

Physical Properties of Cements Produced and Sold in Nigeria

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Abstract

The physical properties of cements produced and sold in Nigeria play a crucial role in determining their quality and suitability for construction applications. This study aims to investigate the physical properties of various cements available in the Nigerian market, with a specific focus on cement physical tests and compressive strength tests. To achieve this objective, a comprehensive analysis was conducted on a representative sample of cements produced and sold in Nigeria. The study employed standard methods for cement physical testing, including fineness, setting time, soundness, and specific gravity. These tests were carried out according to the relevant Nigerian Industrial Standards and internationally recognized protocols. The samples were prepared following the prescribed water-to-cement ratio and cured under controlled laboratory conditions. The compressive strength tests were conducted at various ages, typically 7, 14, and 28 days, using a hydraulic testing machine. The obtained results were compared against the minimum requirements stipulated in the relevant codes and standards. The results of the cement physical tests highlight the variations in fineness, setting time, soundness, and specific gravity among different cement brands. These properties directly influence the workability and durability of cement in construction applications. Furthermore, the compressive strength test of the cement brand A, B, C, D, E, F and G were found to be 31.19, 34, 36.29, 35.33, 31.41 and 33.56 N/mm² respectively. The data obtained at different ages allow for an assessment of early-age and long-term strength performance, aiding in selecting suitable cements for various construction projects. The outcomes of this research contribute to enhancing the understanding of the quality and performance of cements produced and sold in Nigeria.

Keywords: Cements, Concrete, Fine aggregates, coarse aggregates.

1. Introduction

Cement is considered as one of the most commonly used commodities in building construction currently in circulation worldwide (Faleye et al., 2009). The strength of any concrete depends upon the age of the concrete which in turn depends on the cement quality. To attain the desired strength of concrete and to increase the durability of any structure made with it, good quality cement should be assured (Hani, 2011).

One of the most important considerations to make before embarking on the construction of a building is the cement that would be used; the commonest type of cement used in Nigeria is Ordinary Portland Cement (OPC) (faleye et al., 2009). The prevalent use for it is the constituents of composition and most important properties in the compose and solidification of the paste, durability when dry, fireproof nature, effective protection of iron or timber structures, ability to prevent corrosion, its use in ships, tanks and bunkers (ASTM, 1986).

Cement is the most vital component building material used all over the globe with Nigeria inclusive. The major factors used for the assessment of cement properties is that its qualities most have the same effect of the qualities and properties of a cement finished product. Even though Sambo (1991) had studied different characteristics of cement in Nigeria, the results has shown that compressive strength has increase as the compressive strength as their research failed to meet the maximum requirements.

It is of paramount importance to determine the construction material used in any country as measure of standard product. It can be seen as a major component in the creation of concrete, and its ability in developing very strong bond when combined with other construction materials such as fine aggregates and coarse aggregates (Ezeokonkwo & Anyanechi, 2015). The quality of cement is of vital importance but it is the binding material in concrete which is widely used in construction industry and is good to check adulterated ones in Market always.

This study is therefore an attempt to find out from time to time and whether or not cement is up to required standard. The aim of the research is to study the physical properties of Ordinary Portland cement produced and sold in Nigeria. This is pursued through the objectives below:

- a. Determine the physical characteristics of Ordinary Portland cement (OPC) purchased from local markets in Nigeria.
- b. Determine the compressive strength of each OPC in 14 days and 28 days and the strength of each brand of cement.

2. Related Works

This section deals with review of related studies. The review of some of the studies previously carried out on assessments of cement brands used in Nigeria.

2.1 Cement

It is uncertain where it was first discovered that a combination of hydrated non-hydraulic lime and a pozzolana produces a hydraulic mixture (see also: Pozzolanic reaction), but concrete made from such mixtures was first used by the Ancient Macedonians and three centuries later on a large scale by Roman engineers. They used both natural pozzolans (trass or pumice) and artificial pozzolans (ground brick or pottery) in these concretes (Mindess et al; 2022). Many excellent examples of structures made from these concretes are still standing, notably the huge dome of the pantheon in Rome and the massive Baths of Caracalla. The vast system of Roman aqueducts also made extensive use of hydraulic cement.

