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Cement material from calcium carbide residue and broken bricks

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Broken bricks (BB) with dried calcium carbide residue (DCCR) is a potential pozzolana-lime cement. The BB contains mainly SiO2, Al2O3 and Fe2O3 while DCCR contain Ca(OH)2, the major components for pozzolana-lime cements. The BB-DCCR mixture met the ASTM C 593 requirements for use of pozzolana with lime. Rice husk ash (RHA) was used as control pozzolana in this study. BB-DCCR/commercial hydrated lime (CHL) mixes developed higher compressive strength than RHA- DCCR/CHL mixes at the 7th and 28th day of curing. BB-DCCR mix exhibited a higher compressive strength than a BB-CHL mix. At the 28th day of curing, the BB-DCCR and BB-CHL mortar acquired a compressive strength of up to 15.4 and 13.2 MPa respectively. Thermal activation of poorly performing BB improved pozzolanic activity. The setting time of a workable paste of the BB-DCCR and BB-CHL met Kenya standard 02 1263 requirements for Portland pozzolana cements (PPC). The results of compressive strength suggested that the mixture of DCCR and BB could be used as cementing material.

Key words: pozzolana, broken bricks, calcium carbide residue.

INTRODUCTION

Calcium carbide residue (CCR) is a by-product of acetylene production process and its production is described in equation (i) (John, 1993)

\[ \text{CaC}_2 + 2\text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2 + \text{C}_2\text{H}_2 \quad (i) \]

The DCCR is obtained as a dense white slurry, composed mainly of water and calcium hydroxide. When dried appropriately at a temperature that will not cause thermal decomposition of calcium hydroxide, a white solid (DCCR) is obtained. The solid contains a high proportion of calcium hydroxide. In Kenya, the slurry is cheaply sold to road constructors, although elsewhere it is used for neutralizing pickling acids, in industrial wastewater treatment and production of sand-lime bricks. In some countries, for example, Thailand where the demand for acetylene gas is high, the resultant waste has no immediate use and it is disposed off in prescribed areas (Tanalapsakul, 1998; Jaturapitakkul & Roongreung, 2002). Better ways of utilizing the waste would be highly desirable. Recently, Jaturapitakkul and Roongreung (2002) found that DCCR could be used to make cementious material with rice husk ash (RHA)

Broken bricks (BB) results from over-burnt, under-burnt and mishandling of finished product in clay works. In Kenya, BB chips are cheaply sold mainly for paving walkways. The walkways, however, become very dusty after sometime. In brick making, highly rich silica, and/or alumina clay is heated up to 900°C. Between 600-900°C, all common clay minerals make active pozzolanas depending on the nature of clay. At this temperature range, the chemically bound water is driven off rendering silica and/or alumina free to react with hydrated lime at room temperature to form cementious material (Cook, 1986). In India, reject bricks and tiles are ground to be used as pozzolana (Cook, 1986). The aim of this study was therefore to investigate whether
the Kenyan BB could be used as a pozzolanic material together with a suitable hydrated lime material. This work investigates the use of the BB as pozzolanic material with the DCCR. Commercial hydrated lime (CHL) with the BB and RHA were used as control experiments.

The use of BB with DCCR as a cementious material would avail an affordable cementious material. This should lower the cost of building and construction and hence establish affordable housing and shelter especially in developing countries.

MATERIALS AND METHOD

The BB used in this study were sampled from Kenya Clay Products Limited and Clay Works Limited both in Ruiru Municipality and labeled ‘C-W BB’ and ‘G-45 BB’ respectively. The samples were labeled ‘C-W BB’ and ‘G-45 BB’ as per their mother factories. The CCR was sampled from British Oxygen Company - Kenya (BOC-K) in Nairobi. Rice husks (RH) were sampled from Mutithi rice milling station in Mwea. CHL was obtained from commercial chemical dealers.

