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Using Waste Tire Crumb Rubber As an Alternative Aggregate for Concrete Pedestrian Blocks

Khaldoon A. Bani-Hani [1)] and Ahmed Senouci [2)]

[1)] Department of Civil Engineering, Jordan University of Science and Technology, P.O. Box 3030, Irbid-22110, Jordan.
[2)] Department of Construction Management, University of Houston, Houston, TX 77204-4020, Texas, USA

ABSTRACT

This study investigates the performance of using waste tire crumb rubber as an alternative aggregate for concrete pedestrian blocks. It focuses on determining the engineering properties of the crumb rubber concrete pedestrian blocks, such as unit weight, water absorption, compressive and flexural strengths, as well as freeze-and-thaw resistance. Crumb rubber has been previously used in several applications, such as asphalt pavement, waterproofing systems, membrane liners,… etc. In this study, crumb rubber is used to replace portions of fine aggregates in the manufacturing of concrete pedestrian blocks. Crumb rubber concrete pedestrian blocks were found to possess good aesthetics and a smaller unit weight than plain concrete pedestrian blocks. They were also found to have good resistance to repeated freezing and thawing cycles. However, crumb rubber concrete pedestrian blocks exhibited low compressive and flexural strengths. Unlike plain concrete pedestrian blocks, crumb rubber concrete blocks did not demonstrate the typical brittle failure. They exhibited a ductile, plastic failure and showed the ability to absorb a large amount of plastic energy under compressive and flexural loads.

KEYWORDS: Pedestrian block, Rubber crumb, Concrete, Compressive strength, Flexural strength, Freeze-and-thaw resistance.

INTRODUCTION

Recycling discarded automobile tires has become an increasingly important issue, since the disposal of used tires has been banned from landfills. As a consequence of this ban and the lack of an alternative technology to dispose of large quantities of used tires, there are millions of used tires stockpiled, some illegally. The growing stockpiles of discarded tires represent potential fire and health hazards.

Recycling waste tire rubber conserves valuable natural resources and reduces the amount of waste entering landfills. The main method of recycling these waste materials has consisted of using tire rubber particles as coarse or fine aggregate in concrete. Results indicate that rubberized concrete mixtures possess lower density, increased toughness and ductility, lower compressive and tensile strengths and more efficient sound insulation (Siddique et al., 2008). Raghavan et al. (1998) reported that mortars incorporating rubber shreds achieved workability comparable to or better than a control mortar without rubber particles. Because of the low specific gravity of rubber particles, the unit weight of the mixture containing rubber decreases with the increase in the rubber content. They also observed that rubber shreds incorporated into mortar help reduce plastic shrinkage cracking in comparison to control mortar. Eldin and Senouci (1993) studied the mechanical behavior of concrete containing rubber tires and showed that the

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concrete mixtures exhibited lower mechanical strengths but demonstrated a ductile and plastic failure. They also observed that despite a decrease in both unit weight and compressive strength, elastic behavior improved. The addition of silica fume into the matrix improved the mechanical properties of the rubberized concretes and diminished the rate of strength loss (Güneyisi et al., 2004).

In this study, crumb rubber is used to replace fine aggregate in the production of concrete pedestrian blocks. Replacing fine aggregate in concrete pedestrian blocks with crumb rubber produced from waste tires will reduce the consumption of primary aggregates and produce a high value use for the wastes. It will also help minimize the use of high value aggregates in low specification applications.

EXPERIMENTAL PROCEDURE

Five different crumb rubber sizes; namely SRC 12, 20, 30, 40 and 50, have been used in this study. Crumb rubber, which is produced by grinding vehicle tires, was imported from one of the rubber reclaiming plants in Manchester, United Kingdom. The grinding process starts by cutting and sorting out rubber and steel parts. After that, rubber pieces are fed into a cutting wheel several times until the desired size is achieved. At the final stage, crumb rubber is sorted out and grouped together according to particle size. Figure 1 presents a sample of crumb rubber used in the study.