Although any preservation of this knowledge in literary sources from the Middle Ages is unknown, medieval masons and some military engineers maintained an active tradition of using hydraulic cement in structures such as canals, fortresses harbours and ship building facilities. The technical knowledge of making hydraulic cement was later formalized by French and British engineers in the 18th century (Mindess et al; 2022).

2.2 Physical Requirement

The Nigeria Industrial Standard (NIS) specification for Ordinary Portland Cement gives the following physical requirements as stated in the research of Umasabor & Alutu (2022).

A. Fineness

Umasabor & Alutu, (2022) have asserted that the degree of measure for a specific surface is defined as the ratio between the total surface area of a sample and its total weight usually expressed in square centimetres per gram (NIS 1974). Their research covers the test for the determination of the fineness of Portland cement, using blaine air permeability apparatus, in terms of the specific surface and it is covered in NIS 11: (1974). More on that will further be investigated.

B. Soundness

Penneerselvam, (2022) reported to have defined the measure of freedom for the cement from its expansion by a specific test as a soundness. Their research covers the evaluation of the procedures used in determining the soundness of the cement by the le' chatelier methods and is covered in NIS 11 (1974). Even though, the research made the discovery, but failed to present an analytical result of it.

C. Setting time

It was reported by Neville, (2020) that the time required by a reiteratively mixed adhesive of water and cement to acquire an arbitrary degree of compaction as a measured of specific test referred to as setting time. The setting time of cement when tested by the method described in NIS 11 (1974) shall conform to the following requirements:

- i. Initial setting time: Not less than 45 minutes
- ii. Final setting time: Not less than 10 hours
- iii. These will duly be considered in the current research.

D. Specific Gravity

Singh et al. (2019) investigated the specific gravity of cement and further defines the mass of cement of a certain amount to the mass of water of the same volume of cement. The research found that the specific gravity of cement ranges from 3.1 – 3.16 g/cc. Although, the research performed well other parameters needs to be investigated as to compare the ratio of the amount of water to the volume of cement.

2.3 Compressive Strength

Nehdi et al. (2023) defined the maximum load that a test piece most sustain. They found that the compressive strength of cement on mortar cubes compacted by means of a standard vibration machine and also on concrete cubes. A thorough investigation is needed as to attest to the compressive strength and also test on different cement samples.

Findings from the studies carried out by Hodhod and Abdeen (2010), Mathur, Misra and Goel (2020), have shown that in Ordinary Portland Cement, the stronger the cement grade, the stronger the concrete compressive strength, provided the mix ratio remains constant. However, due to the substitution of Portland-Limestone Cement for Ordinary Portland Cement in the Nigerian open market, Kazeem, Festus and Hamzat (2014) studied PLC grades of 32.5N and 42.5 N commonly used for concrete production in Nigeria. In the investigation, different mix ratios related to building construction were utilized. When the 28-day compressive strength values of concrete generated with the two PLC grades were compared, it was discovered that PLC grade 42.5N produced stronger concrete than PLC grade 32.5 N in all the mix ratios used.

Adewole, Ajagbe and Arasi (2015) conducted a study using Portland-Limestone Cement grades 32.5 and 42.5. It was discovered that the concrete produced from PLC grade 42.5 was stronger than the concrete produced from PLC grade 32.5. However, as the mix was changed from 1:2:4 to 1:1:2 in order to increase the cement concentration, the difference in concrete strengths produced by both grades of cement decreased. As a result, it was established that the stronger the concrete grade, the less relevant the cement grade. Furthermore, a cement grade of 32.5 in a 1:2:4 mix cannot be used to produce a concrete of strength class M20/25, which is the minimum concrete strength class recommended for the construction of load-bearing structural elements, but rather with a cement grade of 42.5.

3. Proposed Approach

The research proposed to apply seven different brands of an ordinary Portland cement which were labelled A, B, C, D, E, F and G respectively. They were applied and collected from the markets in Nigeria. We divided it into two parts, the material part which consist of those elements used in conducting the research and the methods which describes the formation of the main work.

