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Research Paper

Production and Strength Evaluation of Sandcrete Hollow Blocks Using Fine sand and Crushed Periwinkle shell

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ABSTRACT

Walls are fundamental in building construction, with sandcrete blocks being the most common unit in Nigeria. Sandcrete blocks are made of natural sand, water, and cement. Due to rising material costs, importation issues, and sub-standard materials that do not meet quality specifications in terms of strength, durability, or composition, there is a need to find cost-effective alternatives. This research explores using Crushed Periwinkle Shell (CPWS) to partially replace fine sand. A 1:12 mix ratio was chosen for its cost-effectiveness and suitability for non-load bearing applications. This mix was tested with 0%, 10%, 20%, 30%, 40%, and 50% CPWS, maintaining a constant water-cement ratio of 0.5. Ninety blocks (450mm x 225mm x 150mm) were molded and cured for 28 days. The compressive strength of seventy-two blocks was evaluated at 7, 14, 21, and 28 days. Blocks with 40% and 50% CPWS had high compressive strength values of 2.55 N/mm² and 2.67 N/mm² at 28 days, within the Nigeria Industrial Standard (NIS) range of 2.5-3.4 N/mm². These results suggest CPWS is suitable for partial sand replacement. Additionally, eighteen blocks were tested for water absorption at 14, 21, and 28 days, showing increased absorption with higher CPWS content but decreasing with curing time.

1 Introduction

Walls are the basic element in the construction of most buildings. They are often required to be load bearing, especially in low rise buildings (1-2 upper floors) [1]. Afolayan [2] also support the fact that sandcrete blocks are now gaining ground in Nigeria as walling units or partition and sometimes as load bearing walls. Sandcrete has a high compressive strength, which increases as density increases [3]. The Nigerian industrial standard [4] specifies a minimum sandcrete strength range of 2.5N/mm² to 3.45N/mm². However, the strength of sandcrete blocks varies depending on the production process used, the curing time, the size of the blocks, and the qualities of the component materials. When compared to other building materials, sandcrete blocks are comparatively inexpensive.

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Periwinkles (Botanical name *Nodilittorina radiata*) are small blackish blue marine snails with spiral conical shell and round aperture. The average periwinkle lives three years and grows to a shell height of 20mm, but the largest recorded periwinkle grew up to 52 mm [5]. They are common in the riverine areas and coastal regions where they are consumed as sea food. The hard shells are dumped waste which ordinarily posed environmental nuisance in the area because of its unpleasant odor and ugly appearance in open-dump sites located at strategic places.

Research is currently looking at ways to supply economical and high-quality building materials for housing, in addition to encouraging a sustainable and clean environment through the recycling of waste materials [5, 6]. The lack of affordable housing, especially in developing countries, is one of the main difficulties facing the building sector, according to a recent study by Ogundipe [5]. This problem was brought up in a prior study by Ezeigwe [7], which focused on the challenges of finding inexpensive accommodation

The increasing cost and scarcity of natural sand used in concrete/sandcrete production have led to the search for cheaper alternative sources of fine and coarse aggregates which can act as substitute in the construction industry. As aggregates, periwinkles shell was described as a single sized aggregate with a shape factor of 0.3 (maximum diameter/length). The resultant lightweight concrete has density range of 1923-2050kg/m³ [8]. Also, Agbede [9], investigated the suitability of periwinkle shell as partial replacement for river gravel and concluded that periwinkle shells can be used as a lightweight aggregate in concrete works, its bulk density of 515kg/m³ resulted in concrete with lower weight, hence lower dead loads in concrete construction, workability of periwinkle shell concrete is reduced with increasing content of periwinkle shells and that the strength development of periwinkle-gravel concrete is similar to those of conventional granite concrete.

Olofinnade [10] in an independent study carried out on sandcrete blocks containing crushed periwinkle shell (CPWS) as a substitute for sand found out that the incorporation of CPWS for 5% and 10% mix at 28 curing day surpassed minimum target strength of 2.5N/mm². Oyedepo [11] evaluated the properties of lightweight concrete using periwinkle shell as a partial replacement for coarse aggregate. In his research, the strength characteristics of each cube of 150mm × 150mm × 150mm produced was evaluated using compressive testing machine at different curing ages of 7, 14, 21 and 28days.

