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USE OF WASTE RUBBER GRANULES FOR THE PRODUCTION OF CONCRETE PAVING BLOCKS

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Abstract: Worldwide uses of rubber products are increasing every year. A significant proportion of waste rubber is generated during the manufacturing process of rubber products, and the disposal of such waste has been a problem due to the non-degradable complex structure of rubber and categorized as hazardous waste. Therefore, disposal of waste rubber as landfill is considered as environmentally unfriendly. However, waste rubber can be used as a replacement of coarse and fine aggregates in concrete for paving blocks for use roadways and walkways. Previous studies have shown that adding waste rubber increases the skid resistance and decreases abrasion resistance while making it more flexible. However, compressive strength get reduced with the addition of rubber waste. Therefore, further studies are necessary to find a balance between the desired properties and come up with an optimum mix design for rubberized concrete. Most of previous studies are related to use of crumb rubber (waste from rubber tires). Therefore, an attempt has been taken by carrying out an experimental study to develop a mix which gives the required compressive strength with the highest proportion of waste rubber content in the mix to give a value addition to this waste product.

Keywords: Compressive strength; Fine aggregates; Concrete paving blocks; Rubber granules

1. Introduction

In Sri Lankan context, paving blocks are mainly categorized into four groups depending on their use and strength class as follows.

- Non-Traffic: Building premises, Foot paths, Shopping malls, Pedestrian plazas, Landscapes, Public gardens etc.
- Light Traffic: Car parks, Office driveways, Commercial complex, Rural roads, Farm houses etc.
- Medium Traffic: City streets, Small market roads, Utility service stations etc.
- Heavy & Very Heavy Traffic: Container/Bus terminals, Dock yards, Industrial complexes, Heavy duty roads, Bulk cargo handling areas, Factory floors/pavements, Airport pavements etc.

Table 1 illustrates the strength classes and corresponding properties of the paving blocks according to Sri Lankan standards [1].

According to the study by Sukontasukkul and Chaikaew [2], compressive strength, flexural strength and abrasion resistance decrease with crumb rubber content in the paving blocks. However, toughness increases with the increase of rubber content. Another study by Gupta et al. [3] found that skid resistance and water absorption of concrete increase with the rubber content. It was also reported that rubber content adversely affects the chloride penetration [4].

Table 01. Sri Lankan standards for paving blocks

Strength Class	Average Compressive Strength (N/mm^2)	Individual Compressive Strength (N/mm^2)	Block Thickness (mm)
1 - Heavy to Very Heavy Traffic	50	40	80,100
2 - Medium Traffic	40	32	80,100

3 - Light Traffic	30	25	80,100
4 - Non Traffic	15	12	60

2. Scope and Objective

The scope of this research was to study the strength properties of concrete paving blocks manufactured using waste rubber granules and ultimately come up with an optimum mix for strong and durable rubber mixed paving blocks. The followings are the main objectives of the study.

- Investigation of the suitability of waste rubber (which is categorized as hazardous waste) as partial replacement of fine aggregate for the use of manufacturing paving blocks
- Development of a mix to achieve physical and mechanical properties required for paving blocks that can be used for non-traffic applications.

3. Experimental Investigation

Although there are five tests to be carried out on pavement blocks to check whether they are satisfying the requirements of Sri Lankan standards [1] such as compressive strength test, dry density test, flexural test, skid resistance test and abrasion test, only the compressive test was given priority in the experimental investigation since it is the most crucial property.

Since it has been reported [2] that the machine made RCPB (Rubberized Concrete Paving Block) has higher compressive strength, higher dry density and higher skid resistance than that of manually made RCPB, it was decided to use manually compacted RCPB to identify the optimum mix and fine tune that mix using machine made RCPB.

Initially 1:4, Cement/Aggregate ratio by volume was selected based on the recommendation given in the reference [1]. Thus, the cement content was maintained at a constant value and components in aggregates were changed to find the ideal mix proportion. Manufactured sand, river sand and rubber granules were used as fine aggregates and 10mm chips were used as coarse aggregates. From those four components, only two components were changed at once maintaining all other components constant. W/C ratio was also maintained close to 0.3.

The experimental investigation was carried out in order to identify the ideal mix proportion which gives the maximum strength with the maximum rubber content.

4. Materials

- Cement - OPC (grade 42.5) complying with Sri Lanka Standard SLS 107:2008 was used.
- River sand (Fine aggregate) - River sand with a bulk density of 1505 kg/m^3 complying with the requirements specified in BS 882 was used. Figure 1 shows the sieve analysis results of river sand used.

