A Study of State Parameters for Road Construction of MSWI Bottom Ash

Thi Kieu Vinh Nguyen
Faculty of Construction
Vinh University
Vinh City, Vietnam
kieuvinhkxd@vinhuni.edu.vn

Thi Thuy Huong Doan
Faculty of Construction
Vinh University
Vinh City, Vietnam
doanhuongkxd@vinhuni.edu.vn

Thi Hao Cao
Faculty of Construction
Vinh University
Vinh City, Vietnam
caohaokxd@gmail.com

Hong Son Pham
Faculty of Construction
Vinh University
Vinh City, Vietnam
hongsonkxd@vinhuni.edu.vn

Abstract-The current work tries to valorize the bottom ash from Municipal Solid Waste Incineration (MSWI). The bottom ash from waste incineration consists of atypical granular materials. They are industrial by-products resulting from the incineration of domestic waste and the way of the considered valorization is road gravel. In this paper, we present the state parameters of bottom ash taken from a recycling company in the North of France. These features can help us evaluate our bottom ash according to the technical guide of realization of embankments and subgrades.

Keywords-bottom ash; compaction characteristics; valorization; incineration; road gravel

I. INTRODUCTION

Municipal solid waste management technologies include landfilling, recycling/recovery, and incineration. In many countries such as France, Sweden, Denmark, and Taiwan, Municipal Solid Waste Incineration (MSWI) for energy recovery represents the most common waste management technology [1]. The incineration reduces the mass and volume of the solid waste dramatically, thus the requirement for landfilling is decreased [2-7]. However, there is still a considerable amount of solid incineration residue, generated after the combustion, typically bottom ash, fly ash, boiler ash, etc. of which bottom ash accounts for about 80% [8]. In the past, MSWI bottom ash was mostly treated by sanitary landfilling. Possibilities other than landfilling have been sought since MSWI started, and reutilization of incinerator bottom ash has already been considered many years ago. In civil engineering, the road field consumes a significant quantity of aggregates [9]. However, the aggregate reserves are not always exploitable for various reasons: they are often inaccessible, they must be integrated into an urban area, in classified or protected sites, and they have too expensive exploitation and risks of environmental impact. In this context, the valorization of the bottom ash in road field is an interesting alternative. Bottom ash is mainly used in civil engineering for constructing embankments, road layers, and parking areas [9, 10]. In France, about 3 million tons of bottom ash are produced annually [11]. The use of bottom ash began during the late '50s. The expansion of its use throughout the country occurred in the late '80s-'90s [12]. This article presents the state parameters by particle size distribution, moisture content, absolute density, Proctor compaction and bearing capacity index tests. These tests results are evaluated according to the technical guide of realization of embankments and subgrades.

Corresponding author: n Thi Hao Cao

II. THE MATERIAL

The MSWI bottom ash used in this study originated from the platform of recycling of the PréFerNord Company located in Fretin, France. PréFerNord recovers "slag" resulting from the combustion of 5 incineration plants. To calibrate the materials, pre-treatment of this bottom ash like sifting, removal of ferrous, and non-ferrous elements, was carried out on site. After, the bottom ash was left to mature for 3 months (Figure 1). The particle sizes range from 0 to 20mm and approache the size range of natural aggregates which are usually used in the road field.

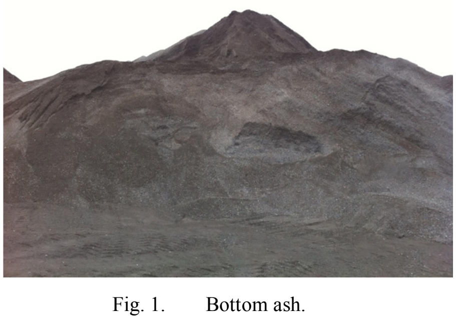

Fig. 1. Bottom ash.

