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# Exploratory Study of Date Seed as Coarse Aggregate in Concrete Production

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**Abstract:**

Coarse aggregates play an essential role in the resulting functional properties of concrete. However due to its high cost and scarcity in some areas in Nigeria, this paper investigated the suitability of Date Seed (DS) as partial or full replacement of Crushed Granite (CG) in concrete production. Physical and mechanical properties of DS and CG were determined and compared. Concrete mix design of ratios 1:2:4 and 1:3:6 were investigated. A total of 90 concrete cubes of size 150 × 150 ×150 $mm^3$ with different percentages by weight of CG to DS as coarse aggregate in the order 100:0, 75:25, 50:50, 25:75 and 0:100 were cast immersed in ordinary water for maximum of 28 days, tested to determine their compressive strengths. The compressive strength test carried out on the concrete specimens showed that all the percentage replacement of CG for DS exception of 100% was quite satisfactory with no compromise in compressive strength requirements for the two concrete mix ratios (1:2:4 and 1:3:6). The research concluded that DS can partially be used to replace CG in production of light weight concrete where it is abundantly available and can be recommended as an alternative material (partial replacement) to coarse aggregate.

**Keywords:** Date Seed, Concrete, Coarse Aggregate and Exploratory.

## 1 Introduction

Provision of housing for developing countries is one of the most important basic needs of the low-income groups. It is a very difficult requirement to meet because the two main conventional or classical construction materials (concrete and steel) are imported and their prices are considerably beyond the reach of the average (low-income group). According to Neville and Brooks (2002), concrete being relatively cheaper is the most widely used these days and as such, efforts have been made by many researchers to reduce the cost of its production. This is achieved by reducing the cost of coarse aggregate and cement since concrete basic constituents are cement, fine aggregate (sand), coarse aggregate (granite chippings) and water. Hence, the overall cost of concrete production depends largely on the availability of these constituents. Fine aggregates are readily available and the cost of cement can be reduced through the use of agro-industrial waste or pozzolanas as observed by Dashan and Kamang (1999); Elinwa and Mahmood (2002); Oyetola and Abdullahi (2006); Dahiru and Zubairu (2008). However, the cost of concrete is directly proportional to the cost of crushed stones or local gravels thus, alternatives lightweight materials are adopted for non-load bearing walls and non-structural floors in buildings. Some of these alternative materials include Palm Kernel Shell, Olive Seed and Periwinkle Shell which can be used to fully or partially replace coarse aggregate in concrete production (Ndoke 2006; Okpala 1990; Ekainu 1991; Falade 1995 and Job 1994).

Ndoke (2006) assessed the performance of palm kernel shells as partial replacement of coarse aggregate in asphalt concrete, while Falade (1992) investigated the suitability of Palm Kernel shells as aggregates in light and dense concrete for structural and non-structural purposes. For instance, Sludge from water treatment, industrial and domestic waste water has been found very suitable as partial economic replacement for cement in concrete works (Adewuyi and Ola, 2005) so also in the production of building bricks (Slim and Wakefield, 1991). Other similar efforts in the direction of waste management strategies as coarse aggregate in concrete production include structural performance of concrete using Olive Seed (OS) as lightweight aggregate (Okpala 1990). Work carried out by Job in 1991 on the properties of concrete produced with Periwinkle Shell (PS) revealed that PS is a light weight material which can be used to produce lightweight aggregate concrete.

Other similar efforts in the direction of waste management strategies include structural performance of concrete using Oil Palm Shell (OPS) as lightweight aggregate (Nimityongskul and Daladar, 1995), Topcu and Canbaz (2007) investigated the use of Crushed Tiles as Aggregate in concrete production while Zekar (2012) carried out similar work to that of Topcus and Canbaz with the use of Broken Pieces of Glass as coarse aggregate.

As part of contribution to the on going research in utilization of waste as solution to the high cost of construction materials, this research was carried out on Date Seed (DS) to investigate its suitability as light weight aggregate material in concrete production since little or no work exists on it. DS is obtained from date palm (Phoenix dactylifera), tree of the palm family (Arecaceae or Palmae) which can be found in Canary Islands, northern Africa, the Middle East, Pakistan, India, and the U.S. State of California. The date palm grows about 23 metres (75 feet) tall. Its stem is strongly marked with the pruned stubs of old leaf bases, terminates in a crown of graceful, shining, pinnate leaves about 5 metres (16 feet) long. Male and female flowers are borne on separate plants. Under cultivation the female flowers are artificially pollinated. The date is a one-seeded fruit or berry usually oblong but varying much in shape, size, colour, quality, and consistency of flesh, according to the conditions of culture. More than 1,000 dates may appear on a single bunch weighing 8 kg (18 pounds) or more. The dried fruit is more than 50 percent sugar by weight and contains about 2 percent each of protein, fat, and mineral matter. Date is highly cultivated for animals and human consumptions (Date Palm Encyclopaedia, 1976). After consumption, the seeds (DS) served as nothing but contribute as wastes and littered the whole environments.

