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# Comparative Study of the Compressive Strength of Concrete made from Different Brands of Cements in Ghana

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***Authors' contributions***

*This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.*

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## ABSTRACT

There is an on-going debate about the strength and durability of the different brands of cements used for construction in Ghana. This has raised doubts on the quality and performance of the strength of the different brands of cements. Concrete is a composite material made of aggregates such as sand and stone that are mixed uniformly in the required proportion together with water for it to achieve the desired strength in its development. Cement is an important ingredient that binds together other building materials by a combination of chemical processes known as setting. Among the various physical properties of cement, compressive strength is the most vital property which gives an overall assessment of quality of concrete as the strength of concrete shows the ability of the structure to withstand various loads during it lifelong performance after construction. This research investigated the compressive strength of six different brands of 32.5R and 42.5R cements used for construction works in Ghana, namely, CIMAF cement, DIAMOND cement, GHACEM cement, SOL cement, SUPACEM cement and DANGOTE cement. Among the 32.5R brands, GHACEM cement developed the highest 28$^{th}$ day compressive strength of 30.96 N/mm$^2$ and CIMAF cement the lowest strength of 25.89 N/mm$^2$. In the 42.5R group, DANGOTE had the highest 28$^{th}$ compressive strength of 37.19N/mm$^2$ while SOL produced the lowest with 31.11N/mm$^2$.

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## 1. INTRODUCTION

Cement is one of the building materials that is potentially a non-metallic substance in nature with hydraulic binding properties and usually applied as a binding agent in building materials such as concrete and other masonry works in the construction of structures in global infrastructural development and has been used in the construction industry for several decades [1]. It has widely been accepted as a construction material for a variety of applications in both civil and structural engineering works where strength forms the core objectives in its development. It is sometimes considered as prime ingredient in concrete and normally accounts for about 5% of global carbon dioxide emission [2]. The quality of cement is often a measure of the specific surface area [3]. It is estimated that, the strength of concrete is normally determined by the type of cement used in producing the concrete. However, in recent times there has been on-going debate about the influx of different brands of cements on the markets of many developing countries such as Ghana that are used for the execution of construction projects in various forms.

The quality of the different brands of cements has raised doubts about their strength and performance in the development of concrete used for structural or other masonry work [4]. In view of this, many researchers have carried out studies in the area of cement technology to assess the quality and strength of concrete made from the different brands of cements used for construction work. As an example, in Ganiron [5], investigated the effects of polymer fiber on the properties of concrete. It was observed that polymer fiber which usually served as a superplasticizer admixture results in concrete's lower rate of water absorption, high-rate water reducer, greater strength and excellence in elasticity. Nayana et al. [6] evaluated the feasibility of using both hemp shives and fiber in Hempcrete (HC) to determine an optimal mix of the different binding agents and to investigate the performance of cement binder to the improvement on the mechanical strength of the material. Masood Rafi et al. [7], observed that concrete is a strong material that possesses high strength in compression and is usually employed to resist compressive stresses in masonry and reinforced concrete structures where strength forms a major aspect of the rigidity of cement used in producing it. Bediako and Amankwa [8] also observed that the performance of Portland cement in concrete or mortar formation is very well influenced by chemical compositions among other factors. In their estimation, many engineers usually have little information on the chemical compositions of cement in making decisions for the choice of commercially available Portland cement in Ghana.

Concrete is a composite material composed mainly of cement, fine aggregates (sand) and coarse aggregates measured in a specified ratio mixed with water which hardens with time [9]. It is a strong material that possesses compression and is usually employed to resist compressive stresses in masonry and reinforced concrete structures where strength forms a major aspect of the rigidity of cement used in producing it [7]. The major requirement of a structure's strength depends mostly on the quality of cement used in producing the concrete [10]. Moreover, in the design of concrete structures, engineers have the flexibility to specify particular types of concrete with the view of meeting the specific performance requirements for their project [11]. However, in reinforced concrete design, a range of properties of concrete used are not normally part of the concrete specification. These may relate to both structural integrity and serviceability. In Abubakar et al. [12], it was observed that durable concrete is expected to achieve maximum strength and last longer when exposed to weather without any form of deterioration. The basic objective in reinforced concrete design is to produce a structure capable of resisting all applied loads without failure during its intended life [13]. The effects of compressive strength of concrete in infrastructural development depend on the brand of cement to be used. Chen et al. [14], observed that some of the brands of cements recently used by builders for construction contain chemicals which alter the compressive strength of concrete. It was reported in their study that designers usually use the 28-day characteristic compressive strength for structural calculations.