3.1 Materials

The materials used in conducting the research as stated in the work of Nehdi et al. (2023) include the following:

Water: - It can be seen as a major constituent of the mixture applied in conducting the research. The water used for this research were that water tapped from the water source for the laboratory of Civil Engineering of Bayero University, Kano.

Fine Aggregate: - Consist of majorly natural sand or a crushed stone thereby allowing its major particles to pass through a 3/8-inch sieve. The fine aggregate used in the research were purchased at Gwarzo road along Bayero University, Kano new campus.

Cement: - Can be seen as a binder or a chemical substance used for construction that allows the mortar to hardens and gets adheres to other materials to coupled them together. Cement is used in this research which were obtained from different locations in the country.

3.2 Methods

Below is the representation of stages involved in attaining the research aim and the respective objectives.

A. Cement Physical Tests

The cement physical tests were carried out on the cement brands sample in accordance with BS EN 196-part3:2008 and BS EN 197-1:2011.

B. Standard Consistency

Apparatus: weighing balance, hand trowel, vicat mould, plunger, and stopwatch.

Procedure: 400g of cement was weighed and a weighed quantity of water and then properly mixed to produce a homogenous paste of cement. The time taken between adding of water to cement and mixing is 3 to 5 minutes. The vicat mould was filled with the cement paste and properly leveled with a trowel. The plunger of the vicat apparatus was gently lowered until it touched the surface of the cement paste. The plunger was then released allowing it to sink into the paste. The reading on the gauge was noted after releasing the plunger into the paste. The above procedure was repeated using fresh sample of cement and different quantities of water until the reading on the gauge was 5-7mm and note that the amount of water was expressed as a percentage of the weight of dry cement to the first place of decimal and the above procedure was repeated for the three brands of cement. The cement mortal test was carried out in accordance with BS EN 12390-2 and BS EN 12390-3:2009 as specified in BS EN 206-1:2000. The cube mould used was of size 150mm.

C. Soundness

Apparatus: Weighing balance, glass plate, split, hand towel, pot, cooker

Procedure: One of the accelerated tests used in BSI (1978) and laboratory work instruction of (WAPCO 1986) created by Le Chatelier (1904). This test was carried out as follows. The cement paste was prepared as of a standard consistency and filled in to the expansion mould, or Le Chatelier mould (Le Chatelier 1904), placed on a glass plate. The split end of the mould was gently closed by tying it with a piece of cotton as the operation was being carried out. The surface of the paste was well smoothed and levelled with the blade of a gauging 33 trowel and was covered with another piece of glass and was immediately immersed in clean water. A 50g weight was placed on top of the plate for compaction. After 24 hours, the mould was removed from the water and the distance between the pointers measured by using a meter rule. The mould was re-immersed in water again and was brought to boiling point within 30 minutes and afterwards allowed to boil for one hour. This material was then kept in the water and allowed to cool. The distance between the pointers was again measured. The difference between the two measurements represents the value for soundness.

D. Specific Gravity

Apparatus: Le Chatelier or Specific Gravity Bottle, Balance capable of weighing accurately up to 0.1gm

Procedure: Weigh a clean and dry Le chatelier Flask with its stopper (W1). Place a sample of cement upto half of the flask and weigh with its stopper (W2). Add kerosene to cement in flask till it is about half full. Mix thoroughly with glass rod to remove entrapped air. Continue stirring and add more kerosene till it is flush with graduated mark.

Dry the outside and weigh (W3). Entrapped air may be removed by vacuum pump, if available. Empty the flask, clean it refills with clean kerosene flush with the graduated mark wipe dry the outside and weigh (W4).

Use the following below to calculate the specific gravity:

$$\text{Specific gravity} = \frac{W2 - W1}{(W2 - W1) - (W3 - W4) \times 0.79} \tag{1}$$

E. Fineness

Apparatus: Weighing balance, 90um, receiving pan, recording sheet, brush, pen, stop watch.

