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Comparative Analysis of Concrete Strength Made from Selected Brands of Cement in Anambra State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author CBNBO initiated the idea, designed, carried out data acquisition and compiled the first draft of the manuscript. Author KCO supervise every stage of the work and proof read the manuscript. Author FOE managed the literature searches while author GCO handles the data experiments and analysis. All authors read and approved the final manuscript.

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ABSTRACT

The strength characteristics of concrete made from different brands of cement used in Anambra State, Nigeria are reported in this paper. Samples of the selected brands of cement were collected and are used in mixing concrete. The study was conducted in Anambra State, Nigeria for 10 months. Samples of the selected brands of cement were collected and are used in mixing concrete. The fine aggregates used was obtained from River Sand (Onitsha), coarse aggregate is 12 mm quarried granite and water used for the concrete mixing is fit for drinking. These samples of concrete are tested in the laboratory (Anambra State Material Testing Laboratory) for workability and compressive strength and the result obtained were presented in simple tables The study found out that the compressive strength (28th day) of BUA, SUPASET, DANGOTE and UNICEM cements were 30.5, 31.70, 29.66 and 29.08 N/mm^2, respectively. Also, the result of the slump value ranges from 70–140 (indicating that the concrete mix is workable) for all the four samples. The results indicate that SUPASET yielded the highest compressive strength (28th day) while UNICEM yielded

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the lowest compressive strength (28th day). The study was concluded by recommending that all the selected brands of cement within the study area met with the required standard. All concrete samples achieved the minimum compressive strength of concrete (i.e., 21 N/mm^2) within 7 days of production. Though the popular cement in the study area is DANGOTE, SUPASET cement is the best cement in terms of strength characteristics while UNICEM possesses the least compressive strength.

Keywords: Concrete; cement; compressive strength.

1. INTRODUCTION

Concrete is a composite construction material, composed of cement (commonly Portland cement) and other cementitious materials such as fly ash and slays cement, aggregates (overall coarse aggregate made of gravel or crushed rocks such as limestone, or granite plus a fine aggregate such as sand), water, and chemical admixture. The word concrete comes from the word "Concretus" (meaning compact and condensed) [1]; the perfect passive participle of "concrescence", from "con" (together) and "crescere" (to grow). Concrete as a material has been known since before Roman times, but it is only since the introduction of Portland cement by Joseph Aspdin, an English Manson, that it becomes widely regarded as a structural material. It is one of the most versatile materials of great strength and durability, provided good control measures are maintained through all the stages of production. To Ezeokonkwo [2], concrete can be described as any product or mass made by binding together particles of some inert materials by the use of cementing medium. Generally, the medium is the product of the reaction between hydraulic cement and water. Also, those inert materials are referred to as aggregates. The materials used as aggregates include sand, crushed stones, gravels, expanded clay etc. Concrete is composed of cement, water, aggregates (fine and coarse) and admixture which enables it to achieve a set goal, and a wide variety of ratio mixes obtained from these ingredients.

