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Soil-Cement Floor Produced with Alum Water Treatment Residues

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Abstract**—**From a concern regarding the environmental impacts caused by the disposal of residues generated in Water Treatment Plants (WTP's), alternatives ways have been studied to use these residues as raw material for manufacture of building materials, avoiding their discharge on water streams, disposal on sanitary landfills or incineration. This paper aims to present the results of a research work, which is using WTR for replacing the soil content in the manufacturing of soil-cement floor with proportions of 0, 5, 10 and 15%. The samples tests showed a reduction mechanical strength in so far as has increased the amount of waste. The water absorption was below the maximum of 6% required by the standard. The application of WTR contributes to the reduction of the environmental damage in the water treatment industry.

Keywords**—**Residue, soil-cement floor, sustainable, WTP.

I. INTRODUCTION

CURRENTLY, the water treatment process requires the use of many chemicals, due to the increasing pollution of water sources, producing a large amount of waste.

The role of WTP's is to treat the water collected in the water sources and make it available for distribution in urban centers. During such processing, oxidation processes are used, coagulation, flocculation, sedimentation, filtration, disinfection, fluoridation and pH stabilization. After oxidation processes coagulant is added to form impurity flakes that are decanted and filtered, retaining impurities not removed in previous steps. These impurities, mainly removed from filters and decanters are called WTP residues or WTR's. These residues vary in their composition depending on the condition of the raw water, the source and process chemicals used, as well as the way to clean the filters and decanters.

The disposal of industrial waste are global agenda on the grounds of improper disposal and pollution generated. The WTR's raise concerns regarding its disposal, the necessity to seek other alternatives, so as not to pollute the environment.

The fate of these residues was the watercourses near the stations. However, the current laws restrict this practice. WTR's in accordance with Brazilian technical standard NBR 10.004 / 2004 should be minimized, reused or recycled.

According Richter (2001) [1], the WTR's are composed of water, suspended solids from raw water and chemicals added during the treatment process. Grandin et al. (1993) [2] points out that WTR's are composed of organic and inorganic matter such as algae, bacteria, viruses, colloids, sands, clays, calcium, manganese, iron and others. The geological nature of the watershed and the external interference such as pollution of water sources by various sources, such as industrial waste, may differentiate the physical and chemical characteristics of the WTR between regions.

Therefore, metals such as zinc, nickel, copper and especially aluminum, make up the WTR in varying proportions, depending on the region where the water is collected. May present positive or negative effects in treatment techniques and reuse of wastes.

There are several studies to reuse of these residues in construction. This practice may help to reduce environmental impact and decrease the quantity of natural aggregate taken from nature. Currently, construction industry consumes 14-50% of all natural resources of the planet.

Paixao et al. (2008) [3] have reported the effects of the incorporation of the residue in clayey ceramic, having observed that the use of up to 10% of WTR does not change the mechanical strength of bricks, but reduces bending resistance of dried bodies. WTR was also used for the production of concrete (between 4% and 8% of the total moisture) [4], and the results have shown mechanical compressive strength greater than 27 MPa. Up to 10% of alum WTR and up to 20% of ferric WTR have been used by [5] for the production of structural ceramics materials and the results have shown good compressive strength for all the samples. Sales et al. (2011) [6] have used 13% of residue for producing concrete for non-structural application and have obtained compressive strength of 11 MPa.

This article aims to evaluate the use of WTR in the production of soil-cement interlocking flooring, making the compressive strength tests and water absorption required by the standard and study its technical feasibility.

II. METHODS

The WTR was collected at the drying lagoon of the WTP of Goiânia (Brazil). The water treatment uses only aluminium sulphate as coagulant. The residue was milled to obtain particle size compatible with fine aggregate, which was

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controlled through granulometric characterization according to the standard [7], using a laser testing equipment. The WTR was also analysed by scanning electron microscopy (SEM), using a Jeol JSM–6610 equipment, and energy dispersive X-ray spectroscopy (EDS), using a Thermo scientific NSS Spectral Imaging, in order to know the morphologic characteristics of its particles, the internal particle porosity and the elemental chemical analysis.

