**International Journal of Engineering and Information Systems (IJEAIS)**
**ISSN: 2643-640X**
**Vol. 7 Issue 12, December - 2023, Pages: 86-92**

# Oxides Assessment of Different Brands of Cement in Nigeria

**Agbaghare, Daniel E. and Agbazue, Vitus E.**

+2349033242194, +2347064524712
**dagbagahre@yahoo.com**
Department of Pure and Applied Chemistry, Faculty of Natural and Applied Sciences, Veritas University Abuja, Nigeria

***Abstract:*** *The composition of Portland cement largely depends on the raw mix design consisting majorly of lime (CaO), silica ($SiO_2$), alumina ($Al_2O_3$) and ferrite ($Fe_2O_3$) which configurations largely defines the quality of the final product. In this study, ten different brands of cement (labelled A-J) randomly obtained from different Nigerian markets were assessed for their physicochemical properties in accordance with the Nigerian Industrial Standard, NIS 444-1: 2014. The results obtained were compared to the Nigerian Industrial Standard (NIS), British Standard (BS) and others. Most of the samples met required specifications with the exception of few. Sample D with 2 and 7 days compressive strengths of 1.5N/mm$^2$ and 9.8N/mm$^2$ respectively is below standard specifications of NIS. In similar vein, the 28 days compressive strengths for samples D (25.9N/mm$^2$), E (42.0N/mm$^2$) and F (40.7N/mm$^2$) are similarly below the BS and NIS. This can be attributed to the low amounts of CaO in the respective samples. The high levels of additives (above NIN specification) as indicated in the Loss on Ignition (LOI) of samples A (8.09%), C(7.43), D(14.56%), E(10.99%), F(11.22%), G(7.83%), H(7.74%), I(7.70%) and J(9.16%) could be responsible for the relatively low values of $SiO_2$ in the samples. The variation of aluminum oxide in the different brands are within advisable range. It is imperative therefore to recommend that use of additives in cement production be applied with moderation and compliance to standards by cement manufacturers should be a paramount objective with optimal consistency.*

**Keywords**: Ordinary Portland cement, oxides, physicochemical properties

## INTRODUCTION

Portland cement is a hydraulic material that gets its strength from the hydration of the di and tri calcium silicates that it contains. The term "hydraulic property" refers to the ability of a cement and water paste to harden in the presence of water [1]. The primary composition of Portland cement is largely dependent on the raw mix design [2]. The major materials in the raw mix are argillaceous (such as $SiO_2$, $Al_2O_3$ and $Fe_2O_3$) material and calcareous (with CaO as major constituent) material. The properties the final product largely depend on the various amount of these oxides.

During sintering reaction, these oxides react thermally with one another to form the four major cement components as shown in the reaction below;

$$CaO.SiO_2 + 2CaO \rightarrow 3CaO.SiO_2 \text{ or } C_3S \text{ (alite or Tricalciumsilicate)}$$

$$CaO.SiO_2 + CaO \rightarrow 2CaO.SiO_2 \text{ or } C_2S \text{ (belite or Dicalciumsilicate)}$$

$$CaO.Al_2O_3 + 2CaO \rightarrow 3CaO.Al_2O_3 \text{ or } C_3A \text{ (tricalciumaluminate)}$$

$$CaO.Al_2O_3\ 3CaO + Fe_2O_3 \rightarrow 4CaO.Al_2O_3.Fe_2O_3 \text{ or } C_4AF \text{ (tetracalciumaluminoferrite)}$$

In order to ascertain the quality of cement brand, full analysis with emphasis on the major oxides is carried out on the sample in cement laboratory. Cement for all important works is subjected to a rigorous system of testing and analysis before it can be accepted for use [3].

Local contractors in Nigeria utilize various brands of Portland cement (PC) for various construction works without prior knowledge of their performances. This calls for regular assessment of cement quality as a fundamental importance for quality assessment, improvement of cement quality, security of lives and properties and for constant check to confirm if they meet up with standards.
In this study, ten different brands of cement (labelled A-J) randomly obtained from different Nigerian markets were assessed for their physicochemical properties in accordance with the Nigerian Industrial Standard. The results obtained were compared to the Nigerian Industrial Standard [4] and British Standard [5].

