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Research Article

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Special Issue

A Themed Issue in Honour of Professor Clement Uche Atuanya on His retirement.

This themed issue pays tribute to Professor Clement Uche Atuanya in recognition of his illustrious career in Metallurgical and Materials Engineering as he retires from Nnamdi Azikiwe University, Awka. We celebrate his enduring legacy of dedication to advancing knowledge and his impact on academia and beyond through this collection of writings.

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Impacts of ground periwinkle shells on the compressive of strength of sandcrete blocks

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Abstract
In the search for sustainable construction practices, the utilization of agricultural waste byproducts holds promise for mitigating environmental impact. This study investigated the efficacy of incorporating periwinkle shell particles as a partial replacement for sand in sandcrete blocks. The periwinkle shells were ground and separated into three groups based on their particle size. Group 1 consists of ground periwinkle shells of size 2mm to 4.75mm, Group 2 of size 0.85mm to 1.18mm and Group 3 of size less than 0.6mm. Compressive strength results on the periwinkle shell sandcrete blocks revealed distinct compressive strength profiles for the three groups. Group 2 exhibits the highest strengths, peaking at 6.7N/mm² at 10% replacement of sand with ground periwinkle shells, surpassing Nigerian Industrial Standard requirements. Group 1 demonstrated consistent strength, while Group 3 shows varying and diminishing strengths. 10% replacement of sand with periwinkle shells for Group 2 gave the highest compressive test results and is therefore the most suitable for load-bearing applications. These findings underscore the potential of periwinkle shell incorporation in enhancing sandcrete block performance while still meeting industry standards.

Keywords: Put Periwinkle shells, sandcrete blocks, compressive strength, agricultural waste, particle size

1. Introduction

In the ever-evolving realm of construction materials and practices, the quest for sustainability and resource efficiency stands as a pivotal imperative. Sandcrete blocks have long held a significant place in the construction industry, valued for their cost-effectiveness and versatility. Sandcrete blocks are used predominantly as walling elements for shelter construction in developing countries like Nigeria. According to Merriam-Webster dictionary, block is a compact, usually solid piece of substantial material especially when worked or altered to serve a particular purpose. Precast composite masonry units called "sandcrete blocks" are made of Portland-limestone cement, sand, and water. They are molded into different sizes and are often utilized in the construction of buildings and other man-made structures. According to the Nigeria Industrial Standard (NIS 87: 2000), sandcrete blocks must have a minimum compressive strength of 2.5 and 3.45 N/mm² for non-load bearing and load bearing walls, respectively. From the study carried out by Awulosi et al. (2021), the density of sandcrete blocks ranged from 2146.46 kg/m^3 to 2209.60 kg/m^3.

Sandcrete blocks are widely used as walling units and over 90% of houses in Nigeria are being constructed with sandcrete blocks (Alejo, 2020; Odeyemi et al, 2015). However, in the face of increasing environmental concerns, there arises an urgent need to explore innovative and sustainable alternatives that can meet the demands of modern construction while mitigating its ecological footprint (Kiani et al, 2021; Leonard 2023). The addition of agro waste to construction materials such as blocks, can have both positive and negative effects, depending on some factors, including the quantity of agro waste used and the specific application of the material (Prusty et al., 2016; Robert et al 2021). Ubachukwu (2021) in his study on the partial replacement of sand in concrete using crushed oyster shell observed that the addition of crushed oyster shells in fresh concrete reduced the slump from 27mm at 0% to 20mm at 25%.

Bagasse ash concrete was cast in beam specimen of sizes 100 mm × 100 mm × 500 mm and cured in water for 28 days. After 28 days, beams were tested as per IS 516: 1959 (Indian Standard, 1959). The results indicated that the flexural strength was increased at 10% replacement and it reduced with further increase in percentage (Shafana and Venkatasubramani, 2014).

Reusing agricultural or marine-based wastes could offer a promising alternative to achieve natural aggregate conservation and a pollution-free environment. One such promising avenue involves harnessing the latent potential of agricultural waste byproducts, such as periwinkle shell dust in the production of sandcrete blocks. By-products of these wastes like the residual ashes from their incineration have proven to be beneficial construction materials (He et al, 2020; Umar et al, 2022; Wang W, 2021). Seashells are probably utilized in concrete manufacture as a substitute for fine aggregate, coarse aggregate, and cement (Ibrahim, 2023). The impetus for this research stems from the interplay between two critical global challenges: the construction industry's insatiable appetite for raw materials and the pressing urgency to reduce waste and mitigate environmental degradation.