The compressive strength is the most fundamental indicator in estimating the mechanical strength of concrete, and usually concrete with different strengths is applicable to different engineering conditions since the growing demand for cement for construction projects in recent has increased tremendously [15]. In most structural applications where cement and concrete are used, the compressive strength technique is often applied as the measure of resistance since it is considered the easier method of measurement as the properties of concrete and cement [16]. Therefore, it is interesting to note that cement should always be tested for its strength at the laboratory before being allowed to be used for any important concrete works [17]. However, strength is not performed on neat cement paste because of the difficulties of excessive shrinkage and subsequent cracking of the cement material. Strength of cement is indirectly found on the cement sand mortar in specific proportion. Normally sand is used as the standard material for finding the strength of cement. In a research by Kallutla et al. [18], a compressive strength of cement was predicted using regression technique with partial replacement of hylam powder in cement mortar. The analysis of their investigation showed that the incorporation of the hylam powder increased the strength of the twenty-eight (28) days in comparison with a control mortar. Bamigboye et al. [19] conducted a laboratory investigation on the assessment of the compressive strength of concrete produced from different brands of Portland cements used for infrastructural development in Nigeria. The investigation of the compressive strength of concrete is a fundamental requirement in assessing the quality and the effective performance of the different brands of cements used for construction work in Ghana. The quality of cement is an essential phenomenon as it materially contributes to the strength and durability of the structure over time. Previous research by Akyen and Kankam [20] found significant variations in the chemical compositions among the various brands of cements in Ghana. These chemical compounds and their contents in the cements are illustrated in Tables 1 (a to d). Hydration of cement is a chemical reaction involving water and the chemical compounds in cement, and it is expected that significant differences in the contents of the chemical compounds will affect the properties such as strength of hydration products.

## 2. EXPERIMENTAL METHODS

### 2.1 Materials and Testing

#### 2.1.1 Materials

Materials used in the research included six selected brands of cements chosen from the Ghanaian markets namely: GHACEM cement, CIMAF cement, DANGOTE cement, SUPACEM cement, DIAMOND cement and SOL cement, coarse aggregate and fine aggregate (sand). However, GHACEM cement, DANGOTE Cement, CIMAF Cement, DIAMOND Cement, SOL Cement and SUPACEM come in different classes. These are Class 32.5R, Class 42.5R and Class 42.5N for GHACEM; Class 32.5R and Class 42.5R for CIMAF Ultimate Plus and Class 42.5R for the CIMAF Smart Superior brand. GHACEM 42.5N was not used in this research due to shortage of the product in the Ghanaian markets at the time of conducting this research. SUPACEM and SOL cements both have the two classes of 32.5R and 42.5R brands and were included in the study. DIAMOND 32.5R and DANGOTE 42.5R were used in the study.

#### 2.1.2 Preparation of concrete test specimens

The test was carried out on six different brands of cements obtained from different locations in the local markets. Samples of well-graded aggregates for each concrete mix were air-dried in the laboratory. The quantity of cement, sand, gravel and water for each batch was determined by weight, to an accuracy of 0.1% of the total weight of the batch in the laboratory. The mix proportions were (cement: sand: gravel) 1: 1.22: 2,27 with w/c = 0.55 for 32.5R, and 1: 1.33: 2.45 with w/c = 0.6 for 42.5R brands of cements. Each cement brand was used to cast concrete to determine the compressive strength at the age of 7, 14, 21 and 28 days using a universal compression testing machine of 3000 kN capacity.

#### 2.1.3 Testing of concrete cubes

The compression machine used in this research was hydraulically operated with a digital display monitor for the rate of loading and peak load at failure. Concrete test cubes were placed centrally in the compression testing machine and a very small load was gradually applied initially to keep the cube in position. The load was then applied to the concrete test cube at a constant rate until failure by crushing. The concrete test cube measured 150 x 150 x 150 mm in accordance with the requirements of ASTM C39/C39M-2020 standards. The concrete cubes were cured in the laboratory at a temperature of 37˚C and relative humidity of 100% prior to testing.

