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Effects of Jujube Seed on the Mechanical Properties of the Normal Strength Concrete

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ABSTRACT. *The effects of jujube seed (JB) as partial replacement of coarse aggregate in concrete production was investigated. Physical properties of jujube seed and coarse aggregate were evaluated and compared. The concrete mix proportion of ratio 1:2:4 was adopted in the study. A total of 45 concrete cube specimens of size 150 × 150 ×150 mm3 with various percentages replacement by weight of coarse aggregate to jujube seeds as coarse aggregate in the order 5%, 10%, 15%, and 20% water cured for a maximum of 28 days. The densities and compressive strengths of the reference sample and the concretes mixed with partial replacement were evaluated. The results showed no significant change in concretes' densities with the partial replacement of aggregate up to 20%. The compressive strength of specimens with percentage replacement of coarse aggregate with jujube seeds at 20% for 7, 14, and 28 days curing age was found to be 6.7 MPa, 11.3 MPa, and 21.6 MPa, respectively. This shows that the compressive strengths at 28 days curing are entirely satisfactory within the range of compressive strength requirements of plain and reinforced concrete structure. The Jujube Seeds could partly be used to replace coarse aggregate up to 20% in the production of concrete where it is easily accessible and can be recommended as an alternative material to coarse aggregate mostly in tropical Africa and Asia region.*

Keywords*: Normal Strength concrete, Jujube seed, coarse aggregate, density, compressive strength*

1. INTRODUCTION

Nowadays, concrete is considered to be the primary material for civil and construction engineering structures on earth, such as buildings, bridges, tunnels, and many more. In ancient times, it was the building material of the Roman Empire. Today concrete is the material for the new generation of gravity-defying skyscrapers. It helped pave the way for innovations and laid the foundation for world civilization. It has almost unlimited engineering potential and takes nearly any shape. Hence it forms a backbone for the variety of world construction projects (Bill graves, 2006). The widespread usage of concrete is connected with the aggregate particles' availability, which forms typically 60 – 80%

of the concrete volume. Its workability when in a fresh state makes it possible to be molded into the desired shape, and its utilization when in the hardened form makes it suitable to aggressive environmental conditions, and its high compressive strength enable it to sustain heavy loads (Bala, 2009).

Despite the global acceptance of concrete as construction material, it has many limitations that inevitably affect its quality and general performance, for example, relatively high density, brittleness, weak tensile strength, low resistance to chemical attacks, etc. For these reasons, researchers are continuously searching for alternative sources of concrete ingredients that are technically suitable, financially feasible, environmentally friendly, and materials that would stand the test of time. Concrete constituents such as cement, sand, and coarse aggregates are expensive, and sometimes in availability to access, either of the material in some particular environment has taken attention nowadays. The need to looks for another source of construction materials is necessary. (Diamond, 2007). As part of the contribution to the ongoing research, the need to search for more durable and recyclable materials should be given due attention, and utilization of waste and natural or agricultural by-products. Proper usage of these waste materials will minimize the exploitation of natural resources and reduce the effect of environmental pollution (Gowsika, 2014). This research focuses on the impact of Jujube seeds as a partial replacement of coarse aggregates in concrete. This study investigates the suitability of the use of jujube seeds as a partial replacement of coarse aggregates in concrete. The subject parameters are the density and compressive strength of the concrete.

2. EXPERIMENTAL PROGRAM

2.1 Material

2.1.1 Natural Aggregate

A natural granite chipping with a nominal size of 20mm surface dry condition was prepared, with the help of sieve analysis, the grading of aggregate was determined. The percentage of the aggregates passing through each series of standard sieves was obtained according to BS 812: part 103, 1995). The basic properties such as specific gravity (SGx), moisture content of various concrete constituents, percentage water absorption, compacted and uncompacted bulk density, void ratio, and porosity were all determined as shown in table

2.1.2 Jujube Seeds

Figure 1 shows the sample of Jujube seeds used for this study. The seeds were extracted from jujube fruit, washed, and surface dry for 15-days to obtained seed for the concrete mixture. Consequently, the seed was dried up again for another 5 days to standard saturated dry condition (SSD) and then stored in a dry environment to avoid further dampness of the prepared seeds. The basic properties such as specific gravity (SG), moisture content, percentage water absorption, compacted bulk density void ratio, and JS porosity was determined and presented in table 1.

