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Mediterranean Journal of Chemistry **2012**, 2(2), 401-407

Cementing material from rice husk-broken bricks-spent bleaching earth-dried calcium carbide residue

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Abstract: A cementious material, coded CSBR (Carbide residue Spent bleaching earth Broken bricks and Rice husks), was made from dried calcium carbide residue (DCCR) and an incinerated mix of rice husks (RH), broken bricks (BB) and spent bleaching earth (SBE). Another material, coded SBR (Spent bleaching earth Broken bricks and Rice husk ash), was made from mixing separately incinerated RH, SBE and ground BB in the same ash ratio as in CSBR. When CSBR was inter-ground with Ordinary Portland Cement (OPC), it showed a continued decrease in $Ca(OH)_2$ in the hydrating cement as a function of curing time and replacement levels of the cement. Up to 45 % replacement of the OPC by CSBR produced a Portland pozzolana cement (PPC) material that passed the relevant Kenyan Standard. Incorporation of the CSBR in OPC reduces the resultant calcium hydroxide from hydrating Portland cement. The use of the waste materials in production of cementitious material would rid the environment of wastes and lead to production of low cost cementitious material.

Key words: Calcium Carbide Residue, Spent Bleaching Earth, Broken Bricks, pozzolana.

Introduction

The production of low cost cementitious material has been an issue that generates interest globally. This has been due to the high cost of Portland cements resulting in poor housing and construction in many developing countries, like Kenya. Voluminous generation of waste materials, resulting in pollution, has necessitated research for reuse of wastes. This is important because of environmental concern worldwide. This paper reports on the use of an ash resulting from calcining a blend of rice husks, waste bricks and spent bleaching earth, CSBR, to substitute OPC with an addition of dried calcium carbide residue to optimize the pozzolanic reaction.

In economies where demand for acetylene gas is high, for example, the resultant calcium carbide residue (CCR), is disposed in waste damps [1]. The gas is manufactured from the reaction of calcium carbide powder with water according to equation (i) [2]

$$CaC_{2\,(s)} + 2H_2O_{(l)} \longrightarrow Ca(OH)_{2(ppt)} + C_2H_{2(g)} \qquad \text{(i)}$$

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The calcium hydroxide precipitate or calcium carbide residue (CCR) is a slurry, with a water residue content of over 38.21 percent by mass [3]. The waste is an environmental hazard due to its pH and potential for fire start up and acceleration. When dried appropriately, a white solid, referred to as Dried Calcium Carbide Residue (DCCR) or dried acetylene lime sludge (DALS), is obtained. The solid is mainly calcium hydroxide[3]. The waste finds limited use in constructions, manufacturing and wastewater treatment.

In any clay works, the possibility of having resultant waste bricks is inevitable. This is either from mishandled finished products or under-burnt bricks. Clay and clay minerals have been documented to be used as partial replacement of cement due to their pozzolanic activity either in natural form or after thermal activation[4]. In Kenya, BB chips are sold cheaply for mainly paving walkways and roads. The material ultimately becomes a health hazard because it is dusty. Clay products are burnt at temperatures of up to 900 °C. Generally at 600 – 900 °C all common clay minerals make active pozzolanas depending on the nature of clay[5]. At this temperature, the chemically bound water is driven off making silica and/or alumina free to react with hydrated lime at room temperature to form cementious material. Kenyan BB are pozzolanic and readily react with commercial hydrated building lime (CBL) and DCCR [3]. Poorly pozzolanic BB have elsewhere been thermally activated [3].

Spent bleaching earth (SBE) is a waste material obtained from bleaching petroleum or vegetable oils. The material has a fair amount of remnant oil and has been found to yield over 15 J/g of energy when holding 38.5 % residual oil by mass[6, 7]. When SBE is thermally activated at 550 °C, the resultant clay is pozzolanic with either commercial building lime (CBL) or DCCR[6, 7].

