete production through waste valorization and reduced dependence on natural stone aggregates, especially in coastal environments. However, the study is limited by its focus on compressive strength, density, and water absorption, as well as the use of a single mix proportion and non-destructive strength assessment method. Future research should investigate durability performance under aggressive exposure conditions, optimize mix designs using supplementary cementitious materials, and evaluate long-term structural behavior. Overall, the study provides empirical evidence supporting the controlled use of seashell aggregates as a sustainable alternative in concrete, contributing to environmentally responsible material selection and circular construction practices.

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