
Effect of Calcium Chloride on the Compressive Strength of Concrete Produced from Three Brands of Nigerian Cement

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To cite this article:

S. O. Odeyemi, M. A. Anifowose, M. O. Oyeleke, A. O. Adeyemi, S. B. Bakare. Effect of Calcium Chloride on the Compressive Strength of Concrete Produced from Three Brands of Nigerian Cement. *American Journal of Civil Engineering*. Special Issue: Predictive Estimation by ANSYS for Laminated Wood Deep Beam. Vol. 3, No. 2-3, 2015, pp. 1-5. doi: 10.11648/j.ajce.s.2015030203.11

Abstract: Concrete is a common material used in the Nigerian building industry. It is obtained by mixing cementitious materials, water, fine and coarse aggregates and sometimes admixtures in required proportions. Admixtures are added to concrete to modify its properties so as to make it more suitable for any situation. In recent times, building collapse in Nigeria has been a source of concern particularly to those associated with the building industry. This has necessitated the need to check the effect admixtures have on some properties of concrete. This study investigated the effect of calcium chloride (CaCl_2) as an admixture on the compressive strength of concrete produced from Dangote, Elephant and Burham brands of cement available in Nigeria. The impact of calcium chloride admixture on the compressive strength of concrete made from these brands of cement was compared with the compressive strength of concrete without calcium chloride. Sieve analysis, natural moisture content and specific gravity tests were carried out on the aggregates used in the production of the concrete and the results were recorded. Slump tests were carried out on the fresh concrete containing CaCl_2 and without CaCl_2 and the results were also recorded. Cubes produced from the concrete were cured for 7, 14, 21 and 28 days respectively. The mean densities of the concrete cubes made from the three brands of cement with and without admixture were computed. The corresponding mean compressive strength for the concrete cubes was also computed. The results showed that concrete with calcium chloride have higher compressive strength compared with those without calcium chloride.

Keywords: Concrete, Admixture, Calcium Chloride, Cement, Compressive Strength

1. Introduction

Concrete has been the most common building material for many years [1]. It is obtained by mixing cementitious materials, water, aggregate (usually sand and gravel or crushed stone) and sometimes admixtures in required proportions. Fresh concrete or plastic concrete is freshly mixed material which can be moulded into any shape for it to harden into a rock-like mass known as hardened concrete. The hardening is as a result of chemical reaction between water and cement. Portland cement is the most common type of cement in general usage. It is a basic ingredient of concrete, mortar and plaster [2]. Anything other than cement, water and aggregate (fine and coarse aggregate), if added in concrete either before or during mixing to alter the properties to our desired requirement are termed as admixtures [3].

In recent times, building collapse in Nigeria has been a source of concern to so many people particularly those

associated with the building industry. This is so because there are so many cases of building collapse all over the world and particularly Nigeria. Most of these cases had resulted into colossal economic losses in terms of lives and property [4]. This has necessitated the need to check the effect admixtures have on some properties of concrete.

This research was aimed at investigating the effect of calcium chloride (CaCl_2) as an admixture on the compressive strength of concrete produced from Dangote, Elephant and Burham brands of cement in Nigeria.

2. Collapse of Building Structures in Nigeria

In recent times in Nigeria, there have been several cases of structural collapse of buildings, especially in Abuja, Lagos and Port Harcourt where several construction works are presently going on. Several of these incidents occurred in

buildings that had outlived their life spans, some were still undergoing construction, some had been declared unsafe and undergoing demolition while others were already completed and in use when the sudden collapse occurred. Figures 1 and 2 show some of the collapsed buildings in Nigeria.



Figure 1. Collapsed Synagogue building in Nigeria [5].



Figure 2. Collapsed Naval building in Gwarinpa, Abuja, Nigeria [4].

