ISSN 2286-4822
www.euacademic.org

EUROPEAN ACADEMIC RESEARCH
Vol. XIV, Issue 4/ July 2026

Impact Factor: 3.4546 (UIF)
DRJI Value: 5.9 (B+)

Mechanical Properties of Concrete Containing Oyster and Periwinkle Shells as Partial Replacement for Cement and Fine Aggregate

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Abstract:

This study investigated the possibility of using Oyster Shell Ash (OSA) to partially replace cement and Ground Periwinkle Shell (GPS) to partially replace fine aggregate in the design of High Strength Concrete (HSC). Cement was partially replaced at 5, 7.5 and 10 percent with OSA while fine aggregate was replaced at 10, 15 and 20 percent with GPS at a water binder ratio of 0.22 and a super plasticizer dosing of 1.2 percent of binder. OSA was obtained by cleaning, washing, drying before calcining Oyster Shells at 800°C then ground into fine powder and passed through a 90-micron mesh with less than six percent residue. Ground Periwinkle Shell was obtained by cleaning, washing, drying and crushing periwinkle then screening to pass a 4.75mm mesh sieve with zero percent residue. Concrete cubes and cylinders were prepared by blending OSA and GPS into the concrete at a water binder ratio of 0.22 and a super plasticizer dosing of 1.2 percent of binder with various replacement levels. The concrete was mechanically mixed and mechanically vibrated before placing them into moulds, demoulded and water cured for 7, 24 and 28 days. Concrete workability test, compressive strength test. The result of the workability test shows that the incorporation of OSA and GPS reduced after 28 days wet water curing as the dosage increased. The results of the compressive strength tests of HSC showed that there was a decrease in strength with the increased incorporation of OSA and GPS after 28 days wet water curing. The optimum compressive strength of 50.07 MPa was observed for the samples tested at 7.5 and 10 percent of OSA and GPS respectively. The optimum compressive strength of 61.93MPa was observed for the samples tested at 5 percent of OSA without the GPSA.

Keywords: Oyster shell ash, ground periwinkle shell, compressive strength, water binder ratio, tensile strength.

1.0 INTRODUCTION

Concrete is one of the most widely used materials in the world due to its versatility. The consistent use of concrete has generated major concerns on its environmental impact and cost intensity (Naqi et al., 2020). Cement is one of the primary raw materials used in concrete production; and cement production releases a high amount of carbon into the atmosphere which poses enormous environmental threat to the environment. Several studies, have been carried out to mitigate this negative environmental impact through the development of green concrete which utilise recycled industrial waste with properties desirable for the production of concrete (Behera et al., 2014).

Agricultural wastes which are cheap and locally available are utilised in concrete production. For example, Seashells which are protective shells discarded on removal of the edible part, are by-products of aquaculture industry which are found in abundance in Nigeria's Niger Delta region. The shells are dumped in large quantities which cause severe environmental hazards. (Agbede & Manasseh, 2009).

Due to their rich chemical compositions, seashells have been utilised in the construction industry as partial or total substitutes for cement and aggregates (Mo et al., 2018). Seashell wastes implemented in concrete production include periwinkle shell, oyster shell, cockle shell, scallop shell, mussel shell etc. (Ezeifula et al., 2018).

Copious studies have been carried out to evaluate the structural performances of concrete blended with periwinkle shell and oyster shell ash. Depending on the applied methodologies of mix designs, the effects of these seashells on the examined properties have either been positive or negative.

The areas of application of seashell blended concrete have been in light weight structural concrete applications which include residential houses, drainage gutters, septic tanks, grave slabs, pavement slabs etc. (Ohimain et al., 2009).

However, studies were carried out on using oyster shell ash as partial replacement for cement in high strength concrete. (Ephraim et al., 2019)

Studies have been carried out to investigate the physical and mechanical properties of seashell blended concrete. In these studies, some employed these powders as partial replacement for cement while others employed them as partial or total replacement for aggregates. However, it is important to note that these studies could not consider the combined use of oyster shell ash and ground periwinkle shell as partial substitutes for cement and fine aggregate content in concrete. Therefore, in this study, the effects of oyster shell ash and periwinkle shell ash as partial substitutes for cement and fine aggregate respectively on the mechanical performance of concrete shall be examined.

