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STRENGTH DEVELOPMENT OF CONCRETE USING SEVERAL NIGERIAN CEMENT BRANDS

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Abstract

This work reported the strength development of concrete using several Nigeria cement brands. This has become imperative due to the recent development of uncertainty of the quality of cement produced in Nigeria. The cement brands used were Dangote, Elephant and BUA Portland cement respectively. They were used to produce concrete specimens of seventy-five (75) moulds with dimensions 100 mm x 100 mm x 100 mm and fifty (50) beam moulds with dimensions 100 mm x 100 mm x 500 mm with input from the surface response methodology. They were cured for 3 days, 14 days, and 28 days respectively.

The result shows that BUA branded cement concrete was best in compressive strength by 26.8 % and 29.4 % over Dangote and Elephant branded cement concrete at 28 days of curing. However, Dangote branded cement concrete has the same flexural strength with Elephant branded cement concrete but was better in flexural strength than BUA branded cement concrete at 28 days of curing by 3.10 %. The quadratic model was able to predict the compressive and flexural strength of the branded cement concrete with a R^2 of 0.9813 and 0.9613 respectively.

***Keywords*:** cement, branded cement concrete, compressive strength, flexural strength

Introduction

Concrete is an artificial stone-like material used for various constructional purposes and manufactured by mixing cement and various aggregates, such as sand, pebbles, gravel, stone, shale, etc with water and sometimes admixture and allowing the mixture to harden by hydration [1]. Better still, concrete could be a composite material, which is made up of filler and a binder. The binder which is the cement paste glues the filler together to form a synthetic conglomerate. The constituents used for the binder are cement and water, while the filler can be fine or coarse aggregates. At times an admixture such as plasticizer may be added to improve some of the properties of concrete [2-5].

Cement is any material that hardens and becomes strongly adhesive after application in plastic form. It is a basic ingredient of concrete, mortar, and plaster. It is a binder material which is formed by the hydration of cement. After adding water to the cement, it begins to hydrate and forms a gel. Gupta et al [4] asserted that cement needs 23 % of water of its weight for hydration and 15 % for filling the space or voids of gel. The strength of concrete depends upon the physical characteristics of this gel. Cements are made in a wide variety of compositions for a wide variety of uses.

Cement may be natural or artificial depending on the purpose of use. Some may contains epoxy resins for the materials they join, such as glass or vinyl cement; for the object to which they are applied, such as boiler cement, or for their characteristic property, such as hydraulic cement, which hardens underwater, or acid-resisting cement, or quick-setting cement [4]. According to Chudley and Greeno [5] cements used in construction are sometimes named for their commonly reported place of origin, like Roman cement, or for their resemblance to other materials, such as Portland cement, which produces a concrete resembling the Portland stone used for building in England. Portland cement is the name given to a cement obtained by intimately mixing together calcareous (containing limestone) and argillaceous (sedimentary rocks made up of clay or silt particles), or other silica-alumina and iron oxide bearing materials, burning them at a clinkering temperature and grinding the resulting clinker [6]. Cements that resist high temperatures are called refractory cements [6].

In the Nigerian construction industry, the most commonly used cementitious material is the Ordinary Portland Cement (OPC) which includes Dangote Cement, Elephant Cement, Ashaka Cement, Ibeto Cement, Bua cement, Sokoto Cement e.t.c. These falls into Type I class of cement according to [7]. Of recent there has been a serious controversy as to whether

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the brands of OPC used in the country can attain adequate strength. In fact, the Standard Organization of Nigeria (SON) even attributes the incidences of building collapse in the country to this assumption. It is also important to know whether the cement brands produced and used in Nigeria develop adequate strength when used to produce concrete to meet the desired strength. Also it is needful to know the rate of strength development, to be able to decide the time to strike the formwork during construction [8].

According to Umasabor and Alutu [9] the strength development of concrete is least affected by the grade of cement but rather the water/cement ratios, aggregate/ cement ratios e.t.c. Several tests are carried out to ascertain the extent of strength development of concrete which includes compressive strength, flexural strength, modulus of elasticity, workability test, and density test e.t.c. This study is therefore an attempt to study the rate of strength development between 3 days to 28 days of some Nigerian cement brands.