Procedure: BS EN 196-6-1992 10g of ordinary Portland cement was weighed on the weighing balance and recorded as W1, then the cement was placed on 90um sieve, after placing it inside the sieve and cover it then it was shake vigorously for 10minute then the residue retain was weighed and recorded as w2. Then I repeated the above step for the remaining two cement samples.

F. Initial and Final Setting Time

Apparatus: Weighing balance, hand trowel, vicat mould, plunger, and stop watch.

Procedure: As stated in BSI (1978), a sample of cement paste of standard consistency was prepared and the time of first mixing the water with cement was noted down. A slight excess of paste was immediately transferred into the mould in one layer by using hand trowel. The top of the mould was smoothed and leveled. The mould was placed under the initial set needle of cross-sectional area of 1mm and the needle was covered gently onto the surface of the paste and was quickly released by allowing it to sink to the bottom. These tasks were repeated several times at regular intervals of 10 minutes in different positions of mould until the paste has stiffened sufficiently for the needle not to penetrate deeper than 5mm above the bottom of the mould. The time interval between the addition of water and the initial setting time was recorded. Finally, the needle was replaced with a 1mm square needle fitted with a metal annular attachment and this probe was allowed to come gently with contact with the surface of the cement paste at an interval of 15 minutes. The final set was reached when the needle makes an impression on the surface but annular cutting edges fail to do so.

4. Results and Discussion

The test results presented in section three were analyzed and discussed to arrive at a reasonable conclusion. These are presented below

4.1 Standard Consistency Tests

The consistency of the seven cement samples stated are shown in Figure 1 below.

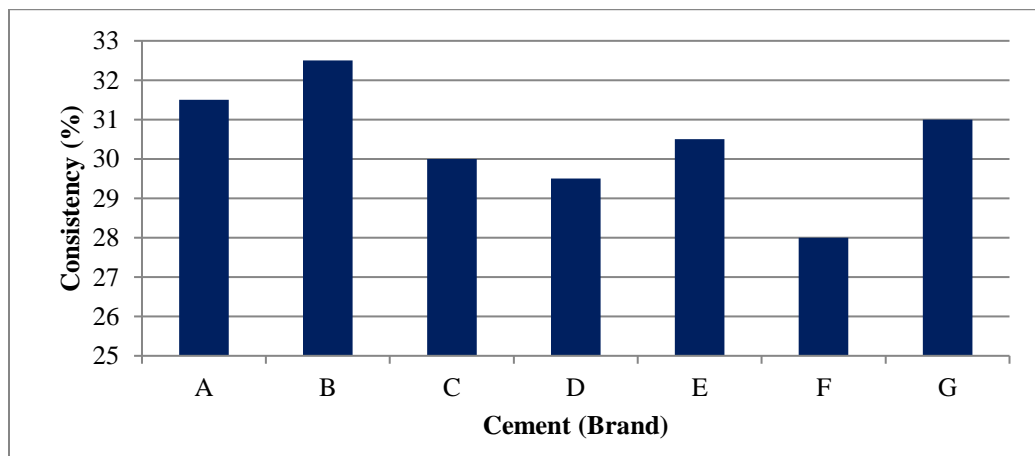


Figure 1: Standard consistency of ordinary Portland cement samples

The normal standard consistency is between 26 and 33 percent. It seen from figure that B has the highest standard consistency followed by A, G, E, C, D and F, even though they all pass the standard consistency. Standard consistency helps in optimizing the water-cement ratios, ensuring the proper setting and strength characteristics of the resulting concrete.

4.2 Soundness Test

The average soundness results of the tests performed on the seven samples of cement were presented in Table 1.

Table 1: Soundness Test

Cement	A	B	C	D	E	F	G
Soundness Test (mm)	2.27	0.94	1.11	2.09	1.13	1.05	1.17

The maximum expansion specified in the standard is 10mm (BS EN 197-1:2011 and BS 12:1996) for ordinary Portland cement. The soundness tests help identify and control potential expansion or contraction problems in cement, contributing to the overall durability and reliability of the concrete. This shows that the unsoundness caused by free lime present in each of the OPC samples studied was minimal (Neville, 2012). The OPC A, B, C, D, E, F and G passed the soundness test.

