Product Marking and Conformity Assessment of Portland Cements on the Ghanaian Market*

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Kuma, J.S.Y., Affam, M. and Asare, N.A. (2021), "Product Marking and Conformity Assessment of Portland Cements on the Ghanaian Market", *Ghana Mining Journal*, Vol. 21, No. 2, pp. 12-18.

Abstract

Cement bound concrete materials and complementary fittings are requisite ingredients for all civil engineering works. In all these, Portland cement, a basic binding ingredient for the concrete work is the dominant binder. In Ghana, there are various brands of cement on the market. Five major brand products currently in circulation include the Ghana Cement (GHACEM), Western DIAMOND Cement (DIAMOND), CIMAF Cement, DANGOTE Cement and SUPACEM Cement. Increased infrastructural development has placed high demand on cement consumption. Consequently, new products keep emerging in the market. Indeed, a standard measure to provide product marking and evaluations of conformity to standard *Class* thresholds are required for the desired specification, properties and the performance quality of the cement products. This research therefore sets to ascertain the strength quality of the five cement brands on the Ghanaian market by checking their conformity to *C-30* and *C-40* standard compressive tests, using their 32.5-R and 42.5-R flagship brands. To achieve this, concrete cubes were moulded with fixed mix ratio of 1:1½:3 and 1:1:2 for *C-30* and *C-40* respectively. To achieve the desired strength conformity, the slump as well as the coarse and fine aggregate constituents were standardised. The results indicated that the cement brands despite parading same strength thresholds in the market, do not exhibit same strength build-up. There are significant variations in growth of compressive strength over time. It was observed also that conformance threshold within 28 days was not attained for a number of the brands. Indeed, not until 56 days or more some of the brands could not achieve their desired compressive strength thresholds.

Keywords: Portland Cement, Brands, Compressive Strength, Conformity Assessment

1 Introduction

Portland cement is by far the most commonly used binding element in building and construction industry. In Ghana, it is the most widely accepted binding material for the construction of residential houses, hospitals, bridges, tunnels, schools, shops, industrial warehouses, among others. Recent development of collapse of buildings in Ghana has necessitated the study of the quality of cement commercially available in Ghana (Sam *et al.*, 2013).

In recent years, Ghanaians have seen increased cases of building collapse in both urban and rural areas, which has resulted in fatalities, injuries and loss of life and properties (Danso and Boateng, 2015). Anon. (2014) reports of serious collapse of a six-storey uncompleted hotel building at Nii Boi Town, near Abeka Lapaz, Accra leading to death of one and injuring several victims.

The usage of low quality cement and the resulting mix proportion is undoubtedly one of the leading causes of the collapse of the building. Therefore, there is the need for critical evaluation of the strength of the Portland cement brands in the country to ascertain their reliability.

The main component of sandcrete buildings is concrete which is essentially made of cement as the binding agent. A good concrete mix needs a right ratio of coarse aggregate, fine aggregate, cement and water. It is important to note that just any proportional mix of the materials would not guarantee the requisite strength of the concrete. Quality and grade of the cement play an essential role to ensure the workability and durability of concrete for construction works. To produce top quality long lasting concrete structures, cement of a high and consistent quality is paramount (Haecker *et al.*, 2003).

With the increasing rate of population growth in the country and the alarming rate of rural-urban drift with its associated risk, the demand for cement for affordable home construction will be on a higher side. Ironically, it must be clear that the more the growing demand for cement in the country the more the need for careful analysis of the various brands of cement to ensure safety in the building structures.

The obvious question then is what brand(s) of cement on the Ghanaian market can best meet the standard requirement and provide the requisite stability in structure among common brands and what quality are they offering to the market? The notable brands are Ghana Cement (GHACEM), Western DIAMOND Cement, SUPACEM, the recently produced Ghanaian cement CIMAF, and the foreign cement brands like DANGOTE, among others. Although GHACEM 42.5 N also exist, it is not easily obtained in the open market. It is against this background that this paper seeks to provide solution through collaborative research of conformity assessment of the notable cement brands to ensure sanity in the market.

**Manuscript received August 17, 2021*
Revised version accepted December 09, 2021
https://dx.doi.org/10.4314/gm.v21i2.2

2 Resources and Methods Used

2.1 Materials

The materials used for this study include: Ordinary Portland Cement (OPC) of five brands in the Ghanaian market (*i.e.* GHACEM, DIAMOND SUPACEM, DANGOTE and CIMAF Cement), water, coarse aggregates (gravels) and fine aggregates (sand). Strictly no additive was used.

