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Effect of Using Waste Tyre Rubber on the Properties of Double Layer Rubberized Concrete Paving Blocks

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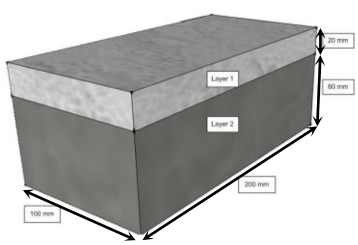
Graphical abstract



Abstract

This paper presents a study on the investigation of waste tyre rubber (rubber granule) as aggregate in the production of concrete paving block (CPB) with double layers. A series of tests were carried out to determine the properties of double layer rubberized concrete paving blocks (DL-RCPB). In this study, there are four series of concrete mix with 10 %, 20 %, 30 % and 40 % of waste tyre rubber replacement level. The dimension of CPB was 200 mm x 100 mm x 80 mm with 20 mm thickness of facing layer. The results showed that the percentage of waste tyre rubber content for DL-RCPB affects the density, porosity and compressive strength. The control concrete paving block (CCPB) and DL-RCPB (10 %) achieve the minimum strength requirement of 45 MPa. The density of DL-RCPB (40 %) recorded reduce 24 % as compared to CCPB. At 28 days, the percentage of porosity increased up to 55 % when 40 % of aggregate were replaced with rubber granule. The skid resistance of concrete block increased by 7 % with the incorporation of rubber granule particle size of 1 – 4 mm and 5 – 8 mm up to 40 % as the replacement of fine aggregate and coarse aggregate, respectively.

Keywords: Double layer, concrete**,** paving**,** block, rubber granule

■1.0 INTRODUCTION

The awareness to reuse or recycle waste materials has been implemented in construction industry. Sustainable development of concrete by utilizing waste to replace natural resources generates positive impact to the nature especially for non-biodegradable waste such as waste tyre rubber [1]. Waste tyre rubber was categorized as non-biodegradable waste because it was tyre was desgn to have high durability to weathering and heat. Hence, it offers a lot of potential to be recycled or reused [2]. Incorporation of waste tyre rubber in concrete blocks was one of the sustainable efforts in order to reduce this type of waste. The use of recycled aggregates in concrete paving block (CPB) production has been successfully implemented and is gaining wider acceptance. Poon and Chan [3,4] have done research on using recycled concrete aggregate and crushed clay bricks in CPB. The reduction in terms of density and compressive strength of CPB were obtained. The water absorption of paving blocks increased with the decreased of density. Soutsos *et al.* produced concrete paving blocks with recycled demolition aggregate from precast product [5]. The results showed strength losses and reduced density, depending on the mix. Besides it is also reported that utilising recycle demolished aggregate (concrete-derived and masonry-derived) increased the water absorption. Ling *et al.* [6-7] discover that the incorporation of waste tyre rubber reduced the density and compressive strength of concrete paving blocks.

This study investigated the effects of using waste tyre rubber as aggregate in production of double layer concrete paving blocks and the properties of these paving blocks with different thickness of facing layer. The result for density, porosity, compressive strength and skid resistance can be used as early indicator to improve this new design of CPB. Therefore, this study will contribute a significant impact for future investigation in this area of studies.

■2.0 EXPERIMENTAL

2.1 Material Properties

In this study, ordinary Portland cement (TASEK Cement) Type I complying with ASTM C150 [8] was used in the production of concrete paving block with minimum strength of 45MPa. 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. Rubber granule was produced from waste tyre rubber (Figure 1) which produced by mechanical shredding. In this study, two particle sizes of crumb rubber were used: 1 – 4 mm and 5 – 8 mm as a partial substitute for fine and coarse aggregate in the production of concrete paving block. Rubber granule was composed of 48 % styrene-butadience rubber (SBR), 47 % carbon black, 1.9 % extender oil, 1.1 % zinc oxide, 0.8 %, sulfur, 0.7 % accelerator and 0.5 % strearic acid [9].

Figure 1 Rubber granule

2.2 Mix Proportion

Two series of concrete mixes were prepared using ordinary Portland cement, coarse and fine aggregate, water, and admixture (0.3% SP). Mix proportion of cement: aggregate: sand is 1: 1.7: 1.5. Two different size of rubber granule was used as substitute for natural aggregate. The mix proportion of DL-RCPBs was summarized in Table 1. In the series I (Layer 1) concrete mix, 5 - 8 mm rubber granules were used to replace the coarse aggregate, whereas 1 - 4 mm rubber granules replaced the fine aggregates in the series II (Layer 2) mix. The optimum water cement (w/c) ratio of 0.47 was used for the concrete mix. The maximum 40 % of rubber replacement were used to determine the optimum rubber content that are suitable for CPB.

