Comparative Analysis Of The Quality Of Portland Cement Sourced From Dangote Cement Factory Obajana And Bua Cement Factory Sokoto

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Abstract: This study emphasizes the critical role of high-quality cement in ensuring the durability and structural integrity of concrete-based construction. The quality of cement significantly impacts a building's compressive strength, workability, and overall performance. Portland cement, a key binding agent in concrete production, is examined in this study through a comparison of BUA Cement from the Sokoto factory and Dangote Cement from the Obajana cement factory. Various physical, chemical, and mechanical tests were conducted according to British standards, involving 30 cubes and 12 beams. Testing occurred at intervals of 7, 14, 21, and 28 days, with selected beams subjected to sulfuric acid immersion. The findings suggest that Dangote Cement excels in terms of compressive strength, crushing strength, workability, and durability, essential attributes for construction. On the other hand, BUA Cement demonstrates faster setting times, enhanced scheduling flexibility, and superior overall performance. The study highlights BUA Cement's higher content of key chemical components, though the differences between compositions are relatively small. These findings emphasize the importance of selecting the right cement type based on specific construction requirements.

Keywords: Cement quality, construction materials, compressive strength, setting time, chemical composition, durability, construction performance.

1. Introduction

Cement is crucial for concrete production, emphasizing the importance of high-quality cement to prevent building failure. High-quality cement contributes to the durability and quality of construction projects, ensuring resistance to environmental factors [10]. Concrete is a widely used building material with cement as a binder, especially in developing countries like Nigeria [1]. Cement and concrete production impact the environment [2]. Portland cement is a vital construction material; its quality is essential for the construction industry's survival. The construction industry plays a pivotal role in economic development. The use of Portland cement is common in construction, and there are various brands available [4]. Portland cement is produced from a mixture of minerals, mainly calcium silicate, and is a hydraulic cement [17]. Quality improvement is crucial throughout the development process as Low-quality cement can compromise the integrity of reinforced concrete structures, potentially leading to structural failures [18].

This study source, compares and analyzes the quality of Portland cement sourced from Dangote Cement Factory Obajana and BUA Cement Factory Sokoto, to ensure good quality cement in the markets for construction purposes. The study, specifically determines the Physical, Chemical, and Mechanical properties, comparing their qualities with standards to assist engineers with the properties in choosing the right cement.

2. Background of the Study:

Portland cement is widely used globally and is made by combining calcareous and argillaceous materials, burning them at a clinker temperature, and then cooling them. It gets its name from the resemblance in color and quality to Portland stone from the Isle of Portland in Dorset, England [16]. The chemical composition of Portland cement includes major oxides like CaO, SiO_2, Al_2O_3, and Fe_2O_3, and minor oxides like MgO, SO_3, Na_2O, K_2O, and others [14]. Portland cement is the most common type used in mortar and concrete for various construction applications [16]. Different brands of Portland cement in Nigeria's market have varying properties, including setting time, workability, fineness, and crushing strength [9]. Good quality cement is crucial for the structural integrity of buildings and structures, as inferior quality cement can lead to reduced lifespan, crumbling, or collapse [15]. The durability of surface finishes, material thickness, and cement layer thickness all depend on cement quality [15].

Physical properties include fineness, soundness, consistency, setting time, heat of hydration, specific gravity, loss of ignition, and bulk density [7], [5]. Chemical properties are Bogue's compounds, including Tricalcium Silicate (C3S), Dicalcium Silicate (C2S), Tricalcium Aluminate (C3A), and Tetracalcium Alumino Ferrite (C4AF), are key components. Other chemical constituents include lime, alumina, alkalis, magnesia, and ferrite [7]. Mechanical properties include flexural strength, durability, and compressive strength [13], [3]. Good cement provides strength, stiffness, early hardening, excellent plasticity, easy workability, and moisture resistance [13], [3].

Standard types include Type I, Type IA, Type II, Type IIA, Type II(MH), Type II(MH)A, Type III, Type IIIA, Type IV, and Type V [11]. Different types of concrete include plain/ordinary, reinforced, prestressed, lightweight, high-density, precast, in-situ cast, fiber-reinforced, glass-reinforced, air-entrained, self-compacting, polymer, and smart concrete [8]. Workability is a measure of how easily concrete can be mixed, transported, placed, and compacted while retaining homogeneity BS EN 12350-2:2009 [6]. Workability is influenced by factors like water-cement ratio, mix proportion, size, shape, grading of aggregates, and use of supplementary materials BS EN 12350-2:2009 [6]. Factors affecting workability include cement content, type and composition of cement, water content, mix proportions, size, and shape of aggregates, grading of aggregates, surface texture of aggregates, and use of supplementary cementitious materials [12].

