Experimental Investigation on bond Improvement between Rubber aggregates and Cement Matrix in Rubberized Concrete

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ABSTRACT

This study was designed experimentally to explore the significance of rubber surface treatment by chemical and nonchemical approaches. A total of 10% of treated rubber and 15% of metakaolin were used to replace fine aggregate and cement, respectively. Two surface treatment methods were applied, namely (1) a non-chemical approach by water soaking treatment with cement coating and (2) a chemical approach using sodium hydroxide (NaOH) solution soaking treatment. A comparable compressive strength was observed due to the improvement of the interfacial gap in the rubberized concrete. Results show that the compressive strength of rubber with water-cement coated (WCC) and NaOH treatments (NaOH) is 44.4 N/mm2 and 46.4 N/mm2, respectively. The study found that there was no significant difference in the mechanical strength of rubberized concrete using the two surface treatment methods. A similar behavior was also observed in the energy absorption capability of rubberized concrete, where the surface treatments did not significantly affect the property of treated rubberized concrete. Overall, the finding suggests that the combining method between rubber surface treatment and cement blended enhances the properties of rubberized concrete and has potential for concrete structural elements. Furthermore, the environmental assessment revealed a significant reduction in the embodied CO2 of rubberized concrete compared to 100% OPC concrete. However, the cost for rubberized concrete production was slightly higher than for non-rubberized concrete. Nevertheless, it was found that the surface treatment methods were easy and practical for application in the construction industry.

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INTRODUCTION

This paper promotes the development of sustainable construction for the industry.
It is noted that a significant amount of research has been conducted on the surface treatment of rubber particles in cement composites, but very limited studies have been performed on combining methods (two-stage approach). This combining method is expected to improve the bonding issues and the densification of the cement matrix of rubberized concrete. Several studies have explored the combined treatment approaches, which deal with various chemical treatments, in obtaining a better result in the adhesion properties of rubberized concrete. Despite the promising results of the chemical treatment on the development of rubberized concrete strength, this method has been scrutinized. Based on the existing studies, the main issue with using rubber particles as one of the constituents for cement composites is the weak bonding of rubber particles within the cement phases, which is associated with a large void/pore at the interfacial zone between the rubber particles and the cement matrix.
Thus, the objective of this investigation was to further bridge the surface modification of rubber particle knowledge gaps in improving the performance of rubberized concrete. Finally, the study also aimed to facilitate the selection of treatment methods and further extend the potential application of rubberized concrete in the construction industry.

METHODS AND MATERIALS

The concrete in this study incorporates metakaolin (MK) and treated rubber as partial cement and fine aggregate replacements, respectively. Ordinary Portland Cement (OPC) with strength class 42.5 N conforming to British Standards and metakaolin (MK) were used as cement binder. The aggregates used were crushed granite and natural river sand, with a nominal maximum size of 20 mm and 5 mm, respectively. The specific gravity for the coarse aggregate was 2.60 and 2.55 for the fine aggregate. Approximately 10% of crumb rubber with sizes between 1 mm and 4 mm was used as a fine aggregate replacement by volume. Two different surface treatments of the crumb rubber were used, namely (1) water soaking with cement coating and (2) sodium hydroxide solution soaking. The effects of treatments on the surface of crumb rubber particles were observed by scanning electron microscopy (SEM), as shown in Fig. 1. All samples were tested at the age of 28 days, with three specimens for each test. drop-weight impact test was carried out by dropping a hammer weighing 5 kg on a cube of concrete with a size of 100 mm.

