DURABILITY CHARACTERISTICS OF CONCRETE PRODUCED WITH DATE SEED AS LIGHT WEIGHT AGGREGATE

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In conventional concrete production, coarse aggregate (crushed granite) plays an essential role in the resulting functional properties of concrete. However due to the high cost of coarse aggregate and its scarcity in some areas in Nigeria, this research investigated the suitability of Date Seeds (DS) as light weight aggregate in concrete production. This was achieved by producing lightweight concrete using cement, sand (fine aggregate) and DS (coarse aggregate) in the ratio 1:2:4. Samples of concrete with Crushed Granite (CG) as coarse aggregate were equally produced and served as control. For the purpose of the research, (15) concrete cubes were produced with DS and 15 concrete cubes with crushed granite. Water- cement ratio of 0.6 was used for the two specimens. The concretes produced (6) from each specimen were immersed in chemical concentrated solutions of 5% Magnesium Sulphate ($MgSO_4$) and 5% Sulphuric Acid (H_2SO_4) for 28 days. The remaining concrete Specimens (9) from each specimen were equally immersed in ordinary water for 28, 56 and 84 days. Specimens in chemicals were crushed at 28 days while those in ordinary water were crushed at 28, 56 and 84 days curing periods. At 28 days, there was a significant difference in the damaging effects of $MgSO_4$ on DS concrete when compared with that of CG concrete. Increase in strength was observed in DS concrete at 56 and 84 days in ordinary water. The research concluded that DS can be used as an alternative material to Crushed Granite (CG) in production of lightweight concrete in an area where there is scarcity of CG. The research recommended that DS concrete should not be exposed to sulphates having concentration close to 5% or more.

Keywords: aggregate, concrete, characteristic, date seed, durability

INTRODUCTION

Shelter is one of the most important needs, in fact second to food in every human being. Yet, housing remains one of the crucial problems of our time. The World Book Encyclopaedia (1976) claimed that one-quarter of the world population live in nondurable dwellings while some 100 million are homeless. Although acute shortage of housing has long been recognised by the government since independence in 1960, yet housing situation today is still characterised by a lot of problems. According to Oluremi (1990), one of these problems is the high cost of conventional or classical building materials. The costs of conventional or classical building material are

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considerably beyond the capacity of average Nigeria. In an attempt to stem the over dependence on conventional building materials, it was discovered that efforts have to be directed towards the local sourcing of alternative building material.

Neville (1983) opined that concrete is the most widely used construction materials 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 aggregate which is the most expensive constituent's part of the concrete. One of the ways of reducing the aggregate cost is by partially replacing it with some cheaper materials. Numerous works have been conducted by many researchers to study how possible construction materials can be developed from locally alternative materials, agro-industrial waste or by-products which are abundantly available. Some of these researchers are: Okpala (1990); Ekainu (1991); Achuenu *et. al* (2005) and Job (1994). Ndoke (2006) and Okpala (1990) assessed the performance of palm kernel shells as a partial replacement for 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. Adewuyi and Adegoke (2008); *Achuenu et. al* (2005) and Job (1994) investigated the performance of periwinkle shell as coarse aggregate in concrete production. Ekainu (1991) carried out work on the properties of concrete produced with Olive Seed (OS) and his work revealed that OS is a light weight material which can be used to produce lightweight aggregate concrete. As part of the 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.

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. Floral spikes branch from the axils of leaves that emerged the previous year. 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. Dates are small, sweet fruits that grow in large bunch on date palm trees. Dried dates have a very high amount of sugar-at least half of their total weight. They are highly cultivated for animals and human consumptions (Date Palm Encyclopaedia, 1976).

Information is lacking as to the estimated quantity of this material, however personal visit by the researcher to some northern parts of the country such as Sokoto, Zamfara and Kebbi States revealed that large quantity of Date is available in the areas for human consumptions. After consumption, the seeds (DS) served as nothing but contribute as wastes and littered the whole environments. It was against this background that research was carried out on DS material if it would find an application in building construction which might contribute immensely to housing delivery, most especially in the areas where it is abundantly available and consequently, reduce the wastes in the societies.

As opined by Neville and Brooke 2002, one of the several methods of testing the durability of Ordinary Portland Cement (OPC) concrete is by determine its resistance to sulphates attack. Sulphates are one of the major compounds that affect the durability of concrete. They cause cracks, deterioration and crumbling of infrastructure in concrete. Sulphate is present in the soil, ground water and sea water. When concrete comes in contact with sulphate, it reacts with both Ca $(OH)_2$ and C_3A present in cement to form $CaSO_4$ and $3CaO.Al_2O_3.3CaSO_4.32H_2O$ (Calcium Sulfoaluminate) known as enttringite. These compounds occupy greater volume than the compounds which they replaced thereby, causing expansion of hardened concrete. The consequence of sulphates attack includes not only the disruptive expansion and cracking, but also loss of strength of concrete due to cohesion in the hydrated cement paste and of adhesion between it and the aggregate particles. The extent of sulphate attack on concrete is a function of the concentration of the sulphate and the permeability of the concrete specimen. The commonest sulphates present in the soil, ground water and sea water are Na_2SO_4 and $MgSO_4$. Saturated solution of $MgSO_4$ leads to serious deterioration of concrete (Neville and Brooks, 2002).

