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Study Of Crushed Doum Palm Shell As Partial Replacement Of Coarse Aggregate In Concrete

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Abstract: This paper highlights the effects of replacing crushed granite (CG) aggregate commonly used in concrete with crushed doum palm shell (CDPS) on the workability, strength and density of concrete. Physical and Mechanical properties of CG and CDPS were determined and compared. It was found that, CDPS has higher water absorption value compared to CG while CG had a reatively higher aggregate impact value and specific gravity compared to CDPS. Furthermore, the compressive strength, workability and density of concrete containing 0, 5,10, 15, 20 and 25% of CDPS as replacement to CG in concrete with a mix ratio 1:2:4 and a water/cement (w/c) ratio of 0.55 was studied. A total of ninety concrete cubes of sizes 150 x 150 x 150 mm^2 were casted, cured in water for 7,14 and 28 days after which compressive strengths and bulk densities of the cured cubes were determined. The result of the tests indicated that the compressive strength of concrete as well as the bulk density of concrete decreases as the percentage of the CDPS increases in the concrete mix. However, the workability of the concrete mix was found to increase up to a maximum value corresponding to 10% replacement of CG with CDPS after which it progressively decreased.

Index Terms— Bulk density, Crushed doum palm shells, Compressive strength, Concrete, Workability

1 Introduction

The high demand for concrete in construction industry has led to a gradual but continuous depletion of natural stone deposit such as the gravel and granite. Also, some environmental problems associated with the continuous usage of these stone deposits (non renewable resource) results in ecological imbalance in the environment hence, the need to explore alternative materials that could be used as a replacement to the conventional aggregates become necessary [1].

According to [2] and [3], between 70 to 80 percent of the total volume of concrete is occupied by aggregates. With this large proportion of the concrete occupied by aggregates, it is expected for aggregate to have a profound influence on the concrete properties and its general performance. Aggregates are therefore very essential in the production of concrete in that, it has significant influence in reducing moisture-related deformation like shrinkage of concrete. Furthermore, it tends to give concrete its volumetric stability.

In developed countries, the construction industries have identified the use of waste natural material as potential alternative to conventional aggregates by reducing the size of structural members. This has brought immense change in the development of high rise structures using Light Weight Concrete (LWC) [4]. Conversly, in developing countries, potentials of the use of LWC is yet to be fully explored. Considering the significant benefits associated with the concept of environmental sustainability, research in this field will prove to be of immense benefit especially in developing countries due to the large availability of agricultural residual materials. It, therefore becomes imperative to explore the possibility of using these residual materials for partial replacement of conventional aggregates (which are non renewable) in the production of concrete. This will in the long run, make concrete a sustainable and environmentally friendly construction material.

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Doum palm Shells being a hard and not easily degradable material, if crushed to the size of coarse aggregate can be a potential material for the replacement of coarse aggregate in concrtee. Doum palm Shell is a residual agricultural waste material sourced from Doum Palm Fruit gotten from Doum palm tree which is in relative abundance especially in northern Nigeria and is a vital socio-economic resource especially to agro-pastoralist. Little is documented in literature about the use CDPS for the purpose of partial replacement of coarse aggregate in concrete hence, the need to investigate so as to possibly integrate it as one of the components in concrete production thus opening a new horizon in agro-concrete research and at the same time offering alternative to preserve natural coarse aggregate for future use. This study thus, aims to investigate the performance of concrete in terms of workability bulk density and compressive strength upon addition of CDPS as a partial replacement material for coarse aggregate. In previous research works, various types of waste and agricultural residual materials have been investigated bassed on their potential to be used as coarse aggregate replacement material in concrete production such as crushed palmyra palm shell [4], perinwikle shell [6], crushed coconut shell [5], [7] and [16], stone dust and ceramic scrap [8], broken tiles [9], cockle shell [10], crushed animal bones [11], Sabbath stone [12], date palm [13], Demolished waste [14], crushed burnt bricks [15], expanded polystyrene beads [17].

2.0 MATERIALS AND METHODS

2.1 Materials

The materials used for the research work includes fine aggregate (river sand), CDPS samples, CG and the binding agent

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which is ordinary Portland cement.

