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Physical and Chemical Study of A New Heterophasic Material Based of Municipal Solid Waste Incinerator Bottom ASH

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Original Research Article

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Abstract: This presented work falls into the valorization of the Municipal Solid Waste Incinerator Bottom Ash in the Civil Engineering field. The bottom ash from waste incineration consists of, by their origin, atypical granular materials. They are industrial by-products resulting from the incineration of the domestic wastes; and the way of considered valorization is road gravel. In this paper, we present the physical and chemical characteristics of bottom ash taken from a recycling company in the North of France. These features can help us to classify our bottom ash according to the technical guide of realization of embankments and subgrades, and to know the mineralogical composition of bottom ash as well as anticipate the problems that could appear in the process of valorization of bottom ash.
Keywords: Bottom ash, heterophasic, valorization, incineration, road gravel.

INTRODUCTION

Municipal solid waste management technologies include landfilling, recycling/recovery and incineration for energy. In many countries, such as France, Sweden, Denmark and Taiwan, municipal solid waste incineration (MSWI) for energy recovery represents the most common waste management technologies [17, 20]. The incineration reduces the mass and volume of the solid waste dramatically, thus the requirement for landfilling is decreased [3,14-16,20]. However, there is still a considerable amount of solid incineration residues, generated after the combustion, typically bottom ash, fly ash, boiler ash, etc., of which bottom ash accounts for about 80% [6, 20].

In the past, MSWI bottom ash was mostly treated by sanitary landfilling. The possibilities other than landfilling have been sought since MSWI started, and reutilization of incinerator bottom ash was already considered many years ago. In the Civil Engineering, the road field consumes a significant quantity of aggregates [1]. However, the aggregate reserves are increasingly not exploitable for various reasons: inaccessible, integrated into an urban area, in classified or protected sites, too expensive exploitation and risks of environmental impact. In this context, the valorization of the bottom ash in road field is an interesting alternative.

Since bottom ash is a granular inert and compactable material, bottom ash is mainly used in Civil Engineering for constructing embankments, road layers, and parking areas, etc [1, 11, 18]. In France, about 3 million tons of bottom ash is produced annually [2]. The use of bottom ash began in Paris in the late 1950s. The expansion of its use throughout the country occurred in the late 1980s - 1990s [4].

This article presents firstly the physical properties concerning the sector of valorization of road works controlled by particle size distribution, methylene blue value, and sand equivalent tests. On the other hand, it presents the chemical properties determined by chemical analysis using X-ray Fluorescence and mineralogical analysis using X-Rays Diffraction.

MATERIALS AND EXPERIMENTAL METHODS
Materials

The MSWI bottom ash used in this study originated from the Platform of recycling of the PréFerNord Company located in Fretin, France (Figure 1). PréFerNord recovers "slag" resulting from the combustion of 5 incineration plants.

Fig-1: Plate-forme of recyclage Fretin

To calibrate the materials, a pre-treatment of this bottom ash like sifting, removal of ferrous and not - ferrous elements, was carried out on site. After, this bottom ash was matured for 3 months (Figure 2). A range of particle sizes from 0 to 20 mm was chosen to approach the size range of natural aggregates which is usually used in the road field.

Fig-2: Bottom ash

Experimental methods

The particle size distribution [8] obtained by sieving three samples that were taken by quartering and washing at 80 µm of diameter.

The activity of the clay fraction was tested by using methylene blue test. The methylene blue test [10] measures the capacity of fine elements to absorb methylene blue. The methylene blue is preferentially adsorbed by the clays, the organic matter and the iron hydroxides; this capacity globally reports the surface activate of these elements. "Methylene blue value" of fine elements is defined as the quantity expressed in grams of methylene blue adsorbed per 100 grams of fine elements. From a bottom ash sample in the rang of 0-5 mm in diameter, the test consist of measuring the quantity of methylene blue which can adsorb itself on the material sample in suspension.

The sand equivalent, making it possible to measure the cleanliness of sand, is performed in the range of aggregate passing to square mesh sieve of 5 mm in diameter [9]. It gives globally the quantity of the fine elements, by expressing a volumetric conventional ratio between the sedimented sandy elements and the flocculated fine elements. The value of the sand equivalent is the ratio, multiplied by 100, between the height of the sedimented sandy part, and the total height of flocculated and sedimented sandy parts.