**Fig. 1. Concrete test specimens**

**Fig. 2. Testing of concrete specimen in the test machine**

## 3. RESULTS AND DISCUSSIONS

The experimental results are divided into two sections. The first section gives a summary and details of the tests results of both of 32.5R and 42.5R brands of cements.

### 3.1 Results

#### 3.1.1 Compressive strength of 32.5R and 42,5R brands of cements

Tables 2 and 3 present the compressive strength of concrete prepared from the different 32.5R and 42.5R brands of cements respectively. The rates of development of strength at ages 7, 14, 21 and 28 days, and their average over the periods are presented in Table 4 for both 32.5R and 42.5R cements brands. In addition, Figs. 3 and 4 illustrate the relationship between the compressive strength and age of concrete produced respectively from 32.5R and 42.5R cements.

### 3.2 Discussions

#### 3.2.1 Target compressive strength

The results generated from the laboratory tests are presented in tables and figures. A $28^{th}$ day compressive strength of $30N/mm^2$ (C30) was set for concrete mix proportions of 1: 1.22: 2.27 (cement: sand: gravel) with w/c =0.55 for the 32.5R cements, and 1: 1.33: 2.45 with w/c = 0.60 for 42.5R cement brands. This target strength was set as the minimum that the various brands were expected to achieve in compliance with their respective specifications. The various cement brands gave appreciable compressive strength at the various test ages. Ghacem (32.5R), SOL (32.5R) and Diamond (32.5R) gained the expected target strength of 30 (C30) after 28 days. It is observed from Table 1 and Fig. 1 that CIMAF (32.5R) and Supacem (32.5R) cement brands did not develop the expected target strength of 30 (C30) at age 28 days. CIMAF and Supacem 32.5R developed lower compressive strength values compared with the other cement brands, which were consistent with the target compressive strength (C30).

As expected, the 42.5R grades of the various of cement also showed progressive increase in their compressive strength as the curing age increased from 7 days to 28 days. However, there was a slight difference between the compressive strengths of the concrete mixes made from three of the brands of cements, namely, CIMAF Smart Superior, CIMAF Plus and SOL, whereas DANGOTE was found to differ largely from the other brands as illustrated in Fig. 2. GHACEM cement on the other hand exhibited different compressive strength values emerging as the next highest brand after DANGOTE whilst DIAMOND and SOL cement showed lower strength values slightly exceeding the target mark of 30 N/mm$^2$.

#### 3.2.2 Rate of strength development

It is pertinent to note from Fig. 1 that the strength attainment at age 7, 14, 21 and 28 days for most brands of cements especially Diamond (32.5R)

**Table 1a. Chemical compounds of 32.5r brands of cements [20]**

| Chemical compounds | Percentage (%) | | | | |
|---|---|---|---|---|---|
| | Ghacem 32.5R | Diamond 32.5R | CIMAF 32.5R | Supacem 32.5R | Sol 32.5R |
| $SiO_2$ | 22.90 | 23.70 | 32.80 | 28.90 | 26.60 |
| $Fe_2O_3$ | 4.55 | 2.34 | 4.45 | 4.52 | 7.68 |
| CaO | 58.00 | 56.40 | 47.20 | 51.10 | 48.50 |
| $Al_2O_3$ | 5.80 | 6.99 | 7.92 | 7.49 | 7.45 |
| MgO | 3.34 | 5.90 | 2.07 | 2.94 | 2.85 |
| $SO_3$ | 3.46 | 2.52 | 2.77 | 2.63 | 4.09 |
| $Na_2O$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $K_2O$ | 0.61 | 0.584 | 1.52 | 1.12 | 0.899 |

