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Comparative Study of the Flexural Strength of Concrete Made from Selected Brands of Cement in Benue State, Nigeria

Helen Wuese Agi[1], Aondoseer Abraham Atoo[1*], Erubi Emmanuel Agida[1]

[1]*Civil Engineering Department, Joseph Sarwuan Tarka University Makurdi, Nigeria*

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ABSTRACT: The flexural strength characteristics of reinforced concrete produced with three brands of Portland limestone cement available in Benue State was studied. Initial and final setting time test was conducted on the cement samples with slump test carried out on the wet concrete. Reinforced concrete beams was produced with the cement brands and tested for deflection and flexural strength. The cements selected where BUA, Dangote's BlocMaster and 3X Portland limestone cement. Dangote BlocMaster cement had a maximum deflection of 9 mm at 28 days, Bua and 3X maintained a deflection of 8 mm at 28 days. A maximum flexural strength of 59.54 N/mm^2 was achieved at 28 days using Bua cement. Flexural strength values of 57.93 N/mm^2 and 55.72 N/mm^2 were obtained for concrete produced with Dangote BlocMaster and Dangote 3X cement, respectively. All the selected brands of cement within the study area met the required standard with Bua cement most preferred to be used in reinforced concrete structural members since it tends to offer more resistance to bending failure.

KEYWORDS: Cement, Concrete, Flexural strength

I. INTRODUCTION

Concrete has been seen as a very durable material with little or no maintenance during its life time. Concrete is a material that is made of up three constituents namely aggregates, water and cement (binding material) [1]. Portland limestone cement is commonly available in the study area. It comprises of fine aggregate (normally river sand) and coarse aggregates which is often crushed granites or river gravel.

Concrete is the most widely used building materials for constructing load bearing elements such as beams, columns, slabs and other works in civil engineering constructions, due to its irreplaceable advantages over other building materials. Civil engineering infrastructure works has rapidly increase in Nigeria with quality problem of construction works also increasing, which has recorded most failures witnessed in our buildings these days [2]. Portland cement is the commonly used cement, though several types such as Portland Pozzolana Cement (PPC) [3], rapid hardening cement [4], Sulphate resistant cement etc [5]. Concrete produced is based on the cement available/desired which also determines its strength [6].

Materials that have high tensile strength and can withstand tensile forces to some certain levels are used for improving concrete's tensile strength to achieve the desired serviceability and resist tensile forces. These materials are called reinforcement materials and they are steel, fibres, and wire mesh. These materials when added to concrete improves the tensile strength of concrete[7].

A reinforced concrete beam is a structure comprising of Cement, aggregates (course and fine), reinforcements and water in a definite proportion. A reinforced concrete beam is a structural member whose properties may be predetermined by careful design, analysis and control of the constituents' materials. Reinforced concrete beams are used in industrial buildings, transport facilities, apartments, houses and other construction projects [8].

Several critical factors influence the flexural strength of reinforced concrete. These factors include concrete mix design, which includes the proportions of cement, water, and aggregates, plays a significant role in determining strength and durability[9]. Another is water-cement ratio (w/c) which is very important; a lower w/c ratio generally enhances strength, while a higher ratio has the potentials to weaken it[10]. Also, the spacing and size of reinforcement bars are essential, as properly sized and spaced bars provide necessary tensile

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strength, whereas inadequate spacing can compromise flexural strength [11]. The type and content of cement also affect the concrete's properties, with different cement types yielding varying results in strength and durability [12]. Lastly, the type and gradation of aggregates contribute to the overall performance, with well-graded aggregates enhancing strength and workability [13]. Together, these factors must be carefully considered to optimize the flexural strength of reinforced concrete. This is the reason why this study concentrated on one of the materials which is cement. Comparing it to see which of them is better out of the ones present in the study area.

The assessment of the quality of three brands of Portland cement in Ghana was studied, the results indicated that two of the three cement brands conform well to the European standard specification [14,15]. The result of the chemical parameters of two indigenous Portland cement brands sold in Nigeria indicated that the chemical composition conforms well to international standards and that majority of the Portland cement sold in Nigeria are better used for structures involved with low loading [16]. This is an indication that qualities of cement may differ based on the production origin.

The incessant collapse of building can be linked to the quality of concrete produced from substandard cement with low compressive strength[17]. Makurdi, the capital city of Benue State in Nigeria is not left out of this situation of building collapsed. Coalition of civil society groups and professional bodies in Nigeria construction industry accused manufacturer and importers of flooding Nigerian markets with substandard cement products but the manufacturer under the umbrella of Cement manufactures Association of Nigeria (CMAN) debunked this allegation, claiming that they are complying with conventional practices in cement production[18]. Although some regulatory and professional bodies like Standard Organization of Nigeria (SON), Council for the Regulation of Engineering in Nigeria (COREN) and Nigeria society of Engineer (NSE) aligned with CMAN'S claim. SON revealed that two major grades of Portland cement are 32.5 N/mm² and 42.5N/mm2 in terms of compressive strength [18].