2.2 Methods

The tests were conducted in accordance to the methods prescribrided in the BS codes. The stepwise procedures to the tests are as outlined below:

i. Specific gravity test was carried out in accordance with the procedure as outlined in [18].
ii. Particle size distribution analysis test was carried out in accordance with the procedure as outlined in [19].
iii. Aggregate water Absorption (AWA) test was conducted in accordance with the procedure as outlined in [20].
iv. Aggregate impact and crushing value test was carried out in accordance with the procedure as outlined in [21].
v. Concrete batching and mixing was conducted in accordance with the procedure as outlined in [22].
vi. Slump test aws carried out on the fresh concrete in accordance with the procedure as outlined in [23].

The concrete cube moulds were cleaned and oiled before each casting. A total of ninety (90) concrete cubes of 150mm x 150mm x 150mm were produced with mix ratio of 1:24.and w/c ratios of 0.55. De-molding of the cubes was done 24hours after casting. The de-moulded cubes were then transfered into the curing tank. The cubes were removed from the curing tank at the end of the 7th, 14th and 28th day and air-dried for at about 5 hours before testing. The partial replacement of CG with CDPS was in of percentages of 0%, 5%, 10%, 15%, 20%, and 25%. For each percentage, a total of five (5) cubes were cubes were casted.

3.0 RESULTS AND DISCUSSIONS

The specific gravity test result shows that the CG has a value of 2.87 whereas CDPS has a value of 1.40 as shown in Table3.1 below. This shows that CG is much denser than CDPS. This is in agreement to findings [4], [5], [7] and [16].

The Aggregate Impact Value (AIV) test result for CG and CDPS were found to be 15.20% and 12.25% respectively as given in table 3.1. The average impact values calculated falls within the acceptable limits as stated in [24] which prescribes a maximum value of 45% for aggregate to be used in concrete for non-wearing surfaces. In addition, it can be observed that the aggregate impact value for CDPS is lower than that of the CG which shows the aggregate to be of good absorbance to shock.The Aggregate Water Absorption test for CG and CDPS were found to be 0.93% and 32.10% respectively hence, CDPS has higher water absorption and this property is attributed to the porosity of its shell.

Table 3.1: Physical and Mechanical Properties of CDPS and CG

S/No	Physical and Mechanical Properties	CDPS	CG
1	Specific gravity	1.40	2.87
2	Aggregate WaterAbsorption (%)	32.10	0.93
3	Aggregate impact value (%)	12.25	15.20

The result of the sieve analysis (particle size distribution) for the coarse aggregate (CG) is presented in the figures 3.1 below. From figure 3.1, it can be seen that 100% of the CG passed through sieve 20mm while 79.2% was retained on sieve 13.20 mm which thus, categorizes it as coarse aggregate. While in figure 3.2, the sieve analysis (particle size distribution) for CDPS shows that 97.75% passed through sieve 20mm and 44.99% of CDPS was retained on sieve 13.20mm as can be seen from the figure below.

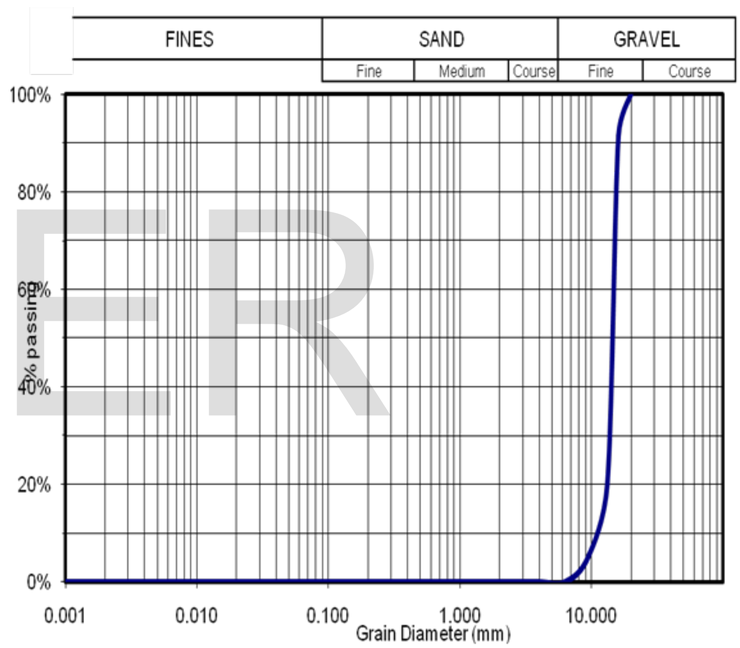

Figure 3.1: Particle size distribution for coarse aggregate (CG)

