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Compressive and flexural strength of cement mortar blended with cassava peel ash and high-range water-reducing (superplasticizing) admixtures

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ABSTRACT

This paper presents the outcome of an experiment carried out by using cassava peel ash (CPA) of varying quantities to partially replace cement in mortar mix and the influence of adding superplasticizer in the mortar mix is further investigated. The experiment was carried out by partially replacing CPA in the range of 0 to 25 percent by weight of cement at 5% intervals. A water binder ratio (w/b) of 0.5 and superplasticizer dosage of 1.5l/100kg were used to produce the blended mortar of mix 1:3. The samples were cured and tested for compression and flexure at 7, 28, and 90 days after demolding. The results of the first experiment confirmed the suitability of the cassava peel ash (CPA) at not more than 15% replacement with cement for mortar and concrete works. In the second experiment, the superplasticizer has a linear relationship with the conventional mortar while the blended cement-cassava peel ash (CCPA) mortar retarded in strength at an early stage. However, 5% CPA mortar with superplasticizer gained 52 percent strength from 7 days to 28 days of the test. In addition, at the 90-day test, 5% CPA mortar with superplasticizer has almost an equivalent strength (96%) of the conventional mortar with superplasticizer. The flexural strength for blended CCPA mortar of 5-15% showed an acceptable value with that of mortar with a superplasticizer. Generally, the addition of admixture to the blended CCPA mortar showed a different trend compared to the conventional mortar.

KEYWORDS

Cassava peel ash (CPA), Superplasticizer, Cement, Compressive strength, Flexural strength.

1. INTRODUCTION

Portland cement has been an essential material in construction industry with current consumption of 1 m^3 per person per year (Gartner, 2010).Though its use remains topical, its production stands for big challenge to human activities. The reuse of agricultural wastes and its resource potential are being appraised as it helps to provide an attractive option that promotes savings and conservation of natural resources from further depletion hence creating a sustainable environment (Ofuyatan *et al*., 2014). Agricultural waste such as corn cob ash and cassava peel ash is attracting interest in construction industry (Adesanya *et al*., 2009; Olusola *et al*., 2013).

Excellent work has been done in investigating the efficient use of various agricultural and industrial by products (such as Natural fibres, corn cob ash, fly ash, rice husk ash, foundry waste) that have been continuously generated. The reuse of these waste products will help to save our environ from environmental pollution and severe ecological (green) problem. As a result of this, an alternative source for the potential replacement of fine aggregates in concrete has been investigated by vaious researchers (Ogunbode *et al*., 2008; Al-Ani *et al*., 1989; Swamy, R.N., 1986; Berry, 1980; Bilodeau, 2000).

Salau and Olonade, (2011) studied the pozzolanic potential of cassava peel ash (CPA) and their investigation showed that cassava peel ash possesses pozzolanic reactivity when it is calcined at 700ºC for 90 minutes. They also concluded that compressive and flexural strengths increase with age but reduce with increase in CPA content in the mix especially when more than 15% CPA is used, at these states, CPA contained more than 70 per cent of combined silica, alumina and ferric oxide (ASTM C 618 & TS 25). Raheem, *et al.,* (2015) carried out similar studies and reported the effects of cassava peel ash (CPA) as an alternative binder in concrete and finally concluded same as (Salau and Olonade, 2011). Ofuyatan O. *et al.,* (2018) presented the assessment of strength properties of cassava peel ash-concrete using a different mix ratio of 1:1:1.5 and concluded that the durability improved considerably at 10% replacement for cement with cassava peel ash. Olutaiwo and Adanikin (2016) also reported the evaluation of the structural performance of lateritic soil stabilized with cassava peel ash (CPA) and cement and concluded that the stabilized lateritic soil with CPA will be most suitable for use as fill materials while the stabilized admixed lateritic CPA + 5% Cement soil will be suitable for use as base courses.

Superplasticizer is a water reducer, it brings about reduction in the water required for mixing (Neville A.M, 2005). The superplasticizer gives the cement particles negative charge and by so doing, they repel each other due to the same electrostatic charge. By breaking the floccules of the cement particles, more water is provided for the concrete mixing (Neville A.M, 2005). The utilization of superplasticizer will have positive effects on properties of concrete (Yamakawa C. *et al*., 1990).