III. THE EXPERIMENTAL METHOD

The particle size distribution was obtained by sieving at 80μm of diameter three samples that were taken after quartering and washing. Moisture content, absolute density and compaction characteristics are the state parameters of bottom ash. The moisture content is equal to the ratio of the mass of water contained in the sample and the dry mass of the sample and is expressed in %. The samples were dried in an oven for 3 days at a temperature of 105°C. The moisture content corresponds to the natural moisture content of the collected bottom ash. The absolute density of bottom ash was determined by using a helium pycnometer of AccuPyc 1330 type. This test is to measure the volume of solid grains from the change of helium pressure by applying the perfect gas law: $PV = nRT$. By knowing the mass of the sample, the absolute density is determined by the ratio between the mass of the solid grain and volume. The measurement was carried out on ground and dried bottom ash.

The compaction is the densification of the soil by applying pressure to it. It contributes in particular to translate or eliminate compaction risk, increase the resistance of soil and slope stability, improve the bearing capacity of road, limit unwanted volume changes, for example, by the action of frost, swelling, or shrinkage [13]. The compaction capacity of the material is assessed through the Normal Proctor and the Modified Proctor tests. Both trials are identical in principle, apart from the difference of the parameters defining the applied compaction energy. The principle of the test is to compact the material at varying moisture content and process energy. For every moisture content, wet and dry masses were determined and compaction characteristics (dry density and optimum moisture content) were determined. The Bearing Capacity Index is the quantity used to assess the capacity of a material to bear directly on its surface the movement of construction equipment. In conjunction with Modified Proctor testing, punching action on compacted specimens was performed to estimate the Bearing Capacity Index.

IV. RESULTS

A. Particle Size Distribution

The results of the particle size distribution presented in Figure 2 show that the bottom ash is characterized by a spread out size distribution (coefficient of uniformity $C_u = 35.5$) along with the too many coarse elements which generate much vacuum (coefficient of curvature $C_c = 2,3$). The C_u and C_c are defined by:

$$C_u = \frac{D_{30}^2}{D_{10} * D_{60}} \quad (1)$$

$$C_c = \frac{D_{60}}{D_{10}} \quad (2)$$

where D_x is the diameter of particles for x% of cumulative passing.

Table I represents the useful parameters for the classification of the acquired bottom ash. The tested bottom ash is a granular material with continued grain size distribution and low proportions of non-plastic fine (< 63μm,) and coarse (> 20mm) fractions. Therefore, this may be easily compacted to obtain a higher resistance. Bottom ash could be considered a well-graded material. The obtained remarks are similar to those obtained by [14, 15].

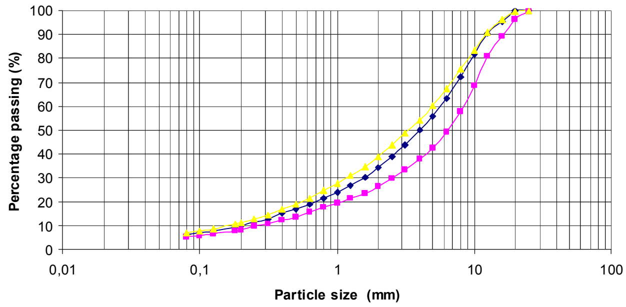

Fig. 2. Particle size distribution by sieving.

TABLE I. PARTICLE SIZE NECESSARY FOR CLASSIFICATION

D_{max}	20mm
Passing to 80μm	6.3%
Passing to 2mm	33.2%

B. Moisture Content

Table II represents the moisture content of the studied bottom ash. The main cause of this high moisture content is the influence of rain before samples were taken from storage.

TABLE II. MOISTURE CONTENT VALUES

	Wet mass (g)	Dry mass (g)	Moisture content (%)
Sample 1	643	542	18.6
Sample 2	697	602	15.8
Sample 3	810	675	20
Average			18.1

C. Absolute Density

The obtained value of the absolute density of the studied bottom ash is about 2.70t/m^3 (Table III). This value is similar to that of quartz-based sand. The obtained density lies in the range of values measured by [16, 17]. This value classifies bottom ash as an aggregate that is lighter than natural ones like sand and gravel. The density is an added benefit that may reduce settlement in use, due to the lower normal stresses caused by the self-weight [18].