4.3 Specific Gravity Test

The specific gravity test was carried out on the seven sample of cement in Table 2.

Table 2: Specific Gravity Test

Cement	A	B	C	D	E	F	G
Specific Gravity	3.14	3.16	3.15	3.16	3.15	3.15	3.14

The standard specification for specific gravity of ordinary Portland cement is 3.14 and 3.15 ASTM C150 (2012). The specific gravity plays a role in quality control, mix design, porosity, permeability and overall performance of concrete in terms of strength, this is in line with Munachiso C. O and Akpabot I. A finding. The cement brands A, B, C, D, E, F and G passed specific gravity test.

4.4 Cement fineness

The results for the fineness of the ordinary Portland cement by specific surface are methods. The specific surface area method of the fineness should be within the range of 300-400 m²/kg for ordinary Portland cement (BS EN 196-6: 2010). The seven ordinary Portland cement passed the fineness tests. This means that a greater surface area for hydration leading to faster development of strength and a higher rate of heat evolution. This is in line with the finding of M. C. Ogbodo and A. I. Akpabot (2021).

5. Initial and Final Setting Time Tests

The results of the initial and final setting time tests carried out on the seven cement samples were presented in table 3 below.

Table 3: Comparison of result of setting times to standard

	Ordinary Portland Cement Samples						
	A	B	C	D	E	F	G
Initial setting time (minutes)	98	93	110	110	100	105	125
Final setting time (minutes)	225	185	210	225	230	175	235
BS EN 196- part 3:2008	Initial setting time ≥ 45 minutes Final setting time ≤ 100 hours (600 minutes)						

The OPC samples A, B, C, D, E, F and G tested passed the final setting test as shown in the figure 2.

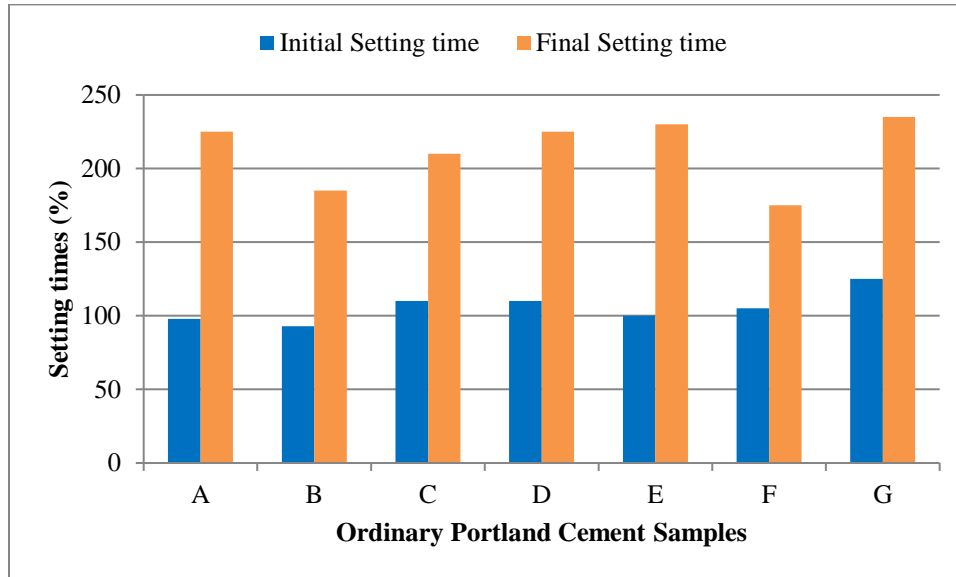


Figure 2: Standard Initial and Final Setting Time of Ordinary Portland Cement Samples

The standard (BS 12:1991) specifies a minimum of 45 minutes for initial setting time of grade 42.5 ordinary Portland cement and the final setting- time is specified as maximum of 10 hours (600 minutes). OPC F have the shortest setting times. This is attributed to its higher values of tricalcium silicate contents than the other brands, this is in line with the finding of Opeyemi J et al., 2019. The tricalcium aluminate are mainly responsible for the early hydration of cement. The OPC A, B, C, D, E, F and G tested passed the final setting time test.

