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Recycling of Water Treatment Plant Waste for Production of Soil-Cement Bricks

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Abstract

The water treatment plants generate large amounts of municipal sludge that must be discarded. A crucial issue is to find an ecological destination for its final disposal. This work studies the possibility of incorporating water treatment plant waste into soil-cement bricks for civil construction. A sample of this waste material was analyzed for chemical composition, X-ray diffraction, particle size, plasticity, and organic matter. Mixtures of soil-cement containing up to 5 wt.% of waste as a partial substitute of soil were pressed and cured for 28 days. The effects of the incorporation of the water treatment plant waste were determined by evaluating different physical properties such as compressive strength, apparent density, and water absorption. The results indicated that the water treatment plant waste is a plastic material composed mainly of kaolinite particles. The results also showed that the water treatment plant waste could be used for production of soil-cement bricks, helping to reduce the environmental impacts of the water treatment plants.

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Keywords: waste; water treatment plant; recycling; soil-cement.

1. Introduction

Currently, the need to preserve the environment has drawn much attention of the academic world and industry, especially for processes involving pollutant solid waste recycling. This derives from the fact that the use of solid wastes greatly contributes to the environmental protection and sustainable development.

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A particular case of the generation of large quantities of pollutant solid wastes is the water treatment plants for human consumption (Richter, 1991; Bernardo and Dantas, 2005). Traditionally, the final destination of municipal sludge from water treatment plants has been water systems nearest to no treatment. This causes environmental problems such as the risk to aquatic life, increasing the amount of solids, changes in the color and turbidity, sedimentation, increase of the concentrations of metals from the waste, and may cause public health risks (Oliveira, 2004). A crucial issue is to find an ecological destination for final destination of the water treatment plant waste.

In recent years, the construction industry has become a promising alternative for the disposal of solid wastes of various types and origins, compared with traditional methods (Oliveira, 2004; Turgut and Algin, 2007; Al-Zboon et al., 2010; Pinheiro and Holanda, 2013; Begum et al., 2013). On the other hand, appears in the literature (Silva, 2009) that there are few studies on the incorporation of municipal sludge (waste) of the water treatment plants in soil-cement bricks.

This work studies the possibility of incorporating water treatment plant waste into soil-cement bricks for civil construction. The soil-cement brick is considered environmentally friendly and economical because is not necessary carry out the firing step, as compared to conventional clay brick. In addition, the soil-cement brick is highly attractive for housing construction mainly in developing countries.

2. Experimental procedure

The representative sample of waste sludge was collected in water treatment plant in the region of Campos dos Goytacazes-RJ, Brazil. The waste sludge was sedimented to remove the excess water, homogenized and subjected to drying in an oven for 48 hours at 110 °C. The dry waste was sieved until a fraction passing through a 35 mesh (425 um ASTM) sieve.

Mineralogical analysis of the water treatment plant waste sample was performed by X-ray diffraction (diffractometer Shimadzu, XRD-7000), using monochromatic radiation of Cu-Kα at a rate of 1.5° (2θ)/min. The chemical composition of the sample was determined by using energy-dispersive X-ray spectrometer (Shimadzu, EDX-700). The particle size analysis was determined by standard procedures according to NBR 7181-84. The Atterberg plastic index was determined according to NBR 6459-84 and NBR 7180-84 Brazilian standards. The content of organic matter was determined according to the Walkley-Black (Rodrigues, 2012).

Mixtures of soil-cement containing up to 5 wt.% of water treatment plant waste as a partial substitute of soil (Table 1) were prepared. A traditional composition of soil-cement (soil: cement - 10:1) was used as reference. Portland cement and soil commercial were used. Soil/waste/cement mixtures were wetted with 16 wt.% of water. Cylindrical pieces were prepared by uniaxial pressing (18 MPa), and then cured for 28 days in a humid chamber (~ 95% humidity at 24 °C).

Table 1. Compositions of the cementitious mixtures.

