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Experimental investigation on the floating of rubber particles of crumb rubber concrete

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HIGHLIGHTS

- The influence of three factors on the floating of rubber particles were investigated systematically.
- A new set of methods were developed including an Image Processing.
- Compressive strength, density and the distribution were used to evaluate the floating.
- As the slump surpasses a certain value, the floating develops sharply and abruptly.
- The floating is more evident with an increased vibrating compacted time.
- Sand ratios that are too high or too low can lead to significant floating.

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ABSTRACT

Crumb rubber concrete has been reported to possess many favorable qualities for engineering applications, such as higher ability of deformation, higher toughness, damping ratio and good performance of freeze-thaw, anti-cracking and resistance to water or chloride ion penetration. However, still there exists a major problem at this stage of applications of crumb rubber concrete, which is the floating of rubber particles when vibrating and compacting fresh Crumb rubber concrete. In order to investigate this "floating problem", a series of experiments were conducted which utilize Crumb rubber concrete cube compressive strength, density and rubber particle distribution inside Crumb rubber concrete specimens as measures of floating of rubber particles. 20 groups of prismatic specimens were casted, among which 11 groups were proportioned with different slump values by adjusting content of water and water-reducing agent, 4 groups were proportioned on basis of one of the 11 groups mentioned above with different sand ratio and vibrating time and the last 5 were controlled groups with no rubber particles. The results show that the floating of rubber particles is not apparent when the slump test value of concrete is low. However, if the slump value is high, and keeps increasing, the floating effect tends to be more apparently and when the slump surpasses a certain value (near 18 cm), the floating develops sharply and abruptly. The floating is more evident with an increased vibrating time. With the sand ratio at a certain value, the floating phenomenon is well-controlled. Sand ratios that are too high or too low can lead to significant floating.

1. Introduction

With the rapid development of transportation and automobile industry and the improvement of living standards, a large quantity of stockpiled scrap tires are generated each year, representing a tricky environment problem to be solved urgently. Traditional solutions are time-consuming and costly, so the treatment of scrap tires around the world tends to be recycling and reusing. The emergence and use of rubber aggregate concrete provides a viable alternative to the disposal of scrap-tires, as demonstrated [1,2]. Crumb rubber concrete, that is introducing rubber particles, a flexible material, into the ordinary concrete.

Theoretical and experimental investigations have been carried out for many years. Reports showed that the crumb rubber concrete possess a series of qualities for engineering applications, such as higher resistance to deformation, higher toughness and

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damping ratio. Eldin [3] reported that crumb rubber concrete mixtures exhibited lower compressive and splitting-tensile strength than did the ordinary concrete and these mixtures did not demonstrate brittle failure, but rather a ductile, plastic failure. Topcu [4] obtained the compressive stress–strain curves which showed that plastic energy capacities began to increase when the high elastic energy capacity of normal concrete was reduced by adding rubber. Toutanji [5] reported that crumb rubber concrete specimens were capable of undergoing post failure significant displacement, exhibiting a ductile mode of failure compared to the normal concrete. Besides, it is reported that rubber particles improves the durability of concrete in many ways, including resistance to freeze-thaw, crack and water/chloride ion penetration. Richardson and Coventry [6] examined the freeze-thaw performance of concrete with 0.6% rubber particles (by volume) which showed that the crumb rubber provided effective freeze-thaw protection and the compressive strength loss was significantly reduced. Turatsinze and Bonnet [7] carried out ring tests which showed that the crack network of crumb rubber concrete exhibits thin crack openings which are less detrimental and addition of 20% rubber is optimal. Ou and Zhu [8] also carried out work on crumb rubber concrete with regard to the freeze-thaw resistance of crumb rubber concrete and results showed concrete with addition of 10% rubber crumb by volume was more effective in resisting chloride penetration, which was similar with the conclusion drawn by Fan and Li [9].

