Experimental Investigation of the Effect of Partial Replacement of Cement in Concrete with Locust Bean Waste Ash

Afolayan J. O, Oriola F. O. P., Sani, J. E.

Abstract— **The cost of construction material such as cement is high and unaffordable; the need for building construction requiring this material keeps growing, thus the need to find alternative binding materials that can be used solely or in partial replacement of cement. Locust Beam Waste Ash (LBWA) was used as partial replacement of cement in concrete. Concrete cubes were produced using various replacement levels of 0, 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50 percent of OPC with LBWA. A total of 132 cubes of size 100 100 100mm were produced and cured by immersing them in water for 7, 14, 21 and 28 days respectively. Properties such as compressive strength, density, Standard Consistency, Setting times, Slump and Compacting Factor Test were determined. The result showed that the density of concrete cubes was 2400kg/m3 and compressive strength for 5% increased from 11.67N/mm2 at 7 days to 22.33N/mm2 at 28days curing; the result of 10 – 15% shows significant reduction in compressive strength.**

Index Terms— **Locust bean waste ash, Cement, Concrete, Compressive strength**

I. INTRODUCTION

Concrete is a man-made composite material, the major constituent are cement, natural aggregate; such as gravel and sand or crushed rock. Alternatively artificial aggregates, for example, blast furnace slag, expanded clay; broken brick may be used where appropriate. The other principal constituent of concrete is the binding medium used to bind the aggregate particles together to form a hard composite material. The most commonly used binding medium is the product formed by a chemical reaction between cement and water. Other binding media are used on a must smaller for special concrete in which the cement and water of normal concrete are replaced either wholly or in part by polyester resins.

In its hardened state, concrete is a rock-like material with a high compressive strength. By virtue of the ease with which a fresh concrete in its plastic state may be moulded into virtually any shape, it may be used architecturally or solely for decorative purposes. Special surface finishes for example expose aggregate can also be used at great effect.

The compressive strength of concrete is taken as the maximum compressive load it can carry per unit area. Concrete strength can be achieved by selective use of the type of cement, mix properties, methods of compaction and curing conditions. Water plays a vital role in the strength of concrete. It is required to start chemical process, also fill the voids. Three ingredients: aggregate, cement and water can be blended and proportioned to make concrete. In concrete, the single most significant influence on most or all of the properties is the amount of water used in the mix. In concrete mix design, the ratio of the amount of water to the amount of cement used (both by weight) is called the water to cement ratio (w/c). These two ingredients are responsible for binding everything together. The water to cement ratio, or w/c ratio, largely determines the strength and durability of the concrete when it is cured properly.

This research is aim at finding the effect of partial replacement of ordinary Portland Cement with locust bean waste ash on properties of concrete mix.

Literature Review

The high cost of construction materials like cement, aggregates and reinforcement bars has led to increased cost of construction. For, it is well known that the production of cement (key building component of concrete) is costly, consumes high energy, depletes natural resources and emits large amount of greenhouse gases (mostly CO_2) [HYPERLINK \l "Ori15" 1]. This has necessitated a search for an alternative binder which can be used sorely or in partial replacement of cement in concrete production 2]. More so, disposal of agricultural waste materials such as rice husk, groundnut husk, corn cob and Locust beans waste have constituted an environmental challenge, hence the need to convert them into useful materials to minimize their negative effect on the environment [HYPERLINK \l "Hab10" 3]. Research indicates that most materials that are rich in amorphous silica can be used in partial replacement of cement 4]. It has also been established that amorphous silica found in some pozzolanic materials reacts with lime more readily than those of crystalline form [HYPERLINK \l "Neh03" 5]. Use of such pozzolanas can lead to increased compressive strength and flexural strengths 6]. The American society of testing materials (ASTM) defined pozzolana as “siliceous or aluminous material which possess little or no cementitious materials but will, in themselves have little or no cementitous properties but finely divided form and in the presence of moisture they can react with calcium hydroxide which is liberated during the hydration of portland cement at ordinary temperatures to form compounds possessing cementitous properties”. Pozzolana have the characteristics of combining with the free lime liberated during the hydration process of Ordinary Portland Cement (OPC) to produce stable, insoluble calcium silicates thus reducing the process of mortar and concrete attacks from sulphates, salts and chlorides [HYPERLINK \l "Tya11" 7]. Use of such pozzolanas can lead to increased compressive and flexural strengths 4]. The American society of testing materials (ASTM) defines Pozzolans as siliceous or aluminous materials which possess

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little or no cementitious properties but will, in the presence of moisture, react with lime [Ca(OH)2] at ordinary temperature to form a compound with pozzolanic properties.

