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Use of stabilized bottom ash for bound layers of road pavements

Emanuele Toraldo, Sabrina Saponaro*, Alessandro Careghini, Edoardo Mariani

Politecnico di Milano, Department of Civil and Environmental Engineering, p.za Leonardo da Vinci 32, 20133 Milan, Italy

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A B S T R A C T

This paper reports about the lab scale results obtained by using stabilized bottom ash (SBA) from an Italian municipal solid waste incinerator as aggregates in cement-bound mixes and asphalt concretes for road pavements.

The investigation focused on SBA content. From the road construction point of view, performance related to compaction, volumetric and mechanical properties were assessed. The environmental aspects were investigated performing leaching tests.

The results suggested that SBA satisfied the environmental Italian law for reuse of non-hazardous waste but affected significantly the stress-strain behavior of the final products. Therefore a maximum percentage of 10% was suggested.

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1. Introduction

Municipal Solid Waste (MSW) management is gaining importance both in developed and developing countries, particularly those with high population density (Demirbas, 2011). The main goal of management is to implement and coordinate activities (such as collection of sorted waste, reduction, reuse, recycling and disposal of waste) in order to minimize the MSW environmental impact and to ensure a sustainable development. Incineration has proven to be crucial in MSW management for the treatment of unsorted waste and residual streams from recycling activities as it can combine waste reduction up to 90% in volume and energy production. However, incineration products (bottom and fly ash) must be properly treated before landfilling to avoid health hazards and pollution due to heavy metal leaching (Reijnders, 2005; Sabbas et al., 2003).

In general, bottom ash exhibits composition similar to natural aggregates. Reuse is a common practice in many countries (Denmark, the Netherlands, Belgium, France, Germany, Japan, Taiwan, USA, etc.) to minimize landfilling and to improve sustainability of MSW management (Shih and Ma, 2011; Lam et al., 2010; Hjelmar et al., 2007; Huang et al., 2006). Bottom ash is mostly used as artificial aggregates or mineral addition (Sorlini et al., 2011; Cioffi et al., 2011; Barbosa et al., 2011; Siddique, 2010; Ginés et al., 2009) in civil engineering applications such as road constructions (embankments, bound and unbound foundations, asphalt concretes) (De Windt et al., 2011; Hassan and Khalid, 2010; Francois and Pierson, 2009; Ma et al., 2007; Alkemade et al., 1994; Eymael et al., 1994; Gress et al., 1991; Jackman et al., 1992; Ksaibati and Stephen, 1999; McBath et al., 1995; Reid et al., 2001; Roffman et al., 1997), Portland cement manufacture (Pan et al., 2008; Saikia et al., 2007; Bertolini et al., 2004; Cheeseman et al., 2005; Filipponi et al., 2003) and concrete production.

Bottom ash contains huge amounts of heavy metals and has variable mechanical properties, which hamper extensive reuse (Shih and Ma, 2011; Weng et al., 2010; Becquart et al., 2009; Bassani et al., 2009; Flyhammar and Bendz, 2006; Lapa et al., 2002).

The laboratory study described in this paper assessed the potential application of Stabilized Bottom Ash (SBA) from unsorted MSW incineration for cement-bound (CM) mix as sub-base and asphalt concretes for base (BaAC) and binder (BiAC) road pavement layers.

2. Materials and methods

2.1. Stabilized bottom ash, cement and bitumen

The unsorted MSW collected throughout the territory (Lombardy, Italy) was biologically dried to reduce moisture content before treatment in a hybrid-supplied incinerator. Bottom ash resulting from the process was stabilized at 1200 °C for 12 h. SBA had particle size up to 30 mm, 60% on weight basis being below 2 mm. Table 1 shows the chemical composition of the stabilized

* Corresponding author. Tel.: +39 02 23996432; fax: + 39 02 23996499.
E-mail addresses: emanuele.toraldo@polimi.it (E. Toraldo), sabrina.saponaro@polimi.it (S. Saponaro).

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Table 1
Chemical composition of bottom ash used in the experiments.

Element	% w/w
Si	18.3
Ca	8.8
Fe	8.1
Al	4.2
Mg	1.96
Na	1.52
K	0.36
Cu	0.23
Zn	0.17

Table 2
Composition of the asphalt concretes tested.

	Base asphalt concretes (BaAC) (%)				Binder asphalt concretes (BiAC) (%)			
Gravel 15/30	38	42	42	45	0	0	0	0
Gravel 12/25	0	0	0	0	19	19	19	19
Gravel 6/12	0	0	0	0	23	23	23	23
Gravel 3/6	10	12	12	9	28	24	18	12
Sand 0/15	47	32	22	12	0	0	0	0
Sand 0/3	0	0	0	0	24	18	15	11
Filler	5	4	4	4	6	6	5	5
SBA	0	10	20	30	0	10	20	30

bottom ash (measured by Energy Dispersive X-Ray Fluorescence spectrometry, Azzellino et al., 2002). The Los Angeles Coefficient (LAC) (EN, 2010a) was 48%.

