Journal of Engineering Innovations and Applications
Volume 1(1), pages 13-22, June 2022
Article Number: DEFB13DF3
ISSN: 2971-673X
https://doi.org/10.31248/JEIA2022.020
https://integrityresjournals.org/journal/JEIA

Full Length Research

Evaluation of organic enhancer on the mechanical properties of periwinkle shells concrete

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Received 31st May 2022; Accepted 26th June 2022

ABSTRACT: The utilization of green materials in engineering applications has become a necessity due to the negative environmental and health consequences of most synthetic materials. Enhancement of periwinkle shell concrete through corn starch treatment was investigated in this study. Twenty-five (25) sets of concrete were produced with various corn starch concentrations (0, 0.5, 1, 1.5 and 2%); and periwinkle shell quantities varying from 0 kg (0%) to 2 kg (20%) were used as a partial replacement for granite. All the concrete sets produced and their mechanical properties were determined in accordance with ASTM (American Society for Testing and Materials) International standards. Statistically, the results revealed that corn starch and periwinkle shells had a significant ($p \leq 0.05$) influence on the concrete mechanical properties. The slump results revealed that the periwinkle shell hindered the concrete's workability, as the slump decreased non-linearly as the periwinkle shell substitution increased from 0% to 20% (per weight of the granite). Contrary, the corn starch enhanced the concrete workability, as the slump increased from 0.0 mm to 48.17 mm, as the corn starch concentration increased from 0% to 2%. Furthermore, it was observed that concretes incorporated with corn starch developed higher density, compared to the concrete produced without corn starch; while the concrete density declined non-linearly, as the periwinkle quantity increased from 0 to 2 kg. Regarding the compressive strength, findings revealed that the compressive strength of the concretes declined from 32.03 to 10 MPa, as the periwinkle shell substitution increased from 0 to 2 kg; though concretes treated (incorporated) with corn starch developed higher compressive strength, compared to the untreated concrete. The results indicated that the incorporation of corn starch as a workability enhancer; with smaller quantities of the periwinkle shell (5% - 15% as coarse aggregates) can be utilized to produce lightweight concrete for engineering applications.

Keywords: Corn starch, engineering materials, granite, mechanical properties, periwinkle shells.

INTRODUCTION

Engineering materials are essential in the construction, medical and automobile sectors. Their main function is resistivity to any applied force, without failing or undergoing extreme deflection/deformation. Some of the major engineering materials widely used in the engineering field include: metals, wood, ceramics, plastics and composites (including concrete) (Materials, 2022). Mechanical properties of engineering materials are essential factors to be considered during structural design and construction. Failure to utilize suitable materials with adequate mechanical strength parameters (such as: compressive, tensile, flexural, etc.) is one of the leading causes of structural failures globally (Olasunkanmi, 2022). Concrete, which falls under particulate composites, is one of the numerous composite materials used for structural construction. Concrete can attain very high compressive strength, low density, and moderate electrical conductivity; depending on the material formulation and the production process (Materials, 2022). The ease of concrete maneuverability into different shapes, forms and sizes, makes it very useful in various engineering applications (Ravikumar *et al*., 2015).

Granite (coarse aggregates) is one of the major constituents in limestone cement concrete. Several researches have been done using organic materials such as periwinkle (*Nodilittorina radiata*) shell, as a substitute for granite during concrete production. Adewuyi and Adegoke (2008) reported that periwinkle shell can be used to produce light-weight concrete with appreciable compressive strength, which can be used for various engineering applications. According to Ettu *et al*. (2013), periwinkle shells can be used as a compromise for granite in concrete production. Likewise, Bamidele (2002) had reported on the prospects of producing concrete with better mechanical properties from periwinkle shell.

The utilization of green materials in the construction and automobile industries is growing rapidly, mainly due to the negative environmental consequences and the high cost of most inorganic (conventional) materials. Globally, the environmental consequences of producing conventional concrete are enormous; hence attempts are being made to reduce these adverse effects (Morbi *et al*., 2010). Although there are thousands of organic materials, used as substitutes for conventional construction materials during the production of engineering structures, their selection depends on their mechanical properties, compatibility with the design, availability and cost (Ede *et al*., 2014; Sulaiman and Olatunde, 2019). The development of new material is the greatest achievement of scientists; since new material tends to create avenues for the production of new and better engineering equipment and structures (Engineering Materials, 2022). Research carried out by Mahmoud *et al.* (2012), Yan and Chouw (2013) and Motaleb (2018) revealed that concretes produced with a lower quantity of organic materials were capable of developing reasonable mechanical properties, which met international standards for concrete used for residential structures.

High-strength concrete produced with special materials has the tendency of absorbing higher vibration, compared to most metals. Additionally, reinforced concrete tends to have good mechanical strength, high resistance to cracking and inflexible; hence it can be used for the construction of autoclave sittings (Fediuk *et al*., 2018). Kalashnikov *et al.* (2019) and Deuse and Sagmeister (2012) reported that concrete can be used for the construction and production of machine frames; noting that they are much cheaper than polymer composites, which are commonly used for machine frame production. According to Kalashnikov (2012), the possibility of producing high compressive strength concrete is achievable, if the rheological properties of the constituent materials are compatible with the concrete matrix. Furthermore, Erofeeva (2018) stated that, the production of high quality concrete for mechanical engineering works is obtainable, through the utilization of environmental friendly concrete admixtures, during the concrete production process.