Materials and Methods

The number of concrete specimen produced according to BS 1881: Part 124 methodology [10] were seventy-five (75) moulds of dimensions 100 mm x 100 mm x 100 mm and fifty (50) beam of dimensions 100 mm x 100 mm x 500 mm. After the curing duration of 3 days, 14 days, and 28 days on the concrete specimens, compressive and flexural tests were carried out. The third point flexural test was conducted according to BS EN 12390-5 methodology [11] to obtain their various flexural strengths. The compressive strengths tests were conducted using BS EN 12390-3 methodology [12]. Several tests which included sieve analysis test for the sand and specific gravity test were also carried using the several cement brands.

Design-Expert 7.0 software was used to carry out the experimental design for the grade 25 concrete and it produced twenty-five (25) factorial designs as shown in Table 1. The selection of this software was due to the ease in which the designs of experiments were done before laboratory works were carried out. The coded value of 1 was taken for Dangote brand, coded value of 2 for Elephant brand and coded value of 3 for BUA brand respectively.

This work studied the responses (compressive and flexural strength of the various branded concrete) on the independent variables (fine aggregate, coarse aggregate, Dangote brand cement, Elephant brand cement and BUA brand cement content, water content, and ages of curing of the concrete). The responses (compressive and flexural strengths of the branded concrete) were obtained as stated in Table 3. The F-test in equation 1 was used to check the significance of the model while adequacy of the model was done by the coefficient of determination (R^2) in equation 2.

$$F = \frac{\sigma_1^2}{\sigma_2^2} \qquad (1)$$

where

$\sigma_1^2 = variance\ of\ dependent\ variable$

$\sigma_2^2 = variance\ of\ independent\ variable$

$$R = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n^*(\sum x^2 - (\sum x)^2]^*\,[n^*(\sum y^2 - (\sum y)^2)]}} \qquad (2)$$

where

$R = coefficient\ of\ determination$

$x = independent\ variable$

$y = dependent\ varaible$

$n = number\ of\ data\ set$

Results and discussion

Sieve analysis test

The fine aggregate were subjected to sieve analysis test according to [13]. The result is shown in Figure 1 below.

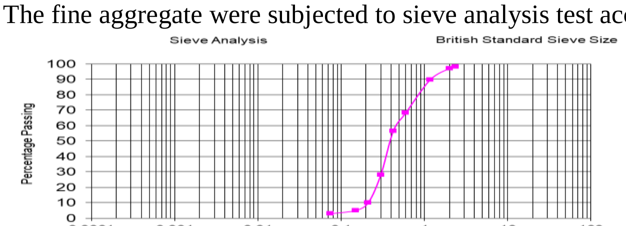

Figure 1: Sieve analysis for the fine aggregate

Specific gravity test

The samples of the fine aggregate were subjected to specific gravity test according to ASTM C127 methodology [14]. The specific gravity of 2.51 was obtained for the fine aggregate. This falls within the minimum requirement for fine aggregate of 2.4 to 2.7

Table 1: Experimental design value for some Nigerian branded cement concrete

Run	Fine Aggregate (Kg/m^3)	Coarse Aggregate (Kg/m^3)	Cement brand	Curing duration (Days)
1	0.633	1.106	3.00	24.47
2	0.569	1.106	3.00	3.00
3	0.630	1.149	2.00	3.00
4	0.633	1.175	2.00	28.00
5	0.633	1.175	3.00	3.00
6	0.633	1.143	2.47	18.01
7	0.595	1.149	1.00	4.95
8	0.633	1.139	1.00	16.12
9	0.569	1.175	1.00	28.00
10	0.633	1.175	3.00	3.00
11	0.633	1.106	1.99	3.00
12	0.569	1.166	2.00	3.00
13	0.569	1.175	3.00	28.00
14	0.624	1.106	1.00	20.62
15	0.603	1.138	2.01	14.96
16	0.571	1.131	2.00	3.00
17	0.600	1.175	2.01	28.00
18	0.569	1.166	2.00	3.00
19	0.569	1.106	2.01	28.00
20	0.569	1.106	3.00	3.00
21	0.569	1.106	1.00	3.00
22	0.624	1.106	1.00	28.00
23	0.569	1.175	3.00	28.00
24	0.633	1.175	1.00	3.00
25	0.592	1.123	2.00	12.40