Several studies used experimental method. Therefore, this study aims at establishing an optimum compressive strength of concrete blended with oyster shell ash and ground periwinkle shell as partial substitutes for cement and fine aggregates respectively.

2.0 MATERIALS AND METHODS

2.1 Materials

The materials used in this experiment include the following;

2.1.1 Cement

The cement used is Portland Limestone Cement grade 42.5R produced by Dangote Cement Company Plc and obtained from Mile 3 building materials market, Port Harcourt, Rivers State. It was well stored and free from lumps. This is the primary binder and is in conformity to NIS 444 -1: 2018.

2.1.2 Oyster Shell Ash

Calcined Oyster shell powder was utilised as partial replacement for cement. The raw oyster shell was obtained from Kaa Waterside in Khana Local Government Area of Rivers State. It was properly cleaned, washed and dried before calcining at 800°C and grinding to the right size.

PLATE 3.1: Oyster Shell

PLATE 3.2: Oyster Shell Ash

2.1.3 Ground Periwinkle Shell

The Periwinkle shells for this research were obtained from Kaa Waterside in Khana Local Government Area of Rivers State. It was properly cleaned, washed, dried and ground to the right size.It was used as partial replacement for sand in the fine aggregate mix of the concrete.

PLATE 2.3: Periwinkle Shell

PLATE 2.4 Crushed Periwinkle Shell

2.1.4 Fine Aggregates (Sand)

River sand which conforms to EN 12620 (2013) was obtained from Etche, in Etche local Government Area, near Port Harcourt and was utilised as fine aggregate. It was clean and free from silt, clay and other deleterious materials. The sieve analysis was carried out in accordance with BS 882: Part 103:1992.

2.1.5 Coarse Aggregates

Crushed Granite of maximum size 12.5 mm as coarse aggregate which conforms to EN 12620 was employed. This material was obtained from Mile 3 Market, Diobu, Port Harcourt in Rivers State, Nigeria.

2.1.6 Water

Clean pipe borne water conforming to BS EN 1008-2002 suitable for drinking was obtained from the Rivers State University water mains at the Civil Engineering laboratory, Rivers State University, Port Harcourt and utilised in this study.

2.1.7 Super Plasticizer

Hydroplast 200 Superplasticizer was used in this research and it is poly carboxylic ethers based. It is a low viscosity, high performance water reducer and advanced high early age strength superplasticizer which conforms to EN 934-2 (2001). This super plasticizing admixture enhances the workability of fresh concrete.

Concrete samples in this study were prepared and tested in the structural laboratory, Civil Engineering Department, Rivers State University.

2.4 Mix Design

The absolute volume method for concrete design using the DoE (Department of Environment) mix design guide was adopted in this work with a combination for the design of high strength concrete using oyster shell; Hence, the mix proportion table is provided in table 2.2.

Table 2.2: Concrete Mix Design Proportions for 1m^3 of concrete

Mix Code	%Replacement of Cement	% replacement of Fine aggregate	Cement (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	Oyster Shell Ash (kg/m^3)	Ground Periwinkle Shell (kg/m^3)	Water (kg/m^3)	Superplasticizer (1.2% of Binder)
A1	0	0	454.55	778	1167	0	0	100	5.45
A2	5	0	431.82	778	1167	22.73	0	100	5.45
A3	7.5	0	420.46	778	1167	34.09	0	100	5.45
A4	10	0	409.1	778	1167	45.45	0	100	5.45
B1	5	10	431.82	700.2	1167	22.73	77.8	100	5.45
B2	5	15	431.82	661.30	1167	22.73	116.7	100	5.45
B3	5	20	431.82	622.40	1167	22.73	155.60	100	5.45
C1	7.5	10	420.46	700.2	1167	34.09	77.8	100	5.45
C2	7.5	15	420.46	661.30	1167	34.09	116.7	100	5.45
C3	7.5	20	420.46	622.4	1167	34.09	155.6	100	5.45
D1	10	10	409.1	700.2	1167	45.45	77.8	100	5.45
D2	10	15	409.1	661.3	1167	45.45	116.7	100	5.45
D3	10	20	409.1	622.4	1167	45.45	155.6	100	5.45
E1	0	10	454.55	700.2	1167	0	77.8	100	5.45
E2	0	15	454.55	661.3	1167	0	116.7	100	5.45
E3	0	20	454.55	622.4	1167	0	155.6	100	5.45

