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# STUDY OF CEMENT-BASED MORTARS CONTAINING SPANISH GROUND SEWAGE SLUDGE ASH

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## Abstract

A study of cement based mortars containing spanish ground sewage sludge ash is presented. The influence of original and ground sewage sludge ash on mortars workability and compressive strength has been studied. An initial decrease of workability is observed when 30 % of Portland cement is replaced by original ash. When ash grinding time increases a little increased of workability is observed. Mortars containing a 15 % of ash cured at 40°C for 14 and 28 days showed equal or higher compressive strength than control mortar. No significative differences sere observed among mortars containing ash with different grinding times.

## Introduction

As a consequence of water treatment processes, a large amount of sewage sludge is obtained. A part of this sewage sludge is used in agriculture as organic fertilizer and soil amendment. But, depending on the origin of water treated (municipal, industrial, ...) chemical parameters change, and in some cases accumulation of heavy metals and other toxic compounds can be occur, producing adverse impacts on human health and the environment (1).

The incineration of sewage sludge is one alternative to manage the excess of sewage sludge production, that some cities are using. This method permits to reduce the volume until 90%, and the sewage sludge ashes obtained can be deposit in controlled landfills. However, landfill sites space limitations and environmental problems have guided the investigations of alternative uses in construction.

Sewage sludge ash (SSA) has been used to manufacture bricks (2), to incorporate into concrete mixtures (3,4),in asphaltic paving mixes (5) and mortars (6).

In a previous research (7) some properties of cement-based mortars containing SSA were studied. The objective of the present work is to study the influence of grinding of SSA on workability and strength of cement-based mortars. SSA were obtained from sewage treatment plant of Pinedo (Valencia, Spain), that produces about 2,000 tons/year.

## EXPERIMENTAL

**Materials.** Portland cement used for mortar preparation was conforming to the specifications of ASTM type I. Fine aggregate was natural sand with 2.94 fineness modulus. SSA were obtained from sewage treatment plant of Pinedo (Valencia, Spain). Sikanol-M was used as plasticizer.

**Apparatus and procedures.** Samples of original SSA were ground using a laboratory ball-mill (Gabrielli Mill-2). SSA samples were introduced into the bottle-mill containing 98 balls of alumina (2 cm diameter) and were ground during 2.5, 5 and 10 minutes.

Mortar specimens cast in square prismatic mortar molds with internal dimensions of (40x40x160) mm were used. Preparation of mortars was carried out according to ASTM C-305 test (8), mixing 450 g. of Portland cement, 1350 g. of natural sand and 225 mL of water for control mortar and the rest of mortars replacing by mass a 15% of Portland cement by original or ground SSA. Mortars were put in a mold for obtaining specimens, which were stored in a moisture room (20±1°C) for 24 hours. Afterwards the specimens were demoulded and cured by immersion in 40±1°C water in order to activate the hydration process until testing at 3, 7, 14 and 28 days.

Mortars for workability studies were prepared according to ASTM C-305 (8), mixing 450 g. of Portland cement, 1350 g. of sand and varying water volumes between 200-225 mL for control mortar. The rest of mortars were prepared replacing growing percentages of Portland cement by ground SSA and workability test were developed following ASTM C-109 (9) test. Some tests were developed using a mortar plasticizer (Sikanol-M) in a 0.1% in weight respecting SSA + cement.

Freshly prepared mortars were placed into a conic mold which is centered on the flow table. Mortar was put on two layers and compacted with a wooden tamper (10 times). Afterwards, the mold was removed and the table was dropped 15 times (one per second). Flow table spread (FTS) was given as a mean of maximum and minimum diameters of the spread cone.

### Results and discussion

SSA obtained from water treatment plant was analyzed and the results obtained are presented in Table 1. From among these data can be emphasized the high concentration of sulfate in SSA (12.4 % expressed in $SO_3$content). High concentration of sulfate are due, chemical reagent used in water treatment.