TABLE III. ABSOLUTE DENSITY

	Sample 1	Sample 2	Sample 3	Average
Absolute density (g/cm3)	2.70	2.70	2.69	2.70

D. Proctor Compaction

Figures 3 and 4 show the Normal and Modified Proctor compaction curves. Table IV shows the obtained characteristics with Optimal Normal Proctor (OPN) and Optimal Modified

Proctor (OPM). The obtained values of compaction characteristics of bottom ash fall within the variability of the field defined by information note of SETRA on the use of bottom ash in road construction. Based on Proctor test results, bottom ash may be considered as a highly compactable material, which is desirable for preventing future settlements and for increased strength and stability of the layer.

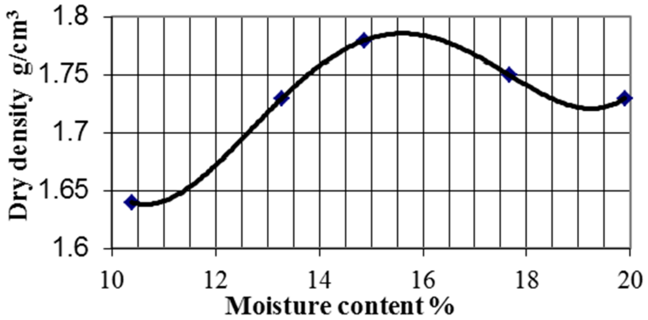

Fig. 3. Normal Proctor compaction curve.

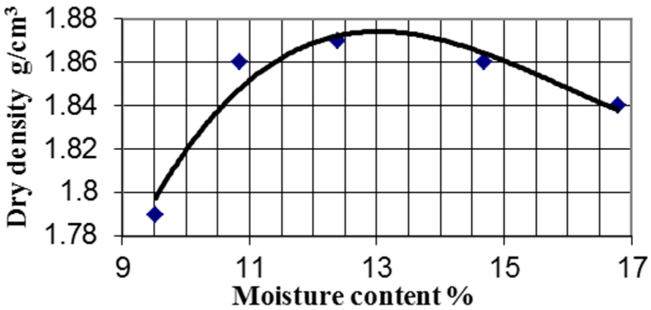

Fig. 4. Modified Proctor compaction curve.

TABLE IV. COMPACTION CHARACTERISTICS

	OPN	OPM
Optimal moisture content (%)	15.0	12.5
Optimal dry density (g/cm3)	1.78	1.87

E. Bearing Capacity Index

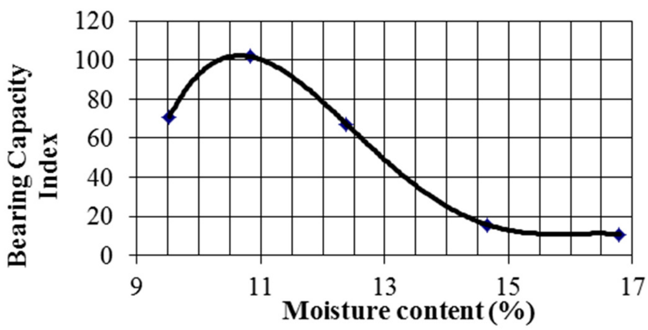

Fig. 5. Bearing Capacity Index curve.

Figure 5 shows the variation of the Bearing Capacity Index with moisture content. According to the recommendations of the French standard (NF P 98 115) [19], to ensure the normal circulation of the machines on a construction site, the desirable values of the Bearing Capacity Index are at least 45 for the base layers and 35 for the foundation layers. This standard also defines the minimum values that must not be less than 35 for the base layers and 25 for the foundation layers. With Bearing Capacity Index of 102 (Figure 5), bottom ash can be considered stable.

V. CONCLUSIONS

The state parameters of the studied bottom ash were analyzed and presented in this paper. From the analysis, the following conclusions can be drawn:

- The bottom ash is characterized by spread out size distribution. Bottom ash can be considered a well-graded material.
- The main cause of its high moisture content is the influence of rain.
- Bottom ash is lighter than natural ashes like sand and gravel. The density is an added benefit that may reduce settlement in use, due to the lower normal stresses caused by the self-weight.
- The obtained values of compaction characteristics of bottom ash fall within the variability of the field defined by information note of SETRA on the use of bottom ash in road construction. Based on Proctor test results, bottom ash may be considered as a highly compactable material, which is desirable in order to prevent future settlements and to increase the strength and the stability of the layer.
- With Bearing Capacity Index of 102, bottom ash can be considered stable.

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