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GRANULATED WASTE TYRES IN CONCRETE PAVING BLOCK

Tung-Chai Ling[1] **and Hasanan Md Nor**[2]
Department of Geotechnics and Transportation, Universiti Teknologi Malaysia,
Malaysia, Skudai, 81300, Malaysia
E-mail: 1: tcling611@yahoo.com, 2: hasanan@fka.utm.my

ABSTRACT: This research studies the potential of using crumb rubber as a partial substitute for course sand in the production of concrete paving block. Laboratory trials were conducted to compare and investigate the effect of using three particle size of crumb rubber (1 - 3 mm), (3 - 5 mm) and combination of both. A series of tests were carried out to determine the properties of the blocks prepared with and without crumb rubber. The dry density, compressive strength and skid resistance were measured for laboratory prepared samples. It is believed that cement acting as a binder mixed with crumb rubber make concrete blocks more flexible and thus, provides softness to the surface. At the same time it also provides sufficient strength or minimum required strength (30 MPa) in accordance to MA20 for 60 mm thickness rectangular block to be used on pavement for vehicles of less than 3 tonnes gross weight.

Keywords: Crumb rubber; Concrete paving block; Skid resistance

1. Introduction

In developing countries, utilization of concrete blocks as paving material is widespread. Cement and aggregate, which are the most important constituents used in concrete block making, are also a vital material for the construction industry. This inevitably led to quarry of natural materials used for production of concrete block. Thus, indicate a growing concern for protecting the environment and a need to preserve natural resources (such as aggregate) by using alternative materials (recycled or waste tire materials). On the other hand, disposal of the waste tyres all around the world is increasing every year. This keeps on increasing every year with the number of vehicles, as do the future problems relating to the crucial environment issues (Epps, 1994). Accumulation of discarded waste tire has been a major concern because waste rubber is not easily biodegradable even after a long period of landfill treatment.

Existing or commercial concrete is characterized as a composite material with high compressive strength, moderate tensile strength and with a low toughness (Li *et al*., 2004). It is anticipated that an ideal concrete block for pavement construction should have high tensile strength and high toughness. Therefore, high strength and high toughness concrete has to be developed for block paving. For concrete, it is found that the higher the strength, the lower the toughness. It is difficult to develop high strength and high toughness concrete without modifications. Owing to the very high toughness of waste tires, it is expected that adding crumb rubber into concrete mixture can increase the toughness of concrete considerably (Toutanji, 1996; Siddique and Naik, 2004; Li *et al*., 2004). Laboratory tests have shown that the introduction of waste tire rubber considerably increase toughness, impact resistance, and plastic deformation of concrete, offering a great potential for it to be used in sound/crash barriers, retaining structures and pavement structures (Eldin *et al*., 1993; Khatib and Bayomy, 1999; Goulias and Ali, 1998).

Unfortunately, not much attention has been paid to the use of waste tires in Portland cement concrete mixtures, particularly for highway use. Limited work was done by researchers to investigate the potential use of rubber tires in concrete paving block mixtures.

In this work, an experimental study was conducted on the concrete block mixtures with and without crumb rubber and the basic engineering properties were investigated.

2. Experimental Work

2.1 Material Properties

Materials used in this study consist of ordinary Portland cement complying with MS 522. The natural aggregates used include natural river sand as the fine aggregate and crushed granite with nominal size less than 10 mm as the coarse aggregate. The weight ratio of course to fine aggregate of all paving blocks was kept to about 1 : 2 throughout the whole experimental works.

Crumb rubber is a fine material with the gradation close to that of the sand (Figure1) is produced by mechanical shredding. In this study, two particle sizes of crumb rubber were used: 1 – 3 mm and 3 – 5 mm as a partial substitute for sand in the production of concrete paving block.

Figure 1: Crumb rubber

2.2 Mixture Proportions

Two series of mixes were prepared using coarse and fine aggregate, cement, water and additive. The difference between the two series was the cement to aggregate and sand ratio. Where, (cement: aggregate: sand) 15 % : 30 % : 55 % and 15 % : 28.3 % : 56.6 % were used in series I and II, respectively.

The first series, three different categories: (a) 1 – 3 mm (b) 3 – 5 mm and (c) Combined (1) & (2) of crumb rubber were used to replace fine aggregate (sand) at equal amount of 10 % by weight. The second series, only (c) Combined (a) & (b) of crumb rubber was used to replace fine aggregate (sand) at equal amount of 10 %, 20 % and 30 % by volume. The mixed materials used were approximately 8.5 kg for each batch of three paving blocks samples.

