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Study of Waste Tires Enriched Concrete

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Abstract- The construction industry has studied alternative materials, whose main concern is the balance between environmental, technological and sustainable economic aspects. In this sense, this work had as objective to carry out a study with the intention to contribute to a better utilization of tire rubber residues by adding them to Portland cement concrete, through comparative tests of the mechanical properties of Portland aggregate concrete of the tire rubber and traditional Portland cement concrete. In the first phase of the research, the tire rubber waste was acquired and the material was processed to obtain a small particle size. Together, the rest of the materials, such as cement, sand and gravel, were acquired. In the characterization phase, a grain size analysis, moisture content, determination of the specific mass, and unit mass were performed according to the Brazilian Technical Standards for the calculation of the specific trace of Portland cement concrete of 35Mpa. The corrected moisture mass trait found was 1: 1.44: 2.44: 0.34 (cement, sand, gravel, cement/water ratio). Subsequently, test bodies were molded exempt and with partial substitutions 5, 10, 15% m/m of the aggregate by the tire rubber residue. In the curing ages of 7, 14 and 28, mechanical strength tests were performed, where it was observed that the axial compressive strength decreases with the increase of the addition of the rubber residue contents in the concrete about 27,77% in the 5%, 46% in the 10% and 63,23% in the 15%, at the age of cure of 28 days. These results demonstrate that for the proportion of 5% sand substitution by the residue in the concrete, the compression results are acceptable for application in places with low demands such as sidewalks, bicycle paths, wall, where by the standard a resistance is required, compressed to a minimum of 21Mpa.

Keywords- C*oncrete with Tire Residue, Rubber Tire Residue, Alternative Materials*

I. INTRODUCTION

The construction industry has played an important role in the economic and social development of the country and, therefore, has been studied possibilities to offer alternative materials to promote the balance between environmental, technological and economic factors. This segment of industry is considered to be one of the spheres of the world economy that consumes the most energy and draws large quantities of natural resources for the production of building materials [1, 18,17, 13].

The transformation of solid waste into new usable products is an ideal solution that allows the optimization of economic resources, where the disposable material becomes the raw material for new products. Discarded tires generally have destinations such as landfills, landfills, and rivers, and this disorderly form of disposal generates an environmental liability with serious public health risks. Besides taking indeterminate time for its complete decomposition, it occupies great volume as residue in places where it is deposited.

Concrete is a versatile product, thus allowing aggregates of different origins in its composition, so the use of tire rubber as part of concrete in the form of aggregate is an essential action both for the preservation of natural resources and for the viability of alternative products with lower costs; in addition, with the reuse of tire rubber, new jobs may arise, as new companies would be created to process such material.

It is fundamental that in the field of civil construction new materials and constructive methods linked to sustainable development are developed, understanding that such materials lead to changes such as the exploration of new resources, the orientation of technological development and institutional changes that meet the expectations present and future quality of life

The aim of this study was to conduct a study to contribute to a better use of tire rubber waste and contribute to the solution of environmental and economic problems. For this, a comparative study of the mechanical properties of Portland cement with partial replacement of aggregates by tire rubber and Portland cement concrete was carried out without replacement, in order to make an analysis of the technical feasibility of production of the concrete enriched with rubber, from of the results found in the study.

II. MATERIALS AND METHODS

A. Collection and treatment of aggregates

For the development of the research, a bibliographical review about the present work was initially sought. Through the bibliographic review, the Portland cement CP-IV 32 RS was chosen for use, together with the local sand from the Piracicaba River (MG) and the local gaseous rock from the Pedreira do Monte (MG).

The tire wastes were donated by the FlexRender Rubber Processing Plant in the city of João Monlevade/MG. Tire waste is obtained through a mechanical process by an equipment composed of cylinders with grooves that cause wear on its tread surface by scraping on used tires.

The only procedure done in the residue was the sieving to exclude particles with a larger particle size than that of the small aggregate. The material passed through the sieve with a mesh opening of 4.75 mm was held in the sieve with a mesh opening of 150 µm.

B. Characterization of aggregates

The necessary analyzes in the characterization stage of the aggregates were carried out in the Technological Center of the University of the State of Minas Gerais (UEMG) of the João Monlevade unit and carried out according to the Brazilian Technical Standards (NBRs) for each test.

1) Granulometric analysis of aggregates

The granulometric analysis of the aggregates (fine and coarse) was performed according to [8]. The samples, previously dried in an oven with a temperature of 105ºC for 24 hours, were sieved in a mechanical sieving through the normal series sieves, allowing the separation of the grains through their sizes.