Conversely, Nigerian is a developing country with an annual increasing stock of building and infrastructure. It has a landmass of 923,768 square kilometres with a population of 140,003,542 according to the report of the 2006 National Population Census. According to the National Bureau of Statistics [3] suggests that Nigeria has an estimated housing deficit of over 17million unit. Emiedafe [4] also opines that Nigeria with a population of about 174 million people is currently facing a national housing deficit of about 17 million units. In 1991, the Nigeria housing deficit was at 7 million, it has since increased from 7 million in 1991, to 12 million in 2007, 14 million in 2010 and currently 17 million units. Emiedafe [4] further suggests that with a population of approximately 180 million, an annual population growth rate of 2.8 per cent (2015) and an annual urban population growth rate of 4.7 per cent, Nigeria needs to build about 700,000 housing units every year to bridge the housing gap. The main materials used for these indices of development are cement and concrete. This material is in high demand in the market because of the high increase in construction and high demand for buildings and infrastructures. In Nigeria, cement production has increased to 28 million metric tonnes as against the installed capacity of 50 million metric tonnes per annum [5] and there is a tendency that the need may double this amount shortly. Given the 44% shortfall, imported cement is used to fill the gap, but even then not enough cement is imported. As a result of this, cement importation business thrived (1999-2012) and Nigeria rose to become the world's third-largest cement importer [6]. They state that as a result of that, local production declined due to stagnant production capacity and shrinking utilization rates, cement imports expanded to meet the rising demand. Oyakhilome [7], in 2012, the Nigerian government went on with the implementation of Backward Integration Policy (BIP). This policy was to help ban the importation of cement and create an enabling environment for cement production and availability within the country. More recently, the policy was revised to 2 phases. Phase 1 was designed to address increased production and availability of cement in Nigeria. This phase has been largely successful given that Nigeria, according to available data, has attained self-sufficiency wherein local cement production is now more than adequate to cover domestic demand. Phase 2 was designed to address the issues of cement pricing, control, quality, uses and export. It is against this background, the study attempts to investigate the strength characteristics of concrete made from common brands of cement available in the market in Anambra State. The study will determine the chemical composition of the different brands of cement as well as the compressive strength of the concrete produced from different brands of cement and they will be compared to the relevant standard.

2. LITERATURE REVIEW

2.1 Concrete Properties

Concrete is a mixture of fine and coarse aggregate bound together by a paste of cement and water, forming a rocklike mass [8-10]. The cement acts as the binder and bonds the other aggregates together after undergoing a chemical reaction with water. Concrete is weak in tension but strong in compression. Introducing steel into the concrete provides the tensile strength lacking in concrete as steel has high tensile strength and this composite material is called reinforced concrete [10]. Bert-Okonkwor [5] suggests that concrete strength can be affected by the following factors:

i. water-cement ratio
ii. type of aggregate used
iii. the surface texture of these aggregates
iv. type/brand of cement used
v. the actual compound contained (compositions)
vi. age of the concrete
vii. the fineness of the cement
viii. the extent to which hydration was progressed

Each concrete mix has its particular characteristics and should be designed to suit the requirements for which it is intended. Mostly concrete strength increases with decrease in water-cement ratio and increase with age of concrete [11], once a particular concrete mix has been selected, it is important to maintain it throughout the series of operations, otherwise change in quality might be created in a structural member due to introduction of another concrete with different quality. Thus, constant checks are required on the quality of the concrete mixes throughout the progress of the structures.

2.1.1 Properties and effects of cement on concrete

a) Chemical Composition– Anosike [12], the ordinary and rapid hardening PC can be tested by the methods given in I.S. 4032. The results of the tests should comply with the following chemical requirements:

a. The ratio of the percentage of lime to the percentage of silica, alumina and iron-oxide when calculated by the following formula:

$$\frac{CaO - 0.7SO_3}{SiO_2 + 1.2\ Al_2O_3\ 0.65\ Fe_2O_3}$$

should be between 0.66 and 1.02.

b. The Ratio of the percentage of alumina to iron oxide should not be less than 0.66.
c. Weight of insoluble residue should not be more than 2%.
d. Weight of magnesia should not exceed 6%
e. Total sulphur content calculated as sulphuric anhydride (SO_3) should not exceed 2.75 or 3.0%.
f. Total loss of ignition should not be more than 2%.

b) Physical Properties- Okoli et al. [13], [14] specifies that the samples of Portland cement shall be tested for the following physical properties: fineness, soundness, compressive strength, and setting time. Each one of these properties influences the performance of cement in concrete. The fineness of the cement affects the rate of hydration. It also affects its place ability, workability and water content of a concrete mix much like the amount of cement used in concrete.

i) The fineness of cement–Fineness is a vital property of cement which influences the rate of reaction of cement with water (hydration). For a given weight of a finely ground cement, the surface area of the particles is greater than for a coarsely ground cement. The advantages of finer cement include;

- Increases the rate of hydration
- More rapid and greater strength development,
- Reduced bleeding rate of concrete,
- Improving the workability of concrete.

