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Performance of high Strength Concrete Using Oyster Shell Ash as Partial Replacement for Cement

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Abstract

In this study, the possibility of using oyster shell ash (OSA) to partially replace cement in the design of High strength concrete (HSC) was investigated. Six mix ratios were used to investigate strength at replacement level of 7.5, 10, and 15 percent of cement at W/B ratios of 0.22, 0.25, and 0.27; Results showed that there was an increase in strength in all mixes as the days of wet curing increased but decreased as the percentage of Oyster shell ash increased with the least strength of 54MPa at 28 days for 0.27 water- binder ratio with 15% replacement level. The value of 72.2MPa was attained at 7.5% replacement at 0.22 water-binder ratio of mix MA1, while the 0% (control concrete) recorded 74.22MPa at 28 days of wet curing

KEYWORDS: *High Strength Concrete, Oyster Shell Ash,*

I. INTRODUCTION

Due to the depletion of natural aggregates and the need to achieved greater environmental sustainability, current research on concrete is geared towards the sustainability aspect. Hence, significant progress has been made in sustainable concrete production through the use of recycled waste materials as a suitable replacement for conventional materials in concrete. Seashells are available in most marine environments and include oyster shells, mussel shells, scallop shells, periwinkle shells, and cockle shells. Oyster shell waste is found in many countries, including China, South Korea, and Taiwan. For every 1 kg of oyster shells, about 370 – 700g of waste shells are produced (Yao et al., 2014). In China, it has been reported that of the total amount of seashell waste available, 300,000 tonnes of oyster shells has been estimated annually (Li et al., 2015). It was reported that only about 30% were re-used.

In Nigeria, an enormous amount of seashell is found in abundance in the Niger Delta region. A variety of sea shale’s foods are consumed while the shells are discarded as waste. These discarded seashells constitute a severe environmental load. A viable solution to the challenge of seashell waste management is its applicability in the production of concrete. Unfortunately, commercial estimates are not available in Nigeria, which necessitates further studies.

From the available literature reviewed, the oyster shell has been used in the production of concrete by partial replacement with either aggregate (fine and coarse) or cement. The majority of published works have replaced fine or coarse aggregate with oyster shells (Lertwattanaruk et al., 2012, Zhong et al., 2012, Kuo et al., 2013, & Ezzaki et al., 2016).

However, few cases have been reported on partial replacement of cement with oyster shell powder in normal concrete. For instance, Ezzaki et al. (2016) reported a significant reduction in compressive strength of up to 61% when cement was replaced with a 33% combination of oyster shell powder-marine sediment in the ratio of 2: 1. Zhong et al. (2012) reported that a 20% replacement level of cement with oyster shell powder resulted in to decrease in compressive strength. However, they observed a slight increase in compressive strength at a 5% replacement level. Eo and Yi (2015) reported that the replacement of normal fine aggregate with oyster shells yielded a lower compressive strength compared to its equivalent replacement with coarse aggregate. A maximum reduction of 10% for coarse replacement and 50% for fine replacement were observed, with replacement levels up to 50%. Varhen et al.(2017) reported an increase in the compressive strength when oyster shells and scallop shells were incorporated as 5% sand replacement, which was due to the effective filling of voids. However, a further increase in the replacement level to 20% and 60%, respectively, yielded lower compressive strength. Other supplementary cementitious materials such as metakaolin and microsilica increase the strength of concrete appreciably [Egwuonwu et al.2019, Obunwo et al.2018 and Ngekpe et al.(2019)].

Therefore, this research work is tailored towards the possibility of using oyster shell ash as the only replacement for cement at a different level in the production of High Strength Concrete.

II. MATERIALS

Materials used for this study include Portland limestone cement, Grade 42.5 produced by Dangote Cement Company, and conforming to NIS 444-1:2003. Sharp river sand from a local supplier was used. Crushed rock has a maximum size of 12mm used as coarse aggregate. All aggregates conform to

BS EN 12620. The superplasticizer (SP) used in this research work FosrocAuracast 200A. It is a polycarboxylic ethers (CE) based high range water reducing agent. The water used for this research work is pipe borne water free from contaminations obtained from the water mains of Rivers State University. Oyster shell Ash made with 75µm size of the sieve.

