

# THE USE OF BALANITE SEED FOR PARTIAL REPLACEMENT AS AGGREGATE IN LIGHTWEIGHT CONCRETE

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## ABSTRACT

*The research aimed to analyze the strength of concrete using Balanite Seed as partial replacement for coarse aggregate for lightweight concrete. The workability, density, compressive strength and flexural strength were determined in accordance with British Standard codes. Preliminary tests were carried out to determine some physical and mechanical properties of Balanite Seed in comparison with Crushed Granite. Furthermore, workability, bulk density compressive strength and flexural strength of concrete at 5%, 10%, 15%, 20% and 25% of Balanite Seed as replacement for Crushed Granite as coarse aggregate in concrete mix of ratio 1:2:4 were studied. Concrete cubes of 150×150×150mm were casted, (whereas for the flexural strength, concrete beams of 150×150×750mm were casted) and cured in water for 7, 14 and 28 days after which workability, bulk density, compressive strength of cubes and flexural strength of beams were determined. It was observed that Balanite Seed absorbs much water compared to Crushed Granite, which implies that Balanite Seed has less resistance to impact and shock compared to Crushed Granite and it also indicates that Balanite Seed is much lighter than Crushed Granite. Furthermore, workability, bulk density, compressive strength and flexural strength (of casted beams) were observably found to decrease as the percentage of the Balanite Seed increases in the concrete mix. However, at 15% replacement of Crushed Granite with Balanite Seed, both bulk density and compressive strength of concrete met the requirement for its use as lightweight concrete.*

**Keywords:** Balanite Seed, Lightweight Concrete, Workability, Bulk Density, Compressive Strength, Flexural Strength

## 1 INTRODUCTION

The demand for construction materials is increasing day by day due to the infrastructural development across the world. Nigeria being a developing country is faced with inadequate provision of physical infrastructure; shelter and related amenities, which are typical factors of under development that need to be addressed through provision of alternatively, cheap and affordable materials. Hence, the need to explore the use of cement and other related materials (especially agricultural residual materials) as coarse aggregate [1]. Concrete, for many years has been one of the major materials used in the construction of civil engineering structures. Concrete is a civil engineering material resulting from the mixture of cement, fine and coarse aggregates and water. The materials when properly batched and thoroughly mixed sets through the process of hydration and hardens into a rock-like mass which is capable of resisting compressive stresses. The strength, durability and other characteristics of concrete depend upon some factors, such as properties of its constituents, mix ratio, curing method, compaction and placement [2]. The inclusion of aggregate in concrete reduces its shrinkage properties and improves many other properties such as compressive strength etc. Coarse aggregate as a major constituent of concrete constitutes about 75% to 85% of the concrete matrix [2], hence the significance and relevance of coarse aggregate in concrete production in all areas of civil engineering practice and building construction cannot be overemphasized. Coarse aggregate could be sourced from naturally occurring aggregates such as gravel or from crushed granite. Balanite tree (*Balanite Aegyptiaca*) also known as desert date in English, and ‘adua’ in Hausa language [3], is an important tree crop of the Sudan savannah zone and semi-arid tropical region of Africa. Two varieties of the tree with seed shapes that corroborate the findings of [4] are common in North Eastern Nigeria.

Therefore, exploring the suitability of using locally available aggregates sourced from Balanite seed in concrete production will help in lowering the cost of production of concrete and it will also lead to environmental sustainability as thousands of tons of Balanite seeds are produce per annum, and are deposited as agricultural residual waste product mostly in the North Eastern part of Nigeria,

## 2 MATERIALS AND METHOD

### 2.1 Materials

Materials used for this research work include: ordinary Portland cement, crushed granite (CG), river sand and Balanite Seed (BS),

### 2.2 Methods

Tests were carried out in accordance to the methods prescribed in the BS code of specifications:

- i. Specific Gravity test was carried out in accordance with the procedure as outlined in [5].
- ii. Aggregate Water Absorption (AWA) test was conducted in accordance with the procedure as outlined in [6]
- iii. Aggregated Impact Value (AIV) test conducted in accordance with the procedure as outlined in [7].
- iv. Slump test was carried out on the fresh concrete in accordance with the procedure as outlined in [8].
- v. Compressive Strength was carried out in accordance with the procedure as outlined in [9] and [10]. 54 cubes of 150mm x 150mm x 150mm were produced with mix ratio of 1:2:4. Water/Cement ratio of 0.55 was used; the cubes were then cured for 7<sup>th</sup>, 14<sup>th</sup> and 28<sup>th</sup> days before testing. Partial replacement of crushed granite with Balanite Seed was in percentages of 5%, 10%, 15%, 20%, and 25%.
- vi. Flexural Strength was carried out in accordance with the procedure as outlined in [11, 12]. 54 beams of 150mm x 150mm x 750mm were produced with mix ratio of 1:2:4. Water/Cement ratio of 0.55 was used; the beams were then cured for 7<sup>th</sup>, 14<sup>th</sup> and 28<sup>th</sup> days before testing. Partial replacement of crushed granite with Balanite Seed was in percentages of 5%, 10%, 15%, 20%, and 25%.