Neville and Brooks [15], three methods of determining the fineness of cement are by sieve analysis, by specific surface area method and by LEA and nurse method.

ii) Standard Consistency Test – this is that consistency which will permit the Vicat plunger to penetrate to a point 5 ± 2 mm from the bottom of the Vicat mould when the cement paste is tested by this apparatus. The water content of the standard paste is expressed as a percentage of the dry cement. Usually, this percentage varies from 26-33%. If the consistency value falls within the required range, it helps in the production of homogenous concrete mix.

iii) Determination of Compressive Strength – for determining the compressive strength of cement, cubes 50mm^2 in surface area are prepared of cement and sand and compacted using a standard vibrating machine. According to the Standard Organisation of Nigeria (SON), the compressive strength of concrete from Portland cement is 25 N/mm2.

2.2 Concrete Materials

Chudley and Greeno [9] assert that the proportions of each of concrete materials control the strength and quality of the resultant concrete. Fresh concrete is a plastic mass, which can be moulded into any desired shape. This is its main advantage as a construction material [16]. They further assert that aggregate, coarse and fine combined occupy about 70% space in a given mass of concrete and the rest 30% space is filled by water, cement and air voids Fig. 1.

Percentages of the Concrete Components

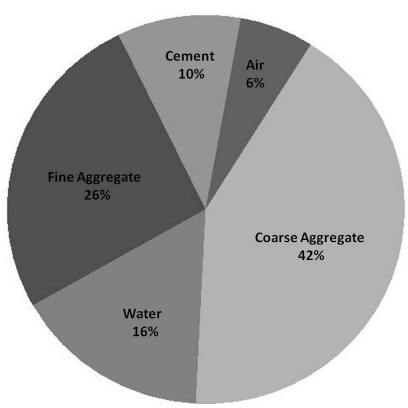

Fig. 1. Constituents of concrete (Anosike, 2010)

Bert-Okonkwor [5] in his definition described concrete as a mixture of Portland cement, fine aggregate coarse aggregate, air and water. Sharma [17] concludes in stating that concrete is a heterogeneous mix consisting of the following materials:-

- Cement
- Aggregates (Fine and coarse)
- Water
- Admixtures (if required).

2.2.1 Cement

Cement is a binder material, a substance made of burned lime and clay which after mixing with water, set and harden independently and can bind other materials together. Ezeokonkwo [2], cement is a cementitious material which has adhesive and cohesive properties necessary to bound inert aggregates into a solid mass of adequate strength and durability. Neville [18] also adds that cement is the binding material constituent of concrete which reacts chemically with water and aggregate to form a hardened mass on hydrating. Iheama [19] further defines it as a finely pulverized product resulting from calcination of natural argillaceous limestone at a temperature below the fusion. In addition to this Ivor [20], defines cement as a mixture of compounds, consisting mainly of silicates and aluminates of calcium, formed out of calcium oxide, silica, aluminium oxide and iron oxide.

Many authors [2,12,19,16] agreed to the fact that on the addition of water to cement, hydration takes place, liberating a large quantity of heat. On hydration of cement, the gel is formed which binds the aggregate particles together and provides strength and water tightness to concrete on hardening. Thus cement has the property of setting and hardening underwater by a chemical reaction with it.

Okereke [21], Portland cement is manufactured by firing a controlled mixture of chalk or limestone ($CaCo_3$) and substances containing silica and alumina such as shale in a kiln at 1500°c temperature. They are heated to clinker and grounded to a fine powder with a small proportion of gypsum (calcium sulphate) which regulates the rate of setting when the cement is mixed with water. Anosike [12] also states that the manufacture of PC consists of the following three distinct processes: Mixing, Burning and Grinding. Mixing can be done by dry-process or wet-process. The wet process is the most common. The main difference between the wet and dry production process is the larger amount of water expelled from the kiln during the production process.

2.2.2 Aggregates

Ezeokonkwo [2], the term aggregate includes the natural sand, gravels and crushed stone used in making concrete. Bert-Okonkwor [5] describes the term aggregate, as inert materials like gravel, crushed stones, broken bottles which are mixed with cement and water to make concrete. [22-23]

in their contribution describe aggregates as inert or chemically inactive materials which form the bulk of concrete and are bound together using cement as a binder.