II. Materials and Methods

Materials

Cement

Dangote cement was used for all the tests. The quality of the cement was considered by checking its consistency, setting time, soundness and strength. These tests were carried out in accordance with [HYPERLINK \l "BS191" 8]. Tests were also carried out on the qualities of the cement with, 10%, 15%, 20 and 30% replacement of the cement with groundnut shell ash. This was used to find out to what extent these qualities comply with the requirement of 8].

Aggregates (Gravel and Sand)

Sharp river sand gotten within Kaduna was used for the experiment. Gravel is gotten from a supplier from quarry in Kaduna state, 3/4inch size of gravel was considered. Particle size distribution and tests like specific gravity tests and silt content test were carried out on the fine aggregate in accordance with the [HYPERLINK \l "BS885" 9] to find out their suitability for the test. Particle size distribution and other quality assurance tests of the coarse aggregates were also carried out in accordance with 9].

Locust bean waste ash

The Locust bean waste ash used in this research was sourced from Kundami, Kokona Local government Area, Nasarawa State. The burnt ash was passed through a BS sieve of 150 microns. The portion passing through the sieve which has the required fineness of 0.063 mm was used for the test while the residue was discarded. The pictorial details re shown in Plates I-

Plate I: LOCUST BEAN PODS

Plate II: LOCUST BEAN SEEDS EXTRACTED FROM THE POD

Plate III: DIFFERENT STAGES OF BURNING OF THE LOCUST BEAN WASTE UNDER ATMOSPHERIC CONDITION

Plate IV: UNSIEVED ASH FROM THE LOCUST BEAN

Plate V: SIEVED ASH FROM LOCUST BEAN WASTE ASH WASTE ASH

Plate VI: BAGGED LOCUST BEAN WASTE ASH

Water
The water used for this research was tap water free from contaminants either dissolved or in suspension collected from civil Engineering Laboratory, Kaduna Polytechnic, Kaduna.

Method
Slump Test
This test is carried out to check the workability of the fresh concrete. Test is carried out in accordance with [HYPERLINK \l "BS183" 10]. The conical mould on the base plate was placed with the smaller opening at the top and held firmly in position. The mould was filled in 3 layers of approximately equal depth, Roding each with 25 strokes of the tamping rod. The top surface was stroke off with trowel and slowly lifted the mould vertically from the shape and the difference in height between the cone and the concrete was noted.

Compacting Factor Test
Compacting factor of fresh concrete is done to determine the workability of fresh concrete.

Test is carried out in accordance with 11]. The test requires measurement of the weight of the partially and fully compacted concrete and the ratio of the partially compacted weight to fully compacted weight.

The upper hopper and lower hopper were oiled and the concrete was filled, levelled to the brim without compacting the concrete in any way. The door of the bottom of the hopper was released and the concrete was allowed to fall into the second smaller hopper. The door at the bottom of the lower hopper was released and the concrete was allowed to fall into cylinder. The excess concrete was cut off. The weight of concrete in the cylinder was determined which was partially compacted weight. The corresponding weight of fully compacted concrete was determined by refilling the cylinder in 5 layers of approximately 50.8mm deep each layer was thoroughly compacted and levelled the top. This was weighed and recorded.

Determination of Compressive Strength
The compressive strength of concrete is prescribed by [HYPERLINK \l "BS116" 12]. The compressive strength of concrete is the maximum compressive load it can carry per unit area.

Production of Concrete Cubes
Locust bean waste ash (LBWA) was used to replace ordinary Portland cement at 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45% and 50% by weight of cement. A 100 1 100 ⨯100mm steel moulds was used to produce concrete cubes of mix ratios 1:2:4 with constant water cement ratio of 0.55. The cube steel moulds were assembled prior to mixing and properly lubricated with engine oil for easy removal of hardened concrete cubes. Each mould was then filled with prepared fresh concrete in three layers and each layers was tamped with taping rod using twenty-five (25) strokes uniformly distributed across the seldom of the concrete in the mould. 12 cubes were casted for each mix proportion bringing the sum total of 132 cubes. The top of each mould was smoothened and leveled with hand trowel and then the outside surfaces cleaned. The moulds and their contents were left in the open air for 24 hours. The concrete cubes were demoulded after 24 hours of the concrete setting under air and later in storage curing tank filled with clean tap water only for periods of 7, 14, 21, and 28 days respectively. The weight of three cubes at each curing age was noted and then placed in the compression test machine with the two cast faces in contact with the plates of the machine. The load applied until failure occurred and the crushing loads on the compression testing machine were recorded.

