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WORKABILITY AND COMPRESSIVE STRENGTH OF CONCRETE CONTAINING BINARY CEMENT, MIXED FINES, AND SUPERPLASTICIZER

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Abstract. *Growing awareness about the influence of buildings on the environment has resulted in a need for more ecologically friendly buildings made of inexpensive but long-lasting construction materials. Experimental findings on the workability and strength qualities of concrete produced by partial substitution of sand with lateritic soil at various percentage replacement levels of cement with Rice Husk Ash (RHA) up to 15% are presented herein. The chemical analysis of RHA and lateritic soil, as well as the consistency and setting times of OPC and OPC/RHA pastes were conducted. They were all found to be within the limits specified by appropriate standards. Slump values for all concrete mixtures reduced with increase in the replacement level of cement with rice husk ash (RHA), with and without the inclusion of superplasticizer. However, for mixtures without superplasticizer, up till 10% replacement of cement with RHA, slump increased with increase in sand replacement with laterite up to 20% and started fluctuating for laterite levels beyond 20%. For mixes with superplasticizer, slump rose for laterite levels up to 10% and fluctuation set in thereafter. The results also revealed that at all ages and for all investigated levels of sand replacement with laterite, the compressive strength of concrete attained its highest value at 95% OPC with 5% RHA. Furthermore, this highest value of the compressive strength is substantially the same with that of the 0%RHA with 0%laterite reference concrete. The findings of this research will be of benefit to concrete professionals interested in the inclusion of laterite and RHA to achieve greenness, sustainability, and cost-effectiveness in concrete.*

Key words: *Ordinary Portland Cement, Supplementary Cementitious Material, Pozzolans, Laterized Concrete, Rice Husk Ash, Superplasticizer, Slump*

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1. INTRODUCTION

Various attempts have been made to maximize the efficient use of a variety of agricultural and industrial byproducts (such as natural fibers, corn cob, rice husk, fly ash, and foundry waste) that are continually generated. The use of these waste products will aid in the reduction of pollution and serious ecological problems in our environment. In a similar vein, a prospective source for fine aggregate substitution in concrete has gained a lot of interest. Thus, research has been carried out to determine the viability of utilizing lateritic soil to substitute sand in conventional concrete and waste ash to replace cement.

Due to the rising cost of producing concrete using conventional materials such as ordinary Portland cement (OPC) as binder, river sand as fine aggregate, and granite as coarse aggregate, recent research efforts have been geared towards the use of low-cost, readily available materials that can serve as perfect substitutes for these materials while still meeting industry standards. Researchers in the last two or three decades have been driven by the growing need to utilize waste effectively and find suitable alternatives to cement and/or aggregates for both normal and laterized concrete production. Despite all of the study on laterized concrete, the literature appears to not contain evidence of an attempt to evaluate the effect of rice husk ash and superplasticizer on laterized concrete's workability and compressive strength, as has been done with conventional concrete. The current study was motivated by the need to expand the knowledge base on the pozzolanic properties of rice husk ash, as well as to conduct a detailed investigation to determine the extent to which different replacements levels of OPC with rice husk ash (RHA), and sand with lateritic soil, would influence the workability and strength characteristics of laterized concrete with and without the addition of superplasticizer.

Research Objectives

The objectives of the research are to determine the chemical composition of the RHA and lateritic soil utilized in the work, assess the standard consistence and determine the setting times of the RHA pastes, evaluate the workability of fresh concretes produced by partial replacement of sand with lateritic soil at various replacement levels of OPC with RHA, with and without the addition of superplasticizer; and finally, to determine the compressive strength of concrete containing various combinations of laterite, sand, OPC, rice husk ash, and superplasticizer.

2. PREVIOUS STUDIES

2.1. Laterized Concrete

Many studies [1, 2] have discovered in recent years that using lateritic soil as a substitute for the conventional fine aggregate component of concrete (sand) or as a supplementary fine aggregate can result in appreciable cost savings while also providing more ecologically friendly concrete. The cost of construction materials has a direct impact on housing. The higher the cost of the materials, the more expensive housing development becomes, and the fewer the individuals who can afford their dream homes. According to [3], one notable way of reducing the cost of conventional building material consists in the provision and use of non-conventional local construction materials alternatives.

Different researchers [1], [2] have investigated the use of lateritic soil either as partial replacement or full substitute for sand in concrete. According to [4], mechanical instability can impact engineering parameters of lateritic soil, such as particle size, Atterberg's limits, moisture content, grain size, and others, affecting the strength of laterized concrete.

