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# TAILOR- MADE BLENDED CEMENT FOR SUSTAINABLE CONCRETE IN GHANA

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## ABSTRACT

Concrete is the most widely used construction material in the world compared to other known construction materials including steel, glass, aluminium and timber. The reason for its wide usage is because of its low embodied energy, an indicator of carbon emissions into the environment. However, since the volume of concrete used globally is very huge, the environmental impact is great and hence any little improvement on concrete ingredients will have real impact. A possible improvement of concrete is a good focus on Portland cement since embodied carbon dioxide in concrete is a function of cement content in the mix. In this work two sets of mortars were formulated; one with clay pozzolans and water reducers and the other was the pozzolans containing no water reducers. The performance of the two sets of mortars were evaluated based on their strength properties which were performed in accordance with the ASTM C109 standards. In the work, Portland cement was replaced by the clay pozzolan between 10% and 40% by weight. The clay pozzolan used was from waste crushed bricks obtained. The results of the blended cement mortars were compared with the unblended cement mortars. The results of the study indicated that for the mortars containing pozzolan and the water reducers, the optimum cement replacement was 30 wt.% of the pozzolan. For the mortars containing only the pozzolans, the strength values recorded a progressive reduction with the increasing content of the pozzolan in the cement matrix. The study recommended that 30 wt.% replacement of cement and the addition of water reducers could be used to formulate 42.5 grade cement whereas between 20-30 wt.% of only pozzolan content could be fit for a 32.5 grade of cement.

**Keywords:** Concrete, embodied energy, carbon emissions, portland cement, clay pozzolans, blended cement mortars.

## 1. INTRODUCTION

Concrete is the second most highly consumed material in the world after water. It is reported that over 25 billion tonnes of concrete are used annually whereas water is 3,656 billion cubic meters (Bediako et al. 2016). Among construction well known construction materials including steel, glass, timber, bricks, etc, concrete is the most widely used construction material (Scrivener, 2014). Scrivener (2014) also mentioned that the reason for the high use of concrete in the construction industry is it low energy impact property compared to other construction materials. The 21$^{st}$ century has a plethora of definitions regarding sustainability and these definitions include the reduction of carbon emissions on the use of products. Today the construction industry has linked sustainable construction to carbon emissions reduction. Though concrete is a low energy impact material, its huge consumption has a great impact on the environment. There is the need to improve the carbon emissions from concrete since it remains the best choice of construction material compared to materials such as glass, timber, bricks, aluminium, steel, etc. One possible area to consider is Portland cement. It has been reported that embodied carbon dioxide in concrete is a function of Portland cement content. Marcau et al (2007) studied the embodied energy of cement blended with pozzolans including fly ash and slag. They found that the embodied energy of the binders reduced as the content of the pozzolans increased.

Atiemo (2005) studied the use of clay pozzolan in Ghana and found that between 10-30 wt. % of cement replacement with the pozzolan could give a cement grade of 32.5. At 40 wt. % of cement replacement, strength class was very weak. Meanwhile pozzolans are used at higher content of cement replacement (≥30%) whilst achieving higher grade cement at 42.5 and even 52.5. In this work the main hypothesis was this "Can we increase the pozzolan content to achieve higher strength grade" ?

The main objective of this work is the achieve higher strength grade of cement from tailor-made blended cement using higher content of clay pozzolan as mineral in conjunction with a chemical admixture.

## Materials and Methods

The materials that were used for the study included ASTM Type I/II Portland cement, clay pozzolan, high range water reducer, potable water and graded sand. The Portland cement was an Ash grove cement product obtained from Kansas, United States. The burnt clay bricks were obtained from CSIR- Building and Road Research Institute in Ghana. The potable water was from the running taps of University of Missouri-Kansas City (UMKC), United States whereas the graded sand used was in accordance with ASTM C778 standards.

The clay pozzolana was produced by calcining a Ghanaian clay in an electric furnace for 2 hr and was taken off after that period of 2 hr and placed on a laboratory working benchtop for cooling. The calcined material was sieved on the 75 microns sieve using an electric sieve shaker. The -75microns sieved material was used for the work. The calcined material was used to replace Portland cement between 10 and 40 wt. %. The flow table was used to control the flow of the mortar and was performed in accordance with ASTM C1437. The desired flow of the mortars were achieved using portable water and the HRWR. The mortar preparation was done in accordance with ASTM C109 and cured in lime saturated water for 3, 7 and 28 days.

## RESULTS AND DISCUSSIONS

Table 1 presents the mix names and the flow of mortars with and without the HRWR. The water-to-cement ratio (w/c) of mortars without HRWR was higher than the control (CON) mortar by approximately 13%. Higher w/c ratio of blended clay pozzolan cement compared to unblended cement system is very common to other investigations of some researchers including Naceri and Chikouche (2009), Bediako et al (2012) and Bediako and Osei Frimpong (2013). The reason for this trend has been attributed to the high porous nature of calcined clays.

The table also shows that as the calcined clay content increased in the cement matrix, the HRWR quantity also increased. This may be attributed to the high porous nature of the calcined clay.