3. Materials and Methods:

The research was conducted at the civil engineering laboratory at Nigeria Defense Academy, Kaduna State, Nigeria. Two brands of Portland cement, Dangote Cement, and BUA Cement were used for analysis. Lab work was conducted at a normal temperature of 32°C. Various tests were performed on the cement, including compressive strength, slump test, crushing test, moisture content, specific gravity test, sieve analysis, consistency, flexural test, durability test, and setting time test. The Portland cement concrete test was carried out according to the procedure for reference concrete BS EN 206:2013+A1:2016.

The materials used included: cement (Dangote Cement and BUA Cement), fine aggregate (river sand), coarse aggregate (crushed granite stone), water, and sulphuric acid. Specific details about the sources and specifications of these materials were provided.

Sample Size: A total of 30 cubes (100 x 100 x 100mm) and 12 beams (100mm x 100mm x 500mm) were cast. These samples were divided between BUA Cement and Dangote Cement. The cubes were cured for different durations (7, 14, 21, and 28 days), and some cubes were used for durability tests. The beams were used for flexural tests after curing for 7 and 28 days.

The methods used included: (i) Absolute Volume Method: The Absolute Volume Method was used to calculate the quantities of materials required for each specimen. Specific calculations for the absolute volumes of cement, fine aggregate, coarse aggregate, and water were provided for both BUA Cement and Dangote Cement. (ii) Batching: Proportioning of the constituent materials was done by weight as per the Absolute Volume Method calculation. (iii) Mixing, Casting, and Compaction: The mixing was done manually in a metal mixing bay. The slump test and compacting factor test were performed on the plastic mass to evaluate workability. Cubes were cast in two layers and vibrated on a vibrating table. (iv) Workability of Concrete: The slump test was conducted to assess the workability of the concrete. A frustum cone mold was used for this test. The compacting factor test was also performed to complement the workability assessment. (v) Durability and Curing of the Concrete: Curing of concrete was emphasized as a critical step in producing concrete. Samples underwent tests to determine compressive strength after 7, 14, 21, and 28 days. Beams were constructed for the concrete's flexural strength test. Some samples were cured in sulphuric acid for an acid durability test after 28 days. (vi) Flexural Test: Center-point loading test procedures were used to determine flexural strength. The formula provided for calculating flexural strength was based on the maximum force applied, span length, width of the span, and depth of the sample. The crushing test for compressive strength was conducted. (vii) Density of the Composite: The hardened concrete density was calculated by dividing the mass of the specimen by its volume. (viii) Compressive Strength Test: A compressive test was conducted to determine the concrete's characteristic compressive strength. The formula for calculating compressive strength was provided.

4. Results and Analysis:

Constituent materials used included cement from Dangote Cement factory (designated as D) and BUA Cement factory (designated as B). The quality of constituent materials significantly affects concrete properties.

4.1 Consistency: Water-cement ratio for BUA cement is 0.264 (26.4%) and for Dangote cement is 0.281 (28.1%).

4.2 Setting Time: Initial setting time of BUA cement is 3 hours 10 minutes and Dangote cement is 2 hours 45 minutes. Final setting time of BUA cement is 8 hours 39 minutes and for Dangote cement is 7 hours 25 minutes.

4.3 Workability of concrete:

It appears that both types of cement labelled in Figure 1 and 2 as B and D resulted in high compacting factors values (0.94 and 0.93) and relatively low slump values (10mm and 16mm) and slump types as "Zero." This indicates that the concrete mixtures casted with both types of cement exhibited limited workability and stiffness.

