

PAPER 91 – PHYSICAL AND MECHANICAL PROPERTIES OF CONCRETE PRODUCED WITH PERIWINKLE SHELL ASH AND QUARRY DUST

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ABSTRACT

The usage of plentiful raw waste resources in the manufacturing of concrete has proven to be a sustainable and environmentally beneficial method of making concrete for a variety of purposes. In this study, the physical and mechanical features of concrete made by partially substituting fine aggregates and ordinary Portland cement with periwinkle shell ash and quarry dust (5%, 10%, 15%, and 20%), respectively, were examined. The water-to-cement ratio utilized for the concrete mixture of 1:2:4 was 0.60. Investigated were the constituent materials' physical and mechanical characteristics. Fresh concrete underwent a slump test, and then 150 mm cubes of cured concrete were subjected to density and compressive strength tests. The results revealed that the increase in the partial replacements with periwinkle shell ash and quarry dust, the more the slump increased from 1.2% to 3%. However, the concrete without the waste materials gave optimum compressive strength of 22.9 N/mm² as against those that were partially replaced having, 18.8 – 15.1 N/mm². The study showed that in order to produce concrete for pavements and other low-strength applications, replacements with periwinkle shell ash and quarry dust of up to 20% can be utilized.

KEYWORDS: Concrete, Periwinkle shell ash, Quarry dust, Compressive strength, Partial replacement

1. INTRODUCTION

Concrete is used and applied in a wide variety of ways in the building sector. Cement, water, and aggregates are the three primary ingredients utilized in the manufacturing of concrete (Raheem et al., 2021). Sadly, the primary components utilized in the manufacture of conventional concrete are harmful to the environment. The manufacturing of ordinary Portland cement makes use of large amounts of energy and releases a high percentage of CO₂ into the atmosphere, which contributes to global warming. The excavation of the aggregates from the river might bring about aquatic pollution and an entire disruption of the ecosystem (Luhar et al., 2019). In order to produce eco-friendly and sustainable concrete, the waste materials which cause environmental pollution are used, most often partially in concrete production. Some of these waste materials include; sea shells, agricultural wastes, fly ash, quarry dust, waste plastics, steel slag, sawdust, and rice husk ash amongst others (Meko & Ighalo, 2021).

Periwinkle is a seafood and belongs to the gastropod molluscs. They are widely available in the rivers and coasts in Nigeria, and when eaten, their shells which are majorly composed of CaCO₃ (up to 96%) are thrown away as waste (Luhar et al., 2019). Periwinkle shell ash has been the subject of several studies looking at its potential use in concrete production as a partial replacement for fine aggregates, coarse aggregates, and cement. Bamigboye et al. (2016) employed periwinkle shell ash as a fractional substitute for both fine and coarse aggregates, reporting that up to 30 wt% of the periwinkle shell for the fine aggregate as well as the aggregates will result in non-compromising compressive strengths. In the investigation carried out by Afolayan et al. (2019) on the replacement of cement partially with periwinkle shell ash, their results showed an increase in compressive strength for 5 wt% periwinkle shell ash, after which the compressive strength decreased on the sisal fibre-reinforced concrete. Umoh & Ujene, (2015) revealed that the addition of sodium nitrate increased the compressive strength and splitting tensile strength of concrete that contains up to 30 weight percent of periwinkle shell ash in place of cement.

Some other studies have reported the blend of periwinkle shells and other agricultural waste; palm kernel shells (Ogundipe et al., 2021) and sawdust (Odeyemi et al., 2020). Quarry dust is released as a result of crushing operations, and they pose serious pollution to water, land and air. In a bid to put them to good use, they are utilized in replacing fine aggregates in concrete production. Scholars have reported enhancement in the mechanical properties of concrete that replaced fine aggregates with quarry dust (Febin et al., 2019; Oorkalan et al., 2020; Ponnada et al., 2020). There is a need to add to the existing knowledge to create enough data on the use of these agricultural wastes for concrete production because of how important concrete structures are to humans and the increasing population growth that places so much demand on their diverse applications. Thus, the study is aimed at ascertaining the physical and mechanical characteristics of concrete made by partially substituting fine aggregate with quarry dust (QD) and cement with periwinkle shell ash (PSA).

