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Review

Investigation on the properties of concrete tactile paving blocks made with recycled tire rubber

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HIGHLIGHTS

- Concrete with replacement of 10–50% of natural sand for tire rubber.
- Excellent compressive strength and flexural strength results.
- With the addition of rubber there was an improvement in abrasion resistance.
- The tire rubber has high performance to use as concrete's aggregate.

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ABSTRACT

Due to the increasing demand for buildings that meet accessibility standards and give access to all users, without restriction to people with a disability or reduced mobility, it arises the search for efficient and quality products. Aiming to develop a concrete paving block that contributes to sustainability in building and to accessibility in the built environment, in this paper recycled tire rubber (crumb rubber) was used as aggregate in concrete to produce tactile paving block. The replacement was made in relation of the mass of sand at the level of 10%, 20%, 30%, 40% and 50%. The concrete characterization was performed by testing the consistency, compressive strength, flexural strength, water absorption, porosity, density, abrasion resistance, impact resistance and microstructure analysis. Although the major limitation of using crumb rubber as aggregate in the concrete is to reduce the compressive strength, the results reached were higher than 40 MPa for the paving blocks with the inclusion of 50% of crumb rubber. The results of flexural strength obtained to all concrete mixes studied were higher than 6.5 MPa. It was found that concrete containing rubber showed a better abrasion resistance.

Contents

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1. Introduction

The improper disposal of scrap tires pose a serious problem in the environment and human health. Tire stacked tires are favorable to the fire hazard, that produces a toxic smoke harmful to health, and the accumulation of water in the tires are attractive environments for vector mosquitoes [1].

The concrete is one of the most commonly used materials in construction because of availability of materials that constitute it, its versatility, durability and performance. Besides providing adequate lifespan for structures at a competitive cost with other materials, enables the use, in large scale, of the environment's potentially polluter waste originated of other industrial processes [2].

Several authors have studied and confirmed the viability of using the crumb rubber in addition or replacement of natural aggregate in concrete [3–9].

One of the properties of concrete with rubber is higher ductility, that is, the concrete with rubber provides greater capacity for deformation before rupture. Sang Son et al. [10] observed that the use of 1% crumb rubber (1% of total aggregate weight) in the concrete mix, can result in 90% improvement in the curvature ductility of reinforced concrete columns, with the possibility to be use in seismic applications.

The major limitation of using crumb rubber as aggregate in concrete is the reduction in compressive strength. However, some researchers have found that at appropriate levels, the rubber provided an improvement in this characteristic of the concrete. Yung et al. [11] verified that with the replacement of fine aggregate to waste tire rubber, at volume ratios of 5%, the compressive strength was increased by 10%.

The increase of compressive strength when the replacement of natural aggregate to crumb rubber is done in the concrete, is related to the existence of an optimal replacing volume ratio of rubber aggregate to the mineral. When the replacing value is lower than the optimum level, the rubber aggregates cannot be distributed uniformly in the concrete and the compressive strength is reduced, because the rubber with low elasticity cooperates with the existence of some weak points in the concrete, so stress concentration occurs around the rubber aggregates. When the rubber aggregate content is enough to be evenly distributed throughout the matrix, the load energy is also distributed evenly, which leads to the increase of the concrete strength. When the replacing value is higher than the optimum value, the soft rubber aggregate makes the concrete more porous and weaker and the strength of concrete reduces again [8].

In Brazil, nowadays, one of the main applications of concrete tactile paving blocks is at sidewalks, aiming accessibility, which is directly related to social inclusion. According to Brazilian standard – ABNT NBR 9050:2004 [12], the tactile paving block is characterized by the differentiation of texture in relation to the adjacent paving blocks, destined to compose alert or guideline, perceived by people with visual disabilities [13,14].

Some specifications for concrete paving blocks of Brazilian standard [15], Colombian standard [16], South African standard [17], European standard [18], American standard [19] and Canadian standards [20] are shown in Table 1.

In this study the recycled tire rubber was used as aggregate in concrete for the production of concrete tactile paving blocks. An analysis of the main characteristics prescribed in the standards for concrete paving blocks was performed such as: compressive strength, flexural strength, abrasion resistance and water absorption, also other important characteristics for concrete as: consistency, impact resistance, density, porosity and microstructure analysis.

2. Experimental materials and methods

2.1. Materials

2.1.1. Cement

The cement used in this study was the Portland cement (named CPV ARI) supplied by Holcim Brazil, with density of 3.11 g/cm^3.

2.1.2. Aggregate

The natural sand with density of 2.63 g/cm^3 and maximum dimension of 2.4 mm and the stone powder with density of 2.76 g/cm^3 and maximum dimension of 4.8 mm, were used as fine aggregate. The basaltic gravel with density of 2.96 g/cm^3 and maximum dimension of 9.5 mm was used a coarse aggregate. The recycled tire rubber, derived from a tire retreading industry, showed density of 1.14 g/cm^3 and a maximum dimension of 4.8 mm. Before being added to the concrete, the tires rubber underwent a sifting process, the sizes varied from 0.15 to 0.6 mm; 1.18 to 2.36 mm and 2.36 to 4.75 mm. The tires rubber with sizes varied are presented in Fig. 1.

2.1.3. Superplasticizer

The superplasticizer used in this study was the GLENIUM® 51 supplied by BASF. Its density is in the range of 1.067–1.107 g/cm^3, it is an additive based on modified polycarbonate ether that acts as dispersant binder materials, providing super plasticity and high water reduction, making concrete with increased workability.

2.2. Concrete mixing

Concrete mix proportions are listed in Table 2. The crumb rubber with size ranging from 1.18 to 2.36 mm was used in this paper, replacing the natural sand in percentages of 10%, 20%, 30%, 40% and 50% in relation to the mass of sand, but considering the difference in the density of materials, was calculated the volume of rubber required to fill the removed amount of sand.