Traditional sandcrete blocks are predominantly composed of sand, cement, and water, with sand being a finite resource susceptible to overexploitation. The use of seashells such as periwinkle shells waste in making concrete and block mixes was described as a sustainable construction practice for the producing a green concrete and blocks that are less detrimental to the environment compared to conventional concrete or block (Iyinoluwa and Emmanual, 2022; Ugwu and Egwuagu 2022; Olofinnade et al 2023). Periwinkle shell dust, a byproduct of the seafood processing industry is abundant in coastal regions and are typically discarded as waste. It represents an untapped resource that could potentially find useful application in the construction sector. By doing so, we hope to address the dual challenges of reducing sand consumption and promoting the valorization of the agricultural waste, ultimately contributing to a more sustainable construction industry.

2.0 Material and methods

2.1 Preparation of The Periwinkle Shells

These periwinkles were harvested. Firstly, expert seafood market sellers separated the periwinkles from their shells before they were packed and moved to the study center in Awka, Anambra state. The periwinkle shells were thoroughly cleaned to remove any contaminants accumulated throughout their aquatic journey.

The shells were then exposed to the sunlight for a week, which helped to remove residual water contents. Using a commercial grinding machine, the shells were methodically crushed into smaller, consistent pieces to ensure consistency in size for integration into the sandcrete block matrix.

Plate 1.0: Ground Periwinkle Shells

After grinding, the periwinkle shells were further sun-dried for another three days to remove any remaining moisture.

In the preliminary test to characterize the sand and ground periwinkle shell used in the experiment their characteristic parameters such as density, specific gravity and particle size distribution were obtained.
Thirty-six (36) unique mixtures were cast. These mixtures consisted of different proportionate sizes of periwinkle shells categorized as coarse (4.750mm - 2.000mm), medium (1.180mm - 0.850mm), and fine (0.600 - tray). For each periwinkle size, cubes of specific percentage replacement of sand with ground periwinkle shells—ranging from 5%, 10%, 15% to 20% were cast. The cubes were tested for compressive strength at the 7th and 28th day of curing.

3.0 Results and Discussions

The results of particle size distribution for sharp sand is as shown in Figure1.
The graph of cumulative percentage passing against the sieve sizes showed that the fine aggregate was well graded and so has a wide range of particle sizes, creating a balanced and robust composition.