Given the rising cost of materials, importation and the use of sub-standard material in construction, it has become increasingly compelling to seek alternative solutions to reduce the cost of building construction [12]. It can be argued that blocks of high compressive strength attained with/from periwinkle shells will provide a virile solution. If adopted, it will not only make building construction more affordable but reduce the rising cost of building materials.

There has been a growing interest recently, especially in developing countries in the use of wastes materials as an alternative for the production of concrete and masonry products. In lieu of this, this study is intended to improve on the study of other researchers by using periwinkle shell and fine sand in replacement of dust/granite. Also the mixes developed for block production will be of great help in assisting commercial block producers in meeting required strength targets.

The objectives of this study are to evaluate the engineering characteristics of fine sand and periwinkle shells, produce and assess the compressive strength of sandcrete hollow blocks using fine sand and periwinkle shells at varying replacement levels; and compare the test results with Nigerian Industrial Standard, produce sandcrete hollow blocks using fine sand and crushed periwinkle shells to encourage the community to adapt technology to reduce the cost of construction of a building. Hence, the aim of the study produce sandcrete hollow blocks using fine sand and crushed periwinkle shells to encourage the community to adapt technology to reduce the cost of construction of a building.

2 Materials and Methodology

2.1 Materials

Ordinary Portland Cement (OPC) of grade 32 with the trade name “Dangote cement” fully certified by the standard organization of Nigeria was used for this research. The cement was purchased locally from a cement shop in Akure. For the purpose of this study, sand with a maximum size gradation of 4.75mm were used as fine aggregate [12] established that the ideal sand/aggregate ratio is 0.40. Thus, 4.75mm is ideal for maximum aggregates.

Periwinkle shells used for this research was sourced locally from Ese-Odo Local Government area of Ondo State, Nigeria, and transported to the concrete laboratory, Civil Engineering Department, FUTA. Water is an important ingredient of concrete and sandcrete as it actually participates in the chemical reaction with cement. The quality of water used was such that the chemical reaction taking place during the setting of the cement is not impaired. Potable water fetched from a well in a neighbouring construction site close to the experimental set-up at concrete laboratory inside the Federal University of Technology, Akure was used for both specimen preparations and curing. Test of aggregates comprising bulk density, specific gravity, particle size distribution and moisture content were conducted using standard protocols.

2.2 Experimental setup

The periwinkle shells were washed to remove dirt, impurities and sun-dried for days at after which it was crushed using a grinding mill to fine aggregate size. The sandcrete block specimens were prepared using the Nigerian Industrial standard [4]. In producing the hollow sandcrete blocks, manual method of mixing was used on a clean batching bay. The weight of the sandcrete mixture required to produce a block from the mould was determine by the weight batched thoroughly and mixed in a dry state to obtain a homogeneous mix with uniform colour constituting cement of the same proportion with fine sand and crushed periwinkle shells at different replacement percentages in ratio of 1:12 (i.e. cement to fine aggregates). Water cement ratio 0.5 was added to form a workable sandcrete. The composite mixture was then poured into the block-moulding machine for vigorous compaction to prevent voids.



Plate 1 – Dried periwinkle shells



Plate 2 – Processed periwinkle shell



Plate 3 – Block preparation



Plate 4 – Array of moulded CPWS sandcrete blocks

The moulded block placed on positioned wooden pallets was afterward removed from the block-moulding machine and arranged in cleared space for proper drying. Sprinkling method of curing was adopted and this was done after the initial setting of the blocks until the blocks attained their full strength at 28 days. The arrays of blocks produced are shown in plate 3. Seventy two (72) sandcrete block specimens of 450 mm × 225 mm × 150 mm were produced for the compressive

strength test, and eighteen (18) sandcrete block specimens of 450 mm × 225 mm × 150 mm were produced for the water absorption test.

Table 1- Summary of the mix ratio for each sample replacement in the experiment

Aggregate Constituent	Mix	FS (%)	CPWS (%)	FS (kg)	CPWS (kg)	Cement (kg)	w/c ratio
Fine sand (FS)	Mix 1	100	0	300	0	25	0.5
Fine sand (FS) and crushed periwinkle shell (CPWS)	Mix 2	90	10	270	30	25	0.5
Fine sand (FS) and crushed periwinkle shell (CPWS)	Mix 3	80	20	240	60	25	0.5
Fine sand (FS) and crushed periwinkle shell (CPWS)	Mix 4	70	30	210	90	25	0.5
Fine sand (FS) and crushed periwinkle shell (CPWS)	Mix 5	60	40	180	120	25	0.5
Fine sand (FS) and crushed periwinkle shell (CPWS)	Mix 6	50	50	150	150	25	0.5

