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Reuse of WTP Sludge - Rio Manso in Ceramic Blocks

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Abstract - This study aims to reuse the sludge sand from WTP - Rio Manso in ceramic blocks. For physical characterization of the residue was carried out, with the tests: granulometry; liquidity limit, plasticity limit, plasticity index. The axial compressive strength of the ceramic blocks produced with the sludge, used as an addition, was evaluated at concentrations of 7% and 10%. From the granulometric curve, it appears that the sludge is uniform and has a behavior similar to that of sand. The plasticity index showed that both samples showed low plasticity. In the compressive strength analysis, the sample with 7% obtained an increase of 4% and the sample with 10% obtained an increase of 21.33%, reaching values above the minimum, 1.5 MPa, for hollow ceramic blocks. The model produced after the heating process reached a reddish color, which is ideal for the ceramics industry, for marketing purposes. Therefore, the reuse of sludge from WTP - Rio Manso can be applied in ceramic sealing blocks.

Keywords- *Sludge, Water Station, Ceramic Blocks*

I. INTRODUCTION

The advance of society, regarding science, population growth and the quality of life, there is an increase in the demand for drinking water, to serve the world population [1]. The process of treating raw water in drinking water generates a waste, called sludge. When water is treated in water treatment plants (WTP), it undergoes processing, such as coagulation and flocculation, where this sludge is generated. Due to these circumstances, some studies have been carried out to use the WTP sludge in ceramic blocks. Sludge is generated in this process of treating raw water in drinking water [2], basically in the coagulation and flocculation phases [3]. Sludge is a solid waste, and its properties depend on the type of water source collected [4], the amount of water treated, the type of process used and the characteristics of the treatment [5].

Some studies show that a typical WTP produces around 100 thousand tons of sludge [6], on the other hand only Taiwan is capable of producing 200 thousand tons per year [7]. However, in any case, the quantity is immense, and they are mostly dumped in nearby water courses [8]. Chemical characterization by means of X-ray fluorescence (XRF); mineralogical characterization by means of X-ray diffraction (XRD) demonstrate that the sludge can present heavy metals (Cr, Cu, Ni, Pb and Zn), and its disposal has technical and economic implications, being that in most cases they are dumped in the nature, causing negative environmental impacts, so reuse is a good alternative [9]. The chemical compounds with the highest sludge content are Al2O3 and SiO2 [12-13]. The most commonly found mineral is quartz [11-13]. The civil construction sector is a favorable place to reuse waste, as it has technical, environmental and economic benefits [10]. Several studies have been carried out on the behavior of incorporating WTP sludge into ceramic compounds. Some analyzes are carried out on the ETA sludge to be used in ceramic blocks, with water absorption and resistance to compression being the most common [11-13]. There was less water absorption [12-13] and there was an increase in compressive strength, being higher than samples with clay only [11-13].

However, other analyzes are also carried out, such as: the liquidity limit, plasticity limit, plasticity index that demonstrated that mixtures of clay and sludge are highly plastic. And other studies have been carried out, such as compaction, bulk density, porosity and microstructure, however the studies are still divergent and need further study [12].

The aim of this study is to analyze the addition of sludge sand, from WTP - Rio Manso, in ceramic blocks. Performing the physical characterization, such as: granulometric analysis of the sludge; plasticity limit; liquidity limit, plasticity index and resistance to compression with the additions of 7% and 10% of sludge. Produce a sample of ceramic block, to analyze the color, after the heating process.

II. MATERIALS AND METHODS

A. Materials

The materials applied in this research were: clay, water and sludge. Clay used was supplied by the materials laboratory, from the civil engineering department of UNIBH. The sludge used comes from the Rio Manso WTP, in the state of Minas Gerais. The water used comes from a public drinking water distribution network by COPASA (Companhia de Saneamento de Minas Gerais).

B. Methodology

The sludge was collected at the Brumadinho WTP, in its liquid state, approximately 20 liters and placed in a container.

Then it was dried at room temperature, approximately 21°C [14], for 21 days. After the drying process, the sludge in its solid state was weighed and a value of 1.5 kg was obtained. The sludge was agglutinated, and therefore, it was necessary to carry out the grinding process, until the sizes of these particles were homogeneous [15]. After the grinding process, the sludge was separated and then placed in the greenhouse, where it remained for a period of 24 hours, at a temperature of 105°C.

After these processes, the granulometry analysis of the sludge was carried out using the sieving method [16]. For the plasticity limit (LP), it was analyzed based on NBR 7180 [17] separating 6 samples, 3 with 7% of sludge addition and 3 with 10%, continuing the analysis and after the samples humidification performed the procedure through the ground glass plate [18, 19]. The analysis of the liquidity limit (LL) was obtained based on NBR 6459 [20] using the Casagrande shell method where 3 samples with 7% and 3 samples with 10% of sludge were separated.