Despite the availability of DS in the world and Nigeria especially with a lot of established research findings on the suitability of many of the aforementioned agricultural wastes as alternative material in concrete production little or no effort has been made toward the utilization of DS. The use of DS in concrete production will not only reduce the problem of Agricultural wastes in the societies but will greatly reduce the cost of concrete production. It is in the light of this that this research exploratory studied the suitability of DS when used as coarse aggregate in concrete production.

### *1.1 Research Hypothesis*

i Is DS in question possess the required properties of CG.
ii What effect would each percentage replacement of CG with DS has on the compressive strength of the hardened concrete.
iii To what extend would DS lead to reduction in cost of concrete.

## 2 Materials and Methods

### *2.1 Materials*

The materials used for the research were obtained within Birnin Kebbi in Kebbi State. Ordinary Portland Cement (OPC (Dangote brand)) was used for the experiment, the fine aggregate (sharp sand) used was obtained from a flowing river. It was dried for some days in the laboratory and then sieved to be free from deleterious materials. Crushed granite was purchased from a quarry site and DS was obtained in sufficient quantities within Birnin Kebbi Town, The DS was collected in beat and sun dried for a period of about two months until the required quantity for the research was obtained. It was dried in the sun to reduce the moisture content. Ordinary clean tap water free for drinking was used for the experiment.

### *2.1 Mix Proportions and Casting of Concrete Cubes*

Batching operation by volume approach was adopted in the study. Preliminary mixes of 1:2:4 (cement: fine sand: coarse aggregate or Date Seed or coarse aggregate/Date Seed) and 1:3:6 were investigated with water/cement ratio of 0.55, 0.60, 0.65 and 0.70 respectively so as to obtain the required w/c ratio for the actual mixes. W/c ratio of 0.6 was adopted for 1:2:4 mix and 0.65 for 1:3:6. Concrete mixes were properly mixed in a machine mixer for about six to eight minute and then cast into 150 × 150 × 150 $mm^3$ size concrete moulds. The moulds were assembled prior to mixing and properly lubricated for easy removal of hardened concrete cubes. Concrete cubes were prepared in percentage by weight of crushed granite to DS as coarse aggregate in the order 100:0, 75:25, 50:50, 25:75 and 0:100 ranging from zero to full replacement for crushed granite by DS. Specimens were made in accordance with BS 1881: (1985) specifications. A total of ninety (90) concrete specimens were produced and used for the actual mix design for the two concrete mix ratios. The specimens produced were cured in ordinary water by complete immersion method and tested for strength at 14, 21 and 28 days. At each testing period, specimens were weighed before testing and the densities of cubes at different time of testing were measured. Prior to testing, the specimens were brought out of the water, left outside in the open air for about 2 hours before crushing. The compressive strengths of the cubes were tested in accordance to BS 1881: (1983) specifications with the use of universal testing machine.

## 3 Results and Discussion

### *3.1 Physical Properties of Materials Used for the Research*

Table 1: Physical Properties of DS, CG and River Sand

| S/No | Properties | Sample type and descriptions | | |
|---|---|---|---|---|
| | | DS | CG | River sand |
| 1 | Specific Gravity | 1.39 | 2.66 | 2.56 |
| 2 | Compacted Bulk Density (kg/m$^3$) | 526 | 1486 | 1680 |
| 3 | Loose Bulk Density (kg/m$^3$) | 462 | 1274 | 1458 |
| 4 | Water Absorption (%) | 8.10 | 0.60 | 0.40 |
| 5 | Moisture Content (%) | 23 | 0.32 | 0.06 |
| 6 | Porosity (%) | 19.5 | 0.80 | 0.04 |
| 7 | Impact Value (%) | 22 | 13 | _ |