## 3 RESULTS AND DISCUSSIONS

### 3.1 Physical and Mechanical Properties of BS and CG

The physical and mechanical properties (specific gravity, aggregate water absorption and aggregate impact value) for BS and CG obtained from this study are as presented in the Table 1 below:

Table 1. Physical and Mechanical Properties of BS and CG

<b>Physical and mechanical property</b>	<b>BS</b>	<b>CG</b>
Specific gravity	1.16	2.64
Aggregate water absorption (%)	25.49	0.90
Aggregate impact value (%)	40.05	15.34

The specific gravity test result shows that the values of CG and BS were 2.64 and 1.16 respectively as shown in Table 1. This shows that CG was much denser than BS. AIV for CG was found to be 15.34% while for BS it was 40.05%. Which implies that BS has a lesser ability to resist impact or shock than CG. However, the average impact value falls within acceptable limit in accordance to [13], which prescribes that the maximum value of 45% for aggregate to be used in concrete for non-wearing surfaces. The BS aggregate water absorption was found out to be 25.49% while that of CG was 0.90% thus, indicating that BS has higher water absorption and it is attributed to the rough texture of the material.

### 3.2 Slump Test at Varying Percentage of BS

The water cement ratio used for the mix and the slump at varying percentage of BS are presented in Table 2 and Figure 1.

Table 2. Slump test at varying percentage of BS

% Replacement CG:BS	Water/Cement ratio	Slump (mm)
100:0	0.55	55
95:5	0.55	48
90:10	0.55	45
85:15	0.55	31
80:20	0.55	23
75:25	0.55	15

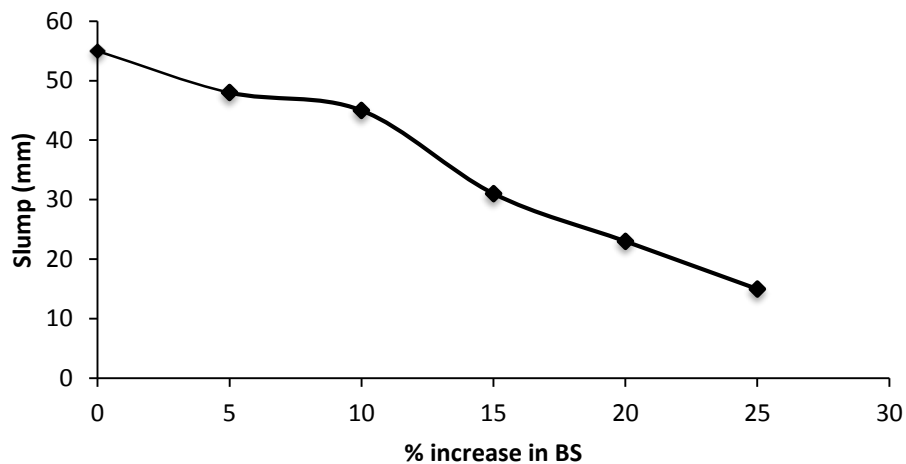


Figure 1. Graph of slump against percentage increase of Balanite Seed

The workability of concrete was determined by slump cone test to find out the consistency of concrete, the slump test result is shown in Table 2 and represented in Figure 1. It was observed that the slump value decreases as the amount of BS aggregate increases. This can be attributed to the rough surface of the BS which creates more friction thus decrease the fluidity of the mix containing higher percentage of BS. The influence of surface texture of coarse aggregate towards concrete workability has been highlighted by [14].

### 3.3 Compressive Strength of Concrete at Varying Percentage of BS

The compressive strength of the concrete cube produced with partial replacement of BS at varying percentage are presented in Table 3 and represented in Figure 2.

Table 3. Compressive Strength of Concrete at Varying Percentage of BS

Partial replacement (%) CG:BS	Compressive Strength at different curing days in (N/mm <sup>2</sup> )		
	7 days	14 days	28 days
100:0	21.47	24.93	29.07
95:5	18.21	21.81	26.55
90:10	16.90	18.19	23.23
85:15	13.29	15.22	18.37
80:20	9.53	13.93	15.79
75:25	6.96	9.11	11.14

The compressive strength of cubes at varying percentage of BS is shown in Table 3. It was observed that the compressive strength of the concrete decreases as the percentage of the BS increases in the concrete mix as presented in Figure 2. It was also observed that the compressive strength of the cubes specimens increases with the increasing curing days. According to [15], concrete is considered structural lightweight concrete when made with lightweight aggregates conforming to [16] and has a compressive strength in excess of 17.25MPa at 28 days of age; therefore, the optimal replacement percentage of crushed granite with Balanite Seed is at 15% replacement which obtains a compressive strength of 18.37N/mm<sup>2</sup> after 28 days of curing as presented in Table 3.