In the analysis of mechanical properties, 12 specimens were made in total. There were 6 specimens with 7% sludge as an additive, and 6 specimens with 10% sludge as an additive. The specimens were cylindrical and had the following dimensions 5x10 cm according to [21] and were placed to dry at room temperature for 28 days. The specimens were molded and placed in the Mufla Microprocessor-Q318M oven, until reaching a temperature of 1000°C, as it is recommended up to 10% of sludge addition, at this temperature [22]. And the specimens were kept for 3 hours at that temperature, and then they were cooled to room temperature (Fig. 1).

Figure 1. Heating process – Mufla oven

The compressive strength analysis of the specimens was performed on the universal machine, Times Group Inc, with a speed of 0.005 to 500 mm / min and with a total capacity of 150 Kgf based on the standard, as shown in Fig. 2.

Figure 2. Compressive strength

III. RESULTS AND ANALYSIS

A. Characterization

Within the physical characterization processes, the granulometric distribution was made by the sieving method [2] generating the result of Fig. 3.

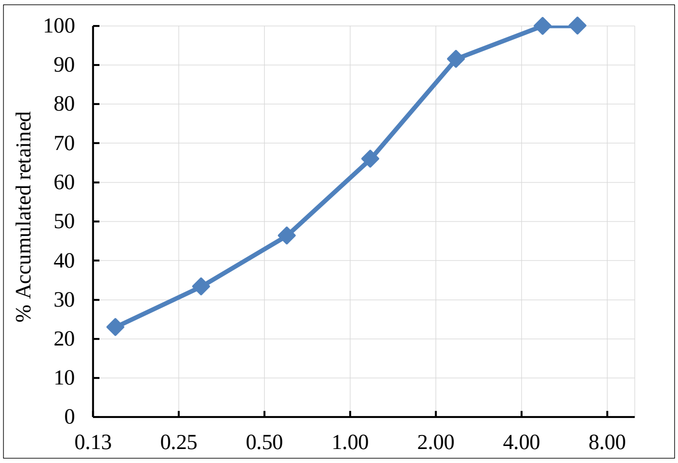

Figure 3. Granulometric curve of the Sludge

The physical characterization analyzes serve to show whether the WTP sludge has characteristics similar to other materials that are also applied in civil construction. Through physical characterization, you can decide the trace of the materials, the percentages to be applied in the mixture, without reducing the mechanical properties of the final material [23].

And by means of this procedure and with other analyzes, it is possible to determine if the sludge behaves like: sand, silt or clay, if there was a granulometry: continuous; discontinuous; uniform; well graded and poorly graded [24]. After analyzing the graph, it can be determined that the studied sludge has a uniform and poorly graded characteristic [2 and 24]. The sludge also presented a behavior similar to fine sand due to its fineness modulus value being 2.3, thus presenting a lower water absorption rate [24].

B. Plasticity and liquidity limit test

The plasticity limit serves to show the minimum amount of water necessary for the ceramic mass to be shaped. The liquidity limit is intended to indicate the maximum amount of water, so that the ceramic mass is moldable [23]. The results found for the LP in the samples of 10% and 7% with the addition of sludge (Fig. 4 and 5), were: 28.51% and 35.32% obtaining a value for the moisture content (W) of respectively, 28,51% and 35.32%. For the results found in the LL analysis in the samples of 10% and 7% with the addition of sludge, they can be determined by means of the graphs, which are in Fig. 4 and Fig. 5. These values: 32.86% for the sample with 10 % and 38.95% for the sample with 7% sludge [25]. With the obtained values it was possible to mold the specimens, and produce a ceramic block.