2.3 Fabrication and Curing of Test Pavers

The paving blocks were fabricated in steel moulds with internal dimensions of 200 mm in length, 100 mm in width and 60 mm in depth as shown in Figure 2. The mix was poured into the mould in two layers of about equal depth. Compaction was applied manually using a hammer at each layer. The concrete blocks were then removed from the steel moulds one day after casting and cured in air at room temperature (Figure 3) for 7 and 28-day until tested.

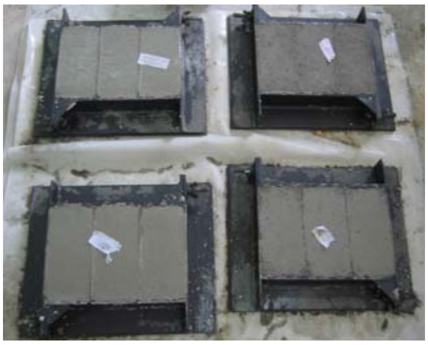

Figure 2: Fabrication of concrete paving block specimens

Figure 3: Air curing of paving block specimens concrete

2.4 Testing Program

A range of tests were carried out at structure and material laboratory, in Universiti Teknologi Malaysia to determine dry density, skid resistance and compressive strength at 7 and 28-day of the paving blocks specimens. The skid resistance of paving block was determined using a British Pendulum Skid Resistance Tester (Figure 4) and it was expressed as the measured British Pendulum Number (BPN) as specified by ASTM E303-93.

The compressive strength was determined using a compressive testing as shown in Figure 5. The load, increased at a rate of 0.30 kN/s, was applied to the nominal area of block specimen. Prior to the loading test, the block specimens were soft capped with two pieces of plywood. The compressive strength was calculated by dividing the failure load by the loading area of the block specimen.

Figure 4: Skid resistance test

Figure 5: Compressive strength test

3. Experimental Results and Discussions

3.1 Dry Density

Results in Figure 6 indicated that dry density decreased to as low as about 2.47 g/cm^3 when 10 % of total sand weight was replacement by rubber. Because of low specific gravity of rubber particles, unit weight of mixtures containing rubber decreases with the increases in the percentage of rubber content. Moreover, increase in rubber content increases the air content, which in turn reduces the unit weight of the mixtures. Figure 7 shows the dry density of the concrete blocks ranged from 2.51 to 2.65 g/cm^3 depending on the replacement of rubber content in the mixture. At 30 % rubber content, the dry density diminished to about 95 % of the normal concrete. However, the decrease in dry density of rubber is negligible when rubber content is lower than 10 – 20 % of the total aggregate volume (Khatib and Bayomy, 1999).

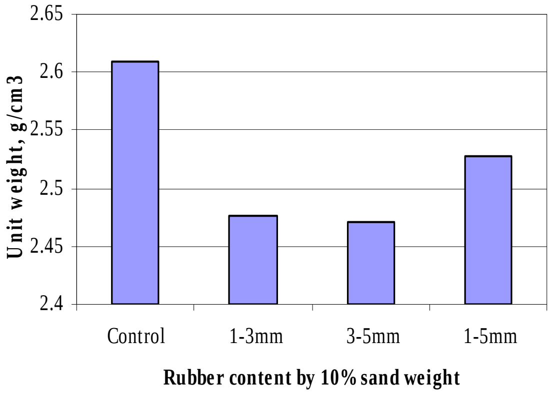

Figure 6: Dry density of series I paving blocks

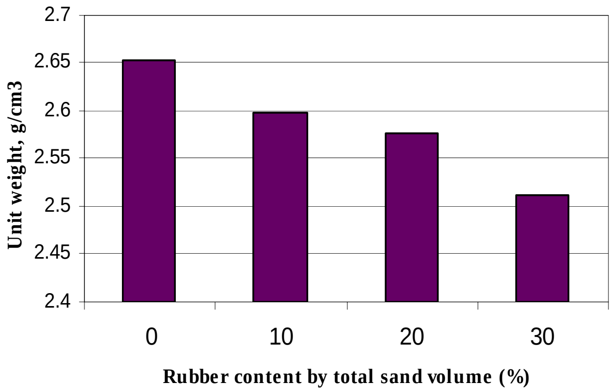

Figure 7: Dry density of series II paving blocks

3.2 Compressive Strength

The results of series I and II are summarized in Figure 8 and 9, respectively. Each presented value is an average of three samples measurement. The results presented in Figure 8 indicated that, the initial 3 and 7-day compressive strength of three different mix crumb sizes were about 9.3 and 17.2 MPa, respectively. Comparing the 28-day compressive strength of three mix crumb size crumb rubber mixture, the paving blocks mixed with crumb size (c) (26.7 MPa) seemed to perform better than those mixed with single crumb size. This was perhaps due to the better grading of the combined rubber which allowed better compaction and higher density.