The Bulk Density test carried out on the samples of material used for the research was in accordance with the provisions of BS 812: Part 2: (1975). The results are shown in Table 1. The ratio of the loose bulk density to the compacted bulk density of DS was 0.88. This value is between 0.87 and 0.96 specified by the code as reported by Neville and Brooks (2002).The specific gravity of the materials was determined in accordance with the requirement of BS 812: Part 2: (1975).The specific gravity of DS was observed to be 1.39. This is less than the values recorded by Neville and Brooks (2002) for natural aggregate which is between 2.6 to 2.7. The water absorption of the materials was carried out in accordance to the provision of BS 812: Part 2: (1975) and DS water absorption was observed to be 8.10. The value obtained is similar to the value obtained by Achuanu et.al (2005) and Job (2008) on periwinkle shell which was found to be 7.18 and 12.8 % respectively. Porosity is the volume occupied by void to the volume of the material. It is usually expressed in percentage (Neville 1981). The porosity of DS was found to be 19.5%. The value obtained was excessively higher than that of CG used for the research. The impact values of materials sample was carried out in accordance with the provision of BS 812 Part 110 (1990) and was obtained to be 22% for DS and 13% for CG respectively. The test is needed when dealing with aggregate of unknown performance (Neville and Brooks, 2002).

### *3.2 Workability Test*

Table 2: Workability of the Pastes (1:2:4 Mix Ratio)

| S/No | Paste Sample (CG:DS) | W/c Ratio | Degree of workability | |
|---|---|---|---|---|
| | | | Slump (mm) | Compacting factor |
| 1 | 100:0 | 0.6 | 5 | 0.76 |
| 2 | 75:25 | 0.6 | 6 | 0.75 |
| 3 | 50:50 | 0.6 | 6 | 0.75 |
| 4 | 25:75 | 0.6 | 7 | 0.74 |
| 5 | 0:100 | 0.6 | 8 | 0.72 |

Table 3: Workability of the Pastes (1:3:6 Mix Ratio)

| S/No | Paste Sample (CG:DS) | W/c Ratio | Degree of workability | |
|---|---|---|---|---|
| | | | Slump (mm) | Compacting factor |
| 1 | 100:0 | 0.65 | 6 | 0.76 |
| 2 | 75:25 | 0.65 | 7 | 0.76 |
| 3 | 50:50 | 0.65 | 7 | 0.75 |
| 4 | 25:75 | 0.65 | 7 | 0.75 |
| 5 | 0:100 | 0.65 | 9 | 0.73 |

There was no significant different in the workability tests carried out on all the pasts for the two mix ratios (1:2:4 and 1:3:6). The workability tests on each sample show that the slumps for all the pastes were within the range of 5-9 mm which indicates low workability (ASTM 1881: Part 2:1970).The result of the compacting factor test on all the pastes ranges from 0.72 to 0.76 which also indicates low workability (Orchard, 1973).The compacting factor test on all the pastes for the two mix is close to the range of 0.85 – 0.92 recommended by Orchard (1973) for roads and slabs concretes.

3.3 Compressive Strength and Density Tests

Table 4: Average Compressive Strengths and Densities of Specimens in Ordinary Water at 14, 21 and 28 Days (1:2:4 mix at 0.6 w/c ratio)

| Specimens CG:DS | Compressive strengths ($N/mm^2$) Days | | | Average density ($Kg/m^3$) Days | | |
|---|---|---|---|---|---|---|
| | 14 | 21 | 28 | 14 | 21 | 28 |
| 100:0 | 14.00 | 20.70 | 25.80 | 2440.38 | 2450.52 | 2496.88 |
| 75:25 | 13.30 | 18.80 | 23.44 | 2410.45 | 2418.00 | 2461.28 |
| 50:50 | 11.30 | 16.90 | 21.68 | 2400.88 | 2408.00 | 2426.66 |
| 25:75 | 10.00 | 15.68 | 20.50 | 2340.78 | 2348.45 | 2391.46 |
| 0:100 | 08.80 | 12.00 | 16.00 | 2310.75 | 2340.98 | 2390.38 |

Table 5: Average Compressive Strengths of Specimens in Ordinary Water at 14, 21 and 28 Days (1:3:6 mix at 0.65 w/c ratio)

| Specimens CG:DS | Compressive strengths ($N/mm^2$) Days | | | Average density ($Kg/m^3$) Days | | |
|---|---|---|---|---|---|---|
| | 14 | 21 | 28 | 14 | 21 | 28 |
| 100:0 | 11.84 | 14.56 | 16.78 | 2446.38 | 2439.51 | 2496.86 |
| 75:25 | 11.00 | 12.50 | 14.40 | 2418.45 | 2426.00 | 2464.29 |
| 50:50 | 08.86 | 10.60 | 12.68 | 2404.88 | 2408.00 | 2426.88 |
| 25:75 | 07.00 | 09.00 | 10.80 | 2350.98 | 2348.86 | 2393.46 |
| 0:100 | 06.00 | 08.10 | 09.00 | 2337.76 | 2328.98 | 2358.98 |