II. EXPERIMENTAL METHODS

2.1 Materials and Laboratory Testing

2.1.1 Materials

Materials used in this research included three selected brands of cement which were obtained in the local market in Makurdi. The brands are namely BUA cement, Dangote BlocMaster and Dangote 3X Portland limestone cement. Figure 1 shows a pictorial image of the various cement brands used in their bagging. The second material is fine aggregate (River sand) which was obtained from river Benue. The third material is the coarse aggregate which crushed granite of 20 mm obtained from court 5 area of North Bank Makurdi was used. The fourth material is steel reinforcement Y10 (RINL – 10 mm-01-23) which was also obtained in the building materials open market. Water which is good enough for drinking and obtained from the school was also used for the experiments. Concrete mix design was done using the Department of Environment (DoE) method with a mix of 1:2:4 maintained for all the brands. A water/cement ratio of 0.57 was adopted. Table 1 shows the quantity of materials used in kg/m^3 as obtained from the mix design calculations for a 1 m^3 of concrete.

Table 1: Quantity of materials needed for 1 m^3 concrete

S/No	Material	Quantity (kg/m^3)
1	Cement	333
2	Fine aggregate	554
3	Coarse aggregate	1293
4	Water	190

All the materials were used in casting a reinforced beam specimen of 150 mm x 150 mm x 600 mm which was cured in a curing tank for 7, 14, and 28 days. Figure 2 shows the casted beams in their mould.

Figure 1: The brands of Portland limestone cement used

Figure 2: The casted beams in their mould

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2.2 Laboratory Testing
The following tests were conducted in the laboratory for this study.

2.2.1 Particle size distribution test
The particle size distribution test was performed according to BS 1377[19]. It is used to determine the particle size distribution of the fine and coarse aggregates used. This is to check if the aggregates are suitable for concrete mixing.

2.2.2 Specific gravity test
The specific gravity carried out on the aggregates and cement with the result of the test for the aggregate conforming to BS 812, [20]

2.2.3 Fineness test on cement
The fineness of cement test was conducted on the cement samples by sieve analysis (dry method) according to ASTM C184 – 94[21]

2.2.4 Setting time test on cement
The initial and final setting time of the cement brands used was determined according to BS-EN 196-1995 [22].

2.2.5 Slump test on concrete
The slump test was conducted on the concrete to determine the workability of the concrete.

2.2.6 Flexural test on beam
This test was conducted to determine the flexural strength of the beam using the universal testing machine. Figure 3 shows a simply supported beam with how the force is applied on it while figure 4 shows the experimental set-up of beam on a universal testing machine. The flexural strength is expressed as modulus of rapture (MR) and is calculated using equation 1.

$$MR = \frac{3FL}{2bd^2} \quad (1)$$

Where, F = maximum applied load (force) at the cracked point (N).
L = total span/length in mm (600 mm used)
b = width of specimen in mm (150 mm used)
d = depth of specimen in mm (150 mm used)

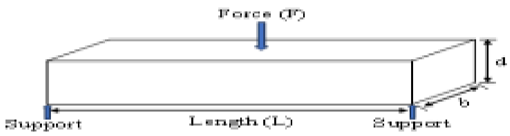

Figure 3: Simply supported beam


Figure 4: Beam set-up on a universal testing machine

III. RESULTS AND DISCUSSION

3.1 Sieve analysis
The sieve analysis test was conducted on the aggregates with figure 5 showing the particle size distribution curve for fine aggregate which is evenly distributed. The fine aggregate particles fall within the limit specified by BS 882 for natural soil. Figure 6 shows the particle size distribution curve for coarse aggregate which shows that majority size ranges from 20 mm to 10 mm.