Although, several works (Okafor, 2008; Abalaka, 2011; George, 2014) had been carried out on the use of green admixtures to enhance the mechanical strength of concrete, there is no literature on the application of organic concrete enhancers to improve the mechanical properties of the periwinkle shell incorporated concretes. Therefore, the purpose of this work is to investigate the impact of corn starch as organic workability enhancers on the mechanical properties and application of concrete made with periwinkle shell, as a partial substitute for granite.

MATERIALS AND METHODS

Materials

Cement

The Portland Limestone cement, having grade 42.5; which was in compliance with Nigeria Industrial Standard –"NIS" (NIS-444, 2003), was used in this research work.

Corn starch

The corn starch was procured from local food vendor in Delta State of Nigeria. It was dried at room temperature (28 ± 4^0C) to reduce the moisture content, since batching by mass was adopted for the concrete production.

Fine aggregates

Clean riverbed sand was utilized as the fine aggregates for the concrete production. The fine aggregates were air-dried for two weeks, to reduce the moisture content and other volatile mineralogical components from the fine aggregates that can interfere with the mechanical properties of the concrete made from them.

Coarse aggregates

Crushed granite of gauge 19 mm was utilized as the coarse aggregates for the concrete production. The coarse aggregates were washed and air-dried for one week. This is to reduce their moisture content and remove debris present in the granite.

Periwinkle shell

Dried periwinkle shell was used to replace the coarse aggregates (granite) at the rate of 0% 5%, 10% 15% and 20% (by granite mass). The periwinkle shells were washed in a plastic drum and air-dried for two weeks as described by Omoniyi *et al*. (2020a), to reduce their moisture content, which can interfere with mechanical properties of the concrete made from them.

Methods

Treatment

The corn starch (treatment) was added to the concrete sets at a concentration of 0.5, 1, 1.5 and 2% (by cement mass).

Mix ratio

A cement-fine aggregates-coarse aggregates mix ratio of 1:2:4 was employed for the concrete production. Likewise, a water-cement (w/c) ratio of 0.5 was used to produce all the concrete sets. Five sets of concrete were made in this research, in order to ascertain the influence of corn starch treatment and periwinkle shells, on the mechanical properties of concrete cubes. Table 1 showed the constituents used for concrete production and their proportion in the concrete.

Batching and mixing methods

Batching by mass was adopted for concrete production. This is because batching by mass gives more accurate quantities of materials (ingredients) used, compared to batching by volume. Also, the mechanical machine mix method was used to mix the raw concrete ingredients homogeneously.

Concrete production and curing

The fresh concrete from the concrete mixer was poured into mould (150 mm x 150 mm x 150 mm), in three equal strata, and each stratum was rammed 35 times, with a 16 mm iron rod. Also, the sides of the mould were tapped severally with an iron rod to expel any entrapped air in the concrete. Then the surface of the mould was levelled with a flat tool as described by Omoniyi *et al.* (2020b).

After the casting, the moulds were shielded with a polyethylene sheet and left for 24 h, before they were removed from the moulds. All the concrete cubes were cured in clean water, under ambient room environmental conditions.

Laboratory tests

Slump test

The slump of the concrete sets produced was determined in accordance to the procedures approved by ASTM International (ASTM C143, 2017), as shown in Figure 1.

Sieve analysis

The sieve analysis of the fine aggregates was done in accordance with ASTM C136 (2006) specified procedures. Then the fine aggregates coefficient of uniformity (Cu) was calculated by using the expression in equation 1 (Odeyemi *et al*., 2018).

$$Cu = \frac{D_{60}}{D_{10}} \quad (1)$$

Where: D_{60} = Sieve size corresponding to 60% finer; and D_{10} = Sieve size corresponding to 10% finer.

Compressive strength

The concrete compressive strength was determined in accordance with procedures approved by ASTM C39/C39M, by using the Compression Testing Machine. For each compression test, a concrete cube was positioned in between the two platens of the machine, compressed axially at a low speed of 5 mm/s, until failure point was attained. The compressive strength of each tested cube was calculated using the expression given in equation 2 (Akpokodje *et al*., 2021).

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

Where: C = Compressive strength (MPa), F = Force recorded at failure point (N), A = Effective surface area of the cube (mm^2).

Density

The concrete density was determined in accordance with procedures approved by ASTM C642 (2021), by using an electronic weighing balance (0.01 kg accuracy). The density of each tested concrete cube was calculated through the expression given in equation 3 (Suhad *et al*., 2016).

$$\rho = \frac{M}{V} \quad (3)$$

Where: ρ = Density of the concrete cube (kg/m^3), M = Mass of the cube (kg), V = Volume of the cube (m^3).