2. MATERIALS AND METHODS

The basic materials complied with the standards outlined in (BS 882: 1992, 2002). The binder used was Dangote ordinary Portland cement (OPC), grade 42.5R, with initial and ultimate settling times of 75 and 150 minutes, respectively, and a consistency of 28%. The materials utilized were granite, river sand, periwinkle shells from Owerri, Imo State, and quarry dust from Isiagu, Ebonyi State. The periwinkle shells were washed, sun-dried, calcined in a muffle furnace at 1000 °C for one hour, and then ground with a grinding machine at Eziobodo market in Owerri. Portable water was obtained from the Federal University of Technology Owerri, and it met the standard according to (BS:EN:1008:2002, 2002). The samples of the granite, river sand, quarry dust and periwinkle shells are shown in Figures 1 and 2.



Figure 1. (a) River sand (fine aggregate), (b) Granite (coarse aggregate)



Figure 2. (a) Quarry dust, (b) Periwinkle shells

The characteristic chemical compositions of the ordinary Portland cement, periwinkle shell ash, and the quarry dust used in the concrete production are presented in Table 1. While as the physical properties of the constituents are as shown in Table 2, and the sieve analysis of the aggregates were in line with and according to the limits specified by ASTM C33 (ASTM C33/C33M – 18, 2010).

Table 1 Chemical compositions of the constituent materials used

Constituents	Oxides and percentages									
	Al ₂ O ₃	CaO	Fe ₂ O ₃	K ₂ O	SiO ₂	MgO	Na ₂ O	SO ₃	MnO ₃	TiO ₂
Cement	3.91	66.55	3.62	0.39	19.21	1.17	0.40	3.23	-	-
Periwinkle shell ash	6.42	52.10	4.64	0.25	0.14	0.82	0.26	0.26	0.14	-
Quarry dust	15.52	14.30	6.53	4.35	45.4	3.54	-	0.55	-	2.65

(Kufre Etim et al., 2021; Sathiparan & De Zoysa, 2018; Umoh & Ujene, 2015)

Table 2. Physical properties of the constituents

Properties	Constituents				
	OPC	Periwinkle shell ash	Quarry dust	River sand	Granite
Specific gravity	3.13	2.00	3.21	2.60	2.60
Bulk density (kg/m ³)	830	727	2147	1397	2711
Particle size (mm)	5.00	4.50	7.50	6.80	20.00
Fineness modulus (%)	2.5	2.62	2.82	2.50	6.78
Colour	greenish-grey	white-ash	grey	pale green	grey/white/black

The Federal University of Technology Owerri in Nigeria's concrete laboratory of Civil Engineering Department, was where the materials were mixed, batched, and tested in accordance with standards. The batching and mix design of the material elements are presented in Table 3, and a mix ratio of 1 is to 2 is to 4 (cement/PSA to sand/QD to granite) and 0.60 water to cement ratio were employed. The concrete was cast in cubes using metallic moulds of 150 mm, then cured for 7, 14, 21 and 28 days.

Table 3 Mix design of the material constituents

Concrete designation	Constituents (%)				
	Cement	PSA	Sand	QD	Granite
A (Control)	100	0	100	0	100
B	95	5	95	5	100
C	90	10	90	10	100
D	85	15	85	15	100
E	80	20	80	20	100

The slump test was done on the fresh concrete in line with ASTM C-143 standard (Clason, 2022), the compressive strength test for the cured concrete was carried out in line with the standard specified by BS 12390 (BS-EN-12390-3-2009, 2009), and the density was done in line with the specified ASTM standard (ASTMC642-06, 2006). Results were presented as average values after triplicate runs.

3. RESULTS AND DISCUSSIONS

3.1 Slump Test Results

Slump test is carried out to understand the level of workability and consistency of the concrete mix. The results of the slump tests on the fresh concrete are shown in Table 4.

Table 4 Effect of PSA and QD partial replacements on the workability of the concrete

Concrete Designation	% Partial replacements		Slump (mm)
	PSA	QD	
A	0	0	66.1
B	5	5	67.0
C	10	10	67.0
D	15	15	68.0
E	20	20	68.2

The effect of percentage partial replacements with PSA and QD on the workability of the concrete is presented in Table 4. It could be seen that the increased percentage of replacements with PSA and QD yielded an increase in workability. This may be because it takes a long time for the PSA cement to chemically react with water (hydration), then in the case of OPC cement and water. The behaviour agrees with that reported by (Tayeh et al., 2020).