In any concrete, aggregates (fine and coarse) usually occupies about 70-75% [15-16]. The aggregates have to be graded so the whole mass of concrete acts as a relatively solid, homogeneous, dense combination with the smallest particles acting as an inert filler for the voids that exist between the larger particles [24]. This statement gives us the suggestion that the selection and proportioning of aggregates should be given due attention as it not only affects the strength but the durability and structural performance of the concrete also.

Aggregates are considered clean if they are free of excess clay, silt, mica, organic matter, chemical salts and coated grains [2]. In addition to that, [22,18,23], support the idea that an aggregate should be physically sound if it retains dimensional stability under temperature or moisture change and resists weathering without decomposition. Ezeokonkwo [2] concludes that for an aggregate to be considered adequate in strength, aggregate should be able to develop the full strength of the cementing matrix. Anosike [12], aggregates provide better strength, stability and durability to the structure made out of cement concrete than cement paste alone. Aggregate is not truly inert because its physical, thermal and chemical properties influence the performance of concrete. While selecting aggregate for a particular concrete, the economy of the mixture, the strength of the hardened mass and durability of the structure must first be considered [16].

2.2.3 Water

Water used in the concrete reacts with cement and causes it to set and harden. It also facilitates mixing, placing and compacting of fresh concrete. Abruckle [1], states that mixing water for concrete is required to be fit for drinking or to be taken from an approved source. Findings in previous works [11,5,2] suggest that, to achieve the required workability and strength of concrete in both its fresh and hardened state, the water used for mixing and curing needs to be of appropriate quality, that is, it should be free from impurities such as suspended solids, organic matter and salts which may adversely affect the setting, hardening, strength and durability of the concrete.

Water is used in the production of concrete, washing of aggregates, mortar and bricks formation. Water is also used for construction operations like casting, painting, terrazzo finishing, plastering and other operations. After casting of concrete, water is poured on the concrete to give it strength in a process known as curing. After completion of the building, water is used for cleaning the building in readiness for inspection, handing-over and occupancy. As a result of these facts, it is obvious that water is very important in building construction and related activities. Neil and Ravindra [11] further define water to cement ratio (w/c) as the weight of water divided by the weight of cement. Eg:-

w/c = Water/ Cement

where 1litre = Ikg

According to (BS8110: Part 1, 1997), the amount of water required in a concrete mix is the minimum for complete hydration of cement. If such concrete is fully compacted without segregation, it would develop the maximum attainable strength at a given age. The BS8110 [14] further states that the water-cement ratio of approximately 0.25 weight is required for full hydration of cement. Omuvwie and Mosaku [25] suggest that if the water is not properly managed, it can turn around to inflict serious structural damage to the building over time and that such damage can lead to structural failure of the building and eventual collapse aside of the economic drain on client, safety risks as well as aesthetic devaluation.

2.2.4 Admixture

Admixtures are not a primary constituent of concrete. They are added to concrete if necessary and not all the time. Brantley and Brantley [26], admixtures are those chemicals that can be added to the concrete mix to achieve special purposes or meet certain construction conditions. Admixtures are mixed into the concrete to change or alter its properties.

The use of admixtures should offer improvement in the properties of concrete by adjusting the proportions of cement and aggregates. However, it should not affect adversely any property of concrete. An admixture should be used only after assessing its effect on the concrete to be used under an intended situation. It should also be known that admixtures are no substitute for good workmanship i.e. the effect of bad workmanship cannot be improved by the use of admixtures.

