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Influence of red mud on fresh and hardened properties of self-compacting concrete

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HIGHLIGHTS

- The influence of red mud on fresh and hardened properties of SCC were studied.
- High superplasticiser dosages required for red mud concrete to meet the SCC requirements.
- Mechanical strength of concrete slightly increased with increasing red mud content.
- No significant difference of ITZ for red mud concrete compared to the control.
- Some albite crystals appearing in triclinic shape were identified by XRD in red mud concrete.

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ABSTRACT

Red mud is a waste product from the production of alumina, it currently has limited industrial use. This study proposed to use red mud to partially replace fly ash (12.5, 25 and 50% by weight) in self-compacting concrete (SCC) and the influence of red mud on the fresh and hardened properties and microstructural behaviour of SCC were studied. Slump-flow, T_{500} and J-ring tests were carried out on fresh SCC mixtures. The hardened properties of red mud SCCs including compressive strength, tensile strength and elastic modulus were studied. Moreover, the chemical composition and microstructural properties of red mud concrete samples were analysed using X-ray diffraction (XRD), scanning electron microscope (SEM) and energy dispersive spectroscopy (EDS), respectively. The results show that the mechanical strength of concrete increased with increasing red mud content. SCC samples consisting 50% red mud performed the best for the compressive strength and elastic modulus. The results from microscopic studies indicated that there was a slight improvement in the interfacial transition zone (ITZ) between aggregate and cement paste for red mud concrete compared with control concrete. The XRD results indicated that the chemical composition of cement paste containing red mud showed higher sodium and iron contents. With increasing red mud content, some albite crystals appearing in triclinic shape were also identified by XRD.

1. Introduction

One of the major environmental issues for the alumina industry is the disposal of massive amount of bauxite residue. Approximately 90 million tonnes of red mud produced each year all over the world [1]. Since there is very limited industrial use for red mud, the stockpiles of red mud are increasing. Fig. 1 shows one of the lagoons in India which is increasing each hour [2].

In Australia, all the primary aluminium smelters are located in coastal cities which require as much land as possible to ensure population growth and tourism, as shown in Fig. 2. Australia produces 30% of the world's bauxite and 20% of the world's alumina, with more than 600 million tonnes of alumina produced in Australia since 1974 [3].

The main red mud disposal methods currently in use around the world are marine discharge, lagooning and dry stacking. The most significant environmental impact arising from red mud disposal and storage is the soil and water pollution caused by the residue suspension fluid. The environmental risk mainly depends on the amount of suspension fluid in the mud and on the possibility of

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Fig. 1. Red mud lagoon [2].

interaction between the mud and the environmental components [5].

