Construction and Building Materials 160 (2018) 308–315

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Performance of mortars with the addition of septic tank sludge ash

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HIGHLIGHTS

- Septic tank ash (SA) addition improved overall condition of mortar.
- Better performance in both the fresh and hardened state.
- Improvement the particle packing by SA filling action.
- SA addition increases density and reduces consistency of mortar.

ARTICLE INFO

Article history:
Received 10 January 2016
Received in revised form 19 October 2017
Accepted 14 November 2017

Keywords:
Septic tank sludge ash
Mortars
Portland cement
Performance

ABSTRACT

This paper studies the performance of mortars with the addition of septic tank sludge ash (SA). The sludge is a non-dangerous and non-inert residue. The cement-sand content is 1:3, in mass, commonly used for masonry in building construction. The percentages of sludge ash additions were 5, 10, 15, 20, 25 and 30% related to the cement mass. The results show that the addition of SA improves the general condition of the mortars, within the limits studied in this paper, providing better performance on both fresh and hardened states.

1. Introduction

The sewage sludge use as a byproduct in the construction industry has been discussed in researches in the last decades [1–7]. Mostly, sewage sludge ash has been utilized in mortars as mineral addition, such as fillers, in bricks and in ceramic floors [8–15].

Although the sludge is not the only waste produced in the sewage treatment system, it is commonly considered as a great environmental concern, specially its final disposal, due to the chemical characteristics and high production [16].

Septic tank sludge or septage is a type of sewage sludge defined as a liquid or solid material removed from a septic tank that receives only domestic sewage [17]. Septic tank systems are commonly utilized in rural areas but also in urban areas without basic sanitation systems. Although EPA regulations includes this type of waste to land applications [18] it have been studied more rarely as raw material in civil construction; probably due to its low production rather than its properties.

In order to use the sewage sludge in construction, its calcination is necessary, having as the main purpose the elimination of water, organic matter and pathogenic micro-organisms. The calcination also brings the interaction of the sewage sludge ash with the compounds from cement hydration.

The properties of sewage sludge as raw material depend on its origin, type of treatment, calcination temperature and fineness. The relevant physical characteristics of sewage sludge are particle size and their morphology. Thus, the filler action of the SSA favors the performance of mortars [19]. The chemical composition is, in fact, a limiting factor to the SSA pozzolanic activities, mainly due to the silica content [7]. Further, a low to moderate pozzolanic activity of the SSA has been reported [14,20] and an increase of the mortar's mechanical performance with the SSA addition [8,9,21].

The irregular morphology of the grains of the SSA particles seems to cause a decrease in mortar mechanical performance. This can be explained by the increase in the water/binder ratio due to the high specific surface of the SSA [19]. In this way, some studies

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https://doi.org/10.1016/j.conbuildmat.2017.11.053
0950-0618/

indicate the water absorption as a limiting factor to the partial replacement of cement by SSA [22].

Regarding the environmental consequences of using the SSA as a raw material in building construction, special attention must be taken on the chemical composition. Cusidó et al. [23] conclude that there is no environmental risk in the application of sewage sludge as a raw material in construction, because the SO_2 emissions in ceramic products with the sludge are below those required by law. Coutand et al. [19] studied the leachage results in mortars with and without the addition of SSA and both mortars had the same order of magnitude of the concentrations of leachaged chemicals.

This experimental work studied the performance of mortars with addition of septic tank sludge ash (SA) as a contribution to the sustainable management practices of domestic wastes.

2. Experimental procedures

2.1. Materials

The cement used in all experiments was the CP-IV-RS-32 (equivalent to ASTM IP - Portland Pozzolan Cement) habitually used in local construction. Tables 1 and 2 show the chemical and physical cement properties, respectively.

The fine aggregate was a quartz sand (natural river sand) (Fig. 1).

The sludge used is a septic tank sludge treated in a system of stabilization ponds, classified as not inert and non-hazardous waste.

The septic tank sludge calcination temperature was 850 °C, adopted due to the full elimination of humidity and organic matter [25].

The milling time was defined on the basis of published work by Pan et al. [8], in which 6 h of milling resulted in greater pozzolanic activity and greater compressive strength.

All tests and analyzes were performed with the ash in its final stage of processing, i.e., all the SA passing through the sieve 0.075 mm.