3. Compressive Strength of Concrete

The quality of concrete is judged largely on the strength of that concrete. Strength is usually the basis for acceptance or rejection of the concrete in a structure. A deficiency in the strength of concrete can lead to expensive and difficult repairs or at worse a failure of the structure. Concrete is an excellent material for resisting compressive loading. Compressive strength of concrete is usually determined by means of test cylinders made of fresh concrete on the job and tested in compression at various ages of the concrete. The requirement is a certain strength at an age of 28 days or such earlier age as concrete is to receive its full service load or maximum stress. Additional tests are frequently conducted at earlier ages to obtain advance information on the adequacy of strength development where age-strength relationship have been established for the materials and proportions used [6].

4. Cement Manufacturers in Nigeria

The following companies manufacture cement in Nigeria:

1. Cement Company of Northern Nigeria Plc: They are the producer and marketer of Sokoto BUA brand of cement in Nigeria. They are located at Km 10, Kalambaina Road, Sokoto, Sokoto State, Nigeria.
2. Dangote Group: The Head office of Dangote Group is located at 1 Alfred Rewane Road, Falomo Ikoyi, Lagos, Lagos State, Nigeria. They are the manufacturer of

Dangote brand of cement in Nigeria.

3. Eastern Bulkem Company Limited: Their Head office is located at 11, Awolowo Road, Flat 5 Block 2, Ikoyi, Lagos, Lagos State. They are the manufacturer of Eagle Cement in Nigeria.
4. Lafarge Cement WAPCO Nigeria Plc: They are the manufacturer of Elephant brand of cement in Nigeria. Their Head office is located at Km 64, Lagos/Abeokuta Expressway, Ewekoro, Abeokuta, Ogun State.
5. Flour Mills of Nigeria Plc: They are the producers of Burham cement. Flour mills began the production of Burham cement in Nigeria in 1975. They are located at No 2, Old dock road, Apapa, Lagos, Nigeria.

5. Admixtures

Admixtures are materials other than cement water and aggregate that is used as an ingredient of concrete and added to the batch immediately before, after or during mixing. They are used to modify the properties of concrete so as to make it more suitable for any situation. Admixtures, although not always cheap, do not necessarily represent additional expenditure because their use can result in concomitant savings, for example, in the cost of labour required to effect compaction, in the cement content which would otherwise be necessary, or in improving durability without the use of additional measures [7].

5.1. Chemical Admixtures

Chemical admixtures are added to concrete in very small amount mainly for air entrainment reduction of water or cement content plasticization of fresh concrete mixtures, or control of setting time [8]. Chemical admixtures are materials in form of powder or fluid that are added to concrete to give it certain characteristics not obtainable with plain concrete mixes. In normal use, admixture dosages are less than 5% by mass of cement and are added to concrete at the time of batching/mixing.

Calcium chloride (CaCl_2) is a chemical admixture and a by-product of the Solvay process in the manufacturing of sodium carbonate. Calcium chloride is available in two forms: (i) Regular flake calcium chloride and (ii) concentrated flake, pellet, or granular calcium chloride [9].

Calcium chloride has been used in concrete since 1885 and finds application mainly in cold weather, when it allows the strength gain to approach that of concrete cured under normal curing temperatures [8]. In normal conditions, calcium chloride is used to speed up the setting and hardening process for earlier finishing or mould turnaround.

Aside from affecting setting time, calcium chloride has a minor effect on fresh concrete properties. It has been observed that addition of CaCl_2 slightly increases the workability and reduces the water required to produce a given slump [10] and reduces bleeding. Initial and final setting times of concrete are significantly reduced by using calcium chloride. The total effect of adding calcium chloride depends on dosage, type of cement used, and temperature of the mix.

6. Methodology

The material constituents, mix proportions, mixing, curing process are paramount important factors that determine the strength of concrete.

6.1. Materials Used

The following materials were used in producing the concrete used in this research work:

6.1.1. Coarse and Fine Aggregates

Granite and Sharp sand which are extremely needful materials for production of concrete are the product of natural or artificial disintegration of rocks and minerals. Clean aggregates, free from waste stone and impurities were used in the production of the concrete used in this research work.