Statistical analysis

Raw data obtained were statistically analyzed by using the SPSS (version 20.0) software. The mean values were separated with the Duncan's Multiple Range Test (DMRT)

Table 1. The concrete constituents.

Concrete set	Cement	Corn starch	Fine aggregates	Coarse aggregates	Periwinkle quantity
Set 1 (Control)	5 kg	0%	10 kg	20.0 kg	0% (0 kg)
Set 2	5 kg	0.5%	10 kg	19.5 kg	5% (0.5 kg)
Set 3	5 kg	1.0%	10 kg	19 .0kg	10% (1.0 kg)
Set 4	5 kg	1.5%	10 kg	18.5 kg	15% (1.5 kg)
Set 5	5 kg	2.0%	10 kg	18.0 kg	20% (2.0 kg)

Figure 1. The slump test.

and compared at a 5% significance level. Also, Microsoft Excel (version 2015) was used to plot the mean values.

RESULTS AND DISCUSSION

Fine aggregates size distribution

Figure 2 shows the plot of the fine aggregates particle size distribution (sieve analysis). As revealed in the plot (Figure 1), the fine aggregates utilized for the concrete production was well graded, because the fine aggregates had a coefficient of uniformity (Cu) value of 6, and the fines content of 1%. According to recommendations by ASTM D2487 (2017), fine aggregates with Cu greater than 6 and fines less than 5% is considered Well Graded, and can be used for concrete production.

Concrete mechanical properties

Table 2 presents the ANOVA results of the effect of corn starch and periwinkle shells on the compressive strength of concrete. Observations made from the findings depicted that corn starch and periwinkle shells had a significant ($p \leq 0.05$) effect on the slump, compressive strength and density of the concrete produced. Likewise, it was observed that interaction of corn starch and periwinkle shells had a significant ($p \leq 0.05$) effect on the concrete mechanical properties.

Density

The concrete density at different starch concentrations and periwinkle shell proportions is tabulated in Table 3. Table 3 showed that the concrete density decreased significantly ($p \leq 0.05$) as the periwinkle shells increased from 0 to 2 kg, regardless the amount of treatment applied, at curing day 28. At 0 kg periwinkle shells, the concrete density ranged between 2406.41 and 2598.98 kg/m^3; while at 0.5 kg periwinkle shell, the concrete density varied between 2293.96 and 2419.84 kg/m^3; furthermore, at 1 kg periwinkle shells, the density was observed to range between 2187.08 and 2318.87 kg/m^3. It was also noticed that the concrete density was within the range of 1988.16 and 2200.75 kg/m^3, when 1.5 kg of periwinkle shell was employed for the concrete production; but when the periwinkle shell quantity was increased to 2 kg, the concrete density transited to a range between 1884.05 and 2126.51 kg/m^3. Similar findings were reported by Dahiru *et al*. (2018), who stated that the density of concretes made from periwinkle shells, were generally lower (<2400 kg/m^3) compared to concrete made with 100% granite. The lower density recorded in the concrete produced with a higher proportion of periwinkle shell could be linked to the considerable lower density of periwinkle shell, compared to the density of the original coarse aggregates removed during the concrete production.

Relatively, Table 3 revealed that the corn starch significantly ($p \leq 0.05$) increased the density, regardless of the periwinkle shell proportions in the concrete. From the results, it can be observed that at 0.5% corn starch concentration, the density generally increased by 1.3%, while at 1% corn starch concentration, the density generally increased by 3.9%. At 1.5% corn starch concentration, the density generally increased by 6.3%, while at 2.0% corn starch concentration, the density generally increased by 7.8%. These findings are in conformity with earlier research findings by Akpokodje *et al*. (2020) who reported that concrete produced with starch developed a higher (5% increment) density, compared to the normal concrete density. According to Suhad *et al.* (2016), starch aids concrete compaction, thereby

Table 2. ANOVA results of the effect of treatment and periwinkle shells on concrete compressive strength.

Source		df	F	p-value
Treatment	Compressive strength	4	739.54	8.41E-44*
	Slump	4	12527.52	2.40E-74*
	Density	4	997.85	5.25E-47*
Periwinkle	Compressive strength	4	6850.37	8.40E-68*
	Slump	4	667.89	1.03E-42*
	Density	4	6880.66	7.53E-68*
Treatment * Periwinkle	Compressive strength	16	10.68	4.49E-11*
	slump	16	13.27	8.22E-13*
	Density	16	23.16	1.09E-17*

*Significant at the 0.05 significant levels according to DMRT.