The past researchers have studied the effect of different types of superplasticizer on properties and performance of concrete. Borsai, (1994) carried out an investigation to study the effect of two types of superplasticizers; acrylic polymer (AP) and sulfonated naphthalene (SN) on concrete containing high fly ash. From the investigation, they concluded that AP performs significantly better than SN superplasticizer, where it provides high slump level, lower slump loss, higher water reduction, higher compressive strength and durability performance. The addition of superplasticizer on concrete has been known to increase the compressive strength and reduce the water required for mixing (Neville A.M, 2005). However, to the best of authors' knowledge, no work has been done on the effect of superplasticizer on the blended cement-cassava peel ash (CCPA) mortar.

The aim of this paper is to investigate the effect of superplasticizer on blended cement-cassava peel ash mortar. In the first experiment, we investigated the effect of CPA on the compressive strength of cement mortar; Secondly we studied the effect of the superplasticizer on the compressive and flexural strength of blended CCPA mortar..

2. EXPERIMENTAL PROCEDURE

2.1. Materials

Cassava peels were collected from the cassava peels dump site at fufu processing centers in Ijebu, Ogun State, Nigeria as seen in Fig. 1. The ash was produced by calcination for 90 minutes at 700ºC at the laboratory kiln of Nigeria Building and Road Research Institute, NBRRI, Sango Ota, Ogun state as seen in Fig. 2 (a). It was sieved, using $150\ \mu m$ sieve size to produce fine ash as shown in Fig.2 (b) and (c). The superplasticizer used in this study is Master Rheobuild850.

(a) (b)

Figure 1: (a) tubers of cassava and (b) cassava peels

(a) (b) (c)

Figure 2: (a) the kiln (b) the non-sieved cassava peel ash (c) sieved cassava peel ash

2.2. Mix proportion and sample preparation

The mortar studied had a mix ratio of 1:3 (cement to sand) with a water/binder ratio of 0.50. A superplasticizer was added at a dosage of 1.5 liters per 100 kg of binder. The cement was partially replaced with cassava peel ash (CPA) at 0%, 5%, 10%, 15%, 20%, and 25% by weight of the cement. This mixture was combined with sand as the fine aggregate. The batching of the mortar mix was done by weight, as shown in Table 1.

Table 1: Mix proportion

CPA replacement (%)	Fine aggregate (kg)	OPC (kg)	CPA (kg)	Water (kg)	Superplasticizer (kg)
0	2.76	0.920	0.000	0.31	0.014
5	2.76	0.874	0.046	0.31	0.014
10	2.76	0.828	0.092	0.31	0.014
15	2.76	0.782	0.138	0.31	0.014
20	2.76	0.736	0.184	0.31	0.014
25	2.76	0.690	0.230	0.31	0.014

2.3. Testing procedures

To determine the optimum water binder ratio that could produce workable blended mortar, a slump was conducted in accordance with BS 1881(102) and BS 1881(103). Mortar cubes of sizes $40 \times 40 \times 40\ mm$ were prepared using a mix ratio of 1:3 and a predetermined constant optimum water/binder ratio (w/b) of 0.50 was used, with varying percentages of cassava peel ash as a substitute for cement. The constituent of the mix was batched by weight and the cubes and beams produced as shown in Fig. 3. Three Cubes for each concrete mix were cast and cured for 7, 28, and 90 days. Before crushing, the specimens were removed at each curing age, weighed, and then tested using a compression machine. The average of three readings was calculated and recorded as the compressive and flexural strength.

(a) (b) (c)

Figure 3: (a) ingredients batched by weight, (b) CPA mortar mixed with portable water and Rheobuild 850, and (c) mortar cubes

Mortar beams measuring 160 x 40 x 40 mm were cast and cured for 7, 28, and 90 days. On the testing day, the beams were marked to indicate the support and loading positions, as shown in Figure 4. The testing procedures followed the guidelines of ASTM C78. The flexural strengths of the beam specimens were determined using the relationship recommended by ASTM C78, expressed as the Modulus of Rupture (MR).