**Workability (FTS).** The influence of original and ground SSA on mortar workability has been studied. In Figure 1. Flow Table Spread (FTS) versus SSA grinding time is represented for mortars containing a 30% of SSA and 0.5 water cement ratio. In this figure is compared the platicizer influence on FTS. An initial decrease of workability is observed when a 30% of control mortar cement is replaced by original SSA (SSA 0), a more marked decrease is observed in mortar containing plasticizer. A different behavior is observed, for mortars with or without plasticizer, when SSA grinding time increases. Mortars containing plasticizer increase FTS when grinding time do. The most important increases is observed between SSA 0 and SSA 2.5. The absence of plasticizer shows a decrease of FTS when grinding time increase. In all cases workability of mortars containing plasticizer was higher than mortars without it.

Table 1. Chemical Composition of Original Sewage Sludge Ash and Portland Cement

| Parameters | SSA (%) | Cement (%) |
|---|---|---|
| Moisture | 0.5 | ---- |
| Loss on ignition | 5.1 | 3.02 |
| Insoluble Residue | 16.1 | 0.95 |
| $SO_3$ | 12.4 | 3.54 |
| $Fe_2O_3$ | 7.4 | 2.85 |
| $SiO_2$ | 20.8 | 21.00 |
| CaO | 31.3 | 62.87 |
| MgO | 2.6 | 1.05 |
| $Al_2O_3$ | 14.9 | 4.94 |
| $P_2O_5$ | 6.7 | 0.1 |

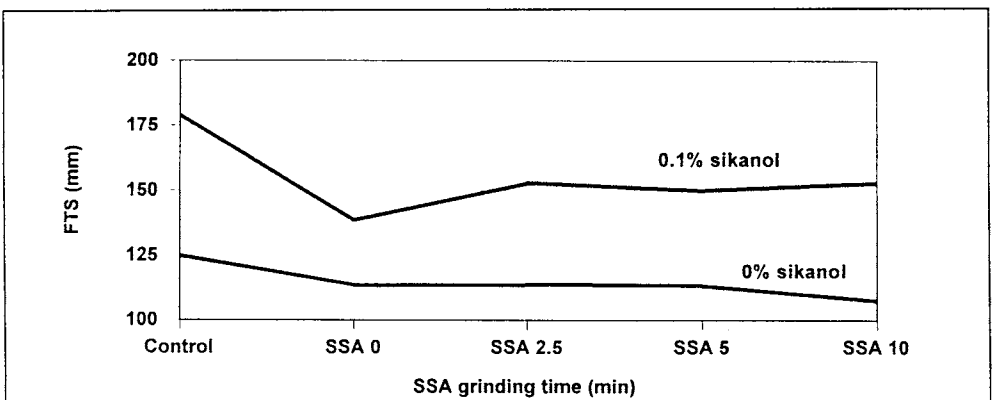


*Figure 1. FTS values of mortars containing 30% of SSA versus SSA grinding time*

In Figure 2. FTS versus volume of water for mortars containing a growing replacement of cement by ten minutes ground SSA and 0.1% (in weight) of plasticizer is represented. As could be expected, a increase of FTS is observed when water volume do, but this behavior is more pronounced when SSA percentage is slow (15 and 30%). Probably, the important adsorption of water on SSA particles surface determines the short increase of FTS when high SSA percentages (45 and 60%) are used.

**Compressive Strength (Rc).** Preliminary studies make clear, in first place, that SSA did not present autocementicious hardening, whereas, secondly, mixtures of $Ca(OH)_2$ -SSA hardened in few days. This behavior indicated that SSA could present pozzolanic activity. The influence of original and ground SSA on mortars compressive strength has been studied. Mortars containing a 15% of ash and 0.5 water / (cement + SSA) ratio were cured at 40ºC and tested at 3,7,14 and 28 days (Figure 3.). No plasticizer was used. The results obtained showed higher Rc in short

curing time (3 and 7 days) for control mortar (without ash). When curing time increases (14 to 28 days) mortars containing ash showed equal or higher Rc than control mortar. This fact confirm pozzolanic behaviour of SSA. No significatives differences were observed among mortars containing SSA with different grinding times.