III. EXPERIMENTAL PROGRAMMES

A. METHOD

Test carried out on aggregate in preparation of mixing include: specific gravity test, particle size distribution test, bulk density (see table 1 and fig 1)

A grade of concrete was designed to achieve a minimum grade of 70Mpa after 28 days. Three water binder ratios of 0.22, 0.25, and 0.27 were considered under two different cement contents of 450kg/m3 and 500kg/m3 resulting in six mixes comprising of control concrete and different replacement levels with oyster shell ash at 7.5, 10, and 15 percent used in the determination of the High strength concrete(see Table 2). Thereafter, mixing was done in accordance with BS 5328:1997 using a 50 litre capacity rotary mixer. A total of 8 cubes were obtained from each batch. The total number of cubes cast were 192

Slump tests were conducted on fresh concrete in compliance with BS EN 12350-2:2009 to ascertain the workability of the fresh concrete. The concrete was cast in 150mm cubes, compacted, and allowed to set. The concrete samples were allowed in the moulds for twenty-four hours, after which they were removed from the moulds and placed in a curing water tank for 28 days. At 3, 7, 14, and 28days, the cubes were tested for compressive strength

Table 2 **Concrete Mix Proportions for 1m^3 of Concrete**

Mix	W/B Ratio	% Rep	Cement Kg/m^3	Fa Kg/m^3	Ca Kg/m^3	Osa Kg/m^3	Water Kg/m^3	Sp Kg/m^3	Total Kg/m^3
MA1 (1:1.78:2.79)	0.22	0	450.0	800.6	1255.5	0.0	99.0	6.5	2605.1
		7.5	416.3	800.6	1255.5	33.8	99.0	6.5	2605.1
		10	405.0	800.6	1255.5	45.0	99.0	6.5	2605.1
		15	382.5	800.6	1255.5	67.5	99.0	6.5	2605.1
MA2 (1:1.74:2.74)	0.25	0	450.0	786.3	1233.1	0.0	112.5	6.5	2581.9
		7.5	416.3	786.3	1233.1	33.8	112.5	6.5	2581.9
		10	405.0	786.3	1233.1	45.0	112.5	6.5	2581.9
		15	382.5	786.3	1233.1	67.5	112.5	6.5	2581.9
MA3 (1:1.73:2.71)	0.27	0	450.0	776.8	1218.2	0.0	121.5	6.5	2566.5
		7.5	416.3	776.8	1218.2	33.8	121.5	6.5	2566.5
		10	405.0	776.8	1218.2	45.0	121.5	6.5	2566.5
		15	382.5	776.8	1218.2	67.5	121.5	6.5	2566.5
MB1 (1:1.54:2.42)	0.22	0	500.0	772.2	1211.0	0.0	110.0	6.5	2593.2
		7.5	462.5	772.2	1211.0	37.5	110.0	6.5	2593.2
		10	450.0	772.2	1211.0	50.0	110.0	6.5	2593.2
		15	425.0	772.2	1211.0	75.0	110.0	6.5	2593.2
MB2 (1:1.53:2.37)	0.25	0	500.0	762.8	1186.1	0.0	125.0	6.5	2573.9
		7.5	462.5	762.8	1186.1	37.5	125.0	6.5	2573.9
		10	450.0	762.8	1186.1	50.0	125.0	6.5	2573.9
		15	425.0	762.8	1186.1	75.0	125.0	6.5	2573.9
MB3 (1:1.49:2.34)	0.27	0	500.0	745.8	1169.6	0.0	135.0	6.5	2550.4
		7.5	462.5	745.8	1169.6	37.5	135.0	6.5	2550.4
		10	450.0	745.8	1169.6	50.0	135.0	6.5	2550.4
		15	425.0	745.8	1169.6	75.0	135.0	6.5	2550.4

B. COMPRESSIVE STRENGTH

Compressive strength Test = Fc = P/A

Where Fc = Compressive Strength

P = Failure Load

A = Cross sectional area of cube

Plate 1: process photographs for Batching, mixing, slump, labelling, curing and crushing.

