

## Effects of Sewage Sludge Ashes Addition in Portland Cement Concretes

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**Abstract**—Due to worldwide awareness of the need for environmental preservation, considerable weight has been given to developing technologies and methods that promote sustainability, underscoring studies on recycling urban solid waste such as sewage sludge ash (SSA) as a source of raw materials for this industry. Following this tendency, the present study aimed at assessing the technical implications of using SSA as an addition in the preparation of Portland cement concrete on the workability, axial compressive strength, void ratio and water absorption properties of samples produced with 0%, 5%, 10% and 15% of waste in relation to mass of sand used. The results of this study showed that up to 10% of SSA could be added to the concrete mixtures without compromising axial compressive strength, void ratio and water absorption. Moreover, it was found that using this waste induced a loss of workability in the concretes produced.

**Keywords**- sewage sludge ash; concrete; solid waste.

### I INTRODUCTION

With the growth and development of the world's population, the consumption of natural resources and energy has increased, as has the production of waste, primarily in large urban centres, causing considerable concern regarding environmental preservation. This concern has been emphasized in studies aimed at recycling wastes produced by civil construction, a major consumer of natural raw materials worldwide.

Sewage sludge is among the main urban wastes because of the large volume produced, difficult treatment and final disposal. Incineration of this waste has emerged as an alternative for reducing its original volume, and according to Donatello and Cheeseman [1], produces around 17 million tons of SSA per year. Although it does not contain pathogenic organisms or toxic organic compounds, it still poses a contamination risk to the environment, given that the existence of ash as a byproduct of incineration, albeit in a smaller volume, requires that it be disposed of.

Different ways of using SSA as construction material are suggested [2-10] as alternatives for the beneficial recycling of raw material.

In this respect, the present study assesses the technical implications of adding different amounts of SSA to the mass of sand used in preparing concrete, analyzing its

effects on the properties of concrete in the fresh and hardened state, using workability, axial compressive strength, void ratio and water absorption tests.

### II EXPERIMENTAL PROCEDURES

#### A. Materials

The SSA used in this study was obtained by burning septic tank sludge at a temperature of 850 °C for 12 h, followed by slow cooling in the same oven until the ambient temperature of 30 °C was reached. Scanning Electron Microscopy (SEM) indicated that this waste, whose chemical composition was determined by XRF analyses (Table 1), exhibited irregular grain morphology and considerably rough surface (Fig. 1) This material had a specific mass of 2,68 g/cm<sup>3</sup>, as determined by Brazilian standard [11], a value similar to that obtained by other authors [7].

TABLE 1. CHEMICAL COMPOSITION OF SSA

Oxides	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	SO <sub>3</sub>	CaO	Fe <sub>2</sub> O <sub>3</sub>	P <sub>2</sub> O <sub>5</sub>	MgO	TiO <sub>2</sub>	K <sub>2</sub> O
(%)	35,14	27,65	5,30	6,16	5,60	5,52	3,72	1,22	0,76
Oxides	ZnO	CuO	MnO	ZrO <sub>2</sub>	Cr <sub>2</sub> O <sub>3</sub>	PbO	SrO	NiO	LOI*
(%)	0,35	0,10	0,05	0,03	0,03	0,01	0,01	0,01	8,37

\* Loss Of Ignition

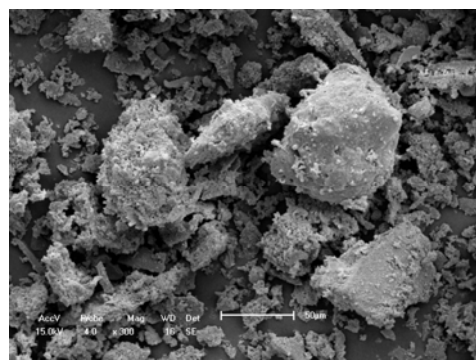


Fig. 1. Grain morphology of SSA

Quartz sand and granite gravel with specific masses of 2,61 g/cm<sup>3</sup> e 2,70 g/cm<sup>3</sup>, respectively, as determined by Brazilian standard NBR NM 52 [12], were used as natural aggregates. Granulometric distribution of these aggregates and the SSA (Fig. 2) were determined according to Brazilian standard NBR NM 248 [13]. Portland pozzolan

cement (32 Mpa), which is resistant to sulfates and an alkali-aggregate reactivity inhibitor, was selected because it is widely produced in Brazil and readily available in the local market. The physical traits of this cement were in accordance with values recommended by Brazilian standard NBR 5736 [14], as shown in Table 2.

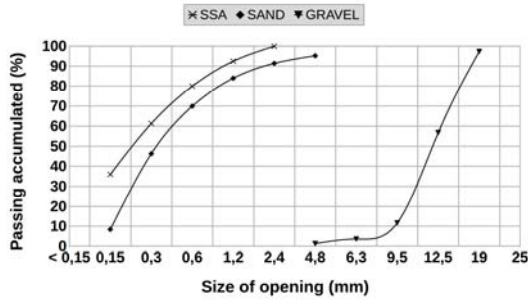


Fig. 2. Grain size distribution of aggregates and SSA

TABLE 2. PHYSICAL CHARACTERISTICS OF CEMENT

	Requirement specified*	Obtained
Fineness (%)	$\leq 8$	0,34
Blaine fineness (cm <sup>2</sup> /g)	Not specified	5458,00
Initial setting time (min)	$\geq 60$	178,40
Final setting time (min)	$\leq 600$	253,60
Soundness by Le Chatelier test (mm)	$\leq 5$	0,00
Compressive strength - 3 days (MPa)	$\geq 10$	20,49
Compressive strength - 7 days (MPa)	$\geq 20$	28,18
Compressive strength - 28 days (MPa)	$\geq 32$ and $\leq 49$	39,94

\* by Brazilian standard NBR 5736 (ABNT 1999)

### B. Specimens

The control mixture consisted of a concrete mass ratio of 1:2:3 (cement: sand: gravel), containing 0% SSA in its composition and a water/cement ratio of 0.65. This composition was used because it is an economically feasible formulation that facilitates the addition of the waste under study without the need for plastifying additives in the other proposed mixtures. The control mixture produced three additional mixtures containing 5%, 10% and 15% in relation to the mass of sand used (Table 3).