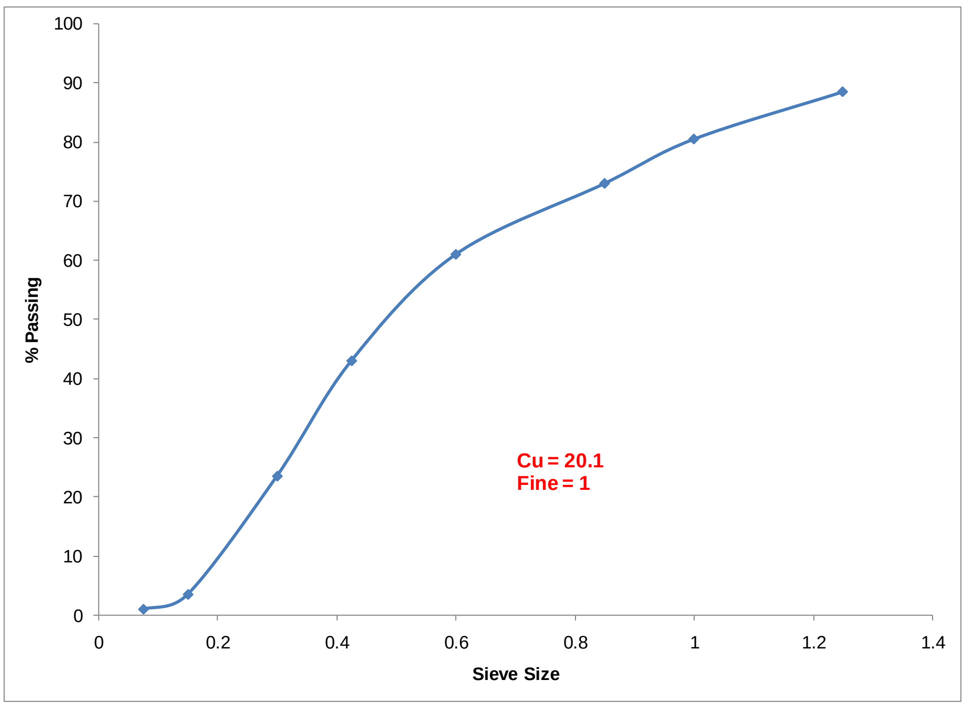

Figure 2. The plot of the fine aggregates sieve analysis.

increasing its density in the process; and the compaction degree is a factor of the starch concentration introduced.

Concrete slump

Figure 3 showed the slump results of the concretes, produced with different periwinkle shell quantities. It was observed from the chat that, the concrete slump was inversely proportional to the periwinkle shells quantity in the concrete. It was obvious that the slump of the concrete produced with 0.5 kg periwinkle shell quantity was lower than the slump of the concrete produced with 1, 1.5 and 2 kg periwinkle shell quantities. Adewuyi and Adegoke (2008) reported similar results, in which the slump decreased from 18 to 5 mm, as the periwinkle shell quantity increased from 0 to 100%. Slump results reveal the consistency of concrete, giving an idea of its workability and compatibility.

The differences observed in the concrete slumps could be attributed to the available water quantity/and paste in the concrete. The poor workability observed in the concrete produced with periwinkle shell can be further linked to the structural and textural qualities of periwinkle

Table 3. The concrete density at curing day 28.

Concrete level	**0%CS**	**0.5% CS**	**1% CS**	**1.5% CS**	**2% CS**
0% P	2406.41^{e}±12	2468.04^{e}±8	2505.8^{e}±8	2563.14^{e}±11	2598.98^{e}±4
5% P	2293.96^{d}±9	2304.99^{d}±6	2347.51^{d}±9	2384^{d}±15	2419.84^{d}±16
10% P	2187.08^{c}±13	2205.09^{c}±6	2231.42^{c}±12	2284.95^{c}±12	2318.87^{c}±10
15% P	1988.16^{b}±5	2013.42^{b}±3	2108.94^{b}±8	2155.43^{b}±9	2200.75^{b}±8
20% P	1884.05^{a}±10	1910.32^{a}±4	2009.89^{a}±4	2099.99^{a}±5	2126.51^{a}±10

Mean ± standard deviation, P = periwinkle shells, CS = Corn starch. Columns with the same common letter (superscript) indicated that the means were not significantly different at p ≤0.05, according to DMRT.