6.1.2. Cement

Ordinary Portland cement (OPC) – Dangote and Elephant and Burham cement brands which conformed to NIS 444 – 1: 2003 were used.

6.1.3. Water

Portable water which is free from suspended particles, salts and oil contamination were used throughout this study as specified by [11].

6.1.4. Calcium Chloride

Calcium chloride was added to the concrete mix as an admixture. 4% of calcium chloride was used.

A mix ratio of 1:2:4 was adopted for the concrete production. Batching was done by weight.

6.2. Tests on Materials

The following tests were carried out:

6.2.1. Sieve Analysis

The test samples were dried to a constant weight at a temperature of $110 \pm 5^\circ\text{C}$ and weighed. The samples were sieved by using a set of IS Sieves and electric sieve shaker. On completion of sieving, the materials on each sieve were weighed. Cumulative weight passing through each sieve was calculated as a percentage of the total sample weighed. Fineness modulus was obtained by adding cumulative percentage of aggregates retained on each sieve and dividing the sum by 100.

$$\text{Fineness modulus} = \text{Total cumulative \% retained}/100 \quad (1)$$

6.2.2. Natural Moisture Content

Sets of container and wet soil were used. The container was clean and dried before use. The weight of the empty container is taken as W_1 . The required quantity of the wet soil specimen was placed in the container and weigh as W_2 (weight of empty container + wet soil). The containers with sample were oven dried in a controlled temperature for 24 hours to a constant weight. After attaining the constant weight, the specimen was removed, allowed to cool, and the reading was taken as W_3 (weight of empty container + dry

soil). Equation (2) was used to determine the moisture content of the aggregate.

$$\text{Moisture content (Mc)} = \frac{\text{weight of water}}{\text{weight of dry sample}} = \frac{W_2 - W_3}{W_3 - W_1} \times 100\% \quad (2)$$

6.2.3. Specific Gravity Test

The samples were first screened on BS sieve thoroughly to remove grass particles and other deleterious materials. The weight of the empty density bottle was recorded as W_1 . The sample used was filled into the density bottle and weighed; the weight was recorded as W_2 (weight of bottle + dry sample). The density bottle was gradually filled with distilled water to gauge mark, soon after the end of soaking, air entrapped and bubbles on the surface of the aggregate sample were removed by heating the density bottle on a water bath and the weight was recorded as W_3 (weight of bottle + dry sample + distilled water), after which the bottle was emptied and allowed to dry. The density bottle was then filled with distilled water to the gauge mark and weighed as W_4 (weight of bottle + distilled water). The equation used to determine the specific gravity of aggregate is given in Equation 3:

$$\text{Specific Gravity (Gs)} = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)} \quad (3)$$

6.2.4. Slump Test

The internal surface of the cone mould used was thoroughly cleaned and applied with a light coat of oil. The mould was placed on a smooth, horizontal, rigid and non- absorbent surface. The mould was then filled in three layers with freshly mixed concrete, and each layer was tamped 25 times with tamping rod. After the top layer was rodded, the concrete was struck off the level with a trowel. The mould was removed from the concrete immediately by raising it slowly in vertical direction. The difference in level between the height of the mould and that of the highest point of the subsided concrete was measured using a meter rule. This difference in height in mm was recorded as the slump of the concrete.