2.5 Experimental Tests on Concrete

The following experimental tests on concrete were implemented;

- Slump test on fresh concrete was carried out to determine its workability.
- Compressive strength tests and density on concrete cubes, splitting tensile test on concrete cylinders.

2.5.1 Compressive Strength Test

In this study, compressive strength test was carried out in conformity to BS 1881: Part 102 (1983). The testing methodology was carried out to establish the compressive load or crush resistance of a material and the ability of the material to recover after a specified compressive force is applied and even held over a defined period of time. The compressive strength test was carried out on 144 concrete cubes of 150mm by 150mm by 150mm out of which 9 cubes were control specimens and 135 cubes were seashells blended concrete. The cubes were tested after 7, 14 and 28 days at room temperature curing. Compressive strength is calculated using equation 1.

$$f_{cu} = \frac{P}{A} \qquad (2.1)$$

Where f_{cu} = Compressive strength of concrete specimen, P = Ultimate compressive load of concrete, A = Surface area in contact with the plate.

The concrete cubes were equally used in obtaining the density of specimen using equation 2.

$$\rho = \frac{\text{Weight of specimen}}{\text{Volume of specimen}} \qquad (2.2)$$

Plate: 2.2 Weighing Concrete Cylinder

Plate 2.3 Crushing Concrete Cubes

3.0 RESULTS & DISCUSSION

3.1 Workability of High Strength Concrete Containing OSA

Concrete slump test was carried out to determine the workability of concrete containing OSA at 0, 5, 7.5 and 10% cement replacement and also 10, 15 and 20% GPS replacement for sand with a water-binder ratio of 0.22.

The result from the slump test is plotted as shown in Fig 3.1.

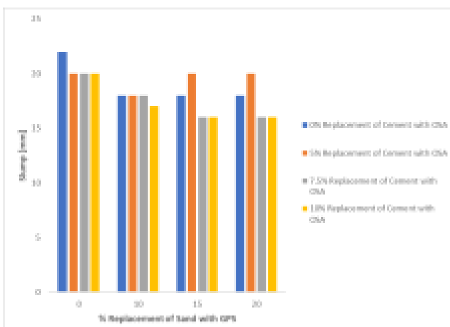

Fig 3.1: Slump of Prepared Concrete Samples

From the bar chart of fig 3.1, the results show that the slump was highest at 0% cement and sand replacements with OSA and GPS respectively. Between 0% and 10% inclusion of GPS in the concrete mix, the slump decreased as inclusion level of OSA increased. However, at 15% and 20% inclusion of GPS, the slump increased at 5% inclusion level of OSA and decreased further at 7.5% and 10% inclusion GPS. OSA blended concrete showed higher consumption of moisture hence the lower slump compared to plane cement-based concrete. However, the workability result obtained showed satisfactory performance for the level required for concrete.

3.2 Density of High Strength Concrete

The densities of the prepared concrete were obtained via the measurement of the masses of the various concrete cubes with the various mix proportions. The densities were obtained by measuring the masses of the concrete samples and dividing the results by the volume of the cube.