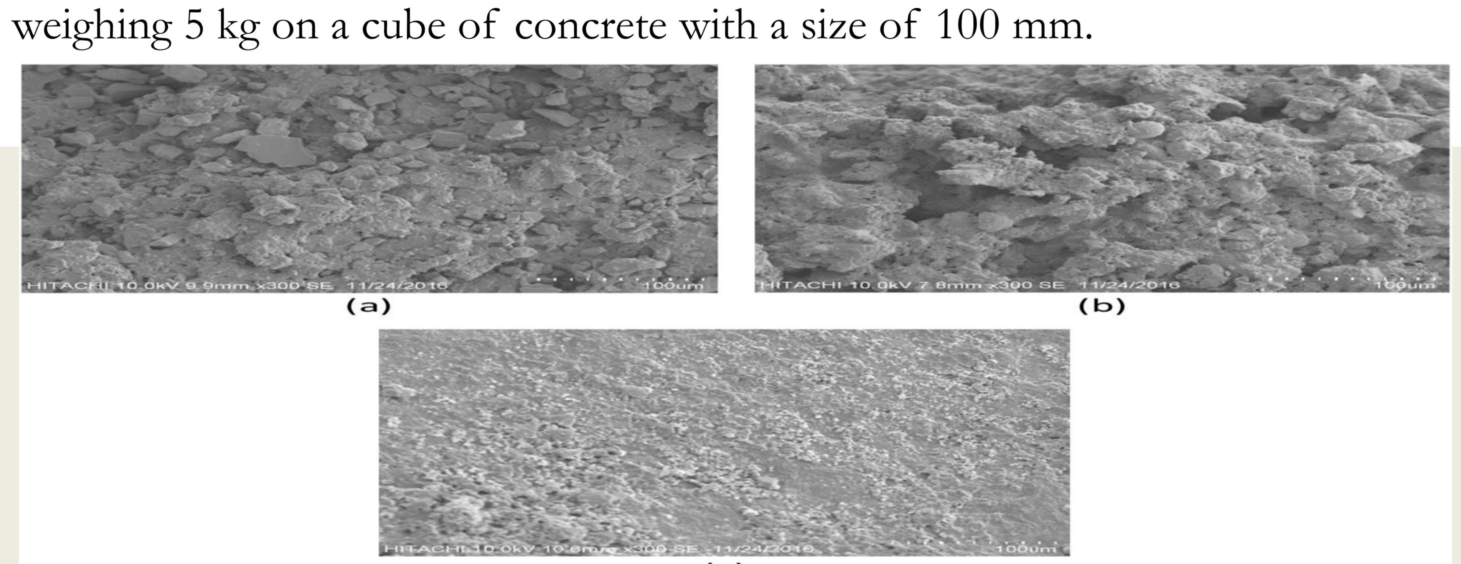

Fig 1. Label in 20pt Calibri. Fig. 3. Micrograph obtained by SEM of crumb rubber particles with different treatments; (a) untreated, (b) water-cement coated treatment and (c) NaOH solution treatment.

RESULTS

According to the SEM image in Fig. 2, the finding observed a denser microstructure of MK Binary concrete, which can be associated with the secondary hydration products of metakaolin. Fig. 2 shows that the presence of metakaolin enhances the compressive strength of concrete significantly compared to 100% OPC for concrete without rubber. It is well accepted that pozzolans, such as silica fume and metakaolin, improve the strength of concrete at an early age and over the long term. Despite the dense cement matrix, the increase in micropores in the firm cement matrix was observed in Fig. 2. The micropores with the smaller size pores (up to 10 μm) have little or no impact on the permeation mechanism. As shown in Fig. 2, a better adhesion interface is visible in the microstructure of rubberized concrete with both surface rubber treatments compared to the transition zone of the rubberized cement composites with non-modified surfaces of rubber particles. This could be associated with the rough surface condition of the rubber particle under WCC treatment. Despite the insignificant performance of tensile strength, a less defined crack failure was physically observed on the tensile splitting test of rubberized concrete regardless of the rubber treatment methods, as shown in Fig. 3. The rubberized concrete remained intact after failure, which could be associated with the property of rubber, which is ductile and resulted in the prevention of full disintegration of concrete.