Figure 1. Sample of Jujube Seeds

Table 1 Physical Properties of Natural Aggregates and Jujube Seeds

Property	Coarse Aggregate	Jujube Seed
Moisture content (%)	0.51	2.9
Absorption (%)	1.46	19.86
Specific gravity	2.6	1.25
Compacted bulk density (kg/m^3)	1537	656.7
Un compacted bulk density (kg/m^3)	1373	600
Porosity (%)	12.6	8.63
Void ratio (%)	14.4	9.45

2.2.Method

An experimental program was established to evaluate the effect of jujube seed as coarse material in concrete at various percentage replacement of natural coarse aggregates. The mechanical and durability properties of conventional concrete at five different replacement percentages of 0%, 5%, 10%, 15%, and 20% were illustrated. Furthermore, five concrete batches were prepared for the

experiment to compare ordinary Portland cement concrete (control sample) with various replacement percentage of the concrete mix made of coarse jujube seed as a natural aggregate. Dangote 3X (42.5 N), an ordinary portland cement, was used as a binder material that complies with (BS12:1996). Chemical composition and specification.

2.2.1 Mix Design

The mix proportion 1:2:4 of the concrete used in this study are depicted in Table 2. The coarse aggregate was mix with cement and sand. Water was then gradually poured while the mixing continues for 5-7 min in a concrete mixer. The concrete specimens were placed in a curing medium and kept in the laboratory ambient condition, and tested at 7, 14, and 28-days (BS1881:Part111: 1983). At 28-days, the ultimate cubic compressive strength of 28.5 MPa was obtained for the concrete.

Table 2 Mix Design

Materials	**Amount of mixed materials (kg/m^3)**
Cement	325.8
Coarse aggregate	1303.2
Fine aggregate	651.6
Free water	162.9

2.2.2 Batching of the Materials

The materials for the concrete were batched by weight. In many situations where the concrete's size is of small volume, batching by volume can be used. However, batching by weight always gave a more accurate proportion of the materials. The quantity of each material for concrete mixed was determined based on the prescribed mix design of 1:2:4, water-cement ratio (w/c) of 0.5, aimed at obtaining a target compressive strength of 25 MPa at 28 days (BS EN 12390-3). A total of 0.1518 m^3 was used in this study.

Firstly, were cast in a metallic cube mold 150mm x 150mm x 150mm and then replaced by Jujube seed at 5%, 10%, 15%, and 20 through four different experimental batches. Metallic molds were lubricated with engine oil to reduce friction, leading to the removal of concrete cubes from the

molds. The concrete was cast in layers, and each particular layer was tamped 35 times. Each layer's top surface was then appropriately leveled with a hand trowel, and later identification numbers were assigned to them. The molds containing the concrete cubes were kept for 24 hours under room temperature for the cubes to set before removing from the mold and then cured at an ambient temperature of 20 ˚C until the prescribed testing date. (BS 1881: part 111: 1983).

Table 3. Quantity of the Materials used

Replacement (%)	Concrete Volume(m^3)	Cement (Kg)	Fine Aggregate(Kg)	Coarse Aggregate(Kg)	Jujube seed (Kg)
0	0.1518	49.46	98.91	197.82	0
5	0.1518	49.46	98.91	187.93	9.89
10	0.1518	49.46	98.91	178.04	19.78
15	0.1518	49.46	98.91	168.15	29.67
20	0.1518	49.46	98.91	158.26	39.56

3.0 RESULT AND DISCUSSION

3.1 Sieve Analysis

The particles distribution for coarse aggregates and Jujube seed used for this study are presented in figure 2(a) and (b). The coarse aggregate used has a maximum nominal size slightly higher than 20mm but less than 40mm. It can be noted that the percentage passing lies within the range of the intermediate grading limit that is often used in the concrete mix design. On the other hand, Jujube seeds have a gab-graded curve, indicating improper particle size distribution of materials

