Geotechnical properties and bearing capacity of MBT waste

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ABSTRACT

In this paper, basic geotechnical properties and bearing capacity of mechanically and biologically treated (MBT) waste are presented. MBT waste samples were obtained from the Regional Waste Management Center Mariscina in Croatia. For the purpose of investigation, the so-called "fine fraction" (maximum particle sizes limited to 25 mm) of biodryed waste was used. This fraction of MBT waste is landfilled into the bioreactor landfill, an artificial embankment in which biogas is produced through the controlled anaerobic biodegradation of the waste material. The CBR tests were performed on three dry MBT waste samples that were prepared with the use of standard compaction energy. Test results show that the measured CBR values correspond to the values that are typically obtained for the case of highly compressible organic and fine-grained soils with high plasticity.

Keywords: MBT waste, geotechnical properties, landfill, CBR

1 INTRODUCTION

Main goals in waste management for the member states of the European Union (EU) are defined in the Waste Framework Directive 2008/98/EC of November 2008. Among other requirements, the Directive demands a significant reduction of the amount of biodegradable waste before its final disposition to a landfill. Because of its high reactivity, biodegradable waste poses a substantial environmental hazard. Biodegradable waste decomposing in landfills produces methane, which is known as one of the primary greenhouse gasses. Additional requirements concerning landfilling of municipal solid waste (MSW) are laid down in the EU Landfill Directive 1999/31/EC of April 1999. The Directive requires member states to only landfill wastes that have been subjected to treatment, leading to a reduction in their quantity or hazard to human health and the environment (Di Lonardo et.al. 2012., Robinson et al. 2005).

Mechanical-biological treatment (MBT) of MSW implies mechanical pretreatment of waste (shredding, separation by size, density and magnetic properties, densification etc.) and subsequent biological treatment (aerobic or anaerobic degradation) of the biodegradable waste components. MBT represents a viable way of fulfilling the requirements laid down by the above-mentioned EU directives. Aims of MBT treatment of MSW can be summarized as follows:

- maximizing the amount of renewable raw materials;
- production of compost and compost-like products;
- production of solid recovered fuel;
- production of material that is suitable for landfilling (bio-stabilized material suitable for landfilling on inert landfills or biodryed material suitable for landfilling on bioreactor landfills);
- production of biogas which can be used for generating heat and/or electricity;

Regarding the production of material suitable for landfilling, the waste pre-treatment objectives should relate to minimizing the adverse consequences of disposal (Heerenklage and Stegmann 1995; Leikam and Stegmann 1995; Rieger and Bidlingmaier 1995; Scheelhaase and Bidlingmaier 1997; Komilis 1999; Soyez and Plickert 2002; Fricke et al. 2005; Munich et al. 2006; Montejo et al. 2010; Velis et al. 2010), including:

- minimization of volume and mass of waste to be disposed in landfill;
- inactivation of biological and biochemical processes in order to reduce leachate and methane production and odour emissions;

- immobilization of pollutants of the waste to be disposed of in order to reduce leachate contamination;
- reduction of landfill settlement;
- reduction of the duration of the landfill site aftercare. (Di Lonardo et.al., 2012)

MBT landfills refer to the artificial embankment structures constructed of MBT waste material. Physical and mechanical characteristics of the material used in such structures play a major role both in the design and construction phases.

In this paper, physical and geotechnical properties: moisture content, physical composition, organic matter content, particle density and particle size distribution of the MBT waste material were determined. Tests were performed according to the widely accepted ASTM standards intended for soil testing. CBR tests were performed in order to determine load bearing capacity of MBT waste. The CBR test is a method most commonly used to evaluate the strength of a sub grade soil, sub base, and base course material for pavement design. Results of the performed tests were used for MBT waste material characterization and in order to evaluate its suitability for supporting structures (such as pavement) to be built atop a landfill during the exploitation phase and in the case of after-use development of a closed MBT landfill.

2 MATERIAL AND METHODS

Waste specimens were sampled during the winter season from the Regional Center for Waste Management Mariscina, located in Istria, Croatia. The center acts as MBT plant for processing primarily MSW collected from the surrounding municipalities.

Upon arrival to the waste management center and before commencement of the mechanical treatment phase, input waste is stored in the receiving pit. Mechanical processing of MSW starts with its shredding to a fraction with particle sizes < 200 mm. The shredded MSW is then transported further to the biological treatment stage which takes place in the biodrying bioreactor. Within the biodrying bioreactor, the thermal energy released during aerobic decomposition of readily degradable organic matter is combined with excess aeration to dry the waste (Velis et. al., 2009). MSW is subjected to biodrying for a period of 7 to 10 days. After the biodrying stage has been completed the biodryed MSW undergoes through various refinement and separation processes that include further shredding, extraction of recyclable materials, ferrous and non-ferrous materials, PVC plastics etc. In that way, waste material is divided into more material streams and outputs of different characteristics.