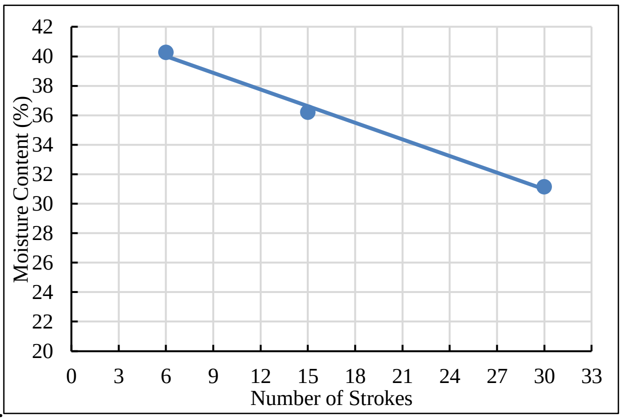

Figure 4. Result of the 10% liquidity limit 10%

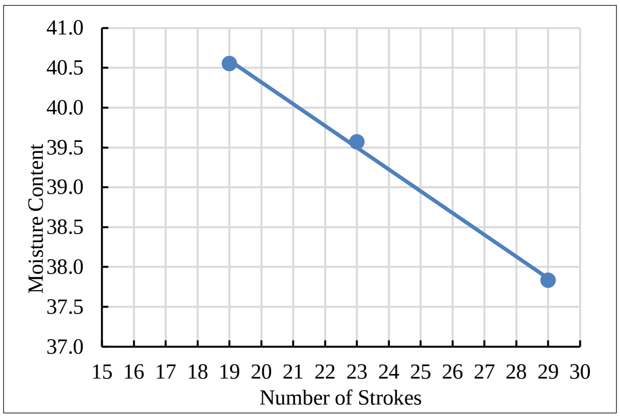

Figure 5. LL result with 7%

The plasticity index (PI), found for samples with 10% sludge addition, was 4.35%. For samples with 7% of sludge, the value of 3.63% was found. The values found for PI are considered to be of low plasticity [7 and 26]. The low values of plasticity index, may be due to the low water absorption capacity of the sludge, as the sludge had a sandy characteristic [2]. This factor can lead to a greater difficulty in molding ceramic bricks, which was verified during the modeling and burning processes of the specimens.

It was observed that the higher the percentage of sludge added to the clay, the lower the values of LL and LP. Since the IP values did not present this same logic, as they increased with the addition of the sludge. It should also be noted that with a higher percentage of sludge, it caused a decrease in the moisture content of the samples. This fact can be related to the sandy characteristic of the sludge, and the greater the amount of clay, the greater the water absorption by the clay-sludge mixture. Table 1 shows the results obtained.

TABLE I. RESULTS ABOUT P.L, L.L AND PI

Samples	P.L	L.L	P.I
7%	35,32%	38,95%	3,63%
10%	28,51%	32,86%	4,35%

C. Compressive strength

Fig. 6 shows the results obtained in the analysis of compressive strength, after going through the firing process, at a temperature of 1000oC for 3 hours. The minimum value required for compressive strength for a hollow brick is 1.5 MPa [27]. The sample containing 7% of sludge as an additive, showed a 4% increase in compressive strength compared to [27]. The sample with 10% of sludge incorporation, presented an increase of 21.33% also in relation to [27]. The increase in compressive strength, when low sludge concentrations are incorporated, can also be observed by [22]. The sample that obtained the greatest resistance to compression was the one that presented the highest index of plasticity, being the sample with 10% of sludge. It may be that the plasticity index may influence the compressive strength, however it would be necessary to carry out further tests and deepen the analysis.

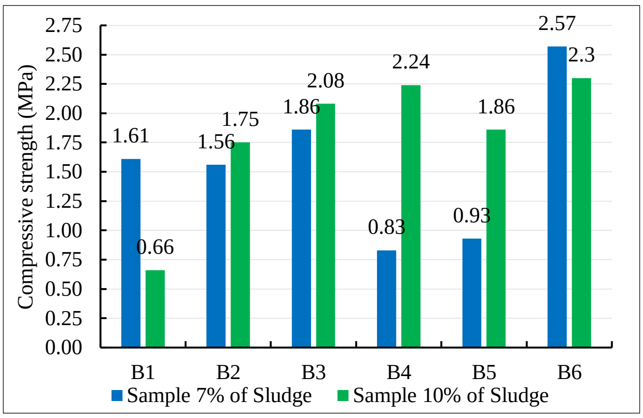

Figure 6. Compression analysis results graph

The increase in resistance may be due to the microstructure of the clay behaving like a durable material similar to glass, being a transition to the glassy state [28].

D. Ceramic block model

Fig. 7, represents a brick model produced with 10% sludge addition, for presentation purposes only. It can be seen that the brick has a reddish color.

Figure 7. Solid Brick

IV. CONCLUSION

In the analysis of physical characterizations of the sludge from WTP - Rio Manso, it can be observed that the sludge sand presents fine granulometry, with its fineness module being 2.39, being considered fine sand. Therefore, because this sand is finer, it absorbed a greater amount of water.

For LP, LL and IP, the sample that presented the highest LP value, was the one with 7% of sludge addition, the value being 35.32%. In the LL analysis, the sample with 7% of sludge presented the highest value, being 38.95%. The sample with the highest moisture content was 7% sludge addition. However, for the analysis of plasticity index, the sample with the highest value was 10% of sludge addition, with a value of 4.35%. Therefore, it was observed that a greater amount of sludge, a lower moisture content occurs.

As for the compressive strength, the sample with the addition of 7% of sludge, showed an increase of 4% and the sample with the addition of 10% of sludge, showed an increase of 21.33%, all in relation to the value of 1, 5MPa. It can be seen that the sample that presented the least resistance, the one with 7% of sludge, presented a higher plasticity index and a higher moisture content. For the sample with 10% sludge addition, which had the highest compressive strength, it had the lowest values for plasticity index and moisture content.

The brick was built for the purpose of visual analysis of color, with the addition of 10% sludge. And it was possible to see that the brick had a reddish color, which makes it viable for the commercialization of the ceramic industries. Therefore, the sludge from WTP-Rio Manso showed positive results in the production of hollow ceramic blocks, requiring further tests to validate the material.

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