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Reuse of thermal power plant slag in hot bituminous mixes

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HIGHLIGHTS

- Reuse of thermal power plant slag in hot bituminous mixes (HMA).
- Substituting natural aggregate in the manufacture of hot mix asphalt.
- A test road section was built with HMA containing slags.
- The mechanical performance of the slag mix was found optimal.
- Boiler slag from thermal power plants can be used as a substitute for the fine aggregate.

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ABSTRACT

The revalorization of industrial waste plays a key role in the solution of environmental and economic problems in the construction sector, thus actions contributing to the symbiosis between industries in the same region are of great benefit since they optimize resources in the area and also open the door to new business opportunities. In recent years, the electricity produced by thermal power stations has become a renewable energy source of great potential. Nevertheless, this type of energy is not without drawbacks because of the coal ash and boiler slag produced by coal combustion. Although the ash has different application as a construction material, boiler slag is more problematic since it must be deposited at landfills. The accumulation of this waste has become a serious economic and environmental problem. This paper presents the results of a research project, which analyzed the viability of reusing thermal power plant slag as a substitute for natural aggregate in the manufacture of hot mix asphalt (HMA). For this purpose, the waste was first characterized and tested in the laboratory with a view to its subsequent use in HMA. Based on the positive laboratory results, a test road section was built with this material so that its performance could be compared with that of the road section paved with a conventional HMA. The results obtained confirmed the aptness of thermal power plant slag for use in road construction.

1. Introduction

In recent years, as a consequence of industrial development, the generation of electricity from fossil fuel combustion in thermal power plants has soared in countries all over the world. However the accumulation of waste generated by such energy production is now the focus of growing social concern [1,2]. Such wastes include bottom ash or boiler slag (material collected at the bottom of the boiler) and fly ash (finer material that rise with the flue gases from the furnace upwards, generally to be captured by particle filtration equipment) [3,4]. It is thus crucial to find ways to recycle these residues, and give them new uses that contribute to sustainable development. Because of the pozzolanic characteristics of fly ash, this waste has many potential applications in the construction sector which is an ideal scenario for the reuse an revalorization of industrial by-products. In this way, fly ash can be used to fill road embankments, to stabilize soils, or to manufacture concrete [5,6]. Indeed, the results of a wide range of research underline the fact that the construction sector and its activities are an ideal scenario for the reuse and revalorization of industrial by-products [7–9].

In contrast to fly ash, boiler slag has received considerably less attention [10] despite the fact that these materials are produced in similar quantities by thermal power plants [3]. As a solution for the socio-environmental problem of boiler slag, certain authors [10,11] propose the use of this waste as a substitute for part of the sand fraction in the manufacture of concrete. According to this research,

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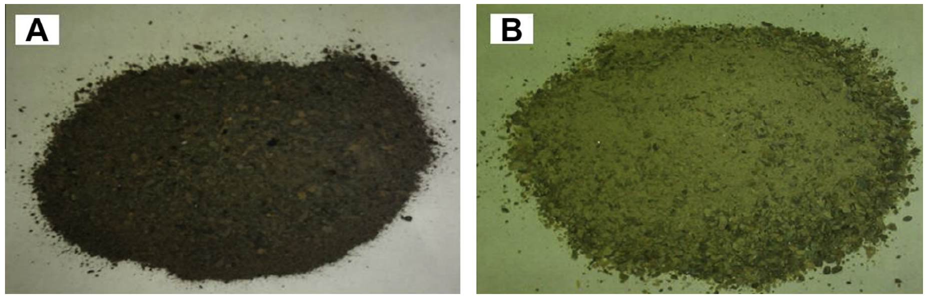

Fig. 1. Comparison of thermal power plant slag (A) and sand (B).

Table 1
Physical properties of thermal power plant slag.

Tests		Slag
Grain size (UNE-EN 933-1) [17]	Sieves (mm)	% material passing
	4	100.0
	2	50.0
	0.5	32.0
	0.25	26.0
	0.063	4.2
Aggregate density in paraffin oil NLT-167/96 (g/cm^3) [16]		1.58
Sand equivalent (UNE-EN 933-8) [18] (%)		79.0
Relative density and absorption (UNE-EN 1097-6) [19]	Apparent density (g/cm^3)	1.73
	ADSS (g/cm^3)	1.57
	Density after drying (g/cm^3)	1.35
	Water absorption after immersion (%)	16.21

ADSS: Apparent relative density on a saturated surface-dry basis

Table 3
Grain size of the reference mix and the slag mix.

AC 16 S mix		
Sieves (mm)	Reference	5% Slag
22.4	99.0	99.0
16	92.0	92.0
8	66.0	66.0
4	39.0	41.0
2	29.0	29.0
0.5	13.0	14.0
0.25	9.0	10.0
0.063	5.9	5.0

boiler slag and fly ash have a similar composition, which means that they have the same pozzolanic nature.

Other authors [3] have assessed the performance of bituminous mixes made from thermal power plant slag. The results showed that when part of the sand fraction of the mineral skeleton was replaced by slag (less than 15% of the aggregate), this did not cause a negative impact on the mix. In fact, the mix with slag was found to have an indirect tensile strength and resistance to rutting comparable to those of conventional asphalt mixes. In contrast, other research studies [12,13] claim that road surfaces paved with bituminous mixes made of thermal power plant residues did not perform as well and deteriorated more rapidly under traffic loads. These contradictory results seem to indicate that the real problem with slag mixes lies in the fact that the characteristics of the slag depend on its origin [12,14]. Consequently, it is necessary to study the performance of this material in each case before using it in bituminous mixes.

Based on these considerations, the revalorization of boiler slag as an alternative material needs to be explored in greater depth. Accordingly, the construction engineering laboratory of the University of Granada (Spain) and Sacyr, a Spanish construction company, carried out a joint research project that studied how to recycle boiler slag from a thermal power plant to manufacture HMA. A further objective of this research was to contribute to the symbiosis between industries in the same region so that the waste produced by one economic sector would become a resource for another, thus giving it added value and contributing to

Table 2
Aggregate characteristics.

Tests		12/18	6/12	0/6
		Limestone	Limestone	Limestone
Particle grain size (UNE-EN 933-1) [17]	Sieves (mm)	% Material passing	% Material passing	% Material passing
	22.4	90	100	100
	16	47	100	100
	8	0	44	100
	4	0	1	72
	2	0	1	50
	0.5	0	0	16
	0.25	0	0	7
	0.063	0.1	0.4	0
Coarse aggregate shape. Flakiness index (UNE-EN 933-3) [20]		2.62	18.76	19.86
Resistance to fragmentation (Los Angeles coefficient) (UNE-EN 1097-2) [21]		9.0	23.0	23.7
Light-weight particles in aggregate (UNE-EN 1744-1) [22]		–	0.05	0.05
Sand equivalent (UNE-EN 933-8) [18] (%)		–	–	75.2
Relative density and absorption (UNE-EN 1097-6) [19]	Apparent density (g/cm^3)	2.87	2.88	2.75
	ADSS (g/cm^3)	2.86	2.86	2.74
	Density after drying (g/cm^3)	2.86	2.85	2.73
	Water absorption after immersion (%)	0.18	1.70	1.9

ADSS: Apparent relative density on a saturated surface-dry basis