The BB as obtained from the sampling site was crushed using a laboratory crusher, and dried at 100°C. It was then finely ground using a laboratory ball mill until the particles retained on Kenya Standard (KEBS, 1993) 90 μm sieve were less than 10%. Some of the ground C-W BB was calcined at 600°C for four hours in an electric furnace model FSE-520-210P. This sample was labeled activated C-W BB. Rice husks as obtained from the sampling site were calcined using a fixed bed kiln at temperatures below 650°C. The resulting RHA was ground to the same fineness as BB. The CCR as obtained from the sampling site was allowed to stand and the excess water decanted. The resultant solid was dried to a constant weight at 100°C (KEBS, 2001). It was then ground using a laboratory blender until the particles retained on 90 μm sieve were less than 10%. CHL was similarly ground.

X-ray fluorescent analysis (XRFA) was adopted for Si, Al, Fe, Mg, and Ca content of the BB and RHA using sequential X-ray spectrophotometer (SRS) model 3000. Gravimetric analysis was also done for the same elements as well as SO₃ while flame photometry was adopted for Na and K content analysis in accordance with the British standards (BSI, 1970). The same standard was adopted for loss on ignition (LOI) analysis. Calcium hydroxide content in DCCR and CHL were determined in accordance with KS 1775 part 5 (KEBS, 2001) by digesting DCCR/CHL with neutralized sucrose solution and the resulting solution titrated against hydrochloric acid using phenolphthalein as indicator. Ca(OH)₂ content in commercial hydrated lime (CHL) was similarly determined.

Setting times of workable pastes of BB-DCCR were determined in accordance with the KS 1263 (KEBS, 1993) procedure for PPC, and compared to those of BB-CHL, RHA-DCCR and RHA-CHL. This was done by plunging a workable test pozzolana-lime paste with a KS 1263 Vicat apparatus using initial and final setting time’s needle for initial and final setting times respectively. Initial setting time was recorded as the time at which the distance between the base plate of the paste and the needle on penetration was 10 mm while final setting time as the time when the final setting time needle circular ring could not make a mark on the paste.

Compressive strength of the mortar mixes was determined in accordance with the ASTM 593 part C (ASTM, 1991) but with slight modifications. KS 1263 (KEBS, 1993) 70.7 mm cubes moulds were used instead of the prescribed 50 mm moulds, while the mortar was compacted into the moulds using a vibrating machine instead of the prescribed Jolting Table. The ratios of the
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test pozzolana: CHL were varied as 2: 1, 1: 1 and 3: 1 while that of test pozzolana: DCCR was 2: 1. Appropriate amounts of water to allow for workability were used. Moulded cubes were cured at 54±2°C in a highly humid environment for 7 days after which the cubes were allowed to cool to room temperature then demoulded. Compressive strength was determined for three cubes for each test pozzolana-lime material. The remaining cubes were cured for an additional 21 days in a highly humid environment at 20±2°C after which their compressive strength was determined. Compressive strength was determined as the maximum load under which a cube would collapse using a standard Avery Denison Machine for compressive strength determination. All the above tests were done in triplicates.

RESULTS AND DISCUSSION

Sieve Analysis

The percentage sieve retention of the ground DCCR, CHL, C-W BB, G-45 BB and RHA on the 90 μm sieve (wet) were 2.13, 2.21, 7.92, 7.31 and 7.48%, respectively. The particles were fine enough for pozzolana-lime reaction and were not expected to affect adversely the water to cement (W/C) ratio. This is because although a higher fineness would be more preferable for any chemical reaction, it would require a higher W/C ratio, which would be detrimental to the compressive strength development. A high W/C ratio results in development of pores in cured mortars due to loss of evaporable free water at early ages of cement hydration (Mehta, 1981).

Chemical analysis

The BB as obtained from their sampling sites were brown in color with a few black specks. The results for chemical analysis of BB and RHA are given in Table 1.