2.3 Concrete Block manufacturing

DL-RCPBs were manufactured in a steel mould with internal dimensions of 200 mm × 100 mm × 80 mm as shown in Figure 2. 60 mm thick series II was poured as bottom layer and compacted on a concrete vibrating table at 60 Hz for 5 seconds. Series I with 20 mm thick was poured as top layer and then compacted for another 5 seconds. The concrete blocks were removed from the steel mould approximately 24 hours after casting and cured in air at room temperature (Figure 3) for 7 and 28 days until tested.

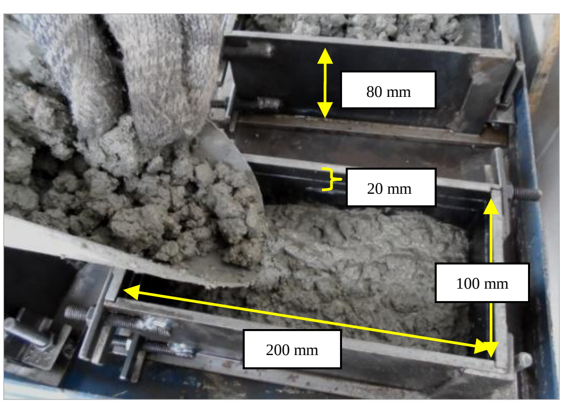


Figure 2 Manufacture of concrete paving block

Figure 3 Air curing of concrete paving block

2.4 Testing Method

A range of tests were carried out to determine the density, porosity and compressive strength at 7 and 28 days of the paving blocks specimens. Density and porosity testing was done according to ASTM C642 [10] The compressive strength was performed using a compression machine with maximum capacity of 3000 kN as shown in Figure 4. Two soft plywood with 5 mm thickness was applied on top and bottom of block specimen according to BS EN 1338 [11]. The load increased at 2.50 kN/s loading rate, was applied to the nominal area of block specimen. The skid resistance of CCPB and DL-RCPBs were determine using British Pendulum Skid Resistance Tester (Figure 5) as specified in BS EN 13036 Part 4 [12].

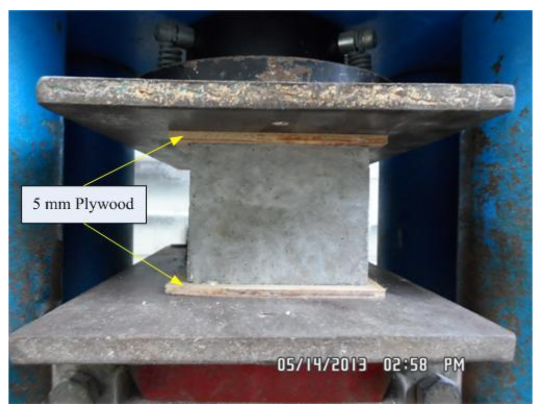


Figure 4 Compression test

Table 1 Mix proportion of double layer rubberized concrete paving blocks

Block Label	Mix proportion Series I (C:A:S)	Mix proportion Series II (C:A:S)	Cement content (kg/m^3) Series I&II	Water/ Cement ratio Series I&II	Rubber content (%) Series I&II
CCPB	1: 1.7: 1.5	1: 1.7: 1.5			0
DL-RCPB (10 %)	1: 1.5: 1.5	1: 1.7: 1.35			10
DL-RCPB (20 %)	1: 1.35: 1.5	1: 1.7: 1.2	489	0.47	20
DL-RCPB (30 %)	1: 1.2: 1.5	1: 1.7: 1.05			30
DL-RCPB (40 %)	1: 1.0: 1.5	1: 1.7: 0.9			40

CCPB: Control concrete paving block
DL-RCPB: Double layer rubberized concrete paving block