The results presented in Figure 9 shows a systematic reduction in compressive strength with the increase in rubber content for the paving blocks. Two grades of paving block having initial 28-day compressive strength of about 26 and 32 MPa were achieved for 20 % and 10 % replacement of sand with crumb rubber by volume, respectively. For another grade, compressive strength of about 42 MPa decreased to almost 20 MPa when 30% replacement of sand volume by crumb rubber was made. This indicated about 52% reduction in the 28-day strength. However, for the 7-day strength, the rate of strength reduction was more or less that of 28-day strength.

The reason for the strength reduction could be attributed both to a reduction of quantity of the solid load carrying material and lack of adhesion at the boundaries of the rubber aggregate, soft rubber particles may behave as voids in the concrete matrix.

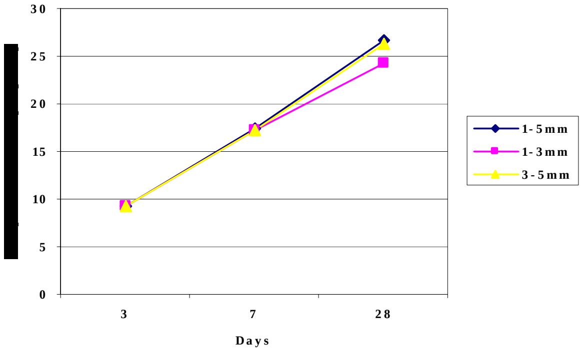

Figure 8: Compressive strength of series I paving blocks

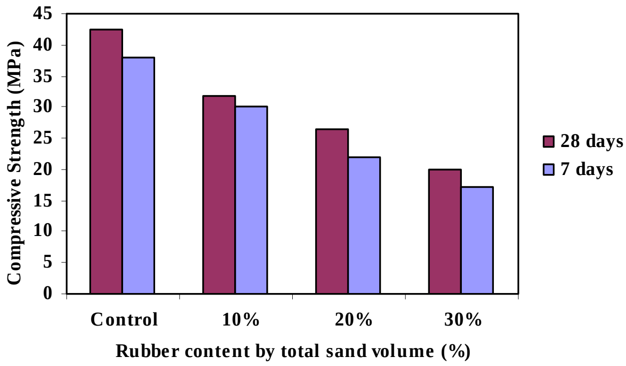

Figure 9: Compressive strength of series II paving blocks

3.3 Skid Resistance

Skid resistance was measured in accordance to ASTM E3030-93, four swings of the pendulum were made for each test surface paving block. In general, results (Figure 10) indicated that the skid resistance was slightly higher for the crumb rubber paving block than the control paving blocks. It was mainly due to the highly elastic properties and surface texture of rubber to create more friction as the pendulum passed across it.

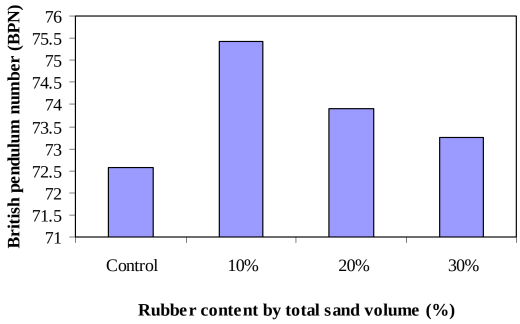

Figure 10: Skid resistance of crumb rubber paving blocks

4. Conclusions

1. Compressive strength of concrete paving block is affected differently depending on the size and content of crumb rubber. Preliminary test results indicated that the compressive strength of three mix crumb size crumb rubber mixture: (a) 1 – 3 mm, (b) 3 – 5 mm and (c) 1 – 5 mm were comparable at 3 and 7-day. Comparing the 28-day compressive strength, (c) 1 – 5 mm seemed to perform better.
2. For the effect of crumb rubber content, the test results shown that there was a systematic reduction in the compressive and dry density with the increase in rubber content from 0 % to 30 %.
3. Concrete paving block containing rubber particles seem to provide better skid resistance.

4. It is possible to fabricate block containing rubber up to 30 % by sand volume using chemical and mineral admixtures, which gives better bonding characteristics to rubber and significantly improves the performance of crumb rubber concrete paving block.

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