IS THE QUALITY OF CEMENT A CONTRIBUTING FACTOR FOR BUILDING COLLAPSE IN GHANA?

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Sub-standard (poor quality) materials have been mentioned as one of the major causes of building collapse worldwide. The main materials mostly identified as sub-standard are cement, reinforcement bars, timber and aggregate. This Paper assesses whether the quality of Type I Portland cement use in Ghana - contribute to the recent building collapse in Accra and Kumasi. This was achieved through experimental study by comparing the properties of Ghana cement with that of UK cement. The study found that the dry density of Ghana Grey cement was higher than both the UK Grey and UK White cements. Furthermore, the Ghana Grey cement performed better in resistance to water absorption than UK Grey cement, while the UK White was better than both Ghana Grey and UK Grey cements. In addition, while UK White cement performed better in compression than Ghana Grey and UK Grey cements, the Ghana Grey was better than the UK Grey cement. The results of the experiment clearly reveal that the quality of Ghana's cement is comparable to that of UK. Therefore, the paper concludes that the quality of Ghana's cement might not be the factor causing building collapses in Ghana. Further studies are therefore recommended for the identification of the sub-standard materials that contribute to building collapse in Ghana.

Keywords: Building Collapse, Cement, Compressive Strength, Concrete, Dry Density, Water Absorption.

INTRODUCTION

The frequent occurrence of building collapse worldwide is becoming a major problem. This does not only lead to loss of valuable lives but also major property loss. Incidents of building collapse have been reported from most countries and the records keep rising. The Royal Plaza Hotel in the city of Nakhon Ratchasima, Thailand collapsed on 13 August 1993, killing 137 people and injuring 227 (Worsak, 1994). According to a report from Siraj and Maha (2006), a hostel housing Muslim pilgrims performing Hajj collapsed in Mecca, Saudi Arabia on 5 January 2006 killing 76 people and injuring 62. Beaumont (2008) reported of the Pétionville school collapse, which occurred on November 7, 2008, in Petionville, a suburb of Port-au-Prince, Haiti, where the church-operated College "The Evangelical Promise School" collapsed. About 700 students from kindergarten through high school attended the school. At least 93 people, mostly children, were confirmed killed, and over 150 injured. The January 25, 2012 Rio de Janeiro building collapsed which also triggered the collapse of two neighboring buildings of which 21 people were confirmed dead.

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Ghana is no exception of building collapses, the past few years have seen some cases in both urban and rural areas which resulted in fatalities, injuries and loss of property. Table 1 presents some of the recent cases of building collapse in Ghana from 2009 to 2013, showing the suspected causes and the casualties involved. Notably among them are the recent cases of Melcom shopping mall building in Achimota, Accra and a three storey-building situated at Krofrom, Kumasi. The Melcom shopping mall building collapsed on Wednesday, November 7, 2012 around 9:00 in the morning when the shop has not opened to the general public for shopping. There were only the shop attendants who were in the building getting ready to open the shop for the day's activities. Eighty one (81) casualties were involved in the total collapse of the building, sixty seven (67) survived with various degrees of injuries while the remaining fourteen (14) died. This was one of the fatal building collapse incidences that have happened in Ghana in the recent past.

Table 1: Recent Cases of Building Collapse in Ghana

S/N	Location of Building	Type of Building	Date	Suspected Causes	Deaths/Injuries
1	Kumasi	Uncompleted storey building	2009	Faulty design	-
2	Accra	Two-storey court complex	2009	Faulty construction	-
3	Zenu, Ashaiman	Two-storey	2009	Structural failure	4 Died
4	Wa, U/W	Residential	2010	Rain storm	5 Died, 4 Injured
5	Baatsona, Accra	Uncompleted storey building	2010	Faulty construction	2 Died, 6 Injured
6	Dompoase-Aprabo	Residential	2010	Rain storm	2 Died, 2 Injured
7	Sawla	Residential	2011	Structural failure	4 Died
8	Kato near Berekum	Residential	2011	Rain storm	2 Died, 3 Injured
9	Ayomso, B/A	Residential	2012	Rain storm	2 Died, 2 Injured
10	Apatrapa, Kumasi	Uncompleted storey building	2012	Structural failure	-
11	Kasoa, C/R	Public toilet	2012	Structural failure	1 Died, 2 Injured
12	Achimota, Accra	Five-storey shopping mall building	2012	Structural failure	14 Died, 67 Injured
13	Krofrom, Kumasi	Three-storey residential building	2013	Rain storm	3 Died, 5 Injured