Plate IX: CONCRETE CUBES FROM LBWA CONTAINING 30% CEMENT REPLACEMENT

III. Results and Discussion

Oxide Composition of Cement and Locust Bean Waste Ash

The oxide composition obtained from the Chemical Analysis of Locust Bean Waste Ash and cement is summarized in Table 1. As may be observed from Table 1, the oxide composition of LBWA shows that it contains 39.01% silica which is higher than 21.55% for cement and this is an important ingredient as it imparts strength to the cement due to the formation of Dicalcium and Tricalcium Silicates [HYPERLINK \l "Sau13" 13]. The result of the sieve analysis for the coarse and fine aggregate are shown in Fig. 1 and 2 respecively.

Table 1: Oxide compositions of Locust bean Waste ash (LBWA) as compared with Ordinary Portland cement

Oxide	Locust bean Waste ash (%)*	Cement (OPC) (%)**
Cao	15.71	64.45
SiO2	39.01	21.55
Al2O3	13.05	5.28
Fe2O3	11.51	3.95
MgO	2.01	1.85
K2O + Na2O	6.83	-
TiO2	-	-
SO3	-	1.50
CO3	-	-

* After 14]}

Plate VIII: SPECIMEN FOR TESTING THE LBWA SETTING TIME

Aggregate Crushing value

The result of the aggregate crushing value (ACV) using aggregate sizes of 12.70 and 9.52mm is shown in Table 4. The average ACV value obained is 16.52%.

Table 4: Result of Aggregate Crushing value (ACV)

Description	Test 1 (kg)	Test 2 (kg)
Wt. of empty mould ‘C’ (g)	10.45	10.45
Wt. of material in mould ‘D’ (g)	14.15	14.13
Wt of aggregate (W1)=D-C (g)	3.7	3.68
Wt of aggregate passing (W2)	0.576	0.643
ACV = (W2/W1) X 100	15.57	17.47
Average ACV	16.52	

Aggregate Impact value

The result of he aggregate impact value is shown in Table 5. The AIV obained was 5.64%

Table 5: Result of Aggregate Impact Value (AIV)

Description	Test 1 (kg)	Test 2 (kg)
Wt. of empty mould ‘C’ (g)	2.8	2.8
Wt. of material in mould ‘D’ (g)	3.5	3.5
Wt of aggregate (W1)=D-C (g)	0.7	0.67
Wt of aggregate passing (W2)	0.032	0.045
AIV = (W1/W2) X 100	4.57	6.7
Average AIV	5.64	

Slump Test of concrete

The resul of the slump test for the concrete and the LBWA replacement of the cement is shown in Table 6. The w/c ratio of 0.55 was only workable for 0%, 5% 10% and 15% replacement. For remain percentages, the w/c was increase to 0.65 for the mix to be workable. This shows that the LBWA absorbs more water. The slump result indicates true slump which shows that the concrete is workable.

Table 6: Result of Slump test

Percentage Replacement of cement with ASH	Height of sample cone (cm)	Height of Slump (cm)	Nature of Slump
0	30	27.5	True Slump
5	30	26.5	True Slump
10	30	26.1	True Slump
15	30	27.6	True Slump
20	30	26.30	True Slump
25	30	25.6	True Slump
30	30	27.4	True Slump
35	30	27.6	True Slump
40	30	25.9	True Slump
45	30	26.1	True Slump
50	30	27.2	True Slump

Compacting Factor Test of concrete

The variation of the compacting factor with varying LBWA replacement is shown in Fig. 3. The compactive factor decreases as the LBWA content increases to a minimum value of 0.86 at 30% LBWA conten and thereafter increases. The compacting factor was beween 0.87 to 0.92 for all the mix. These results conform to the BS Standard of low and medium workability of concrete. Similar trend was recorded by [HYPERLINK \l "Afo15" 15]

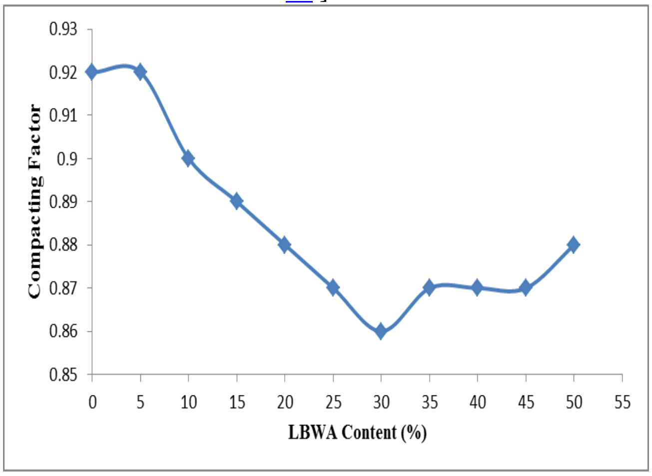

Fig. 3: Result of compacting *factor* at varying LBWA content

Compressive Strength Test

Effects of curing age (days) on compressive strength

The results of the Compressive strength test at various curing age for all percentage replacement is shown in Fig. 4. It shows increasing strength with age for all the blends. Higher strength values were obtained at 28 days curing period therefore the target of 20N/mm2 were obtained at curing at 21 days and beyond.