Red mud is a good binder material [6] and the use of red mud in cement matrices is attractive. Many studies were conducted on the utilisation of red mud in concrete and cement based materials. For example, Ribeiro et al. [7] investigated the influence of the addition of red mud on the characteristics of cement mortars in terms of setting time, pozzolanic activity and mechanical strength. They found that the addition of red mud accelerated the setting process and reduced the pozzolanicity, and the compressive strength decreased with increasing amount of red mud. It was concluded that red mud can be used to partially replace cement in mortars and concrete for non-structural applications. Similarly, Senff et al. [8] studied the effect of red mud on the rheological behaviour and hardened state characteristics of cement mortars. The results show that the addition of red mud did not affect the hydration process, but when the content of red mud is higher than 20% (by weight of cement), the hydration of cement paste decreased. When increasing red mud levels, the compressive strength of samples decreased, and the water absorption increased. Kushwaha et al. [9] found that the use of red mud as an admixture up to 2% improved the compressive strength of SCC. When the red mud content was more than 2%, the compressive strength started to decrease. Similar results were found by Shetty et al. [10] that the maximum compressive strength was obtained for SCC with 2% red mud and 10% used foundry sand, then the strength decreased when the red mud content was over 2%. Another study by Shetty et al. [11] revealed that the SCC with 2% red mud and 10% iron ore tailings presented the highest compressive, tensile and flexural strengths. Shendure et al. [12] studied the influence of neutralized red mud on strength properties of SCC and indicated that SCC with 35% fly ash and 15% neutralized red mud achieved the highest compressive strength. Oliveira and Rossi [13] employed red mud in the production of coarse aggregates for concrete, and conducted a series of tests to determine the physical properties of aggregates with red mud and the hydraulic abrasion strength of concrete with red mud aggregates was evaluated. Their studies were motivated by the direct use of red mud to produce different types of new red mud coarse aggregate. They stated that the application of red mud in aggregate for concrete resistant to hydraulic abrasion is proved to be technically feasible. Liu and Poon [14,15] investigated the use of red mud as a viable alternative to fly ash in self-compacting mortar and concrete. In their studies, red mud reduced the flowability of mortar and concrete, however, an increase of red mud content enhanced the compressive and flexural strengths. They showed mixes containing red mud contents of 30% and 40% by weight of fly ash replacement had compressive strength 8–9% higher than the control at 56 and 90 days. They also reported that the SCC mixes containing red mud showed less drying shrinkage due to internal curing [14]. Though the variation in chemical composition between different RMs worldwide is high due to the different bauxites used and the different process parameters, they are having typical characteristics such as produced during the

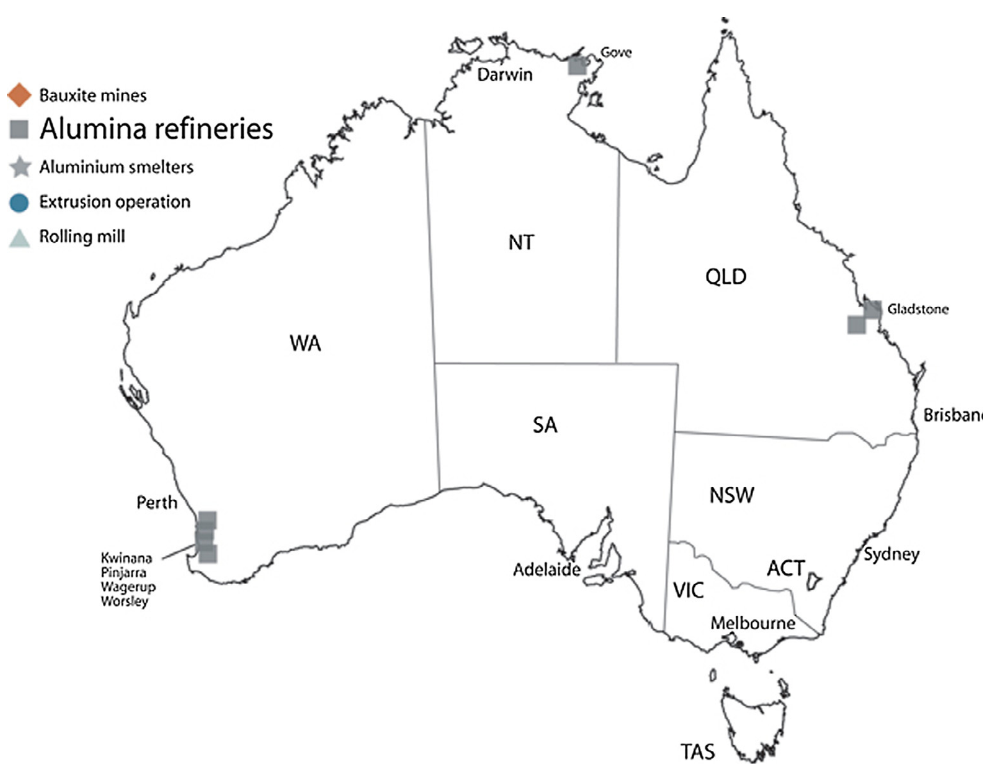

Fig. 2. Alumina refineries in Australia [4].