External View before Collapse

Internal View before Collapse

Figure 1: Melcom Shopping Mall Building before Collapse

The appearance of the building before collapse is presented in Figure 1 and after the collapse can also be found in Figure 2. The building experienced a total collapse with all the structural components falling down. This accounted for the high fatality rate.

External View of Building after Collapse

Figure 2: Melcom Shopping Mall Building after Collapse

A very recent incident of building collapse in Ghana was the three-storey residential building situated at Krofrom, a suburb of Kumasi, the Ashanti regional capital, which collapsed on Monday, April 15, due to a heavy downpour of rain trapping many people under the rubble. 3 people were confirmed dead whiles 5 others sustained various injuries. Figure 3 presents the external view after the collapse of the building.

External View of Building after Collapse

Figure 3: Krofrom Three-Storey Residential Building after Collapse

A study conducted in Nigeria by Fakere *et al.* (2012) assessed the collapse of a Naval building, a two storey building in Gwarimpa, Abuja, which occurred on Saturday, 28th January in 2012. Their investigation found that the structure was defective, thus sub-standard materials were used for the construction, which included the reinforcement bars, concrete mix ratio among other things. Studies by Ede (2011) and Ayedun *et al.* (2012) on the causes of building failure and collapse identified the use of sub-standard building materials, poor workmanship by contractors, among others as the major causes of building collapse in Lagos State. Sub-standard materials have been mentioned as one of the major causes of building collapse.

The main materials mostly identified as sub-standard are cement, reinforcement bars, timber and aggregate. There is the need to investigate, which of the materials contribute to the collapse of buildings in Ghana. Sam *et al.* (2013) assessed the

chemical composition of the various brands of Portland cement products available on the Ghanaian market. This Paper assesses the quality of cement use in Ghana to ascertain whether it contributes to building collapse. The assessment was done by comparing the strength properties of Type I cements from UK and Ghana, in order to find out whether Ghana's cement is of sub-standard or not.

EXPERIMENTAL WORK

Materials

The materials that were used for the laboratory experimental work are cement, sand and water. Three Type I Portland cements were used for this study. One was obtained from Ghana which is known as Ghacem Portland cement (Ghana Grey), and the other two were obtained from UK known as Portland cement (UK Grey) and Snowcrete white Portland cement (UK White). The Ghana Grey and UK Grey were of the same class of 32.5R and therefore are placed at the same level for comparison. The UK White has a higher class of 52.5R, but was included to find out if it will make any difference. The sand used was clay-free and obtained from Portsmouth, UK. *X-Ray Diffraction* (XRD) analysis of the sand showed to be pure quartz sand with no significant impurities. The water used was drinkable from the Civil Engineering laboratory tap of Portsmouth University, UK.

Methods of testing

The tests performed include dry density, water absorption and compressive strength. Concrete cylinder specimen 75 × 40 mm were made using cement sand ratio of 1:2 for mortar and only cement for cement paste with single water cement (w/c) ratio of 0.35 by mass. After 28 days of curing, the cylinders were tested for dry density, water absorption and compressive strength. Compressive strength test was performed to determine the strength of the cement specimen under the influence of compression stress. The compressive strength of the specimen was carried out by using ELE ADR-Auto compression 2000 test machine with a maximum capacity of 2000 kN. The compressive strengths were calculated as:

$$\sigma c = \frac{F}{A} \quad (1)$$

Where: σ_c is compressive strength; F is the maximum force (N) applied at which the specimen failed; and A is the cross-sectional area (mm^2) of specimen on which the force was applied.