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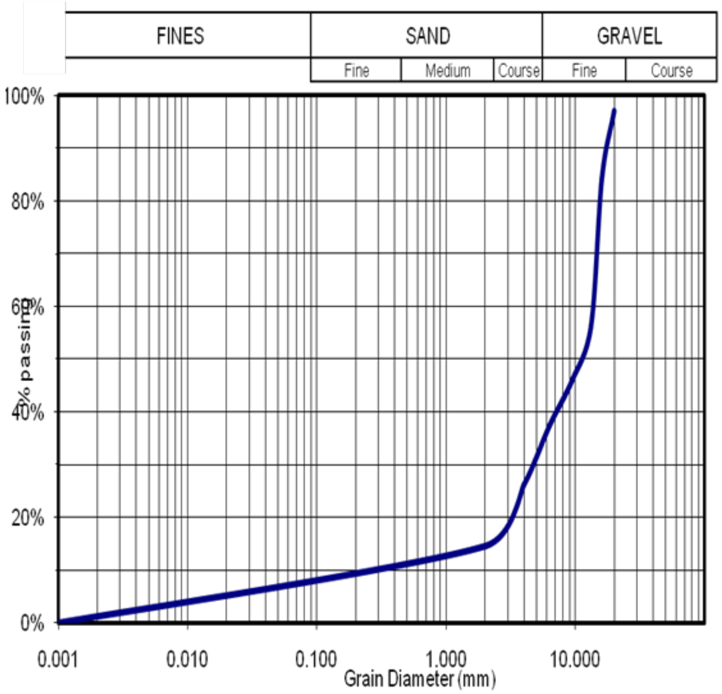

Figure 3.2: Particle size distribution for coarse aggregate (CDPS)

Table 3.2: Varying Percentages of CDPS in concrete in relation to Slump Height.

Mixed ratios of CDPS/CG CDPS : CG	Water/Cement Ratio	Slump (mm)
0% : 100%	0.55	30
5% : 95%	0.55	45
10% : 90%	0.55	49
15% : 85%	0.55	40
20% : 80%	0.55	35
25% : 75%	0.55	31

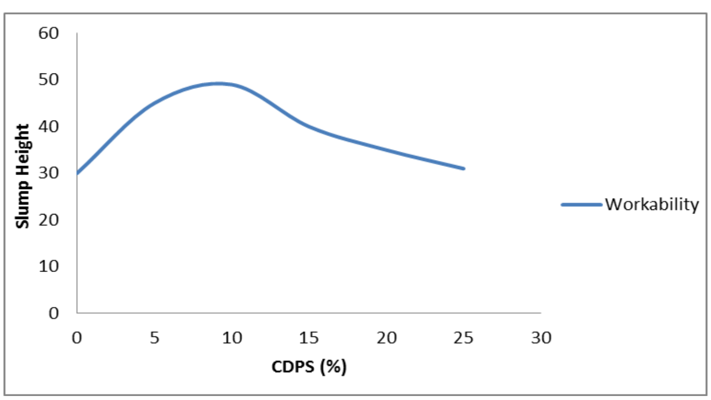

Figure 3.3: Graph of slump height against percentage of CDPS

The workability of concrete batches for different percentages of CDPS using slump test is shown in table 3.2 and represented in figure 3.3. The mix samples with constant w/c ratio of 0.55 exibited medium to high workability. It is obvious that the workability of concrete increased as the percentage of CDPS increased up to a maximum value of 49 mm at 10% replacement of CG with CDPS, where it shows a spike in workability, after which from that point, as the percentage of CDPS increases the workability reduces. This is in agreement with findings in [1], [4] and {25].

Table 3.3: Compressive Strength (MPa) of concrete at varying percentages of CDPS in concrete

Design Strength (MPa)	PPS content (%)	7 days (MPa)	14 day (MPa)	28 days (MPa)
	0	20.10	24.01	28.61
	5	15.45	17.17	19.36
25	10	13.36	15.85	18.15
	15	11.51	12.70	15.30
	20	9.62	11.22	13.01
	25	8.70	9.72	11.05

The results of the compressive strength are as shown in table 3.3. The effect of replacement of CG with CDPS on compressive strengths of the concrete cubes is as represented in Fig3 .4. It can be observed that the compressive strength of the concrete produced decreases as the percentage of the CDPS increases in the concrete mix. The strength is maximum at 0% replacement of CG with CDPS and minimum at 25% replacement. The 28-day strengths represented by 5 and 10% replacement of CG with CDPS satisfies the criteria for lightweight concrete [26].