The elementary composition of the bottom ash is a significant parameter in the comprehension of their chemical behaviour. In order to determine the elementary composition of bottom ash, one carried out measurements using a spectrometer with X-ray Fluorescence Siemens SRS 300. X-ray Fluorescence is a technique for none destructive elementary analysis of the sample. It is used for quantitative analysis of the chemical composition (from boron to uranium except nitrogen) of solid or liquid samples. A beam of x-rays is projected through the sample. This beam is subjected to 3 processes: absorption, dispersion and X-ray Fluorescence which is a secondary emission of x-ray, characteristic of the atomic elements which constitute the sample.

The analysis by X-Rays Diffraction specifies the mineralogical phases presented in material. The used apparatus is a Diffractometer with the Rayon X Siemens D5000 destined for the qualitative identification of the mineral crystallized phases in a given compound. The crystalline state is characterized by periodic distribution in the space of a basis atomic. This orderly distribution constitutes parallel and equidistant plans named reticular plans. A beam of monochromatic x-rays which strikes a crystal is diffracted in a direction given by each family of the reticular plans. We thus obtain direct information on the crystalline compounds in the sample.

EXPERIMENTAL RESULTS
Physical characteristics
Particle size distribution

The results of the particle size distribution presented in Figure 3 show that the bottom ash is characterized by various or spread out size distribution (coefficient of uniformity Cu = 35,5) along with the too many coarse elements which generate much vacuum (coefficient of curvature Cc = 2,3).

With: Coefficient of uniformity $C_u = \frac{D_{30}^2}{D_{10} * D_{60}}$

Coefficient of curvature $C_c = \frac{D_{60}}{D_{10}}$

D_x is the diameter of particles for x % of cumulative passing ones. The Table 1 represents the useful parameters for the classification of our bottom ash.

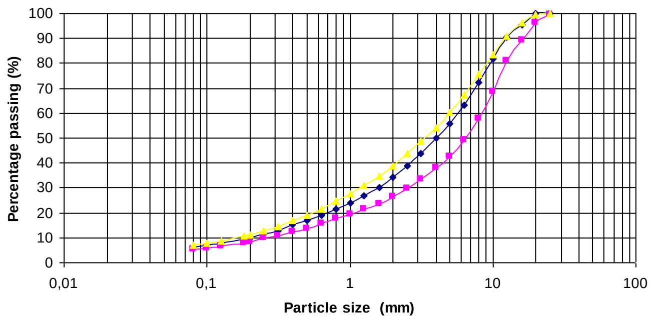

Fig-3: Particle size distribution by sieving

Table-1: Particle size necessary for classification

D max	20 mm
Passing to 80 µm	6.3 %
Passing to 2 mm	33.2 %

Methylene blue values

The methylene blue values (MBV) determined in three tests are presented in Table 2. The obtained methylene blue value indicates that the bottom ash is similar to the sandy soil and thus insensitive to water [18].

Table-2: Methylene blue values

	Sample 1	Sample 2	Sample 3	Average
MBV	0.05	0.06	0.06	0.057

Sand equivalent

The obtained equivalent sand values Es and the visual equivalents sand values Esv for our bottom ash are presented in Table 3. The sand equivalent is very high (> 85) show that bottom ash can be considered as very clean sand due to the absence of clay fines [13].

Table-3: Sand equivalent values

	Sample 1	Sample 2	Sample 3	Average
Es	168	153.9	167	163
Esv	105	97.4	96.4	99.6

DISCUSSIONS

These results physical tests show that bottom ash is a sandy soil and absence of clay fines. Thus, the obtained methylene blue value is 0.057, lower than 0.1, coupled with the results in Table 1 show that our aggregate can be classified in the category D2 [18]. The category D2 corresponding to alluvial gravel is insensitive to water. According to the technical Guide SETRA-LCPC, this aggregate could be used in road embankment either in the state or treated with a hydraulic binder.

Chemical characteristics

Analysis by X-Ray Fluorescence

The bottom ash was finely crushed with a size smaller than 200 µm. The Table 4 summarizes the different compounds determined on three representative samples. It shows that the major elements of bottom ash are Silicium, Calcium, Iron, Sodium, Aluminium and Magnesium. This is commonly observed for bottom ash [11, 13, 19].