2) Surface moisture content of the small aggregate

Moisture is the ratio of the water mass contained in the fine aggregate to its dry mass, expressed as a percentage (%). The calculation of the surface moisture content was done by the oven drying method [10]

The sand samples were analyzed in triplicate, they were dried for 24 hours at a temperature of 105º C. For the calculation of the surface moisture was performed through Equation 1.

$$h = \frac{M_h - M_s}{M_s} \, x \, 100 \qquad (1)$$

At where:

h = aggregate humidity (%);

Mh = mass of the wet sample (g)

Ma = mass of water (g);

Ms = mass of the dry aggregate (g).

3) Specific Aggregate Mass

The determination of the specific mass of sand, fine aggregate was based on [9]. In the first moment the sample was dried in an oven (105 ° C - 110 ° C), until mass constancy. Thereafter, 200 ml of water was placed in the Chapman flask. Subsequently, 500g of the dry fine aggregate was introduced into the vessel, the mixture was stirred to remove all possible air bubbles. The reading of the water level in the bottleneck showed the volume in cm^3 occupied by mixing water with the fine aggregate.

The specific mass of the fine aggregate was calculated by Equation 2:

$$\rho = \frac{M_s}{L - L_0} = \frac{500}{L - 200} \qquad (2)$$

At where:

ρ = Specific mass of the aggregate expressed in kg/dm^3;

Ms = Mass of the dried material (500 g);

Lo = Initial reading of the bottle (200 cm^3);

L = Final reading of the bottle.

4) Unitary Mass

The determination of the unit mass was performed according to [12]. First, weighed weights of the empty container and then the container with the dry aggregate sample were made after the unit mass was calculated through Equation 3.

$$\delta = \frac{M(container + sample) + M(container)}{V(container)} \qquad (3)$$

5) Calculation of conventional concrete mix proportion

The method chosen for the determination of the trait was the ABCP (Brazilian Association of Portland Cement), because according to [14], due to the fact that it is based on tables and tables, the method is quick to apply and understand, since it follows a script with the sequences of steps that requires little laboratory experience.

The molding procedures of the cylindrical specimen followed the standard [4]. A standard concrete specimen free of the tire residue was produced according to the trait found, in order to compare the results, and from it were elaborated three different types of concrete, according to the literature, and The first with 5%, the second of 10% and the third of 15% of partial replacement of the small aggregate (sand) with the tire residue.

After production, the concrete was cast in the following dimensions: 10 cm x 20 cm, and the molding and curing of the same were performed according to [4], being 3 test pieces of each percentage, broken for each age of cure, 7, 14 and 28 days

III. RESULTS AND ANALYSIS

A. Characterization of the materials and composition of the mix ratio

1) Aggregates

The lot of the fine aggregate (sand) used in the research is from the Rio Piracicaba - MG. The result of sand characterization is shown in Table 1.

TABLE I. CHARACTERISTICS OF FINE AGGREGATE

Characteristics	Values
Especific mass	2,57g/cm^3
Unitary Mass	1,23g/cm^3
Fineness Module	2,52mm

Ref. [19] in their characterizations of fine aggregates found values of specific mass of 2.79g / cm^3 and modulus of fineness of 1.95 mm, which are approximate values to those found in the present analysis. The highest percentage of grains is between the sieves with a mesh opening of 4.75 mm and those of 150 µm, thus characterizing the material as a fine aggregate according to [6].

The coarse aggregate (gravel) used in this work was of metamorphic origin of gneiss from the quarry Belo Monte - MG. For the present work the crushed stone 1, with a minimum diameter of 9.5 mm and a maximum diameter of 19.0 mm was used. The results of its characterization are presented in Table 2.

TABLE II. CHARACTERISTICS OF COARSE AGGREGATE

Characteristics	Values
Especific mass	2,78g/cm^3
Unitary Mass	1,80g/cm^3
Maximum Characteristic Dimension	12,5mm

Ref. [19] in their characterizations of coarse aggregates found values of specific mass of 2.90g / cm3 and unit mass of 1.47g / cm^3 and maximum dimension of 19 mm, which are values that are between those stipulated by the norm and the found in the present analysis. The highest percentage of grains is in the sieve with a mesh opening of 4.75 mm, thus characterizing the material as a coarse aggregate according to [6].

2) Surface Moisture Content

The surface moisture content was calculated by the oven drying method. Three samples of fine aggregate (sand) were separated and after 24h of drying were reweighed to measure the moisture content. Results related to the surface moisture test are presented in Table 3.

TABLE III. RESULTS OF THE SURFACE MOISTURE TEST

Sample 1	Sample 2	Sample 3
76,38g	54,94g	66,29g
Dry mass: 75.9g	Dry mass: 54,51g	Dry mass: 65,85g

After the calculation, it was verified that the sand in question has a moisture content equal to 0.7%, which should be corrected in the water/cement ratio in the calculation of mix proportion.