2.3 Test Methods

Two major tests were carried out to determine the water capacity and strength characteristics of the CPWS sandcrete blocks. They include water absorption test, and compressive strength test. The mix ratio for each sample replacement in the experiment was appropriately designated and summarized in Table 1

2.3.1 Water absorption test

Water absorption test was carried out to determine the amount of water absorbed by a given sample under specified conditions. The initial weight of the blocks at dry state was measured using weigh balance. Three (3) samples were selected for each replacement percentage, weighed and soaked in water tank for 24 hours, thereafter it was allowed to drain and re-weighed to determine their water absorption rates [13] claimed that the rate of water absorption of aggregate has an impact on the cement paste-aggregate bond, the chemical stability, the resistance to abrasion, and the specific gravity of concrete..

Thus, the ratio of the reduction in mass to the mass of the dry sample is used to measure water absorption. The decrease in mass of a saturated block and a surface dry sample is shown in Eq. 1.

$$\frac{M_2 - M_1}{M_1} \times 100\% \quad (1)$$

where:

M_1 is the Mass of dry sample in kg

M_2 is the Mass of wet sample in kg (after 12 to 24 hours in water)

2.3.2 Compressive strength test

Compressive strength tests were carried out on the blocks. The blocks were weighed and placed in the compression testing machine with plates placed at top and bottom of the sample for even distribution of load. The compressive strength for each sample was then calculated using equation 2.

$$f_{cc} = \frac{F}{A} \quad (2)$$

where:

f_{cc} is the Compressive crushing strength, in N/mm²

F is the Crushing load, in N

A is the Net Area of Block, in mm²

All results were adequately computed, presented and analyzed using both graphical and statistical tools.



Plate 5- Weighing of block



Plate 6- Compressive strength test

3 Results and Discussion

3.1 Materials chemical composition

Table 2 provides the cement's chemical composition results. This is done to determine the amount or percentage of oxide in the cement in order to check its compliance with the Nigerian standard. According to the results of the test, calcium oxide present in the OPC is (64%) which is responsible for the early strength development of OPC, followed by silicon oxide (22.5%), and aluminum oxide (5.25%) which also contributes to its strength and durability. This outcome is expected because limestone, which is primarily composed of CaCO_3 , decomposes to produce the primary reactant oxide and various minor byproducts. This result complies with the Nigerian standard for cement production and use and is also consistent with the findings of Akani [14] on the chemical composition of the different brands of ordinary portland cement available in the construction market in Nigeria. This is shown on the table below

Table 2 – Oxides composition of the cement

Chemical properties	Composition (%)
CaO	64.00
SiO_2	22.50
Al_2O_3	5.25
Fe_2O_3	2.50
MgO	1.40
SO_3	2.31
Na_2O	0.60
P_2O_5	0.05
K_2O	0.15
MnO	0.20

Periwinkle shell (PS) is an organic material, composed mainly of high calcium carbonate, which are lightweight, durable, and cost-effective. Their use in block production offers adequate compressive strength and better workability for non-load bearing applications, while also providing environmental benefits by reducing reliance on traditional aggregates and utilizing waste materials. The chemical composition of periwinkle shell (PS) and fine sand are quite different from each other. The result shows that periwinkle shell (PS) contains primarily CaCO_3 (89.80%). Table 3 provides the periwinkle shell chemical composition results

Table 3 – Chemical composition of periwinkle shell

Chemical Properties	Composition
CaCO ₃	89.8
LOI	4.25
MgO	1.25
P ₂ O ₅	0.22
Na	0.45
TiO ₂	0.40
K ₂ O	0.12
K	0.05

3.2 Specific Gravity

The specific gravity of the fine aggregates are calculated using equation (3),

$$G_s = \frac{w_2 - w_1}{(w_2 - w_1) - (w_3 - w_4)} \quad (3)$$

where:

G_s = the specific gravity,

w_1 = weight of empty bottle

w_2 = weight of empty bottle + sample,

w_3 = weight of empty bottle + sample + water

w_4 = weight of empty bottle + water

Specific gravity of CPWS

$$w_1 = 409.10g; w_2 = 473.70g; w_3 = 995.60g \text{ and } w_4 = 931.00g$$

From equation (3), $S.G = 2.65$

Specific gravity of fine sand

$$w_1 = 409.10g; w_2 = 489.20g; w_3 = 980.29g \text{ and } w_4 = 931.00g$$

From equation (3), $S.G = 2.60$

Fine sand and crushed periwinkle shell both have specific gravities of 2.65 and 2.60, respectively. In general, lightweight aggregates (fine or coarse) have a specific gravity under 2.40, whereas typical weight aggregates have a specific gravity between 2.70 and 2.80 [15]. Additionally, all obtained values are within the permissible range of 2.40 to 2.70 for fine aggregates as defined by British Standard [16].