Rice Husks (RH) is a waste resulting from rice milling. On incineration, it generates approximately 15 J/g of energy [8]. Controlled incineration of RH produces pozzolanic Rice Husk Ash (RHA) [9, 10].

RH, ashed SBE and BB are plausible pozzolanas for making PPC's up to 25 percent replacement of the OPC[3, 6] . Further investigations revealed that their chemical constituents, initial and final setting times surpassed the pozzolanic requirements[3, 6, 7, 11]. They have also been observed to be pozzolanic with CBL or DCCR[1, 6].

This paper reports on work carried out to investigate the $Ca(OH)_2$, a hydration product of OPC, reduction extent of CSBR. The possibilities of blending OPC with CSBR and DCCR have also been investigated in terms of compressive strength development up to 60 percent replacement levels. Up to 45% replacement, made a Kenya Standard Portland Pozzolana Cement (PPC) material[12]. The material was considered a low-cost cement candidate while the process could provide a promising method for profitable utilization of wastes.

Results and Discussion

Pozzolanicity Test

Figure 1 gives the pozzolanicity test results.

The results indicated that the OPC exhibited a continued increase in the $Ca(OH)_2$ phase as curing proceeded. The increase is expected due to the hydration of tricalcium silicate ($3CaO.SiO_2$) and dicalcium silicate ($2CaO.SiO_2$) phases of cement[13].

The noted reduction of $Ca(OH)_2$ in the substituted cement was therefore a contribution of both the lower fraction of OPC as well as the reaction of the produced lime with pozzolana. The reaction of $Ca(OH)_2$ with pozzolana reduces the amount of $Ca(OH)_2$ which is susceptible to acid attack. Pozzolana – $Ca(OH)_2$ reaction introduces secondary cementitious products that make concrete or mortar denser and hence less permeable.

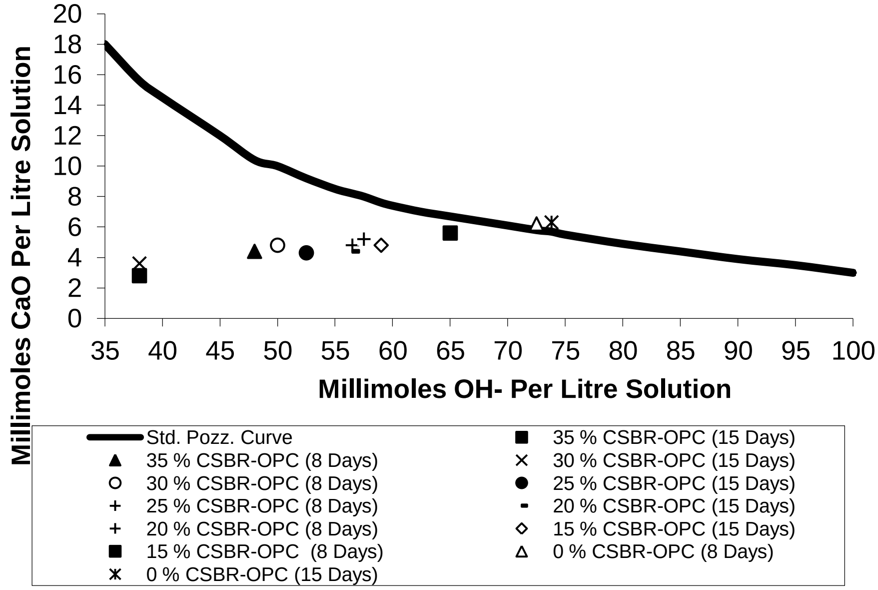

Figure 1: Pozzolanicity Test Diagram for CSBR-OPC

This improves the concrete durability[14, 15, 16]. Beyond 35 % replacement of OPC, the produced $Ca(OH)_2$ was so low that the points were outside the pozzolanicity diagram margins. This must have been due to excess pozzolana. In order to react the resultant excess pozzolana, DCCR was added to higher replacement levels and the compressive strengths determined.