Figure 5 British Pendulum

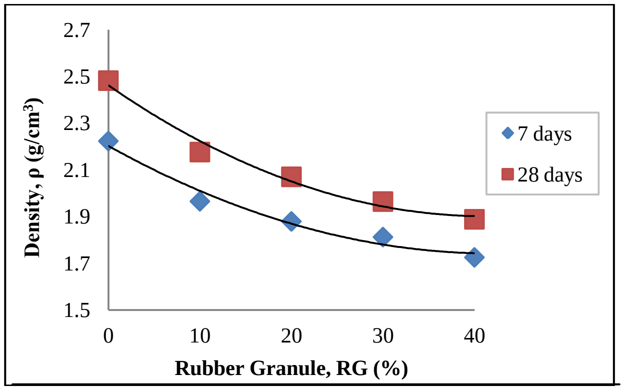


Figure 6 Density of double layer RCPBs

3.0 RESULTS AND DISCUSSION

3.1 Density

The density results of DL-RCPBs were illustrated in Figure 6. For instance, the density of DL-RCPBs at the age of 7 days was ranged from 2.20 g/cm^3 to 1.70 g/cm^3 as the rubber content increased up to 40 %. The densities of DL-RCPBs for 28 days dropped from 2.48 g/cm^3 to 1.89 g/cm^3 with the increased of rubber granule percentage. It was observed that the increase of 10 % rubber granule may reduce the DL-RCPBs density for 12 %. It was generally agreed that the low specific gravity of rubber granule [13-15] contribute to the reduction of concrete blocks density. Furthermore, the unit weight of the mixtures was reduced with the increasing rubber content due to increases air content. Low density of DL-RCPBs may give some credits in terms of sound and energy absorption especially for CPB used for highway.

3.2 Porosity

The results in Figure 7 indicate that the porosity of specimens varied from 10.17 % to 17.58 % for 7 days, whereas porosity ranged from 6.44 % to 15.34 % for 28 days. As reported in Figure 7, substitution of 40 % rubber granule increase porosity up to 55 % as compared to concrete mixture at 28 days. The non-polar nature of rubber aggregates and their ability to entrap air in their jagged surface texture caused high air content of rubberized concrete mixtures. The jagged surface texture were clearly seen through scanning electron microscopy (SEM) test carried out by Euniza *et al.*[9]. According to Sandberg and Ejsmont [16], porosity effectively reduces the air pumping effect, thereby reducing the tyre-pavement interaction noise.

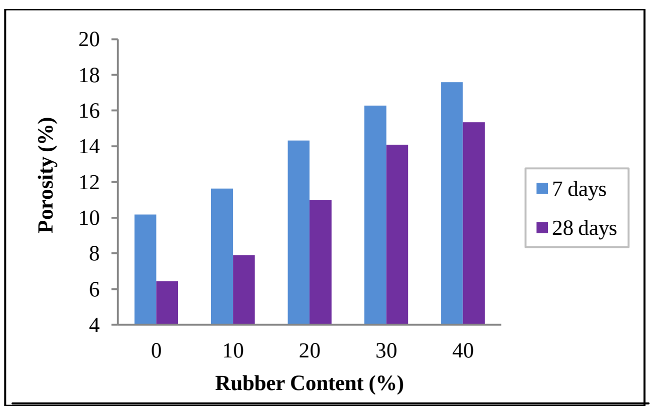


Figure 7 Porosity of double layer RCPBs

3.3 Compressive Strength

The compressive strength of the double layer CPB containing rubber granule was illustrated in Figure 8. Each value presented was the average of five sample measurements. The results indicated a progressive loss in compressive strength with an increase in the rubber content of the CPB. At 28 days, the compressive strength of CCPB obtained was 47 MPa. For instance, DL-RCPB (10 %) and DL-RCPB (20 %) recorded compressive strength of 45 and 40 MPa, whereas the compressive strengths of concrete block with DL-RCPB (30 %) and DL-RCPB (40 %) were 34 and 28 MPa, respectively. As reported in Figure 8, concrete specimen of DL-RCPB (30 %) and DL-RCPB (40 %) decrease in compressive strength of about 28 % and 41 % as compared to CCPB. The incorporation of 10 % rubber in the DL-RCPB produced the highest level of strength compared with 20 %, 30 %, and 40 % rubber granule. The reduced of concrete block strength could be attributed to the reduced quantity of solid load carrying material and lack of interfacial bond between rubber granule and cement paste . According to Topcu [17], fracture occurs when continuous application of compressive load produced cracks and the bonding between rubber particle and cement paste were overcome.