RESULTS

Table 3: Average Experimental Values of Compressive Strength (N/mm^2) for Various Durations of Wet Curing, OSA Content, and W/B Ratios

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S/No	Mix	W/B	Percentage Replacement of cement	3 Days compressive strength (MPa)	7 Days compressive strength (MPa)	14 Days compressive strength (MPa)	28 Days compressive strength (MPa)
1	MB1	0.22	0	46.67	52.44	66.67	74
		0.22	7.5	44	51.11	65.33	71.11
		0.22	10	43.11	50	64.44	66.44
		0.22	15	41.11	46.67	57.33	61.78
2	MB2	0.25	0	46.22	51.11	63.11	72.89
		0.25	7.5	43.56	50	60	70.22
		0.25	10	42	47.11	57.33	64
		0.25	15	39.33	44.89	55.56	60.89
3	MB3	0.27	0	45.78	50	61.78	70.67
		0.27	7.5	42.67	48.67	58.22	70
		0.27	10	41.33	46.67	55.56	63.78
		0.27	15	38.89	44.44	54.67	60

Table 4: Average Experimental Values of Compressive Strength (N/mm^2) for Various Durations of Wet Curing, OSA Content, and W/B Ratios

S/No	Mix	W/B	Percentage Replacement of cement	3 Days compressive strength (MPa)	7 Days compressive strength (MPa)	14 Days compressive strength (MPa)	28 Days compressive strength (MPa)
1	MB1	0.22	0	46.67	52.44	66.67	74.00
		0.22	7.5	44	51.11	65.33	71.11
		0.22	10	43.11	50	64.44	66.44
		0.22	15	41.11	46.67	57.33	61.78
2	MB2	0.25	0	46.22	51.11	63.11	72.89
		0.25	7.5	43.56	50	60	70.22
		0.25	10	42	47.11	57.33	64
		0.25	15	39.33	44.89	55.56	60.89
3	MB3	0.27	0	45.78	50	61.78	70.67
		0.27	7.5	42.67	48.67	58.22	70
		0.27	10	41.33	46.67	55.56	63.78
		0.27	15	38.89	44.44	54.67	60

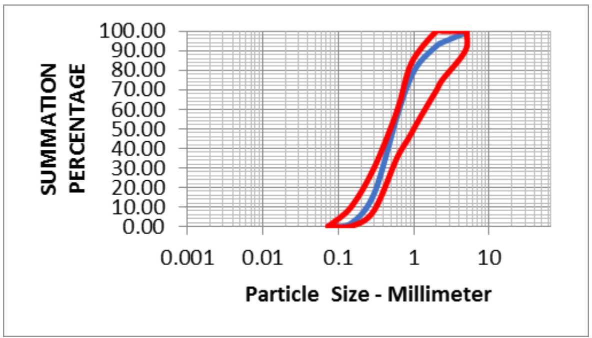


Fig 3.1: Particle Size Distribution for Fine Aggregates

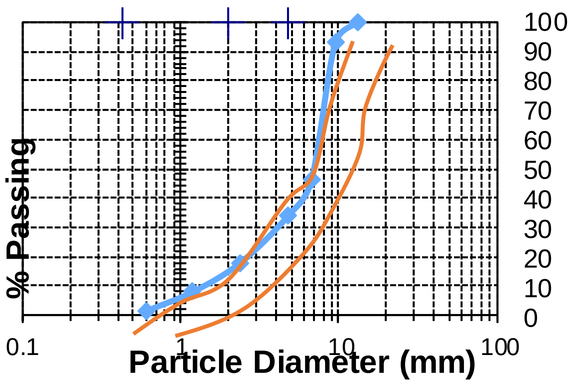


Fig 3.2: Particle Size Distribution for Coarse Aggregates

3.1 Workability of HSC Containing OSA

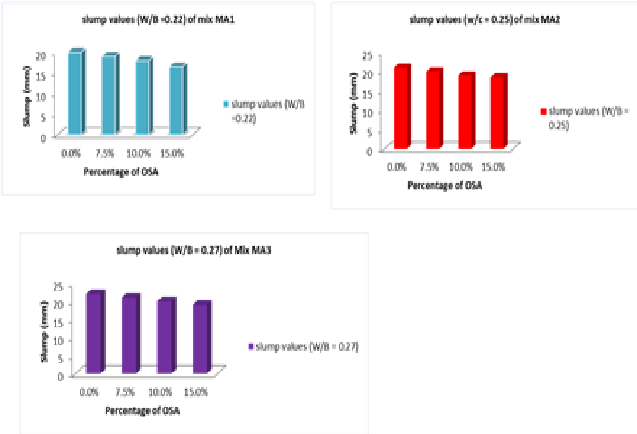


Fig 3.3 Variation in Workability of high strength concrete with percentage Replacement of OSA for Different mixes.

