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Bearing capacity of bottom ash and its mixture with soils

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Abstract

This study characterizes two types of silica–aluminous bottom ashes, produced at Spanish power stations situated in Soto de Ribera (SR) and Aboño (AB), for their use in roads. Using laboratory tests, it was verified that these ashes can be used in embankments when they are appropriately compacted, given that their dry densities are very low. CBR index values of over 30% were obtained. Three soils have been mixed with different percentages of the bottom ashes. Soils can be improved by adding bottom ash contents that vary from 15% to 40% of the soil weight, thus improving their load-bearing capacity and reducing their plasticity.

Keywords: Power station; Bottom ash; Road; Soils

1. Introduction

This paper presents the work done in the Roads Laboratory of the University of Cantabria in collaboration with the Iglesias Technological Centre (Asturias). The main aim of the investigation was to validate two types of silica–aluminous bottom ashes for use in road construction, in such a way that this industrial by-product becomes recyclable to a large extent leading to economical and environmental benefits.

Some authors have investigated the effective dosage rates of waste products to improve the properties of fine-grained soils. It is possible to add up to 30% of bottom ashes to soils in order to stabilize them (Gullu, 2014). Some clay soils are stabilized using a blend of calcium carbide residue and biomass ash (Vichan and Rachan, 2013). There are also soils whose strength can be improved by calcium carbide residue from acetylene gas factories and fly ash from power plants (Horpibulsuk et al., 2013). Many marginally useful materials do not comply with the specifications (plasticity, free swell and organic matter content) required for use in embankments (Parrilla Alcalde (2007)). One common solution is to stabilize these materials with a hydraulic binder, such as lime or cement (Herrero Núñez, 2008; Jofré et al., 2008; Bauzá Castelló, 2005). The durability of clay soils can be improved with recycled Bassanite and furnace cement mixtures (Kamei et al., 2013). Lime can also be used as the stabilizing element for very clayey soils (Daniel Castro-Fresno et al., 2010).

It has been demonstrated that the finer part (< 0.4 mm) of the ash produced in a power station is capable of reducing the plasticity of most plastic clays, such as bentonite (Kumar and Stewart, 2003). In other studies of ash–soil mixtures (Senol

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et al., 2003), mixtures were made with distinct percentages of fly ash (12, 16 and 20%), leading to notable improvements in the CBR index.

Another case (Kim et al., 2005), evaluated the possibility of mixing bottom ash with distinct percentages of fly ash. As the proportion of fly ash was increased, the maximal dry densities decreased and the optimal Proctor moisture content increased.

Recently, a large number of studies undertaken with power station ash, mixed with hydraulic binders, have taken advantage of their pozzolan properties for use in road soils. However, there are few studies oriented to improving the soils through the addition of ash alone, without other additives. This investigation validates two types of silica–aluminous bottom ashes for use in the construction of embankments and in the improvement of soils for roads, studying their composition, dry density, plasticity and load-bearing capacity.

2. Materials and methods

2.1. Methods

The physical, chemical and mineralogical properties of the bottom ashes in this study were initially characterized and evaluated. An X-ray fluorescence test was used for chemical analysis, while X-ray diffraction was used to obtain the mineralogical spectrograms. The specific weight of the particles and the pozzolanic character of the ashes were also determined. The physical characterization was based on swelling and collapse tests in an oedometric cell, granulometric tests and Atterberg limits.

In the next stage, the suitability of the two ashes was verified. Standard Normal Proctor tests (–PN-) were carried out and the CBR index was determined, comparing the results for different compactions. The last stage involved mixing three soils of different categories and qualities with varying percentages of added ash (10, 20, 30 and 40%), and comparing the properties of the mixtures through compaction tests, CBR tests, granulometry and Atterberg limits. Important improvements and changes were obtained in these parameters with respect to the original soils analyzed for different degrees of compaction.

The soils and soil–ash mixtures were classified according to the Spanish General Technical Specifications for Roads PG-3 standards.

2.2. Materials

2.2.1. Bottom ash

Two types of ashes were used from Spanish power stations situated in Soto de Ribera (SR) and Aboño (AB).

2.2.1.1. Chemical and mineralogical analysis. The chemical analysis was done by X-ray fluorescence spectroscopy, which consists of the excitation of the sample using an X-ray source.

The chemical composition of the two ashes reflects the silica and alumina contents as well as other oxides to a lesser extent (Table 1). The SR sample shows a high carbon content which may be the result of the deficient combustion of the carbon in the furnace giving rise to a high percentage of unburnt residues (Pardo and Oteo, 1991).

As for the mineralogical composition, the mineralogical spectra of both ashes were obtained through X-ray diffraction, applying Bragg's law.

Table 1
Chemical composition of bottom ash.

Component	SR	AB
SiO_2(%)	43.6	49.4
Al_2O_3(%)	23.5	27.8
Fe_2O_3 (%)	6.77	8.56
CaO (%)	4.62	7.07
K_2O (%)	2.72	2.15
MgO %	1.32	1.64
TiO_2(%)	0.93	1.34
C (%)	15.3	0.55
Other	< 1	< 1

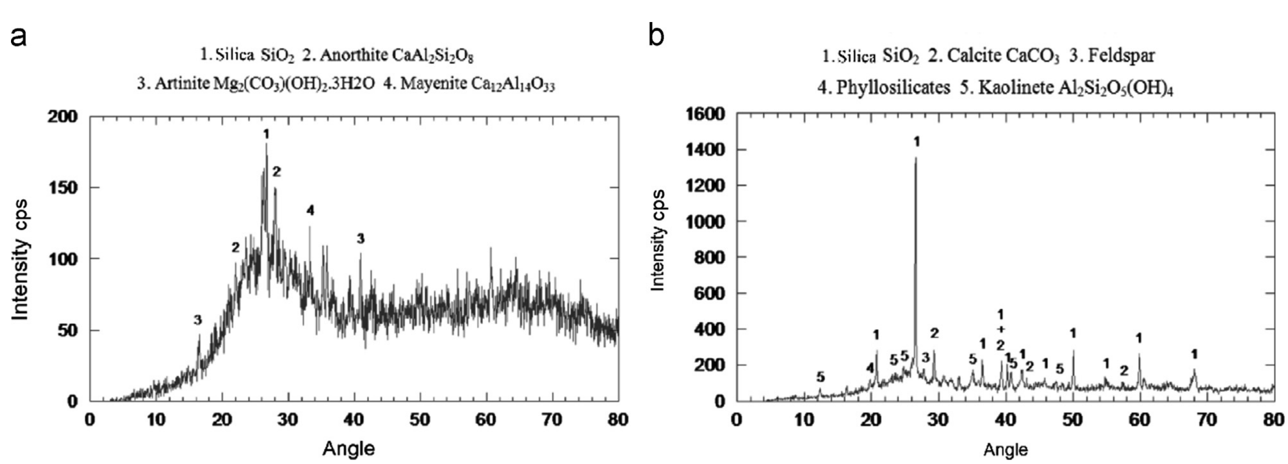

Fig. 1. X-ray diffraction patterns of bottom ashes (1.a Aboño; 1.b Soto Ribera).