According to [5], for a range of 50% to 75% replacement of conventional fines (sharp river sand) with laterite, a concrete mix ratio of 1:1.5:3 [cement: fine aggregate (combination of lateritic soil and/or sharp river sand): coarse aggregate (granite)] with a water cement ratio of 0.65 is ideal. [6] employed laterite as a sand substitute in concrete and found that as the quantity of laterite in the concrete grew, the workability of the concrete improved up to 40%. Their findings suggest that as more sand is replaced with laterite, the concrete becomes more workable, which is verified by [7], who found that workability increases with commensurate increases in laterite content up to 50% only for 0.6 water/cement ratio.

Several properties of concrete incorporating laterite as a partial or full replacement for sand had previously been investigated in an experimental program [6]. Sand was replaced with 0%, 20%, 40%, 60%, 80%, and 100% laterite in a concrete mix ratio of 1:2:4:0.56 (cement: sand: coarse aggregate: water-cement ratio). The results revealed that with up to 40% sand replacement by laterite, the required strength of 20 N/mm^2 was attained by the concrete, which is an indication that laterite can be used as a partial sand replacement up to this level. The percentage water absorption of the concrete and its compressive, split tensile and flexural strengths all decreased as the replacement amount of sand increased.

2.2. Supplementary Cementitious Materials

Continuous efforts are undertaken in the cement industry to minimize the cost of Portland cement manufacturing and raw material consumption, as well as energy costs, environmental protection, and cement quality. OPC production uses a lot of energy, emits toxic gases and pollutes the climate since it proceeds at a high temperature (1500ºC) [8]**.** Furthermore, naturally existing raw resources to produce Ordinary Portland Cement (OPC) (limestone, sand, shale, clay, and iron ore) continue to diminish, creating an unsustainable scenario.

To address these issues, studies have been conducted, while others are on-going, to ascertain the feasibility of blending locally available pozzolanic materials with OPC as a more sustainable option than using the more ecologically harmful and often more expensive OPC as the sole binder. As a result, a replacement to OPC must be found that is not only more ecologically friendly but also more affordable.

Supplementary Cementitious Materials (SCMs) are materials that, when employed in conjunction with OPC, add to the properties of the hardened concrete by hydraulic, pozzolanic, or both activities. By this definition, SCMs include all pozzolans, rice husk ash, fly ash, and ground granulated blast-furnace slag (GGBFS).

Owing to cost reductions, long-term strength improvements, and increased durability that occur in concrete from blending SCMs with Portland cement, SCMs give significant benefits to the concrete industry.

In [9], it was noted that when ashes from various agricultural or other biogenic wastes are combined with suitable volumes of conventional Portland cement (OPC), they may be utilized as low-cost, environmentally acceptable binders for concrete production, rather than utilizing OPC alone. The study observed that when RHA was partially substituted with cement up to 10%, the strength increased. There was a continual drop from 15% upward.

Research carried out by [10] concluded that adding these SCMs to concrete improves its workability and compressive strength substantially.

2.3. Superplasticizer

Superplasticizers, which are also called high range water reducers, are chemical admixtures used in applications that require well-distributed particle suspension. Being polymers, they are employed as dispersants in suspensions to prevent particle segregation and enhance flow properties. Their inclusion in concrete reduces the water to cement ratio without adversely affecting the workability of the mixture while allowing for the development of concrete that has self-consolidating and high-performance properties. This effect greatly enhances the performance of the hardening fresh paste. Concrete strength increases with a lowering of water to cement ratio.

In the research by [11], an investigation was conducted on the effect of admixtures on the characteristics of Corn Cob Ash-cement concrete. The study focused on the workability and compressive strength of concrete. Three different types of admixtures were employed which are; Accelerant, plasticizer, and retarder. Based on their findings, all of the admixtures improved the workability and compressive strength of corn cob ash cement concrete at all ages.

In a different study by [2], the effects of superplasticizer (Conplast SP430, 500ml per 100kg of cement) and varying aggregate size, on the drying shrinkage and compressive strength of laterized concrete, were assessed. The research revealed that increasing the water/cement ratio and adding superplasticizer to laterized concrete boosted its workability from medium to extremely high.

3. Materials and Methods

3.1. Materials

Dangote brand of Portland cement grade 32.5N conforming to BS EN 197-1, 2000 was used. It was obtained from the open market. Crushed granite with a size of 19.5 mm was employed as coarse aggregate (coarse aggregate of size 19.5 mm was used because when sand was replaced by 25 percent of laterite in the study of [1], 19.5 mm and 12.5 mm coarse aggregate particle sizes gave satisfactory results in terms of workability and compressive strength respectively at 28 days of curing age, compared to all other sizes tested). Sharp sand was obtained from Akure metropolis and lateritic soil was sourced from the campus of the Federal University of Technology, Akure (FUTA). Other materials include potable water and superplasticizer (Conplast SP 430) conforming to BSI [12].

