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Stabilization of Recycled Demolition Aggregates by Geopolymers comprising Calcium Carbide Residue, Fly Ash and Slag precursors

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HIGHLIGHTS

- Calcium Carbide Residue, Fly Ash and Slag precursors in geopolymers.
- Strength tests on geopolymer stabilized RCA and CB.
- Resilient modulus (M_R) tests on geopolymer stabilized RCA and CB.
- Three-parameter model capturing effect of confinement and deviator stresses on M_R.

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ABSTRACT

Calcium Carbide Residue (CCR) is the by-product of acetylene gas production. In this research, the alkali activation of Calcium Carbide Residue (CCR) was studied as an economical and low-carbon precursor for development of geopolymer binder. Recycled Concrete aggregates (RCA) and Crushed Brick (CB) are the two major demolition material sources for the Construction and Demolition (C&D) industry. The cement stabilization of C&D materials has been evaluated in recent years, however due to the large carbon footprint associated with Portland cement, geopolymers which utilize the alkali activation of industrial waste by-products have garnered increasing interest from industry. Evaluation of the geopolymer stabilization of C&D materials with CCR precursor were also compared with traditional Fly Ash (FA) and Slag (S) precursors. In addition, the performance of CCR based geopolymers with supplementary FA and S precursors were also evaluated. The three precursors (CCR, FA, S) were combined with contents of up to 10% for the geopolymer stabilization of the C&D materials. A liquid alkaline activator comprising sodium silicate solution (Na_2SiO_3) and sodium hydroxide (NaOH) was used for the alkali activation of the CCR based geopolymers. The strength and durability of the geopolymer stabilized C&D materials were evaluated to ascertain their application in pavement bases/subbases. The results of Unconfined Compressive Strength (UCS) and Resilient Modulus (M_R) testing of these geopolymer stabilized CB and RCA aggregates indicate that different mixtures of CCR based geopolymers can be used to improve the strength properties of the C&D aggregates for pavement base/subbase applications. CCR + 5% S with the C&D materials resulted in the optimum combination for CCR based geopolymer stabilization of C&D aggregates.

1. Introduction

Demolition materials account for about half of all materials used and about half the solid waste generated worldwide [1]. Construction and Demolition (C&D) materials along with commercial and industrial wastes account for more than 80% of the waste materials received for reprocessing in the state of Victoria,

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Table 1
Chemical composition of CCR, FA and S from X-ray fluorescence analysis.

Chemical	Component (wt.%)		
	CCR [19]	FA [16]	S [16]
Al_2O_3	2.55	25.56	13.8
SiO_2	6.49	51.11	34.2
CaO	70.78	4.3	43.1
Fe_2O_3	3.25	12.48	0.4
K_2O	7.93	0.7	0.4
MgO	0.69	1.45	5.4
Na_2O	–	0.77	0.1
SO_3	0.66	0.24	0.8
LOI[a]	1.35	0.57	1.8

[a] Loss on Ignition.

Australia [2]. Oksri-Nelfia et al. [3] reported that about 20 million tons of wastes were generated per year by the construction industry in France.

Recycled Concrete Aggregates (RCA) and Crushed Brick (CB) are the largest C&D components that enter the waste stream in developed countries [4,5]. Various alternative solutions are increasingly being sought to divert demolition wastes from landfills. C&D aggregates have been used in the production of structural concrete as well as fillers in the concrete industry [3,6,7]. C&D aggregates have also been used to produce asphalt mixtures [8,9]. In recent years, C&D materials have been used in the construction of pavements and footpaths [10,11].

The production of Portland clinker is a highly energy-intensive process [12]. Replacement of Portland cement with new cementing agent with low carbon footprints has been increasingly sought by industry. Use of calcium- and silica-rich geopolymers for the stabilization of pavement aggregates and clays have garnered increasing interest in recent years [13–18].