Work carried out by Job 2008 on durability of light weight concrete revealed that the percentage concentration of most sulphates in the soil is in the range of 0.34 to 1.59. Furthermore, ASTM C 1012 recommends 5% sulphate concentration to carry out concrete chemical attack test in the laboratory. In the light of the above, this research investigated the durability of concrete produced with DS as lightweight aggregate if exposed to chemical solutions of 5% $MgSO_4$ and 5% H_2SO_4 at 28 days

MATERIALS AND METHODS

Materials

The materials used for the research work are: cement (Dangote brand which was used for the research due to it availability in the studied area), naturally occurring clean river sand (fine aggregate), Crushed Granite (CG) which was obtained from a single quarry site in Birnin Kebbi, Kebbi State, Date Seeds sourced within Birnin Kebbi Town, ordinary water, $MgSO_4$ and H_2SO_4.

Methods

The research started in the laboratory by determining some of the physical properties of DS and CG. Properties such as bulk density, specific gravity, water absorption, porosity, crushing value, impact value and workability were thus investigated. Two concrete design mixes in ratio 1:2:4 were prepared for the research. The first one contains DS as coarse aggregate while the second mix contains crushed granite. Mix design with crushed granite served as control and w/c ratio of 0.6 was used for the two design mix. This was obtained from the result of preliminary design mix that was first carried out. Absolute volume method of calculation was adopted to determine the quantities of materials required for the production of each specimen. The tests that were conducted on the two specimens were in two stages; the chemical test and ordinary water test. For chemical test, six (6) concrete cubes were produced for each specimen, while nine (9) concrete cubes were produced for each specimen for water test.

Preparation of Chemical Aggressions

The chemical aggressions used for the experimental work were 5% H_2SO_4 and 5% $MgSO_4$. They were prepared in accordance to ASTM C 1012 recommendation. ASTM C 1012 recommends 5% Sulphate solution to carry out sulphate attack on OPC concrete. The chemicals were prepared in the laboratory by method of chemical-water dissolution ($MgSO_4$) and chemical water addition.

Testing Procedures in Aggressive Media

Specimens (DS and CG concretes) were completely immersed in chemical solutions of 5% H_2SO_4 and 5% $MgSO_4$. At 28 days immersions, three concrete cubes from each specimen were removed. They were thoroughly rinsed with clean tap water and airdried in the laboratory for one hour and tested to determine their 28 days compressive strength.

Testing Procedures in Ordinary Water

Specimens (DS and CG concretes) were completely immersed in ordinary water for 28, 56 and 84 days. At 28 days immersions, three concrete cubes from each specimen were removed and air-dried in the laboratory for one hour and tested to determine their 28 days compressive strength. This was also repeated at 56 and 84 days respectively.

RESULTS AND DISCUSSION

Physical Properties of the Materials Used for the Research

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).

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	–

Workability of the Pastes

Workability test was carried out on DS and CG fresh concretes. The tests in accordance to BS 1881: Part 2 (1970) includes slump and compacting factor. Slump and compacting factor tests were performed in accordance with the provision of BS 1881: Part 102 (1983) and BS 1881: Part 103 (1993). The results obtained are shown in Table 2. The slump tests carried out on DS and CG mixes observed to be 8 and 7 mm respectively which indicate low workability (ASTM 1881: Part 2:1970). The result of the compacting factor tests on the two specimens (0.72 and 0.74) also indicate low workability (Orchard, 1973).The compacting factor test for the two specimens are closed to the range of 0.85 – 0.92 recommended by Orchard (1973) for roads and slabs concretes.

Table 2: Workability of the Pastes

Paste Sample	W/c Ratio	Degree of workability	
		Slump(mm)	Compacting factor
DS	0.6	8	0.72
CG	0.6	7	0.74

Average Compressive Strengths and Densities of Specimens in Ordinary Water at 28, 56 and 84 Days (1:2:4 mix at 0.6 w/c ratio)

The compressive strength of DS at 28 days hydration is close to the value recommended by BS 8110 (1995) for structural concrete. Increase in strength was observed in the compressive strength of DS at 56 and 84 days hydration period.