2.1.1 Ordinary Portland Cement (OPC)

A total of eight (8) bags of different cement classes were purchased from certified depots and retail stores of random choice (see Fig. 1). After collection, each cement bag was kept in an air-tight plastic bag to prevent unwanted hydration with of moisture and kept in dry and moist-free environment. The labels and inscriptions on the cement bags were carefully recorded. Summary of the brands and classes are presented in Table 1.

Fig. 1 Brands of Cement in the Ghanaian Market

No additional test was performed to re-check the chemical composition of the content of the cement purchased from the open market. The researchers sought to make use of the cements just as they were sold in the market.

Table 1 Ghanaian Cement Brands and Classes on the Market

Cement Brand	Cement Class		Country of Origin
	32.5 R	42.5 R	
GHACEM	Yes	Yes	Ghana
SUPACEM	Yes	Yes	Ghana
WESTERN DIAMOND	Yes	Yes	Ghana
CIMAF	No	Yes	Ghana
DANGOTE	No	Yes	Nigeria

2.1.2 Fine and Coarse Aggregates

Fine aggregates were obtained from the River Tano in Western Region. Coarse aggregates were also obtained from Omni Quarry in Takoradi in the same region (Fig. 2). Requisite mechanical property tests were performed on the fine and coarse aggregates in accordance with *ASTM C33/C33M* (Anon., 2016a) protocols for evaluating the suitability of aggregate for such engineering works. Summary of the geomechanical tests performed on the aggregates are presented in Table 2.

Table 2 Summary of Results of the Geomechanical Properties of the Aggregates

Test Name	Average of Obtained Value	Permissible Limits	Remark
Los Angeles Abrasion	19.3 %	Max. 30 %	Pass
Dry 10 % Fines	16.4 %	Max. 30 %	Pass
Aggregate Impact Value	9.6 %	Max. 10 %	Pass
Aggregate Crushing Value	24.1 %	Max. 30 %	Pass
Elongation	26.9 %	Max. 30 %	Pass
Flakiness Index	27.3 %	Max. 30 %	Pass
Water Absorption	0.185 %	Max. 3 %	Pass
Particle Density	2.67 g/cm^3	Min. 2.60 g/cm^3	Pass
Silt Content	4.2 %	Max. 10 %	Pass

Fig. 2 Measured Fine aggregate and 19 mm Coarse Aggregate for the Mixing

2.2 Mix Ratio and Slump Test

ASTM C192 (Anon., 2016b) protocols for making and curing concrete in the laboratory were employed for the general preparation of the cubes. The mix ratio for the design strength of 30 MPa and 40 MPa were 1:1½:3 and 1:1:3 respectively at constant cement/water ratio of 0.5.

High quality control measures were observed during the general preparation and mixing of these materials to ensure zero error. Slump test was performed for each mix ratio for the class of cements used (see Fig. 3a-b).Three cubes of concrete were prepared for each class of cement and cured for 7, 14, 28 and 56 days respectively (see Fig. 4a-b).

Fig. 3 (a) Mixed Cements and Aggregates (B) Slump Test

Fig. 4 (a) Casted Concrete Cubes (b) Dried Concrete Cube

2.3 Compressive Strength (CS) Test

The compressive strength test was performed in accordance with *ASTM C39M* (Anon., 2016c). After the specific age of the cube was reached, it was removed from water, dried for approximately

Eight (8) hours in open air in the laboratory and weighed afterwards as shown in Fig. 5a. The cube was then subjected to intensive and constant pressure under compression test machine as shown in Fig. 5b-c. The load at failure was recorded to aid in the computation of the compressive strength. The mass of the cube was used to calculate for its density as shown in Equation 1. The compressive strength of the cubes was calculated by dividing the maximum load at failure by the area (Equation 2).

