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Effects of Partial Replacement of Normal Aggregates with Lateritic Stone in Concrete

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ABSTRACT: Lateritic stones abound in the tropical and semi tropical areas of the world more than the igneous and other standard rocks that are used as concrete aggregates and road chippings. The increasing utilization of natural aggregate for concrete production have created negative impact on the environment. Therefore searching for alternative material which has potential to replace the use of coarse aggregate from normalrocks in concrete mix either wholly or partially is very much in need. This research presents the engineering properties of concrete containing lateritic aggregate as partial coarse aggregate replacement. The coarse aggregate was replaced by 10, 20, 30, 40 and 50% with lateritic aggregate. All the specimens were cured and compressive strength test were carried out at the age of 7, 14, 21 and 28 days respectively. The result revealed that replacement of lateritic aggregate up to 30% was able to produce lateritic concrete exhibiting the target strength which is 30 N/mm$^{2.}$ However, the slump decreases as the percentage of lateritic aggregate in the mix increases, this may be due to the porosity of the lateritic aggregate due to absorption of the water in the mix. The result of the two way analysis of variance shows that both lateritic aggregate and curing age (days) has significant effects of the compressive strength of concrete.

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Concrete has replaced most of other competitive construction materials, because of its versatility, and easy availability. It is a material of choice by the architects and structural engineer with the belief that it is a durable material needing no maintenance and protection. By volume, the largest manufactured product in the world today is concrete. Construction in Nigeria uses mostly concrete because it is cheap and made using locally available material. Concrete is obtained by mixing cement materials, water and aggregate in required proportions. The mixture when placed in forms and allowed to cure hardens into rock like mass known as concrete. The hardening is caused by chemical reaction between water and cement and it continues for a long time, and consequently the concrete grows stronger with age. The hardened concrete may also be considered as an artificial stone in which the voids of larger particles are filled by the smaller particles, the voids off in aggregate are filled with cement hence the importance of using the right type and quality of aggregates cannot be over emphasized. The aggregate element in concrete comprises some 60–75% of the total volume. Aggregate inclusion in concrete reduces its drying shrinkage and improves many other properties. Aggregate is also the least expensive per weight unit, but it makes the most amount of the weight. The global consumption of aggregate is in the range of 8–12 billion (*Kumar et al 2012).* The aggregate itself is categorized as fine and coarse aggregate. Aggregates for concrete may be obtained from natural sources or may be artificially produced. Since concrete is the most important part in structural construction, the aggregate content should be in a form of good strength for structural purposes. Naturally aggregates have a pronounced influence on the properties of fresh as well as hardened concrete.The most common types of aggregate generally used for making concrete in Nigeria are crushed granite. Production of granite aggregates required skills and labor in order to crush it from boulder into small size aggregates. Extensive use of granite aggregates in construction will eventually run out Nigeria's granite supply and might lead to increase in granite aggregates price (*Hainin et al 2012).* Therefore, Suitable material should be found to replace the use of granite aggregates, to prevent this problem.The availability of laterite aggregate has initiated research to investigate the possibility of using this material as partial coarse aggregate replacement in concrete production. The aim of this study is to know the effects of partial replacement of coarse aggregate with lateritic stone in concrete production, and a suitable percentage that can replace it.

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MATERIALS AND METHODS

*Cement:*The cement used is the Dangote Ordinary Portland cement grade 42.5R (OPC) brought from a local dealer at kabala west area of Kaduna State, Nigeria with properties conforming to (BS, 12 1971).

*Coarse Aggregate:*Coarse aggregate is gravel which has been crushed, washed and sieved. Coarse aggregates are particles greater than 4.75mm, but generally range between 9.5mm to 37.5mm in diameter. Gravels constitute the majority of coarse aggregate used in concrete with crushed stone making up most of the remainder. Secondary aggregates are materials which are the by-products of extractive operations and are derived from a very wide range of materials. The coarse aggregate used was machine crushed granite chippings obtained from kabala junction, Kaduna state.