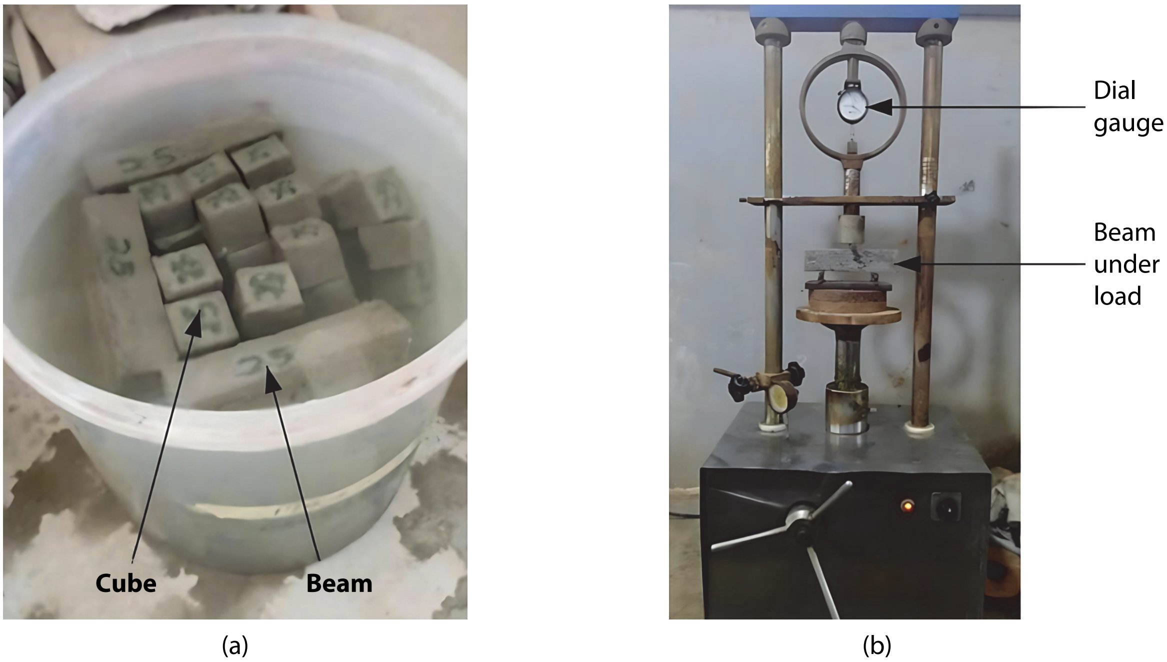

Figure 4: (a) curing of samples (b) flexural test

3. RESULTS AND DISCUSSION

3.1. Fine aggregate size distribution

The grading for the fine aggregates was done according to BS 1377 Part 1 and section 9 of part 2. The coefficient of uniformity (*Cu*) for the sand is 3.21 while the coefficients of curvature (*Cc*) is 1.15 as shown in Fig. 5 below.

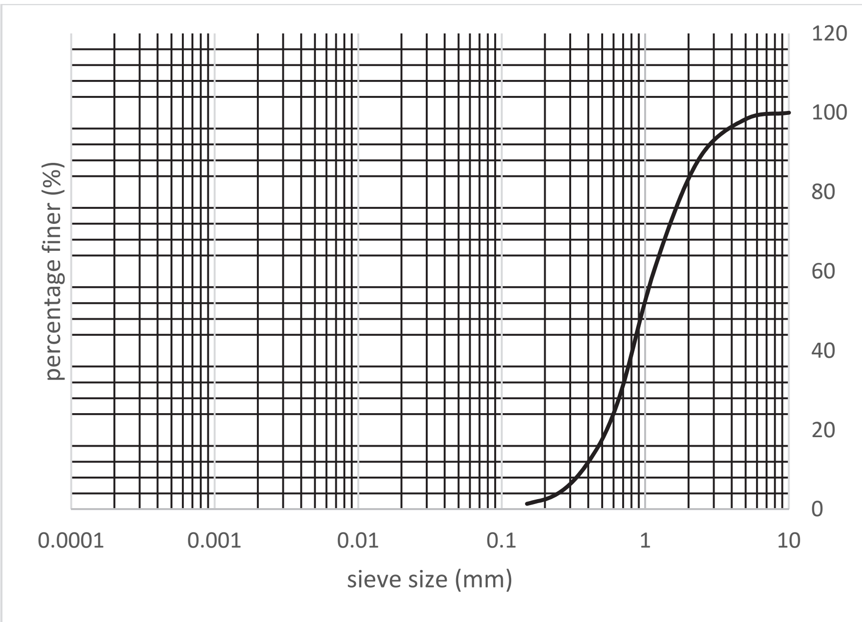

Figure 5: Gradation curve of fine aggregate (sand)

3.2. Compressive Strength

For the first investigation, the compressive strength of the convectional mortar for 7, 28 and 90 days test are 19.79, 22.92 and 23.96 N/mm^2 respectively which confirms that strength increases with age. 28 days test for 5, 10, 15, 20 and 25% CPA replacement are 20.83, 19.79, 18.57, 15.63 and 15.63 N/mm^2 which represent 90.9%, 86.3%, 81%, 68.2% and

68.2% of the conventional mortar strength (22.92N/mm^2) respectively and the values of 5, 10 and 15% were greater than 75% specified by ASTM C311-98 confirming that up to 15% is adequate. The compressive strength of the blended CCPA mortar with age is shown in Fig. 6. The results presented here confirmed and validated the earlier work done by Salau and Olonade (2011).