Compressive and Flexural Strength Development

Table 1 shows the experimental design for the branded concrete while Table 2 shows the experimental design and responses (compressive and flexural strengths) of the concrete using the several brands of cement. There was an early increase in compressive strength of the branded cement concrete at 3 days of curing. The strength development were 87.7 % of its 28 days compressive strength was achieve in 3 days of curing duration for Dangote branded cement concrete, 73.2 % of its 28 days compressive strength was achieved at 3 days curing duration for BUA branded cement concrete and 74.4 % of its 28 days compressive strength was achieved at 3 days curing duration for Elephant branded cement concrete. This conforms to BS EN 197:1 minimum standards [15]. However, Dangote branded concrete was 6.0 % and 8.7 % higher in compressive strength than BUA and Elephant branded concrete. This was corroborated [16].

At 28 days of curing duration, the optimum concrete compressive strength for Dangote branded concrete was 23.5 N/mm^2. While the compressive strength for Elephant and BUA branded concrete at 28 days of curing were 22.67 N/mm^2 and 32.1 N/mm^2 respectively. These show that BUA cement concrete is 26.8 % and 29.4 % higher in compressive strength over Dangote and Elephant branded cement concrete at 28 days curing duration. This was collaborated by [9,16].

There was an early increase in flexural strength of the concrete for all branded cement concrete at 3 days of curing. However, BUA branded concrete flexural strength development was 21.2 % and 38.4 % higher than Dangote and Elephant branded concrete at 3 days curing duration. At 28 days of curing duration, the optimum concrete flexural strength for Dangote branded concrete was 2.26 N/mm^2. While the flexural strength for Elephant and BUA branded concrete at 28 days of curing were 2.26 N/mm^2 and 2.19 N/mm^2 respectively. These show that Dangote cement concrete has same flexural strength with Elephant cement concrete but has a 3.10 % increase in flexural strength over BUA cement concrete. The difference of flexural strength which was negligible was corroborated by [9].

The adjusted coefficient of determination (R^2) of the quadratic model for compressive strength of the branded concrete showed a value of 0.9813. This is a pointer that 98.13 % of the variations in the compressive strength of the concrete were explained by the independent variables (branded cement, fine aggregate, coarse aggregate and curing duration). The p-value of 0.0001 has shown that the quadratic model is significant as reported in Table 3. Similarly, the result of the quadratic model for the flexural strength of the branded concrete gives an adjusted R^2 of 0.9613. It indicates that 96.13 % of the variations in the flexural strength of the branded concrete were explained also by the independent variables (brand cement, fine aggregate, coarse aggregate and curing duration). The significance of the quadratic model for the flexural strength of branded concrete was explained by the F-test value of 43.55 and the p-value of 0.001 respectively as reported in Table 4.

Table 2: Experimental design and responses for some Nigerian branded cement concrete

Run	Fine Aggregate (Kg/m^3)	Coarse Aggregate (Kg/m^3)	Cement brand	Curing duration (Days)	Compressive Strength (N/mm^2)	Flexural Strength (N/mm^2)
1	0.633	1.106	3.00	24.47	32.1	2.19
2	0.569	1.106	3.00	3.00	23.5	1.425
3	0.630	1.149	2.00	3.00	16.9	1.275
4	0.633	1.175	2.00	28.00	22.67	2.154
5	0.633	1.175	3.00	3.00	23.5	1.425
6	0.633	1.143	2.47	18.01	18	1.425
7	0.595	1.149	1.00	4.95	25	1.35
8	0.633	1.139	1.00	16.12	22.83	1.725
9	0.569	1.175	1.00	28.00	23.5	2.2575
10	0.633	1.175	3.00	3.00	16.9	1.425
11	0.633	1.106	1.99	3.00	16.9	1.275
12	0.569	1.166	2.00	3.00	16.9	1.275
13	0.569	1.175	3.00	28.00	32.1	2.19
14	0.624	1.106	1.00	20.62	28.5	2.2575
15	0.603	1.138	2.01	14.96	32.1	2.19
16	0.571	1.131	2.00	3.00	22.83	1.725
17	0.600	1.175	2.01	28.00	18	1.425
18	0.569	1.166	2.00	3.00	16.9	1.35
19	0.569	1.106	2.01	28.00	22.67	2.2575
20	0.569	1.106	3.00	3.00	23.5	2.19
21	0.569	1.106	1.00	3.00	25	1.35
22	0.624	1.106	1.00	28.00	28.5	1.425
23	0.569	1.175	3.00	28.00	32.1	2.19
24	0.633	1.175	1.00	3.00	25	1.35
25	0.592	1.123	2.00	12.40	18	1.425