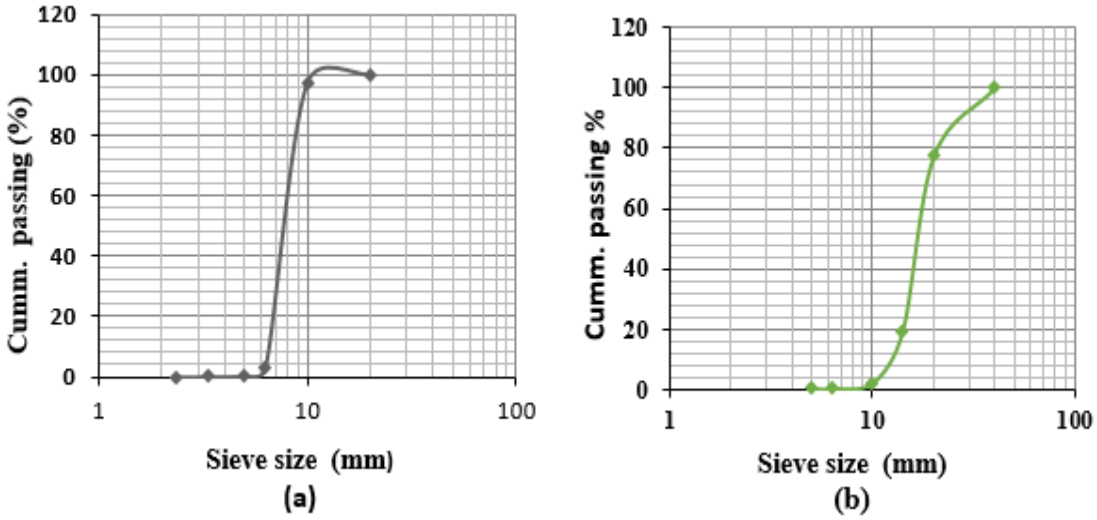

Figure 2. Sieve Analysis for Coarse aggregate and Jujube Seed

3.2 Natural Moisture Content

The average natural moisture content for fine and coarse aggregate stands at 0.67% and 0.51%, respectively. These results of the aggregate's moisture content fall within the range of 0 – 1.13% at the dry condition for most aggregate (Neville 2011). This implies that the materials used were relatively dry. The average natural moisture content of jujube seeds was measured at 2.9%. Jujube seed has a moisture content higher than that of the aggregates used for the experiment and generally higher the aggregate in dry condition. Natural moisture content can be determined using equation 1

$$\% \text{ Absorption} = \left(\frac{M_1 - M_2}{M_3 - M_1}\right) \qquad (1)$$

Weight of can only =M_1

Weight of can + saturated sample = M_2

Weight of can + dried sample = M_3

Table 6. The Moisture Content of the Materials

Materials	**% Moisture Content**	**%Absorption**
Fine aggregate	0.67	9.39
Coarse aggregate	0.51	1.46
Jujube seeds	2.90	19.86

3.3 Water Absorption Capacity

Equation (1) above, the average 24-hr water absorption of each concrete mix material was evaluated and found to be 9.39%, 1.46%, and 19.86% for fine aggregate, coarse aggregate, and jujube seeds, respectively, as shown in table 6. This is within the standard range of 5 to 15% for fine aggregate and 0.5 to 5% for coarse aggregate, a limit specified in (BS 102: part 107). The result obtained for jujube seeds (19.86%) is evidence that it absorbs lots of water just like lightweight aggregate due to their cellular pore structure.

3.4 Slump Test Result.

The workability test result for various concrete mixes containing jujube seed was shown in figure 3. The reference concrte mix had the lowest slump value and maximum value was obtain from the concrete mixture prepared with 20% replacement of coarse aggregate by jujube seed. This indicates that the fresh concrete mixes' workability increases with an increase in percentage replacement. The concrete with a slump value of less than 25 mm is classified as the low concrete workability (Shetty, 2005) and confirmed by BS 1881, part 103 (1983) specifications.