For the second experimental studies, the compressive strength of the conventional mortar on addition of superplasticizer for 7, 28 and 90 days test are 23.44 (18.4% increase), 27.08 (18.2% increase), and 28.13 N/mm^2 (17.4% increase) respectively when compared to the conventional mortar without the admixture. It can be said that the addition of admixture like Rheobuild 850 has a positive influence on the strength of mortar. While for the superplasticizer blended CCPA mortar, the 7 days test for 5, 10, 15, 20 and 25% CPA replacement are 17.19 (8.3% decrease), 17.19 (8.3% decrease), 15.63 (5.8% decrease), 15.63 (7.2% increase), and 14.07 N/mm^2 (12.6% increase) respectively when compared to the blended CCPA mortar without admixture. However, 28 days test for 5, 10, 15, 20 and 25% CPA replacement are 26.04 (25% increase), 20.83 (5.3% increase), 19.79 (6.6% increase), 18.57 (18.8% increase) and 14.58N/mm^2 (6.7% decrease). The compressive strength of the blended superplasticizer CCPA mortar with age is shown in Fig. 7.

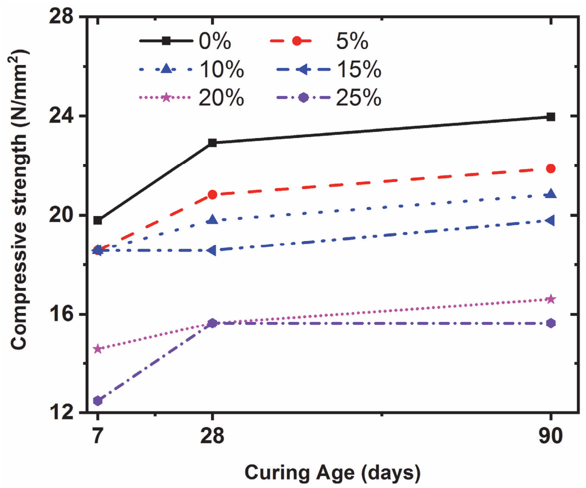

Figure 6: Compressive strength of blended CCPA mortar without superplasticizer

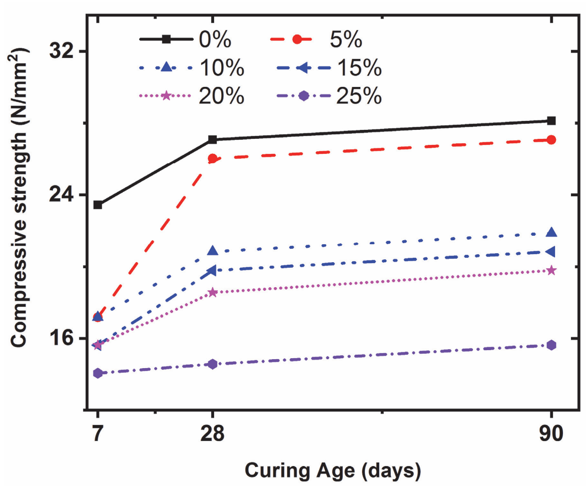

Figure 7: Compressive strength of blended CCPA mortar with superplasticizer

The variation in compressive strength between the blended CCPA with and without superplasticizer is shown in Fig. 8. The result shows that the addition of superplasticizer to conventional mortar increases the strength by approximately 4 N/mm^2 which conforms with the general believe that superplasticizer has a linear relationship on compressive strength (Yamakawa C. *et al*., 1990). However, the addition of superplasticizer to the blended CCPA mortar retarded in strength at the early age of curing, then later accelerated to a satisfactory strength at 28 days and above. It can be observed that there is a late reaction between the CPA and superplasticizer, which led to the late contribution of strength in the mortar. This outcome is contrary to the general believe that admixture increases the strength of conventional mortar. At 25% CPA replacement the effect of superplasticizer was annul which implies that the higher the CPA content the less the effect of the superplasticizer in the mix.