Figure (1): Crumb Rubber Sample

The control mix was prepared with cement, limestone aggregate and fine aggregate in the proportion of 1:1.72:1.93 by weight to achieve a target compressive strength of not less than 30 MPa after curing. Table 1 shows the proportions of one cubic meter of the control mix. The control mix was the basis for preparing three crumb rubber mixes, where the fine aggregate of the control mix was replaced by crumb rubber at a percentage of 20, 40 and 60%, respectively. Table 2 summarizes the experimental design of the study. Five replicates were used for the determination of the physical properties (*unit weight, water absorption and freeze-and-thaw resistance*) of crumb rubber pedestrian blocks.

Table 1. Control mix design

Material	Quantity
	(kg/m^3)
Limestone Aggregate	258
Fine Aggregate	290
Type I Cement	150
Water	51
Admixture	0.8

Table 2. Experimental design summary

Mix label	Crumb Rubber	Number of replicates	
		Physical Properties	Mechanical Properties
Control	0%	5	8
R-20	20%	5	8
R-40	40%	5	8
R-60	60%	5	8

On the other hand, eight replicates were used for the determination of the mechanical properties (*compressive and flexural strengths*) of crumb rubber blocks.

TEST RESULTS

Aesthetics

Crumb rubber concrete pedestrian blocks showed good aesthetic qualities. The appearance of the finished surfaces was similar to that of plain concrete pedestrian blocks and the finishing of the block surfaces was not a problem. Figure 2 shows the appearance of crumb rubber concrete pedestrian blocks. The color of crumb rubber concrete pedestrian blocks did not differ from that of plain concrete pedestrian blocks. Additionally, Figures 3 and 4 show testing performed on the crumb rubber samples.

