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Expansion under water and drying shrinkage of rubberized concrete mixed with crumb rubber with different size

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ABSTRACT

In this study, the expansion under water and the drying shrinkage of rubberized concrete used in pre-cast lightweight panels are investigated. Two sizes of crumb rubber are used: No. 6 (passing sieve No. 6) and No. 26 (passing sieve No. 26). Four experiments are carried out: absorption, compression, expansion and shrinkage. The size of the crumb rubber affected the properties of crumb rubber in different ways. Rubberized concretes with large sized crumb rubber (6CR) appear to have higher absorption than those with small sized crumb rubber (26CR). In the case of strength, both crumb rubbers clearly cause the compressive strength to decrease. The 6CR also exhibits higher expansion and lower shrinkage than the 26CR. The crumb rubber's size and shape together with the non-polar effect are believed to play an important role on this phenomenon.

1. Introduction

The use of crumb rubber aggregate, derived from used automobile tires in concrete has become increasingly popular over the past twenty years. The reason comes from the accumulation of huge volumes of wasted tires which has become a major waste management problem. In general, the easiest way to decompose waste or used tire is by burning them, however, it causes enormous amount of smoke and pollution. Another conventional solution is to store them on empty land, which also creates several other problems such as fire hazard or insect and animal habitation.

Another solution is to grind them in forms of small particles (rubber crumb) and use in applications such as asphalt [1–4], sealants, rubber sheets or in cementitious materials like concrete [5–12]. In Thailand, crumb rubber can be manufactured in several grades and sizes from finer than 0.425–4.75 mm for several applications. When mixed with concrete, crumb rubber can be used to replace portions of either coarse or fine aggregate. Crumb rubber aggregates have a low specific gravity, the density of rubberized concrete usually decreases with increasing percentage weight replacement [1–8].

Although rubberized concrete has great potential in lightweight concrete applications, it does suffer from its major weakness which is its lack of strength. Several studies report compressive and tensile strength and modulus of elasticity for rubberized concrete decreases significantly with increased amounts of rubber aggregate replacement [5–10]. In general, rubberized concrete is not recommended for structures requiring a high load intensity. Its applications are best suited for purposes not requiring strength, such as, insulated panels, sound proofed wall panels, precast components, or road shoulder.

In our previous study, the sound and thermal properties of the moderate lightweight panel made with two different sizes of rubberized concrete had been investigated. The rubberized concrete panels were proofed to have better sound and thermal properties than plain concrete [11,12].

In this study, our objective is to further investigate the effect of crumb rubber content and size on long term drying shrinkage and expansion of the rubberized moderate lightweight concrete panel. In actual applications, these panels may experience both shrinkage (under drying condition) and expansion (under high moisture). For example, when manufacturing panels using a moist cure-expansion is a likely consequence. Or when a panel is used as an external wall and exposed to natural weathering, both drying shrinkage and expansion could also occur.

Unfortunately there is only a handful of existing research which investigated the shrinkage of rubberized concrete. The most recent appears to be Turatsinze et al. [13,14], they carried out free shrinkage test on rubberized concrete mixed with crumb rubber with MSA of about 4.0 mm. They found an increase in shrinkage of both 20% and 30% replacement rubberized concrete as compared to plain concrete. However, in their study, they did not investigate the effect of crumb rubber size had on shrinkage.

In the case of expansion, there is only one research study investigating this issue. A related study by Benazzouk et al. [15] investigated the effect of capillary water absorption–sorptivity of

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Table 1
Properties of crumb rubber and aggregates.

Categories	Crumb rubber			Coarse aggregate	Fine aggregate
	No. 6	No. 26	Nos. 6 + 20		
Average bulk specific gravity	0.96	0.62	0.77	2.68	2.43
Average bulk specific gravity (SSD)	0.97	0.62	0.78	2.69	2.47
Average apparent specific gravity	0.97	0.62	0.78	2.70	2.55
Average absorption (%)	0.92	1.05	0.95	0.25	2.04
Finess modulus	4.93	2.83	3.77	–	2.9

Table 2
Composition of rubber crumb.