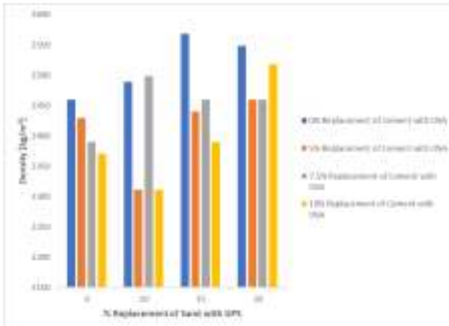

Fig 3.2: Density of Concrete Cubes Cured after 7 Days

From the figure above, it is observed that the density of the concrete cube samples as examined after 7 days wet curing were affected by the partial replacement of cement and fine aggregates with oyster shell ash and periwinkle shell respectively. However, the effects as observed in the trend of the plots shown in Fig 3.3 above do not follow a particular order.

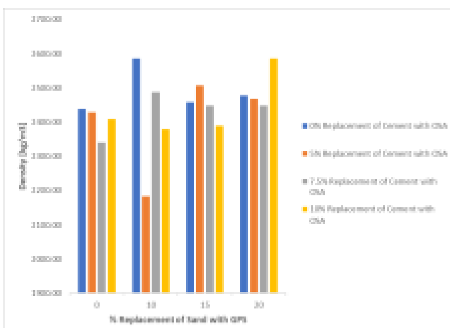

Fig 3.3: Density of Concrete Cubes Cured after 14 Days

Similar to the samples cured after seven days, the samples tested after 14 days curing show that the inclusion of oyster shell ash and periwinkle shell affect the density of the prepared concrete. The trend of change in density was not uniform as observed in the bar chart in Fig. 3.3., therefore, showing that the effect was not only influenced by the number of partial substitutes introduced into the concrete matrix.

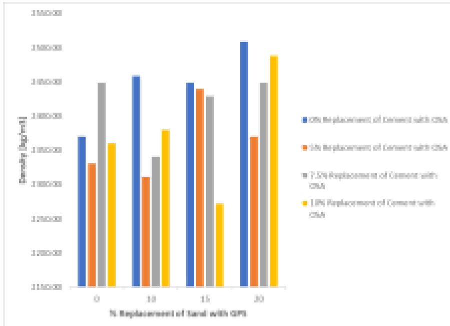

Fig 3.4: Density of Concrete Cubes Cured after 28 Days

Figure 3.4 shows that similar observation made for concrete samples tested after 7 and 14 days of wet curing, the 28 days concrete samples show similar trend for density result.

3.3 Compressive Strength of High Strength Concrete

High Strength Concrete prepared with OSA and GPS at 0.22 water – binder ratio and cured for 7, 14, and 28 days was subjected to a compressive strength test.

The results are plotted and presented as figures 3.5, 3.6 and 3.7. The result shows that the compressive strength of the concrete is influenced by the inclusion of OSA and GPS. The partial replacement of cement with 7.5% oyster shell ash resulted in the reduction of compressive strength of the samples by 10.7% at 0.22 water binder ratio. The study implemented by Ephraim et al., (2019) where the OSA was used as partial substitute for cement achieved their optimum strength at 7.5% compared to this study at 5%.

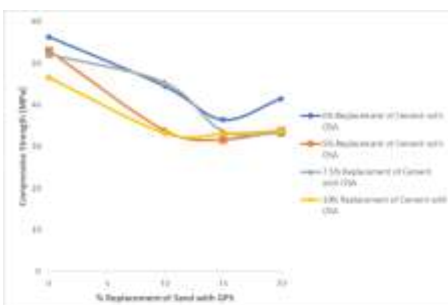

Fig 3.5: Compressive Strength of Seven (7) Days Cured Concrete

From Figure 4.6, the compressive strength of the concrete samples tested after 7 days for 5% inclusion gave a maximum value of 53.04N/mm^2, while that of 7.5% gave 52.15N/mm^2 and 10% gave 46.52N/mm^2. From the above, it is obvious that 5% inclusion of OSA gave the optimum compressive strength.