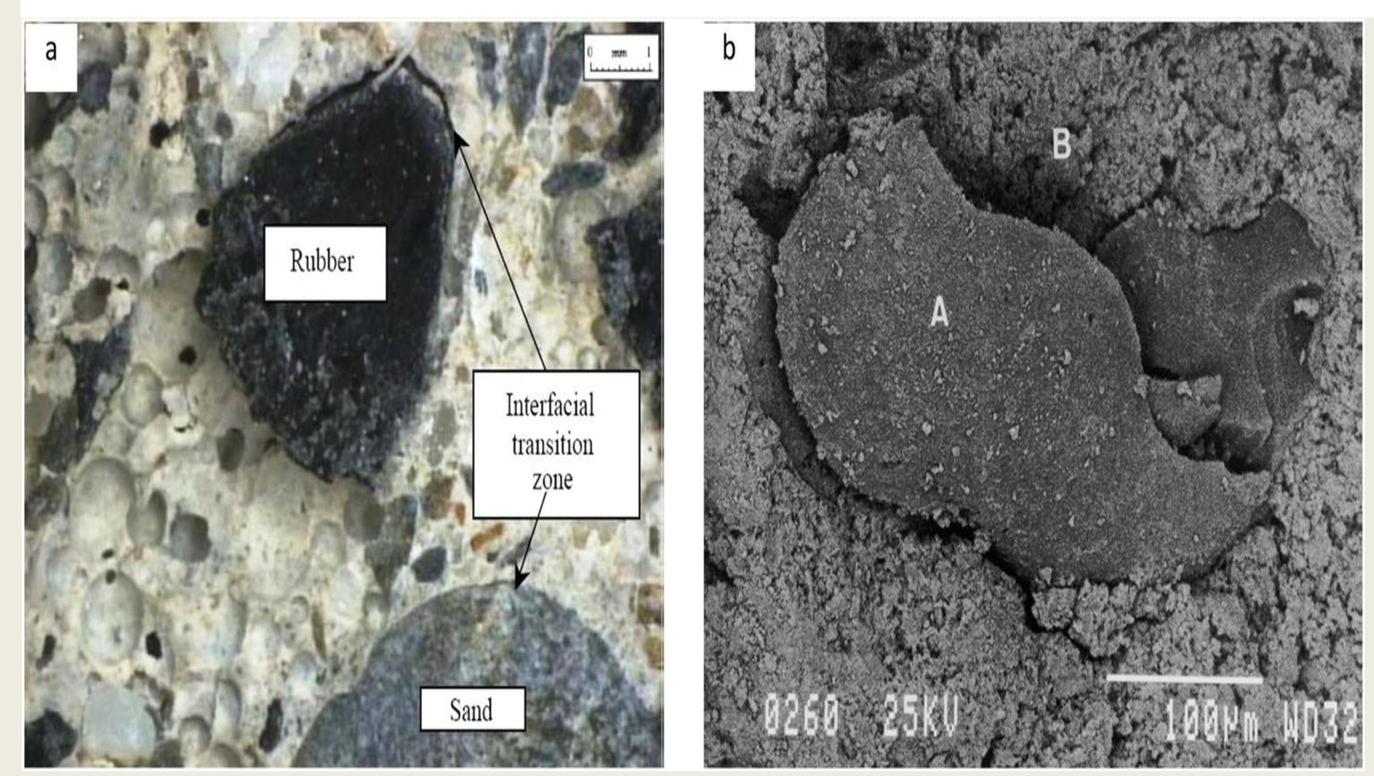

Fig. 2. (a) Interfacial transition zone between "cement paste and rubber aggregate" and between "cement paste and natural sand aggregate",(b) SEM image of fracture surface of cement test specimen with 10% by mass of as-received tire rubber. BEI image (A) Rubber particle; (B) Cement paste.