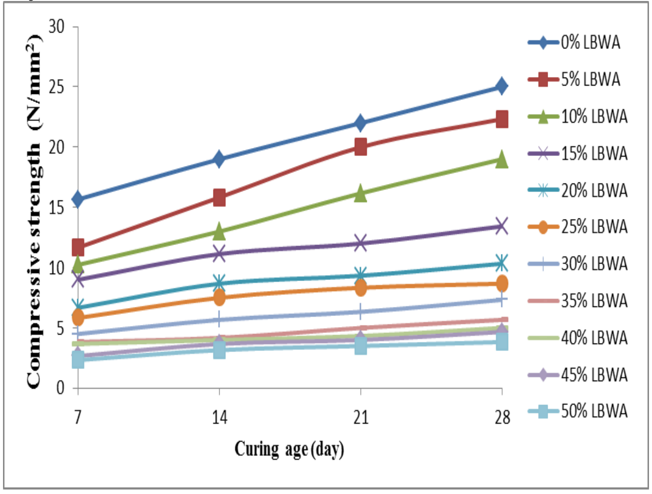

Fig. 4: Variation of concrete compressive strength with age at different percentages of cement replacement with LBWA

Effects of Locust bean waste ash on compressive strength

The variation of concrete compressive strength with locust bean waste ash at varying curing period is shown in Fig. 5. The result of Compressive Strength for various replacement of LBWA showed that the density of concrete cubes were between 2400 - 2600kg/m3. The general trend is that compressive strength steadily decreases with increase in the percentage of replacement of cement with LBWA in the concrete. However, the target value of 20N/mm2 was achieved at replacement value not up to 10% LBWA. At 28 days curing period the compressive strength values recorded are; 25.00N/mm2 for 0% LBWA replacement, 22.33N/mm2 for 5% LBWA replacement and 19.00N/mm2 for 10% replacement. Replacement up to 10% percentage recorded values lower than that of the target strength. Similar trend were recorded by 17]}, [HYPERLINK \l "Afo15" 15] and 18]}.

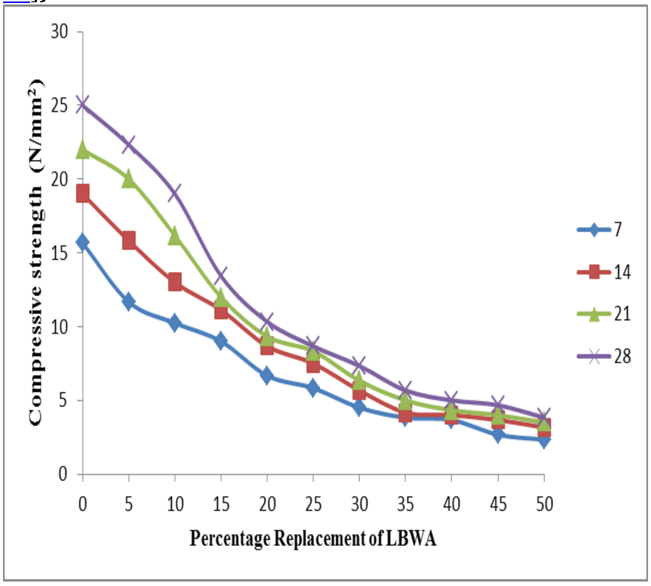

Fig. 5: Variation of concrete compressive strength with LBWA replacement of cement at different curing age

IV. Conclusion and Recommendations

Conclusion

The following conclusion can be drawn:

The w/c ratio of 0.55 was only workable for 0%, 5% 10% and 15% replacement. For 20 – 50% replacement, the w/c was increase to 0.65 for the mix to be workable..

The target grade of 20N/mm2 was achieved at replacement of not up to 10% (25.00N/mm2 at 0% LBWA replacement, 22.33N/mm2 at 5% LBWA replacement and 19.00N/mm2 at 10% LBWA replacement). For replacement up to 10%, the grade obtained fell well short of target 20.00N/mm2.

The use of cement with 5% LBWA replacement will reduce the cost of cement in concrete.

Recommendations

It is recommended to use a maximum replacement of GSA in concrete production of 5% LBWA

It is recommended that the concrete curing should be extended beyond 28 days to ascertain the long term strength development of LBWA modified concrete.

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