3.2. Methods

3.2.1. Sample preparation

Rice husk was collected, and sun dried before being burnt into ashes. Rice husk ash from a charcoal-fired incinerator was used in this experiment. The entirely burnt ash was collected, allowed to cool for 72 hours and thereafter grinded. The particles were sieved at the Civil Engineering Laboratory of the Federal University of Technology, Akure

(FUTA) using a 75µm sieve. RHA was analyzed for chemical composition in the Chemistry laboratory of the same institution.

3.2.2. Physical analysis of materials

Particle size distribution, specific gravity, aggregate crushing value, aggregate impact value, and Atterberg limits are the various laboratory tests performed on all aggregates in line with the codes relevant to them.

3.2.3. Determination of standard consistence

This test was carried out on Dangote brand of ordinary Portland cement with rice husk ash (RHA) replacement levels of 5%, 10%, and 15% in line with the standards of BSI [13]. The test was performed using the Vicat apparatus in the Concrete Laboratory of the Civil Engineering Department of FUTA.

3.2.4. Determination of setting times

For varied replacement levels, the initial and final setting times for OPC, as well as blends of OPC and the case study ash of rice husk (OPC/RHA) pastes, were determined. The setting time tests were carried out according to the requirements of BSI [13].

3.2.5. Determination of workability

The workability of OPC concrete, RHA/OPC laterized concrete with superplasticizer, and RHA/OPC laterized concrete without superplasticizer were evaluated. The slump values were calculated using 40 distinct submixes (with and without superplasticizer). The impact of RHA on the workability of various fresh RHA/OPC laterized concrete mixes (with and without superplasticizer) was investigated, and the test was carried out in line with BSI [14].

3.2.6. Casting of concrete cubes, and compressive strength test

As shown in Table 1, three levels of cement replacement with RHA at 5%, 10%, and 15%, as well as four levels of sand replacement with lateritic soil at 10%, 20%, 30%, and 40%, were investigated, totaling 240 cubes when combined with the controls.

Throughout the experiment, a 1:2:4 mix (Cement: Fine aggregate: Coarse aggregate) with a water-cement ratio of 0.60 was used, with the fine aggregate being a combination of lateritic soil and/or sharp river sand. The proportion of lateritic soil was varied between 0% and 40%, the RHA percentage between 0% and 15%, and all other parameters were maintained constant.

Table 1 Experimental design for number of Cubes cast.

S/No.	Factors	Level	Description
1.	Percentage lateritic soil content	5	0, 10, 20, 30, 40%
2.	Percentage rice husk ash (RHA) content	4	0, 5, 10, 15%
3.	Curing ages	4	7, 28, 56, 90
4.	Replicates	3	
	Total number of cubes	240	

The concrete was mixed by weight and according to the guidelines of BSI [15]. The compressive strength testing was done in accordance with BSI [16].

3.2.7. Concrete mix design for each replacement level at different ages

Volume of a cube used = 0.15 × 0.15 × 0.15 = 0.003375 m^3
Twelve (12) cubes were cast for each replacement level at different ages.
Mix ratio used is 1:2:4.
Weight calculation = mix ratio × volume of concrete × density × factor

Weight of cement = (1/7) x 0.003375 x 1440 x 12 x1.5 = 12.50 kg
Weight of sand = (2/7) × 0.003375 × 1620 × 12 × 1.5 = 28.12 kg
Weight of granite = (4/7) × 0.003375 × 2300 × 12 × 1.5 = 79.84 kg
Weight of water = 0.60 × 12.50 = 7.5 kg

Rice husk ash (RHA) replacement
RHA @ 5 % = (5/100) × 12.50 = 0.63 kg
Weight of cement at this level = 12.50 – 0.63 = 11.87 kg
RHA @ 10 % = (10/100) × 12.50 = 1.25 kg
Weight of cement at this level = 12.50 – 1.25 = 11.25 kg
RHA @ 15 % = (15/100) × 12.50 = 1.88 kg
Weight of cement at this level = 12.50 – 1.88 = 10.62 kg

Laterite replacement
Laterite @ 10 % = (10/100) × 28.12 = 2.81 kg
Weight of sand at this level = 28.12 – 2.81 = 25.31 kg
Laterite @ 20 % = (20/100) × 28.12 = 5.62 kg
Weight of sand at this level = 28.12 – 5.62 = 22.50 kg
Laterite @ 30 % = (30/100) × 28.12 = 8.44 kg
Weight of sand at this level = 28.12 – 8.44 = 19.68 kg
Laterite @ 40 % = (40/100) × 28.12 = 11.25 kg
Weight of sand at this level = 28.12 – 11.25 = 16.87 kg

Superplasticizer

One (1) litre per One hundred (100) kilogram of cementitious material was used as recommended in the Conplast SP430 Chart. Therefore, 12.5kg of cementitious material equals 125millilitre (ml).

4. RESULTS AND DISCUSSION

4.1. Properties of Constituent Materials

The results of tests carried out on constituent materials (sharp sand, lateritic soil and granite) are shown in Table 2.