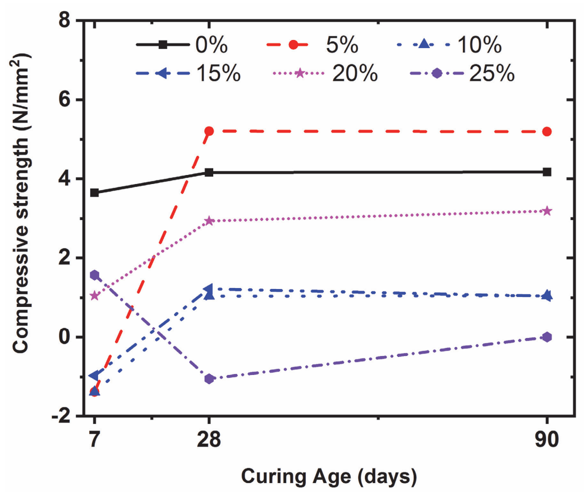

Figure 8: Compressive strength variation against age for blended CCPA mortar with and without superplasticizer

3.3. Flexural strength of CCPA blended concrete beam

The flexural strength of mortar refers to its capacity to withstand bending without failure. This strength is measured as the modulus of rupture (MR) in N/mm^2. When a mortar beam specimen is loaded, the top half experiences compression while the bottom half undergoes tension. The critical (failure) section is located in the middle third of the span, where the maximum flexural moment occurs. As the tensile stress in the uncracked beam reaches the modulus of rupture, cracks form in the concrete, starting from the tension face and extending towards the neutral surface, eventually reaching the compressive face and causing the beam to fail. Observations showed that cracks consistently appeared within the middle third of the beam across all mixes, and the failure mode was unaffected by the amount of CPA in the mortar. Since mortar is a brittle material and not reinforced, the failure occurred rapidly.

Since cracks occurred within the middle third of the beam span, the modulus of rupture (MR) was calculated using the formula $\mathrm{MR}=3PL/2bd^2$, where P is the maximum applied force (N), L is the length of the beam (160 mm), b is the breadth (40 mm), and d is the depth of the beam (40 mm). Figure 9 illustrates the variation in flexural strength with different percentages of cassava peel ash (CPA) replacement over various curing ages. The flexural strength follows a similar trend to the compressive strength, increasing with curing age for all mixes but decreasing as the CPA content increases for all mixes but decreasing as the CPA content increases.

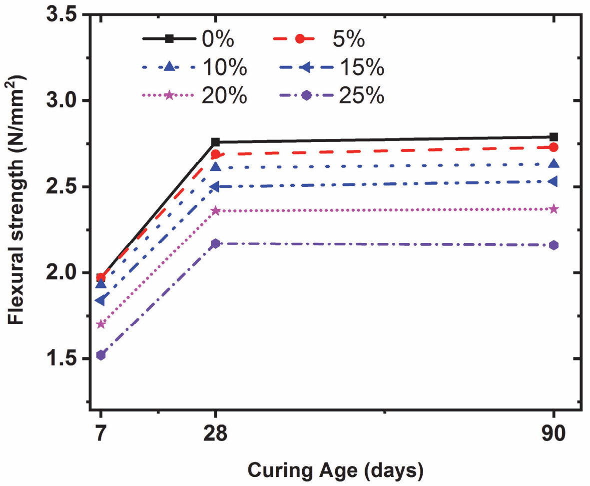

Figure 9: Flexural Strength of blended CCPA Mortar with Superplasticizer.

4. Conclusions and recommendations

From the results of the experiments the following could be concluded:

I. Compressive strength of blended CCPA mortar for 5 to 15 % replacement is adequate for mortar works.

II. Replacement of cement with 5% CPA in mortar with superplasticizer has an equivalent strength (96%) of the conventional mortar with superplasticizer.

III. Unlike the constant effect of superplasticizer on the compressive strength of conventional mortar for all testing days, blended CCPA with superplasticizer produced an uneven effects on the compressive strength.

IV. The usage of blended CCPA is enhanced by the addition of superplasticizer; the compressive strength of 20% CPA replacement with superplasticizer gained more than 75% strength of conventional mortar.

V. The reaction between CPA and superplasticizer is a case study as it contributed late to the strength of the mortar. It is recommended that the chemical reaction between pozzolan and superplasticizer that resulted to retardation in strength at early age and the late contribution to strength of mortar should be further investigated.

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