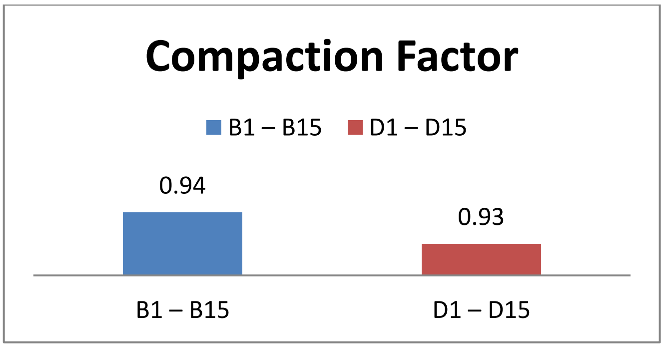

Figure 1: Compaction Factor

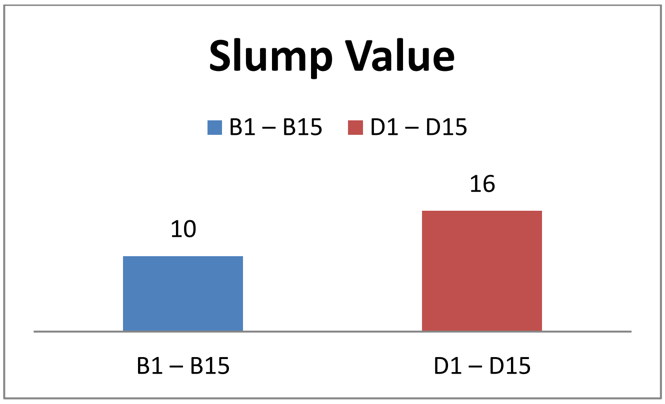

Figure 2: Slump Value

4.4 Crushing Test:
Figure 3 represents the strength at which different groups of cubes were crushed during testing. The cubes were labeled and tested at different ages ranging from 7 days to 28 days. BUA cement exhibited higher strength values compared to Dangote cement. The difference in strength varies at different time intervals ranging from 0.5 N/mm^2 to 2.5 N/mm^2. The strength of the concrete typically increased over time as it cured and gained more strength. BUA cement maintained a consistent strength advantage over Dangote cement throughout the testing time interval.

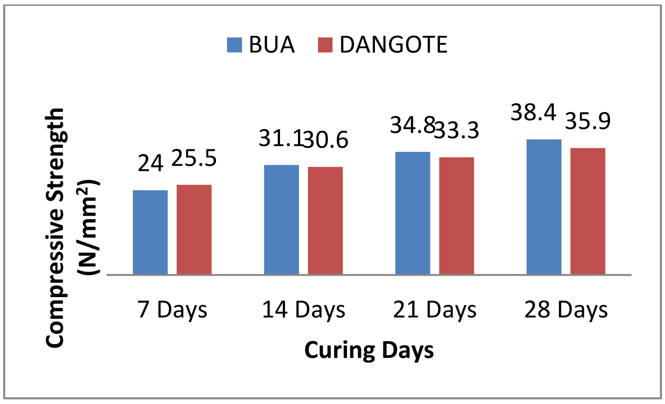

Figure 3: Crushing Strength Test

The density at failure varied as the concrete days of age increased (See Figure 4). Therefore, BUA exhibited a higher density compared to Dangote cement except for the day 14th when Dangote's density was higher. Both BUA and Dangote recorded the same density (2.55g/cm^3) at 21 days of age and BUA the highest density (2.77g/cm^3) at 28 days of age.

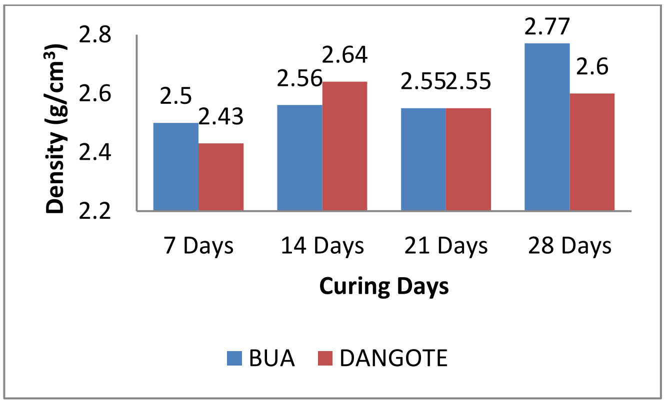

Figure 4: Density at Failure

BUA cubes had strength to be (12.6N/mm^2) and density (2.35g/cm^3) (See Figure 5) while Dangote cubes recorded strength of (10.3N/mm^2) and density (2.24g/cm^3). Dangote had less absorption of the acid solution as compared to BUA with the highest values.

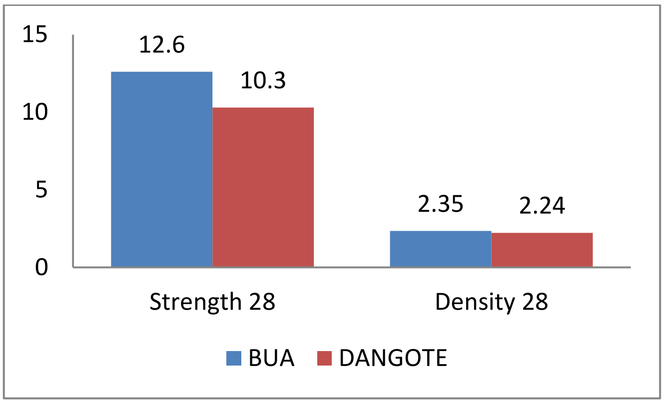

Figure 5: Crushing Test for Acid Solution

4.5 Flexural test:
The density values for both groups of beams are relatively close, with some overlap in the range. The specific differences in density between the B and D beams are not significant (See Figure 6). The flexural strength values for the B and D beams are also relatively similar, with overlapping ranges (See Figure 6). But we can conclude that Dangote cement have a higher flexural strength, which means it is harder and more durable to withstand failure and stress bending as compared to BUA cement.