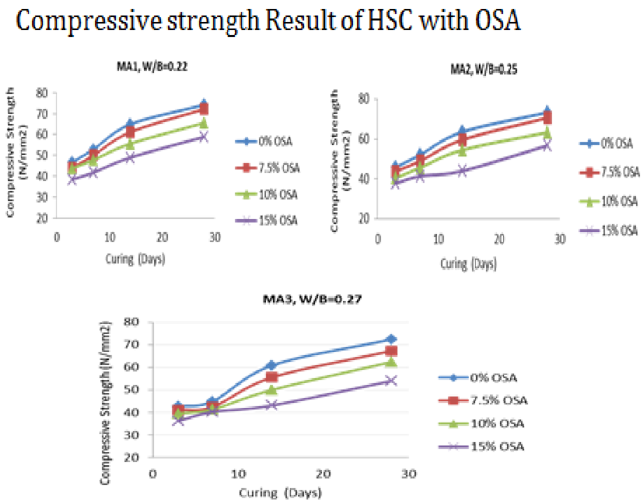


Fig 3.4 Variation of compressive strength of HSC with Duration of Wet Curing for Various % OSA Content.

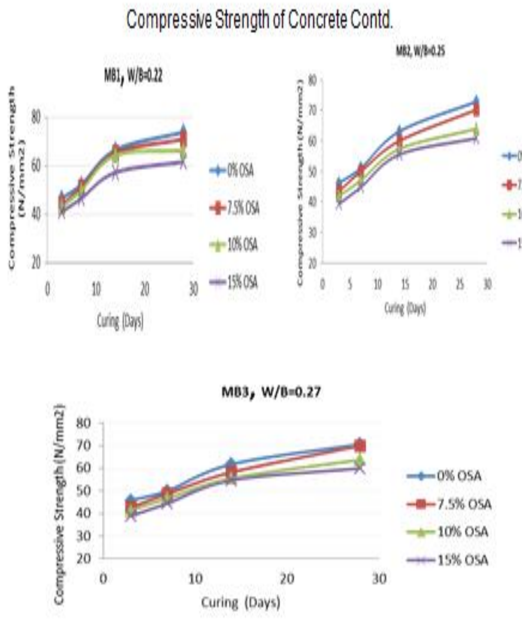


Fig 3.5 Variation of Compressive Strength of HSC with Duration of wet curing for various % OSA Content.

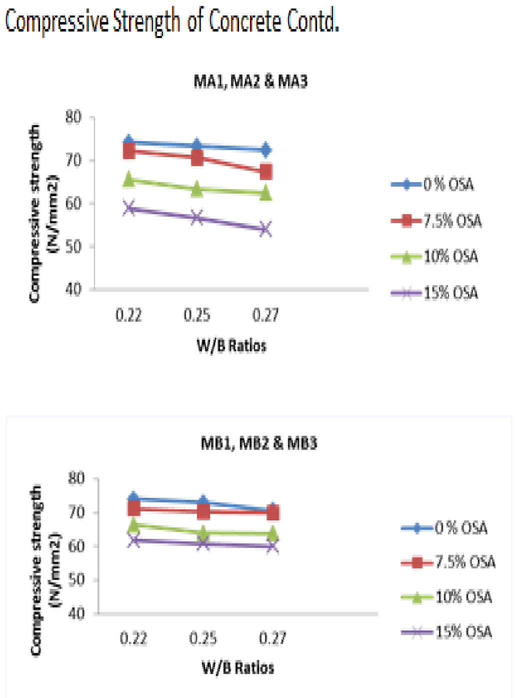
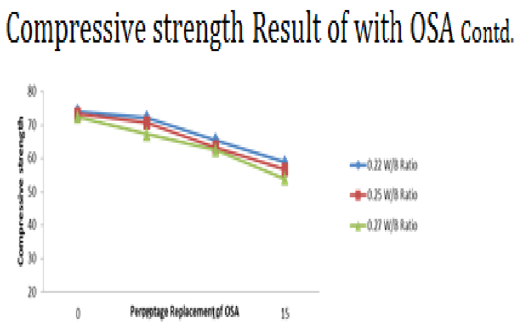


Fig 3.6 Variation of Compressive Strength of High Strength Concrete with Water Binder Ratios for Various % Replacement of OSA at 28 days of wet curing