3.3 Particle size distribution

The British Standard BS [17] was followed for the particle size range. The values obtained with the appropriate particle size distribution curves of each aggregate are shown in Figure 1. The fine aggregates were also subjected to the fineness modulus test, which is an empirical measurement created by summing the percentages of aggregate samples retained on each of a predetermined series of sieves and dividing the result by 100.

From the particle distribution curves in fig 1

The uniformity coefficient C_u of fine aggregate is defined as

$$C_u = \frac{D_{60}}{D_{10}} \quad (4)$$

where D_{60} = diameter of soil particles, 60% of which are finer and 40% of which are coarser

D_{50} = average particle size

D_{30} = diameter of soil particles, 30% of which are finer and 70% of which are coarser

D_{10} = diameter of soil particles, 10% of which are finer and 90% of which are coarser

For fig 1, the uniformity coefficient and coefficient of gradation cannot be computed as it contains several finer particles passing through the first four set of sieves.

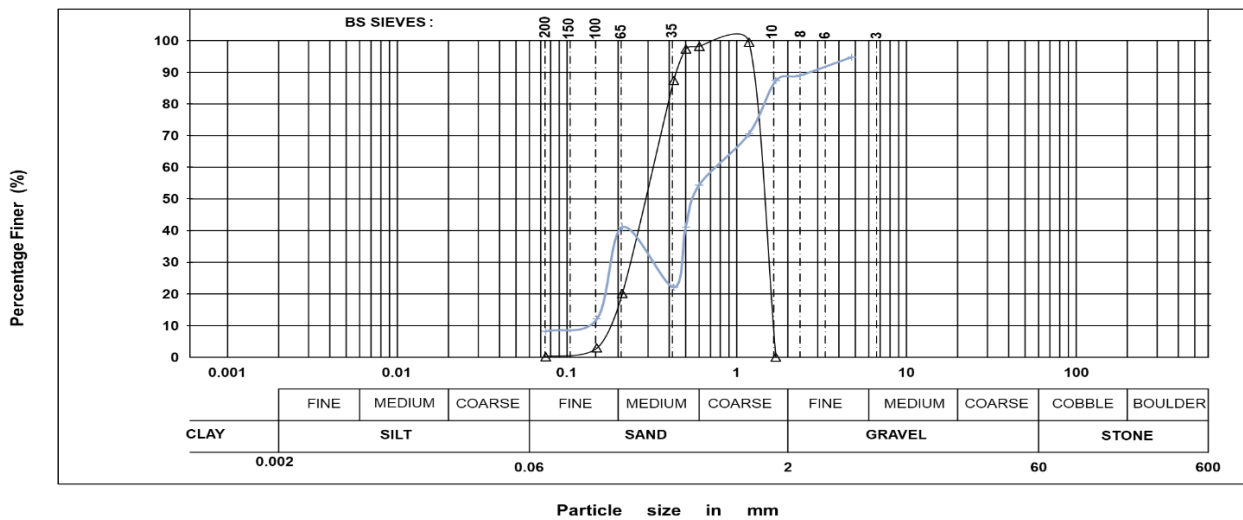


Fig 1 – Particle size distribution curve for fine sand and crushed periwinkle shell

From fig 1

$$D_{60} = 1.20, \quad D_{30} = 0.65, \quad D_{10} = 0.30$$

From equation 4

$$C_u = \frac{D_{60}}{D_{10}} = \frac{1.20}{0.30}, \quad C_u = 4.0$$

The sample is a well graded sample because it falls between 2 and 8. A soil sample is said to be well graded when the uniformity coefficient is greater than 2 and poorly graded when it's less than 2.

Coefficient of gradation C_c

$$C_c = \frac{D_{30}^2}{D_{60} \times D_{10}} \quad (5)$$

$$C_c = \frac{0.65^2}{1.20 \times 0.30} = \frac{0.422}{0.36} = 1.17$$

Based on the result, the sample is classified as a well graded sample because coefficient of gradation falls in the range 0.5 to 3.