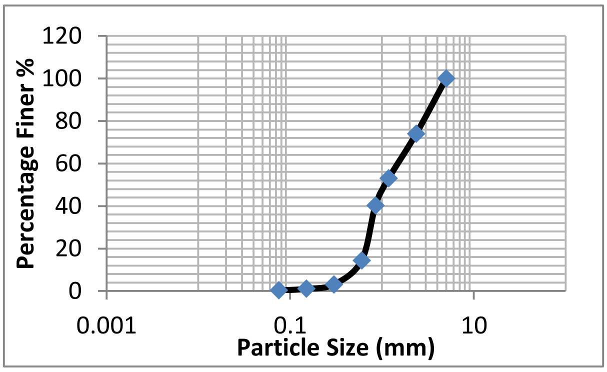

Fig. 01. Particle size distribution of river sand

- Manufactured sand (Fine aggregate) - Manufactured sand (Bulk density – 1536 kg/m^3) with a 5mm maximum size was used. Particle size distribution is shown in Figure 2.

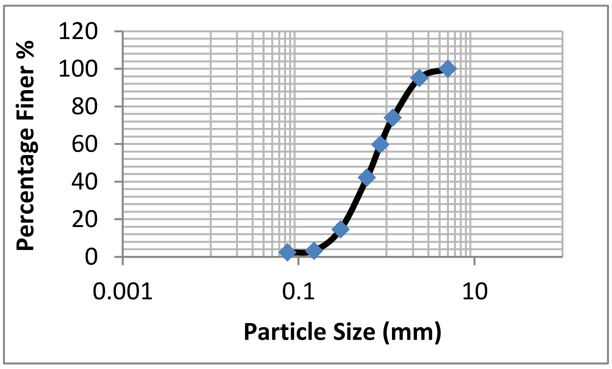

Fig. 02. Particle size distribution of manufactured sand

- Rubber granules - Rubber granules of 5mm maximum size with bulk density of 426 kg/m³ was used (Figure 3). Particle size distribution is shown in Figure 4.

Fig. 03. Rubber Granules

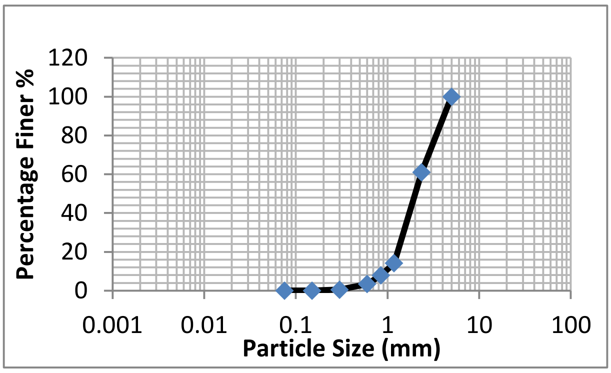

Fig. 04. Particle size distribution of rubber granules

- Chip (Coarse aggregate) - Chips of 10mm maximum size and bulk density 1600kg/m³ was used.

5. Analysis of Test Results

First set of paving block samples were cast to identify the effects of river sand and manufactured sand content on compressive strength. Therefore, only river sand and manufactured sand contents were altered in the mix while keeping cement, rubber granules and chip contents a constant. Water/cement ratio was maintained at 0.32 and slight changes of the water content were made in order to maintain the workability and to obtain a better surface finish for the paving blocks.

Two controlled samples were cast with following mix proportions and the compressive strengths of the samples are given in Table 2.

Table 02 - Mix proportions (by volume) and strength characteristics of controlled samples

Cement	River Sand	Manufactured Sand	Rubber Granules	10mm Chips	w/c Ratio	7 - day Compressive	28 - day Compressive	Density (kg/m³)
20%	40%	-	-	40%	0.3	33.4	50.5	2343
20%	-	40%	-	40%	0.32	25.8	40.4	2492

When river sand was replaced with manufactured sand, compressive strength of paving blocks reduced significantly. These results are tallying with the previous study [5]. One potential reason for this behaviour could be the particle size distribution of the two fine aggregate types.

Table 3 shows the mix proportions and compressive strength characteristics of paving blocks manufactured with different mix proportions of river sand and manufactured sand.