**Table 1b. Chemical compounds of 42.5R brands of cements [21]**

| Chemical compounds | Percentage (%) | | | | | |
|---|---|---|---|---|---|---|
| | CIMAF Smart Superior 42.5R | CIMAF Ultimate Plus 42.5R | Dangote 42.5R | Ghacem 42.5R | Sol 42.5R | Supacem 42.5R |
| $SiO_2$ | 22.90 | 24.40 | 15.70 | 22.10 | 22.10 | 21.50 |
| $Fe_2O_3$ | 3.59 | 3.77 | 3.49 | 4.04 | 5.18 | 4.17 |
| CaO | 60.90 | 59.20 | 70.10 | 61.10 | 59.80 | 61.50 |
| $Al_2O_3$ | 5.09 | 5.38 | 3.78 | 5.20 | 5.18 | 5.36 |
| MgO | 2.05 | 2.37 | 1.08 | 3.25 | 1.78 | 3.22 |
| $SO_3$ | 3.43 | 2.85 | 4.13 | 2.51 | 3.47 | 2.39 |
| $Na_2O$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $K_2O$ | 1.04 | 0.85 | 0.773 | 0.68 | 0.889 | 0.766 |

**Table 1c. Combined chemical compounds of 32.5 brands of cements [22]**

| Chemical compounds | Percentage (%) | | | | |
|---|---|---|---|---|---|
| | Ghacem 32.5R | Diamond 32.5R | CIMAF 32.5R | Supacem 32.5R | Sol 32.5R |
| CaO+ $SiO_2$ +$Fe_2O_{3+}$ $Al_2O_3$ | 91.25 | 89.43 | 92.42 | 92.0 | 90.26 |
| CaO +$SiO_2$ ++ $Al_2O_3$ | 86.7 | 86.99 | 82.76 | 87.49 | 82.55 |
| CaO + $SiO_2$ | 80.9 | 80.1 | 80.0 | 80.0 | 75.1 |

**Table 1d. Combined chemical analysis of 42.5R brands of cements [22]**

| Chemical Compounds | Percentage (%) | | | | | |
|---|---|---|---|---|---|---|
| | CIMAF Smart Superior 42.5R | CIMAF Ultimate Plus 42.5R | Dangote 42.5R | Ghacem 42.5R | Sol 42.5R | Supacem 42.5R |
| CaO+ $SiO_{2\,+}$ $Fe_2O_3$+ Al2O3 | 92.48 | 92.75 | 93.07 | 92.44 | 92.26 | 92.53 |
| CaO+ SiO2 + $Al_2O_3$ | 88.89 | 88.98 | 89.58 | 88.40 | 87.08 | 88.36 |
| CaO + $SiO_2$ | 83.8 | 83.6 | 85.8 | 83.2 | 81.9 | 83.0 |

**Table 2. Compressive strength of 32.5R brands of cements**

| Cement brand | Class | Compressive strength (N/mm$^2$) | | | |
|---|---|---|---|---|---|
| | | 7-Days | 14-Days | 21-Days | 28-Days |
| CIMAF | 32.5R | 17.19 | 19.56 | 21.11 | 25.89 |
| Diamond | 32.5R | 22.81 | 25.33 | 28.59 | 30.29 |
| Ghacem | 32.5R | 20.67 | 24.59 | 27.41 | 30.96 |
| Sol | 32.5R | 22.44 | 29.11 | 30.52 | 30.81 |
| Supacem | 32.5R | 20.44 | 24.81 | 26.96 | 28.44 |