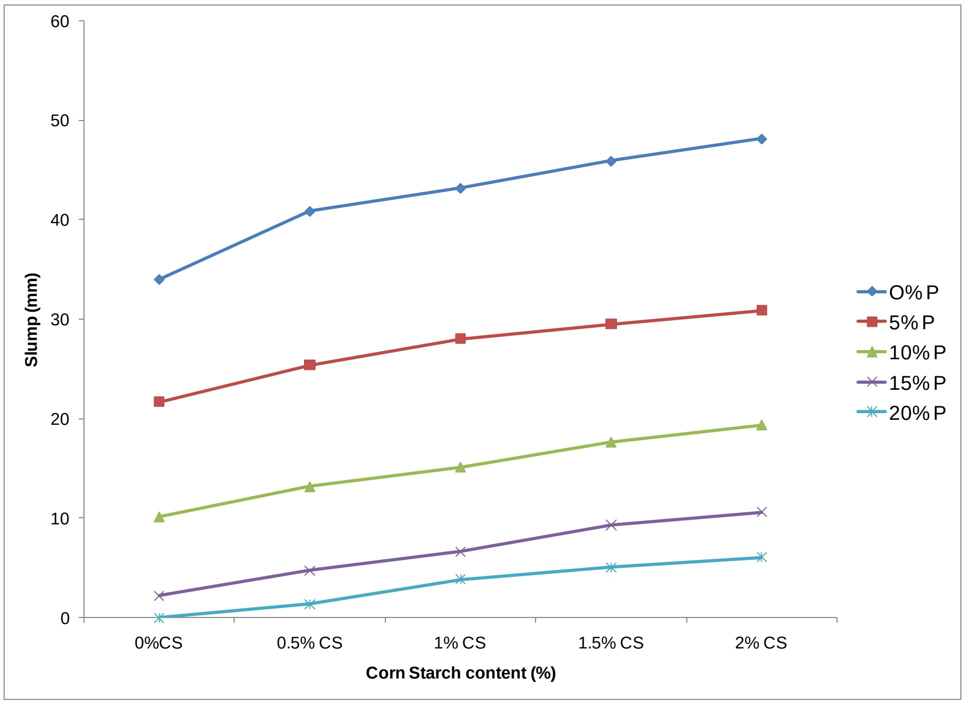

Figure 3. The concrete slump.

shells. The roughness of the periwinkle shell hinders the free flow of the cement paste and the other constituents in the concrete. Similarly, Soneye et al. (2016) reported that the structural pattern of periwinkle shell causes a decline in the workability of concrete, as the periwinkle shell quantities in the fresh concrete increases.

Regarding the impact of the treatment on the concretes' workability, it was observed that the corn starch boosted the concrete slump (Figure 3). Generally, the slump increased from 3.25 to 42.43 mm as the starch concentration increased from 0 to 2%, portraying that the corn starch was a good concrete workability enhancer. This confirms the results of previous related works by Suhad *et al*. (2016) and Joseph and Xavier (2016) on the suitability of using starch as a workability booster in concrete work. Abalaka (2011) reported that increment of starch concentration in concrete, tends to causes non-linear increment in concrete workability; hence providing some advantages in its use in the concrete industry. But on the contrary, Akindahunsi and Uzoegbo (2015) in their research observed that an increment in cassava starch quantity in the concrete, resulted to a decline in the concrete slump, this the authors attributed to the adsorption of the starch granules onto the aggregate and cement grain surfaces, thus introducing more friction between the particles. The differences in the slump values obtain by the various authors, despite using the same starch concentration, can be attributed to the nature (moisture content) of the fine aggregates, because excess water in the fine aggregates, will definitely alter (increase) the w/c ratio. This will thus increase the concrete's workability.

Compressive strength

The results of the concrete compressive strength at curing day 28 are plotted in Figure 4. Figure 4 revealed that periwinkle shell quantities had a negative impact on the concrete compressive strength. The compressive strength declined irregularly as the periwinkle shell quantity increased from 0 to 20%. In the untreated concrete, the compressive strength falls by 64.38% (from 28.07 to 10 MPa) as the periwinkle shells used as granite substitutes increased from 0 to 20%. On the other hand, in the concrete treated with 0.5% corn starch, the compressive strength falls by 59.54% (from 30.57 to 12.37 MPa) as the periwinkle shell used as granite substitutes increased from 0 to 20%. Likewise, as the periwinkle shells used as granite substitute increased from 0 to 20%, a decline of 53.30, 53.29 and 60.66% in the concrete compressive strength was observed in the concrete treated with 1, 1.5 and 2% corn starch respectively. A similar reduction in concrete compressive strength was reported by Osarenmwinda and Awaro (2009), stating that the concrete strength reduced by 44.4% as the periwinkle shell quantity was increased by 25%. Likewise, Oyedepo (2016) in his investigation into light-weight concrete, reported an arbitrary decline in the concrete strength as the periwinkle shells increased from 0% to 100%.

Figure 4 illustrates that the corn starch treatment enhanced the mechanical properties of the periwinkle shells concrete. Concrete produced with corn starch generally developed higher compressive strength, compared to the concrete produced without corn starch treatment, irrespective of the periwinkle shell quantity in the concrete. It was noted that the concrete compressive strength increased non-linearly as the corn starch concentration increased from 0 to 1.5%, and then declined sharply as the corn starch concentration was further increased from 1.5 to 2%. This revealed that 1.5% corn starch concentration produced concrete with the highest compressive strength. These findings are similar to previous reports by Akindahunsi and Uzoegbo (2015) which stated that both cassava and maize starch can boost the mechanical properties of plain concrete; with an optimization point around 1.5% starch solution. Equally, Suhad et al. (2016) reported that concrete compressive strength can considerably increase with corn starch solution, with the optimization concentration around 1% corn starch in solution.

The discrepancies in the optimization concentration obtained by the various authors can be linked to the age of the starch, the variety of the corn used for the starch production, the concrete production process and physicochemical properties of the starch. According to Purnomo *et al*. (2019), citric and hydrocyanic acids found in corn starch significantly affect the mechanical properties of concretes, a higher concentration of these acids tends to reduce the concrete's compressive strength. Additionally, Akpokodje *et al*. (2020) in their research into the effect of cassava starch on concrete mechanical properties observed that, fresh cassava starch tends to produce concrete with higher compressive strength and density.