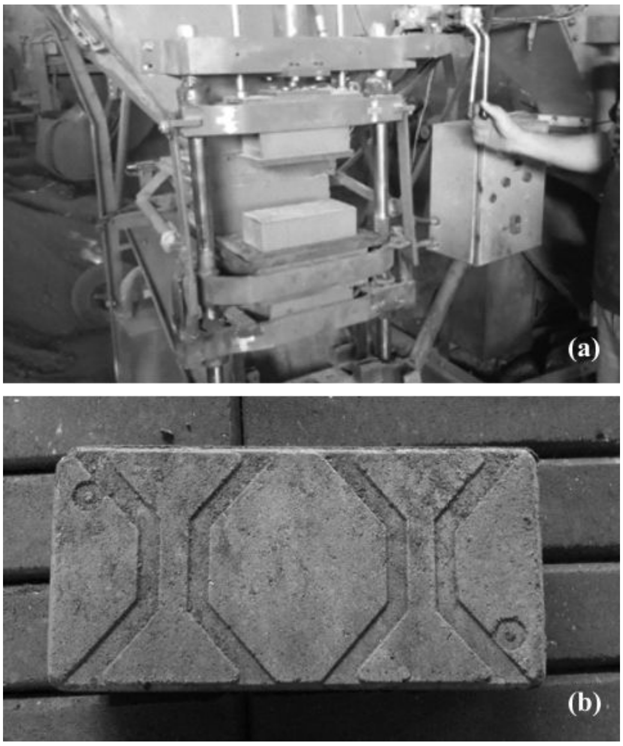

Fig. 1 (a) Hydraulic press manufacturing a floor, (b) Soil-cement floor made with residues from WTP

The WTR was used in different mixtures for replacing soil for the production of soil-cement floor, following the procedures of the standard [8]. Soil-cement floor having dimensions of 12.5 (W) x 25.0 (L) x 7.0 cm (H) were produced according the procedures setup in the standard [8], using WTR mixed with soil as aggregate and cement, to have a minimum strength of 35 MPa and 6% of maximum rate of water absorption. Four compositions were prepared, as presented in Table I, include a control composition with only soil and cement (composition 1).

20 pieces of each composition were produced for testing in a local factory of artefacts soil-cement (*Ecofaber Artefatos de Solo-Cimento, Goiânia, Brazil*), using a hydraulic press model Eco Premium 2600, with a pressure of 6 ton/brick, as presented in Fig. 1. Compressive strength and water absorption were determined for curing times of to 7, 28, and 56 days after production.

III. RESULTS AND DISCUSSION

The particle size analysis of the WTR was performed on homogeneous sample of the residue. Grains with size ranging from 1.944 µm to 2000 µm were identified on the laser testing. The moisture content was 25.9%. The results also show a higher percentage of small particle size, with grains ranging from 0.075 to 1.20 mm, forming 79.23% of the total sample, and grains with dimensions smaller than 0.075 mm totalizing only 5.39% of the sample. The larger grains are 20.77% of the particles ranging from 2.40 to 9.50 mm. The grain sizes are a bit greater than the ones used by [11] for the production of lightweight concrete produced with a composite based on WTR and sawdust.

In the four compositions a progressive increase in water consumption was observed, (from 7L to 10L) as the percentage of WTR increases (from 0% to 15%), which reach a maximum of approximately 42% for the composition 4. This evidence could be explained by the higher need of water for the aggregation of cement, residue and soil for the compositions with more WTR, which is proven by the higher absorption of water evidenced by the compositions 3 and 4 for lower curing times.

The compressive tests show that using a cement/aggregates ratio of 1:3 with up to 15% of WTR, the compressive strength is above 14 MPa. The higher value was obtained for the composition 1 with 32 MPa, after 56 days of curing time. Samples of the compositions 2, 3 and 4 have presented resistance below than the control sample (composition 1) for curing times between 14 and 56 days, as shown in Fig. 2.

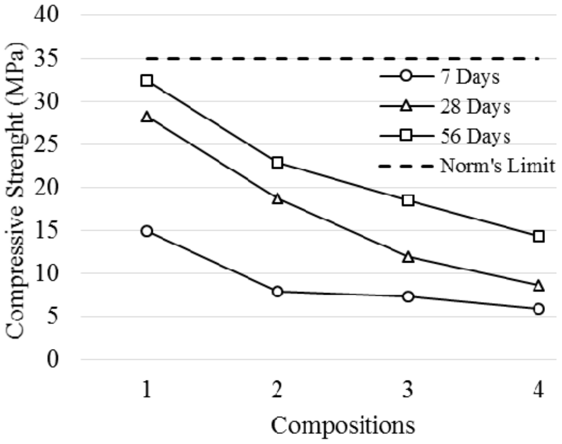

Fig. 2 Compressive strength of soil-cement floor for all compositions at 7, 28, and 56 days of curing time

The maximum rate of water absorption should be 6%, according to the standard NBR 9781 [8]. Fig. 2 shows that for 28 days of curing time, the compositions 2 and 3 were obtained values above 5% and the composition 4 approximately 6%. For the higher curing time (56 days), all the compositions show water absorption below 6% and, therefore, all compositions show compressive results below than the norm allows, for high traffic. According to [9] after

28 days approximately 65% of the anhydrous cement was already reacted.