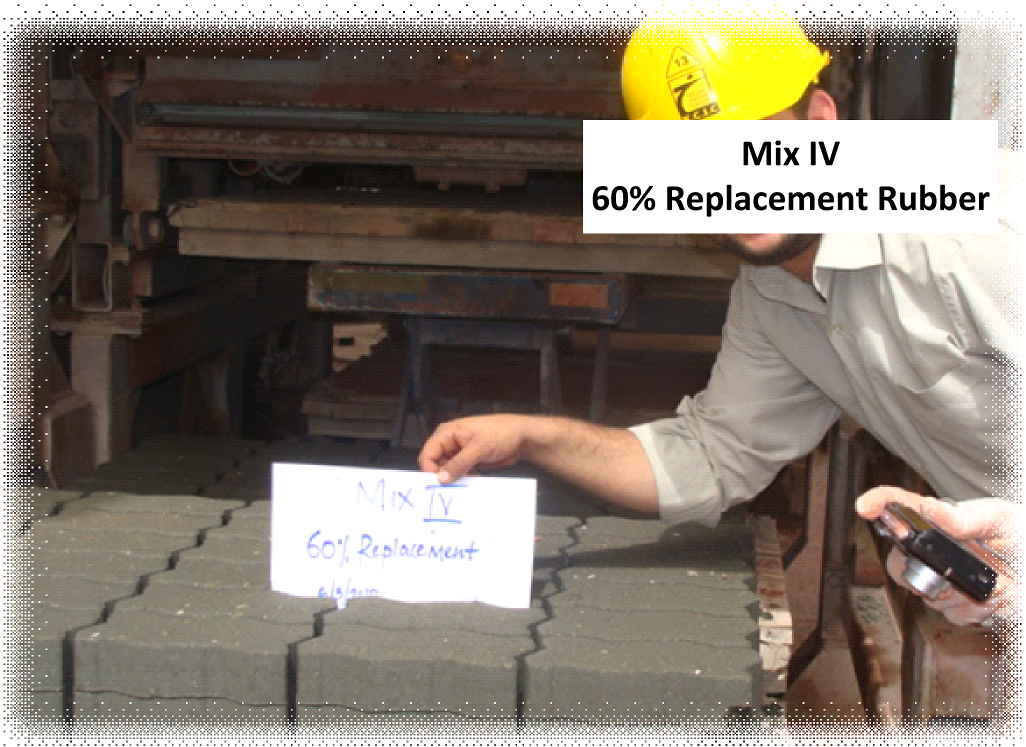

Figure (2): Sample of Crumb Rubber Concrete Pedestrian Blocks

Figure (3): Testing on Masonry Bricks

Figure (4): Testing on Pavement Blocks

Unit Weight

Due to the low specific gravity of crumb rubber particles, the weight of the blocks decreases with the increase in the percentage of crumb rubber content. Moreover, the increase in the crumb rubber content creates more air voids, which in turn reduces the unit weight of the mixtures (Siddique and Naik, 2004). The decrease in weight of pedestrian blocks is negligible when the rubber content is less than 10% of the total aggregate volume. This reduction was verified by computing the unit weight of crumb rubber concrete pedestrian blocks as a function of the unit weight of their components and was found to be in agreement with the test results. Figure 5 summarizes the unit weights for the tested crumb rubber concrete pedestrian blocks.

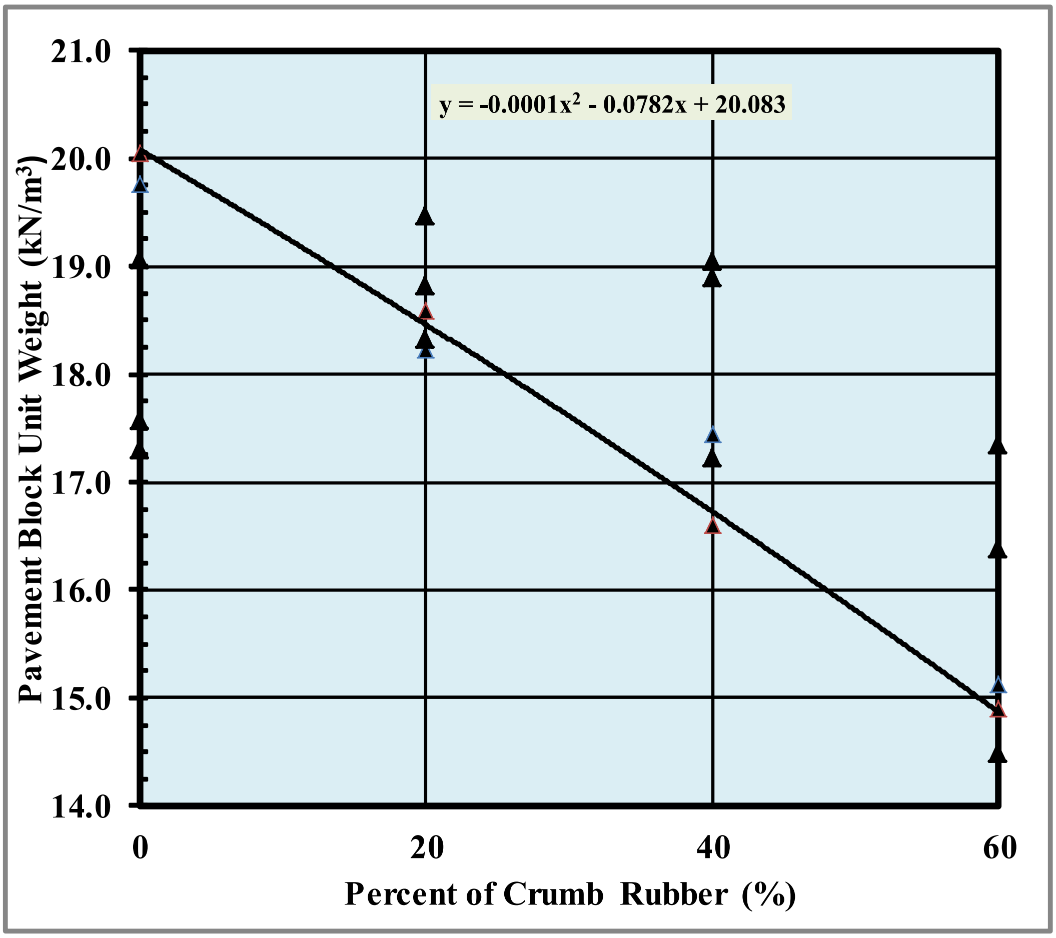

Figure (5): Unit Weights of Crumb Rubber Concrete Pedestrian Blocks

Water Absorption

The water absorption of crumb rubber concrete pedestrian blocks was determined. Figure 6 presents the relationship between the percent water absorption and the percentage of crumb rubber used. The results show a slight reduction of the water absorption with the increase in the percentage of crumb rubber used. This can be explained by the fact that crumb rubber has a relatively very low water absorption.