Table 03 - Mix proportions (by volume) and strength characteristics of paving blocks with varying river and manufactured sand contents

Cement	River Sand	Manufactured Sand	Rubber Granules	10mm Chips	w/c Ratio	7 - day Compressive	28 -day Compressive	Density (kg/m³)
20%	20%	-	20%	40%	0.32	16.8	23.7	2153
20%	10%	10%	20%	40%	0.32	18.9	25.5	2196
20%	-	20%	20%	40%	0.32	22.8	29.6	2214

From these test results, it is evident that the compressive strength of the paving blocks enhances with the increase of manufactured sand replacing with river sand in the mix. These results indicate a behaviour opposite to controlled samples. In the controlled samples, compressive strength reduced with increase of manufactured sand content. This may be due to better interaction of manufactured sand with rubber granules to form dense product.

When considering the surface texture, there is no significant difference between the blocks with higher proportion of river sand or manufactured sand. All samples were failed in the same failure mode; i.e. edge failure. Figure 5 illustrates the failure patterns of paving blocks.

Fig. 05. Failure mode of sample paving blocks

Based on preliminary test results, it was decided to use manufactured sand instead of river sand for manufacturing of paving blocks. The next attempt was to identify the effects of the content of manufactured sand and coarse aggregate on compressive strength of paving blocks. Therefore, in all samples, cement and rubber granules content was maintained constant whilst the w/c ratio was maintained at 0.32. Slight changes for the water content was made in order to maintain the workability and to obtain a better surface finish of the paving blocks.

From these results, it is evident that the compressive strength of the samples is decreasing with the increasing manufactured sand content and decreasing 10mm chip content. Also, there was a significant difference in surface texture as the coarse aggregate content increased. Surface of the paving block got rougher as the coarse aggregate content increased. Paving blocks with lesser coarse

Table 04 - Mix proportions (by volume) and strength characteristics of samples with varying manufactured sand and 10mm chip content

Cement	Manufactured Sand	Rubber Granules	10mm Chips	w/c Ratio	7 - day Compressive Strength (N/mm^2)	28 - day Compressive	Density (kg/m^3)
20%	20%	20%	40%	0.32	22.8	29.6	2214
20%	30%	20%	30%	0.32	14.9	20.1	2102
20%	40%	20%	20%	0.35	11.9	16.0	2170

aggregate content exhibited a better surface finish than that of blocks with higher coarse aggregate content. As per the previous literature, it has been identified that the manufacturing procedure also has an impact on the compressive strength [6] as well as the surface texture. Therefore, a better surface finish was expected from machine made paving blocks with the same mix proportions.

As the next step, an attempt was made to identify the effects of coarse aggregate content and the rubber granules content on the compressive strength of paving blocks. Therefore, cement and river sand contents in the mix were maintained at a constant value whilst changing the coarse aggregate content with rubber content. The w/c ratio was maintained at 0.32 and slight changes for the water content were made in order to maintain the workability and to obtain a better surface finish of the paving blocks.

From test results shown in Table 5, it is evident that the compressive strength of paving blocks drastically drops with the increase of rubber content in the mix. No significant differences in the surface finish of samples were observed. Figure 6 illustrates the surface finish of two set of samples with different mix proportions.

Table 05-Mix proportions (by volume) and strength characteristics of samples with varying rubber granules and 10mm chip content

Cement	Manufactured Sand	Rubber Granules	10mm Chips	w/c Ratio	7 - day Compressive Strength	28 - day Compressive Strength	Density (kg/m³)
20%	20%	20%	40%	0.32	22.8	29.5	2214
20%	20%	30%	30%	0.33	10.4	14.0	2129
20%	20%	40%	20%	0.32	5.5	6.5	1982

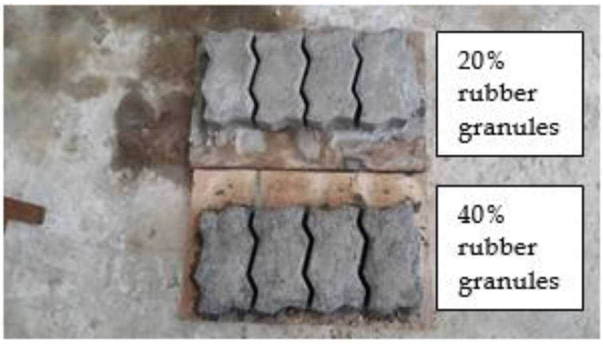

Fig. 06. -Two sets of paving block samples with different rubber granules content

In Figure 6, mix proportion of the upper set of paving blocks is 20%: 20%: 20%: 40% (cement: m-sand: rubber granules: 10mm chip) whereas the mix proportion of the bottom set of s paving blocks is 20%: 20%: 40%: 20% (cement: m-sand: rubber granules: 10mm chip). From this figure, it is evident that there is no significant difference in the surface texture of the paving blocks other than the colour. Paving blocks with higher rubber granules content possess a darker surface which was expected due to the dark colour of rubber granules.