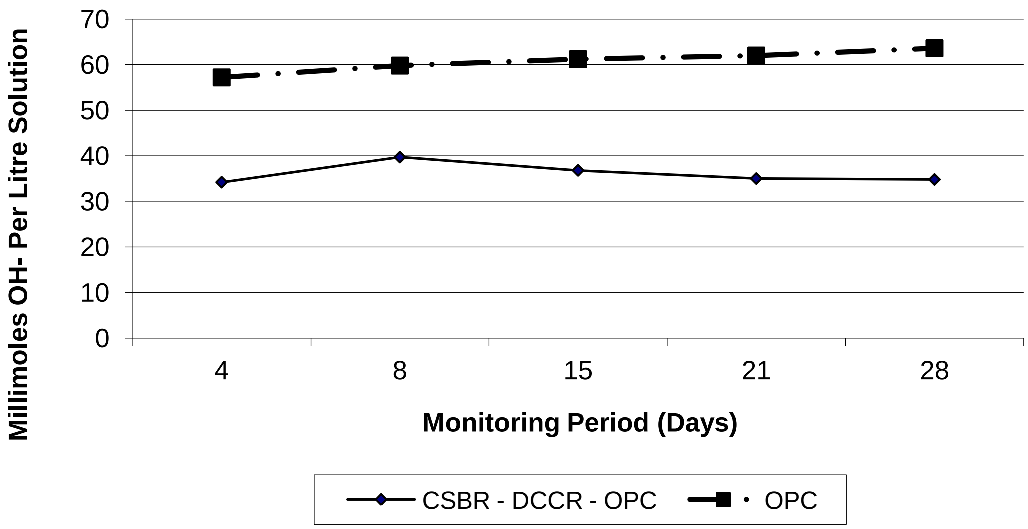

Figure 2: OH^- Concentration Change as a Function of Curing Period

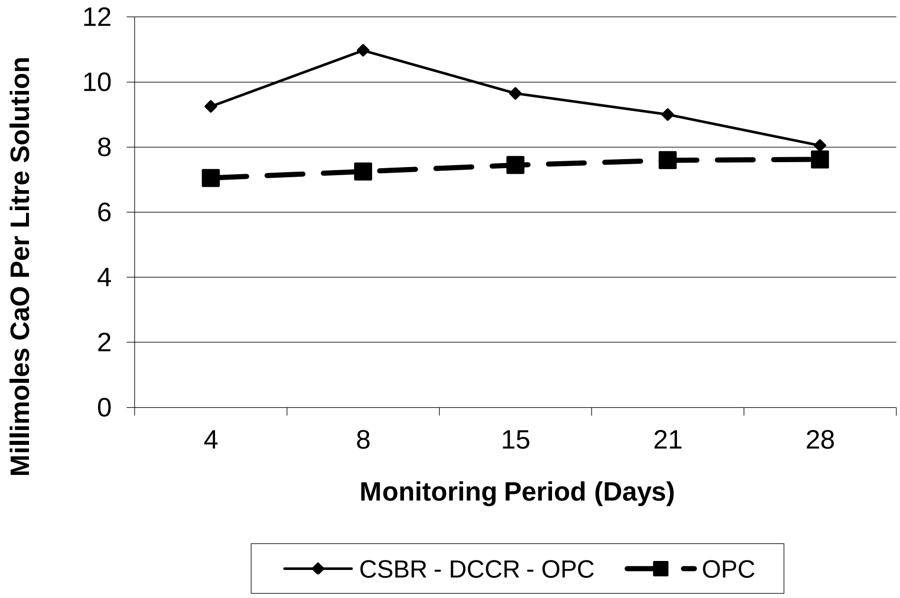

Figure 3: CaO Concentration Change as a Function of Curing Period

The results for the CaO and OH^- in the modified pozzolanicity test for the CSBR – DCCR – OPC mix at the 45 percent replacement levels of OPC and neat OPC are shown in Figures 2 and 3.