The ACV and AIV are 28.78% and 15.79% respectively which are within the required limit set by BSI [17] and BSI [18] respectively. The lateritic soil sample was classified using the AASHTO soil classification system. The sample fell under the silt-clay materials based on the general classification as the percentage passing sieve size no 200 is more than 35%. The lateritic soil sample fell within A-6 group based on the liquid limit and plasticity index. According to [19], the lateritic soil sample has low plasticity because the liquid limit is less than 30%. Furthermore, the soil's plasticity index is low indicating that it is plastic for very short range of water content. This soil can therefore be stable for relatively small amounts of water and with little increase of water it reaches its liquid limit and starts flowing. This suggests the possibility of an increase in slump value of concrete containing such laterite because of the low plasticity of the lateritic soil.

Table 2 Summary of Properties of Constituent Materials

Parameters	Sand	Laterite	Granite
Specific Gravity	1.62	-	2.30
Aggregate Crushing Value (ACV) (%)	-	-	28.78
Aggregate Impact Value (AIV) (%)	-	-	15.79
Liquid Limit (%)	-	25.59	-
Plastic Limit (%)	-	7.80	-
Plasticity index (%)	-	17.79	-

The percentage of sand particles that passed 75 µm sieve size was 24.42 %. This shows that the sand contains a high amount of silt particles. According to [20], silt contents should not be more than 4%. With the result graphically presented in Figure 1, it shows that the sand is very fine sand (Zone IV) as stated by BSI [18]**.** The result obtained in Fig. 1 suggests the possibility of reduction in the compressive strength because of the fineness of the sand. This was observed in the research carried out by [20] whereby concrete produced with grade zone iv aggregate has the lowest compressive strength when compared to grade zones i, ii, and iii results.

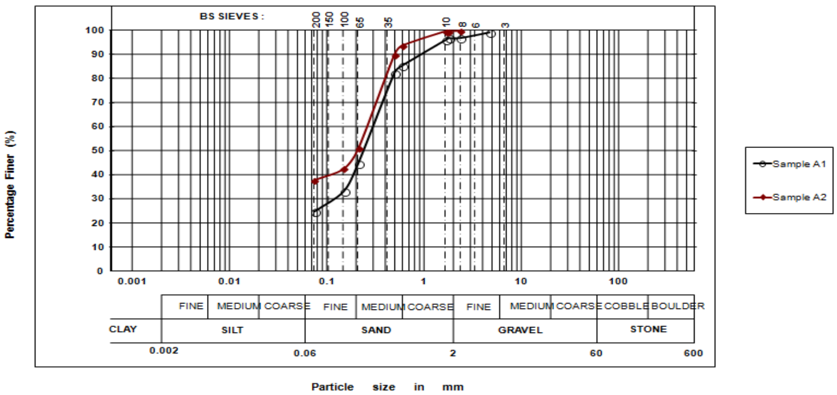

Fig. 1 Particle size distribution curves for sand (sample A1) and laterite (sample A2)

4.2. Chemical Composition

The results of the properties of the ashes investigated and the lateritic soil used are presented in Tables 3 and Table 4 respectively.

Table 3 Percentage Oxides Composition of the RHA Ash used.

Oxide	Chemical formula	Percentage composition (%) in ash of RHA
Silica	SiO_2	92.46
Alumina	Al_2O_3	0.26
Iron oxide	Fe_2O_3	0.30
Calcium oxide	CaO	1.63
Magnesium oxide	MgO	0.38
Carbon	C	0.54
Aluminium dioxide	Al_2O(aq)	1.24
Sulphur trioxide	SO_3	0.11

The oxide composition reveals that silica is the main component of the RHA (about 92.46 percent). Calcium oxide, alumina, and iron oxide are cementitious chemicals found in RHA (total about 2.91 percent). The total percentage composition of the oxides SiO2+ Al2O3+ Fe2O3 is 93.02 %, which is greater than the minimum value of 70% recommended by ASTM [21]. As a result, the tested material meets this criterion for pozzolanicity.

Table 4 Percentage Oxide Composition of Lateritic soil used.

Oxide	Chemical formula	Percentage composition (%) in ash of RHA
Lead monoxide	PbO	0.00
Copper(II) oxide	CuO	3.005
Sodium oxide	Na_2O	12.09
Potassium oxide	K_2O	16.501
Calcium oxide	CaO	11.10
Iron oxide	Fe_2O_3	1.03
Chromium oxide	Cr_2O_3	5.001
Alumina	Al_2O_3	1.330
Manganese dioxide	MnO_2	1.185
Magnesium oxide	MgO	30.00
Cadmium oxide	CdO	2.010
Silica	SiO_2	2.090
Zinc oxide	ZnO	9.333

4.3. Standard Consistence

The result of the standard consistence test is presented in Table 5 for OPC and RHA.