Table 3: ANOVA for the quadratic model (compressive strength)

Source	Sum of Squares	Df	Mean Square	F Value	P Value
MODEL	637.30	14	45.52		<0.0001
A-FINE AGGREGATE	0.21	1	0.21	0.42	0.5314
B-COARSE AGGREGATE	0.16	1	0.16	0.32	0.5819
C-CEMENT TYPE	10.46	1	10.46	20.92	0.0010
D-DAYS	113.42	1	113.42	226.86	<0.0001
AB	1.58	1	1.58	3.16	0.1057
AC	0.61	1	0.61	1.21	0.2969
AD	0.51	1	0.51	0.30	0.5935
BC	1.67	1	1.67	3.34	0.0975
BD	0.37	1	0.37	0.74	0.4104
CD	30.32	1	30.32	60.65	<0.0001
A^2	4.73	1	4.73	9.46	0.0117
B^2	5.85	1	5.85	11.71	0.0065
C^2	271.20	1	271.20	542.45	<0.0001
D^2	17.74	1	17.74	35.48	0.0001
Residual	5.00	10	0.50		
Cor Total	642.30	24			

Table 4: ANOVA for the linear model (flexural strength)

Source	Sum of Squares	Degree of freedom	Mean Square	F Value	P Value
MODEL	3.86	14	0.28	43.55	<0.0001
A-FINE AGGREGATE	3.466E-003	1	3.466E-003	0.55	0.4765
B-COARSE AGGREGATE	3.038E-003	1	3.038E-003	0.48	0.5043
C-CEMENT TYPE	1.559E-003	1	1.559E-003	0.25	0.6305
D-DAYS	2.62	1	2.62	413.33	<0.0001
AB	1.911E-003	1	1.911E-003	0.30	0.5949
AC	8.138E-005	1	8.138E-005	0.013	0.9120
AD	1.136E-003	1	1.136E-003	0.18	0.6808
BC	7.743E-003	1	7.743E-003	1.22	0.2948
BD	3.282E-	1	3.282E-	0.52	0.4881
	003		003		
CD	1.358E-003	1	1.358E-003	0.21	0.6532
A^2	4.869E-004	1	4.869E-004	0.077	0.7872
B^2	5.976E-003	1	5.976E-003	0.94	0.3543
C^2	0.083	1	0.083	13.09	0.0047
D^2	0.10	1	0.10	16.28	0.0024
Residual	0.063	10	6.334E-003		
Cor Total	3.39	24			

Conclusion

Based on the findings, it can be deduced that all the branded cement examined in concrete was satisfactory in compressive and flexural strength respectively. The BUA branded cement concrete was best in compressive strength by 26.8 % and 29.4 % over Dangote and Elephant branded cement concrete at 28 days of curing. However, when early compressive strength is required for any work, Dangote branded cement concrete may be better. BUA branded cement concrete has an early flexural strength increase at 3 days of curing better than Dangote and Elephant branded cement concrete. However, Dangote branded concrete has the same flexural strength with Elephant branded cement concrete but was better in flexural strength than BUA branded cement concrete at 28 days of curing by 3.10 %. The quadratic model was able to predict the compressive and flexural strength of the branded cement concrete with a R^2 of 0.9813 and 0.9613 respectively.

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