The results suggested that, although the CSBR – DCCR – OPC mix had an initial high CaO levels, by the end of the analytical period, this had almost leveled the OPC's. This was an indication that the included pozzolana and DCCR exhibited pozzolana – $Ca(OH)_2$ reaction albeit slow. OPC on the other hand exhibited higher OH^- levels throughout the test period. Diamond while studying the pore solution pH concluded that the pH and hence the OH^- is governed by the alkali hydroxides with the $Ca(OH)_2$ only providing the buffering effects especially at later stages of cement maturity[17, 18]. Elsewhere, Byfor[19] attributed the lowering of the pozzolana blended cements pore solution pH being majorly due to the dilution effect. Pozzolana – $Ca(OH)_2$ reaction has also been cited as a lowering factor in pore solution pH[20, 21].

The results from the different mixes of CSBR – DCCR – OPC suggested that the reduction in $Ca(OH)_2$ would be basically from a dilution factor as the level decreased with increasing replacement levels of OPC. Pozzolanic reaction also played a major role because the $Ca(OH)_2$ decreased with curing period as can be observed of a given replacement level with time.

Compressive Strength of CSBR-DCCR-OPC Cements

Figure 4 gives the compressive strength development of the CSBR - DCCR -OPC mixes as a function of replacement and curing time.

The test materials, up to 45 % replacement, met Kenya Standard (KS 02 1263) requirement of 38 MPa at the 28th day of curing. The performance of this highly substituted cement could be attributed to the high pozzolanicity of the CSBR as well as the reactivity of the DCCR. Although the inclusion of DCCR may have increased the formation of more cementious material from the reaction with CSBR, its incorporation could introduce excess $Ca(OH)_2$ in the cement, that would be prone to acid attack especially at early curing period as observed from the pozzolanicity test above.