Density test was performed in order to determine how compact the specimen were. The dry density of the specimen was determined by drying the specimens at constant temperature of approximately 110 ^{O}C in an oven for 48 hours. After, the dimensions of each specimen were measured in centimeters to the nearest millimeter and the overall volume computed in cubic meters. The specimens were then weighed in kilograms to the nearest 10 gm. The density of each specimen was calculated as:

$$\rho = \frac{m}{V} \quad (2)$$

Where: ρ is the density; m is the mass (kg); and V is the volume (m^3).

Water absorption test was conducted to measure the ability of the specimen to resist the absorption and retention of water. The weights of the specimen were measured with electronic scale after drying, and then immersed in water for 14 hours. The

saturated weights of the specimen were measured, after which the water absorption percentage of the specimen was determined mathematically as:

$$WA = \frac{M1-M}{M} \times 100$$

(3)

Where: WA is water absorption; M_1 is the mass of saturated specimen (kg); and M is the mass of dry specimen (kg).

RESULTS AND ANALYSIS

The results obtained from the experimental work are presented and discussed. The strength properties of the cements were determined through dry density, water absorption and compressive strength tests. The results of the test are presented in Tables 2 and 3 for mortar and cement paste specimen respectively.

Table 2: Mortar Mix

Item	Dry Density (kg/m^3)	Water Absorption (%)	Compressive strength mean (MPa)
UK White	1824	8.7	31.7
Ghana Grey	1832	9.3	30.0
UK Grey	1779	9.2	29.9

Table 3: Cement Paste Mix

Item	Dry Density (kg/m^3)	Water Absorption (%)	Compressive strength mean (MPa)
UK White	1682	5.1	63.3
Ghana Grey	1795	8.6	43.8
UK Grey	1707	10.1	41.9

Dry Density

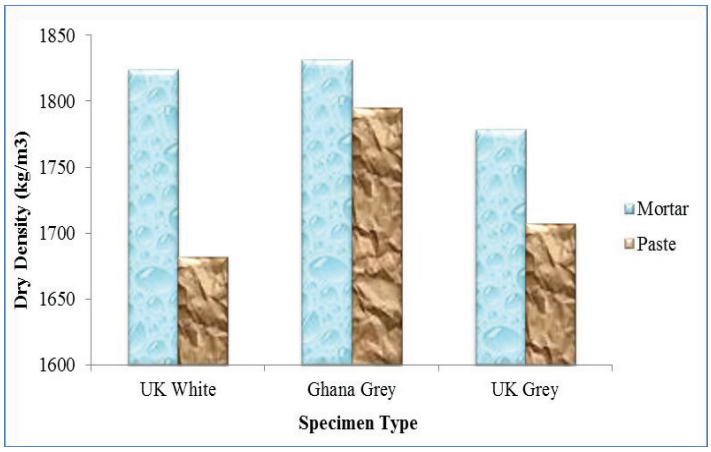

Figure 4: Comparison of Dry Density Results

The comparison of the dry density test results is shown in Figure 4. The results show that the Ghana Grey specimen increased average density of 3% and 5% for mortar and cement paste respectively than UK Grey. In addition, the density of Ghana Grey cement was higher than UK White cement both for mortar and cement past specimen. However, the density of the UK Grey was higher than that of the UK White for cement paste specimen, while it was the opposite for the mortar specimen. It could be concluded the results that the density of Ghana Grey cement is higher than both the UK Grey and UK White cements. This implies that the Ghana Grey cement when used for preparing mortar or concrete could provide more compact unit.

Water Absorption

Figure 5 presents the results of the water absorption test values for the specimen. The UK Grey recorded about 17% increase in water absorption than the Ghana Grey for cement paste specimen, while the Ghana Grey had an increase of 1% than that of the UK Grey for mortar specimen. On the other hand, the UK White had lower water absorption than both Ghana Grey and UK Grey specimen. This result indicates that the UK Grey cement has higher water absorption properties than that of the Ghana Grey cement, implying that Ghana Grey cement performed better in resistance to water absorption than UK Grey cement. While the UK White performed better in water absorption than both Ghana Grey and UK Grey cements. The practitioners in the construction industry as well as academicians in Ghana should therefore know that the cement produce in Ghana have good resistance the water absorption.