The densities of the two specimens (1:2:3 and 1:3:6 concrete mixes) decrease with increase in percentage replacement of CG for DS. This was so because DS is lighter than CG and as more quantity of CG is being replaced with DS, the higher the reduction in density of the concrete produced. The densities of all the specimens in ordinary water at 28 days are within the range recommended for normal weight concrete which is between 2355 to 2560 kg/m$^3$ (Everett,1990). The compressive strengths of concrete specimens for different percentages of DS are shown in Table 4 and 5 for concrete mix ratio 1:2:4 and 1:3:6 respectively. For each mix, significant reduction in strength was observed between the mix with 100% CG and the one with partial or full replacement of DS. The reduction in strength increased as more quantity of CG is being replaced with DS. Concrete produced with 100% DS (mix ratio 1:2:3) did not attain the minimum compressive strength recommended by BS 8110 (1995) for structural concrete of mix ratio 1:2:4 at 28 days which is between 20-40 N/mm$^2$. The compressive strength of 100% DS concrete (1:3:6 mix ratio) was far less than 15 N/mm$^2$ recommended by BS 8110 (1995) for structural concrete of mix ratio 1:3:6 at 28 days.

### *3.4 Percentage Lost in Strength of DS Concretes at 28 days*

Table 6: Percentage Lost in Strength of DS Concretes at 28 days (Mix Ratio 1:2:3)

| Specimens CG:DS | Compressive strengths (N/mm$^2$) at 28 Days | Percentage Lost in Strength (%) at 28 Days |
|---|---|---|
| 100:0 | 25.80 | 0.00 |
| 75:25 | 23.44 | 09.15 |
| 50:50 | 21.68 | 15.97 |
| 25:75 | 20.50 | 20.54 |
| 0:100 | 16.00 | 37.98 |

Table 7: Percentage Lost in Strength of DS Concretes at 28 days (Mix Ratio 1:3:6)

| Specimens CG:DS | Compressive strengths (N/mm$^2$) at 28 Days | Percentage Lost in Strength (%) at 28 Days |
|---|---|---|
| 100:0 | 16.78 | 0.00 |
| 75:25 | 14.40 | 14.18 |
| 50:50 | 12.68 | 24.43 |
| 25:75 | 10.80 | 35.64 |
| 0:100 | 09.00 | 46.36 |

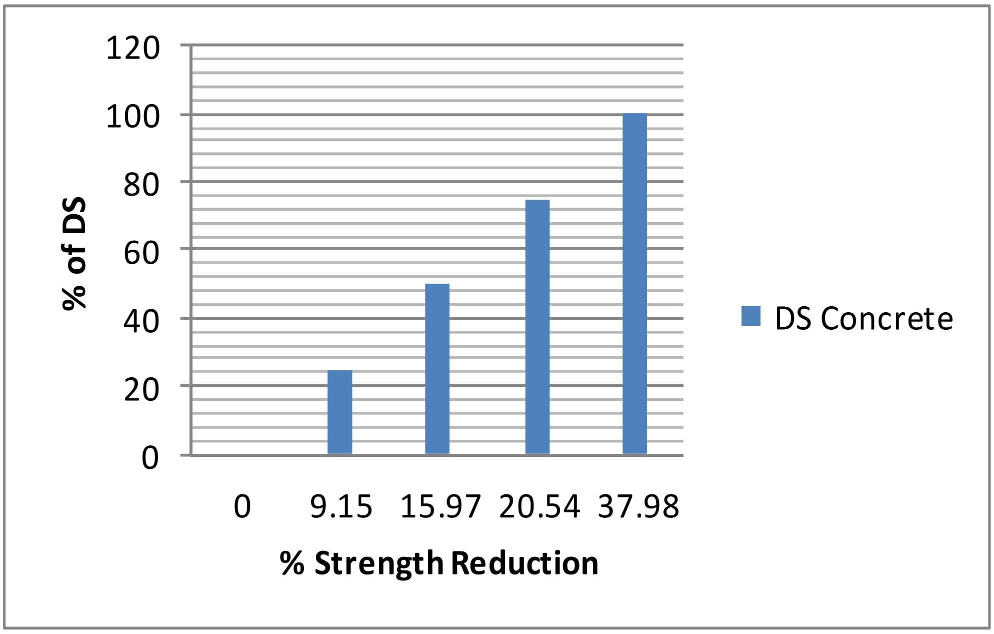


Figure 1: Percentage Lost in Strength Variation with Different % of DS as Coarse Aggregate for Mix Ratio 1:2:3

