Product Marking and Conformity Assessment of Portland Cements on the Ghanaian market

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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* (DANGOTE) and *SUPACEM Cement* (SUPACEM). 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 job 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 $1:1\frac{1}{2}:3$ and 1:1:2 for *C-30* and *C-40* respectively. To achieve the desired strength conformity, the slumps as well as the coarse and fine aggregate constituents were standardized. The results indicated that the cement brands despite posting the same strength thresholds in the market, do not exhibit the same strength build-up. There are significant variations in growth of the compressive strength over time. It was observed also that the conformance threshold after 28 days was attained for GHACEM and DANGOTE respectively for 32.5R and 42.5R brands. After 56 days all the 32.5R brands passed the threshold and 42.5R brands, three namely, GHACEM, SUPACEM and DANGOTE achieved 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 the 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.

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

The use of low quality cement is one factor that can cause a structure to collapse. Other factors are the ground condition, the quality and quantity of iron rods and their positions within the structure, the quality and quantity of coarse and fine aggregates *etc.*, therefore, there is the need to evaluate the inputs used in building and construction.

The main component of sandcrete buildings is concrete which is essentially made of cement as the binding agent. A good concrete mix needs the correct ratio of coarse aggregate, fine aggregate, cement and water. Any other mix of the materials mentioned would not guarantee the optimum strength of the concrete. Quality and grade of cement play an essential role in the workability and durability of concrete for construction works. To produce quality concrete structures, cement of high and consistent quality is required (Haecker *et al.*, 2003).

With a population growth of 2.7 % in Ghana and a high rural-urban migration, the demand for cement to build affordable houses for the people is high and increasing. The growing demand for cement coupled with the collapse of some structures means that as part of the steps required to investigate the causes of failure of the structures, the assessment of the brands of cement sold on the market is necessary to ensure safety of the structures being built.

The Ghanaian brands of cement currently on the market are Ghana Cement (GHACEM), Western Diamond Cement (DIAMOND), SUPACEM, and CIMAF, while the foreign cement brand is DANGOTE. Although GHACEM 42.5 N also exists, it is not easily available on the market. This paper seeks to conduct a conformity assessment of the notable cement brands in the market.

2 Materials and Methods Used

2.1 Materials

The materials used for this study are five brands of Ordinary Portland Cement (OPC) in the Ghanaian market namely; GHACEM, DIAMOND, SUPACEM, DANGOTE and CIMAF Cement in addition to water, coarse aggregates (gravels) and fine aggregates (sand). 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 randomly (see Fig. 1). After collection, each cement bag was kept in an air-tight plastic bag to prevent hydration of moisture and kept in a dry and moist-free environment. The labels and inscriptions on the cement bags were recorded. A summary of the brands and classes are presented in Table 1.

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
DIAMOND	Yes	Yes	Ghana
CIMAF	No	Yes	Ghana
DANGOTE	No	Yes	Nigeria

Figure 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. The 32.5R or 42.5R on the label of cement means that the cement's compressive strength after 28 days must not be less than 30 or 40 MPa respectively and "R" is "Rapid", that means that the cement has early strength.

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 (Figure 2a-b). Requisite mechanical property tests were performed on the fine and coarse aggregates in accordance with *ASTM C33/C33M* protocols for evaluating the suitability of aggregates for such engineering works (Anon., 2016a). The 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 %	30	Pass
Dry 10 % Fines	16.4 %	30	Pass
Aggregate Impact Value	9.6 %	10	Pass
Aggregate Crushing Value	24.1 %	30	Pass
Elongation	26.9 %	30	Pass
Flakiness Index	27.3 %	30	Pass
Water Absorption	0.185 %		
Particle Density	2.67 g/cm^3		
Silt Content	4.2 %		

Figure 2: (a) Fine Aggregate (b) 19 mm Coarse Aggregate

2.2 Mix Ratio and Slump Test

ASTM C192 protocols for making and curing concrete in the laboratory were employed for the general preparation of cubes for the compressive strength analysis (Anon., 2016b). The mix ratio for the design strength of 30 MPa and 40 MPa were $1:1\frac{1}{2}:3$ and 1:1:3 respectively at constant cement/water ratio of 0.5.

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

Figure 3: (a) Mixed cements and Aggregates (b) Slump test

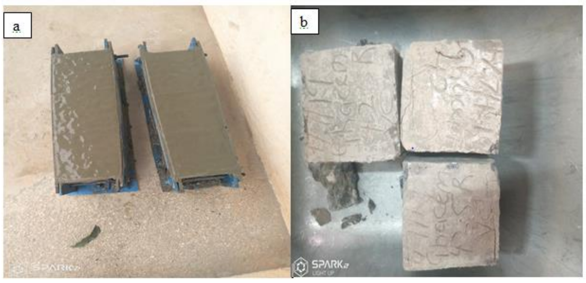

Figure 4: (a) Casted Concrete Cubes (b) Dried Concrete Cube

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 Figure 5a. The cube was then subjected to intensive and constant pressure under the compression test machine as shown in Figure 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*).