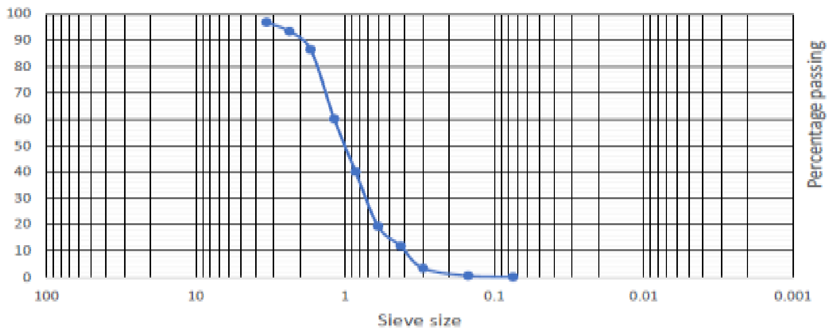

Figure 5: Particle size distribution curve for river sand

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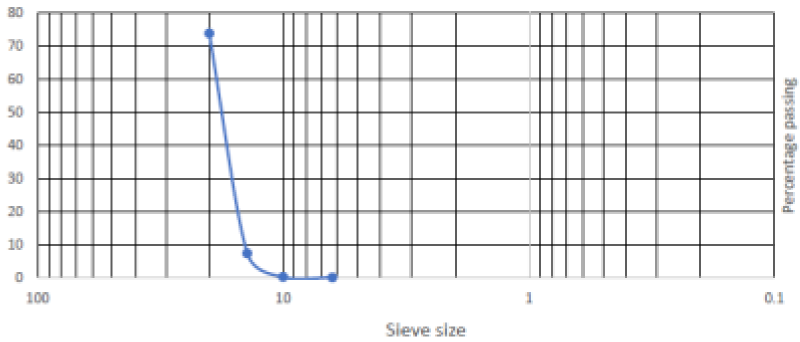

Figure 5: Particle size distribution curve for coarse aggregate

3.2 Specific Gravity

The specific gravity of the cement specimens was examined for each brand of cement and the results are presented in table 2. It shows that the specific gravity of BUA cement falls slightly below the standard 3.15 requirement for cement, though it has the best value for specific gravity at 3.14; followed by Dangote 3X at 3.13 and Dangote BlocMaster with 3.12. The specific gravity of the river sand and granite coarse aggregate used was found to be 2.6 and 2.66 respectively which conforms to BS 812 [20] specification (see table 3).

3.3 Fineness test

Table 4 shows the fineness test result obtained from the various brands of cement with all the values ranging from 98 – 100% which agrees with BS EN 196-6[22] requirements.

Table 2: Specific gravity of cement used

S/No	Brand of Cement	Test 1	Test 2	Average Specific Gravity
1	BUA	3.20	3.07	3.14
2	Dangote 3X	3.12	3.13	3.13
3	Dangote BlocMaster	3.11	3.13	3.12

Table 3: Specific gravity of aggregates used

S/No	Aggregate	Test 1	Test 2	Average Specific Gravity
1	Fine aggregate	2.59	2.60	2.60
2	Coarse aggregate	2.64	2.68	2.66

Table 4: Fineness test result on cement used

Cement brand	Experiment No.	Total weight of Cement (g)	Weight of residual (g)	Fineness %	Average fineness
BUA	1	100	0.2	99.9	99.85
	2	100	0.1	99.8	
Dangote 3X	1	100	0.5	99.5	99.65
	2	100	0.2	99.8	
Dangote BlocMaster	1	100	0.6	99.4	98.85
	2	100	1.7	98.3	

3.4 Setting time test

The initial setting time and final setting time results falls within limits with Dangote 3X and BlocMaster having an initial setting time of 30 minutes each while BUA is 35 minutes. BUA also has the highest final set time of 600 minutes with Dangote 3X and BlocMaster having 545 minutes and 430 minutes respectively.

3.5 Slump test

The results of the slump test shows that all the cement brands have true slump with Dangote 3X having 22 mm, BlocMaster 24 and BUA 20 with the cone used having a common cone height of 300 mm.

3.6 Flexural strength test

The flexural strength test results shown in table 5 reveal that Bua cement gains more strength than BlocMaster and Dangote 3x cement, after 7 days of curing to withstand failure load while Dangote has the least strength to resist failure in bending after 7 days of age. Also, after 14 and 28 days of curing, Bua cement still maintains the highest strength to withstand failure in bending than BlocMaster and Dangote 3x cement with flexural strength of 59.54 N/mm^2.

Table 5: Average flexural strength test results on the beams

S/No	Specimen	Average flexural strength (N/mm^2)		
		7 days	14 days	28 days
1	BUA	51.88	55.56	59.54
2	Dangote BlocMaster	46.81	53.45	57.93
3	Dangote 3X	46.77	52.52	55.72

IV. CONCLUSION

The comparative analysis of flexural strength of reinforced concrete of three brands of Portland limestone cement used in Makurdi, Benue state was investigated. The following were highlighted from the experimental investigation.

1. Setting time of the cements did not differ significantly, however, BlocMaster and Dangote 3x set earlier than Bua.
2. The specific gravity test for the three brands of Portland limestone cements obtained were within the range of 3.12-3.14 as specified by BS-EN 196-6 [22]. All values obtained for the specific gravity test of the cements were below the standard value of 3.15 as verified by Nwankwojike and others [17].
3. At 28 days of age, Bua cement had the highest flexural strength of 59.54 N/mm² with low progressive strength development, while BlocMaster had a higher rate of strength development, though with a low flexural strength as well as Dangote 3x at 28 days.
4. All cements brands used are fit for normal construction works, but for the purpose of major reinforced structural constructions, Bua cement could be given preference since it had the highest strength to resist failure due to bending.

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