B. Concrete recipe calculation

From the results of the characterization of the aggregates the concrete recipe was elaborated by ABCP (Brazilian Portland Cement Association) method for a concrete base of 35Mpa. The corrected moisture mass was found to be 1: 1.44: 2.44: 0.34 (cement, sand, gravel and water/cement ratio).

In order to study the mechanical strength of the concrete with the use of rubber residues in its composition, the fine aggregate was substituted in the proportions of 0%, 5%, 10% and 15% m/m. The construction of the concrete was carried out at the Technological Center of the UEMG João Monlevade unit, with the aid of a free-fall concrete mixer. Subsequently, 36 cylindrical specimens were made in the dimensions of 10cm x 20cm. The proportions of materials used in the relevant test specimens are presented in Table 4:

TABLE IV. CONSUMPTION OF MATERIALS

Materials	CP0	CP5	CP10	CP15
Cement	8.10 Kg	8.10 Kg	8.10 Kg	8.10 Kg
Fine Aggregate	11.664 Kg	11.08Kg	10.49Kg	9.91Kg
Coarse Aggregate	19.76Kg	19.76Kg	19.76Kg	19.76Kg
Waste Tire	0 Kg	0,583Kg	1.16Kg	1.74Kg
Water	2.75L	2.75L	2.75L	2.75L

Compression tests were performed at 7, 14 and 28 days of submerged curing (Figure 1), according to [7].

Figure 1. Submersible curing test specimens

For the mechanical characterization, the test specimens were rectified and later submitted to mechanical tests, in the technological control laboratories of the Valemix concrete in João Monlevade-MG, which were carried out in a universal testing machine. This equipment provides the maximum breaking force and strain-strain curve, which were used to calculate the mechanical strength

C. Compressive strength

In this topic we present the results obtained in the mechanical tests mentioned above. These data allow to evaluate the resistance properties of concrete with aggregates of rubber tire residues compared to conventional concrete.

It can be seen in figure 2 and in Table 5 that the axial compressive strength decreases with the increase of the addition of the rubber residue contents in the concrete by about 27.77% in the 5%, 46% in the 10% and 63%, 23% in the 15%, at the age of cure of 28 days. This reduction may be related to the increase in the content of air incorporated in the fresh state, because rubber is a highly elastic material and because of its low specific mass [16].

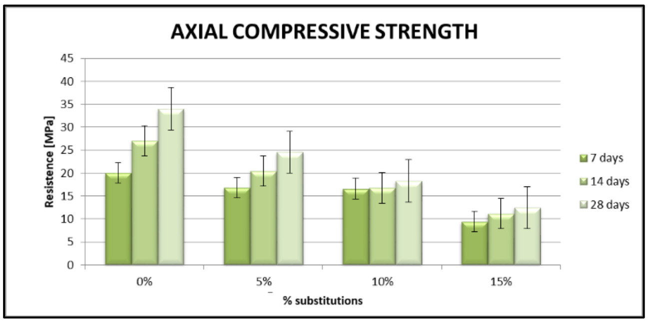

Figure 2. Axial compressive strength

TABLE V. AVERAGE AXIAL COMPRESSIVE STRENGTH

Sample/age	7 days	14 days	28 days
CP0	20 MPa	27 MPa	34 MPa
CP5	16,83 MPa	20,50 MPa	24,56 MPa
CP10	16,63 MPa	16,77 MPa	18,33 MPa
CP15	9,5 MPa	11,24 MPa	12.5 MPa

Compared with the results found by [15], which in their analyzes obtained 23.10 MPa with 5%, 17,22 MPa with 10% and 14,04 MPa with 15% substitution in a trait for concrete of 20 MPa, and 24, 30 MPa with 5%, 16.96 MPa with 10% and 15.06MPa with 15%, in a concrete of 25 MPa, it is noticed that the decrease of the resistance is approximated with the values found in this research.

In the literature, several authors, such as [15, 16], found that with the increase of the rubber residue in the concretes, the compressive strength decreases.

IV. CONCLUSION

These results demonstrate that for the 5% sand substitution ratio of the concrete residue, the compressive results are acceptable for application in places with low demands such as sidewalks, bicycle paths, walls, etc., where, as a rule, resistance is required at compression of at least 21Mpa, and can also be used in molded concrete walls, according to [11]. The use of tire rubber as part of concrete in aggregate form is an essential action both for the preservation of natural resources and for the viability of alternative products with lower cost, leading to a greater awareness of its beneficiation in society.

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