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Rubberized Concrete Durability Against Abrasion

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Abstract. Durability performance of rubberized concrete against abrasion is presented in this paper. Surface depth loss was measured when abrasion load was constantly applied on concrete surface at each 500 interval rotation. Specimen with water-to cement ratio of 0.50 and 0.35 was prepared and tested at 28 days of curing age. In addition, 10% silica fume, SF was added to provide denser concrete and to understand its effectiveness against wear when added with crumb rubber. Results showed that crumb rubber shows good potential in providing abrasion resistance to concrete mix. However, in the case of rubberized concrete with silica fume, abrasion resistance was found to be slightly decreased with compressive strength more than 50N/mm^2 due to the lack of low elastic modulus of CR particles to accommodate with denser cement matrix.

1 Introduction

Abrasion is described as the behavior of the construction element against destructive influences due to scraping, rubbing, skidding or sliding of the object on the surface which leads to surface erosion. Concrete durability is influenced by several factors such as concrete compressive strength, surfacing finishing, aggregate properties, types of hardeners and curing type [1]. The effectiveness of crumb rubber to improve wear resistance tested by using surface abrasion test is discussed in this paper. Research done by Filipe Valadares et al.[2] on various rubber replacement ratio and size shows significant benefit in enhancing the abrasion resistance. Thus, an experimental study was conducted to see the behavior of crumb rubber with silica fume on abrasion wear resistance under different water to cement ratio. This testing was carried out to explore the possibilities of CR (without any surface treatment) to resists load from abrasion. The objective of the test was to evaluate the resistance of abrasion due to crumb rubber, different water-to-cement ratio and addition of silica fume as binder.

2 Mix Design and Specimen Preparation

In this concrete mix design, CR replacement was 10%, 15% and 20% of sand by volume. Silica fume, SF with 2200kg/m^3 density was added at 10% weight of Ordinary Portland Cement, OPC (density 3160kg/m^3). The mix design was divided into three main group of water to cement ratio, w/c as shown in Table 1. As for workability, ether-based polycarboxylate superplasticizer was added at 0.5%-0.7% of 5% maximum allowable dosage. Air content was controlled by using air-entrained

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agent (to increase air content) for mixing without SF and air-modifying agent (to reduce air content) for mixing with SF. In this study, air content for all mixes was set from 4% to 5%. Sea sand passing 5mm sieve with density of 2580 kg/m^3 and water absorption of 1.72% which was less than 3.5% as stated in JIS Standard was used as fine aggregate. Combination of 10mm and 20mm crushed stone was used as coarse aggregate with density of 2910kg/m^3. All aggregates were prepared under surface saturated dry condition. Meanwhile, for concrete specimen, diameter, D was 100 mm and height, H between 45 mm to 55 mm. As for example, three small specimens was cut from the origin concrete cylinder (Ø100 x 200 mm) as illustrated in Figure1. Surface for each small specimen should be flat and 90^0 to ensure uniform surface contact with rotating disc.

Table 1. Mix proportion of rubberized concrete.

Group	CR/(S+CR)	SF/C	w/c	Water	Cement	Silica Fume	Sand	Crumb Rubber	Coarse Aggregates		Chemical Admixture		
				W	C	SF	S	CR	G1	G2	Ether-based polycarboxylate superplasticizers	Air-entrained agent	Air-modifying agent
	(Vol %)	(%)					kg/m^3				%	%	%
Control	0	0	0.50	165	330	0	790	0	636	329	0.5	0.8	
10CR-0SF	10						711	35			0.5	0.8	
15CR-0SF	15						671	53			0.5	0.8	
Control	0	0	0.35	160	457	0	741	0	608	405	0.5	0.8	
10CR-0SF	10						667	34			0.5	0.8	
15CR-0SF	15						629	50			0.7	0.8	
20CR-0SF	20						594	67			0.7	0.7	
10CR-10SF	10	10	0.35	160	457	46	613	34	608	405	0.7		1.5
15CR-10SF	15						575	50			0.7		2.2
20CR-10SF	20						540	67			0.7		2.8

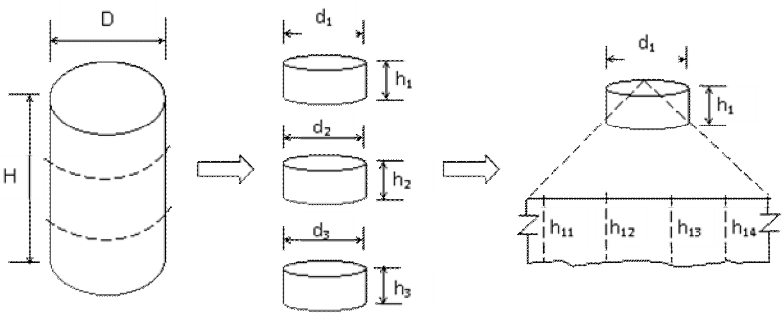

Figure 1. Specimen preparation.