## EXPERIMENTAL

Ten different cement brands labelled A to J were purchased randomly from Nigerian building material markets. 2.5kg sample of each brand was measured, parceled into an air tight container and taken for analysis. All the sample analyses were carried out at the Quality Assurance Department of Dangote Cement Plc, Gboko Plant, Benue State, Nigeria. For the analysis, the chemical and physical properties of the ten (10) samples were analyzed in accordance with the Nigerian Industrial Standards [5].

## RESULTS AND DISCUSSION

**Table 1: Physicochemical properties of Cement brands**

| Properties | A | B | C | D | E | F | G | H | I | J | BS | NIS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 days compressive strength ($N/mm^2$) | 19.7 | 23.8 | 16.5 | 1.5 | 15.1 | 14.3 | 23.8 | 24.6 | 23.2 | 23.7 | | ≥ 10.0 |
| 7 days compressive strength ($N/mm^2$) | 36.4 | 43.9 | 33 | 9.8 | 31.9 | 30.4 | 39.8 | 35 | 42.9 | 40.9 | | ≥16.0 |
| 28 days compressive strength ($N/mm^2$) | 46.1 | 52.3 | 43.9 | 25.9 | 42.0 | 40.7 | 50.0 | 48.6 | 50.1 | 43.9 | ≥43.5 | ≥42.5 |
| LOI % | 8.16 | 4.45 | 7.43 | 14.56 | 10.99 | 11.22 | 7.83 | 7.74 | 7.70 | 9.16 | | ≤ 5.0% |
| CaO% | 62.1 | 63.9 | 61.41 | 56.44 | 59.61 | 59.89 | 61.25 | 60.86 | 61.34 | 60.29 | 63-69% | |
| $SiO_2$% | 18.93 | 19.2 | 18.7 | 17.86 | 18.48 | 18.2 | 18.26 | 18.6 | 18.68 | 18.8 | 21-22% | |
| $Al_2O_3$% | 5.4 | 5.71 | 5.52 | 4.87 | 5.24 | 5.17 | 5.52 | 5.61 | 5.35 | 5.12 | | |
| $Fe_2O_3$% | 2.97 | 4.58 | 4.64 | 3.14 | 3.47 | 3.41 | 4.11 | 4.27 | 4.06 | 3.97 | | |
| SiR | 2.26 | 1.86 | 1.84 | 2.23 | 2.12 | 2.12 | 1.9 | 1.88 | 1.98 | 2.07 | | |
| AlR | 1.82 | 1.25 | 1.19 | 1.55 | 1.51 | 1.52 | 1.34 | 1.32 | 1.32 | 1.29 | | |
| LSF | 0.99 | 0.99 | 0.98 | 0.95 | 0.98 | 1 | 0.99 | 0.97 | 0.98 | 0.97 | | |
| $C_3S$% | 64.29 | 65.25 | 60.78 | 51.37 | 58.79 | 63.01 | 62.5 | 57.92 | 61.2 | 58.08 | | |
| $C_2S$% | 5.85 | 5.91 | 7.84 | 12.53 | 8.7 | 4.72 | 5.27 | 9.71 | 7.46 | 10.15 | | |
| $C_3A$% | 9.29 | 7.39 | 6.79 | 7.6 | 8.04 | 7.95 | 7.66 | 7.66 | 7.32 | 6.85 | | |
| $C_4AF$% | 9.02 | 13.93 | 14.11 | 9.54 | 10.54 | 10.35 | 12.51 | 12.97 | 12.35 | 12.06 | | |
| Le Chatelier's Expansion (mm) | 0.50 | 0.25 | 1.00 | 0.00 | 0.25 | 0.50 | 1.25 | 0.50 | 0.25 | 0.00 | | ≤ 10 |

Source: Laboratory analysis, 2021

### 3.1. Calcium oxide variants

Amount of CaO as specified by the British standards should be within the range 63% to 67% [British standard] as indicated in table 1 above. Sample D with 2 and 7 days compressive strengths of 1.5N/mm$^2$ and 9.8N/mm$^2$ respectively is below standard specifications of Nigerian Industrial Standard (NIS). In similar vein, the 28 days compressive strengths for samples D (25.9N/mm$^2$), E (42.0N/mm$^2$) and F (40.7N/mm$^2$) are similarly below the British Standard (BS) and NIS. This can be attributed to the low amounts of CaO in the respective samples as seen in figure 1 below.