The particle size distribution (Fig. 2) indicates that the average diameter of the used SA is of 30.23 μm. Much smaller than the sand (720 μm) and greater than that of cement (which varies between 10 and 15 μm), giving the ash a filler characteristic. This feature allows the filling of the voids in the mortar and improves the cement matrix.

Regarding the specific gravity, the SA presents intermediate values between the cement and sand. As the SA has a higher specific gravity than the sand, it is expected that the densities in the fresh and hardened state of the produced mortars with it will not increase.

Table 1
Chemical of cement CP-IV-32-RS.

Oxides	Content (%)
SiO_2	27.27
Al_2O_3	7.04
Fe_2O_3	3.78
CaO	50.59
MgO	2.23
SO_3	3.59
Na_2O	0.64
K_2O	1.15
CO_2	1.48
CaO free	1.06
Insoluble Residue	14.28
LOI	3.56%

LOI – Loss on Ignition.

Table 2
Physical properties of cement CP-IV-32-RS.

Physical properties	Results
Fineness- 75 μm sieve opening (%)	2.04
Fineness- 44 μm sieve opening (%)	12.81
Specific gravity (kg/m^3)	2860
Specific rea (m^2/kg)	434
Water for paste of normal consistency (%)	30.8
Initial setting time (h), Vicat	3.0
Final setting time (h), Vicat	4.5
Soundness- Le Chatelier Method (mm)	0
Compressive strength (Mpa)	
3 days	21.0
7 days	26.8
28 days	34.2

(*) Brazilian Standard NBR 5736 [24].

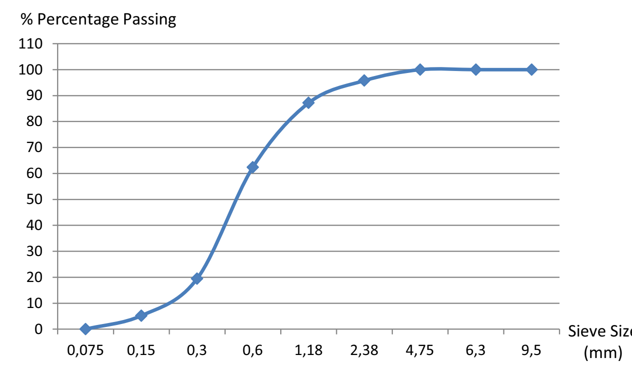

Fig. 1. Sieve analysis of the natural sand.

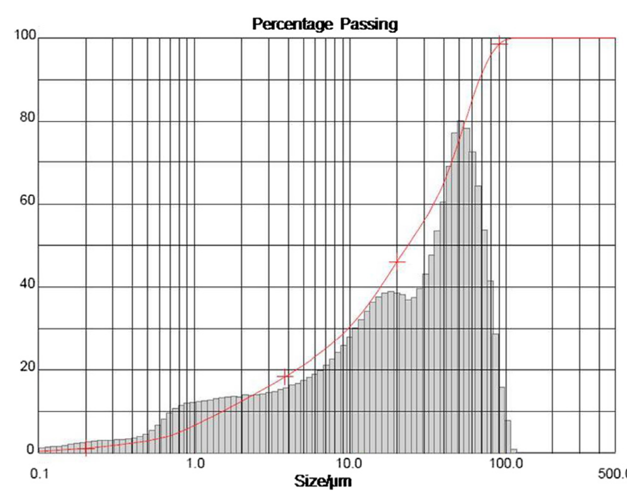

Fig. 2. Particle size distribution of the SA.

Observed by Scanning Electron Microscope (SEM), the SA morphology (Fig. 3) shows an irregular surface formed by angular particles with low sphericity, whose grains have a diameter smaller than 100 μm (Fig. 3a). With the larger particles, there is a number of very small particles having the same angular morphology, whose diameters are smaller than 2 μm (Fig. 3b). There is still a conglomerate of ash particles, which will certainly have a positive influence on the filler effect improving the cement matrix.

Chemically, the septic tank ash is mainly composed of SiO_2 (34.9%), Al_2O_3 (26.6%) and smaller proportions of CaO (5.8%), SO_3 (5.8%), Fe_2O_3 (5.4%), P_2O_5 (5.2%), MgO (3.5%). The sample presented a loss on ignition of 10.22% (Table 3).