3.4 Result of fine aggregates

The results on the physical properties and maximum size of the aggregate materials, especially the fine sand and CPWS used to make the hollow sandcrete block samples, are shown in Table 4. The obtained moisture content readings for the sand and CWPS, 13.3% and 12.05%, respectively, showed that they were in the permissible ranges defined by BS [16]. Aggregate specific gravity values were expected to range from 2.40 to 2.70. The recorded specific gravity value of 2.65 for the CPWS material was seen to be higher than the sand readings of 2.60, falling within the advised specific gravity range of 2.40 to 2.70 for fine aggregates as described by BS [16]. The hollow sandcrete block samples were made with sand and CPWS aggregate, which have bulk density values of 2110 kg/m³ and 1930 kg/m³, respectively. The values obtained fall within the permitted range of bulk density as specified by BS [16].

Table 4- Physical properties of fine aggregates

S/N	Properties	Fine sand	CPWS
1	Moisture content (%)	13.3	12.05
2	Specific gravity (Kgm^{-3})	2.60	2.65
3	Fineness modulus	1.96	4.89
4	Bulk density (Kgm^{-3})	2110	1930

3.5 Compressive Strength Test

Compressive strength tests were carried out on three samples of each replacement level at day 7, 14, 21 and 28, respectively. Results are presented in figure 2

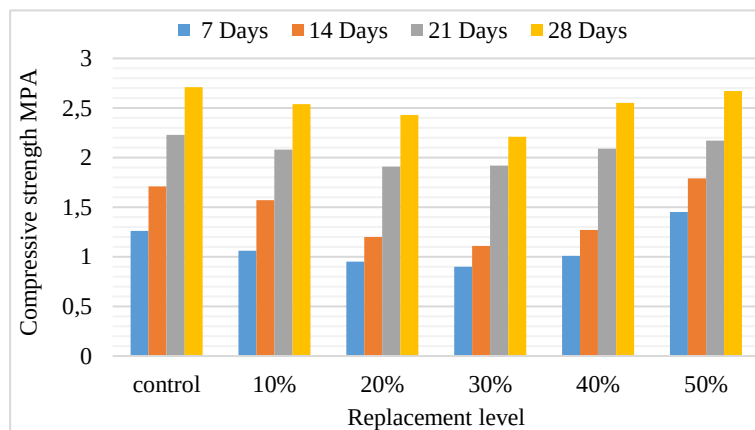


Fig 2 – Average compressive strength of CPWS sandcrete blocks at curing day 7, 14, 21 and 28

From the findings shown in Figure 2, all of the compressive strength values for the CPWS sandcrete blocks at curing days 7, 14, 21, and 28 exhibit the same pattern of results.

For the control mix, there was a steady increase in the compressive strength from curing ages 7 to 28 days. Observedly, the sandcrete mix attained about 53.5% of its final compressive strength after 7days of curing and 83% after 21days of curing.

On the other hand, there was a decrease in compressive strength of the CPWS sandcrete mixes up till the 30% replacement level, after which the trend changes. Though the compressive strength of the CPWS sandcrete block at 10%, 20% and 30% replacement level was about 15%, 24.6% and 28.5% lower than the control's after 7 days of curing, its final compressive strength was 6.2%, 4.7%, 9.5% still lower than the control block at day 28. Indeed, there was a 38% and 21% increase in the compressive strength of the CPWS sandcrete block between 30% and 50% replacement level at curing day 7 and 28 respectively.

This increase in compressive strength of the CPWS sandcrete block over time can be suggested to be the uniformity of particle packing of the entire mix from 40% to 50% replacement levels. This points to the potential of a further increase in the compressive strength of CPWS sandcrete mix beyond 50% replacement level. Furthermore, the results obtained at curing day 28 for 40% (2.55 N/mm²) and 50% (2.67 N/mm²) replacement level are somewhat comparable to those of study obtained by [4], which were (2.83 N/mm²) and (3.27 N/mm²). This measured values for hollow CPWS sandcrete blocks were within the limits of the Nigerian Industrial Standard (NIS) [4] recommendations of (2.5 N/mm²) and (3.45 N/mm²).