TABLE I
SOIL-CEMENT COMPOSITION OF THE INTERLOCKED FLOOR

Composition Number	Soil (%)	WTR (%)	Cement (%)	Crushed Gravel (%)
1	60	0	30	10
2	55	5	30	10
3	50	10	30	10
4	45	15	30	10

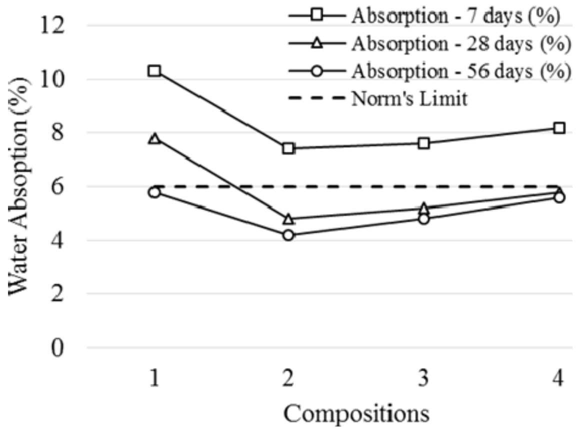

Fig. 3 Water absorption by soil-cement bricks for all compositions at 7, 28, and 56 days of curing time

Alum WTR normally contains colloidal iron and alum hydroxides, colloidal or dissolved organic matter, clay and silt [10]. Therefore, as WTR increases, the amount in organic colloids and clay can cause retardation of cement set, which could have been responsible for the worst results observed for the compositions 2 to 4.

Fig. 4 shows the morphological structure and the elemental chemical analysis of WTR sample. It was observed the concentrated presence of aluminium, which can be associated to isomorphous substitution of Si by Al or disassociation of hydroxyl ions into the alumsilicate structure of the residue. The EDS spectrum also shows a crystalline phase, which contrast with clay minerals that are commonly amorphous. The composition shows considerable presence of Al, Fe and Ca, which are favorable cations for cement hydration. Sales et al. [11] have produced lightweight concrete with WTR and sawdust and have shown that the concentrations of Al, Fe and Pb were reduced in the leached from the concrete samples, because the cations have reacted with the alumsilicate structure of the cement. These results may mean that the incorporation of WTR in cementitious artifacts can also contribute for reducing the impact of leaching metals from the residues to the environment.

IV. CONCLUSIONS

The preliminary results of this project show that WTR can be used for the production of soil-cement floor, by replacing the soil content of the mixture, which is also an environmental advantage for the reuse of this type of residue.

The residue may have influenced the floor curing time, because the cement hydration was affected. Therefore, WTR modifies the mixture, causing a decrease in resistance. New compositions may be performed with a higher percentage of cement and with inclusion of additives for increasing mechanical strength. which could facilitate to achieve the minimum strength required by the standard.

The results show that the composition with 5% of WTR, can be used in the manufacture of interlocked floor to pedestrian traffic as in sidewalks and landscaping.

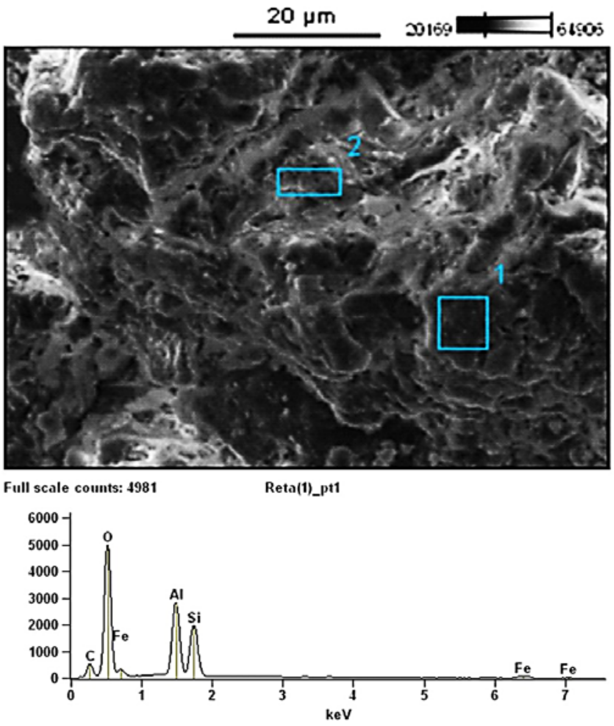

Fig. 4 SEM micrograph and EDS spectrum of WTR

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