<table>
<thead>
<tr>
<th>Compound</th>
<th>CaO</th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
<th>SO₃</th>
<th>MgO</th>
<th>K₂O</th>
<th>Na₂O</th>
<th>LOI</th>
<th>S+A+F</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-W BB</td>
<td>0.44</td>
<td>65.71</td>
<td>20.47</td>
<td>7.89</td>
<td>0.22</td>
<td>1.95</td>
<td>3.52</td>
<td>1.55</td>
<td>0.90</td>
<td>94.07</td>
</tr>
<tr>
<td>G-45 BB</td>
<td>4.08</td>
<td>63.31</td>
<td>17.66</td>
<td>6.70</td>
<td>0.39</td>
<td>2.32</td>
<td>2.34</td>
<td>1.02</td>
<td>0.57</td>
<td>87.67</td>
</tr>
<tr>
<td>RHA</td>
<td>1.38</td>
<td>80.61</td>
<td>0.53</td>
<td>0.47</td>
<td>0.01</td>
<td>2.39</td>
<td>0.15</td>
<td>0.20</td>
<td>3.49</td>
<td>81.61</td>
</tr>
</tbody>
</table>

The results showed that the materials met the KS 1263 (KEBS, 1993) requirements for pozzolanas that the sum of the major oxides of silicon, aluminium and iron be at least 70% for use in making Portland pozzolana cements. The material, similarly, met the ASTM 593 standard requirements for use with lime (ASTM, 1991).

The main cementious materials upon hydration of Portland cement are calcium silicate hydrate (3CaO·2SiO₂·3H₂O), calcium ferrite hydrate (4CaO·Fe₂O₃·13H₂O) and calcium aluminium hydrate (3CaO·Al₂O₃·6H₂O). 3CaO·2SiO₂·3H₂O contribute more towards the strength of the hydrated cement than the others. The reactions of hydration are as shown in equations (ii) to (v) (Neville, 1995).
Similar products are formed from the reaction of SiO₂, Al₂O₃, and Fe₂O₃ in pozzolana with Ca(OH)₂ from the cement hydration or any other lime. While CHL is commonly used for this reaction, it was important to check whether CCR could be used. Ca(OH)₂, being a hydration product implies that presence of a pozzolana in the cement would result in more cementious material. The reaction of pozzolana with Ca(OH)₂ to form calcium silicate hydrates (CSH) is given in equation (vi) (Takeketo & Uchikawa, 1980).

\[ \text{SiO}_2 + n\text{Ca(OH)}_2 \rightarrow n\text{CaO. SiO}_2. n\text{H}_2\text{O} \] (vi)

The CCR as obtained from the sampling site was a white-dense slurry. It had a water content of 38.21% by mass. On decanting and drying the residue, a white powdery solid was obtained. The powdery solid was a fine material and did not require a ball mill for it's grinding, the blender used was enough to grind it to the required fineness. The residual dry solid had a calcium hydroxide content of 96.33% compared to that of commercial building lime of 84.04%.

### Compressive strengths and Setting Times

The results for the initial and final setting times (IST and FST) of the test pozzolana-lime materials are given in Table 2 while for compressive strength are given in Figure 1.

**Table 2.** Setting time (IST, FST) for the test pozzolana-lime materials.

<table>
<thead>
<tr>
<th>Mix</th>
<th>Ratio</th>
<th>IST /Minutes</th>
<th>FST/Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-W BB: CHL</td>
<td>2: 1</td>
<td>850</td>
<td>1702</td>
</tr>
<tr>
<td>RHA-CHL</td>
<td>2: 1</td>
<td>351</td>
<td>498</td>
</tr>
<tr>
<td>G-45 BB: CHL</td>
<td>2: 1</td>
<td>160</td>
<td>239</td>
</tr>
<tr>
<td>C-W BB: CHL</td>
<td>1: 1</td>
<td>1002</td>
<td>1352</td>
</tr>
<tr>
<td>RHA-CHL</td>
<td>1: 1</td>
<td>360</td>
<td>445</td>
</tr>
<tr>
<td>G-45 BB: CHL</td>
<td>1: 1</td>
<td>180</td>
<td>266</td>
</tr>
<tr>
<td>C-W BB: CHL</td>
<td>3: 1</td>
<td>645</td>
<td>1226</td>
</tr>
<tr>
<td>RHA-CHL</td>
<td>3: 1</td>
<td>323</td>
<td>471</td>
</tr>
<tr>
<td>G-45 BB: CHL</td>
<td>3: 1</td>
<td>175</td>
<td>253</td>
</tr>
<tr>
<td>G-45 BB: DCCR</td>
<td>2: 1</td>
<td>143</td>
<td>207</td>
</tr>
<tr>
<td>'C-W BB: CHL</td>
<td>2: 1</td>
<td>284</td>
<td>549</td>
</tr>
<tr>
<td>'C-W BB: DCCR</td>
<td>2: 1</td>
<td>628</td>
<td>923</td>
</tr>
<tr>
<td>'C-WBB: DCCR</td>
<td>2: 1</td>
<td>263</td>
<td>526</td>
</tr>
<tr>
<td>RHA-DCCR</td>
<td>2: 1</td>
<td>349</td>
<td>462</td>
</tr>
</tbody>
</table>