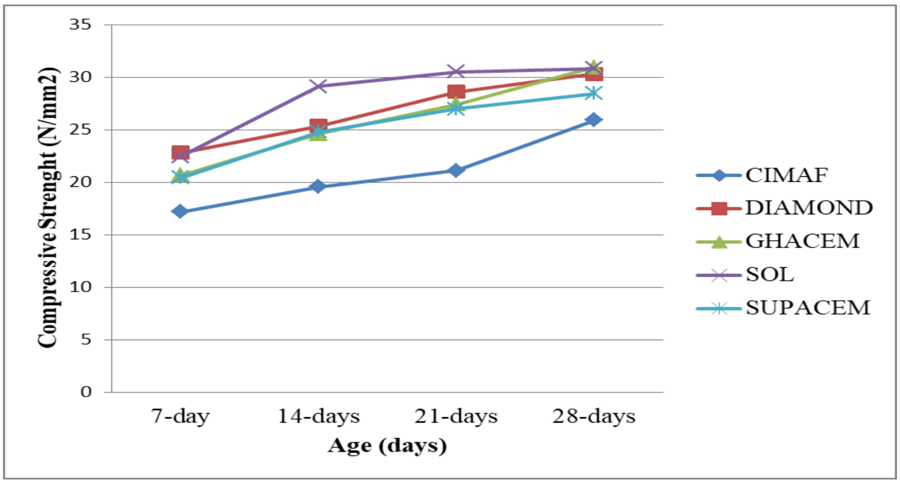


**Fig. 3. 32.5R brands of cements**

**Table 3. Compressive strength of 42.5R brands of cements**

| Cement brand | Class | Compressive strength (N/mm$^2$) | | | |
|---|---|---|---|---|---|
| | | 7-Days | 14-Days | 21-Days | 28-Days |
| CIMAF Smart Superior | 42.5R | 22.96 | 25.63 | 28.89 | 31.56 |
| CIMAF Ultimate Plus | 42.5R | 24.59 | 26.15 | 28.15 | 31.48 |
| Dangote | 42.5R | 26.74 | 31.26 | 36.07 | 37.19 |
| Ghacem | 42.5R | 21.33 | 24.89 | 27.33 | 32.29 |
| Sol | 42.5R | 21.63 | 23.78 | 26.93 | 31.11 |
| Supacem | 42.5R | 18.22 | 22.37 | 25.66 | 31.41 |

**Table 4. Rate of strength development(N/mm² per day)**

| Cement brand | Age(days) | | | | Average |
|---|---|---|---|---|---|
| | 7 | 14 | 21 | 28 | |
| **32.5 R** | | | | | |
| CIMAF | 2.456 | 1.397 | 1.005 | 0.925 | 1.446 |
| DIAMOND | 3.258 | 1.809 | 1.361 | 1.082 | 1.876 |
| GHACEM | 2.933 | 1.756 | 1.305 | 1.106 | 1.78 |
| SOL | 3.206 | 2.079 | 1.453 | 1.100 | 1.960 |
| SUPACEM | 2.920 | 1.772 | 1.284 | 1.016 | 1.748 |
| **42.5 R** | | | | | |
| CIMAF SMART SUPERIOR | 3.280 | 1.831 | 1.376 | 1.127 | 1.903 |
| CIMAF ULTIMATE PLUS | 3.513 | 1.868 | 1.340 | 1.124 | 1.961 |
| DANGOTE | 3.82 | 2.233 | 1.718 | 1.328 | 2.275 |
| GHACEM | 3.047 | 1.778 | 1.301 | 1.153 | 1.820 |
| SOL | 3.09 | 1.699 | 1.282 | 1.111 | 1.796 |
| SUPACEM | 2.603 | 1.598 | 1.222 | 1.122 | 1.636 |