3.2 Unit weight of the concrete

The density test was used in measuring the unit weight of the concrete samples and the result is revealed in Figure 3. It could be understood that concrete A (control) without any partial replacements has density slightly higher (3 - 5%) than the other concrete mixtures that were partially replaced with PSA and QD. This implies that partially replacing river sand and OPC with 5%, 10%, 15%, and 20% PSA and QD respectively, slightly affects the concrete's unit weight. The result agrees with that reported by (Tayeh et al., 2020) Also, the concrete samples A to E, for all the days of curing (7, 14, 21, and 28 days) fit into the class of normal-weight concrete, as their densities are above 2000 kg/m³ (Eziefula et al., 2018). Then as the days of curing increase, the unit weights for all the concrete samples increase, for more voids are filled with concrete mixes as the days of curing linger.

3.3 Compressive strength of concrete samples

Figure 4 gives the compressive strength of the investigated concrete samples that were cured for 7 days, 14 days, 21 days, and 28 days. For each concrete sample, the highest compressive strength was observed at 28-day curing, for the longer days of curing, the more compression force the concrete could carry. The concrete without waste addition showed the highest compressive strength, maybe there were more voids introduced in the bonds when the waste materials (PSA and QD) were added as against their non-inclusion (Kareem et al., 2022). However, the concrete cured at 28 days and with partial replacements of 5 to 20% of PSA and QD can be used in pavements and low-strength concrete applications as they belong to normal-weight concrete.

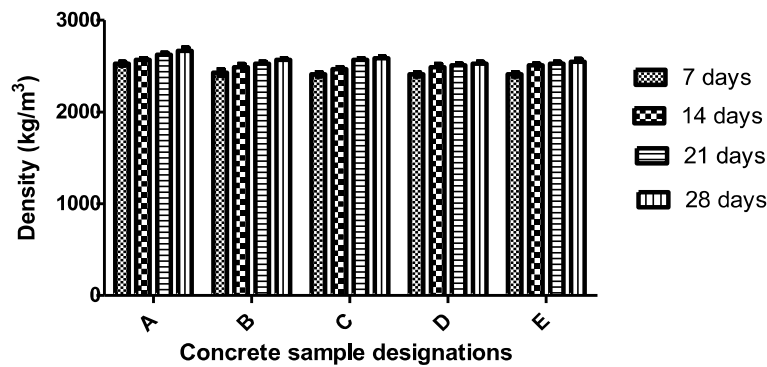


Figure 3 Unit weight of concrete samples

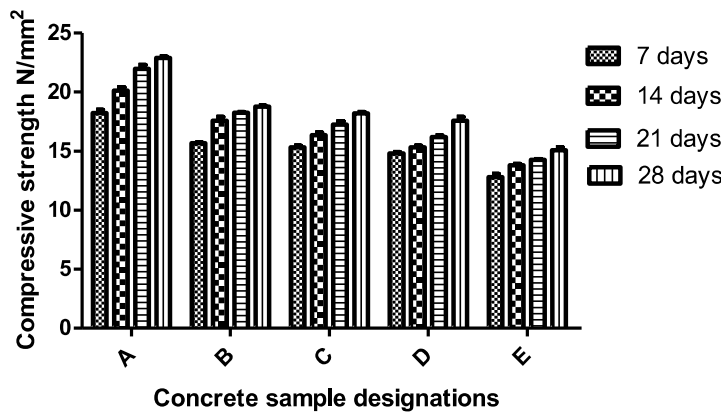


Figure 4 Average Compressive strengths of the produced concrete

4 CONCLUSION

The effect of partial replacement of ordinary Portland cement (OPC) with periwinkle shell ash (PSA), and river sand with quarry dust (QD), of varied weight percent (5, 10, 15 and 20) on the physical characteristics and mechanical characteristics of concrete was studied. The results showed that as there was increase in the partial replacements of OPC and sand gave rise to improvement of workability of the concrete. The unit weight of the concrete sample without partial replacement showed up to 3 to 5% higher than the ones with partial replacements. The control sample gave the optimum compressive strength of 22.9 N/mm², higher than those that were partially replaced, ranging between 18.8 – 15.1 N/mm². It could be deduced that partially replacing with PSA and QD for up to 20 wt% can yield normal weight concrete for applications in pavements and other low-strength structures. Thus, converting the waste materials to very useful construction products.

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