6.2.5. Density Test

At the end of each curing age (7, 14, 21 and 28 days respectively), the concrete cubes were removed from the curing tank and allowed to drain off. The weight of each cube was obtained by a weighing balance to determine the density of the concrete cube. Equation (4) was used to obtain the density of each cube.

$$\text{Density, } \rho = \frac{\text{Weight of Cube}}{\text{Volume of Cube}} \left(\text{kg/m}^3 \right) \quad (4)$$

6.2.6. Compressive Strength Test

The compressive strength test was carried out immediately after obtaining the density of the concrete cube. The weighed cube was carefully placed in the compression test machine with the smooth face in contact with the plates of the machine. Then, the compression testing machine was turned on from the power source and the gear of the machine turned clockwise. At failure, the dial gauge of the compression testing machine

stops and the gear was reversed. The load at which failure occurs was recorded. 72 cubes (36 cubes for concrete with calcium chloride and 36 cubes for concrete without calcium chloride) were crushed.

7. Results and Discussion

7.1. Physical Properties of Aggregates

Sieve analysis, natural moisture content and the specific gravity of the aggregate were determined and recorded.

7.1.1. Sieve Analysis

From the sieve analysis, the following fineness moduli were obtained:

Fineness modulus for Fine Aggregate = 3.08

Fineness modulus for Coarse Aggregate = 6.31

These values fall within the acceptable limits for fine and coarse aggregates [12]

7.1.2. Natural Moisture Content

Average moisture content of Fine Aggregate (Sand) = 0.94%

Average moisture content of Coarse Aggregate (Crushed Granite) = 0.16%

These values fall within the acceptable limits for fine and coarse aggregates [12].

7.1.3. Specific Gravity

Average Specific Gravity (Gs) of Fine Aggregate (Sand) = 2.6

Average Specific Gravity (Gs) of Coarse Aggregate (Crushed Granite) = 2.65

These values are within the acceptable limits for fine and coarse aggregates [13].

7.2. Workability

Workability is the ability of fresh concrete mix to mould or form properly with the desired work without reducing the concrete quality.

7.2.1. Slump Test Results

Table 1 shows the slump test results for the concrete with and without calcium chloride. True slump was exhibited by the concrete in the fresh concrete mix. The slump was satisfactory as segregation was minimized. The highest slump height was obtained using Dangote cement without CaCl_2 and the least height was obtained using Burham cement with CaCl_2 .

7.3. Tests on Hardened Concrete

Hardened concrete assumes important properties that are retained for the life of the concrete and these properties include density, strength and deformation under load and durability among others.

7.3.1. Density Test Results

The mean densities of concrete cubes made from dangote,

elephant and burham cement with and without calcium chloride for age 7, 14, 21 and 28 days hydration period are given in Tables 2 and 3. All concrete cubes produced falls within the range $2300\text{Kg/m}^3 - 2600\text{Kg/m}^3$. The densities of all the samples tested fell within the normal range of concrete [14]. It was noticed that the densities of the concrete increased with days irrespective of whether it contains CaCl_2 or not.

7.4. Compressive Strength Test

Tables 4 and 5 shows the mean compressive strength test results of the concrete cubes cast from the three brands of cement with calcium chloride admixture and without calcium chloride admixture respectively. The Tables reveal that the compressive strength of concrete cubes made from Dangote, Elephant and Burham cement with calcium chloride were greater than the compressive strength of concrete cubes made without calcium chloride at the different curing ages. The highest compressive strength was obtained from the concrete made from Dangote brand of cement containing calcium chloride while the lowest compressive strength was obtained from the concrete made from Elephant brand of cement without calcium chloride. The results are represented graphically in Figure 3 and Figure 4.

Table 1. Result of Slump Test for Concrete Made with different brands of Cement

Serial Number	Brands of cement with and without CaCl_2	Slump Height (mm)
1	Dangote with CaCl_2	70
2	Dangote without CaCl_2	73
3	Elephant with CaCl_2	60
4	Elephant without CaCl_2	63
5	Burham with CaCl_2	60
6	Burham without CaCl_2	65

Table 2. Results of Mean Densities of Concrete Cubes with Calcium Chloride

Age (Days)	Mean Densities of Concrete Cubes (Kg/m^3)		
	Dangote Cement	Elephant Cement	Burham Cement
7	2397.93	2377.38	2397.93
14	2414.02	2419.16	2450.47
21	2441.48	2488.69	2556.35
28	2419.16	2520.29	2556.74