Table 3: Average Compressive Strengths and Densities of Specimens in Ordinary Water at 28, 56 and 84 Days (1:2:4 mix at 0.6 w/c ratio)

Concrete Specimens	Compressive strength (N/mm^2)			Average density (Kg/m^3)		
	Days			Days		
	28	56	84	28	56	84
DS	18.90	21.55	22.80	2380.45	2390.50	2390.60
CG	26.80	28.10	30.00	2449.38	2450.00	2455.00

Average 28 Days Compressive Strengths and Densities of Specimens in 5% $MgSO_4$

The results of densities and compressive strengths of the specimens (DS and CG concretes) in water and 5% $MgSO_4$ at 28 days hydration periods are presented in Table 4. Little or no significant difference exists in the densities of CG concrete in ordinary water and 5% $MgSO_4$ at 28 days hydration periods. However, slight increase in density was observed in DS concrete in 5% $MgSO_4$ at 28 days while compared to its density in ordinary water. This might mean that there was more sulphate penetration in DS concrete than CG concrete that could have led to density increase (Neville, 1981). Increase in density of a specimen in $MgSO_4$ solution may also mean that the specimen was being permeable to chemical denser than water and as a result, being penetrated by $MgSO_4$ which adds to the densities of the specimen due to crystal (gypsum ($CaSO_4$)) deposition on the pores of the specimen. Hence, the higher increase in densities specimen (DS concrete) may mean the least resistant to sulphate attack. Increase in density of a specimen in $MgSO_4$ solution may also mean crystal deposition on the surface and corner of the specimen most especially when there are cracks on the specimen (Neville, 1981). The densities of 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).

There was a significant difference in the compressive strengths of DS concrete in water and 5% $MgSO_4$ at 28 day. At 28 days, the compressive strength of DS concrete was observed to be 18.90 N/mm^2 in water and 16.55 in 5% MgSO4 with percentage reduction in strength of 12.43. There was no significant difference in compressive strengths of CG concrete both in water and in 5% $MgSO_4$ at 28 days. At 28 days, the compressive strength of CG concrete was observed to be 26.80 N/mm^2 in water and 26.40 in 5% $MgSO_4$ with percentage reduction in strength of 1.49.

Table 4: Average 28 Days Compressive Strengths and Densities of Specimens in 5% $MgSO_4$

Specimens	Compressive strengths (N/mm^2)		Average density (Kg/m^3)		Percentage strength reduction (%)
	Water	5% $MgSO_4$	Water	5% MgSO4	
DS Concrete	18.90	16.55	2380.45	2439.51	12.43
CG Concrete	26.80	26.40	2449.38	2450.40	1.49

Average 28 Days Compressive Strengths of Specimens in 5% H_2SO_4

Table 5 shows the densities and compressive strengths of specimens in 5% H_2SO_4 at 28 days. High strengths reduction was observed in the specimens tested in 5% H_2SO_4 at 28 days. The percentage strengths reduction of DS and CG concretes at 28 days was observed to be 45.55 and 33.58 respectively.

Reductions in densities were also observed in the specimens at 28 days in 5% H_2SO_4. Reduction in density of a specimen in H_2SO_4 may mean that H_2SO_4 was too corrosive which might have led to loss of mortar on the specimen and the consequent reduction in density of the specimen. Hence, specimen with lower reduction in strength in H_2SO_4 may mean the higher resistant to attack by the corrosive media (H_2SO_4).

Surface Deformation

Warping was observed in the two specimens in chemical solutions of MgSO4 at 28 days. This was not found in the specimens immersed in ordinary water. Also, cracking was not observed in the specimens immersed in water, but was observed at the corners and edges of all the specimens immersed in 5% MgSO4 and 5% H2SO4 at 28 days.

Table 5: Average 28 Days Compressive Strengths and Densities of Specimens in 5% H_2SO_4

Specimens	Compressive strengths (N/mm^2)		Average density (Kg/m^3)		Percentage strength reduction (%)
	Water	5% H_2SO4	Water	5% H_2SO4	
DS concrete	18.55	10.10	2380.45	2350.61	45.55
CG concrete	26.80	17.80	2449.38	2360.49	33.58

CONCLUSIONS

The research concluded that DS can be used as an alternative material to (CG) in production of lightweight concrete in an area where CG is not available or scarce. The research further concluded that DS should not be used for production of concrete that will be exposed to magnesium sulphates with concentration close to 5% or more since this % concentration has significant damaging effect on the concrete when compared with CG concrete. The two specimens (DS and CG concretes) performed poorly in chemical solution of H_2SO_4 at 28 days but the performance of DS concrete was worse than that of CG. The Physical properties of DS are completely different from that of CG and the water-cement ratio to be used for production of DS concrete for adequate workability is 0.6.

RECOMMENDATION

1 DS is recommended as alternative material to coarse aggregate for production of lightweight concrete.

2 DS concrete should not be used for substructures in environments having close to or more than 5% sulphate concentration.

3 Tests different from compressive strength test in aggressive environment should also be carried out on the two hardened concretes. Tests such as tensile strength and shrinkage tests should thus, be carried out.

4 Effects of other sulphates different from $MgSO_4$ should be carried out on DS and CG concretes to further examine their performances in sulphates environments.

5 Partial replacements of CG with DS in concrete production should be carried out and tested in sulphate environment.

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