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}(\text{kg/m}^3) \quad (1)$$

$$\text{CS} = \frac{\text{Force(N)}}{\text{Cross Sectional Area}}(\text{MPa}) \quad (2)$$

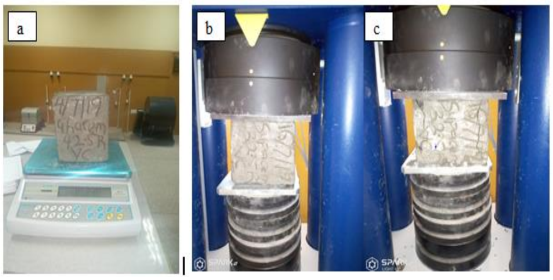

Fig. 5 (a) Weighed Cube (b) Concrete Cube under Compressive Machine (c) Crushed Concrete Cube under Compressive Machine

3 Results and Discussion

3.1 Concrete Cube Results

This section presents and discusses the results obtained from crushing of the concrete cubes cured for 7, 14, 28 and 56 days under the unconfined compressive strength test machine. A total of ninety-six (96) cubes were molded and cured for testing. The individual dimensions of the samples were taken and stressed to failure. The relationships between the cement class and strength/density/slump were also evaluated. The cumulative result for standard 28 days of cube curing is presented in Table 3. However, the respective results of individual curing days is shown in Table 4.

Table 3 Summary of Compressive Strength Results for 28 days Cubes

Cement Type	Dimension (mm)	Weight (g)	Density (kg/m^3)	Class C30	Failure Load (kN)	Compressive Strength (MPa)	Av. Comp. Strength (MPa)	Slump (mm)	Mix Ratio
GHA (32.5R)	150×150×150	8619	2553.8	30	776.9	34.5	34.6	65	$1:1\frac{1}{2}:3$
	150×150×150	8622	2554.7	30	773.1	34.4			
	150×150×150	8637	2559.1	30	787.0	35.0			
SUPACEM (32.5R)	150×150×150	8966	2656.6	30	661.3	29.4	29.9	60	$1:1\frac{1}{2}:3$
	150×150×150	9000	2666.7	30	691.4	30.7			
	150×150×150	9000	2666.7	30	668.8	29.7			
DIAM. (32.5R)	150×150×150	8867	2627.3	30	668.8	29.7	29.5	70	$1:1\frac{1}{2}:3$
	150×150×150	8832	2616.9	30	663.5	29.5			
	150×150×150	8835	2617.8	30	655.6	29.1			
GHA (42.5R)	150×150×150	9048	2680.9	40	847.3	37.7	37.9	60	1:1:2
	150×150×150	9027	2674.7	40	854.9	38.0			
	150×150×150	9027	2674.7	40	854.9	38.0			
SUP (42.5R)	150×150×150	9008	2669.0	40	854.9	38.0	37.4	55	1:1:2
	150×150×150	9010	2669.6	40	829.7	36.9			
	150×150×150	9012	2670.2	40	842.3	37.4			
DIAM (42.5R)	150×150×150	9200	2725.9	40	828.5	36.8	35.6	60	1:1: 2
	150×150×150	9213	2729.8	40	818.4	36.4			
	150×150×150	9222	2732.4	40	754.3	33.5			
CIMAF (42.5R)	150×150×150	9230	2734.8	40	754.3	33.5	33.7	50	1:1: 2
	150×150×150	9255	2742.2	40	754.3	33.5			
	150×150×150	9266	2745.5	40	764.3	34.0			
DANG (42.5R)	150×150×150	8921	2643.3	40	897.6	39.9	40.3	50	1:1:2
	150×150×150	8926	2644.7	40	905.1	40.2			
	150×150×150	8917	2642.1	40	920.2	40.9			

Table 4 Cumulative Results of the Cement Class and their respective Compressive Strength

Ceme nt Class	Ceme nt Type	Average Compressive Strength (MPa)			
		7 days	14 days	28 days	56 days
32.5 R	GHA	24.2	24.5	34.6	37.4
	SUP	21.0	21.2	29.9	32.3
	DIA	20.8	20.9	29.5	31.6
42.5 R	GHA	26.5	26.9	37.9	40.9
	SUP	26.2	26.5	37.4	40.4
	DIA	24.9	25.2	35.6	38.4
	CIMA F	23.6	23.9	33.7	36.4
	DAN G	28.2	28.6	40.3	43.5

3.2 Relationship between Cement and Slump

Results of the slump measured for the mix ratios of the various cement classes are presented in Table 5 and graphical representation of 32.5R and 42.R cement classes are shown in Figs. 6 and 7 respectively.