Samples	Soil (%)	Waste (%)	Cement (%)
LR1	100.00	0.00	10.00
LR2	98.75	1.25	10.00
LR3	97.50	2.50	10.00
LR4	95.00	5.00	10.00

The following technological properties of soil-cement bricks were determined according to standard procedures: water absorption (ABNT, 1994a), compressive strength (ABNT, 1994a), and bulk density (Rodrigues, 2012).

3. Results and discussion

Figure 1 displays the X-ray diffraction pattern of the water treatment plant waste sample used in this work. The mineral phases identified included kaolinite, quartz, gibbsite, mica, and goethite, with predominance of kaolinite.

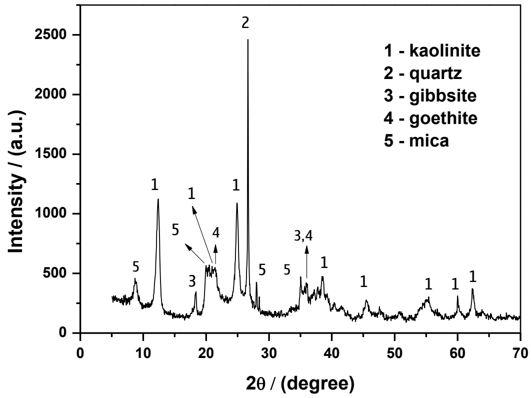

Fig. 1. X-ray diffraction pattern of the water treatment plant waste.

Table 2 presents the results of the chemical composition and the ignition loss of the water treatment plant waste. It is observed that the waste is essentially composed of Al_2O_3, SiO_2 and Fe_2O_3, about 70.98%. These results agree with the results of X-ray diffraction (Fig. 1). On the other hand, the waste sample has a high loss on ignition (at 1000 ºC) of about 24.50 wt.%. According to (Oliveira, 2004), this is due mainly to the loss of water from clay minerals and dehydration of the hydroxides, and also the decomposition of organic material. In fact, the sample waste has a high content of organic matter (25.85 wt.%).

Table 2. Chemical composition of the waste sample.

Compounds	Wt.%
Al_2O_3	31.18
SiO_2	29.59
Fe_2O_3	10.21
TiO_2	1.04
K_2O	1.27
SO_3	1.61
CaO	0.34
ZnO	0.02
MnO	0.14
Loss on ignition	24.50

The water treatment plant waste sample presented a large particle size range (1 to 600 μm), whose median size is about 5 μm. It was found that the amount of clay fraction (< 2 μm) was relatively high in the order of 35 %. The high percentage of fine particles of the waste is essentially related to the presence of kaolinite, as shown in Fig. 1. The high content of clay fraction is very annoying to the homogenization step of the soil-cement mixture. This may affect the cement hydration process (Rodrigues, 2012). The waste sample presented high plasticity (Atterberg plastic index = 25.4 %), and is well correlated with the particle size distribution data. In addition, the plasticity index value suggests that the water treatment plant waste could be used to manufacture soil-cement bricks, since it is added in small amounts.

Figure 2 shows the results of the compressive strength of the soil-cement bricks incorporated with water treatment plant waste and cured for 28 days. The effect of the waste addition was to decrease the mechanical strength of the soil-cement bricks. Despite this, the values of mechanical strength of the soil-cement bricks are higher than the specified value (≥ 2 MPa) in NBR 10834 (ABNT, 1994).

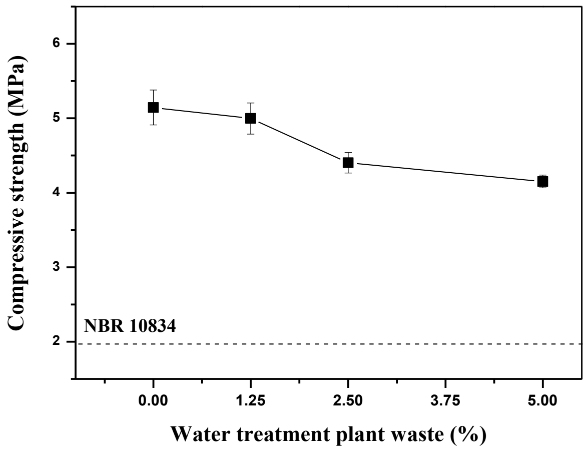

Fig. 2. Compressive strength of the soil-cement.