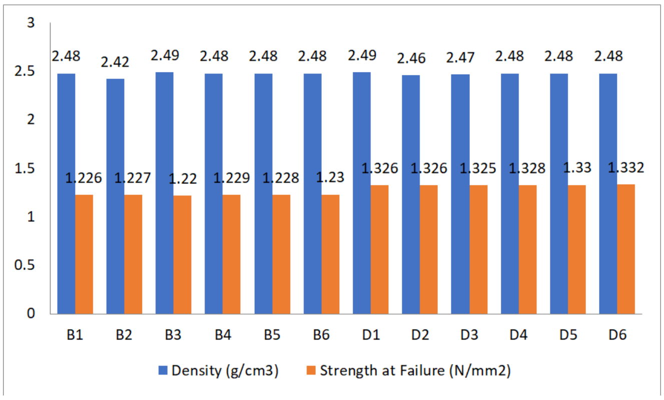

Figure 6: Flexural Test of Concrete

4.6 Durability Test:
The result of the durability test which is resistance to loss is shown in Figure 7 to Figure 9. Generally, higher percentages indicate low durability, as a greater proportion of the cube's weight was lost over time. Considering BUA cement, they exhibit higher percentages of weight loss compared to Dangote cement at each point. This suggests that BUA cement may have lower durability compared to Dangote cement. Therefore, it can be concluded from Figure 7, Figure 8, and Figure 9 that Dangote cement has better durability as a lower proportion of the cube's weight will be lost over the number of days. This is also indicative of their strength and integrity.