Gupta and Gupta [16] and Anosike [12] suggest that admixtures perform the following functions:

1. accelerate the initial setting and hardening of concrete
2. retard the initial setting of concrete
3. increase the strength of concrete
4. improve the workability of fresh concrete
5. improve the durability of concrete
6. reduce the heat of evaluation
7. control the alkali-aggregate expansion
8. aid in the curing of concrete
9. improve wear resistance to concrete
10. reduce shrinkage during the setting of concrete

Bamibgoye et al. [28] undertook particle size distribution analysis, slump test and compressive strength on hardened concrete in exploiting economics of gravel as a substitute to granite in concrete production. Sulymon et al. [29] reported that sources of gravel greatly influence compressive, flexural and split-tensile strength of concrete [30].

3. MATERIALS AND METHODS

Data for this study were obtained through:

a. Secondary sources: Secondary data was used to extract relevant data and information from texts, local and foreign journals, dissertations/thesis, technical papers, local and foreign documents on standards, specifications, quality management and control, some selected codes of practice, and the internet.
b. Primary sources: Primary data involved field survey, laboratory tests of concrete FROM different cement samples.

3.1 Laboratory Test

Two major laboratory tests are carried out in the course of this investigation. They include

a) Slump test:- To determine the workability of the concrete used.
b) Compressive Strength test:- To determine the compressive strength (that is load on failure) of concrete cubes from different brands of cement.
c) Sample A – Bua, Sample B – Supaset, Sample C – Dangote and Sample D – Unicem.

3.1.1 The slump test

Objective: Slump test is used to determine the workability of concrete.

Procedures: The apparatus for this test consists of a hollow frustum of a cone which has a diameter at the top 100 mn and the bottom 200mm and a vertical height of 300 mm; the cone is fitted with two handles on the sides for lifting. This equipment is also available in a more elaborate design. This has the same basic conic shape which is held in a steel frame and allowed to side freely up and down. The whole of the apparatus rests on a steel base. The tapping bar is a 16 mm diameter rod, 600 mm long, with a bullet nosed end. The test is carried out by placing the metal plate on a level surface. The cone is held down by placing the feet on the metal plate and the cone is filled in form of district layers. Compaction is achieved by tapping each layer of the concrete 25 times. When the cone is filled, the top is smoothened off with the rod and lifted the cone with a clean upward sweep. Then the cone is placed alongside the concrete and the reduction in height is measured. If the range of the slump is between 70-140 mm, the concrete is said to be good and okay in consistency but beyond that range, it is not okay. The test is repeated for the four brands of cement. The result of the slump test is tabulated.

APPARATUS FOR SLUMP TEST

FILLING OF CONE WITH CONCRETE

Plate 1. Slump test apparatus and filling of cone with concrete

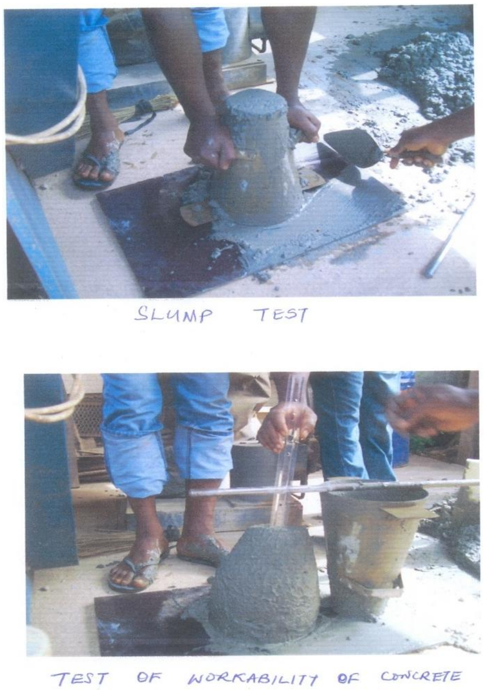

Plate 2. Slump test

Plate 3. Universal testing machine

3.2 Compressive Strength Test

Objective: This is aimed at determining the compressive strength of concrete made from different brands of cement.

Procedures: The apparatus for this test consists of cubes (150 mm), the bullet-nosed rod (600x16 mm) and the steel plate and float. The samples are collected and filled in a clean concrete cube. When the cube is half-filled, the concrete is compacted by tapping with a rod 25 times. This was also repeated when the cube is filled. After compacting, the cube is put in a cool dry place to sit for at least 24 hours. The concrete cube is then sent to the laboratory where it is cured and crushed to test the compressive strength. Samples were tested at 7, 14 and 28 days.