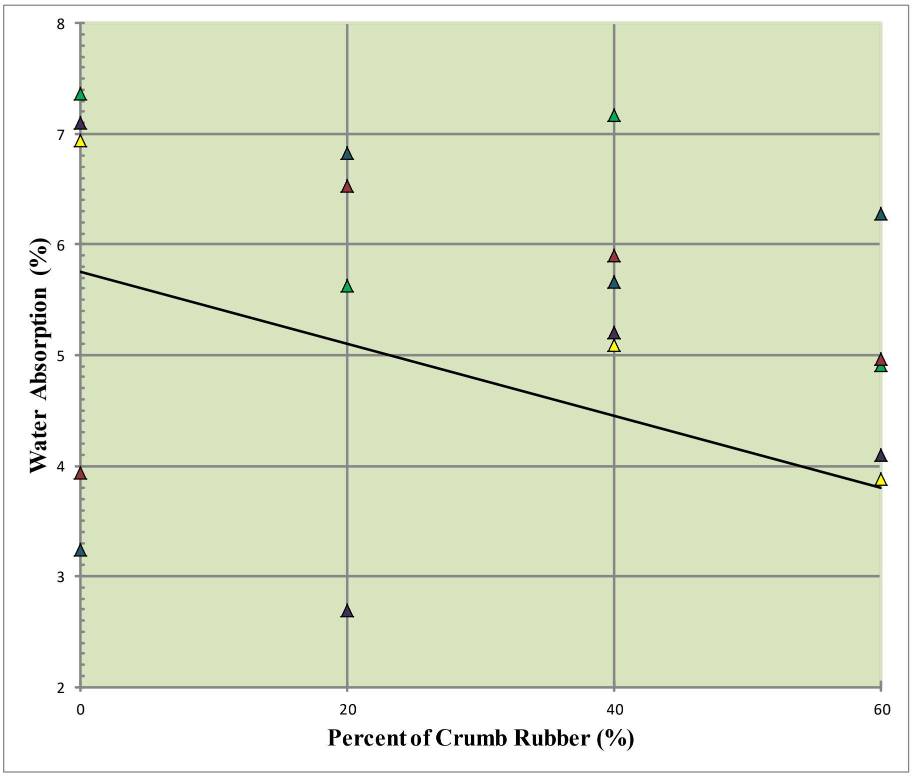

Figure (6): Water Absorption of Crumb Rubber Concrete Pedestrian Blocks

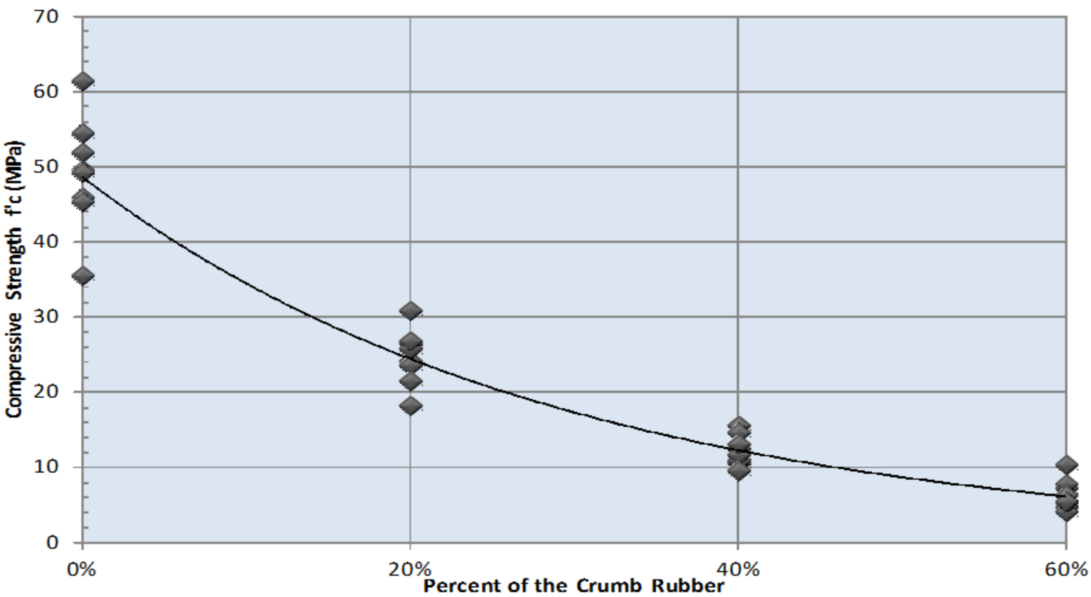

Figure (7): Compressive Strength of Crumb Rubber Concrete Pedestrian Blocks

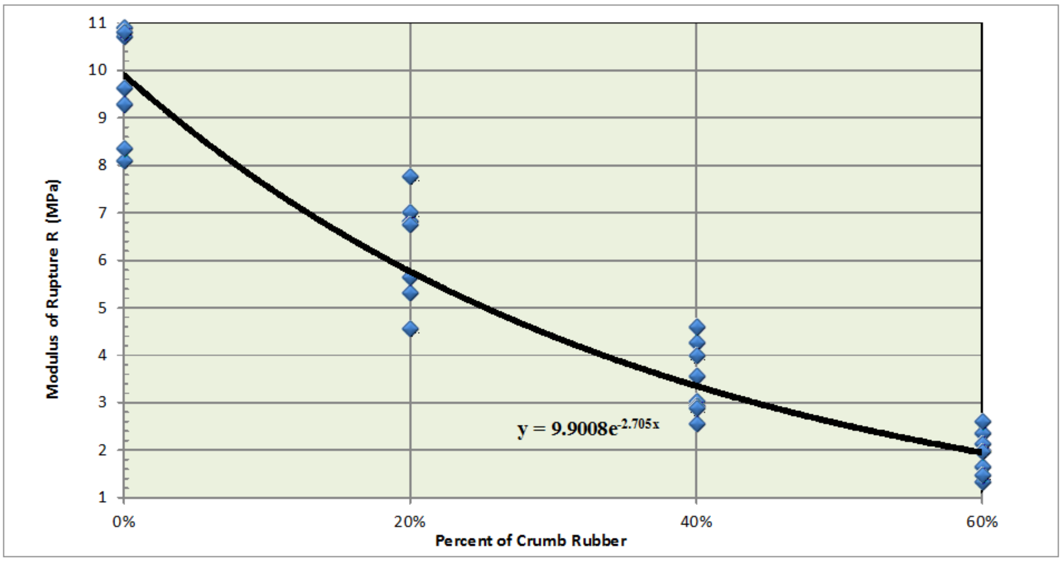

Figure (8): Flexural Strength of Crumb Rubber Concrete Pedestrian Blocks

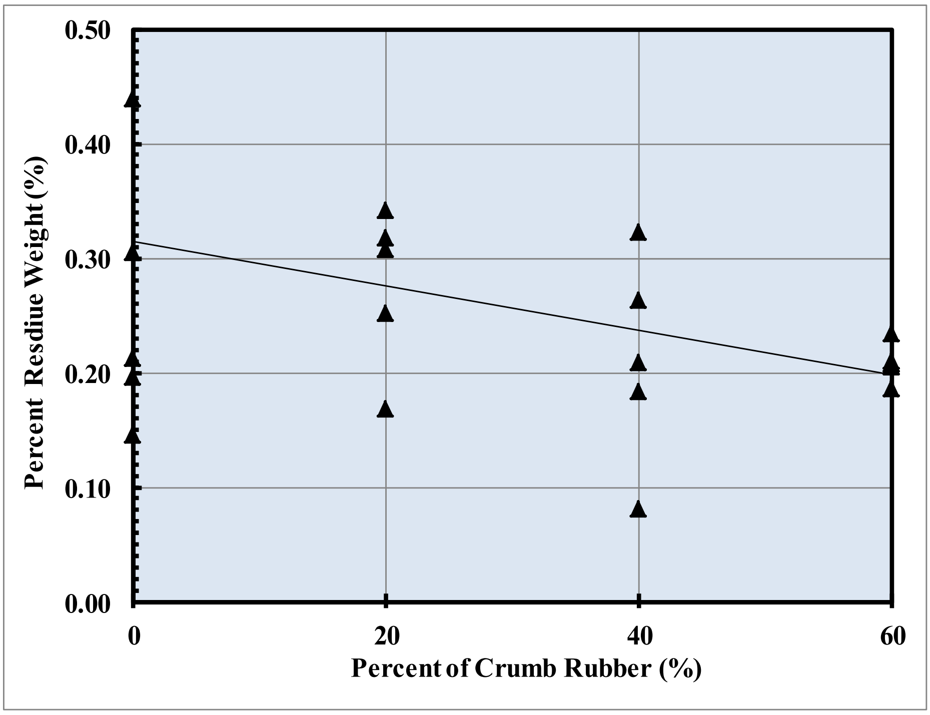

Figure (9): Cumulative Weight Loss

Compressive and Flexural Strengths

The compressive and flexural strengths of crumb rubber concrete pedestrian blocks were determined according to ASTM C39 and ASTM C78, respectively. Figures 7 and 8 present the relationship between the compressive strength and flexural strength, respectively, and the percentage of crumb rubber used. Considerable loss of strength was observed when the crumb rubber content in the mix was increased. Losses up to 90% of the compressive strength and up to 80% of the flexural strength, depending on the percentage of crumb rubber in the mix, were measured.

Freeze-and-Thaw Resistance