*Lateritic Aggregates:*Laterite is a highly weathered material, rich in secondary oxides of iron, aluminium, or both, it is nearly void of bases and primary silicates, but it may contain large amounts of quartz and kaolinite, and it is either hard or capable of hardening on exposure to wetting and drying. A modern interpretation on laterite states that laterite are the products of intensive and long lasting tropical rock weathering which is intensified by high rainfall and elevated temperatures. The lateritic stone used is from Zokoriko village, Kudenda, Chikun Local Government area Kaduna State. Figure 1 showing the sourcing and sieving of Laterite aggregate

Fig 1: Showing (a) the sourcing of laterite aggregate from lateritic rock formation (b) sieving of laterite aggregate to be use as coarse aggregate

*Sand:*The fine aggregate used was river-bed sand passing 4.75mm sieve and falls within zone 2.It was free from deleterious substances such as clay, loam, dirt and any organic or chemical matter.

*Water:*Water to be used for the production of concrete must be free of suspended particles, inorganic salts, acids and alkalis, oil contamination and algae. Potable water is recommended for use in the production of concrete by (BS3148, 1980). Clean tap water at civil engineering laboratory Kaduna polytechnic free from contaminants either dissolved or in suspension was used to prepare the specimen cubes.

*Aggregate Impact Value:*This test was done to determine the aggregate impact value of coarse aggregates as per (BS:, Standard test for aggregate impact value test, 812 Part 112- 1990).

*Aggregate Crushing Value***:** This test helps to determine the aggregate crushing value of coarse aggregates are are carries out according to (BS:, Aggregate crushing value , 812 Part 110 - 1990).

*Mixing Proportioning for Lateritic concrete Cubes:*The term proportioning in this content refers to the estimation of different quantities of lateritic stone and cement as well as water required for the mix. Water/cement ratio adopted was 0.55; and mix ratio of 1:2:4 and the size of lateritic aggregate-concrete cube for the test was 100mm x 100mm x 100mm; Volume of lateritic concrete cube=$0.1\times0.1\times0.1= 0.001m^3$. The required quantities (as per mix proportion) of different ingredients were weighed and kept separately. The mixing procedures for making different grades of concrete as shown in Figure 2 are as follows: (i) First cement and sand were mixed thoroughly. (ii) Coarse aggregate was then added to the mix and mixed thoroughly until the mixture is of uniform color. (iii) The water is added and mixed thoroughly until the mix is uniform consistency

Fig 2: Showing (a) the mixing of concrete constituent (b) mixing of all constituent with water to form concrete

*Casting of Test Specimens:*Cube specimens (100×100×100mm) used in this study consist of two types of mixes namely plain concrete and laterite concrete. Initially, the plain concrete that act as control specimen were produced using 100% granite aggregate as coarse aggregate. After that, laterite concrete was prepared by integrating a range of laterite aggregate content as partial coarse aggregate replacement. The laterite aggregate replacement used is from 0% to 50% with 10% interval. All specimens were demolded after 24 hour before subjected to water curing for 28days prior to immersing them into water.Weighed quantities of coarse and fine aggregate and cement poured in steel tray and mixed thoroughly until the mixture is uniform. The measured quantity of water is added and mixed thoroughly until mix is uniformly consistent. The molds are first placed on table vibrator. The concrete is then poured into the molds and compacted using table vibrator. After the concreting and compaction the upper surfaces are finished smooth with mason's trowel and corresponding identification marks are labeled over the finished surface. It is worthwhile to note that the concreting operation is completed within 25 to 30 minutes from the instance of adding water to the dry mix. The molds are left undisturbed in the laboratory for a period of 24hours before demolding (see Figure 3). Similar procedure has been adopted for subsequent concreting and casting operation on the other day.

Fig 3: Production of Lateritic Concrete.

*Slump test:*Concrete slump test is to determine the workability or consistency of concrete mix prepared at the laboratory or the construction site during the progress of the work. Concrete slump test is carried out from batch to batch to check the uniform quality of concrete during construction. The slump test is the most simple workability test for concrete, involves low cost and provides immediate results. Due to this fact, it has been widely used for workability tests since 1922. The slump was carried out as per procedures mentioned in (BS:EN12350, Part 2 2000). Equipment for Concrete Slump Test: Mold for slump test, non-porous base plate, measuring scale, temping rod. The mold for the test is in the form of the frustum of a cone having height 30 cm, bottom diameter 20 cm and top diameter 10 cm. The tamping rod is of steel 16 mm diameter and 60cm long and rounded at one end. Figure 4 shows the sample of a slump test been carried out.