Generally, compared with the ordinary concrete, the crumb rubber concrete has lots of good engineering properties and as an effective solution to the problem of scrap tires, it shows unique advantages in environmental protection. However, still there exists a major problem at this stage of applications of rubber aggregate concrete and that is the problem of floating of rubber particles which is the focus of this paper. The density of the rubber particles is lower than that of other materials in the concrete. Its density is only about 1/3 to 1/2 of the density of aggregates and the cement, causing rubber particles to float. Floating of rubber particles can cause the non-uniformity of mechanical properties of concrete such as non-uniform strength and modulus. Even worse, the floating of rubber is easy to cause the local flaw in concrete after hardening which is harmful to the durability of the concrete structure, shortening its using life. Disadvantages like this will affect the widely-use of the crumb rubber concrete in the engineering area.

In view of the phenomenon of rubber particles floating, a set of methods were developed, the basic idea of which is to use three different measures, cubic compressive strength, density and the distribution of rubber particles, to evaluate the floating and obtain the relationships between three selected factors and the floating of rubber particles with a view to the future engineering reference.

2. Experimentation

2.1. Materials

The rubber particles used in the investigation were 1–2 mm in size with an apparent density value of 1050 kg/m3 as shown in Fig. 1 and its sieve analysis results are showed in Fig. 2.

All mixtures are proportioned using the Ordinary Portland cement of Chinese Grade 42.5 produced in Tianjin of which the chemical composition is showed in Table 1, medium sand as fine aggregates with a 2588.3 kg/m3 apparent density and a 2.41 fitness modules of which the sieve analysis results are showed in Fig. 2, 0–20 mm crushed stone as coarse aggregates of a 5–20 mm size, apparent density of 2800 kg/m3 and a specific gravity of 2.8 of which the sieve analysis results are showed in Fig. 2. Water-reducing agent used here is the Naphthalene superplasticizer of which the water-reducing ratio is 25% as showed in Table 2.

Fig. 1. Rubber particles.

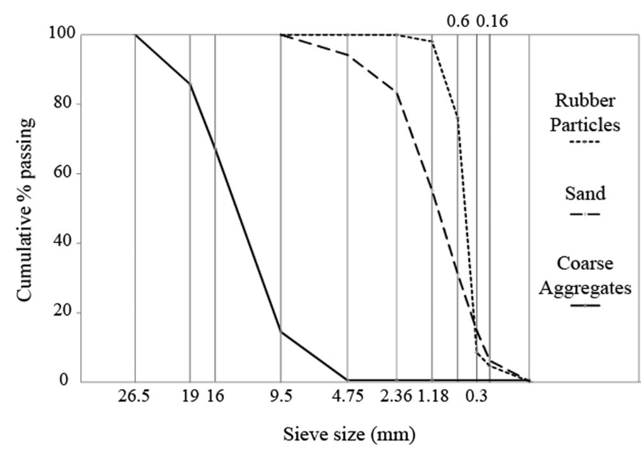

Fig. 2. Sieve Analysis.

2.2. Mixture design

To investigate the relationship between slump and the floating of rubber particles, 11 groups of prismatic specimens 100 × 100 × 300 mm (denoted as A-0, A-3, B-0 to B-4, and C-0 to C-3, as shown in Table 3) were proportioned to have different slump values. Table 3 summarizes the experimental design for the concrete mixes and presents different test results of slumps ranging from 2.5 to 22.1 cm obtained by reduction of water content and introducing water-reducing agent.

The water-cement ratio of all specimens from the 11 groups is 0.489 and their sand ratio is 33.3%. Typically, the rubber particles in CRC arranges from low 40 to high 100 kg/m3. This article takes a moderate value: 60 kg/m3. These specimens are specified by group A, B and C according to different water content which means that the water content of group A, B and C is 285 kg, 260 kg and 220 kg respectively. Number 0–4 stand for the content of water-reducing agent as shown in Table 3.

To investigate the influence of vibrating compacted time on the floating, groups D-3 and E-3 were designed on basis of group B-3. The vibrating time of D-3 and E-3 is 5 s and 15 s respectively. To investigate the influence of sand ratio, groups F-3 and G-3 were designed on basis of B-3. The specimen compaction follows the procedure specified in Chinese Standard GB50666-2011 "Code for