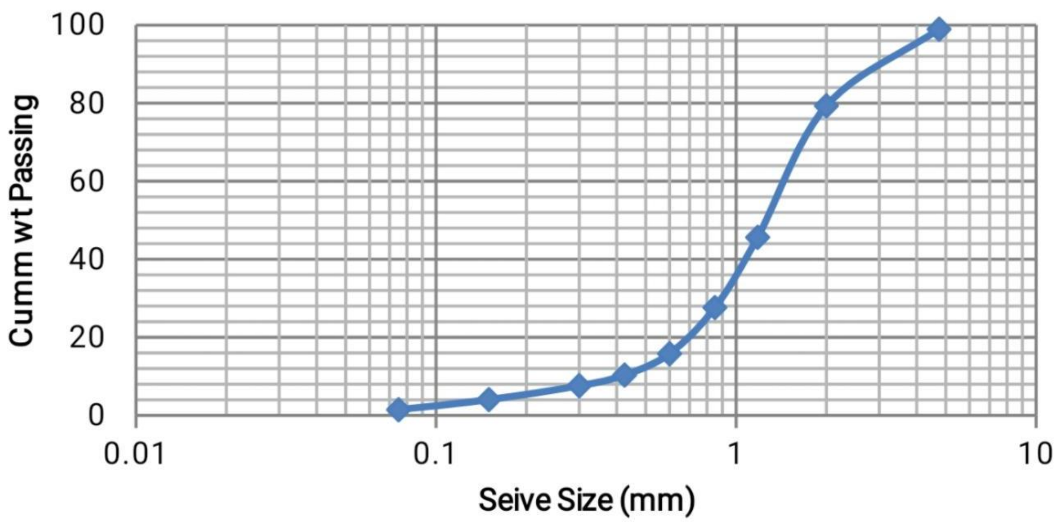


Figure 1: Sieve analysis test results on sharp sand

From Fig. 1.0, D_{60} = 1.5 mm, D_{30} = 0.89 mm, and D_{10} = 0.35 mm.
Coefficient of Uniformity, $C_u = \frac{D_{60}}{D_{10}} = 4.29$
Coefficient of Curvature, $C_c = \frac{D_{30}^2}{D_{10} \times D_{60}} = 1.51$
Its coefficient of uniformity and coefficient of curvature are 4.29 and 1.51 respectively.
According to Unified Soil Classification System (USCS) specification for well graded soils, a coefficient of uniformity (CU) of 4.29 and a coefficient of curvature (CC) of 1.51 suggests that the sand has a fairly uniform distribution of particle sizes, which can be beneficial for certain construction applications.
The specific gravity of a material unveils essential information about its density characteristics, which is crucial for evaluating its suitability in construction. The value of the specific gravity of the sharp sand used in our experiments was found to be 2.60.

The density of sharp sand is its mass per unit volume. It has a direct impact on the structural integrity of sandcrete blocks. The obtained density of sharp sand was 2.86g/m^3.
The graphical results of particle size distribution for ground periwinkle shells (Figure 2) depicted a well-graded curve, illustrating a balanced distribution of shell sizes.

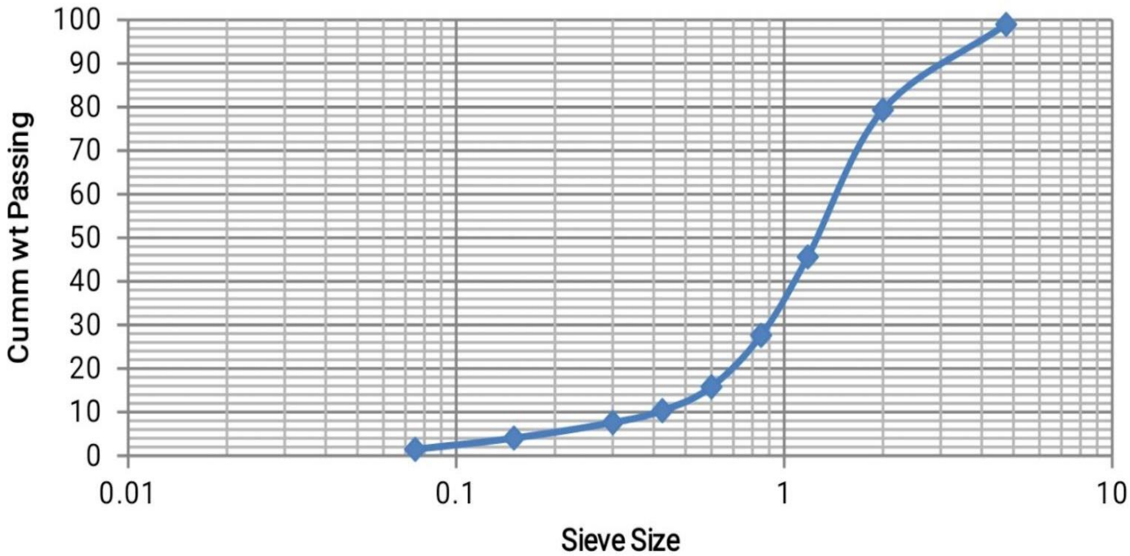
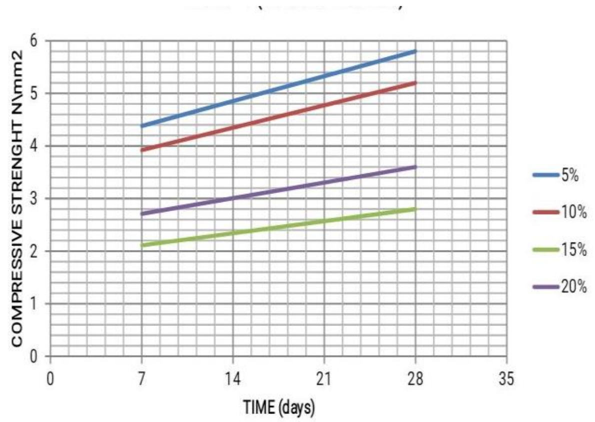