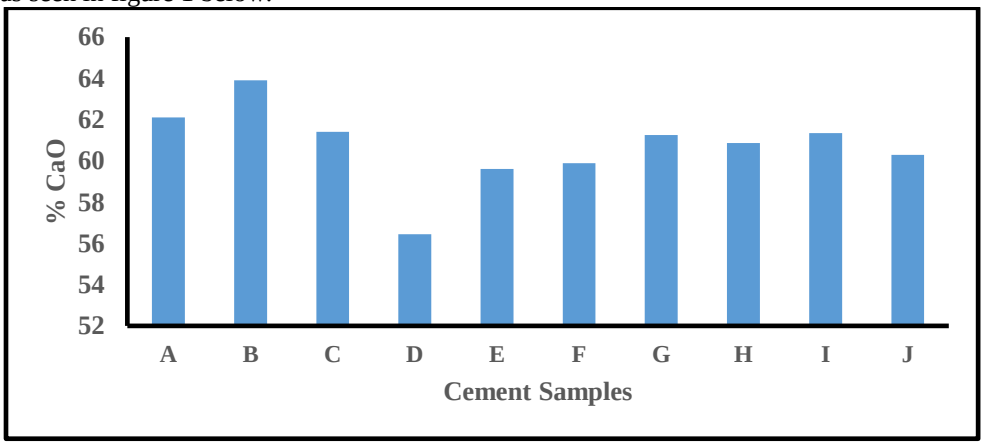


Figure 1: Variation of Calcium oxide

All other samples met the minimum requirement with sample B (63.9%) having the highest amount of CaO which justifies its $C_3S$ (65.25%) value and 28 days compressive strength of 52.3N/mm$^2$ as the highest. According to Chandan *et al*., [6] in order to increase compressive strength it is necessary to raise the lime content, or grind finer, or both. But higher temperatures are required to burn the high lime mixtures.

### 3.2. Variation of Silica ($SiO_2$)

British standards specify amounts of $SiO_2$ in Portland cement within the range 21% to 22%. None of the brands met the minimum range of the BS with sample B having the highest value of $SiO_2$ as seen in the figure 2 below:

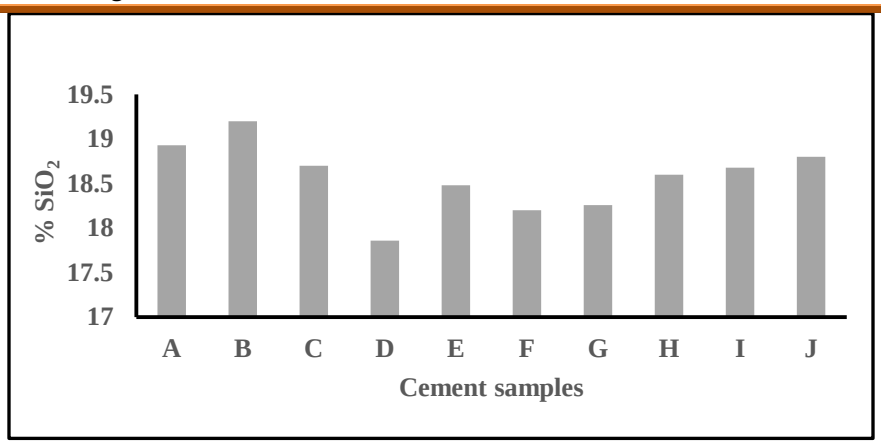


Figure 2: Variation of Silica

According to Okoye *et al.*, [7], the addition of high level of additives to clinker decreases the amounts of oxides such as $SiO_2$, $Al_2O_3$ and $Fe_2O_3$. The high levels of additives as indicated in the Loss on Ignition (LOI) levels of samples A (8.09%), C(7.43), D(14.56%), E(10.99%), F(11.22%), G(7.83%), H(7.74%), I(7.70%) and J(9.16%) could be responsible for the relatively low values of $SiO_2$ in the samples.