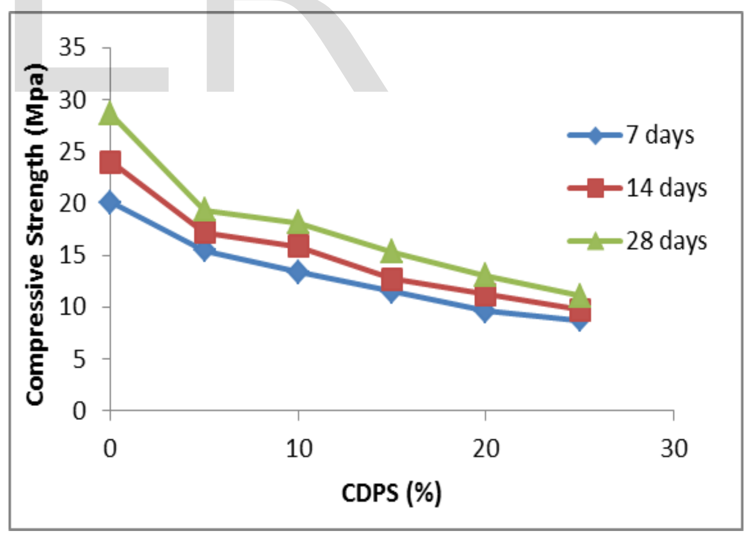

Figure 3.4: Graph of compressive strength against percentage of CDPS in concrete cubes

DENSITY:

Densities of the concrete cubes at varying percentage replacement of CG with CDPS are as given in table 3.4 and represented in Figure 3 5.

Table 3.4: Density of the concrete at varying percentages of

CDPS in concrete mix

CDPS content (%)	7 days (Kg/m³)	14 days (Kg/m³)	28 days (Kg/m³)
0	2623	2677	2791
5	2302	2398	2494
10	2174	2305	2393
15	2102	2246	2378
20	1992	2179	2261
25	1942	2145	2202

From figure 3.5, it can be observed that the density of concrete reduces as percentage content of CDPS increases. The minimum and maximum densities were obtained at 25 and 0% replacement of CG with CDPS respectively. The densities of all the concrete cubes casted within the range of 0-25% replacement of CG with CDPS in concrete at 28 days of curing was found to be above 2000 Kg/m³ thus, satisfying suitability requirement of its use for LWC purpose [26].

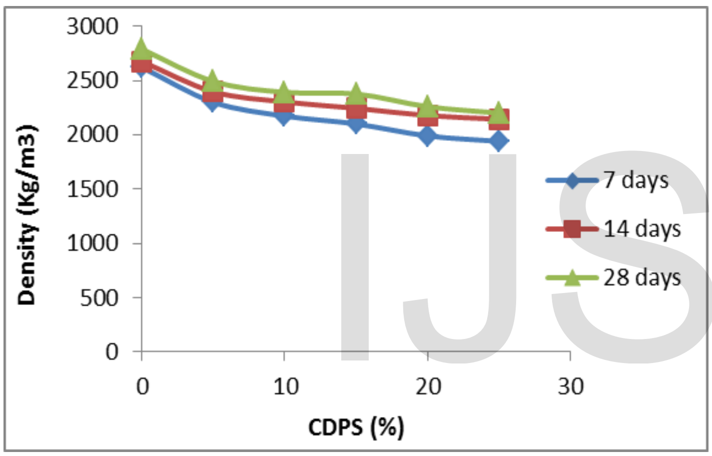

Figure 3.5: Graph of Density against percentage of doum palm shell in concrete cubes

4.0 CONCLUSIONS AND RECOMMENDATIONS

From the study, it is concluded that the 28-day compressive strength of the concrete produced using CDPS as replacement at 5, 10% replacement for CG produce concrete with a compressive strength above the minimum value required for LWC [26]. This is similar to the findings of obtained in [4] and [27]. Furthermore, 10% replacement of CG with CDPS produced a concrete mix with the highest value of workability of the concrete mix. Hence it can thus be concluded that at 10% replacement of CG with CDPS is the ideal percentage for the production of LWC using CDPS as a partial replacement to CG in concrete.

Based on the findings of this study, the following recommendations were drawn.

i. CDPS can be used as partial replacement of coarse aggregate for lightweight concrete for non structural members.

ii. It is recommended that admixtures be used for the purpose of improving the poisolanic property of the CDPS for its use as a partial replacement material for conventional coarse aggregates.

iii. Durability studies on CDPS as replacement to conventional coarse aggregate in concrete be carried out so as to assess its behavior in aggressive environments.

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