Table 5 Summary Results of the Cement Class and their respective Slump Values

Cement Class	Cement Type	Slump (mm)
32.5 R	GHACEM	60
	SUPACEM	63
	DIAMOND	70
42.5 R	GHACEM	55
	SUPACEM	55
	DIAMOND	60
	CIMAF	68
	DANGOTE	50

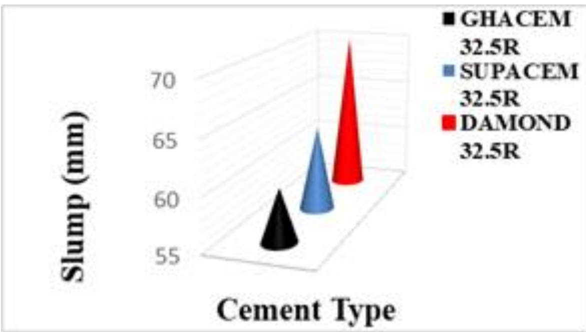

Fig. 6 32.5R Cement Class against Slump

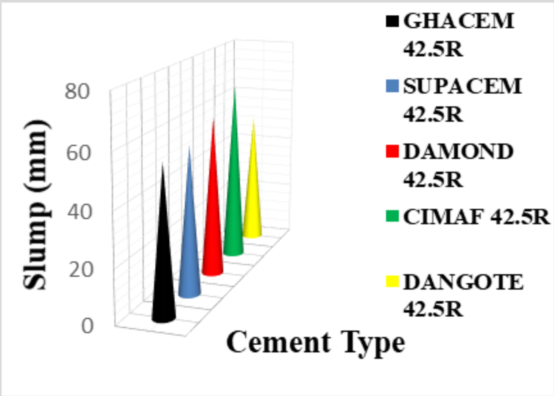

Fig. 7 42.5R Cement Class against Slump

For 32.5R cement class, the DIAMOND cement had the highest slump value followed by SUPACEM and GHACEM as shown in Fig. 6. Also for the 42.5R cement class the order of decreasing slump value is CIMAF > DIAMOND > SUPACEM > GHACEM > DANGOTE as illustrated in Fig. 7. Comparing the slump values of Cements with both 32.5R and 42.5R class, it is observed that the 42.5R cement class for the various cement types had lesser values as compared to the its corresponding 32.5R Cement type.

3.3 Relationship between Cement Class and Compressive Strength

Summary results of the compressive strengths for the various cement class at different curing days has been presented in Table 6. Figs. 8 and 9 illustrates the graphical representation of the strength values at various curing days for 32.5R and 42.5R cements respectively.

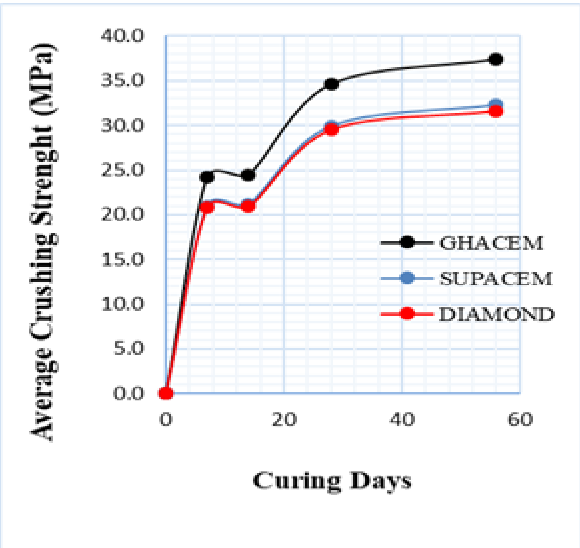

Fig. 8 Strength against Curing Days for 32.5 R Cement

The variations in compressive strength with respect to the age of curing as demonstrated in Table 6 indicates variability in the cement brands in the market.

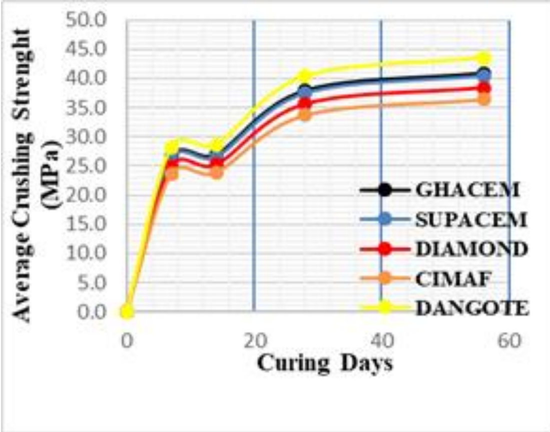

Fig. 9 Strength against Curing Days for 42.5 R Cement

Conformity assessment of the cement brands show from Fig. 8 that, for day 7, 14. 28 and 56 curing, GHACEM 32.5R had the highest strength for 30 MPa class followed by SUPACEM and DIAMOND. For the 42.5R cement class (see Fig. 9), DANGOTE cement had the highest strength for all the number of curing days. The order of increment for the 42.5R cement class is DANGOTE > GHACEM > SUPACEM > DIAMOND > CIMAF.