Table 5 Standard consistence test result (%)

SCM Content (%)	Mass of cement (g)	Mass of SCM (g)	Mass of water (g)	Water content (%)
0	300	0	75	25
5	285	15	75	25
10	270	30	75	25
15	255	45	81	27

It was discovered that the water content was constant for the SCM content at 0%-10% but for the maximum replacement of cement with RHA, the water consumption for standard consistency increased. This is predicted, according to [3], due to the presence of carbon in the SCMs, which boosts the material's water absorption capacity.

4.4. Setting Times of OPC/RHA Mix

For the OPC/RHA mix, the results of the setting times test for the case study ash are graphically depicted in Figure 2.

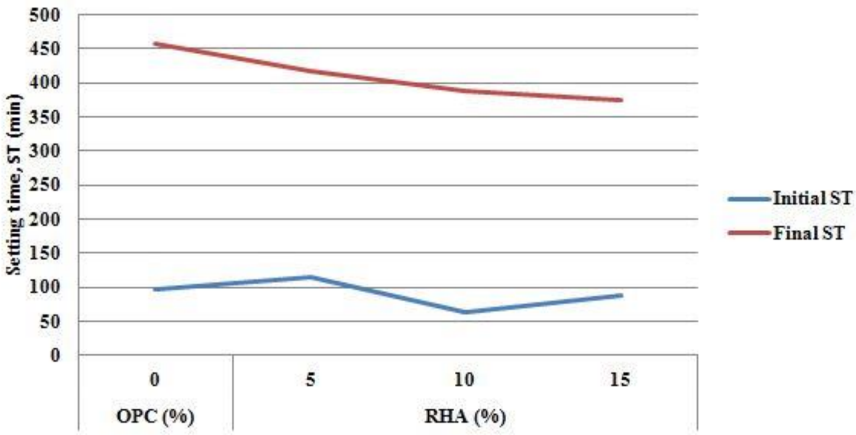

Fig. 2 Curves of setting times for OPC/RHA pastes

The initial setting time for RHA at 10% and 15% replacement levels is shorter than that of the control mortar samples, whereas the value for RHA at 5% is more than that of the control mortar samples. Figure 2 demonstrates that when the replacement level increases, the final setting time decreases, corroborating the findings in [22]. This is due most likely to the RHA being obtained by an open burning process at a temperature of less than 450^0 C. [23] reported that this temperature will only form crystalline RHA, and that the setting times of crystalline RHA may be different from those of amorphous RHA. The final setting time for 0% and 15% cement replacement levels was 457 minutes and 375 minutes, respectively. According to BSI [13] guidelines, the initial setting times for OPC/RHA were greater than 45 minutes, while the final setting times were less than 600 minutes. As a result, at the replacement levels utilized in this study, adding SCMs to OPC had no effect on the concrete binder's setting time.

4.5. Workability

The ease and uniformity with which freshly mixed concrete or mortar may be mixed, placed, consolidated, and finished is determined by its workability [23].

The slump test findings are graphically represented in Figures 3 and 4.

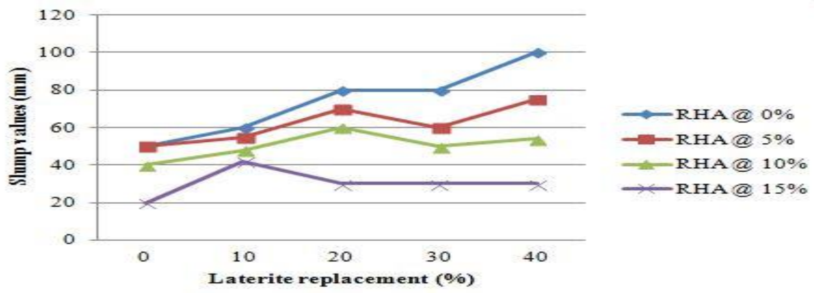

Fig. 3 Slump values for each replacement levels without Superplasticizer

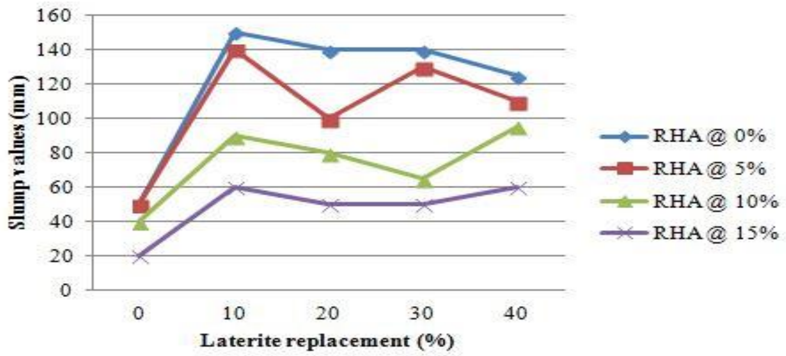

Fig. 4 Slump values for each replacement levels with superplasticizer

The figures show that for mixtures without laterite, slump decreased with increase in replacement level of OPC with RHA with or without the addition of superplasticizer. However, for RHA replacement level up to 10%, slump increased with the addition of laterite up to 20% replacement level of sand with laterite before slump value started to fluctuate, for mixes without superplasticizer (Fig. 3). For mixes with superplasticizer (Fig. 4), the rise in slump was up to 10% laterite replacement level before fluctuations in its value started.