*Activated
The use of the bigger 70.7 mm cube moulds instead of the ASTM 593 prescribed 50 mm would be expected to provide an even more severe test and therefore dependable results. A vibrating machine was likewise not expected to significantly affect the results. The use of the RHA, one of the most studied pozzolanic material and CHL as control test materials provided valuable comparative significance to the results.

C-W BB had a higher major oxides content than the G-45 BB. It was therefore expected to exhibit a higher compressive strength but this was not the case. Dhir (Dhir, 1986) observed that a higher major oxide content in pulverized fuel ash (PFA) does not always provide a high glassy phase content of the major oxides and therefore a high pozzolanic activity. The results were therefore not unusual.

Deviation from the 2:1 ratio of pozzolana to CHL adversely affected the compressive strength and setting times of the materials. This could be attributed to either an excess of the pozzolanic material or the CHL in the mixes. The excess material in the mixes on their own have low or no cementious material because the CSH or calcium aluminium hydrates (CAH) can not be made.

The C-W BB exhibited a lower compressive strength and had very long curing times with CHL compared to the G-45 BB-CHL in all the experimented cases. This could be attributed to a lower glassy phase in C-W BB and therefore a poor firing regime. The C-W BB was therefore thermally activated to improve on this. On thermal activation, C-W BB exhibited an improvement as shown in Table 2. More research is necessary to establish optimum conditions for activating poorly performing BB as well as establishing more economical modes of activating the BB other than those that are electricity based.

The test pozzolana exhibited a higher pozzolanic activity with DCCR than CHL in all cases as shown in Table 2. This could be attributed to the higher Ca(OH)₂ content in the DCCR than in CHL and therefore a higher Ca(OH)₂ at any time to react with the test pozzolana to make the
cementitious CSH and CAH. More research is necessary to establish the optimum mix design and mix ratio of the BB to the DCCR.

In Kenya, for example, in Machakos, there are many houses constructed with fired bricks and therefore a ready source of BB. Research is therefore needed to establish the viability of using BB with lime as mortar. Similar work has been done on Kenyan rice husks (Waswa-Sabuni et al., 2002).

Generally, the BB exhibited a higher compressive strength and shorter setting times than the RH in all the cases considered in this work. This therefore shows that the BB are potential pozzolanic materials with DCCR.

CONCLUSION

Cementitious material for Kenyans can be obtained from waste or broken bricks in a mix with dried calcium carbide residue. The use of such materials would not only introduce a cementitious material but would also avail a more environmentally friendly disposal technique for the residue. The cement material would lower the building costs in areas near the source of raw materials. It would also improve the quality of housing in such areas.

RECOMMENDATION

More research should be done on the durability, early strength as well as optimum mix design of the materials to ascertain use of broken bricks and dried calcium carbide residue as raw materials for cement making. This is important because of transformation of waste materials to useful products. Further work is also necessary to establish the performance of the material for a longer period, either in a laboratory condition with corrosive media, for example acidic media or in field environments.

ACKNOWLEDGEMENT

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REFERENCES


