INCORPORATION OF TEXTILE WASTE IN CONCRETE

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Abstract: The textile sector is described as one of the sectors of the economy that generates the most effluents. Such generation is due to the physical and chemical processes that the fabric undergoes until it reaches the finished product. After the final process of obtaining the product, the effluent must undergo treatments to minimize the environmental impacts caused by its disposal. The sludge from the textile industry's effluent treatment systems is destined for disposal, most of the time, to landfills. The aim of this work is the implementation of a new route of inertization of waste (before treatment) from dyeing in the textile industry through its incorporation into concrete. Concreting was carried out with contents of 2.5%, 5%, 7.5% and 10% of textile waste in relation to the cement mass, both for addition and replacement, leaving them in normal cure for 28 days for tests of mechanical resistance to compression and leaching analysis. The mix added with 2.5% of residue obtained the highest resistance, with the exception of the reference, which had a slight difference. The same trace for leaching was classified as non-inert class IIA.

Keywords: Textil waste, waste valorization, concrete.

1. INTRODUCTION.

According to Oliveira et al. [1], the global textile sector produces around 83 million tons, and 25 m^3 of sludge is generated in each million. Among the waste generated by the sector, liquid effluents are the ones that draw the most attention to the issue of process sustainability. The consumption of 150 liters is estimated for the production of 1 kg of fabric, 88% of which is discarded as effluent for treatment and the remaining 12% is lost during the process by evaporation. After the process, the effluent must undergo treatments to minimize the environmental impacts caused by its disposal. As a result of the treatment techniques the textile sludge is obtained.

Waste generated by the textile sector may contain heavy metals, such as Si, Al, Ca, Fe, K, Na, Mg, Zn, Cu, Ba, Mn, Cr, Cd, Pb and Ni [2,3], which have great influence on chemical reactions in concrete, and which are due to the extensive type of fibers, chemicals, dyes and fibers. It is worth mentioning that the amount of water in the sludge can vary, with values between 30 and 80%. This variation occurs due to the last stage of the treatment process, where the sludge is pressed to remove excess water. The sludge from the textile industry's effluent treatment systems is mostly sent to landfills.

Many contaminated residues can be mixed directly into the cement, allowing the incorporation of the contaminants in the solidified matrix. This process is particularly efficient for residues with high levels of toxic metals, because the pH of the cement matrix favors the formation of cations in insoluble hydroxides and carbonates, and many metal ions can be incorporated into the crystalline structure of the cement matrix. Textile sludge is a material with a high moisture content. This feature is advantageous because, in addition to saving energy by not needing to dry the material, drinking water is saved by using the water present in the residue in the cement hydration process. It should be noted that the presence of inorganic compounds and organic impurities, in the waste or in the water used in making the matrix, can negatively interfere with the curing reactions and mechanical characteristics of the cement matrix.

The purpose of this study is to provide a route for making inert the textile waste before its treatment process (necessary measure for its disposal) with its incorporation into concrete. In order to provide new ways for its use and reduce the amount of waste destined for landfills, consequently reducing the volume of landfills, enabling its use as an alternative raw material in concrete and contributing to the preservation of health and the environment.

2. MATERIALS AND METHODS.

Portland cement (CP II-Z 40), a coarse aggregate, two fine aggregates and textile waste were used to produce the specimens of concrete. The textile waste was stored in a greenhouse for three weeks to eliminate the excess of water. Then, it could be characterized and used in concreting later.

The materials used were classified and tested according to NBR NM 248[4] for the maximum dimension and fineness modulus, NBR NM 52 [5] for fine aggregates and textile waste, and NBR NM 53 [6] for coarse aggregates regarding the determination of the specific mass.

The aggregates were submitted to the furnace for drying NBR NM 248 [7]. Subsequently, with the measurement of the total mass of each material for the test, the aggregates were subjected to their granulometric distribution in normal series sieves to determine maximum dimension (the accumulated percentage retained equal to or less than 5% in mass), and as for the fineness modulus (the sum of the retained percentages accumulated by mass of the aggregate divided by 100). The specific mass was determined according to NBR NM 52 [5], for fine aggregates. Coarse aggregate was characterized according to NBR NM 53 [6].

The characterization of the textile waste was accomplished by chemical analysis, x-ray diffraction, thermogravimetric analysis and BET. For this, the waste was milled in a ball mill.