*Compressive Strength Test:*The most common of all tests is the compressive strength test since the desirable characteristics of concrete are qualitative related to its strength. The compression test was conducted on cubes at the age of 7days, 14days, 21 days and 28 days of curing respectively and conforming to (BS1881, Testing of Concrete , Part 116 - 1983). Cubes stored in water were tested immediately on removal from water in the damp condition.

Fig 4: Slump test been carried out

The surface water and grit was wiped off from the specimen. The actual dimensions and weight of the specimen was noted. The specimen was placed on the testing platform of the compression testing machine (see Figure 5) in such way the load was applied to the surface other than the top and bottom surface as cast. The load was applied without shock and increase until the resistance of the specimen to the increasing load broke down and no greater load was sustained. The total load applied at failure was recorded. The maximum load applied divided by its cross sectional area given the compressive strength. Averages of three specimens were taken, provided the individual variation was not more than ± 15 percent of the average.

Fig 5: Compressive strength testing machine

RESULTS AND DISCUSSION

*Presentation of Test Results on Aggregates:*The test results on aggregate (i.e. Laterite aggregate, Fine aggregate and coarse aggregate) are shown in Table 1. From the table the aggregate impact value for the laterite is 12.64 while that of the coarse aggregate is 16.56 which shows that laterite aggregate also have a high value of aggregate impact value. The crushing strength of the coarse aggregate on the other hand is almost two times that of laterite aggregate which shows that at higher percentage of aggregate replacement will eventually lead to reduction in compressive strength of the concrete. The specific gravity of the laterite aggregate and coarse aggregate are 3.8 and 2.89 respectively while the silt content of the fine aggregate is 1.84 %. The flakeness of laterite aggregate and coarse aggregate are 2 and 8 respectively.

Table 1: Test results on aggregate.

EngineeringProperties	Laterite Aggregate	Fine Aggregate	Coarse Aggregate
Aggregate ImpactValue	12.64	-	16.56
Aggregate Crushing Value	23.56	-	40.00
Specific Gravity	2.80	2.67	2.89
Silt Content (%)		1.84	-
Flakeness	2		8

*Concrete Workability:*Workability properties for the lateritic/coarse aggregate specimen were assessed through the slump tests. The results of the workability tests through the slump are presented in Table 2. From the results it is observed that slump value decreases with increase in the percentage replacement of coarse aggregate with laterite aggregate in the concrete mix. Similar trend was recorded by(*Afolayan et al 2017)*. It can however be seen that the slump decreased as the percentage of the laterite in the mix increased. This indicates that to make the concrete workable at this replacement a water-reducing agent such as a super plasticizer may have to be used *(Mannan et al 2001)*.

Table 2: Slump test

Laterite Replacement (%)	Slump (mm)
0	True slump/90
10	True slump/45
20	True slump/40
30	True slump/30
40	True slump/24
50	True slump/20

*Compressive strength:*Compressive strength test was conducted on the specimens to determine the influence of laterite aggregate as partial coarse aggregate replacement towards compressive strength of concrete. The variation of compressive strength with laterite aggreate replacement at varying curing period is shown in Figure 6.

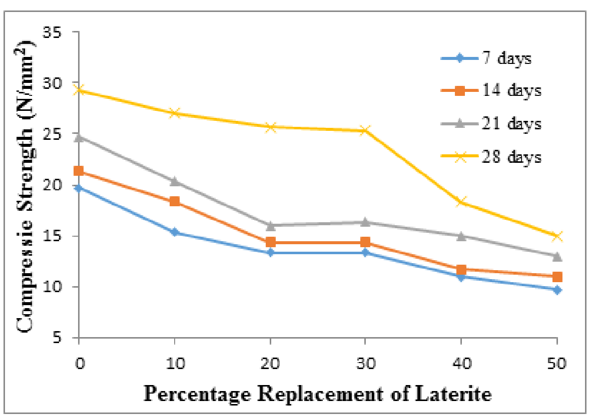

Fig 6: Variation of concrete compressive strength with Laterite aggregate replacement at varying curing age (days)