The poorer strength developed as the quantity of the periwinkle shell is increased in the concrete can be linked to the poor bonding developed between the periwinkle shell and the cement paste. Also, the hollow parts of the periwinkle shells will capture the matrix (cement paste); hence, depriving the other constituents (granite and sand) of enough bonding material (matrix). This can also be linked to the poor slump observed in concrete with higher periwinkle shell quantities, as the cement paste which is a lubrication material in the matrix, which enhances the workability of the concrete becomes deficient.

This study indicated an optimum compressive strength (20.17 MPa), utilizing green materials, can be produced with 15% periwinkle shell and 1.5% corn starch treatment in 1:2:4 concrete. This value is above the 17 MPa recommended by ASTM-77 for light-weight concrete for use in residential and commercial structures. Although, periwinkle shell has been proven to be a good substitute for granite in concrete production, efforts should be made by the government to protect over-harvesting of this animal species; hence protecting it from going into extinction and balancing the eco-system.

Pearson correlation

The Pearson correlation (Table 4) revealed that there is a relationship (α=0.01) between the periwinkle shell, corn starch treatment, concrete compressive strength, concrete slump and density. The correlation relationship showed that periwinkle shells and treatment influenced the concrete mechanical properties. Table 4 revealed that there was a strong correlation relationship ($r>\pm0.9$) between the compressive strength and density, periwinkle quantity and density, corn starch treatment and slump, and periwinkle quantity and compressive strength. Also, the Pearson correlation revealed that a weak relationship ($r = \geq 0.5 < 0.6$) existed between the slump and density. Furthermore, the Pearson correlation revealed that a very poor relationship ($r<0.5$) occurred between the periwinkle shell quantity and slump, and compressive strength and slump of the concretes.

The Pearson correlation illustrates the strength of the linear relationship, between the mechanical behaviours of the hybridized concrete. The negative correlation coefficient value depicted that an increase in one variable automatically leads to the decline of other relating variable. This was affirmed (Table 4), as it was noticed that a decrease in the concrete slump value, translates to increment in its compressive strength; also, an increment in the periwinkle shell quality from 0 to 2 kg, led to a

Table 4. Pearson correlation between treatment, periwinkle shell and the concrete mechanical properties.

	Treatment	Periwinkle shells	Compressive strength	slump	Density
Treatment	1				
Periwinkle shells	0.0	1			
Compressive strength	0.195	-0.934**	1		
Slump	-0.946**	0.222	-0.439**	1	
Density	0.351**	-0.925**	0.933**	-0.539**	1

** Correlation is significant at the 0.01 level (2-tailed).

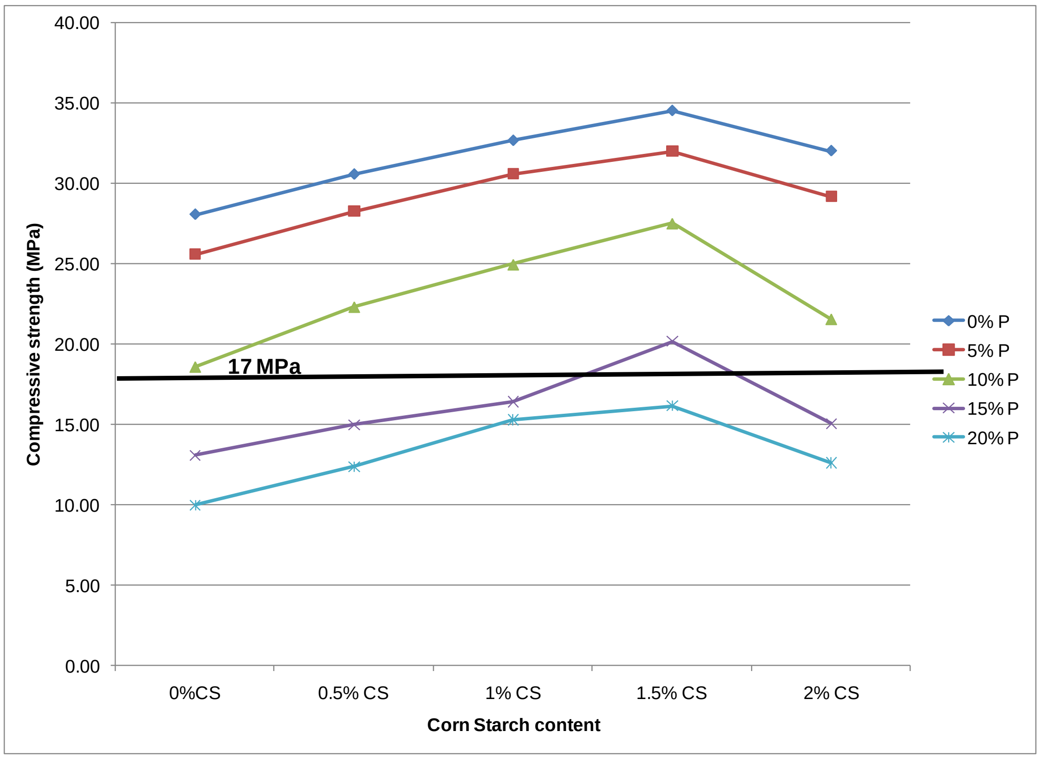

Figure 4. Concrete compressive strength at curing day 28.

reduction in the concrete's compressive strength and density. Likewise, a positive correlation coefficient portrayed that an increase in one variable, automatically leads to an increment in the other relating variable. This positive correlation is acknowledged by the increment in the concrete strength, as its density increases. Also, it was observed that the slump increased non-linearly, as the corn starch treatment concentration increased from 0 to 2%.