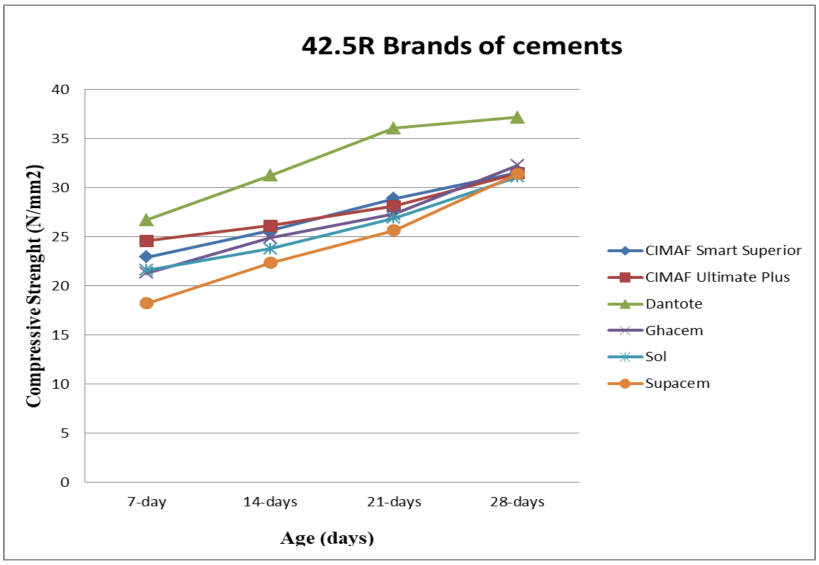


**Fig. 4. 42.5R brands of cements**

and Ghacem (32.5R) were gradual and continued to increase gradually through the 28 days period, slightly exceeding the target compressive strength of 30 N/mm$^2$. However, Supacem (32.5R) could not reach the expected target strength of 30 N/mm$^2$ whilst the strength achieved by SOL cement at age 7 days was gradual but became very rapid after 14 days. This behavior might be attributed to some additive in the cement during its production. It further continued to increase gradually through the 28 days at the target compressive strength of 30 N/mm$^2$ when tested. As illustrated in Fig. 2 and Table 2, Dangote cement shows a progressive increase in the compressive strength from the initial age of 7 days with strength of 26.74 N/mm² to the maximum strength of 37.19 N/mm². Ghacem (42.5R) cement shows an appreciable early compressive strength at 7 days with an average strength of 21.33 N/mm² and increased progressively to an average strength of 32.29 N/mm² at later age 28 days.

Furthermore, it is important to mention that, slight differences were observed among the compressive strength values of four of the 42.5R cement brands, namely, Ghacem, CIMAF Ultimate Plus, CIMAF Smart Superior and Sol, concrete mixes, at all the curing ages 7, 14, 21 and 28 days. Ghacem (42.5R) cement developed strength values of 21.33 N/mm$^2$, 24.89 N/mm$^2$, 27.33 N/mm$^2$ and 32.29 N/mm$^2$ at ages 7, 14, 21 and 28 days, respectively. This shows that there was a progressive increase in the strength of Ghacem (42.5R) cement. A similar behavior was observed with the CIMAF grades of cement concrete, in which strength values were slightly above 30 N/mm$^2$. The CIMAF Ultimate Plus (42.5R) cement performed steadily well by showing gradual increase in compressive strength of 24.59 N/mm$^2$ at age 7 days to a maximum of 31.48 N/mm$^2$ at age 28 days. CIMAF Smart Superior (42.5R) cement also developed strength values ranging from 22.96 N/mm$^2$ after 7 days to a maximum value of 31.56 N/mm$^2$ after 28 days, thus slightly exceeding the target compressive strength C30 set for the 32.5R cement brands. Moreover, the average compressive strength values for SOL (42.5R) cement increased steadily at all ages. It developed a significant increase from 21.63 N/mm$^2$ on the 14$^{th}$ day to 31.11 N/mm$^2$ on the 28$^{th}$ day.

### 3.2.3 Ranking of the brands of cements

A ranking of the 32.5R brands of cements in respect of their 28$^{th}$ day compressive strength in descending order is as follows: GHACEM, SOL, DIAMOND, SUPACEM and CIMAF in that order.

In the case of the 42.5R brands of cements, the ranking order is: DANGOTE, GHACEM, CIMAF Smart Superior, CIMAF Ultimate Plus, SUPACEM and SOL as illustrated in Fig. 2. A comparison of their average rate of strength gain over a period of 28 days gives values in N/mm$^2$ per day as shown in Table 4 and ranks the brands from highest to lowest as: DANGOTE, CIMAF Ultimate Plus, CIMAF Smart Superior, GHACEM and SUPACEM.

The trends in the ranking order of both 32,5R and 42.5R brands of cements in respect of their compressive strength generally confirm the findings by Akyen and Kankam (2022) that the brands that contained the largest combined chemical compounds (viz. CaO, $SiO_2$ and $Al_2O_3$) mostly required in hydration processes of cements would develop highest strength. In addition, the results confirm that 42.5R brands of cements were expected to develop higher compressive strength since they were found to contain larger combined chemical compounds of CaO, $SiO_2$ and $Al_2O_3$ for hydration process when compared with 32.5R cements (Akyen and Kankam, 2022).

## 4. CONCLUSIONS

The following conclusions are drawn from the test results of the study:

1. The various brands of cements have all demonstrated their capacity of providing the strength performance of concrete when used in structural applications and other civil and construction works.
2. It was also noticed from the results that though a good number of cements have the 7$^{th}$ day compressive strength less than (C30), most of the 32.5R have their 28$^{th}$ day compressive strength slightly above C30.
3. It was observed that some brands of 32.5R cements do not meet the strength requirements of C30 (viz. 30 $N/mm^2$) as specified to be their minimum standard strength and adopted for use in this study. The mix design (1: 1.22: 2.27 ; w/c = 0.55 for 32.5R, and 1: 1.33: 2.45; w/c = 0.6 for 42.5R cements was calculated to ensure that cements used in the experimental investigations meet the minimu strength requirements of C30 grade.
4. A comparison of the 32.5R cements shows that the highest 28$^{th}$ day compressive strength was developed by GHACEM, followed by SOL, DIAMOND, SUPACEM and CIMAF in that order.
5. In the case of 42.5R, the order of ranking from the highest strength is DANGOTE, GHACEM, CIMAF Smart Superior, CIMAF Ultimate Plus, SUPACEM and SOL