Figure 2: Graph of sieve analysis results for ground periwinkle

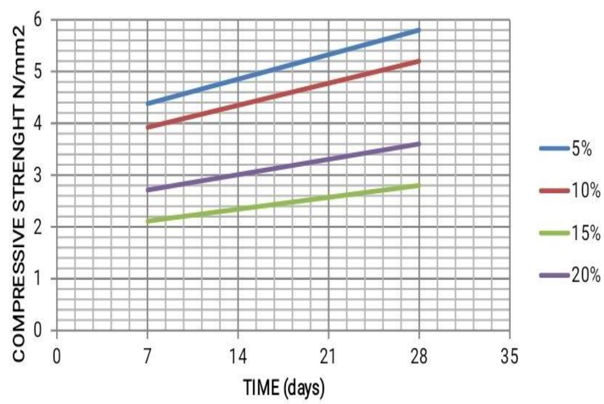
From Figure 2, D_{60} = 1.5 mm, D_{30} = 0.9 mm, and D_{10} = 0.42 mm.
Coefficient of Uniformity, $C_u = \frac{D_{60}}{D_{10}} = 3.57$
Coefficient of Curvature, $C_c = \frac{D_{30}^2}{D_{10} \times D_{60}} = 1.29$
According to USCSkoo specification for well graded soils, a coefficient of uniformity (CU) of 3.57 and a coefficient of curvature (CC) of 1.29 suggest that the particles have a fairly uniform distribution of particle sizes.
The specific gravity of periwinkle shells was obtained as 2.59. Table 1 contains the results of the 7-day and 28-day compressive strength test carried out on sandcrete containing different percentages of ground periwinkle shells. Figures 3 is a graph showing the increase in strength of the periwinkle shell blocks from day 7 to day 28 of curing. The compressive test results for Group 1, 2 and 3 comprising ground periwinkle shells, reveal a noteworthy increase in strength from 7 to 28 days. This upward trend signifies a progressive development in the structural strength of the sandcrete blocks over the curing period. Figure 4 is a graph of compressive strength against percentage ground periwinkle shells.

Table 1: Result of Compressive Strength Test on Sandcrete Blocks

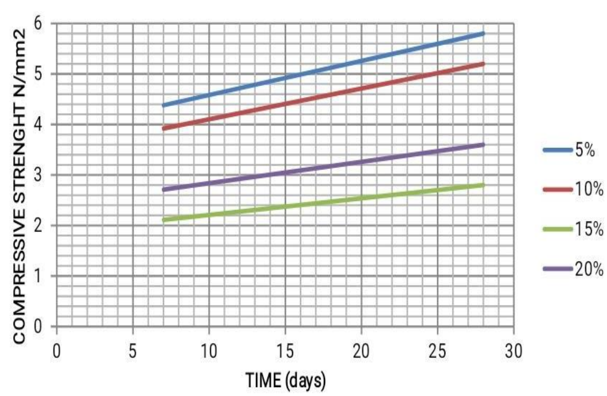
Cube Group	Age in Days	Percentage Sand	Compressive Strength
Control	7	0	3.38
	28	0	5.2
Group 1 (4.75mm to 2mm)	7	5	3.86
		10	4.31
		15	4.45
		20	4.08
	28	5	5.1
		10	5.7
		15	5.9
		20	5.4
Group 2 (1.18mm to 0.85mm)	7	5	3.84
		10	5.07
		15	4.88
		20	4.38
	28	5	5.1
		10	6.7
		15	6.5
		20	5.8
Group 3 (0.6mm to tray)	7	5	4.38
		10	3.92
		15	2.11
		20	2.71
	28	5	5.8
		10	5.2
		15	3.6
		20	2.8



Strength gain with time for Group 1 (4.74mm – 2.00mm) periwinkle shell size



Strength gain with time for Group 2 (1.18mm – 0.85mm) periwinkle shell size



Strength gain with time for Group 3 (0.6mm – tray) periwinkle shell size

Figure 3: Graphs of compressive strength against time for periwinkle shell - sandcrete blocks