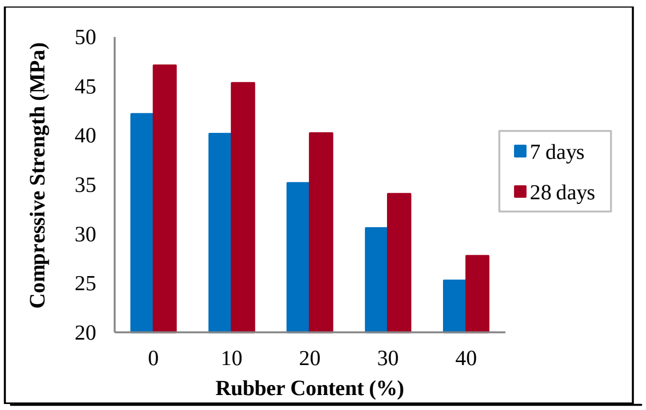


Figure 8 Compressive strength of double-layer RCPB

3.4 Relationship Between Density And Compressive Strength

The relationship between density and compressive strength was shown in Figure 9. Density of concrete blocks more than 2.20 g/cm^3, the compressive strength of DL-RCPBs were increased more than 45MPa. Concrete blocks subjected to 28 days of curing exhibited higher density. Figure 9 shows the maximum density and compressive strength at 28 days apparently ranges from approximately 2.20 g/cm^3 to 2.46 g/cm^3 and 45.31 MPa to 47.12 MPa, respectively.

3.5 Relationship Between Porosity And Compressive Strength

A graphical illustration of the relationship between porosity and compressive strength were presented in Figure 10. The plotted readings clearly show that the compressive strength increases when the porosity decreases. The porosities of the concrete are expectedly reduced with an increase in curing period. The compressive strength of concrete block was lower than 30 MPa when porosity increases up to 15 %. The maximum porosity and compressive strength recorded in Figure 10, at 28 days ranges from approximately 7.89 % to 6.44 % and 45.31 MPa to 47.12 MPa, respectively. Increased in porosity may reduced the strength of DL-RCPB because less adhesion between cement paste and rubber granule immediately formed micro crack once the compression load was applied. Hence, the bonding was easily overcome. Thus, the compressive strength DL-RCPBs may be increased with the reduction of porosity.

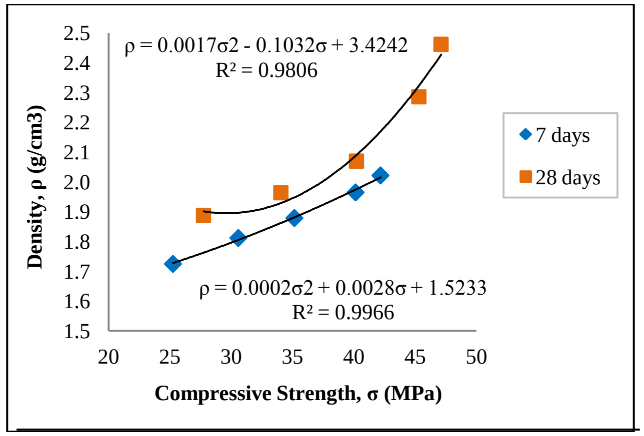


Figure 9 Relationship between density and compressive strength

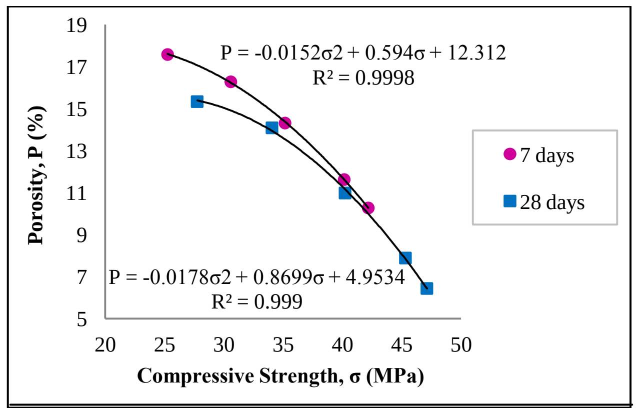


Figure 10 Relationship between porosity and compressive strength

3.6 Skid Resistance

In general, results in Figure 11 indicated that the skid resistance was slightly higher for the DL-RCPBs as compared to CCPB. The skid resistance for DL-RCPB (40 %) increased by 7 % as compared to CCPB. This is due to rubber granule has high elastic properties and rough surface texture which results in higher friction as the pendulum passed across the concrete block surface. The control specimens and all double layer RCPBs produced met the minimum BS EN 13036 Part 4 requirement [12].