Calcium Carbide Residue (CCR) is the by-product of acetylene gas production. The slurry is directed to disposal areas where it dries out and converts to a solid form which contains high calcium hydroxide, $Ca(OH)_2$, content [19].

$$CaC_2 + 2H_2O \rightarrow C_2H_2 + Ca(OH)_2 \quad (1)$$

Stabilization of clays with CCR has been investigated to ascertain their strength development and durability [20,21]. A utilization of the CCR in combination with silica-rich waste materials such as kaolin, rice husk ash, bottom ash and fly ash as an innovative green binder has generated recent interest. Alkali activated precursors termed as "zeolitic precursor" [12] or "geopolymer cement" is the product of dissolving aluminosilicate of the semi-inert material with high silica or alumina content in a very high pH environment of over 12 [17,22,23].

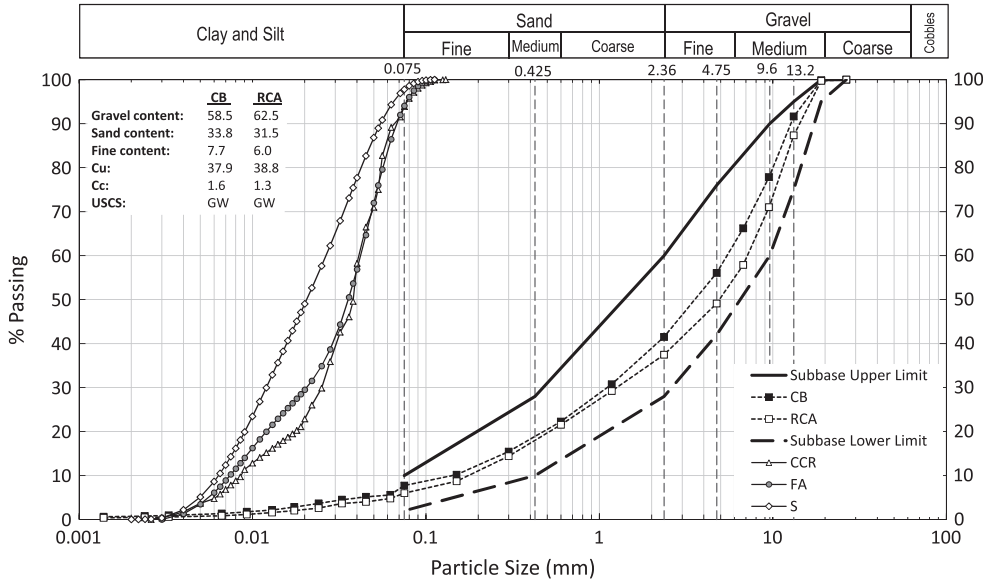

Fig. 1. Particle size distribution of C&D materials and additives.

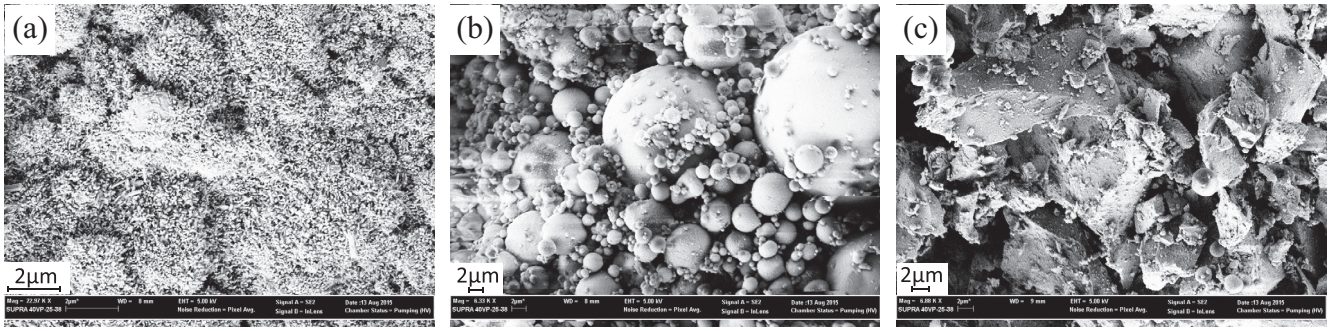

Fig. 2. SEM image of the additives (a) CCR, (b) FA, (c) S.