Generally, the strength for all cement type increased with increasing number of curing days. The observation is that generally, about only 60% of the optimum strength is achievable in 7 days without additive, for the available cements brands.

For the pre-optimal analysis (see Table 6), the percentage increment from 7 to 14 days curing was gradual occurring between 1-2%. The least value was recorded for DIAMOND Cement in both 32.5R and 42.5R Cement Class, whereas, higher values were recorded for GHACEM (32.5R) and DANGOTE (42.5R). However, there was a significant percentage increment in strength for both cement type (*i.e.* 32.R and 42.5R) from 14 to 28 days curing. It was observed that GHACEM 32.5R was the only brand which was able to attain and exceed its market rating within the optimal curing days of 28, whilst the remaining cement types secured marginal thresholds at 28 days. For the case of the cement types for the 42.5R, none of them was able to meet or exceed its market rating, although DANGOTE met the minimum *Class* threshold of 40 MPa.

Table 6 Summary Results of Variations in Compressive Strength with Respect to Curing Days

Cement Class	Cement Type	Average Compressive Strength (MPa)				Pre - Optimal		Post - Optimal
		7 days	14 days	28 days	56 days	Percentage change in Strength (7 - 14 days) (%)	Percentage change in Strength (14 - 28 days) (%)	Percentage change in Strength (28 - 56 days) (%)
32.5 R	GHA	24.2	24.5	34.6	37.4	1.24	41.22	8.09
	SUP	21.0	21.2	29.9	32.3	0.95	41.04	8.03
	DIA	20.8	20.9	29.5	31.6	0.48	41.15	7.12
42.5 R	GHA	26.5	26.9	37.9	40.9	1.51	40.89	7.92
	SUP	26.2	26.5	37.4	40.4	1.15	41.13	8.02
	DIAM	24.9	25.2	35.6	38.4	1.20	41.27	7.87
	CIMAF	23.6	23.9	33.7	36.4	1.27	41.00	8.01
	DANG	28.2	28.6	40.3	43.5	1.42	40.91	7.94

For the post-optimal analysis, cube strength appreciated for all brands of cement at different rates. It was observed that, GHACEM 32.5R cement was able to meet its market rating on the 56 day, whereas the other cement types did not conform or meet the rating. Marginal thresholds were obtained. The order of percentage increment for the 32.5R Cement class, is GHACEM > SUPACEM > DIAMOND.

The 42.5R cement *Class* had only DANGOTE meeting its market mark and the remaining achieving marginal strength at 56 days. The order of percentage appreciation after the optimal curing day (*i.e.* 28-day) is SUPACEM > CIMAF > DANGOTE > GHACEM > DIAMOND for the 42.5R Cement. This indicates that, some cement take a much longer time to attain their peak of bond strength whereas others are quicker.

4 Conclusions and Recommendation

4.1 Conclusions

The research concludes that:

(i) There are currently five major brands of cement on the Ghanaian market, ie., GHACEM, DIAMOND SUPACEM, DANGOTE and CIMAF Cement. Some brands showcase two classes, others parade one.
(ii) The conformity analysis revealed that, slump and compressive strength has an inverse relationship.
(iii) The dominant cement *Class* are 32.5R and 42.5R. Although 42.5 N also exist, it is not common in the open market.
(iv) For the 32.5R, GHACEM Cement had the highest strength as compared to the SUPACEM and DIAMOND.
(v) For the 42.5R Cement type, the order of strength was DANGOTE > GHACEM > SUPACEM > DIAMOND > CIMAF.
(vi) At the optimal curing days of 28 days, the bond strength of some of the cement brands did not pass the requisite 30 MPa and 40 MPa strength thresholds until 56 days.
(vii) It was observed generally that the bond strength of some of the cement brands despite parading impressive inscriptions, would not meet the requisite standard strength thresholds unless given more days to cure.

4.2 Recommendation

It is recommended that further laboratory analysis including the chemical content, bleeding, as well as initial and final setting time should be conducted to further understand the quality and grade of the cement brands in the market.

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