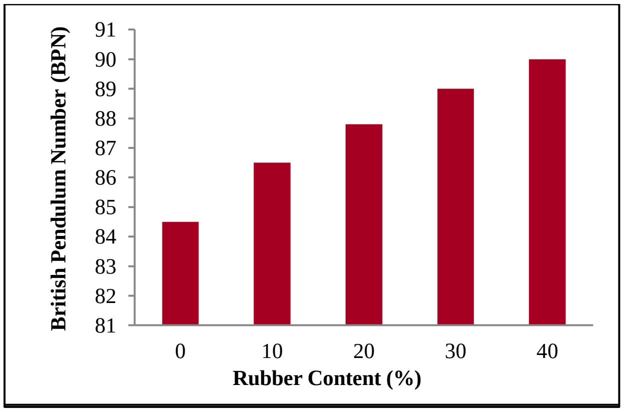


Figure 11 Skid Resistance of double-layer RCPBs

4.0 CONCLUSION

In this study, the effect of using waste tyre rubber (rubber granule) on the properties of double layer rubberized concrete paving blocks was studied. Based on the results, the following conclusion can be drawn:

a. Density of DL-RCPBs decreases as low as 1.88 g/cm^3 when 40 % of total aggregate is replaced with rubber granule.
b. Low density of DL-RCPBs may contribute to positive effect in terms of sound and energy absorption especially for CPB used for highway.
c. Porosity of DL-RCPBs increase up to 15.34 % when 40 % of total aggregate is replaced with rubber granule.
d. The effects on the compressive strength of DL-RCPBs are dependent on the percentage of rubber granule content.
e. Double layer rubberized concrete paving blocks has better skid resistance compare to control block.

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References

[1] Ganesan, N., Bharati Raj, J., and Shashikala, A.P. 2013. Flexural fatigue behavior of self compacting rubberized concrete. *Construction and Building Materials*. 44: 7–14.
[2] Aziz, A.A., Rao, S.P., and Salleh, E. 2013. Waste Tyres as Heat Sink to Reduce the Driveway Surface Temperatures in Malaysia. *Journal of Design and Built Environment*. 13: 1–11.
[3] Poon, C.S. and Chan, D. 2006. Paving blocks made with recycled concrete aggregate and crushed clay brick. *Construction and Building Materials*. 20: 569–577.
[4] Poon, C.S. and Chan, D. 2007. Effects of contaminants on the properties of concrete paving blocks prepared with recycled concrete aggregates. *Construction and Building Materials*. 21: 164–175.
[5] Soutsos, M.N., Tang, K. and Millard, S.G. 2011. Use of recycled demolition aggregate in precast products , phase II : Concrete paving blocks. *Construction and Building Materials*. 25: 3131–3143.
[6] Ling, T.C., Nor, H., Hainin, M.R. and Lim, S.K. 2010. Long-term strength of rubberised concrete paving blocks. *Institution of Civil Engineers*. Institution of Civil Engineers :19–26.
[7] Ling, T., Nor, H., and Hainin, M.R. 2011. Properties of Crumb Rubber Concrete Paving Blocks with SBR Latex. *Road Materials and Pavement Design*. 10(1): 213–222.
[8] American Society for Testing and Materials 2012. Standard Specification for Portland Cement. *American Society for Testing and Materials*. United States: ASTM C150–12.
[9] Euniza, J., Hasanan, M.N., Ramadhansyah, P.J. and Zaiton, H. 2014a. Chemical Properties of Waste Tyre Rubber Granules. *Advanced Materials Research*. 911: 77–81.
[10] American Society for Testing and Materials. 2013. Standard Test Method for Density , Absorption , and Voids in Hardened Concrete. *American Society for Testing and Materials*. United States: ASTM C642–13.
[11] British European Standard. 2003. Concrete paving blocks — Requirements and test methods. *British European Standard*. British Standard Institution, UK: BS EN 1338 Part 3.
[12] British European Standard. 2011. Method for measurement of slip / skid resistance of a surface : The pendulum test. *British European Standard*. British Standard Institution, UK: BS EN 13036 Part 4.
[13] Aiello, M.A. and Leuzzi, F. 2010. Waste tyre rubberized concrete: Properties at fresh and hardened state. *Waste Management*. 30: 1696–1704.
[14] Euniza, J., Hasanan, M.N., Ramadhansyah, P.J. and Zaiton, H. 2014b. Mechanical Properties of Double Layer Rubberized Concrete Paving Blocks. *Advanced Materials Research*. 911: 463–467.
[15] Khatib, Z.K. and Bayomy, F.M. 1999. Rubberized portland cement concrete. *Journal of Materials in Civil Engineering*. 11(3): 206–213.
[16] Sandberg, U. and Ejsmont, J.A. Tyre / Road noise reference book. Informex, Kisa, Sweden, 2002.
[17] Topcu, I.B. 1995. The properties of rubberized concrete. *Cement and Concrete Research*. 25(2): 304–310