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A Review of Double Layer Rubberized Concrete Paving Blocks

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Abstract— The objective of this paper is to presents and study a review of waste material i.e. rubber granules as a partial aggregate replacement in different percentage and size of rubber granules; and different thickness of block facing layer. Tyre is designed to be very high in toughness and owing to its technological and economical advantages, both strength and toughness of concrete can be increased. Incorporation of rubber granules as aggregates in concrete mixture not only improves the toughness of concrete, but also improves the acoustics element by the increase of sound absorption level. Previous studies on low-noise concrete paving blocks are very limited. Physical, chemical and mechanical test will be carried out to evaluate properties of double layer rubberized concrete paving blocks (DL-RCPBs) with 10, 20, 30, and 40% replacements of RG by weight of aggregate and the blocks aredesigned with 10 mm, 20 mm, 30 mm and 40 mm of facing layer thickness. The sound absorption level and noise reduction coefficient of DL-RCPBs with different thickness of facing layer will be studied.

Index Terms— Waste tyre rubber; Rubber granule; Rubberized concrete; Concrete Paving Block

I INTRODUCTION

In various countries, the concrete block pavement (CBP) becomes an attractive engineering and economical alternative to the both flexible and rigid pavement. The CBP has been developed in early fifties in the Netherlands whereby its potential usage started to be known worldwide [1]. In general, CBP is suitable for aircraft hard standing, car parks, cycle paths, domestic drives, factory floors, industrial pavements, paving for exceptional loads, pedestrian areas, roads for low speed traffic, medium speed traffic and service areas. CBP provides a durable surface that is comfortable to walk on, pleasant to look at, easy to maintain and ready for immediate use. Furthermore, CBP is used in the areas subjected to large point loads due to its durability against huge loading. The CBP is also used extensively for traffic calming where the intention is to improve safety by reducing traffic speeds. Althought CBP offers many advantages, however this type of pavement is not suitable to be used for high speed traffic. This is due to generation of tyre-road interaction noise which contributes to the increased of traffic noise and disturbants for residents living near roads and highways. Implementation of noise barrier would be costly when compared to the cost of using low-noise pavement. In order to employ the existing advantages of CBP in trems of strength and durability, this study is conducted to add another advantage which is the development of low-noise CBP. According to previous researches, rubberized concrete shows positive results on the sound absorption factors and was suggested to be used as sound insulator. In this study, the purpose of replacing natural aggregate with rubber granules (RG) is to increase concrete's flexibility, elasticity, and capacity to absorb sound. It is believed that concrete acting as a binder mixed with rubber aggregate can make blocks more flexible and provide softness to block surface. The increase of demand to develop new technology of concrete materials that leads to the application of sustainable and green technology. Blending waste tyre rubber in concrete mixture is one of the best ways to reuse this type of waste and has become a common recommendation in concrete technology research.

II WASTE TYRE RUBBER CLASSIFICATION

According to Ganjian et al. [2] and Siddique and Naik [3], generally, three broad categories of waste tyre rubber have been considered in most of the researches which are shredded or chipped tyres, ground and crumb rubber. The processed used tyres also involve two stages of magnetic separation and screening. Shredded or chipped tyres were used as coarse aggregate replacement. Irregular shape of torn tyre shred with 300-460 mm long and 100-230 mm wide is produced in the first shredding stage. In the second stage tyre shreds were tears apart by passing between rotating corrugated steel drums and produce tyre withdimension 100-150 mm. By the end of this stage, particles size of about with 13-76 mm in dimensions is produced and known as ‘‘shredded particles”. Rubber granule is produced by extracting larger tyre particles into smaller particles through granular process. Tyre particles were shears apart using revolving steel plates. Different sizes of rubber particles may be produced depending on the kind of mills used and the temperature generated in this stage. The size of particle produced varies from 4.75 to less than 0.075 mm and normally used to replace sand. Various size fractions of rubber are recovered in more complex procedures. In micro-milling process, the particles size (crumb rubber) produced are in the range of 0.075-0.475 mm. For crumb rubber less than 0.075 mm may be used to replace binder or cement depending on the equipment for size reduction.