6. Compressive Strength

The current code BS EN 206-1:2000, compressive strength test at 7 days and 28 days BS EN 206-1:2000 specified a minimum compressive strength of 13N/mm² and 30N/mm² with 5% tolerance. OPC A, B, C, D, E, F and G passed the test as shown in Figure 3 below.

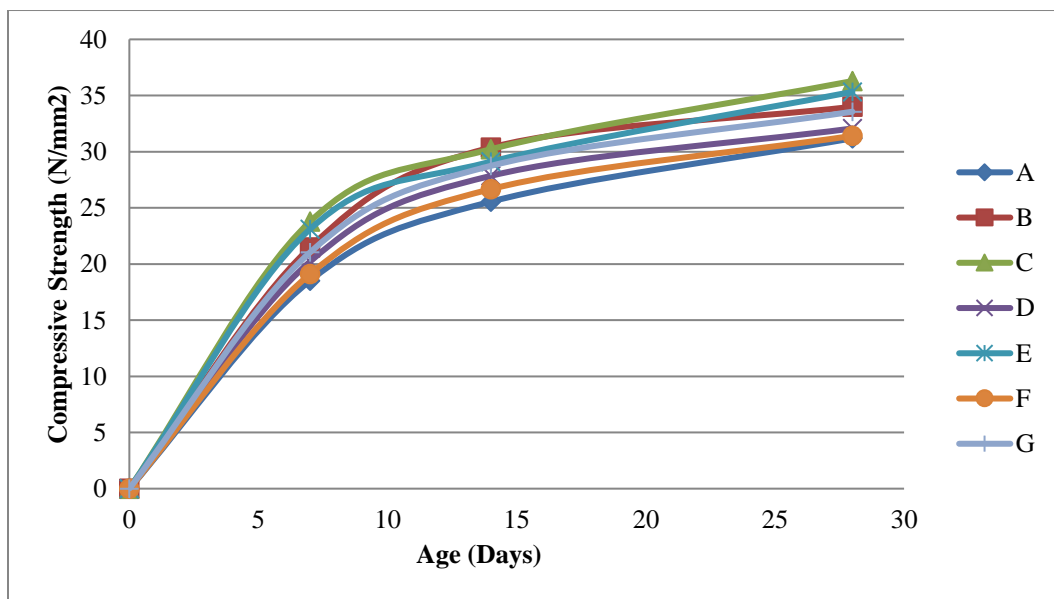


Figure 3: Compressive Strength

From figure 3 above shows that as the curing age increases the compressive strength increases, with C has the highest compressive strength followed by E, B G, D, F and the least is A. Even though they all pass the compressive strength test. This is in line with Joseph et al., 2014.

5. Conclusion

The research made assessment on the properties of cement produced and sold in Nigeria. Based on the above findings, the following conclusions were drawn: All the Ordinary Portland Cement (OPC) from A, B, C, D, E, F, G and H has passed the physical characteristics such as the consistency, Final setting time, soundness and specific gravity test. For the initial setting time, all the Ordinary Portland Cement passes the test with the exception of F which has the shortest setting time and it is attributed to its higher values of tricalcium silicate contents than the other OPC. All the OPC studied passes the compressive strength test. There is a need for the Nigerian Industrial Organization (NIS) to constitute a committee that will be in charge of testing the quality of cement produce in the country periodically. It is also desirable for the purchase to have certificates of tests from the producer signed by Nigerian Industrial Standard organization. This is to guide against bad OPC on site. The federal government should also establish more railways to connect the cement factories. So that all the cement factories will be linked of rails and roads for easy transportation to all part of the country. In future, we intend to test the physical and chemical properties of the Portland cements on both foreign and local so as to come up with a better result to justify our findings.

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