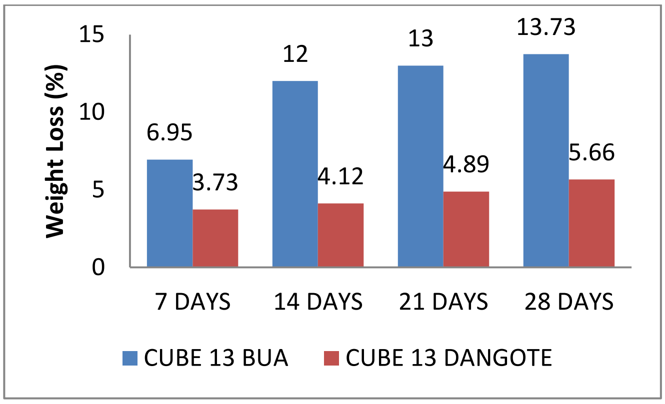

Figure 7: Weight loss of cube 13 casted over the curing days

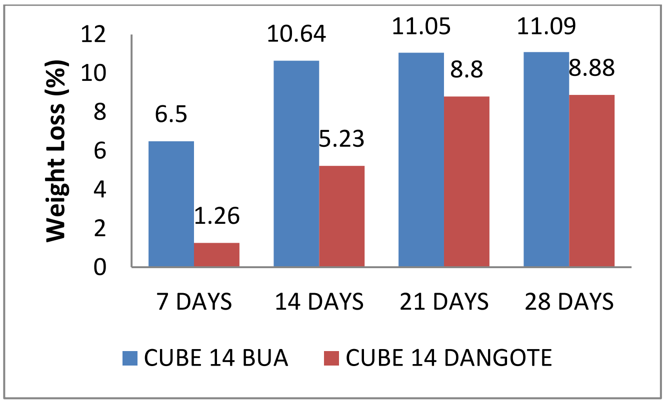

Figure 8: Weight loss of cube 14 casted over the curing days

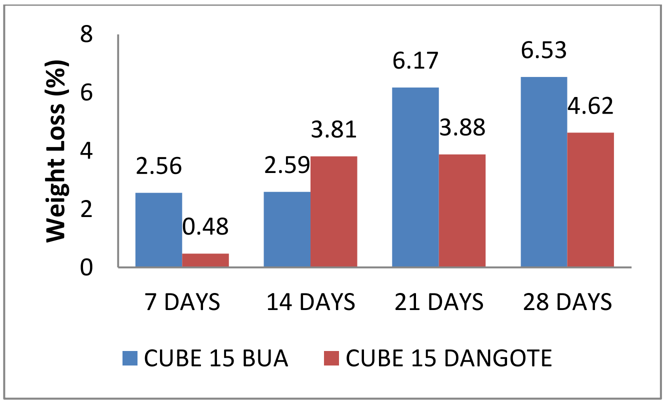

Figure 9: weight loss of cube 15 casted over the curing days

4.7 Chemical Oxide Composition

The oxide composition of BUA and Dangote cement is shown in Figure 10. The oxide composition was used to compute the values of Tricalcium Silicate, Dicalcium Silicate, Tricalcium Aluminate and Tetracalcium Aluminoferrite.

(i) Tricalcium Silicate (C3S): BUA Cement has a higher percentage of C3S (50.21%) compared to Dangote Cement (45.65%). C3S contributes to early strength development, and the higher value in BUA Cement suggests potentially faster strength gain.

(ii) Dicalcium Silicate (C2S): The percentage of C2S is comparable between the two cements, with BUA Cement having a slightly higher value (9.97%) compared to Dangote Cement (8.98%). C2S contributes to long-term strength development and the difference is relatively small.

(iii) Tricalcium Aluminate (C3A): BUA Cement has a higher percentage of C3A (8.99%) compared to Dangote Cement (6.56%). C3A contributes to early strength development and can affect the heat generation during hydration. The higher value in BUA Cement suggests potentially faster early strength development.

(iv) Tetracalcium Aluminoferrite (C4AF): BUA Cement has a higher percentage of C4AF (10.01%) compared to Dangote Cement (8.75%). C4AF contributes to color development and late strength. The higher value in BUA Cement suggests potentially better color and late strength development.

(v) Loss on Ignition (LOI): LOI represents the loss of mass in the cement when heated. BUA Cement has a lower LOI (3.29%) compared to Dangote Cement (6.46%). A lower LOI indicates a lower loss of volatile components and moisture during heating, which can contribute to better overall quality.

Therefore, considering these factors, BUA Cement indicates certain advantages over Dangote Cement in terms of higher CaO content, higher C3S content, higher C3A content, higher C4AF content, lower LOI, and slightly higher percentages of SiO_2 and AL_2O_3. These properties imply that BUA Cement provides better strength development, improved chemical resistance, and potentially enhanced color development.

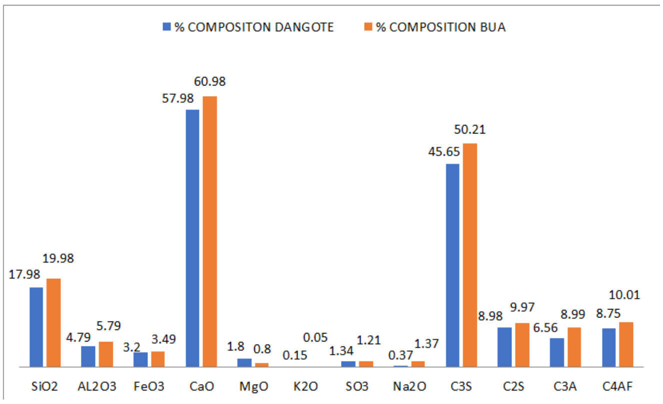

Figure 10: Chemical Oxide Composition for Dangote Cement and BUA Cement

5. Conclusion

Base on the results from the research the following conclusions can be made:

1. Chemical Composition and Strength Development: BUA Cement exhibited advantages in terms of higher significant chemical compounds and a lower water-to-cement ratio. This suggests that BUA Cement offers superior strength development, increased workability, and potentially higher overall performance.
2. Setting Time and Workability: BUA Cement displayed longer initial and final setting times, contributing to improved workability and construction schedule flexibility. Extended final setting time can facilitate enhanced curing and ensure the cement attains maximum strength.
3. Workability and Flowability: Dangote Cement outperformed BUA Cement in terms of workability

and flowability based on compacting factor and slump value tests.

4. Crushing Strength and Density: Dangote Cement consistently demonstrated higher crushing strength values, indicating superior compressive strength and durability for construction. Flexural strength values were relatively similar, but Dangote Cement exhibited a slight advantage.
5. Durability: Dangote Cement showed better durability with lower weight loss percentages, highlighting its suitability for construction materials.

Chemical Composition: BUA Cement displayed a well-balanced composition of chemical compounds, including higher CaO, C3S, C3A, C4AF content, and lower LOI. These properties suggest better strength development, improved chemical resistance, and potential for enhanced color development.

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