### 3.3. Variation of Iron Oxide

Tyopne *et al.*, [2], opined that the more the iron content or tetraluminoferrite the grayer the cement texture. Figure 3 below, describes the variation of Iron Oxide in different brands of cement samples:

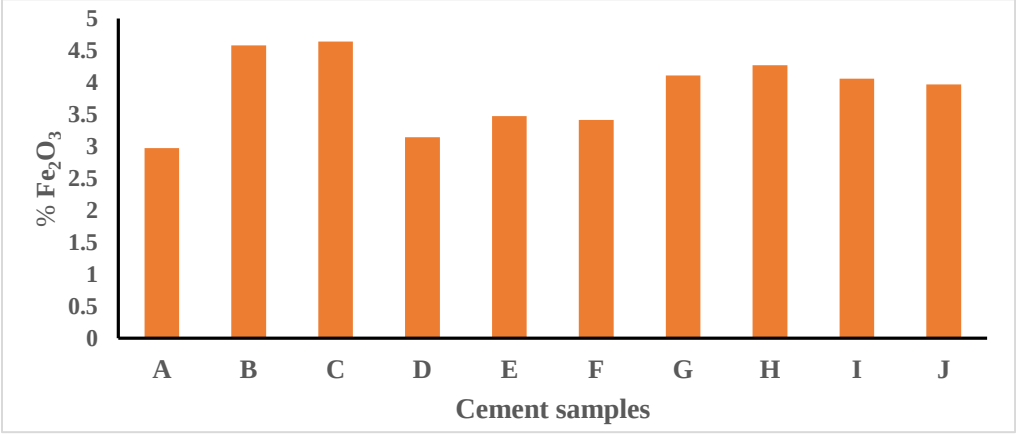


Figure 3: Variation of Iron oxide

A glance at the figure 3, gives a clear information of samples B (4.58%) and C (4.64%) having the high values of $Fe_2O_3$. The high values of $C_4AF$ for B (13.93%) and C (14.11%) as indicated in table 1 is therefore not surprising, making them to appear more greyish than the rest brands.

### 3.4. Variation of Alumina ($Al_2O_3$)

The alumina in tricalciumaluminate reacts with gypsum to form a hydrated product ettringite, a thick layer deposit on hydrating molecules thereby regulating available water for hydration [8]. It is advisable that alumina range falls between 3% and 8% and figure 4 below shows the variation of aluminum oxide in different brands of cement are within advisable range. The higher the values of alumina, the higher values of $C_3A$ and the more the plasticity (workability) of the cement brand.

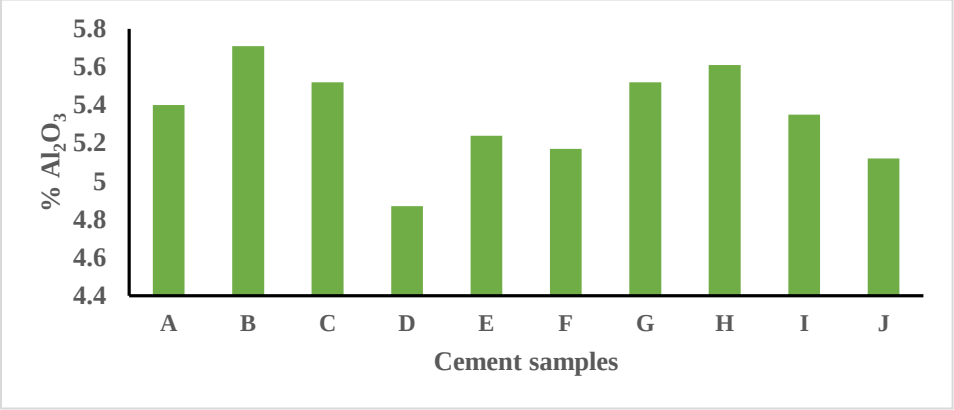


Figure 4: Variation of Alumina ($Al_2O_3$)

**Variation of Lime saturation factor (LSF)**

Lime saturation factor is a very useful process guide. When the LSF approaches unity, the clinker is difficult to burn and often shows excessive high free lime contents. The variation of lime saturation factor for the ten cement brands are as shown in figure 5 below.