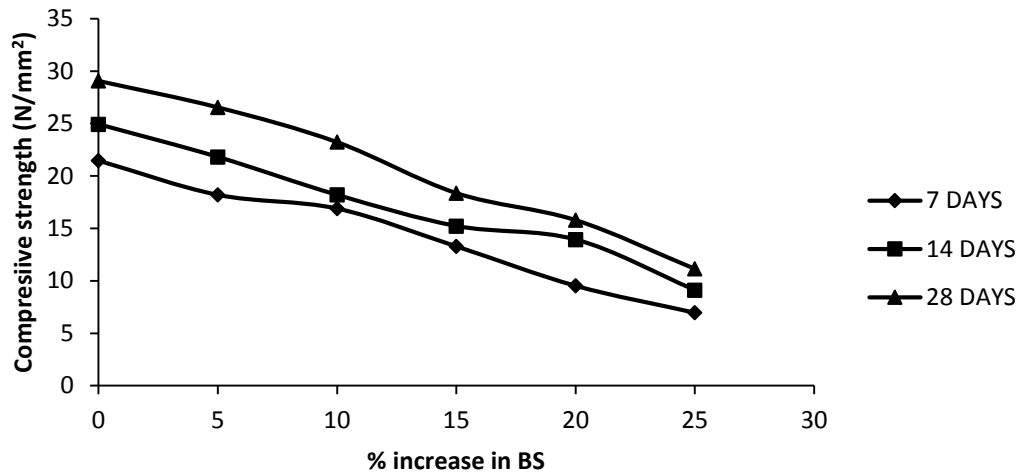


Figure 2. Graph of compressive strength against percentage of BS in concrete

### 3.4 Bulk Density at Varying Percentage of Balanite Seed

The variation of densities of concrete in relation to percentage replacement of BS to CG in concrete are shown in Table 4 and represented in Figure 3.

Table 4. Bulk Density at Varying Percentage of Balanite Seed

Partial replacement (%)	Density at different curing days in (Kg/m <sup>3</sup> )		
	7 days	14 days	28 days
<b>CG:BS</b>			
100:0	2520	2593	2625
95:5	2400	2528	2569
90:10	2346	2445	2467
85:15	2315	2335	2428
80:20	2256	2279	2381
75:25	2188	2226	2321

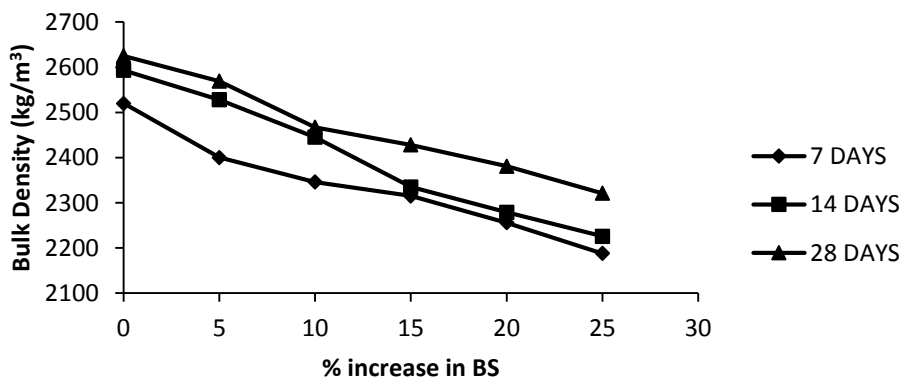


Figure 3. Graph of bulk density against percentage of BS in concrete

It can be seen that as the percentage of BS increases, the density of concrete produced reduces, since the CG is denser than BS and the replacement is by weight, the specific surface area increases with the increment of BS content in the mix hence the weight of concrete cube reduces as the percentage of BS increases. The densities of all the concrete cubes casted within the range of 0 to 25% replacement of crushed granite with BS in concrete was found to be above  $2000\text{kg/m}^3$  making it suitable for use as lightweight concrete [17].

### 3.5 Flexure Strength at varying percentage of BS

The variation of flexural strength of concrete in relation to percentage replacement of BS to CG in concrete are shown in Table 5 and represented in Figure 4.