Table-4: Chemical composition of bottom ash (% mass)

Element	Symbol	Unit	Average
Oxygenate	O	%	47.0
Sodium	Na	%	4.3
Magnesium	Mg	%	1.4
Aluminum	Al	%	4.0
Silicon	If	%	20.5
Phosphorus	P	%	0.5
Sulphur	S	%	1.0
Chlorinate	Cl	%	0.6
Potassium	K	%	1.0
Calcium	Ca	%	12.3
Titanium	Ti	%	0.3
Zinc	Cr	%	0.3
Manganese	Mn	%	0.1
Iron	Fe	%	6.3
Copper	Ni	%	0.1
Nickel	Cu	%	Traces
Chromium plate	Zn	%	Traces
Strontium	Sr	%	Traces
Zirconium	Zr	%	Traces
Stannum	Sn	%	Traces
Barium	Ba	%	Traces
Lead	Pb	%	Traces

Analysis by X-Ray Diffraction

The bottom ash was finely crushed with a size smaller than 200 µm. The measurements were made on 3 representative samples. The Table 5 represents the crystallized compounds identified by Diffraction with X-Rays. Figure 4 shows an example of test results.

Table-5: Composed crystal

Phases	Character	Phases	Character
Quartz	Some	Gehlenite	Probable
Calcite	Some	Pseudowollastonite	Probable
Hematite	Some	Anhydrite	Probable
Magnetite	Some	Gypsum	Probable
Wustite	Some	White feldspar	Probable
		Diopside	Probable

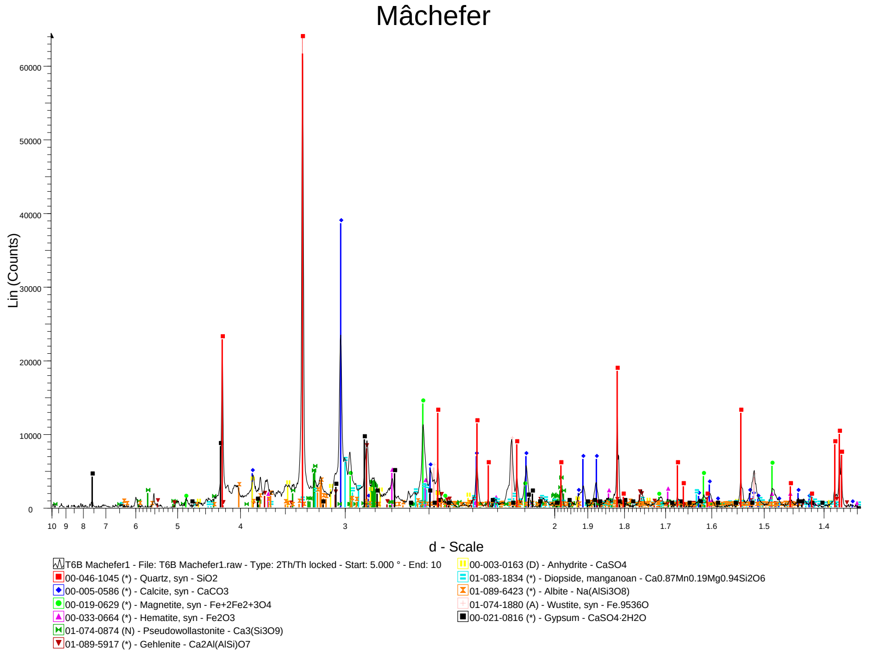

Fig-4: Analysis by X-Rays Diffraction

DISCUSSIONS

The chemical analysis show that the major elements are: SiO_2, CaO, Fe_3O_4, Na_2O, and Al2O3. These elements in particular SiO_2 create the skeleton of the bottom ash. The principal sources of SiO_2 are particles of glass (bottle, glass, etc.). The grand glass quantity of bottom ash proves of a high degree of angularity. Whereas, the presence of CaO and Al2O3 are the origin of the phenomena of swelling that restricts the use of the bottom ash in the road field [7] Swelling causes problems like the cracking and the loss of mechanical resistance etc. To remedy these disorders, it is necessary to add hydraulic binders as well as other solutions like separating from the aluminium particles etc.

CONCLUSIONS

The physical characteristics show us that our material is sandy soil, insensitive to water and has a small proportion of fines. This bottom ash has a varied or spread out particle size distribution along with too many coarse elements what generate much vacuum. According to SETRA-LCPC, our aggregate can be classified in the category D2. The category D2 corresponding to alluvial gravel is insensitive to water. And this aggregate could be used in road embankment either in the state or treated with a hydraulic binder.

SiO_2, CaO, Fe_3O_4, Na_2O, Al_2O_3 are the major elements in our bottom ash. A high degree of angularity was shown by the grand quantity of SiO_2 in bottom ash. Moreover, we can anticipate the phenomena of swelling which could appear in the process of valorisation of the bottom ash because of the presence of the CaO and Al_2O_3. From that, we can use solutions to avoid or decrease the phenomenon of swelling.

These above characteristics coupled with mechanical characteristics will help us to better understand the characterizations of bottom ash during the process of the valorisation of the bottom ash.

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