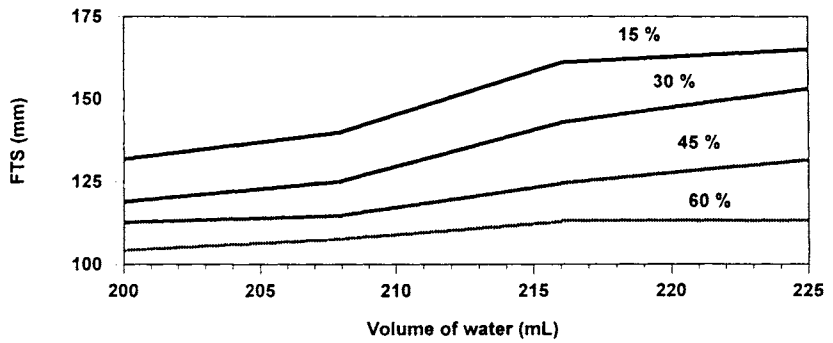


*Figure 2. FTS values of mortars containing from 15% to 60% of SSA versus volume of water*

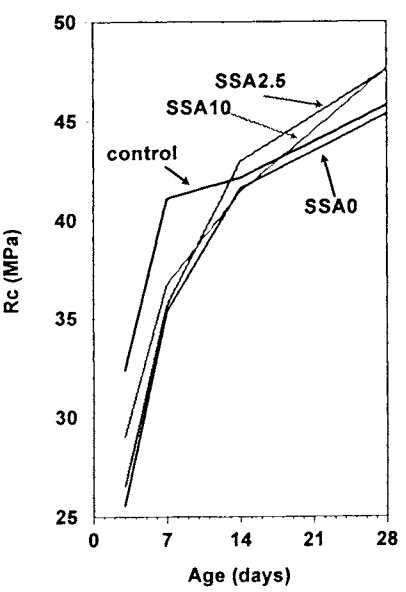


*Figure 3. Compressive strength of mortars containing 15% of SSA with different grinding times*

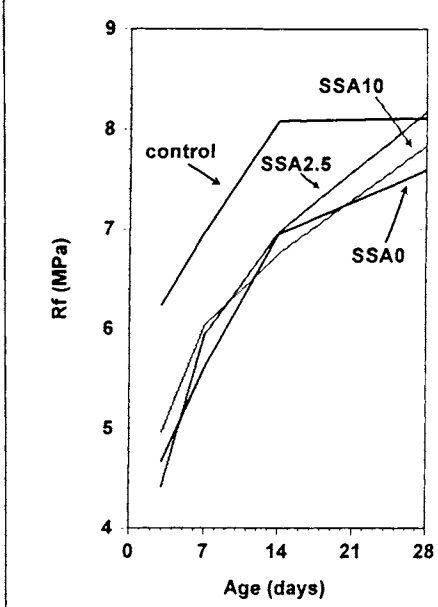


*Figure 4. Flexural strength of mortars containing 15% of SSA with different grinding times*

**Flexural Strength (Rf).** The influence of original and ground SSA on flexural strength of mortars has been studied (Figure 4). The results obtained showed higher Rf for control mortar than ash mortars except for 28 days curing time that mortar containing 2.5 minutes ground SSA that gave same Rf than control mortar. No significative tendency between SSA grinding time and Rf is observed.

## Conclusions

1. High concentration of sulfate are present in SSA, due to chemical reagents used in water treatment

2. A cement replacement by SSA in mortars produces a decrease of workability, being a more marked decrease when mortar contains plasticizer

3. A increase of workability in mortars containing plasticizer is observed when SSA grinding time do

4. Mortars cured 14 to 28 days at 40°C containing 15 % of Portland cement replaced by ground SSA gave equal or higher compressive strength than control mortars. No significative differences were observed among mortars containing SSA with different grinding times

5. Flexural strength for mortar was higher than 15 % SSA replaced mortars except for 28 days curing times

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