III WASTE TYRE RUBBER PROPERTIES

Rubber granules (RG) used in this study was obtained from continuous shredding process of waste tyre. The particle size of RG ranges from 1-4 mm and 5-8 mm (see fig. 1). The physical and chemical properties of waste tyre rubber from previous studies are shown in Table 1 and Table 2. The physical and chemical properties in Table 1 and 2 varies may be due to the rubber origin, as well as to the tyre type, namely car, truck or motorcycle tyres.

Figure 1 Waste tyre rubber (Rubber Granules)

TABLE 1
Physical Properties of Waste Tyre Rubber

Researcher	Specific Gravity	Fineness Modulus
Khatib & Bayomy [9]	1.18 (Tyre chips) 1.12 (Crumb rubber)	-
Topcu [6]	0.65	1.58 - 1.91
Sukontasukkul [4]	0.77-0.96	3.77-4.93
Khaloo *et al.* [8]	1.16	-

TABLE 2
Chemical Composition of Waste Tyre Rubber

Composition	Percentage (%)		
Reference	[5]	[8]	[3]
Natural rubber	23.1	-	14
Synthetic rubber	17.9	-	27
Carbon black	28	29	28
Steel	14.5	-	14-15
Fabric, fillers, accelerators, antizionants, etc	16.5	-	16-17
Ash content	5.1	5	-
Plasticizer	-	10	-
Polymer	-	50	-

IV RUBBERIZED CONCRETE

Eldin and Senouci [7] studied the variation in strength of portland-cement concrete incorporating with waste tyre. Aggregates (fine or coarse) were partially replaced with rubber aggregate by the increments of 25 percent by volume. It was observed that higher reduction of compressive strength (85%) and tensile strength (50%) of concrete with coarse rubber aggregate, whilst smaller reduction of compressive strength (50%) when sand was replaced by crumb rubber. Specimen tested does not exhibit brittle failure under compression and split tension. It shows that the rubberized concrete able to absorb higher capacity of plastic energy for both compression and tension loading. Khaloo et al [8] include two type of scrap tyre in their study which consist of crumb rubber and coarse tyre chips with maximum size of 4.75 and 20 mm respectively.

Toutanji [10] demonstrated that by incorporating rubber tyre chips in concrete mixture results in reduction of compressive and flexural strength. It was indicated that the reduction of compressive strength is doubled compare to the flexural strength of rubberized concrete. However, it is found that the higher toughness of concrete incorporating with rubber tyre chips.

Li et al. [5] investigated the effect of using different form of waste tyre rubber on hardened concrete characteristics. In this study, waste tyre rubber chips and fibers were used to evaluate the characteristics of waste tyre modified concrete.

As a result, the waste tyre rubber fibers perform better compare to waste tire chips. Rubberized concrete is found to have higher post-crack toughness compare to normal concrete without waste tyre.

Ling [11] reported that the density of rubberized concrete blocks decreased with the increased of the rubber content. The density was reduced by about 8% when 50% of the total sand was replaced by rubber, irrespective of the w/c ratio. This is mainly attributed to the low specific gravity of rubber particles as compared to natural river sand. Similar finding were also reported by Sukontasukkul and Chaikaew [12]. Flocculation of the rubber particles during concrete mixing creates large voids inside the block and leads to a higher porosity. Siddique and Naik [3] mentioned that the non-polar nature of rubber particles may tend to entrap air if their rough surfaces increase, which in turn increases the air content and reduces the density of the concrete mixtures.

Sukontasukkul and Chaikaew [12] and Ling and Nor [13] reported that the rubberized concrete block exhibit better skid resistance as compared to control block (Portland concrete cement block). This is mainly due to the higher elastic properties of rubber which allow block surface to deform more and create more friction. Sukontasukkul [4] claimed that crumb rubber concrete exhibits superior sound properties than normal concrete as measured by the increase in sound absorption coefficient and noise reduction coefficient (NRC). Owing to the advantages of the lower density of crumb rubber concrete, it seems that this type of concrete is suitable to be applied as sound insulator especially for highway construction.