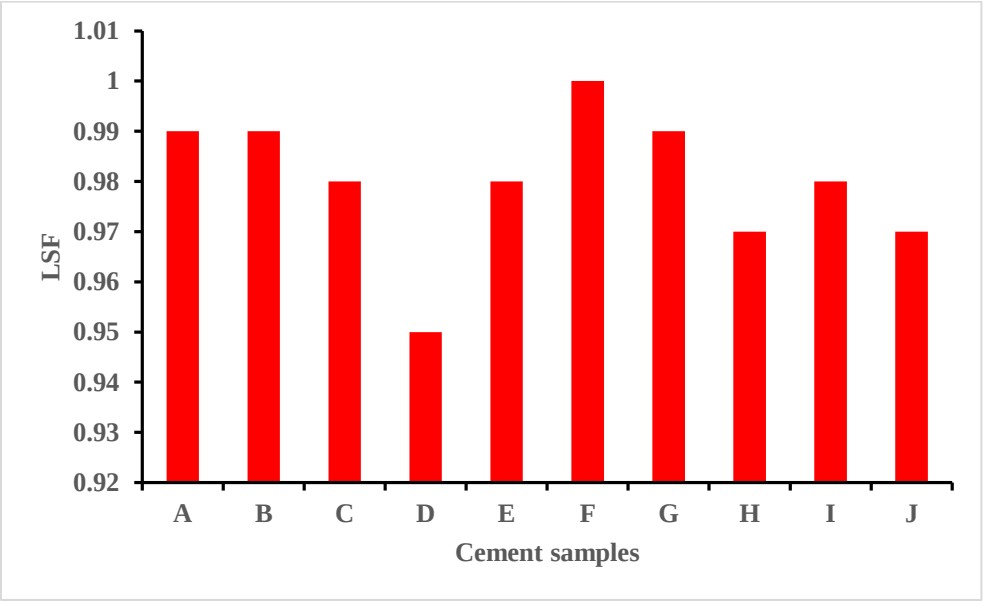


Figure 5: Variation of Lime saturation factor

**Silica Ratio (SiR)**

Clinker with high silica ratio is more difficult to burn and exhibits poor coating properties in the kiln. Low values of Silica ratio often lead to ring formation and low early strength (1-3 days) in the cement. Usually, SiR of 1.5 – 3.0 is preferred. From the figure 6 below it can be seen that all the cement brands are within advisable range.

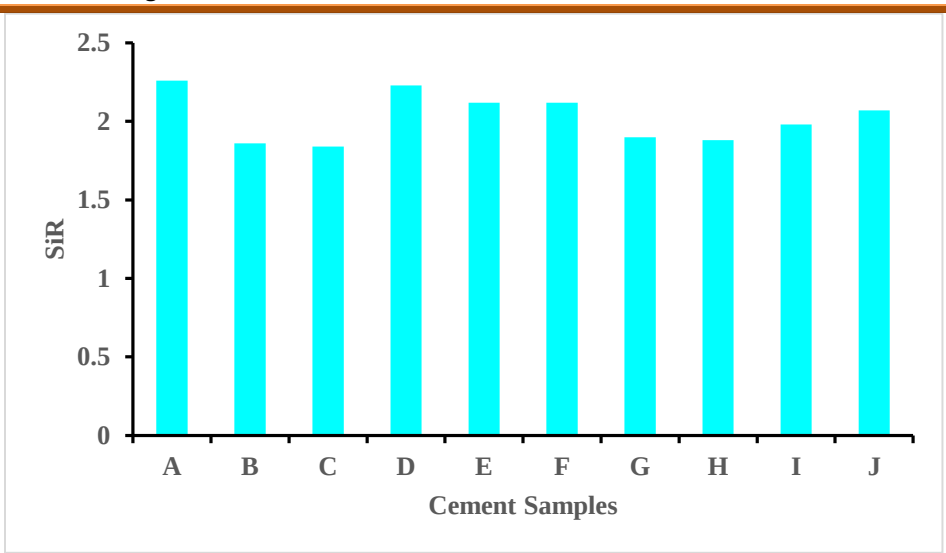


Figure 6: Variation of Silica Ratio (SiR)