The slump value for the concrete decreased below the level of the control mix (i.e., at 0% laterite replacement) as RHA increased up till 15%. This observation is in consonance with the findings of [24] which found that as the replacement of cement by RHA in concrete increases, the workability of concrete decreases. These findings suggest that as the RHA % increases, concrete becomes less workable, necessitating additional water to make the mixtures more workable. The increased quantity of silica in the mixture causes a higher need for water as the RHA level rises [25].

The result shows that as more sand is replaced with laterite, the concrete becomes more workable, which corroborates the findings by [7], who concluded that workability increases with commensurate increases in the laterite content up to 50% only.

The inclusion of superplasticizer boosted the workability of laterized concrete from medium to high. This observation is consistent with the findings of [11] and [2], which found that adding a superplasticizer to concrete without lowering the water content (i.e., with a constant w/c ratio) normally results in a mixture with higher slump. This is because superplasticizer disperses the cement particles, improving the flow properties of the mix.

4.6. Compressive Strength

The results of the compressive strength tests on rice husk ash laterized concrete are graphically presented in Figures 5 to 9.

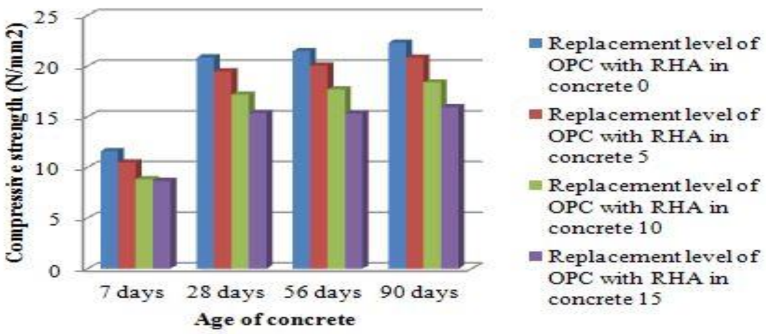

Fig. 5 Comparison of OPC/RHA concrete compressive strength @ 0% laterite replacement

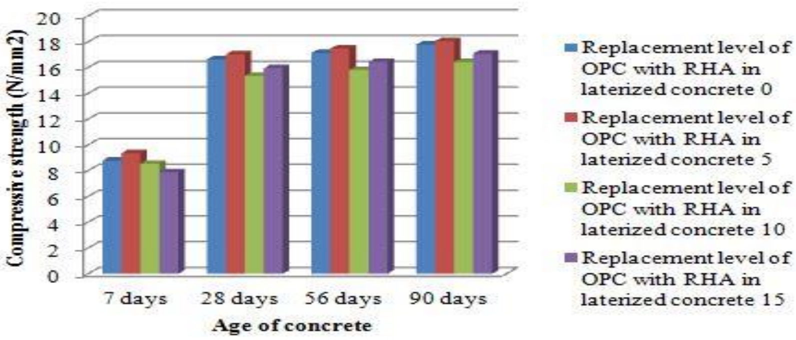

Fig. 6 Comparison of OPC/RHA laterized concrete compressive strength @ 10% laterite replacement

Figure 5 shows that with increasing RHA content, compressive strength decreases at all ages for mixes without laterite. For mixes containing laterite (Figs. 6 to 9), compressive peaked at 5% replacement level of OPC with RHA for all curing ages. The compressive strength is reduced as the amount of ordinary Portland cement and sharp sand in the mix decreases.

Figure 6 shows reduction in strength is observed at 10% replacement of sand by laterite with 0% replacement of cement by RHA (10%lat.RHA0%) compared to 0%lat.RHA0% at all hydration ages. At 10% laterite replacement, there is a reduction in compressive strength commencing at 10% lat.RHA10 percent. This is understandable given the decrease in regular Portland cement and sharp sand content in the mix as RHA and laterite percentages increased.

The compressive strength increased with the addition of 5% RHA at this point but decreased as the amount of RHA added increased.

Figure 7 shows an increase in compressive strength at 20% lat.RHA5% when compared to the compressive strength achieved at 10% lat.RHA5% at all ages. This improvement in compressive strength is greater than that found at 0% lat.RHA5%. The strengths attained at 20%lat.RHA5 % across the ages are the greatest at 20% laterite replacement.