The output material that was used for the purpose of performing laboratory investigations is biodryed waste material which is suitable for landfilling to the bioreactor landfill. This is the so-called "fine fraction" of biodryed MBT waste which is characterized by nominal particle size less than 25 mm (Figure 1).

Figure 1. MBT waste material - fine fraction

2.1 Moisture content

Moisture content was determined according to the ASTM D 2216 standard for laboratory determination of water content of soil and rock by mass. Since the MBT waste contains a high portion of organic matter, to reduce the decomposition of organic material, samples were dried at 60 °C, as is suggested in the standard, for the period of 24 h. Initial and final (constant) masses of samples after oven drying were recorded. Average value of moisture content for MBT waste samples for in-situ conditions was calculated as 9.60 %.

2.2 Physical composition of MBT waste

A sample of approximately 1000 g of mass was prepared by quartering method. Individual components of MBT waste sample were visually identified and separated manually.

As a result of being subjected to various prior treatment processes in MBT plant, the MBT waste material was in a state such that it was impossible to determine the exact physical component type for around 70 % of the mass of MBT waste sample using the chosen approach. The unidentified material was sieved on a 2 mm sieve and separated into two parts, one passing and the other contained on the 2 mm sieve. In that way, the unidentified material was designated as "Miscellaneous<2 mm" and "Miscellaneous>2 mm" respectively.

Each component, including the unidentified material, was weighed and mass percentages of each component of the sample was calculated. The results are presented in Table 1.

Table 1. Mass percentages of different components of MBT waste

Component	Mass percentage [%]
Plastics	6.43
Textile	0.22
Glass	10.62
Metal	0.94
Paper/Cardboard	4.71
Wood	1.18
Bones/Skin	0.20
Stones	2.76
Ceramics	0.46
Rubber	0.13
Kitchen waste	2.15
Miscellaneous>2 mm	42.48
Miscellaneous<2 mm	27.71
Total	100

2.3 Organic matter content

The test method was conducted in accordance with the ASTM D 2974 standard, Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils.

A representative oven-dried sample of MBT waste, having a total mass of 50 g, was composed according to the calculated mass percentages of each individual component of MBT waste, as presented under the subchapter 2.2. in Table 1. The representative sample was heated in a muffle furnace at the temperature of 440 °C until no change of mass occurred after a further period of heating. Subtracting the mass of sample after heating from the mass before heating, the organic matter content was calculated as 51.6 %.

2.4 Particle size distribution

Particle size distribution analysis was conducted according to the ASTM D 422 standard which is used for particle size analysis of soils.

The obtained MBT waste material was dried in a laboratory oven for a period of 24 hours at the temperature of 60°C and divided into 25 samples. Mass of samples ranged between 231 and 600 g. A total mass of 9975 g of MBT waste was sieved with a mechanical shaker through the series of sieves with the following sizes of screen openings (listed from the top to bottom sieve): 31.5 mm, 16 mm, 8 mm, 4 mm, 2 mm, 1 mm and 0.5 mm.

Results of the sieving analysis are presented graphically in the granulometric diagram (Figure 2).

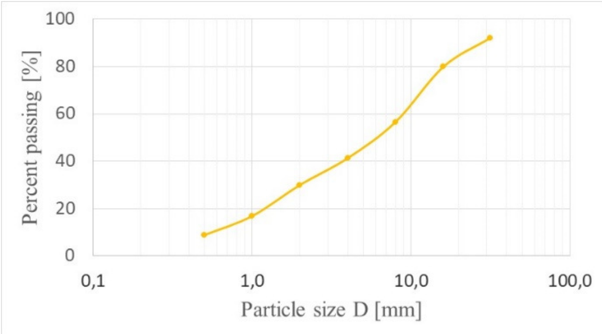

Figure 2. Particle size distribution curve of MBT waste

The granulometric curve shown in Figure 2 presents an average curve that was constructed based on the results of the sieving analysis of all 25 samples of MBT waste.

Based on the granulometric curve, two characteristic coefficients that are used for classifying coarse grained soils were calculated: coefficient of uniformity (C_u) and coefficient of curvature (C_c). The calculated values are: C_u=14.23 and C_c=1.07. It can be concluded that the MBT waste is a coarse-grained and well graded material similar to well graded gravel (GW).

2.5 Particle density

Particle density of MBT waste was determined using a modified constant-volume gas pycnometer, in accordance with the ASTM D 5550 standard.

The measured values vary in the range from 1.691 g/cm^3 to 2.188 g/cm^3 with an average value being 1.88 g/cm^3 for the case of in-situ conditions of MBT waste material.