Table 1 : Mix name and flow of mortars with and without HRWR

| **Mix name** | **Mix without HRWR** | | | | **Mix with HRWR** | | |
|---|---|---|---|---|---|---|---|
| | **PC** | **CP** | **Flow** | **w/c** | **HRWR (%)** | **Flow** | **w/c** |
| CON | 100 | 0 | 105 | 0.485 | 0 | 105 | 0.485 |
| 10CP | 90 | 10 | 111 | 0.550 | 0.14 | 106 | 0.485 |
| 20CP | 80 | 20 | 110 | 0.550 | 0.27 | 114 | 0.485 |
| 30CP | 70 | 30 | 107 | 0.547 | 0.54 | 109 | 0.485 |
| 40CP | 60 | 40 | 108 | 0.546 | 0.68 | 107 | 0.485 |

Figures 1 and 2 show the compressive strength performance of mortars with and without the HRWR. Figure 1 indicates and optimum strength values at 30% cement replacement whereas that of Figure 2 is at an optimum value of 20%. From the two graphs, it was obvious that the inclusion of the HRWR produced an higher cement grade of 42.5 even with higher cement replacement content. On the other hand, without HRWR it is impossible to achieve high grade cement of 42.5 in the case of blended cement.

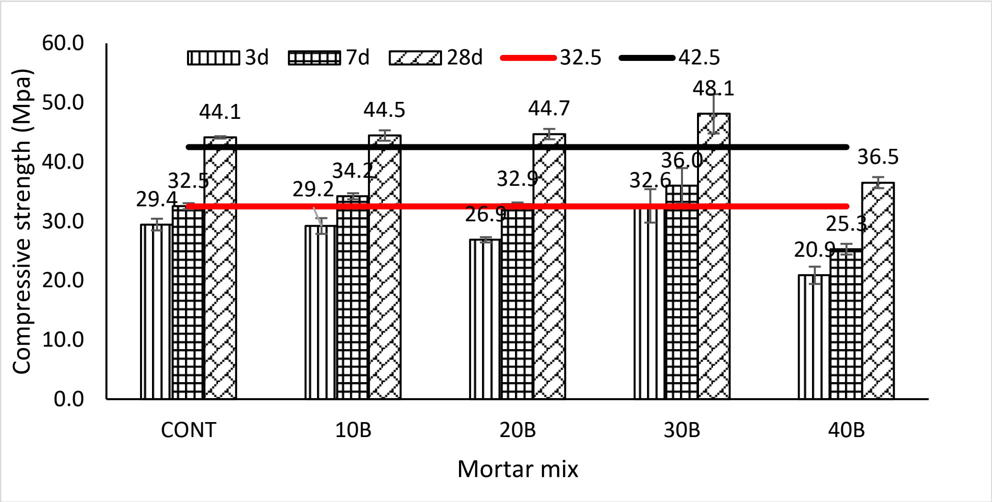


Figure 1 : Compressive strength of mortars containing HRWR

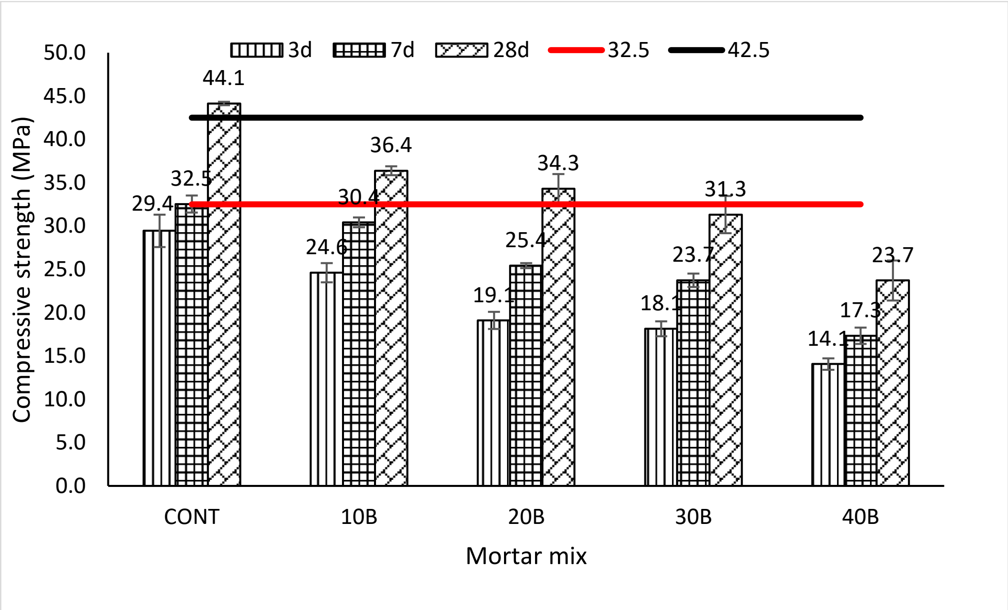


Figure 2 : Compressive strength of mortars without HRWR

## CONCLUSIONS

The following conclusions are drawn from the study:

1. Compressive strengths were generally increased with the inclusion of HRWR in the blended cement
2. The optimum pozzolan content for blended cement with HRWR was 30% whereas that of the blended mix without was 20%
3. The ultimate strength (28 days) of blended cement with HRWR at the optimum content of 30% cement replacement was 35% higher than that the blended cement without HRWR

4. With a minimum water-to-cement ratio and an optimum HRWR, high grade cement (grade 42.5) could be achieved

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