3.6 Water Absorption Test

In order to evaluate the differences in water absorption capacity between the curing periods, the water absorption test was performed on samples from each replacement level of the experiment after 14, 21, and 28 days of curing. Because most sandcrete blocks appear weak and poorly dried at curing day 7, the water absorption test for day 7 was not conducted. The outcomes of the testing on a total of eighteen (18) CPWS sandcrete blocks is shown in Figure 3.

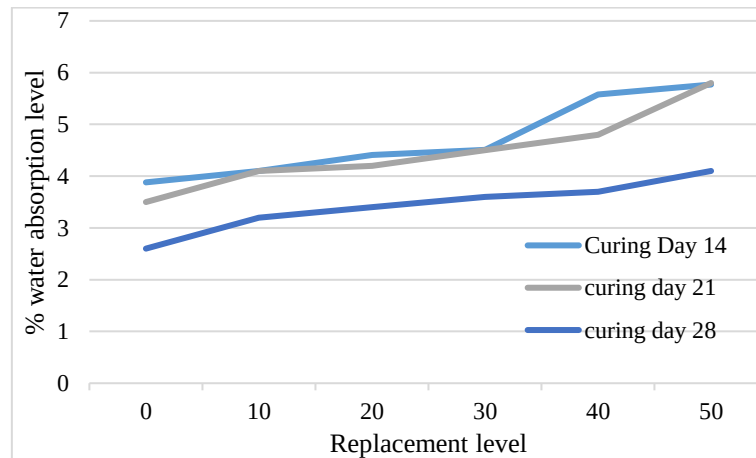


Fig 3 – Percentage water absorption test of CPWS sandcrete blocks at curing days 14, 21 and 28

For curing days 14, 21, and 28, Figure 3 displays the plot for the percentage of water absorption test performed on the samples at each replacement level of crushed periwinkle shell and fine sand. According to the findings, the three considered curing periods, water absorption percentages vary from 2.60 to 5.80%.

It was noted that water absorption increases with percentage increase in CPWS but in all, water absorption is less than the max limit for water absorption recommended for sandcrete blocks [18, 19].

In general the percentage mean and standard deviation of water absorbed overall for curing days 14, 21, and 28 are 4.70 ± 0.31 , 3.43 ± 0.48 , and 4.48 ± 0.34 respectively, with day 14 having the greatest absorption rate. A possible reason for this is the curing time because as curing progresses hydration process continues leading to further bonding of the cementitious materials which can lead to reduced porosity and lower water absorption. Finally, since none of the results for the different mixes exceed 12%, which is the maximum water absorption rate for sandcrete blocks, they all match the requirements of the Nigerian Industrial Standard (NIS) [4].

4 Conclusions and Recommendations

4.1 Conclusion

The strength of the sandcrete hollow blocks made using crushed periwinkle shell as a partial replacement of fine sand at various percentages has been evaluated in this study. Major tests on the CPWS sandcrete blocks, including water absorption capacity and compressive strength, were conducted while the aggregates were tested to ensure sufficient conformity before use. The following conclusions were reached based on the test results obtained from the experimental study. Each and every one of the aggregates (sand, crushed periwinkle shell) used in the experiment complied with the standards outlined in the different BS codes. The cement that was used also exhibits excellent qualities that are deserving of approval. The total average percentage of water absorption on days 14, 21, and 28 of curing yield standard error means of 5.44 ± 0.31 , 4.84 ± 0.48 , and 4.90 ± 0.34 , respectively. All of the samples' water absorption findings, which range from 2.60 to 5.80 percent, match the Nigerian Industrial Standard (NIS). With values ranging from 0.90 to 2.71 N/mm², the compressive strength values for each curing day rise gradually as the curing period extends. The control was found to have the highest compressive strength values across all curing periods. It was also noted that the periwinkle shell had a higher compressive strength at the 50% replacement level with a combination of sand at curing day 28.

4.2 Recommendations

Based on the results obtained from this study, the following are recommended. The use of periwinkle shell to partially replace sand at 50% replacement is recommended for possible use within the locality studied due to its large availability. It will be required to further investigate the durability capabilities, mechanical properties, and adherence to quality standards of sandcrete block using crushed periwinkle shell or marine-based waste materials as alternatives to natural aggregate to ensure the successful implementation of these alternative materials in sandcrete block production. Government and private

research funding organizations should allocate enough funds for thorough research to be conducted in quest of best and environmentally friendly replacement building/moulding materials. The prices of some building materials, which are continuously rising, will typically decrease as a result.

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