Conclusion

In this study, corn starch was used to enhance the mechanical properties of "periwinkle shell incorporated concrete". Concrete cubes were produced with varying concentrations (0, 0.5, 1, 1.5 and 2%) of corn starch; while the coarse aggregates (granite) was partially replaced with 0 5, 10 15 and 20% dried periwinkle shells. It was observed from the results that the slump, density and compressive strength developed by the concrete, were factors of the treatment (corn starch) concentration and periwinkle shell quantity in the concrete. Generally, by increasing the periwinkle shell quantity from 0 to 20%, the compressive strength of the concrete reduced by 58.0%, while the slump declined by 40.8%, and the density was reduced by 20.1%. Similarly, increasing the corn starch concentration from 0 to 2%, increased the concrete slump, density and compressive strength by 92.3, 7.7 and 26.84%, respectively. Findings of this research revealed that a lower quantity of periwinkle shell and corn starch (an organic material) can be used to produce light-weight concrete from a convectional 1:2:4 mix, with mechanical properties that will meet International construction standards.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

REFERENCES

Abalaka, A. E. (2011). Comparative effects of cassava starch and simple sugar in cement mortar and concrete. *ATBU Journal of Environmental Technology*, *4*(1), 13-22.

Adewuyi, A. P., & Adegoke, T. (2008). Exploratory study of periwinkle shells as coarse aggregates in concrete works. *ARPN Journal of Engineering and Applied Sciences*, *3*(6), 1-5.

Akindahunsi, A. A., & Uzoegbo, H. C. (2015).Strength and durability properties of concrete with starch admixture. *International Journal of Concrete Structures and Materials*, 9(3), 323-335.

Akpokodje, O. I. Agbi, G. G., Uguru, H., & Nyorere, O. (2021). Evaluation of the compressive strength of commercial sandcrete blocks produced in two metropolises of Delta State, Nigeria. *Applied Journal of Physical Science*, 3(2), 61-71.

Akpokodje, O. I., Agbi, G. G., & Uguru, H. (2020). Evaluation of cassava effluent as organic admixture in concrete production for farm structures. *Turkish Journal of Agricultural Engineering Research*, 1(2),271-282.

ASTM - C136 (2006). Standard test method for sieve analysis of fine and coarse aggregates. Retrieved from https://www.astm.org/standards/c136

ASTM C143 (2017) Standard test method for slump of portland cement concrete. Retrieved from https://www.astm.org/standards/c143.

ASTM C39/C39M (2014). Standard test method for compressive strength of cylindrical concrete specimens. Retrieved from https://www.astm.org/c0039_c0039m-14.html

ASTM C642 (2021). Standard test method for density, absorption, and voids in hardened concrete. Retrieved from https://www.astm.org/c0642-21.html.

ASTM D2487 (2017). Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System). Retrieved from https://www.astm.org/d2487-17.html.

Bamidele, I. O. D. (2002): Properties of periwinkle granite concrete. *Journal of Civil Engineering*, 8, 7-36.

Dahiru, D., Yusuf, U. S., & Paul, N. J. (2018). Characteristics of concrete produced with periwinkle and palm kernel shells as aggregates. *FUTY Journal of the Environment, 12*(1), 1-10.

Deuse, T., & Sagmeister, B. (2012). Concrete plant international. *BetonWerk International,* 1, 1–6.

Ede, A. N., Adebayo, S. O., Ugwu, E. I., & Emenike, C. P. (2014). Life cycle assessment of environmental impacts of using concrete or timber to construct a duplex residential building. *Journal of Mechanical and Civil Engineering*, *11*(2), 62-72.

Engineering Materials (2022). What is Materials Engineering? Purdue University. Retrieved from https://engineering.purdue.edu/MSE/aboutus/whatsmaterials

Erofeeva, I. V. (2018). Physical and mechanical properties, biological and climatic stability of powder-activated concrete. *Autoreferat of the Dissertation of the Candidate of Technical Sciences* (Saransk: Publ. H. of the Mordovian University) 28.

Ettu, L. O., Ibearugbulem, O. M, Ezeh, J. C., & Anya, U. C. (2013). A reinvestigation of the prospects of using periwinkle shell as partial replacement for granite in concrete. *International Journal of Engineering Science Invention*, 2(3), 54-59.