The concretes were made through the standard trace of the data obtained from the granulometric composition of the aggregates to obtain mechanical strength of 30 MPa. In this paper mixtures were carried out to replace the cement, as well as mixtures in which the textile waste was added on the concrete. The slump test was determined according to NBR NM 67 [8], in which, first, the mold and the base plate are moistened. Subsequently, the mold is placed on the base and is kept fixed on the plate with the feet of an assistant who begins to fill the cone up to its top in three layers, each layer receiving 25 blows with a tamping rod, distributing uniformly the blows over the layer and never passing through the previously compacted layer with the rod. The top of the mold is leveled and removed, the slump of the concrete is measured by determining the difference between the height of the mold and the height of the axis of the specimen. The water/cement (w/c) ratio was kept constant for all mixes.

For the preparation of the specimens, the concrete was introduced into the mold, in three layers, each layer being subjected to 12 blows with a tamping rod, never crossing the previous layer with the rod during the blow ABNT NBR 5738 [9]. The surface of the specimen is leveled and placed in the desired curing process, in this case, normal curing for 28 days, with an average temperature of 22°C and relative humidity of 63%.

The compressive strength test was performed in an universal testing machine with a variable loading speed from 0.3 MPa/s to 0.8 MPa/s.

3. RESULTS AND DISCUSSION.

The chemical composition of the textile waste is presented in Table 1, with predominance of aluminum (11.30%) and of smaller values, such as silica (4.62%) and sodium (3.58%). The large percentage of these elements in the residue is related to the chemical products and processes used to make the textile material to obtain the final product.

The textile waste consists mainly of water and organic matter, as can be seen in the chemical analysis (Table 1) and thermogravimetric analysis (Figure 1). There was a great loss of mass, around 84.62%, due to the elimination of water and organic matter, resulting in a residual mass of 15.38% at the end of the test, and the mass loss stabilized from 650°C.

Table 1. Chemical Analysis of the textile mud used in the experiments.

Element	Percentage (wt%)
Manganese	0.04%
Magnesium	0.14%
Potassium	0.35%
Calcium	0.49%
Iron	0.63%
Sodium	3.58%
Silica	4.62%
Aluminum	11.30%
Loss on Ignition	78.85%

Both tests demonstrate that the constituent mass of the residue is a large percentage of water alone, this factor is explained by the various treatments, chemical processes and use of chemical products to obtain the final product, a good example for this is starch ($C_6H_{10}O_5$), a product widely used in fabric sizing and which provides a gelatinous consistency to the residue, in addition to being a material with high water absorption, a factor that is extremely important in terms of the characteristics [10].

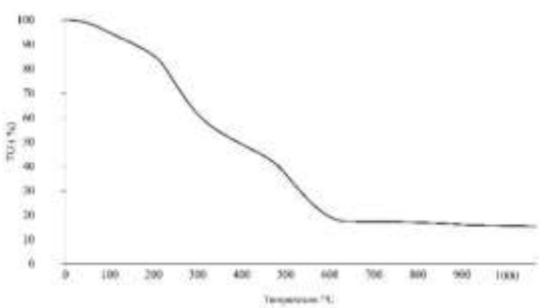

Figure 1. Thermogravimetric analysis of textile waste.

The X-ray diffraction (figure 2) shows that the textile waste did not present great variations of crystallinity peaks, demonstrating an amorphous structure.

The BET test showed that the textile waste presented a surface are of 8.1 m²/g. The granulometric analyzes of the inputs are presented in table 2.

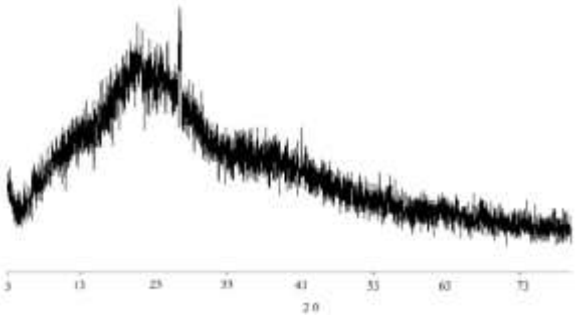

Figure 2. X-ray diffraction of the textile waste.

Table 2. Size analyses of the inputs used in this paper.

Material	Maximum dimension	Fineness modulus	Especific mass
Textile waste	4.8	3.28	1.53
Coarse aggregate	9.5	2.91	2.9
Fine aggregate 1	4.8	3.45	2.58
Fine aggregate 2	0.6	1.88	2.64

The water/cement ratio was maintained in all mixtures, in which during the concreting period, a constant reduction in slump test was clearly perceived as the textile waste content increased, both for addition and replacement, as it can be seen in table 3.