V ONGOING STUDIES

The authors of this paper are conducting research on engineering and sound absorption properties of double layer rubberized concrete paving blocks (DL-RCPBs) (fig. 2) incorporating with RG as partial replacement of aggregates (fine and coarse). Rubber granules were produced by Yong Fong Rubber Industries, Malaysia. The experimental work includes the properties of hardened concrete containing RG and sound absorption level of DL-RCPBs with 100 x 200 x 80 mm in dimension. The concrete mixes containing 10%, 20%, 30% and 40% of RG as substitution for fine and coarse aggregates and water/cement ratio of 0.47. Sound absorption coefficient (α) and noise reduction coefficient (NRC) of DL-RCPBs with 10 mm, 20 mm, 30 mm and 40 mm thickness of Layer 1 will be measured. For Layer 1, the coarse aggregate will be replaced with 5-8 mm RG, whereas 1-4 mm RG will be used to replace fine aggregate in Layer 2. In order to maximize the sound absorption especially tyre-road interaction noise, coarser RG is used on the facing layer (Layer 1) of the DL-RCPBs. This experimental work is still ongoing, and is expected to be completed by the end of August 2014.

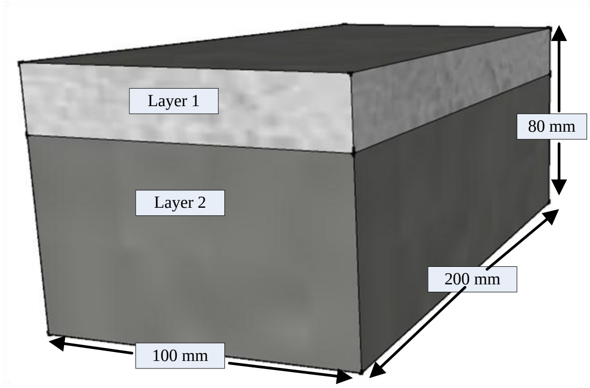

Figure 2 Double Layer Rubberized Concrete Paving Block (DL-RCPBs)

VI EXPERIMENTAL PROGRAM

A Hardened Concrete Characteristics

The test of hardened concrete can be classified into two tests which are destructive and non-destructive test. In this study, destructive test will cover compressive strength test, flexural strength test and tensile splitting strength. Non-destructive test will cover density, porosity, water absorption, weight loss and skid resistance.

B Field Emission Scanning Electron Microscopy

The morphology of RG and rubberized concrete will also be explored. Field emission scanning electron microscopy (FESEM) is an instrument designed primarily for studying the surface of solids at high magnification. Information about the sample including external morphology (texture), chemical composition, crystalline structure and orientation of materials making up the sample will be determine using FESEM (fig. 3).

Figure 3 Field Emission Scanning Electron Microscopy (FESEM)

C Thermogravimetry Analysis (TGA/DTA)

The amount and rate of change in the weight of a material as a function of temperature or time in a controlled atmosphere will be determined by Thermogravimetry Analysis (TGA) as shown in fig. 4. The composition of materials and prediction of thermal stability of temperature up to 1000 °C will be analyzed. Characterization of materials that exhibit weight loss or gain due to decomposition, oxidation, or dehydration can be developed in TGA.

Figure 4 Thermogravimetry Analysis (TGA/DTA)

D X-ray Fluorescence (XRF)

The chemical compositions of the RG and rubberized concrete were determined by using XRF, which is generally used to identify the elements or components present in a sample by irradiating the test sample with monochromatic X-rays. A Rigaku RIX3000 wavelength XRF will be used to distinguish the samples (fig. 5).

Figure 5 X-Ray Fluorescence (XRF)

E X-ray Fluorescence (XRF)

Fourier Transform Infra-Red (FTIR) as shown in fig. 6 is a widely used qualitative technique to characterize raw materials. The FTIR analysis is carried out using the potassium bromide (KBr) pellet method (1 mg sample per 100 mg KBr) on a spectrometer, with 32 scans per sample collected from 4000 to 650 cm^{-1} at 32 cm^{-1} resolution.