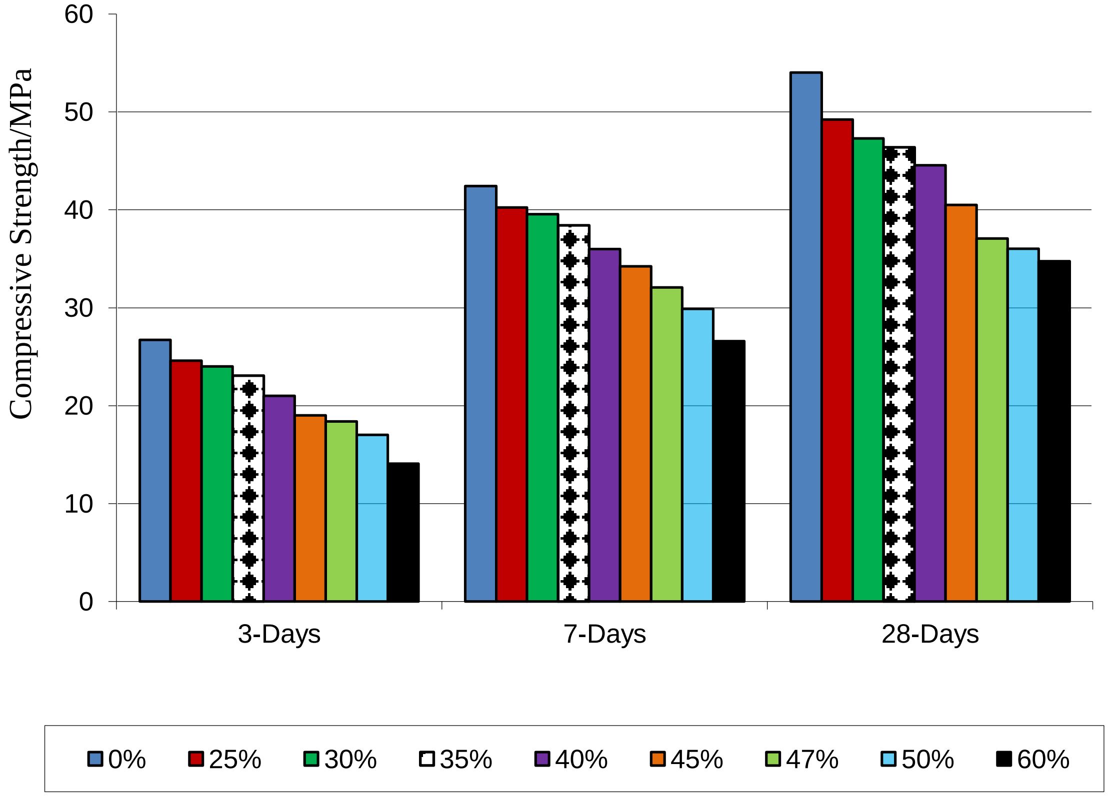

Figure 4: Compressive strength Development of CSBR-DCCR-OPC Cement

More work is therefore necessary to establish the susceptibility of the cement material to the attack. The high OPC replacement levels with waste materials requires evaluation to establish any economic gain from the product.

Conclusion

The results of this work suggested that substituting OPC with CSBR and DCCR, up to 45 percent replacement produced a cementitious material that met the Kenya Standard (KS 02 1263) requirements for Portland pozzolana cement in terms of compressive strength. The dilution effect and pozzolanic reaction have been shown to reduce the susceptible $Ca(OH)_2$ phase from the potential CSBR – DCCR – OPC mix. The material is a potential low cost cement that would profitably rid the environment of obnoxious wastes. Further work is recommended to investigate effects of normal and corrosive environments on the potential cement.

Acknowledgements

The authors wish to acknowledge assistance accorded by Kenyatta University.

Experimental Section

All the test materials were collected from local Kenyan manufacturing industries or processing plants. RH, SBE and BB were incinerated using a method described by Muthengia[6] . A ratio of 1: 1: 5 of raw SBE: BB: RH mix was calcined using a fixed bed kiln (FBK) by uniformly spreading 5 kg of RH at the base, then 8 kg of crushed and ground BB followed by 5 kg of RH, then 8 kg of SBE and finally 30 kg of RH. A little paraffin was used for ignition to fire the whole mass through from the door of the kiln. Temperatures were controlled below 700 ºC by opening and closing the windows of the kiln. The resultant ash was milled using a laboratory ball mill until the particles retained on a Kenya Standard[12] 90 µm sieve were less than 10 percent by mass. This was labeled CSBR for identity purpose. CSBR was mixed in different mass ratios with OPC and ground for ten minutes using the ball mill to ensure complete uniformity. The resultant mixes were subjected to the usual pozzolanicity test in accordance with International Standards Organization (ISO 863:, 1990 (E) [22].

CCR as obtained from the sampling site was allowed to stand for some time and the excess water decanted. The resultant sludge was dried to a constant weight at 100 °C. It was then ground using a laboratory blender to the same fineness as the above test materials and labeled DCCR.
CSBR and DCCR were then blended in a 2: 1 ratio. The CSBR – DCCR mix was further mixed with OPC in different mass ratios and inter – ground using the laboratory ball mill for ten minutes to ensure uniformity. The resulting CSBR-DCCR-OPC samples were analyzed for their compressive strength in accordance with the KS 02 1263[11] of PPC . The samples were also subjected to the usual pozzolanicity test at 8 and 15 days. The CSBR – DCCR – OPC mix at 45 percent replacement of OPC and neat OPC were subjected to pozzolanicity test as above, but a further analysis of $Ca(OH)_2$ reduction was carried out for a longer period. The CaO and OH^- were analyzed at the 4th, 8th, 21st and 28th day.

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