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

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

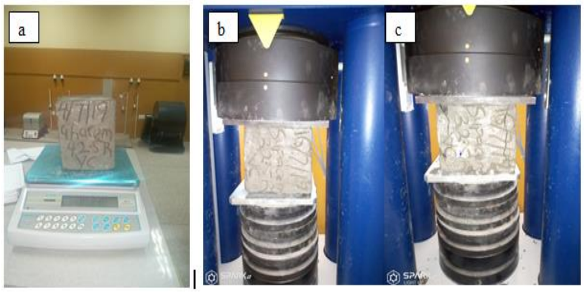

Figure 5: (a) Weighed Cube (b) Concrete Cube under Compressive Machine (c) Crushed Concrete Cube under Compressive Machine

3 Results and Discussions

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 calculated. The cumulative result for standard 28 days of cube curing is presented in Table 3.

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
GHACEM (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			
DIAMOND (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			
GHACEM (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			
SUPACEM (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			
DIAMOND (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			
DANGOTE (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			

3.2 Relationship between Cement and Slump

Slump which determines the workability or consistency of concrete was measured. Results of the slump measured for the mixed ratios of the various cement classes are presented in Table 4 and graphical representation of 32.5R and 42.5R cement classes are shown in Figure 7 and 8 respectively.

Table 4: 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

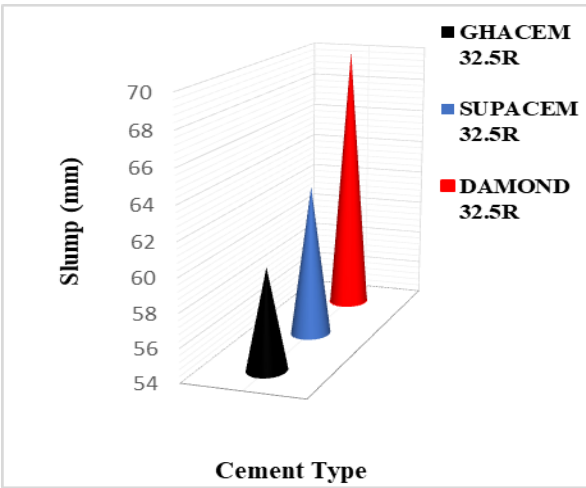

Figure 7: 32.5R Cement Class against Slump

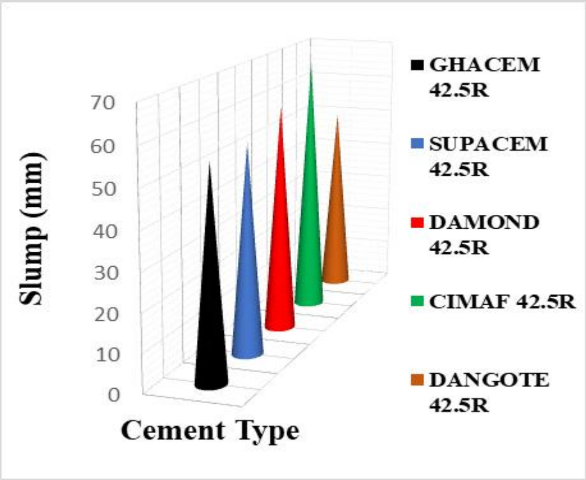

Figure 8: 42.5R Cement Class against Slump

For 32.5R cement class, the DIAMOND cement had the highest slump value followed by SUPACEM and GHACEM as shown in Figure7. Also for the 42.5R cement class CIMAF had highest slump value, followed by DIAMOND, SUPACEM, GHACEM and DANGOTE as illustrated in Figure 8. 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. This is due to high absorption rate in the 42.5R cement.

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 5. Figure 9 and 10 illustrates the graphical representation of the strength values at various curing days for 32.5R and 42.5R cements respectively.

Table 5: Summary Results of the Cement Class and their respective Compressive Strength

Cement Class	Cement Type	Average Compressive Strength (MPa)			
		7 days	14 days	28 days	56 days
32.5 R	GHACEM	24.2	24.5	34.6	37.4
	SUPACEM	21.0	21.2	29.9	32.3
	DIAMOND	20.8	20.9	29.5	31.6
42.5 R	GHACEM	26.5	26.9	37.9	40.9
	SUPACEM	26.2	26.5	37.4	40.4
	DIAMOND	24.9	25.2	35.6	38.4
	CIMAF	23.6	23.9	33.7	36.4
	DANGOTE	28.2	28.6	40.3	43.5