It was observed that there is a reduction in the compressive strength starting from 20%lat.RHA10% at 20% laterite replacement. These compressive strength results obtained at 20%lat.RHA10% at all ages are higher than the compressive strength obtained at 20%lat.RHA0% which happens to be the control at 20% replacement level of sand with laterite.

The compressive strength improved with the addition of 5% RHA, but decreased as the percentage of RHA added increased, yet strength development was equivalent to the control specimens up to 15% cement substitution with RHA.

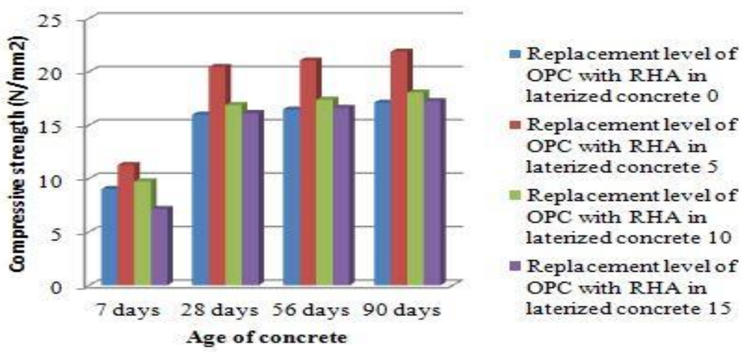

Fig. 7 Comparison of OPC/RHA laterized concrete compressive strength @ 20% laterite replacement

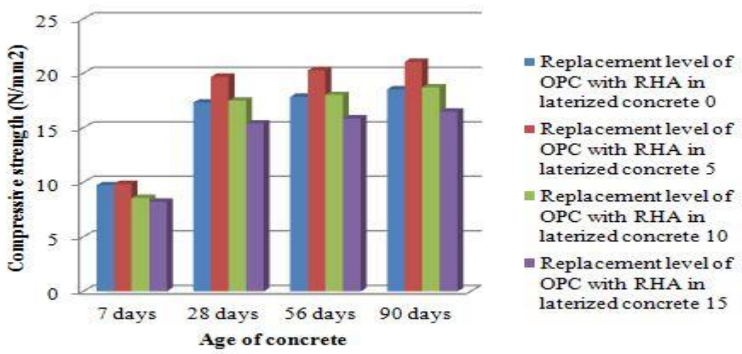

Fig. 8 Comparison of OPC/RHA laterized concrete compressive strength @ 30% laterite replacement

In Figure 8, at 30%lat.RHA5%, there is decrease in compressive strength compared to the strength obtained at 20%lat.RHA5% but greater than the compressive strength obtained at 10%lat.RHA5% and 0%lat.RHA5% at all ages. The strengths obtained at 30%lat.RHA5% are the highest across all curing ages for mixes with 30% laterite replacement of sand.

At 30 percent laterite replacement, there was a reduction in compressive strength commencing at 30% lat.RHA10 %.

The compressive strength of the blended concrete with 5% RHA rose dramatically, and up to 15% replacement could be replaced by RHA without compromising strength.

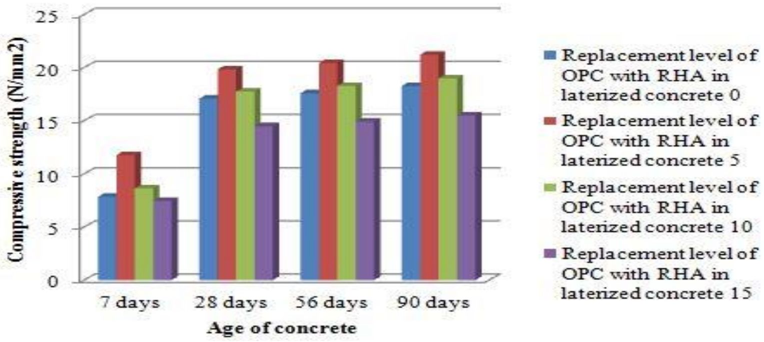

Fig. 9 Comparison of OPC/RHA laterized concrete compressive strength @ 40% laterite replacement

From Fig. 9, a decrease in strength is observed at 40%lat.RHA0% compared to the compressive strength obtained at 0%lat.RHA0% at all hydration ages. At 40%lat.RHA5%, there is an increase in the compressive strength when compared to the strength obtained at 0%lat.RHA5%. The strengths obtained at 40%lat.RHA5% are the highest across all curing ages for mixes with 40% laterite replacement of sand. At 40% laterite replacement, there was a reduction in compressive strength commencing at 40% lat.RHA10 %.

In general, the compressive strength is reduced as the amount of ordinary Portland cement and sharp sand in the mix decreases. At 10%, 20%, 30%, and 40% laterite replacement of sand, the compressive strength is observed to decrease as the RHA percentage increases, indicating that as the RHA percentage increases, the compressive strength decreases.