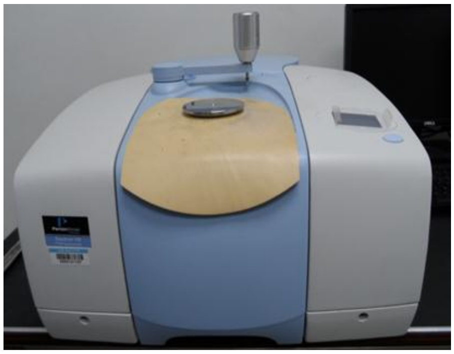

Figure 6 Fourier Transform Infra-Red (FTIR)

F Sound Absorption

The acoustic measurement is limited to the sound absorption coefficient. The method used to measure the sound absorption coefficient is described in ASTM E1050 [14]. Impedance tube as shown in fig. 7 will be used to measure the sound absorption coefficient of double layer RCPB. Sound absorption coefficient is determined for frequencies from 60 Hz to 1600 Hz.

Figure 7 Impedance Tube

VII CONCLUSION

Different replacement percentage of rubber granules at 0%, 10%, 20%, 30% and 40% will be obtained to determine the optimum level of rubber granules in concrete mixes. Microstructure analysis covers FESEM, TGA/DTA, FTIR and XRF analysis will be related to the ability of double layer RCPBs to absorb sound. The highest sound absorption level of double layer RCPBs for different thickness of layer will also be evaluated.

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REFERENCES

[1] A. A. Van der. Vlist, "The development of CBP in Netherlands", *First International Conference on Concrete Block Paving*, pp. 14–22,1980.

[2] E. Ganjian, M. Khorami, A.A. Maghsoudi, "Scrap-

tyre-rubber replacement for aggregate and filler in concrete", *Construction and Building Materials*, vol. 2, no. 5, 1828-1836, 2009.
[3] R. Siddique, and T. R. Naik, "Properties of Concrete Containing Scrap-Tire Rubber – An Overview", *Waste Management*, vol. 24, 563–569, 2004.
[4] P. Sukontasukkul, "Use of crumb rubber to improve thermal and sound properties of pre-cast concrete panel", *Construction and Building Materials*, vol. 23, 1084–1092, 2009.
[5] G. Li, M. A. Stubblefield, G. Garrick, J. Eggers, C. Abadie and B. Huang, "Development of waste tire modified concrete", *Cement and Concrete Research*, vol. 34, 2283–2289, 2004.
[6] I. B. Topcu, "The properties of rubberized concrete", *Cement and Concrete Research*, vol. 25, no. 2, 304–310, 1995.
[7] N. N. Eldin and A. B. Senouci, "Rubber-Tire Particles as Concrete Aggregate", *Journal of Materials in Civil Engineering*, vol. 5, no. 4, 478–496, 1994.
[8] A. R. Khaloo, M. Dehestani and P. Rahmatabadi, "Mechanical properties of concrete containing a high volume of tire–rubber particles", *Waste Management*, vol. 28, no. 12, 2472–2482, 2008.
[9] Z. K. Khatib and F. M. Bayomy, "Rubberized portland cement concrete", *Journal of Materials in Civil Engineering*, vol. 11, no. 3, 206–213, 1999.
[10] H. A. Toutanji, "The Use of Rubber Tires Particles in Concrete to Replace Mineral Aggregates", *Cement and Concrete Composites*, vol. 18, 135–139, 1996.
[11] T. C. Ling, "Prediction of density and compressive strength for rubberized concrete blocks", *Construction and Building Materials*, vol. 25, 4303–4306, 2011.
[12] P. Sukontasukkul and C. Chaikaew, "Properties of concrete pedestrian block mixed with crumb rubber", *Construction and Building Materials*, vol. 20, no. 7, 450–457, 2006.
[13] T. C. Ling and H. Nor, (2006). Granulated Waste Tyres in Concrete Paving. *Engineering, 6th Asia-pacific Structural Engineering and Construction Conference*, pp. 65–70, Kuala Lumpur, 2006.
[14] American Society of Testing and Materials, "*Standard Testing Impedance and Absorption of Acoustical Materials Using a Tube, Two Microphones and a Digital Frequency Analysis System"*, United States: ASTM E1050, 2010.

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