**Alumina Ratio (AlR)**

Clinker with high alumina ratio produces cement with high early strength but makes the reaction between the silica and calcium oxide in the burning zone more difficult. It is advisable that AlR should be in the range of 1.0 – 2.5 and a glance at figure 7 below gives acceptable information on the ten brands as all are within the advisable range. From the results of $C_3S$ and $C_2S$ (as shown in table 1), it is significant to note that the reaction between silica ($SiO_2$) and Calcium Oxide (CaO) for the respective brands was spontaneously smooth as indicated by the values of alumina ratio.

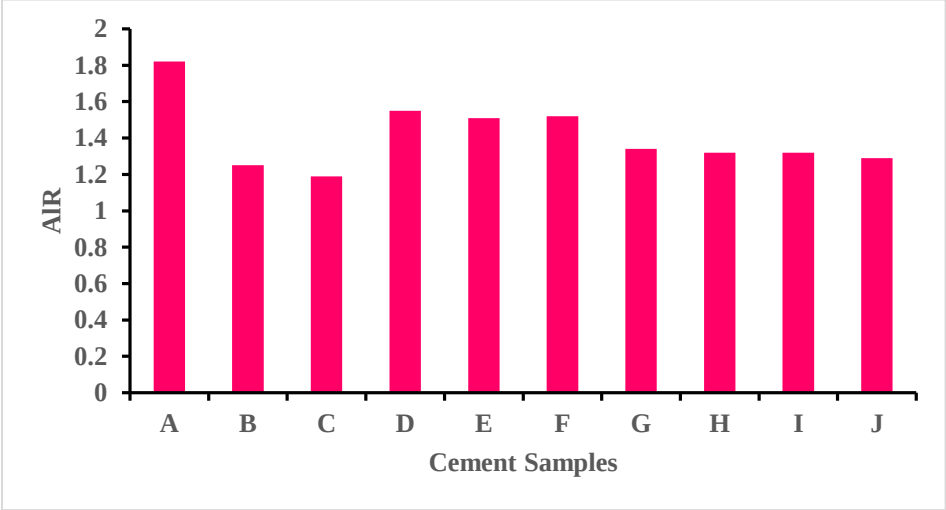


Figure 7: Variation of Alumina Ratio (AlR)

**Clinker Components variation**

Ordinary Portland Cement (OPC) clinker consists mainly of four crystalline phases: tricalcium silicate ($C_3S$), dicalcium silicate ($C_2S$), tricalcium aluminate ($C_3A$), and tetracalcium aluminoferrite ($C_4AF$).

OPC should have about 50-64% of $C_3S$, 25% of $C_2S$, 10% of $C_3A$ [9]. $C_3S$ is the strength-producing constituent of cement whose amount depends on the composition of the clinker, burning temperature, and rate of cooling of the clinker. From figure 8 below, it can be seen that the value of $C_3S$ falls within 50 to 65% with samples B and D having the highest and lowest values respectively.