Cement was a Cem II/B-LL Portland-limestone with strength Class 32.5 R, based on the EN 197-1 (EN, 2011) standard. According to EN 12591 (EN, 2009), bitumen grade was 50/70 pen.

2.2. Cement-bound mix

Gravel was classified as Class A1-a according to AASHTO M145 (AASHTO, 2008) and was well-graded in the range 0–40 mm. The LAC (EN, 2010a) was 34%. Water content (5.2%) was optimized according to the Proctor method (EN, 2010b), resulting in gravel dry bulk density of 2.31 kg/dm^3 and wet bulk density of 2.45 kg/dm^3. Four amounts of SBA (0, 10, 20 and 30% on dry weight basis) and three amounts of cement (3, 4 and 5% on dry weight basis) were investigated.

The mixing procedure was performed using a lab mixer. Mixture homogeneity was verified by size distribution analysis.

Specimens, prepared in triplicate by both a Proctor Hammer (PH) (EN, 2005) and a Gyratory Compactor (GC), were cured for 7 days in climatic chamber at 20 °C and 95% relative humidity. Bulk density was measured by both PH and GC compaction methods. The constructability of the mixtures was evaluated through self-compaction (C_1) and workability (k) parameters of the GC-prepared specimens, following the methods currently used for asphalt concretes (Bassani and Santagata, 2002; Cominsky et al., 1994). Unconfined Compressive Strength (UCS) tests were performed at stress speed of 0.5 kPa/s on PH-compacted cylindrical specimens with height to diameter ratio of 0.5 (EN, 2006a). Indirect Tensile Stress at Failure (ITFS) tests were performed at speed of displacement of 50.8 mm/min on GC-compacted cylindrical specimens with height to diameter ratio of 2 (EN, 2006b).

Further specimens (5% cement; 0 or 10% SBA), GC-prepared and cured in climatic chamber for 7, 14 and 21 days, were used to perform Elastic Stiffness (ES) tests under dynamic conditions (pulse load at 2 Hz frequency and 100 kPa horizontal stress) at temperature of 20 °C.

2.3. Asphalt concretes

According to Table 2, different mixes were prepared for both BaAC and BiAC with gravel, sand and filler whose particle size distribution (EN, 2012) is shown in Fig. 1. The LACs (EN, 2010a) of BaAC and BiAC lithic aggregate mixes without SBA were 18% and 20% respectively. 4% bitumen was added to all mixes, based on the average results of tests performed in triplicate on specimens without SBA, prepared by both a Marshall Hammer (MH) (EN, 2007a) and a GC (EN, 2007c) (Table 3).

Voids (EN, 2003), self-compaction and workability (Bassani and Santagata, 2002; Cominsky et al., 1994), Marshall stability and stiffness (EN, 2007d), ITSF (EN, 2006c) and ES (EN, 2007b) at 20 °C were measured in asphalt concrete samples prepared in triplicate. ITSF and ES were also measured in specimens previously soaked in water for 15 days to investigate bitumen/SBA adhesion under water aggression (Bassani et al., 2009; Christensen et al., 1999; Maupin, 1998). The mixing procedure was performed and verified

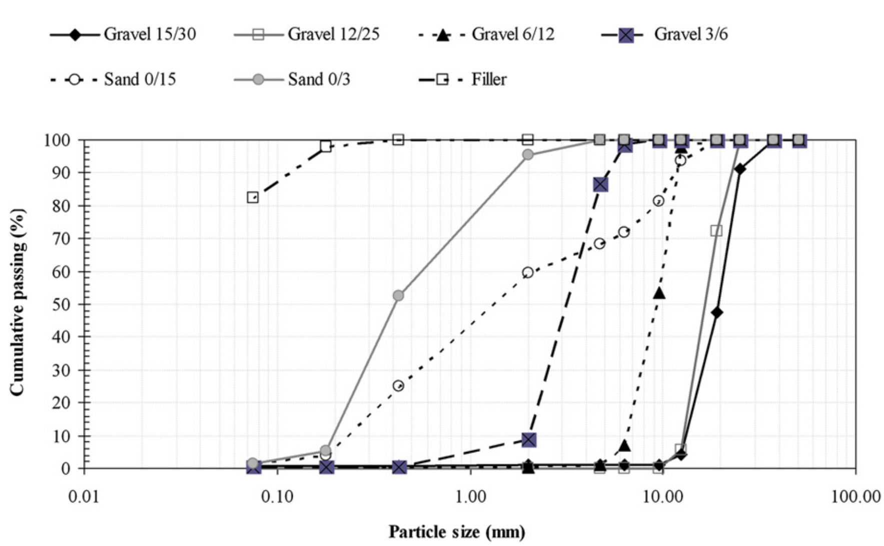

Fig. 1. Particle size distribution of gravels, sands and filler used for asphalt concretes.

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