When considering all the test results, it can be concluded that the maximum compressive strength that can be achieved using waste rubber granules with 1:4 cement : aggregate ratio is 29MPa. Therefore, these paving blocks can only be used for non-traffic applications such as for building premises, foot paths, shopping malls, pedestrian plazas, landscapes, public gardens etc.

Since the aim of this research is to obtain a mix for non-traffic applications, the mix proportion 20% : 30% : 20% : 30% (cement : m-sand : rubber granules: 10mm chip) which gave a compressive strength of 20MPa in manually cast process was selected for further improvement using hydraulic press paving block making machine. The block making plant at SMS Holding (pvt) Ltd was selected, where they use large pan mixers for mixing and hydraulic machines for compressing in manufacturing concrete paving blocks.

In order to achieve the required consistency in the new process of manufacturing the paving blocks, the mix proportion was adjusted as 20% : 28% : 20% : 32% (cement : m-sand : rubber granules: 10mm chip). The strength results of the machine made paving blocks are given in Table 6.

Fig. 07. -Pan mixer and Hydraulic press paving block making machine

Table 06-Strength characteristics of machine made RCPB

Cement	Manufactured Sand	Rubber Granules	10mm Chips	w/c Ratio	7 - day Compressive Strength	28 - day Compressive Strength	Density (kg/m³)
20%	28%	20%	32%	0.32	18.2	22.7	2160

From the test results, it is evident that there is a significant improvement in the compressive strength of machine made RCPB when compared with manually made RCPB. From the Figures 8 and 9, it can be seen that the surface finish of machine made RCPB is better than that of manually made RCPB.

Fig. 08. -Surface of machine made RCPB

Fig. 09. -Sides of machine made RCPB

6. Further Research

This research study was carried out to find a suitable mix proportion with waste rubber to satisfy the strength requirement of paving blocks for non-traffic applications. Further research is necessary to find the durability issues related to waste rubber mixed concrete paving blocks.

7. Conclusions

Based on the test results, following conclusions can be made.

- Compressive strength of the concrete paving blocks reduced drastically with the increase of rubber content in the mix.
- Compressive strength of the concrete paving blocks with waste rubber granules has reduced significantly when 10mm chips were replaced with manufactured sand.
- Machine made RCPB is having higher compressive strength when compared with manually made RCPB.
- The following mix proportion (by volume) with rubber granules gave a compressive strength of 22.7 MPa which is suitable for non-traffic applications.

Cement – 20%
Manufactured Sand – 28%
Rubber granules – 20%
10mm coarse aggregate – 32%

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References

[1]. W. K. Mampearachchi, Concrete Paving Block Technology, Hand book for concrete paving blocks technology in Sri Lanka

[2] P. Sukontasukkul, C. Chaikaew, Properties of concrete pedestrian block mixed with crumb rubber, Construction and Building Materials 20 (2006) 450–457

[3] T. Gupta, S. Chaudhary, R. K. Sharma, Assessment of mechanical and durability properties of concrete containing waste rubber tire as fine aggregate, Construction and Building Materials 73 (2014) 562–574

[4] F. Pacheco-Torgal, Y. Ding, S. Jalali, Properties and durability of concrete containing polymeric wastes (tyre rubber and polyethylene terephthalate bottles), Construction and Building Materials 30 (2012) 714–724

[5] E. Ganjian, G. Jalull, H. Sadeghi-Pouya, Using waste materials and by-products to produce concrete paving Blocks, Construction and Building Materials 77 (2015) 270–275

[6] T. Ling, Effects of compaction method and rubber content on the properties of concrete paving blocks, Construction and Building Materials 28 (2012) 164–175

[7] T. Gupta, R. K. Sharma, S. Chaudhary, Impact resistance of concrete containing waste rubber fiber and silica Fume, International Journal of Impact Engineering 83 (2015) 76-87

[8] O. Onuaguluchi, D. K. Panesar, Hardened properties of concrete mixtures containing pre-coated crumb rubber and silica fume, Journal of Cleaner Production 82 (2014) 125-131