It is further observed that the compressive strength of concrete samples tested after seven days curing reduces on the increasing content of OSA and GPS. However, at 0%, 7.5% and 10% the inclusion of GPS into the concrete matrix resulted in an increment in compressive strength at 10% inclusion of GPS. Also, beyond 10% inclusion of GPS, the best performance is observed for 5% inclusion of OSA. While the decrement due to GPS inclusion is small, the decrease observed due to inclusion of OSA is significant.

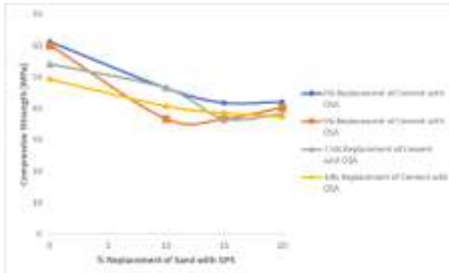

Fig 3.6: Compressive Strength of Fourteen (14) Days Cured Concrete

From the above figure it observed that for 0%, 7.5% and 10% inclusion of OSA, the compressive strength of concrete samples decreased as the content of OSA increased. The optimum compressive strength of 46.52N/mm^2 was obtained at 7.5% OSA and 10% inclusion of GPS. Beyond 10% inclusion of GPS, the compressive strength decreased sharply.

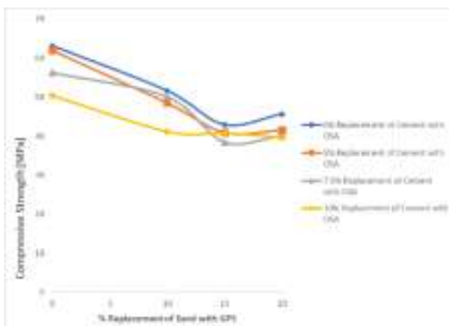

Fig 3.7: Compressive Strength of Twenty-Eight (28) Days Cured Concrete

From Figure 4.8 above, it is observed that while at the inclusion level of 0% and 7.5% OSA, the compressive strength of the concrete decreased gently up to 10% inclusion level of GPS beyond it started to decrease sharply. Whereas, at 5% and 10% inclusion level of OSA, the compressive strength show, a steady decline as the GPS content increases.

Generally, it is observed from the result for 7,14 and 28 days compressive strength that best performance of oyster shell is observed up to inclusion level of 7.5% while that of GPS is observed for inclusion level of 10%.

4. CONCLUSION

In this study, the fresh and hard state properties of concrete blended with oyster shell ash (OSA) and ground periwinkle shell (GPS) implemented as partial substitutes for cement and fine aggregates respectively have been examined through experimental procedure. Preliminary studies were implemented to study the physical properties of the aggregates implemented.

From the results obtained, the following conclusions are drawn:

The partial replacement of cement and fine aggregate with OSA and GPS respectively results in the reduction of compressive strength of the prepared concrete. The optimum compressive strength of samples tested was observed at 7.5% and 10% dosages of OSA and GPS respectively. The result which is in agreement with that obtained by Ephraim, M. E. et al., (2019) which investigated the mechanical and fresh properties of concrete with OSA as partial substitute of cement. In that study, the optimum dosage of OSA was obtained at 7.5%. However, in this current study, the performance of concrete with combined replacement of fine aggregate with GPS and cement with OSA has been examined. The results obtained showed that the optimum inclusion level of OSA is 7.5% whereas, that of GPS is 10% across curing ages of 7, 14 and 28 days. The compressive strength obtained at these levels of inclusion were considerably lower than the control. However, the optimum compressive strength for OSA alone was obtained at 5%.

- The reduction in compressive strength and splitting tensile strength of concrete upon the inclusion of OSA and GPS are due to better polymerization of cement than OSA and better Interfacial Transition Zone (ITZ) of nature fine aggregates (sand) than that of GPS. This shows that the control samples have better bonding between aggregates than the blended samples.
- The slump results obtained showed that the workability of the concrete was positively impacted by the inclusion of OSA and GPS in the concrete matrix. Hence, satisfactory performance was observed for the slump of the prepared concrete samples.

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