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES

1. Omoniyi KI, Okunola OJ. Comparative studies of physio-chemical properties of some selected cement in Nigeria. Nigeria Technological Development. 2014;12(2): 54-60.
2. Mantur A, Shivananda KP, Dattatreya JK. Investigation of strength characteristics of cement bagasse ash mortars using full factorial approach. International Journal of Research and Advanced Technology. 2016;2(7):2454-6135.
3. Arvaniti EC, Maria CG, Juenger SA, Bernal JD. Determination of particle size, surface area, and shape of supplementary cementitious materials by different techniques. Materials and Structures. 2015;48:3687-3701.
4. Aryal BE. Field based quality assessment of cement. Saudi Journal of Civil Engineering. 2019; 135-140.
5. Ganiron TJ. Influence of polymer fiber on strength of concrete. International Journal of Advanced Science and Technology. 2013;55:53-66.
6. Nayana MTK, Sunil HG, Devika R, Akshay K. Manufacturing of building blocks using Hempcrete, International Journal of Latest Research in Engineering and Technology. 2016;2: 62-73.
7. Masood RM, Murtaza NM. Experimental investigation of chemical and physical properties of cements manufactured in Pakistan. Journal of Testing and Evaluation. 2014;2014;42(3):1-3.
8. Bediako M, Amankwah EO. Analysis of chemical composition of portland cement in Ghana: A key to understand the behavior of cement. Advances in Materials Science and Engineering; 2015;2-5.
9. Xiong MX, Wang Y, Liu X, Chen G. Composite use of high strength steel and construction materials for sustainable civil engineering. Frontiers in Materials. 2021;8:1-2.
10. Kaiyu J, Xiaojian W. Quality control and evaluation of methods of concrete engineering and its analysis. The Open Civil Engineering Journal. 2015;9:639-643.
11. Osalu SM, Shakib H. The effect of foundation flexibility on probabilistic seismic performance of plan-asymmetric buildings with different strength distributions. Hindawi Journal Advances in Civil Engineering. 2020;1-23.

12. Abubakar MA, Aguwa JI, Adejuma TWE. Effect of water-cement ratio on compressive strength of spray cured concrete. Nigeria Journal of Engineering and Applied Sciences. 2018;5(1):102-111.
13. Roggema R. Research by design: Proposition for a methodological approach. Urban Science; 2017;1-19.
14. Chen W, Elkatatny S, Murtaza M, Mahmoud AA. Recent advances in magnesia blended cement studies for geotechnical well construction-a review. Frontiers in Materials. 2021;1-24.
15. Khoury GA. Compressive strength of concrete at high temperature: a reassessment. Magazine of Concrete Research. 2015;44(161):291-309.
16. Salih MA, Aldikheelli MR, Shaalan KA. Evaluation of factors influencing the compressive strength of Portland cement statistically, IOP Conference Series: Materials Science and Engineering. 2020;1-10.
17. Huang H, Shen XD. Analysis of variance for testing method of cement in determination of strength. Progress in Natural Science: Materials International. 2011;21:341-346.
18. Kallutla M, Sreenivasulu G, Sashidhar C. Prediction of compressive strength of cement by using regression technique with partial replacement of hylam powder in cement mortar. Civil Engineering and Urban Planning. An International Journal. 2016;3(2):137-144.
19. Bamigboye GO, Ede AN, Egwuatu C, Jolayemi J. Assessment of compressive strength of concrete produced from different brands of portland cement. Civil and Environmental Research. 2015;8(8):31-38.
20. Akyen T, Kankam CK. Comparative study of the chemical analysis of different brands of cements used in Ghana. Journal of Engineering Research and Reports. 2022;23(5):68 – 78.



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