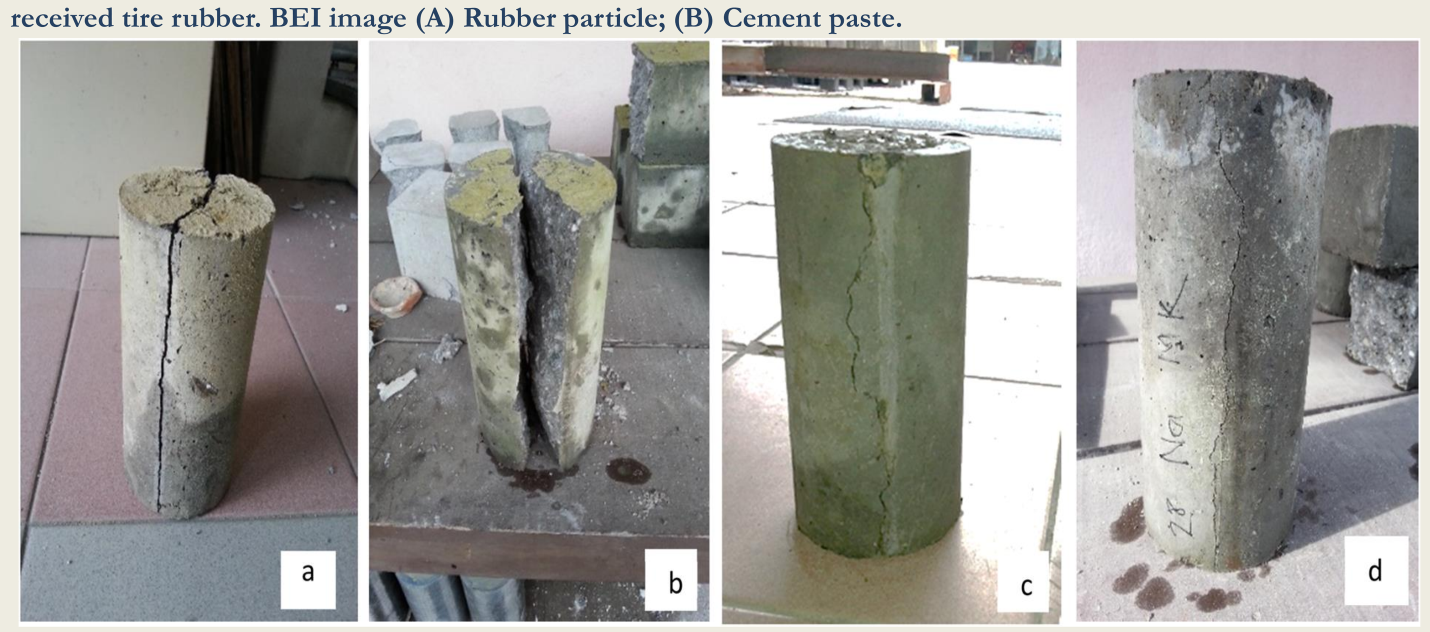

Fig. 3. Concrete failure of subjected to splitting tensile stress (a) 100% OPC, (b) MK Binary, (c) MK Binary-WCC and (d) MK Binary-NaOH.

DISCUSSION

In the case of the flexural test, the rubberized concrete failed immediately while the concrete remained intact. However, this contradicts the work done by Khatib [3] and Lewis et al. [2], which found that the rubberized concrete exhibited a ductile failure mode for the specimen with a rubber content of more than 10 %. This ductile behavior is due to the resistance of microcrack propagation at the interfacial zone between the rubber particle and the cement matrix.
The results also revealed that the water-cement coated treatment slightly improved both tensile splitting (6.8 %) and flexural strengths (4.8 %) of rubberized concretes compared to 100% OPC. Conversely, relatively small strength reductions are observed on both tensile splitting (10 %) and flexural strengths (2.3 %) of the rubberized concretes with NaOH rubber treatment, compared to 100% OPC. Similarly, Nasir et al. [1] observed a tensile strength loss in rubberized concrete, which uses sodium hydroxide (NaOH) for rubber treatment compared to concrete containing untreated rubber. This indicates the ability of the rubber in the concrete to bridge the crack, resulting in slightly higher tensile and flexural strengths even though the compressive strength is lower than the 100% OPC.

CONCLUSIONS

In this paper, the effects of surface rubber treatment with metakaolin as cement replacements on the mechanical properties and microstructure of the rubberized concrete were investigated. Despite the strength reduction of metakaolin-rubberized concrete, the obtained strength is more than 40 N/mm2, which is suitable for use in structural elements for the construction industry. The water-cement coated and NaOH treatments had a compressive strength of 44.4 N/mm2 and 46.4 N/mm2, respectively. The small differences were due to the bonding between the rubber and the surrounding concrete.
The energy absorption of rubberized concrete decreased by 19–23 % in comparison to concrete with no rubber. Although there was no significant effect by the treatment method on the energy absorption characteristic of rubberized concrete, the reduction in energy absorption of rubberized concrete with NaOH treatment could be due to the reduction of rubber particle mass, which resulted from a long immersion period.

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