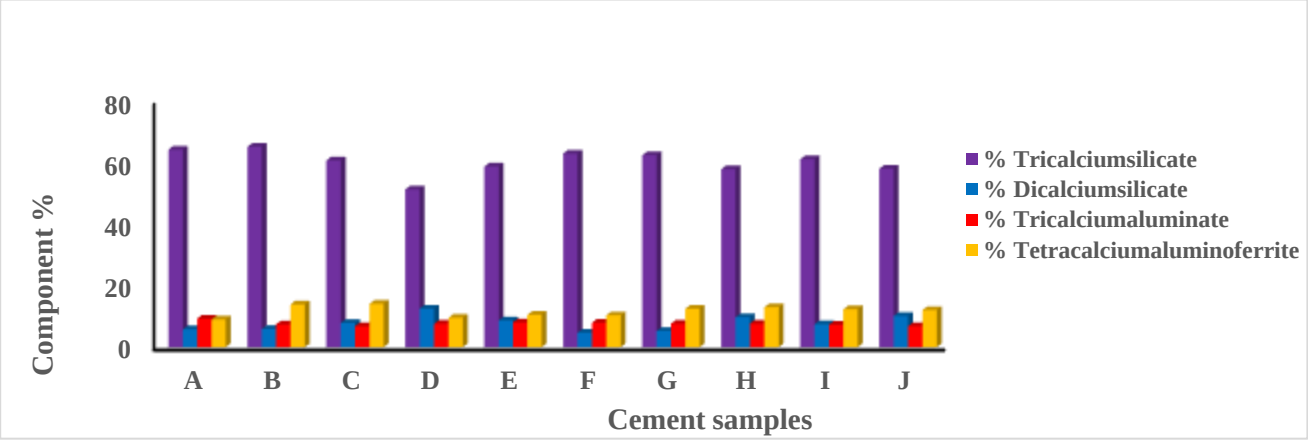


Figure 8: Clinker Components variation

Brand F has good 2 and 7 days compressive strengths that fall within specifications. However, its 28 days' compressive strength of 40.7N/mm$^2$ is slightly below both the NIS and BS specifications. This is not surprising considering its low value of $C_2S$ (4.72%) which is responsible for strength development.

In ordinary Portland cement (OPC), $C_3A$ content is preferred to be about 10%, as cement higher in $C_3A$ is not resistant to sulphate attack [9]. No wonder from the trend of the results in Table1, the $C_3A$ of all the ten samples range from 6.85 to 9.29%.

**Soundness (Lech atelier's Expansion)**

The capacity of cement to retain its volume after setting is referred to as soundness. After hardening, a cement is considered to be sound if it is free of expansion, i.e. no fractures [10]. The degrees of soundness of the 10 samples are shown in Fig. 9. All indicators suggest that all cement brands are in compliant with the requirement. This implies that they have very low (negligible) levels of free CaO, MgO, or excess sulphate, all of which can produce lime, magnesia, or sulphate expansion.