3 Abrasion Test

Abrasion wear resistance of rubberized concrete was performed using Dorry abrasion testing machine as shown in Figure 2. It consists of a disc rotating shaft that connected to a motor to facilitate the removal of abrasive material which flow from above reservoir. Specimen was placed in the grip according to the size and then was tightened to ensure firm condition. Grip was then resting on disc rotating surface. Abrasive material used in this research was silica sand as shown in Figure 3. Silica sand was placed in the reservoir and flow down towards the rotating disc to provide friction on specimen surface. Initial data was recorded before each test and then disc was rotated and stop at each

500 rotation interval. At each interval, the change of weight and depth was recorded; where depth changes were calculated at the average of four points.

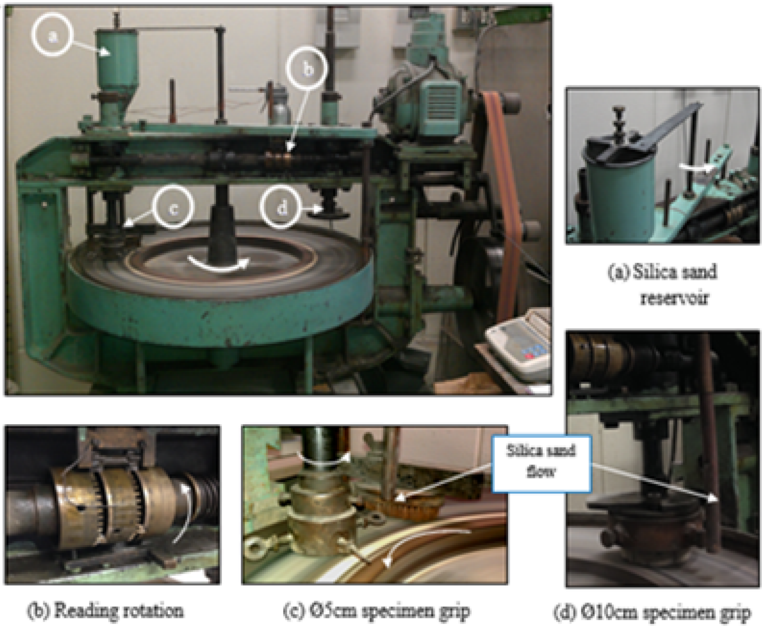

Figure 2. Specimen preparation.

Figure 3. Silica sand.

4 Results and Discussion

Figure 4 shows results of surface abrasion wear resistance with the presence of CR at 10%, 15% and 20%. A larger difference was observed between control mix (0CR-0SF) and mix with CR. At 4000 disc rotation the depth loss was 0.85mm compared to mixture with 10% CR addition which was 0.62mm; with 30% reduction difference. Resistance against surface abrasion wear was continuously improving with 15% and 20% CR replacement with depth loss of 0.58 and 0.52 respectively at 4000 disc rotation. Effect of CR added with SF on abrasion resistance is shown in Figure 5. At 4000 disc rotation, the depth loss of rubberized concrete with SF was reducing from 0.85mm for control mix to 0.67mm, 0.61mm and 0.51mm at every 10%, 15% and 20% CR addition as sand replacement.

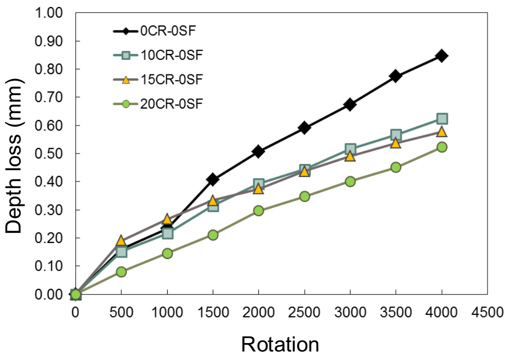

Figure 4. Depth loss of rubberized concrete without silica fume due to abrasion test (w/c = 0.35).

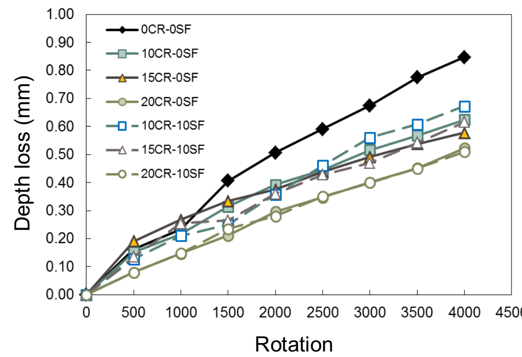

Figure 5. Depth loss of rubberized concrete with silica fume due to abrasion test (w/c = 0.35).