Therefore, this demonstrates that the insertion of textile waste affects the water/cement factor in terms of workability and cohesion between the constituent materials of concrete [11].

Table 3. Slump Test of the concretes with both addition and replacement of textile waste.

Concretes	Slump (cm)
Reference	9.00
Addition of 2.5%	8.20
Addition of 5.0%	5.40
Addition of 7.5%	2.80
Addition of 10.0%	1.50
Replacement of 2.5%	4.50
Replacement of 5.0%	3.20
Replacement of 7.5%	2.40
Replacement of 10.0%	1.20

The mechanical resistance to compression was reduced according to the continuous addition of the textile waste. This can be explained according to the constituent components of the residue, which react strongly with the hydration of the cement. During the hydration process, chloride ions dissolve calcium hydroxide ($Ca(OH)_2$) – Portlandite (CH), which is abundant in the matrix paste, causing an increase in the porosity of the cementitious mass. Chloride ions can also combine with aluminum, dissolved or complexed, forming hydrated calcium monochloroaluminate, which enhances the properties of concrete. However, the presence of the sulfate anion can cause a mass expansion due to the formation of the crystalline structure of ettringite ($C_3A.3CSH_{32}$), which is formed when the sulfate combines with the hydrated or anhydrous calcium aluminate. The chloride anion can replace the sulfate anion in the formation of ettringite, as well as silica and aluminum. Matrix cracking can occur if there is excessive ettringite formation [12].

Chlorides can enter concrete in several ways, and one of the main ones is through the materials used in the manufacture. Chlorides can be found in contaminated aggregates, mainly in coastal regions, in brackish or excessively chlorinated waters, and even in cements, since chlorides contribute to initial resistance [13]. After a period of 28 days, the specimens were tested to determine the compressive strength, in which the mixture with addition of 2.5% of the textile wastes reached the highest mechanical resistance, just not being superior to the reference, as shown in table 4.

Table 4. Test of mechanical resistance to compression

Concretes	Average compressive strength (MPa)
Reference	30.41
Addition of 2.5%	28.63
Addition of 5.0%	25.14
Addition of 7.5%	17.73
Addition of 10.0%	12.90
Replacement of 2.5%	26.47
Replacement of 5.0%	23.50
Replacement of 7.5%	21.90
Replacement of 10.0%	13.47

With the data obtained through the leaching test, shown in table 5 and table 6, and according to ABNT NBR 10004 [14], the textile waste was classified as class II A - Not inert. The element that cooperated for its classification from the beginning was Aluminum (Al), which exceeded the value stipulated by the standard far beyond what is allowed, more specifically 3.5 times, having 0.71 mg/L in its general composition. Barium (Ba) also exceeded the limit established in the norm, but it was not such an exorbitant value compared to aluminum. The pH of the residue was 12.5.

Table 5. Metal leaching test.

Metals		
Element	Result (mg/L)	Maximum limit (mg/L)
Aluminum	0.71	0.20
Copper	0.07	2.00
Iron	0.02	0.30
Manganese	< 0.01	0.10
Nitrate	0.2	10.00
Sodium	43.61	200.00
Zinc	< 0.01	5.00
Chrome	0.05	0.05
Mercury	< 0.001	0.001
Lead	< 0.01	0.01
Selenium	0.01	0.01
arsenic	< 0.01	0.01
Barium	1.11	0.70
Cadmium	< 0.01	0.005
Silver	< 0.01	0.05

Table 6. Leaching test of physicochemical properties.

Element	Result (mg/L)	Maximum limit (mg/L)
Chlorides	7.90	250.00
Surfactants	< 0.10	0.50
Sulfates	10.50	250.00
Phenols	< 0.01	0.01
Fluorides	0.40	1.50

4. CONCLUSIONS.

It is understood that nowadays, rationalization and sustainability are predominant and very important factors for any manufacturing process, mainly in terms of reducing expenses with waste generation as well as the elaboration of alternative means that can be carried out for reuse.

In the study, it was noticed that the incorporation of the textile waste in the concrete presented a satisfactory performance on the mechanical resistance, in which the mixture with addition of 2.5% of the waste presented a decrease of 5.8% on the mechanical resistance. However, the leaching test showed an excess of aluminum, indicating that the concrete did not inert the textile waste. Therefore, complementary studies are needed to investigate the influence of waste in other methodologies with its incorporation in concrete, or even beyond, such as, for example, in ceramics, so that viable alternative routes for its reuse can be analyzed and studied.

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