TABLE 3. PROPORTION OF THE CONCRETE MATERIALS

Concrete	Cement	Sand	Gravel	Water	SSA
Control	1,00	2,00	3,00	0,65	0,00
Type 01	1,00	2,00	3,00	0,65	0,10
Type 02	1,00	2,00	3,00	0,65	0,20
Type 03	1,00	2,00	3,00	0,65	0,30

Ash was used to complement the sand because its granulometry and specific mass are similar to that of the natural aggregate used in the mixtures.

Immediately after production of the concretes proposed in Table 3, they underwent slump tests, in accordance with Brazilian standard NBR NM 67 [15], followed by the casting of 9 100 x 8 200 mm (diameter x height) cylindrical concrete samples for each mixture, with a slump of more than 0 mm and subsequent damp curing according to Brazilian standard NBR 5738 [16]. For each type of concrete, 3 of the cylindrical cast samples were used in the void ratio and water absorption tests at 28 days and 6 in uniaxial compressive strength tests at 7 and 28 days, conducted in accordance with Brazilian standards [17,18].

## III RESULTS AND DISCUSSION

### A. Concrete workability

As observed in experiments performed by Monzó et al. (2003) e Cyr et al. (2007), who observed a decline in mortar workability with an increase in SSA in their mixtures, the results of the present study also showed that a rise in SSA significantly reduced concrete workability, causing zero slump in the sample containing 15% addition (Fig. 3).

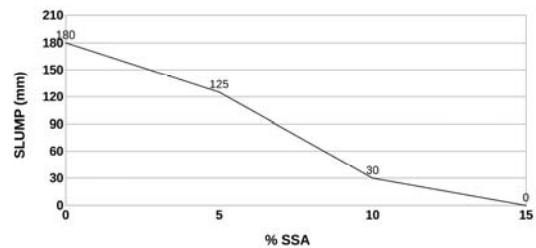


Fig. 3. Workability of concrete produced

This tendency to slump reduction in concrete as a function of the increase in SSA content is provoked by both the decrease in water/dry matter ratio in the mixtures and the hygroscopic nature of the SSA, owing to its granulometric characteristics and grain morphology, which allowed this waste to act in cement matrices as structures that absorb the free water in the mixture.

### B. Axial compressive strength

The addition of ash resulted in a significant improvement in the cohesion of these structures, in addition to reducing exsudation in these samples. These factors contributed to the findings exhibited in Fig. 4, where addition of the waste under study provides greater strength to concretes compared to that of concrete with no waste at both control times tested.

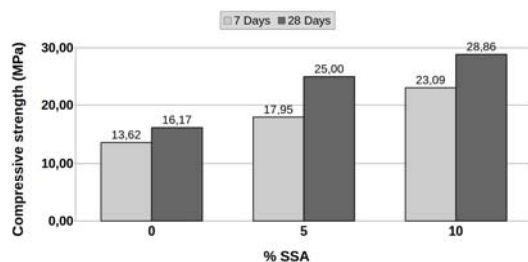


Fig. 4. Compressive strength of concrete produced

### C. Void index and absorption water

Taking the concrete with 0% SSA as reference, the results obtained for these tests (Fig. 5) demonstrate that the addition of SSA to concretes provokes a slight decrease in both void ratio and water absorption in the samples analyzed. This behavior is attributed to the refinement of pore structure in these concretes, due to the thin fraction ( $< 150 \mu\text{m}$ ) of grains present in the waste under study.

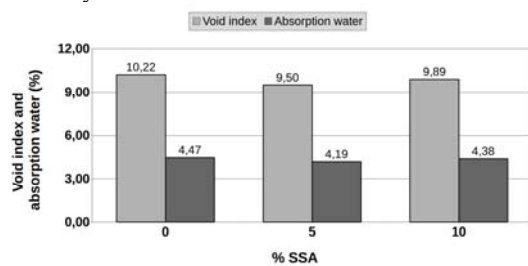


Fig. 5. Void index and absorption water of concrete produced

## IV CONCLUSIONS

Although SSA caused a significant loss in workability in fresh concrete during the castings, this waste was considerably beneficial in retaining the existing free water, as well as increasing the cohesion of mixtures containing 5% and 10% of these ashes. These improvements in fresh concrete have a direct effect on the mechanical properties of samples in the hardened state, where SSA produced significant gains in compressive strength in concretes containing this waste. Moreover, the addition of ash to the mixtures led to an improvement in both void ratio and water absorption in the samples analyzed. However, at very low levels, the use of SSA in the concretes, in the manner and percentages applied in the present study, did not significantly change these properties. This study concluded that the maximum addition of SSA to concrete manufactured without plastifying additives is 10% in relation to the mass of sand used in concrete composition. This is because higher concentrations require an increase in the water/agglomerate ratio in the mixture, a condition that may result in increased porosity and consequent reduction in the mechanical strength of these cement matrices.

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