Table 3. Results of Mean Densities of Concrete Cubes without Calcium Chloride

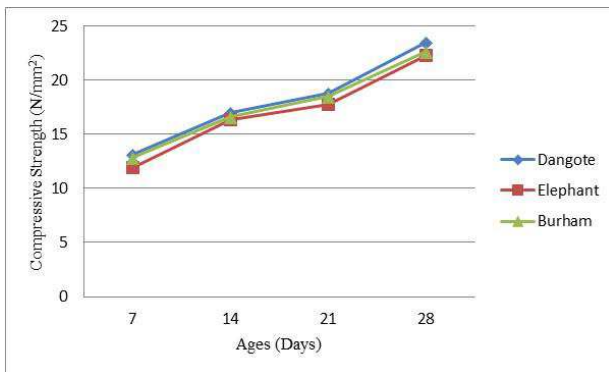
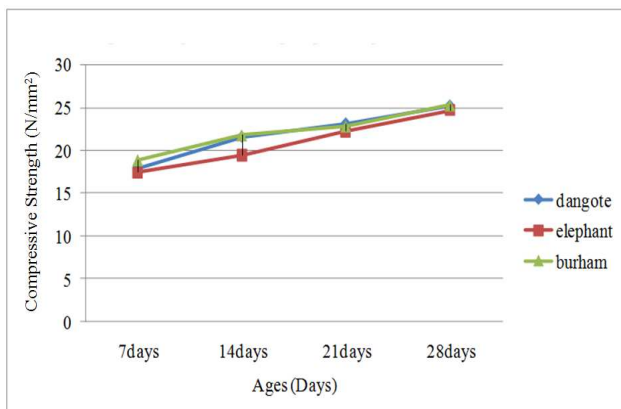
Age (Days)	Mean Densities of Concrete Cubes (Kg/m^3)		
	Dangote Cement	Elephant Cement	Burham Cement
7	2419.16	2350.72	2397.93
14	2430.91	2430.91	2450.47
21	2437.14	2474.77	2409.77
28	2441.48	2491.65	2556.35

Table 4. Mean Compressive Strength of Concrete Cubes Made from the three brands of Cement with Calcium Chloride

Age of cubes (Days)	Mean Compressive Strength of concrete cubes (N/mm ²)		
	Dangote Cement	Elephant Cement	Burham Cement
7	17.93	17.48	18.89
14	21.56	19.48	21.78
21	23.13	22.22	22.81
28	25.23	24.67	25.29

Table 5. Mean Compressive Strength of Concrete Cubes Made from the three brands of Cement without Calcium Chloride

Age of cubes (Days)	Mean Compressive Strength of concrete cubes (N/mm ²)		
	Dangote Cement	Elephant Cement	Burham Cement
7	13.17	11.91	12.90
14	16.99	16.38	16.60
21	18.80	17.78	18.51
28	23.54	22.25	22.67

**Figure 3.** Graph of Compressive Strength against Ages of concrete without Calcium Chloride.**Figure 4.** Graph of Compressive Strength against Ages of concrete with Calcium Chloride.

5. Conclusion

The results of the mean compressive strength test at 7, 14, 21 and 28 days shown in Tables 4 and 5 shows that the compressive strength of concrete cubes made from Elephant

cement with calcium chloride is lesser than that of Dangote and Burham cement with calcium chloride. It was noticed that the compressive strength of concrete cubes made from Dangote, Elephant and Burham cement with calcium chloride increases as the curing age increases at almost the same rate, but concrete made with Burham cement with calcium chloride has the highest compressive strength. Conclusively, the compressive strength of concrete cubes made from Dangote, Elephant and Burham cement with calcium chloride is greater than compressive strength of concrete cubes made from Dangote, Elephant and Burham cement without calcium chloride at different curing ages.

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