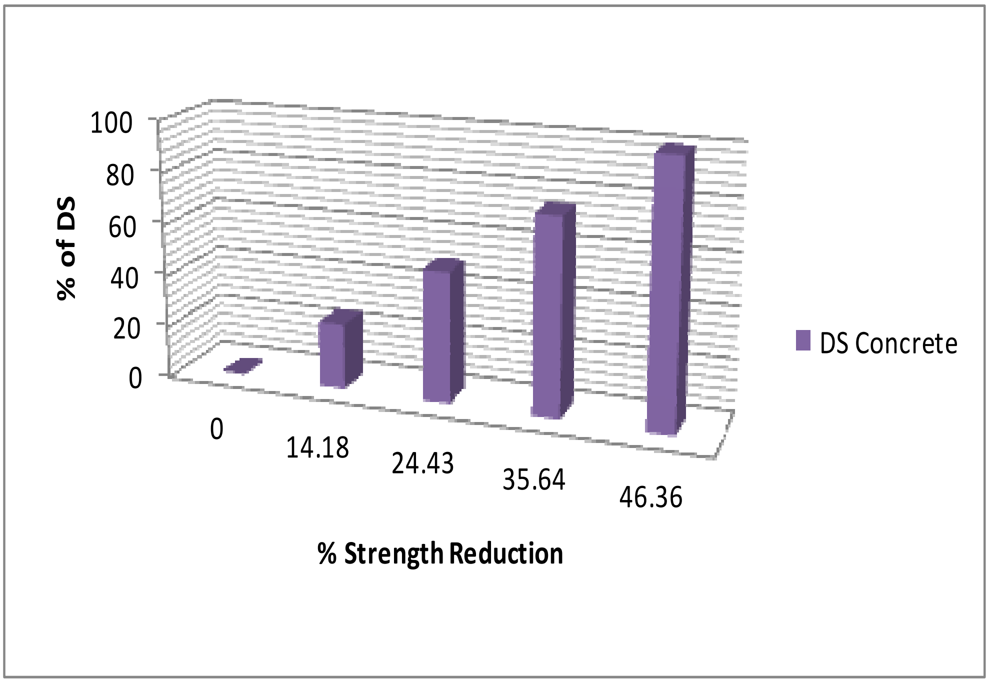


Figure 2: Percentage Lost in Strength Variation with Different % of DS as Coarse Aggregate for Mix Ratio 1:3:6

Table 6,7 and Figure 1 and 2 show the percentage reduction in strength of DS concretes for all the percentage replacement level of CG for DS in the two mix ratios (1:2:3 and 1:3:6). It was observed that the percentage reduction in strength of mix ratio 1:3:6 was higher than that of 1:2:3 at all level. It was also observed that the percentage reduction in strength of DS concrete was not much at 25% replacement (75:25) while compared to that of full replacement (0:100) in the two mix ratios as can be seen in the tables. Replacing CG with DS (75% (25:75)) will only lead to 20.54 % strength reduction at 28 days for mix ratio 1:2:3 which are highly satisfactorily for non load bearing structural construction.

## 4 Conclusions

DS has physical properties such as specific gravity, bulk density and absorption capacity far less in values to that of CG. DS concretes with mix ratio 1:2:3 attained the requirement of BS 8110 (1995) for structural concrete at 28 days exception of 100% replacement. All the Concrete produced with DS can be regarded as normal weight concrete. Replacing CG with 100% of DS could lead to 37.98% strength reduction for mix ratio 1:2:4 and 46.36 therefore, concrete produced with DS should not be fully but partially replaced of CG if adequate compressive strength is to be obtained at 28 days.

### *4.1 Recommendations*

DS is recommended as alternative material (partial replacement) to CG in production of light weight concrete but the concrete produced should not be fully but partially replaced of CG, hence, 25, 50 and 75% replacements are recommended. Further studies should be carried out to determine the durability of DS concrete in certain aggressive environments such as fire and chemicals.

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