Figure 3 shows the apparent density values of the soil-cement bricks incorporated with water treatment plant waste. It is noted that, with increasing amounts of water treatment plant waste, there is a tendency for the lower value of the apparent density of the soil-cement bricks. This is in accordance with the results of mechanical strength (Fig. 2).

Figure 4 shows the water absorption values of the soil-cement bricks incorporated with water treatment plant waste and cured for 28 days. It is observed that the water absorption values of the soil-cement bricks are strongly influenced by the waste addition. In general, the water absorption has been increased with the waste addition. This behavior can be attributed to the fact that the water treatment plant waste sample presents high percentage of clay fraction (35 %) and high plasticity (plastic index = 25.4%), which influence the cement hydration reactions. The water treatment plant waste absorbs large amount of water, and therefore do not have sufficient water to complete the formation of hydrated phases of the cement. Despite this, the values of water absorption of the soil-cement bricks incorporated with up to 1.25 % of water treatment plant waste are within the specified values (≤ 20 %) in NBR 10834 (ABNT, 1994b).

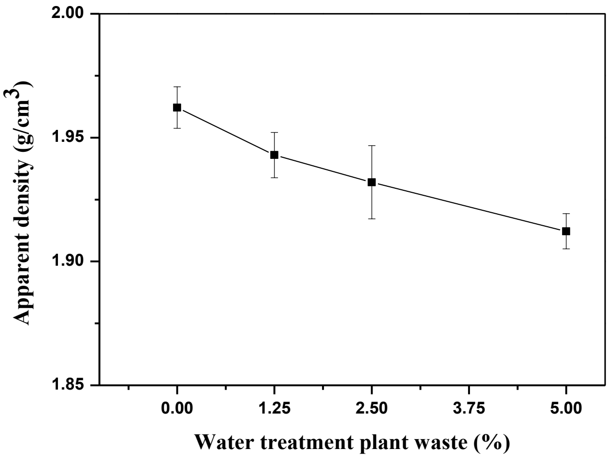

Fig. 3. Apparent density of the soil-cement bricks.

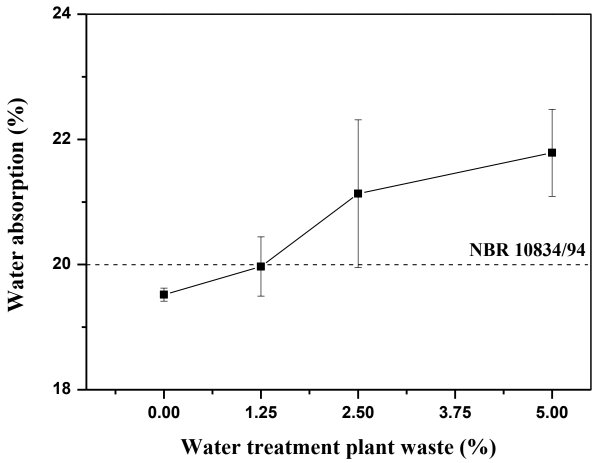

Fig. 4. Water absorption of the soil-cement bricks.

4. Conclusions

The following conclusions can be drawn from the experimental results and their discussion.

The water treatment plant waste is a plastic material (IP = 25.4 %) rich in Al_2O_3, SiO_2, Fe_2O_3, and organic matter. The results of X-ray diffraction showed that the waste sample is composed predominantly of kaolinite. In this work, it was demonstrated that the soil can be replaced with up to 1.25 % water treatment plant waste in the production of soil-cement bricks. The main limitation for the recycling of water treatment plant waste in soil-cement brick is associated with the increase of water absorption. Despite this, the incorporation of water treatment plant waste in the production of soil-cement bricks is an excellent alternative for the reuse of materials and solid waste recycling practices.

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