Table 5. Flexure Strength at varying percentage of BS

Partial replacement (%) CG:BS	Flexural Strength at different curing days in ( $\text{N/mm}^2$ )		
	7 days	14 days	28 days
100:0	4.22	5.07	6.71
95:5	3.51	4.36	5.60
90:10	3.11	3.65	4.67
85:15	2.62	2.89	3.65
80:20	2.05	2.22	2.98
75:25	1.38	1.60	2.05

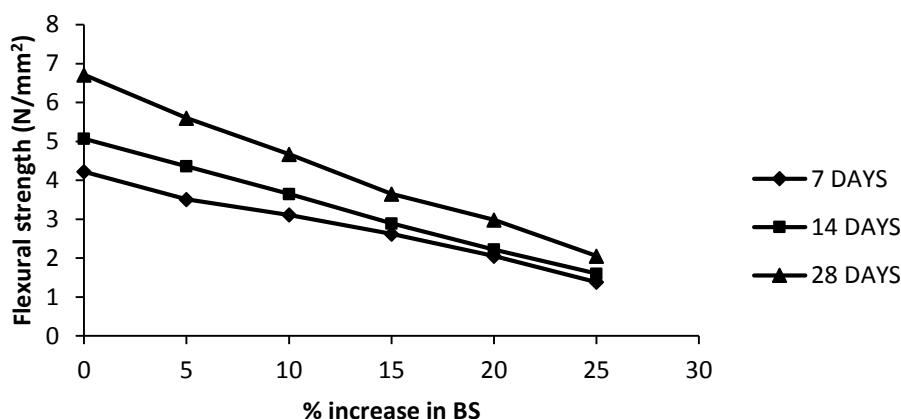


Figure 4. Graph of flexural strength against percentage of BS in concrete

The flexural strength result is shown in Table 5. From Figure 4 it was observed that flexural strength decreased as percentage replacement of BS increased, its decrease was attributed to low workability of the concrete and it agrees with the result of previous researched by [18]. It was also observed that there was sudden failure of the beam without prior notice.

## 4 CONCLUSION

Based on the experimental results of this study it can be concluded that the physical/mechanical properties such as specific gravity, aggregate impact value and aggregate water absorption of the Balanite Seed are lesser value in values than Crushed Granite. The optimal compressive strength was obtained at 15% of Crushed Granite with Balanite Seed with a value of  $18.37\text{N/mm}^2$  which satisfies requirement of concrete produced with 15% replacement of Crushed Granite with Balanite Seed. Therefore, it can be recommended that Balanite Seed can be used to partially replace Crushed Granite as coarse aggregate for light weight concrete for non-structural members at an optimum replacement percentage of 15%.

**REFERENCES**

1. Elinwa, A.U. (2003). Timber ash as pozzolana in concrete, Unpublished Ph.D Theses, Department of Civil engineering, ATBU, Bauchi.
2. Gambhir, M.L. (2005). Concrete Technology, Third Edition Tata McGraw-Hill Publishing Company Limited. New Delhi.
3. Hall J.B and Walker D.H., (1991). *Balanites aegyptiaca*; A monograph, School of Agricultural and Forest Sciences Publication, University of Wales, No. 3.
4. Launert, E. (1963). *Balanitaceae*. In: *Flora Zamesiaca* (Exell A W., Fernandes A. and Wild H. eds) Crown Agents, London, pp. 221–224.
5. BS-EN 1377-2 (1990). Soils for Civil Engineering purposes, London: British Standard Institution.
6. BS-812-109 (1990). Testing Concrete. Methods for determination of moisture content, London: British Standard Institution.
7. BS-812-112 (1990). Testing aggregates. Methods for determination of aggregate impact value (AIV). London: British Standard Institution
8. BS-1881-102 (1983). Testing Concrete. Method for determination of slump, London: British Standard Institution.
9. BS-1881-108 (1983). Testing Concrete. Method for making test cubes from fresh concrete. London: British Standard Institution.
10. BS-1881-116 (1983). Testing Concrete. Method for determination of compressive strength of concrete cubes, London: British Standard Institution.
11. BS-1881-109. (1983). Testing Concrete. Method for making test beams from fresh concrete. London: British Standard Institution.
12. BS-1881-118. (1983). Testing Concrete. Method for Determination of Flexural Strength, London: British Standard Institution
13. BS 882 (1992) Specifications of aggregate for natural sourced for concrete, London: British Standard Institution.
14. Mindess, S., Young, J. F., and Darwin, D. (2003), Concrete, 2nd Edition, Prentice-Hall Inc., Englewood Cliffs, New Jersey.
15. ACI 213R-87 “Guide for Structural Lightweight Aggregate Concrete”. American Concrete Institute. Detroit, Michigan.
16. ASTM C330 Standard Specification for Lightweight Aggregates for Structural Concrete.
17. BS-8110-1. (1997). The structural use of Concrete, London: British Standard Institution.
18. Abubakar, A. and Duna, A. (2017). Utilization of Scoria as Aggregate in Lightweight Concrete, *International Journal of Engineering Research*, vol. 6, no. 1, pp. 34-37.