No.	Composition	
1	Natural rubber	23.1%
2	Synthetic rubber	17.9%
3	Carbon black	28.0%
4	Steel	14.5%
5	Fabric, fillers, accelerators, antiozonants, etc.	16.5%
6	Ash content (%)	5.1%

Data provided by reclaiming plant.

concrete mixed with fine particle crumb rubber (MSA less than 1 mm) plus polypropylene fiber (about 20%). They found a decrease in absorption with a rubber content of up to about 50% replacement. However, in their study, the effect of large size crumb rubber particle on absorption and the expansion under water was not investigated.

Therefore a big gap of information is missing. Especially, when different sizes of crumb rubber are used, its effects on the absorption, shrinkage and expansion might cause the concrete to behave differently from one another.

2. Experimental procedure

2.1. Materials

Materials used in this study consisted of

- Cement Portland type I with SG of 3.15.
- *Fine aggregate:* River sand (Table 1).
- *Coarse aggregate:* Crush limestone with MSA of 3/8" (Table 1).
- *Crumb rubber:* Two sizes of crumb rubber No. 6 and No. 26 (passing through sieve No. 6 and No. 26, respectively), their properties are given in Tables 1 and 2 and Figs. 1 and 2.

2.2. Mix proportions

The mix proportion for the control concrete was set at 1.00:0.47:1.75:1.45 (Cement:Water:Fine:Coarse aggregate). In the case of crumb rubber concrete, the crumb rubbers were used to replace fine aggregate at 10%, 20% and 30% by volume (Table 3).

2.3. Casting and testing

In the mixing process, the concrete was dry-mixed using pan mixer for about 5 min, then added water and mixed for further 5 min. Then cast and compacted into different specimen sizes (according to the tests). Four tests were carried out: (1) Compression test (ASTM C39-01). (2) Density, absorption and voids (ASTM C642-97). (3) Expansion under water. (4) Drying shrinkage (ASTM C157/C157 M and ASTM C490).

To prepare the specimens for expansion and shrinkage test, concrete was cast in rigid steel mold with dimension of 75 × 75 × 285 mm (Fig. 3). Two gage studs (made of stainless steel type 316) were carefully embedded at both ends of the specimen in such a manner so as each of their principle axes coincide with the principle axes of the test specimens.

The specimens were removed from the mold after 24 h and submerged in the water at controlled temperature of 23 ± 0.5 °C for at least 30 min. After that, the specimens were taken out of the water and immediately towel dried the outer surfaces. Initial weight and length were measured and recorded.

For the expansion test, the specimens were submerged in water storage tanks as shown in Fig. 4. The tanks were sealed and placed in a controlled temperature (23 ± 0.5 °C) and humidity room (50 ± 4%). The specimens are left in the controlled room until the test dates (4, 7, 14, 28, 56 and 120 days).

For the shrinkage test, immediately after measuring weight and length, the specimens were placed on the storage racks for drying (Fig. 5) in a room with controlled temperature of 23 ± 0.5 °C and humidity of 50 ± 4% until the test dates (4, 7, 14, 28, 56 and 120 days).

3. Results and discussion

3.1. Density and absorption

Results on density and absorption are given in Fig. 6. The density of the concrete is found to decrease with the increasing percentage of crumb rubber replacement. This is due to the low specific gravity of crumb rubber (about 37% of the natural fine aggregate) and by partially replacing parts of the fine aggregate with the crumb rubber, the concrete density decreases. The effect of crumb rubber on density is more pronounced when smaller sized crumb rubber is used. At the same replacement percentage, concrete mixed with crumb rubber No. 26 (26CR) exhibits lower density than the one mixed with crumb rubber No. 6 (6CR).

The effect of crumb rubber on absorption depended on both crumb rubber content and size. For concrete mixed with crumb rubber No. 6 (6CR), the absorption is found to be higher than plain

Fig. 1. Crumb rubber Nos. 6 and 26.