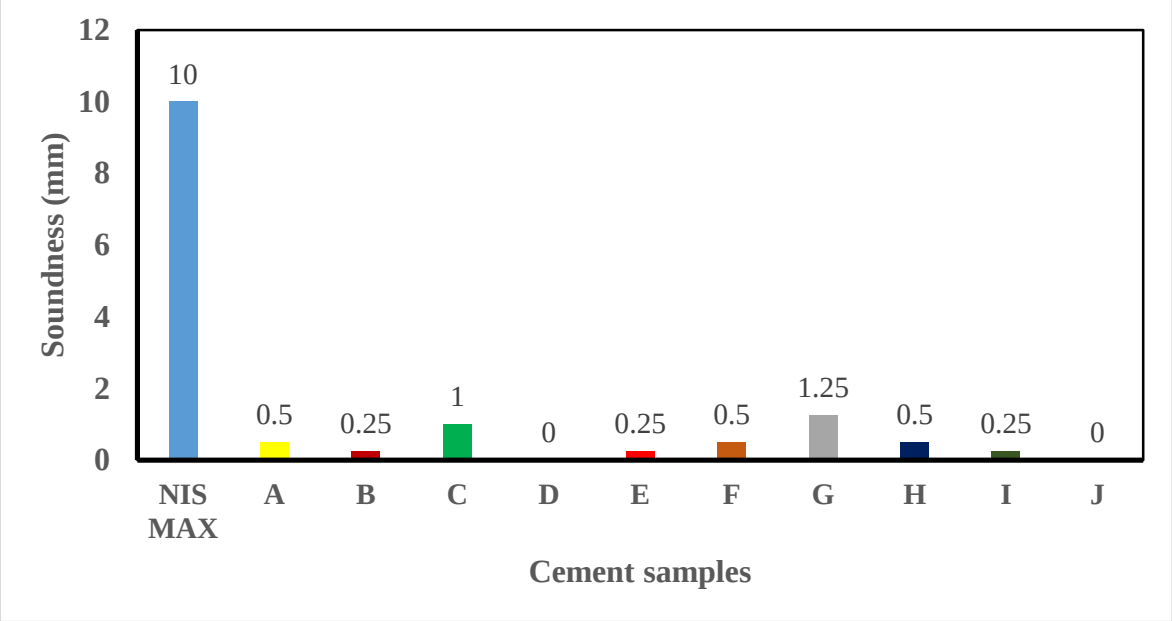


Figure 9: Variation of soundness

**CONCLUSION**

The physicochemical parameters of ten cement brands collected at random from various parts of the country were analyzed in accordance with the Nigerian Industrial Standard (NIS). The findings were discussed in terms of the four major oxides (CaO, $SiO_2$, $Al_2O_3$, and $Fe_2O_3$) that constituted up the major components ($C_3S$, $C_2S$, $C_3A$, and $C_4AF$) in each cement, as well as some quality

control parameters. The results of all the brands was compared against each other and against the Nigerian Industrial Standards (NIS) and British Standard (BS).

Sample D had compressive strengths of 1.5N/mm2 and 9.8N/mm2 after 2 and 7 days, respectively, which are below NIS standards. Similarly, sample D (25.9N/mm2), E (42.0N/mm2), and F (40.7N/mm2) had 28-day compressive strengths that are lower than the BS and NIS. The low quantities of CaO in the samples can be attributed to this. The relatively low values of SiO2 in the samples could be due to the high levels of additives (above NIN specification) as indicated in the Loss on Ignition (LOI) of samples A (8.09 percent), C(7.43), D(14.56 percent), E(10.99 percent), F(11.22 percent), G(7.83 percent), H(7.74 percent), I(7.70 percent), and J(9.16 percent). The differences in aluminum oxide between brands are within an acceptable range. It is imperative therefore to recommend that use of additives in cement production be applied with moderation and compliance to standards by cement manufacturers should be a paramount objective with optimal consistency.

## ACKNOWLEDGEMENT

I wish to express my gratitude to Dangote Cement Plc, Gboko Plant, Benue State, Nigeria, for providing me with the opportunity and required support that aided me in carrying out this study using their laboratory.

## REFERENCES

1. Simpson, J. & Weiner, E. (1989). The Oxford English Dictionary, 2nd edition, Clarendon Press publishing Co. Ltd, Enugu, pp. 1-54.

2. Tyopine, A. A., Okoye, C. O. % Agbazue, V. E. (2015). An investigation of the effect of thermally untreated limestone on chemical composition of ordinary Portland cement produced in Nigeria. African Journal of Science and Research, 2(4), 16-19

3. Obiajunwa, E. I. & Nwanchukwu, J. I. (2000). Elements analysis of limestone samples from Ewekoro limestone deposit, Nuclear Instruments and Methods in Physics Research section B: Beam Interaction with Materials and Atoms. 170(53), 427-431

4. NIS 444-1: 2014, Composition, Specification and Conformity criteria for common cements. Nigerian Industrial Standard (NIS) in the Standard Organization of Nigeria (SON). Lagos

5. British standard Institutes, Section BS 4550: Part 2: 1970 and BS 12: 1991.

6. Chandan K. P., Venugopal N. V. and Prabhakar Y. S. (2018), Studies on the assessment of cement parameters of different brands of cements. International Journal of Civil Engineering and Technology (IJCIET). 9(6), 807-812

7. Okoye, C., Tyopine, A., & Agbazue, C. (2015). An investigation of the effect of thermally untreated limestone on chemical composition of ordinary Portland cement produced in Nigeria. *African Journal of Science and Research*. **2**(4): 16-19

8. Lea, F. (1970). Chemistry of Cement and Concrete. Edward Amold Ltd, London 3rd ed. p. 250

9. Agbazue, V. E. (1992). A Guide to cement industry and quality control in Nigeria: Fourth Dimension Publishing Company Ltd. Enugu.

10. Neville, A. M. (2000). Properties of Concrete. Fourth Edition, Pearson Education Asia pvt. Ltd.