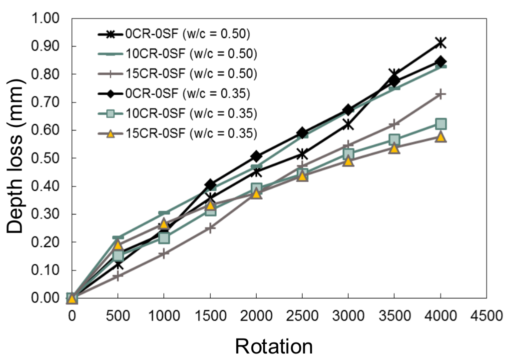

Figure 6. Depth loss of rubberized concrete without silica fume due to abrasion test (w/c=0.50 and 0.35).

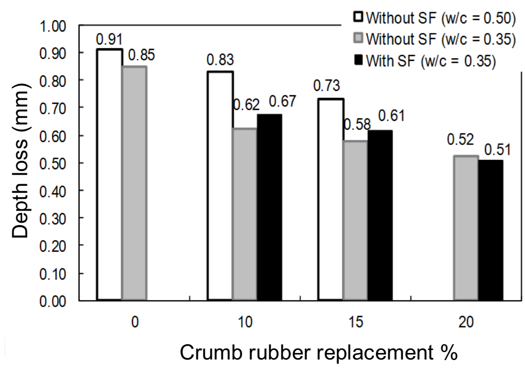

Figure 7. Depth loss of concrete surface at 4000 rotations.

Table 2. Data of abrasion wear resistance at 4000 disc rotations for all mixture.

Abrasion wear resistance at 400 rotation			
Mix		**Compressive strength, N/mm2**	**Depth loss, mm**
Without SF (w/c = 0.35)	0CR-0SF	68.8	0.85
	10CR-0SF	56.52	0.62
	15CR-0SF	50.46	0.58
	20CR-0SF	43.81	0.52
With SF (w/c = 0.35)	10CR-10SF	63.43	0.67
	15CR-10SF	58.31	0.61
	20CR-10SF	51.38	0.51
Without SF (w/c = 0.50)	0CR-0SF	46.18	0.91
	10CR-0SF	33.72	0.93
	15CR-0SF	31.89	0.73

However, this reduction was slightly larger than mixture without silica fume at 10% and 15% CR replacement and no difference can be concluded for 20% CR replacement. Effect of water-to-cement ratio of 0.35 and 0.50 on the depth loss was presented in Figure 6. As for mixture with w/c = 0.50 the same reduction pattern with w/c = 0.35 mixture was observed. The depth loss was 0.91mm for conventional concrete and 0.83mm and 0.73mm, respectively, for each 10% and 15% CR replacement. Due to the high w/c, the abrasion resistance was smaller compared to w/c = 0.35.

It was clearly seen that 10% crumb rubber addition as sand replacement provide good resistance than that control mix in all mixes According to Blessen Skariah Thomas et al., this improvement may due to the restriction of the surface grinding due to the CR position which was beyond the smooth surface and acted like a brush [4]. CR with 20% replacement gave much higher resistance against abrasion with 50% depth loss difference for both rubberized concrete with and without SF.

Looking back to the effect of SF, it was found that the inverse behavior was seen; where the abrasion resistance of rubberized concrete was much lower than that mixture without silica fume. Generally, it was stated that, higher compressive strength due to 10% SF addition gave better abrasion resistance as reported by Ghafoori and Diawara in 1999 [5]. But, when CR was added in mixture with higher compressive strength, the bonding between CR particles and cement matrix started to distress when subjected to friction force and may cause certain CR to jut out from the surface. In this research, this fundamental behavior was observed on specimen with compressive strength higher than 50 N/mm^2 (refer Table 2). This situation indicates that the compressive strength was an important factor affecting concrete abrasion resistance. When dealing with water-to-cement ratio effect, it was noted that higher w/c gave higher loss of surface depth due to small compressive strength value compared to mixture with low w/c. However, as discussed above, there was a limitation of abrasion resistance in relation with strength. This limitation was only applicable for CR without any treatment and this fundamental discovery may be further investigated. Abrasion resistance of high strength mixture could be improved by enhancing the bonding of the matrix by applying certain treatment on the rubber surface.

5 Conclusion

Several conclusions can be drawn from this research as follows, (i) The depth loss of concrete surface was decreasing with the increase of crumb rubber volume which indicates that abrasion resistance was improved with the presence of crumb rubber in the mix, (ii) Compressive strength is important factor affecting the abrasion resistance, where abrasion resistance is increase with increasing in compressive strength, and (iii) However in this research, it was found that strength was limited to 50 N/mm^2 due to the lack of crumb rubber elastic modulus to accommodate with high strength of cement paste.

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