Finally, for each percentage of RHA replacement, the compressive strength improved as the number of days of curing increased.

4.7. Density

The results of the density test are shown in Table 6.

Table 6 Results of density test of hardened concrete (kg/m^3)

Laterite content (%)	Ash replacement (%)	Age of concrete at testing (days)	
		7	28
0	0	2370	2400
	5	2400	2450
	10	2459	2350
	15	2379	2320
10	0	2548	2726
	5	2320	2361
	10	2341	2361
	15	2252	2302
20	0	2370	2459
	5	2409	2400
	10	2213	2193
	15	2439	2350
30	0	2370	2281
	5	2290	2302
	10	2498	2450
	15	2290	2361
40	0	2104	2400
	5	2391	2533
	10	2311	2468
	15	2391	2341

The results in Table 6 showed that there is no meaningful change in the density of laterized concrete as the replacement level of OPC by RHA ranges from 0% to 15%. According to [11] pozzolans of biogenic origin do not adversely affect the density of concrete.

5. Conclusion

Rice husk ash (RHA) could be employed as a resource in cement matrix, with lateritic soil as a suitable fine aggregate replacement. It could be employed in low-cost construction, particularly in locations where these materials are prevalent. The following conclusions were drawn from the analysis of this research:

1) The chemical composition of rice husk ashes was found to meet the fundamental requirements for pozzolans, as recommended by appropriate Codes and Standards.
2) As the quantity of RHA replacement in OPC increased, the amount of water required to achieve the appropriate consistency increased.
3) The higher the replacement level of RHA, the lower the initial and final setting times of OPC/RHA mixes which could be as a result of the open burning method used to obtain the RHA. All the values obtained for the setting times are within the parameters established by the requisite standards.
4) Slump values decreased with increase in replacement level of OPC with RHA with or without the addition of superplasticizer.
5) The addition of superplasticizer (Conplast SP430) to laterized concrete without lowering the water content (i.e., with the same w/c ratio) resulted in a mixture with a higher slump.
6) The compressive strength decreased with increase in RHA content.

7) For each percentage of RHA replacement, compressive strengths improved as the number of days of curing increased.
8) For mixes without laterite, the compressive strength continuously decreased as the replacement level of OPC with RHA increased.
9) For all replacement levels of sand with laterite in this study, the compressive strength is highest for 5% replacement of OPC with RHA across all curing ages.
10) The density of RHA/OPC laterized concrete is similar to that of the control and is within the acceptable range for normal weight concrete.

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UGRADLJIVOST I PRITISNA ČVRSTOĆA BETONA KOJI SADRŽE DVOKOMPONENTNE CEMENTE, POMEŠANE SITNE ČESTICE I SUPERPLASTIFIKATORE

Rastuća svest o uticaju zgrada na životnu sredinu rezultirala je potrebom za ekološki prihvatljivijim zgradama od jeftinih ali dugotrajnih građevinskih materijala. Ovde su prikazani eksperimentalni nalazi o ugradljivosti i kvalitetu čvrstoće betona dobijenog delimičnom zamenom peska lateritnim zemljištem u različitim procentima zamene cementa pepelom od pirinčane ljuske (RHA) do 15%. Urađena je hemijska analiza RHA i lateritnog zemljišta, kao i konzistencije i vremena vezivanja OPC i OPC/ RHA paste. Utvrđeno je da su svi u granicama određenim odgovarajućim standardima. Vrednosti sleganja svih betonskih mešavina se smanjuju sa povećanjem nivoa zamene cementa pepelom od pirinčane ljuske (RHA), sa superplastifikatorom ili bez njega. Međutim, kod smeša bez superplastifikatora, do 10% zamene cementa sa RHA, opadanje se povećava sa povećanjem zamene peska lateritom do 20% i počinje da varira za nivoe laterita preko 20%. Za mešavine sa superplastifikatorom, opadanje je poraslo za nivoe laterita do 10% i posle toga je došlo do fluktuacije. Rezultati su takođe otkrili da je kod svih starosti betona i za sve ispitivane nivoe zamene peska lateritom, pritisna čvrstoća betona dostigla najveću vrednost na 95% OPC sa 5% RHA. Štaviše, ova najveća vrednost čvrstoće na pritisak je suštinski ista kao kod 0% RHA sa 0% lateritnog referentnog betona. Nalazi ovog istraživanja će biti od koristi stručnjacima za beton koji su zainteresovani za primenu laterita i RHA kako bi se postigli efekti zelene gradnje, održivost i isplativost betona.

Ključne reči: *obični portland cement, dopunski cementni materijal, pucolani, laterizovani beton, pepeo od pirinčane ljuske, superplastifikator, opadanje*