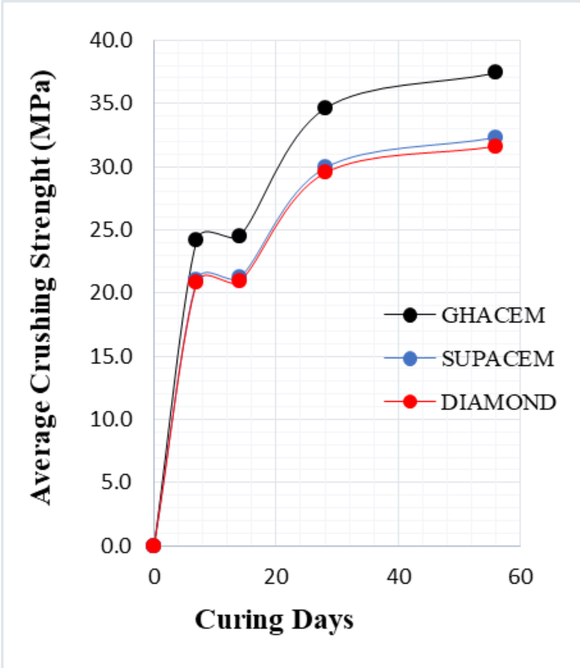

Figure 9: 32.5R Cement Class against Slump

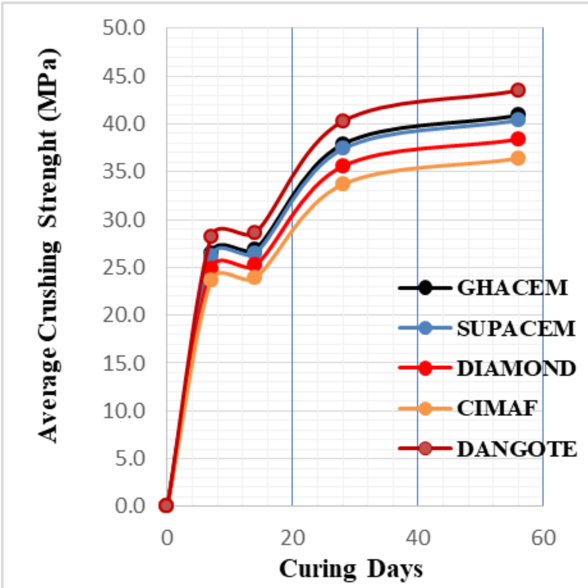

Figure 10: 42.5R Cement Class against Slump

For 32.5R cement class, the Diamond cement had the highest strength value followed by SAPACEM and GHACEM as shown in Figure 9. Also for the 42.5R cement DANGOTE had the highest strength value followed by GHACEM, SUPACEM, DIAMOND and CIMAF Figure 10. Generally, all the cement types appreciated as the curing days increased.

3.4 Variations in Strength with Respect to Age

Results of variations in compressive strength with respect to the age of curing have been presented in Table 6.

For the pre-optimal analysis (see Table 6), the percentage increment from 7 to 14 days curing was minimal falling between 1- 2 %. The least value was recorded for DIAMOND Cement in both 32.5R and 42.5R Cement Classes, whereas, higher values were recorded for GHACEM (32.5R) and DANGOTE (42.5R). However, there was a significant percentage increment in strength for both GHACEM and DANGOTE cement types (*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 posted marginal thresholds at 28 days. For the case of the cement types for the 42.5R, none of the brands were able to meet or exceed its market rating, although DANGOTE met the minimum *Class* threshold of 40 MPa.

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 day 56, whereas the other cement types did not conform or meet the rating, although 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 the 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 of cement brands take a much longer time to attain their peak bond strength whereas others are quicker.

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	GHACEM	24.2	24.5	34.6	37.4	1.24	41.22	8.09
	SUPACEM	21.0	21.2	29.9	32.3	0.95	41.04	8.03
	DIAMOND	20.8	20.9	29.5	31.6	0.48	41.15	7.12
42.5 R	GHACEM	26.5	26.9	37.9	40.9	1.51	40.89	7.92
	SUPACEM	26.2	26.5	37.4	40.4	1.15	41.13	8.02
	DIAMOND	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
	DANGOTE	28.2	28.6	40.3	43.5	1.42	40.91	7.94

4 Conclusions and Recommendation

4.1 Conclusions

The study concludes that;

- There are currently five major brands of cement on the Ghanaian market, *i.e.*, GHACEM, DIAMOND, SUPACEM, DANGOTE and CIMAF Cement. Some of the brands have two classes and others one.

- The conformity analysis revealed that, slump and compressive strength have an inverse relationship.

- The dominant cement *Classes* are 32.5R and 42.5R. Although 42.5 N also exist, it is not common in the open market.

- For the 32.5R, GHACEM Cement had the highest strength followed closely by SUPACEM and DIAMOND brands.

- For the 42.5R Cement type, DANGOTE had the highest strength followed closely by GHACEM, SUPACEM, DIAMOND and CIMAF in that order.

- At the optimal curing days of 28 days, the bond strength of GHACEM passed the requisite 30 MPa while SUPACEM and DIAMOND brands were marginally less for their 32.5R brands. In the case of 42.5R, only DANGOTE cement passed the requisite 40 MPa strength.

- It was observed generally that the bond strength of some of the cement brands despite parading impressive inscriptions, did not meet the required standard strength thresholds at day 28, 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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