2.6 Bearing capacity

In order to evaluate the bearing capacity of biodryed MBT waste, California Bearing Ratio (CBR) of the waste samples was determined. A total of three MBT waste samples (denoted as "Sample #1" to "Sample #3") were tested. The tests were performed according to the ASTM D 1883 standard. Figure 3 shows the testing device with the installed MBT waste sample. Prior to testing, the samples were oven-dried at 60 °C for a period of 24 h. Dry samples were compacted in three layers, with the use of standard compaction effort, according to the ASTM D 698 standard.

Figure 3. CBR testing device with installed MBT waste sample

During the course of the CBR test, stress readings were recorded at 0.5 mm penetration increments. Results are presented on stress-penetration curves on Figure 4.

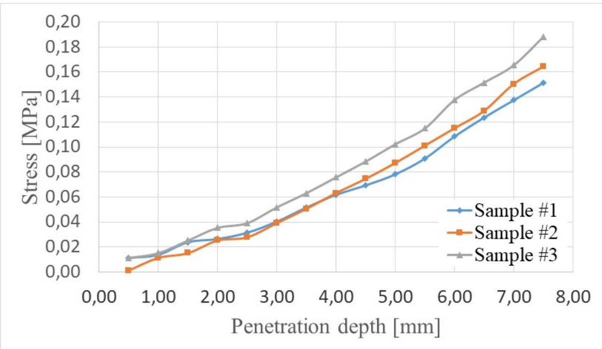

Figure 4. Stress-penetration curves of MBT waste samples

California Bearing Ratio was calculated using the corresponding stress values for the 2.54, 5.08 and 7.62 mm penetrations taken from the stress-penetration curve. Calculated CBR values are listed in Table 2.

Table 2. CBR values of MBT waste

Sample	CBR [%]		
	For 2.54 mm penetration	For 5.08 mm penetration	For 7.62 mm penetration
#1	0.5	0.8	1.2
#2	0.4	0.8	1.3
#3	0.6	1.0	1.4

CBR values are widely used for relative ratings of supporting strengths of the subbase and subgrade materials which are used in the construction of pavement structures. The higher the CBR value of a particular material, the more strength it has to support the pavement. Relative ratings of supporting strengths as a function of CBR values are given in Table 3 (Schaefer et al., 2008).

Table 3. Relative CBR values for subbase and subgrade material

CBR [%]	Material	Rating
> 80	Subbase	Excellent
50 - 80	Subbase	Very good
30 - 50	Subbase	Good
20 - 30	Subgrade	Very good
10 - 20	Subgrade	Fair-good
5 - 10	Subgrade	Poor-fair
< 5	Subgrade	Very poor

For comparison, typical ranges of CBR values and associated soil types according to the Unified Soil Classification System (USCS) are presented in Table 4.

Table 4. Characteristic ranges of CBR values for various soil types

CBR [%]	Soil Type (according to USCS)
0 - 3	OH, CH, MH, OL
3 - 7	OH, CH, MH, OL
7 - 20	OL, CL, ML, SC, SM, SP
20 - 50	GM, GC, SW, SM, SP, GP
> 50	GW, GM

The results revealed that the CBR values of the biodryed MBT waste material vary between 1.2 and 1.4% for the 7.62 mm piston penetrations. Based on the relative ratings shown in Table 3, a CBR value less than 5 % implies that the supporting strength of such material is very poor and cannot provide adequate strength for subbase and subgrade applications. In comparison to soil, the tested MBT waste material is similar to organic soils of high and low plasticity and fine-grained soils of high plasticity.

3 CONCLUSIONS

Geotechnical properties of MBT waste were determined in this study. The so-called "fine fraction" of biodryed MBT waste which is characterized by nominal particle size less than 25 mm was analysed. All tests were performed according to the globally recognized ASTM standards for soil testing.

Moisture content for in-situ conditions of the MBT waste samples was 9.60 % with average particle density of 1.88 g/cm^3. Organic matter content showed a value of 51.6 %. Physical composition of MBT waste was determined by means of manual separation of the different materials found in the MBT waste sample. The most prevailing materials, in terms of mass, were glass, plastics and paper/cardboard. Particle size analysis revealed that the MBT waste, when compared to soil, is a coarse-grained and well graded material similar to well graded gravel (GW).

CBR tests were performed on dry MBT waste samples prepared with the use of standard compaction energy. CBR values were calculated using the corresponding stress values for the 2.54, 5.08 and 7.62 mm penetrations. For the case of 5.08. mm penetration the CBR values fall in the range of 0.8 to 1.0 % while the calculated values for 7.62 mm penetration are in the range from 1.2 to 1.4 %. Low CBR values show that the bearing capacity of MBT waste material is very poor and suggest that it cannot provide adequate support for structures (e.g. pavement) to be built upon a MBT landfill. Similar CBR values can be obtained for the case of highly compressible organic and fine-grained soils with high plasticity.

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