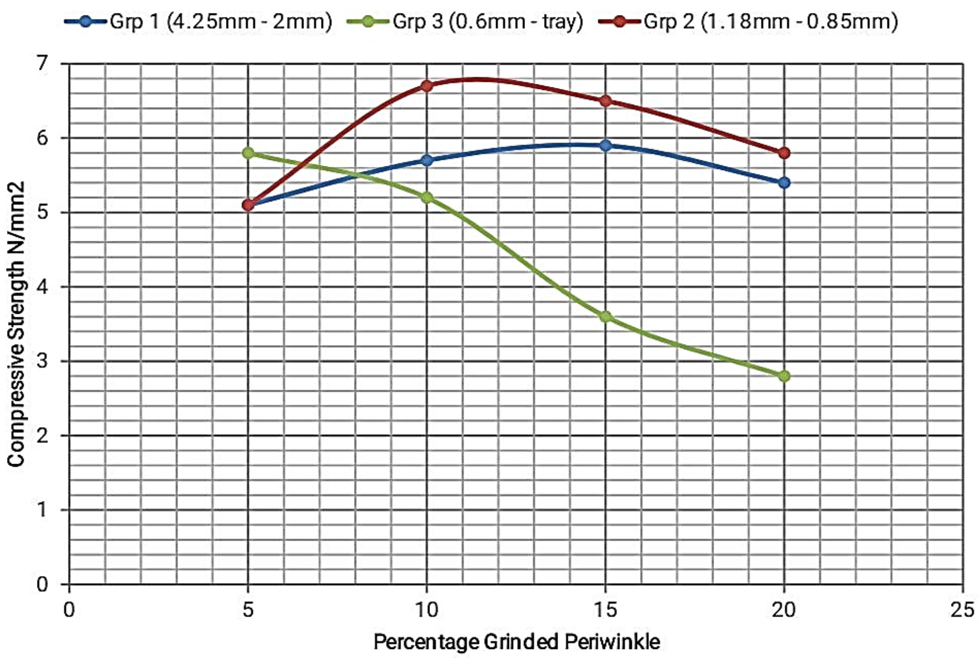


Figure 4: Compressive Strength for sandcrete blocks containing Group 1, Group 2 and Group 3 periwinkle shells

From the graph of Figure 4, it can be observed that at the 28th day, Group 1 (which contained the shells retained in BS sieve sizes 4.75mm and 2.00mm) exhibited compressive strengths ranging from 5.17N/mm² to 5.9N/mm², with the highest strength observed at 15% replacement. Group 2 (which contains the shells retained in BS sieve sizes 1.18mm and 0.85mm) showed strengths ranging from 5.17N/mm² to 6.7N/mm², with 6.7N/mm² peaking at 10% replacement. Conversely, Group 3 demonstrated strengths varying from 2.8 to 5.8N/mm², with the highest strength at 5% replacement. Replacement with ground particles of group 2 gave better results probably because it they fall within the size of coarse sand which is best suited for sandcrete block moulding. Periwinkle shells within group 3 are very fine (like silt) and has hence provide a very wide surface area for bonding. This weakens the strength of the sandcrete as the binder (cement paste) will have to be spread (too thin) around the wide surface area.

4.0. Conclusion

This work investigated the effects of the use of periwinkle shell as a partial replacement for traditional sand in the production of sandcrete blocks. Based on the 28th day compressive strength test results, Group 2 consisting of periwinkle particles trapped in sieve size 0.85mm to 1.18mm gave the highest strength values at each percentage replacement, notably reaching 6.7N/mm³ at 10%. Group 1(consisting of periwinkle sizes 2mm to 4.75mm) also demonstrated consistent strengths, peaking at 5.9N/mm³ at 15%. In contrast, Group 3(the finest consisting of particles less than 6mm) exhibited varying strengths, with a notable decline at 15% and 20% replacements.

Considering the Nigerian Industrial Standard requirements, which mandates a minimum compressive strength of 2.5 N/mm² for non-load bearing and 3.45 N/mm² for load-bearing blocks, all percentages within each group surpassed these benchmarks. However, Group 2, particularly at 10%, stands out as it not only exceeds the standards but gave us the highest values for compressive strength therefore making it the most suitable for construction use.

The impressive strength values of sandcrete blocks made from Group 2 affirm the potential of periwinkle shells for enhancing the load bearing capacity of sandcrete blocks. The utilization of these waste periwinkle shells are also of benefit to our environment.

5.0 Recommendation

This work dwelled on the usefulness of ground periwinkle shells as an additive to sandcrete blocks. It further revealed the importance of particle sizes of these shells on the mechanical properties of sandcrete. There is need to extend the work to other shells of aquatic animals which are also in abundance in our riverine areas. The ample utilisation of these agricultural wastes will reduce the demand on sand mining and thereby help in protecting our coastal areas.

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