Fediuk, R. S., Ibragimov, R. A., Lesovik, V. S., Akopian, A. K., Teleshev, A. A., Khankhabaev, L. R., & Ivanov, A. S. (2018). Application of cementitious composites in mechanical engineering. *IOP Conf. Series: Materials Science and Engineering,* 327, 1-7

George, R. O. (2014). Minimizing hot weather effects on fresh and hardened concrete by use of cassava powder as admixture. *European International Journal of Science and Technology*, *3*(2), 1-8.

Joseph, S. K., & Xavier, A. S. (2016). Effect of starch admixtures on fresh and hardened properties of concrete. *International Journal of Scientific Engineering and Research*, *4*(3), 27-30.

Kalashnikov, V. I. (2012). What is powder-activated concrete of the new generation. *Building Materials*, *10*, 70-71.

Kalashnikov, V., Moskvin, R., & Belyakova, E. (2019). Using new generation concrete in mechanical engineering. *AIP Conference Proceedings* 1785, 040021

Mahmoud, H., Beleland, Z. A., & Nwakaire, C. (2012). Groundnut shell ash as a partial replacement of cement in sandcrete blocks production. *International Journal of Development and Sustainability,* 1(3), 1-13.

Materials (2022). Engineering Materials. Retrieved from https://mechanicalc.com/reference/engineering-materials.

Morbi, A., Cangiano, S., & Borgarello, E. (2010). *Cement based materials for sustainable development*. In: Naik, T. R., Canpolat, F., Claisse, P., Ganjian, E. (eds.). *Proceedings of session in honor of Dr. Enrico Borgarello, Professor Theodore W. Bremner, Professor David W. Fowler, Professor Konstantin Kovler, Professor Koji Sakai*. Ancona, Italy.

Motaleb, K. Z. M. (2018). Improvement of mechanical properties by alkali treatment on pineapple and jute fabric reinforced polyester resin composites. *International Journal of Composite Materials, 8*(2), 32-37.

Nigeria Industrial Standard - NIS-444 (2003). Quality standard for ordinary Portland cement. Standard Organization of Nigeria, Lagos, Nigeria.

Odeyemi, S. O., Akinpelu, M. A., Atoyebi, O. D., & Orire, K. J. (2018). Quality assessment of sandcrete blocks produced in Adeta, Kwara State, *Nigeria. Nigerian Journal of Technology*, 37(1), 53-59.

Okafor, F. O. (2008). The potentials of cassava flour as a set-retarding admixture in concrete. *Nigerian Journal of Technology*, 27(1), 5-11.

Olasunkanmi, H. O. (2022). Quantifying frequent building collapse and disaster risk reduction in Nigeria. Retrieved from https://www.brookings.edu/blog/africa-in-focus/2022/04/06/quantifying-frequent-building-collapse-and-disaster-risk-reduction-in-nigeria/.

Omoniyi, O. O., Aweda, J. O., Ohijeagbon, I. O., Busari, R. A., & Ndagi, M. (2020b). Modeling and simulation of mechanical properties of pulverized cow bone and lateritic paving tiles. *The Civil Engineering Journal*, *4*, 551-558.

Omoniyi, P., Ohijeagbon, I., Aweda, J., Abolusoro, A., & Akinlab, E. (2020a). Experimental data on the compressive and flexural strength of lateritic paving tiles compounded with pulverized cow bone. *Data in Brief*, *33*, 106511.

Osarenmwinda, J. O., & Awaro, A. O. (2009). The potential use of periwinkle shell as coarse aggregate for concrete. In: *Advanced Materials Research* (Vol. 62, pp. 39-43). Trans Tech Publications Ltd.

Oyedepo, O. J. (2016). Evaluation of the properties of lightweight concrete using periwinkle shells as a partial replacement for coarse aggregate. *Journal of Applied Science and Environmental Management*, 20(3), 498-505.

Purnomo, J., Sumarni, S., & Saputro, I. N. (2019). Effect of citric acid on setting-time and compressive strength of concrete. *IOP Conference Series: Materials Science and Engineering*, 578, 1-9.

Ravikumar, C. S., Ramasamy, V., & Thandavamoorthy, T. S. (2015). Effect of fibers in concrete composites*. International Journal of Applied Engineering Research*, *10*(1), 419-429.

Soneye, T., Ede, A. N., Bamigboye, G. O., & Olukanni, D. O. (2016). The study of periwinkle shells as fine and coarse aggregate in concrete works. *International Conference on African Development Issues (CU-ICADI 2016)*. Pp. 1-4.

Suhad, M. A., Qasssim, Y. H., Alaa, S. K., & Zainab, H. A. (2016). Effect of using corn starch as concrete admixture. *International Journal Engineering Research and Science & Technology*, *5*(3), 35-44.

Sulaiman, A. O., & Olatunde, O. A. (2019). Study on the use of palm kernel shell and periwinkle shell as coarse aggregates in concrete. *International Journal of Engineering Applied Sciences and Technology*, 4(3), 454-460.

Yan, L., & Chouw, N. (2013). Behavior and analytical modeling of natural flax fibre-reinforced polymer tube confined plain concrete and coir fibre-reinforced concrete. *Journal of Composite Materials*, *47*(17), 2133-2148.