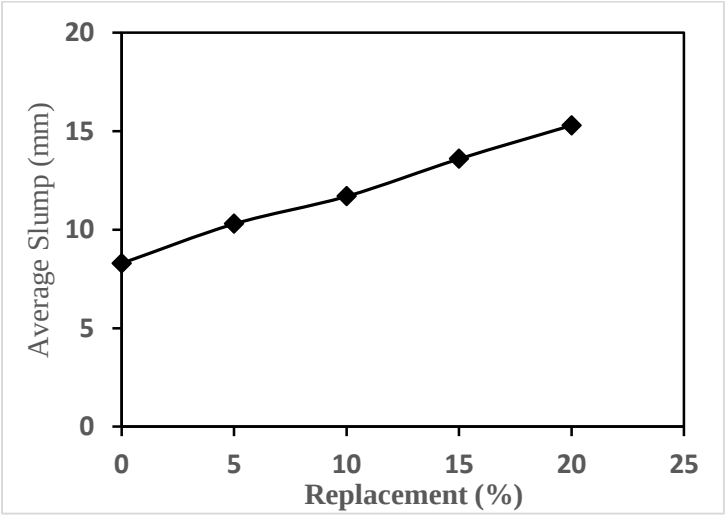

Figure 3. Result of Slump test for concrete mixtures

3.5 Compressive Strength

Figure 4 presents the result of compressive strength of the concrete mixes used in this study with and or without jujube seed as a partial replacement at specified curing age. The corresponding densities of each percentage replacements were also determined. To evaluate the effect of replacing specific percentages of coarse aggregate with jujube seeds on normal concrete's physical and mechanical properties. A comparison was made between normal concrete and four concrete mixes containing different proportions of jujube seeds.

Generally, the strength of all concrete mixes decreases gradually with an increase in percentage replacement of coarse aggregate with jujube seed. The compressive strength of normal concrete specimen at 28 days was found to 28.5 MPa against 21.6 MPa obtained from the concrete mix with a 20% replacement of JS. The noticeable decrease in cubic compressive strength resulted from the addition of Jujube seed based on the prescribed percentage increment in the concrete mix. Replacing natural coarse aggregate with jujube seeds leads to a reduction in the concrete's compressive strength by 24.2%.

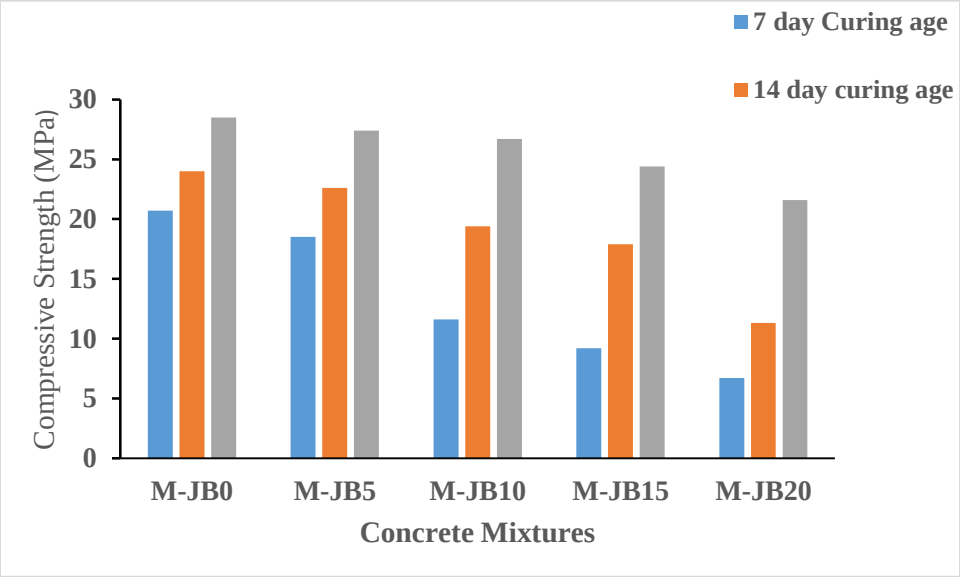

Figure 4. Compressive strength of Concrete mixtures

According to Concrete Mix Design Manual (COREN 2017), for reinforced concrete members, the concrete to be used should have a minimum compressive strength of 20 N/mm^2 and 10 N/mm^2 for plain concrete. Hence, the compressive strength results at 28 days for various percentages of

replacements satisfied the requirement for reinforced concrete members and most suitable for plain concrete. According to A.M Neville (2011), a normal weight concrete density has a range of 2200 – 2600 kg/m^3. The average densities obtained at 28 days for the various mixes all fall within that range.

4.0 CONCLUSION

This experimental study presented the results of concrete's physical and mechanical properties consisting of Jujube Seed at various amounts to assess the future use of Jujube seeds (JS) as coarse aggregate (partial replacement) in making concrete structures. Base on this study, the following conclusion can be derived:

- Jujube seed is a lightweight aggregate, with physical properties similar, lower than that of coarse aggregate values but satisfied with lightweight aggregates. It has high absorption property also emulates that of lightweight aggregates.
- Jujube seeds can be employed in concrete production, specifically as partial replacement of coarse aggregate. (up to 10% replacement). It is suitable for both plain concrete and reinforced concrete members of less structural importance
- The workability of concrete mixes produced was relatively low. (Slump of less than 25mm) and steadily increase to a maximum value of 15.3mm at 20% replacement.

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