The study maintained a 1:2:4 design mix for all the brands of cement and achieved that through batching by weight.

Plate 4. Testing of the specimen

1:2:4 by Weight Batching Design

Dimension of mould = 150 x 150x 150 mm

Actual Concrete Weight for 1 mould = 8.65 kg

CEMENT- 1/7 * 8650 g = 1.2 kg

12 moulds * 1.2 kg= 14.4 kg (cement)

SAND- 2/7 * 8650 g = 2.47 kg

12 moulds * 2.47 = 29.66 kg (sand)

AGGREGATE- 4/7 * 8650 g = 4.9 kg

12 moulds * 4.9 kg = 59.31 kg

Aggregates comprises of both fine and coarse aggregate.

Thus for Coarse Aggregates (15/22 mm) - 60% of 59.31 kg = 35.6 kg (coarse aggregates)

Fine Aggregates (5/15 mm) – 40% of 59.31 kg = 23.7 kg (fine aggregates).

Tabulated results for the Crushing Strength and Compressive strength of concretes from different brands of cement.

4. RESULTS AND DISCUSSION

Table 2 indicates that the compressive strength (28^{th} day) of sample A, B, C and D are 30.5 N/mm^2, 31.70 N/mm^2, 29.66 N/mm^2 and 29.08 N/mm^2, respectively. Also, the result of the slump value from Table 1 ranges from 70–140

Table 1. Slump results of concrete from different cement brands

Cement brand	Slump (mm)
Sample A	75
Sample B	76
Sample C	76
Sample D	79

Source: Field survey (2019)

Table 2. Strength of concrete from different brands of cement

Cement brand	Crushing strength (KN)			Compressive strength (N/mm2)		
	7th Day	14TH Day	28th Day	7th Day	14TH Day	28th Day
Sample A	550.8	612.8	677.3	24.5	27.2	30.05
Sample B	626.3	667.5	714.45	27.8	29.6	31.70
Sample C	605.5	611.4	667.3	26.9	27.2	29.66
Sample D	541.0	606.3	654.2	24.0	26.9	29.08

Source: Field survey (2019)

(indicating that the concrete mix is workable) for all the four samples. Table 2 indicates also that sample B yielded the highest compressive strength (28th day) while sample D yielded the lowest compressive strength (28th day). The concrete cube compressive strength can be as high as 150 N/mm2 (strength still raising due to the use of better materials procedures and technologies), but the minimum strength required for ordinary reinforced concrete is about 21 N/mm^2 [26]. Based on this, it could be deduced that on the 28th day, all the samples attained the needed minimum strength. Brantley and Brantley [26] also states that when compressive strength of concrete at 28th day is above 60 N/mm^2, 20-60 and below 20 N/mm^2 is regarded as High, normal and low strength respectively. Considering the compressive value of the samples in Table 2, it was discovered that none of the value is below $20N/mm^2$. Therefore, none of them belongs to the lower classification of concrete on 28th day.

5. CONCLUSIONS AND RECOMMENDATION

There are many brands of cement found within the study area, but the four brands selected for this study is the most dominant in most building markets found within the state. This can be attributed to different factors like; Availability of raw materials, Government policies, transportation problems and poor distribution network. The study focused more on the properties and strength characteristics of concrete made from different brands of cement. From the findings of this research the following conclusions and recommendations were drawn:

1. All concrete samples achieved the minimum compressive strength of concrete (i.e. 21N/mm2) within 7 days of production.
2. The crushing strengths/compressive strength attained by the samples fall within the normal/acceptable/minimum strength of concrete (20-60 N/mm2) within 7 days of age.
3. Sample B (Supaset) yielded the highest compressive strength at 28th day.
4. Sample D (Unicem) yielded the least compressive strength at 28th day but that does not mean it did not certify the required standard.
5. Within the study area, Dangote is the leading cement available in the market.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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