Variation of 28 days Compressive Strength of High Strength Concrete with Percentage Replacement of OSA for various Water Binder Ratios (MA1,MA2 & MA3)

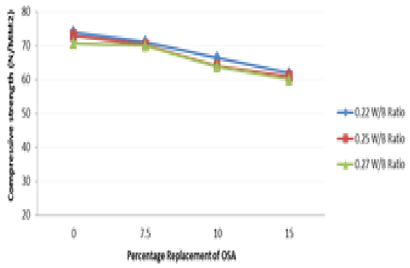


Fig 3.7 Variation of 28 days Compressive Strength of High Strength Concrete with Percentage Replacement of OSA for various Water Binder Ratios (MB1,MB2 & MB3)

IV. DISCUSSION

A. Workability

The laboratory observations yielded slump values of 20, 21, and 22mm at W/B ratios of 0.22, 0.27, and 0.27 of 0% OSA, indicating that as the W/B ratio increases, there is a corresponding increase in the slump value. This increase is a result of an increase in the W/B ratio

As a percentage of replacement with OSA for a particular mix ratio increased, the slump value decreased, resulting in low workability. This is attributed to the fact that the fine nature of the oyster shell ash requires more water for wetting the surface and to form a paste of standard consistency. A similar result was obtained by umoh & olusola (2012) when who used perinwinkle shell ash to replace cement

The least slump value is 16.5mm at 0.22 W/B ratios with 15% OSA replacement

B. Compressive strength

it can be seen that the compressive strength for a given oyster shell content and water-cement ratio increased with the duration of wet curing. The results indicate that across all curing durations and water-cement ratios, the compressive strength of the concrete mixes decreased as the percentage of replacement of cement with oyster shell ash increased. The decrease in the compressive strength of the concrete with the increase in the grounded oyster shell could be accounted for by the poor binding effect of oyster shell ash compared to cement. Irrespective of the reduced microstructural pores in the concrete mix by the inclusion of finer oyster particles, the pozzolanic ability of oyster shell ash is observed to be rather low. This could be validated by the chemical composition of oyster shells as carried out, which show lower composition content of calcium oxide as compared to cement.

From Fig 3.4, A closer analysis of the results shows the percentage strength decrease of 5.72, 6.19, and 17 .63 against the control mix for W/B ratio of 0.22 of mix MA1 for oyster shell content of 7.5%, 10%, and 15%, respectively. The corresponding decrease for 0.25 water-cement ratio of mix MA2 constituted 4.37%, 11.66% and 17.47% at 7.5%, 10% and 15% respectively. 3.66%, 7.29% and 15.12% for W/B ratio of 0.27. The average percentage decrease in compressive strength at 3 days for mix MA1, MA2, and MA3 mixes constituted about 5%, 8%, and 17%. Thus, a 15% replacement of cement with OSA will result in a strong reduction of about 17 percent across the water/cement ratios range of 0.22 – 0.27. Similarly, at 7 days, for mix, MA1 constituted 5.46%, 5.98%, and 5.46% decrease in strength against the control mix for oyster shell content of 7.5%, 10%, and 15%, respectively. 6.19%, 11.66% and 7.93% constituted MA2 mix and for MA3 mix, the percentage decrease of 17.65%, 17.47% and 15.12% were observed for oyster shell content of 7.5%, 10% and 15% respectively. The average percentage decrease in compressive strength at 7 days of curing for mix MA1, MA2, and MA3 constituted about 4.5%, 8.5%, and 16.75% at replacement levels of 7.5%, 10%, and 15%, respectively. Here, 15% cement replacement by OSA resulted in 16.75% strength reduction across the water/cement ratios range of 0.22 to 0.27. Furthermore, at 14 days for mix MA1, constituted 5.83%, 14.38%, and 24.66% decrease in strength against the control mix for oyster shell content of 7.5%, 10%, and 15%, respectively. 6.29%, 14.38% and 24.66% constituted MA2 mix and for MA3 mix, the percentage decrease of 8.75%, 17.88% and 29.20% were observed for oyster shell content of 7.5%, 10% and 15% respectively. The average percentage decrease in compressive strength at 14 days of curing for mix MA1, MA2, and MA3 constituted about 6.96%, 15.54%, and 28.21% at replacement level of 7.5%, 10%, and 15%, respectively. Here, 15% cement replacement by OSA resulted in 28.21%

strength reduction across the water/cement ratios range of 0.22 to 0.27. At 28 days of wet curing, the average percentage decrease in strength for mix MA1, MA2, and MA3 constituted 4.4%, 13.03%, and 22.96%. Similar results are seen in mix MB1, MB2, and MB3.