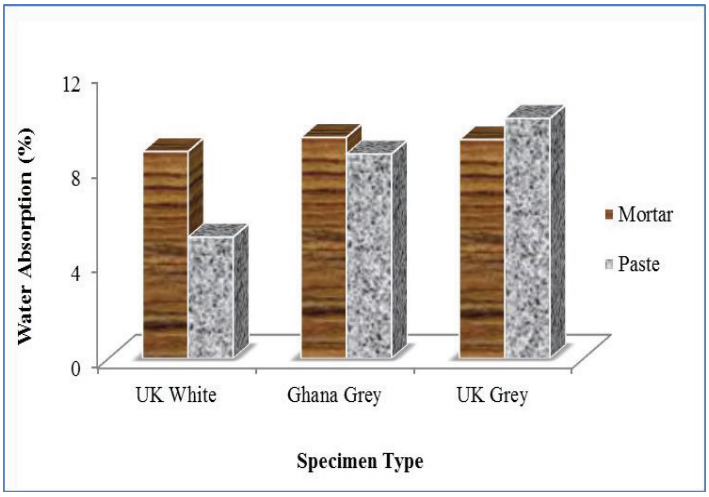

Figure 5: Comparison of Water Absorption Results

Compressive Strength

The compressive strength test results comparison is presented in Figure 6. The results show that the Ghana Grey cement had less than 1% and 5% increase in compressive strength for mortar and cement paste respectively than UK Grey cement specimen. The UK White cement on the other hand, recorded higher compressive strength than both Ghana Grey and UK Grey cement specimen. It can be concluded that while UK White cement performed better in compression than Ghana Grey and UK Grey

cements, the Ghana Grey was better than the UK Grey cement. Building contractors and other practitioners in the construction industry as well as academicians in Ghana should therefore know that the cement produce in Ghana have good resistance under the influence of a compression stress.

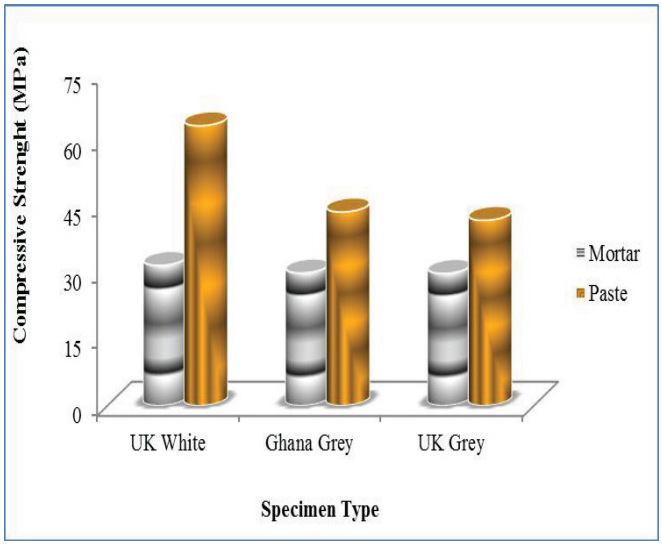

Figure 6: Comparison of Compressive Strength Results

CONCLUSION

This paper adopted the approach of determining the quality of Ghana Type I Portland cement by comparing its strength properties with that of UK cement. The assessment found that the dry density of Ghana Grey cement was higher than both the UK Grey and UK White cements. Furthermore, the Ghana Grey cement performed better in resistance to water absorption than UK Grey cement, while the UK White was better than both Ghana Grey and UK Grey cements. In addition, while UK White cement performed better in compression than Ghana Grey and UK Grey cements, the Ghana Grey was better than the UK Grey cement. Building contractors and other practitioners in the construction industry as well as academicians in Ghana should therefore know that the cement produce in Ghana have good strength properties. It can therefore be concluded that the quality of Ghana cement is comparable to that of UK, and therefore may not be a contributing factor of building collapses in Ghana. It is therefore recommended that further studies should be conducted on the quality of sand, standard of cement to sand mix ratio in Ghana and the quality of other building materials such as reinforcement bars, timber, aggregate and water in order to establish which material is of sub-standard and contribute to the collapse of buildings in Ghana.

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