Crumb rubber pedestrian blocks were subjected to repeated freeze and thawing cycles according to ASTM C1262. A total of 5 blocks from each mix were tested for at least 20 repeated freeze and thaw cycles. Figure 9 shows the cumulative weight loss expressed as a percent of the calculated initial weight of the blocks.

The results show that crumb rubber concrete pedestrian blocks performed better than plain concrete pedestrian blocks under freeze-and-thaw tests. This finding was also echoed by Marzouk et al. (2007) who investigated the effect of adding rubber to concrete mixes on freezing-and-thawing resistance. They concluded that concrete with crumb rubber performed better under freeze-and-thaw conditions than plain concrete.

A visual inspection showed that no apparent deteriorations were observed in all the blocks.

CONCLUSIONS

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

1. Crumb rubber concrete pedestrian blocks showed acceptable aesthetics.
2. The use of crumb rubber resulted in an appreciable reduction of block unit weight.
3. Crumb rubber concrete pedestrian blocks experienced a rather ductile failure and the ability to absorb a large amount of plastic energy under compression and flexure.
4. The use of crumb rubber reduced the compressive and flexural strengths of pedestrian blocks. The reduction correlates to the percentage of crumb rubber by volume in the mix.

Only a small number of engineering properties of crumb rubber concrete pedestrian blocks have been examined in this study. Other properties such as skid resistance, abrasion resistance, falling weight test, deformation, volume change, fatigue resistance and environmental impact must be examined for a comprehensive evaluation of this new block material.

Overall, crumb rubber concrete pedestrian blocks have been observed to show a more inferior performance than plain concrete pedestrian blocks in compression and flexure, but showed a great improvement in toughness. Thus, crumb rubber concrete pedestrian blocks have a great potential to be used for pedestrian pavements. Replacing fine aggregate in concrete pedestrian blocks with crumb rubber produced from waste tires will reduce the consumption of primary aggregates and produce a high value use for the wastes. It will also help minimize the use of high value aggregates in low specification applications.

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