An increase in cement replacement with OSA resulted in a decrease in compressive strength across all mixes with different water/cement ratios. However, from the result, as the number of days for wet curing increased, the average percentage of decrease in compressive strength of 7.5% OSA replacement at 28 days of wet curing for cement improves to 4.4% across all mixes of water/cement ratios of 0.22 to 0.27 and the average percentage of decrease in compressive strength of 15% OSA replacement decreased to about 23 %. A similar result was reported by Lertwarttanaruk et al. (2012) on the Utilisation of ground waste seashells in cement mortars for masonry and plastering and Monita et al. (2015) on Mechanical properties of seashell concrete.

From Fig 3.5, At 3 days wet curing, the percentage strength decrease of 5.72, 7.63, and 11.91 against the control mix for W/B ratio of 0.22 of mix MB1 for oyster shell content of 7.5%, 10%, and 15% respectively occurred. The corresponding decrease for 0.25 water-cement ratio of mix MB2 constituted 5.76%, 9.13% and 14.91% at 7.5%, 10% and 15% respectively. 5.72%, 7.63% and 11.91% for W/B ratio of 0.27. The average percentage decrease in compressive strength at 3 days for mix MB1, MB2, and MB3 mixes constituted about 5.73%, 8.13%, and 12.91%. Thus, a 15% replacement of cement with OSA will result in a strong reduction of about 13 percent across the water/cements range of 0.22 – 0.27. Similarly, at 7 days, for mix MB1, constituted 2.54%, 4.65%, and 11% decrease in strength against the control mix for oyster shell content of 7.5%, 10%, and 15%, respectively. 2.17%, 7.83% and 12.17% constituted MB2 mix and for MA3 mix, the percentage decrease of 2.66%, 6.66% and 11.12% were observed for oyster shell content of 7.5%, 10% and 15% respectively. The average percentage decrease in compressive strength at 7 days of curing for mix MB1, MB2, and MB3 constituted about 2.46%, 6.38%, and 11.43% at replacement levels of 7.5%, 10%, and 15%, respectively. Here, 15% cement replacement by OSA resulted in 11.43% strength reduction across the water/cement ratios range of 0.22 to 0.27. Furthermore, at 14 days for mix MB1, constituted 2.01%, 3.34%, and 14.01% decrease in strength against the control mix for oyster shell content of 7.5%, 10%, and 15%, respectively. 4.93%, 9.16%, and 11.96% constituted MB2 mix, and for MB3 mix, the percentage decrease of 5.76%, 10.07%, and 11.51% was observed for oyster shell content of 7.5%, 10%, and 15%, respectively. The average percentage decrease in compressive strength at 14 days of curing for mix MA1, MA2, and MA3 constituted about 4.23%, 7.52%, and 12.49% at replacement levels of 7.5%, 10%, and 15%, respectively. Here, 15% cement replacement by OSA resulted in a 12.49% strength reduction across the water/cement ratios range of 0.22 to 0.27. At 28 days of wet curing, the average percentage decrease in strength for mix MB1, MB2, and MB3 constituted 2.84%, 10.72%, and 16.83% at replacement levels of 7.5%, 10%, and 15%, respectively.

V CONCLUSION

The strength of concretes blended with the grounded oyster shell as a partial replacement of cement has been examined in this study. From the results obtained from the experiments and analyses carried out, the following conclusions are drawn;

1. High strength concrete (HSC) with partial replacement of cement with oyster shell Ash (OSA) exhibited good workability with slump value within an acceptable range of BS EN 12350-2:2009. The slump of the concrete decreased with an increasing amount of oyster in the concrete mix.
2. There was a general increase in strength in all mixes with a duration of wet curing, but decrease as the percentage of Oyster shell ash increased with the least strength of 54MPa at 28 days occurring in the mix with a 0.27w/B ratio and 15% cement replacement level. The value of 72.2MPa was attained for a mix with 7.5% replacement and 0.22 w/B ratio; the corresponding value for the control mix was recorded 74.22MPa.

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