From the graph, it can be observed that the compressive strength of the specimen increased with the curing age at all the replacement levels. This is an indication of undisturbed strength forming hydration process. However the compressive strength decreased as the amount of laterite in the concrete increased. The effect of this is to progressively increase the total water-cement ratio as the percent replacement of coarse aggregates with laterite in the mix increased. The results revealed that replacement of laterite aggregate up to 30% is able to produce laterite concrete which met the requirements for use as structural lightweight concrete (ACI, 211.2 (2003)). which is between 21 – 35 N/mm^2 at 28 days curing age and also the targeted grade strength which is 25 N/mm^2.

However, replacement beyond 30% causes significant strength reduction. Addition of too much laterite aggregate results to lower density compared to granite which leads to lower strength. Substituting natural aggregates, at different replacement levels, by laterite aggregates definitely have influence on the mechanical behavior of the concrete.

This is probably due to variation in the physical characteristic of laterite aggregate compared to granite in term of denseness, surface texture and shape. Similar trend were recorded by (*Dewanshe et al 2006)*, (*A-Khalaf et al 1984)* ,(*Oyetola et al 2006)*, and (*Afolayan et al 2017)*.

*Two-way analysis of variance (ANOVA):*Two way analysis of variance tests was carried out to determine the level of significance of the lateritic aggregate on the compressive strength of the concrete and also the level of significance of the influence of curing age (days) on the compressive strength of the concrete. Table 3 shows the result of the two way analysis of variance

The two-way analysis of variance (ANOVA) for compressive strength of laterite aggregate cured at different curing age (see Table 3) shows that the effect of laterite aggregate and curing period (days) on the compressive strength of concrete were statistically significant (F_{CAL} = 30.41704> F_{CRIT} = 2.901295) for laterite aggregate and (F_{CAL} = 47.9253> F_{CRIT} = 3.28738) for curing age (days). The effect of curing age (days) was more pronounced than that of laterite aggregate.

Table 3: Two-way analysis of variance results for compressive strength of laterite aggregate at different curing age (days).

Summary	**Count**	**Sum**	**Average**	**Variance**		
0% Laterite Aggregate	4	95	23.75	18.16187		
10% Laterite Aggregate	4	80.99	20.2475	24.48723		
20% Laterite Aggregate	4	69.33	17.3325	32.10816		
30% Laterite Aggregate	4	69.32	17.33	30		
40% Laterite Aggregate	4	56	14	11.3926		
50% Laterite Aggregate	4	48.67	12.1675	5.438892		
7 Days Curing	6	82.33	13.72167	12.41994		
14 Days Curing	6	90.99	15.165	15.79623		
21 Days Curing	6	105.33	17.555	17.90371		
28 Days Curing	6	140.66	23.44333	30.65127		
ANOVA						
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Laterite Aggregate	349.3952	5	69.87905	30.41704	2.42E-07	2.901295
Curing Age (Days)	330.3057	3	110.1019	47.9253	6.41E-08	3.287382
Error	34.46048	15	2.297365			
Total	714.1615	23				

*Conclusion***:** The replacement of normal aggregate with lateritic aggregate has influence on engineering properties of concrete. The study discovered that replacement of 10% lateritic aggregate can produce lateritic concrete exhibiting comparable strength with normal concrete. However, replacement of lateritic aggregate up to 30% was able to produce lateritic concrete exhibiting the targeted strength of 25 N/mm^2. The use of lateritic as partial replacement of coarse aggregates in the concrete resulted in specimens with reduced workability, the workability reduced with increasing addition of lateritic aggregate in the mix. This is significant especially as the capacity of the concrete (from such mix) to develop adequate compressive strength may have been inhibited. It is possible that some of the mixing water necessary to sustain the strength forming hydration process may have been entrapped or absorbed by the lateritic. The result of the two way analysis of variance also shows that lateritic aggregate and curing age (days) has significant effect on the compressive strength of concrete. From the result of this study it is recommended that 30% lateritic aggregate is adequate for partial replacement of coarse aggregate in concrete production for structural lightweight concrete.

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