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# Applicability of the Large pycnometer method for determination of specific gravity of mechanically and biologically treated waste

Nikola Kaniski[1], Nikola Hrncic[1] and Igor Petrovic[1]

[1]Department of Environmental Engineering, University of Zagreb, Faculty of Geotechnical Engineering, Croatia

## ABSTRACT

In this paper authors presented results of specific gravity of fine fraction of mechanically and biologically treated (MBT) waste material. The water pycnometer procedure was adapted from BS 1377: Part 2: 1990 standard for determination of particle density with a simple Large water pycnometer (LWP) method. To prevent floating of the light mass components (e.g. plastics, Styrofoam, cardboard), a mechanical bridging (aluminum screen) was placed into the bottom of a conical screw cap. The results of specific gravity of fine fraction of tested waste material varied in range from 1.35 to 1.77. In order to examine the accuracy of the water pycnometer method, a series of tests were conducted on a sand specimen with a known specific gravity. In spite its simplicity, the method proved to be fairly accurate for sandy specimens with “only” a 3.3% error, whereas for waste specimens the LWP method has proven to be unreliable with 18.19% error with respect to the reference point. As a referent value for waste, results of specific gravity determined with gas pycnometer were used. The arithmetic mean value of measured specific gravity of waste specimens with gas pycnometer method was 1.88.

Keywords: MBT waste, specific gravity, biodried waste.

## 1 INTRODUCTION

One of the most common ways of disposing of municipal solid waste (MSW) is mechanical and biological treatment (MBT). The aim of the MBT process is reducing the amount of biodegradable portion of waste material before landfilling (Nelles et al., 2012).

The process is composed of a mechanical treatment step in which waste is mechanically separated to recover recyclables, and a biological treatment step which can be treated aerobically (biodrying, composting) or anaerobically (digesting) with aim to reduce the organic portion of waste materials.

Apart from the useful outputs, about 40% of treated waste materials cannot be reused and it has to be landfilled. Since landfills can be observed as artificial embankments and slopes with the main building block being MSW, the examination and determination of the basic geotechnical properties of waste material, like for example specific gravity, are of substantial importance to a quality design process.

Solid particle density and specific gravity of various waste types have been investigated by many researchers. In most cases the specific gravity was determined with water pycnometer method.

Gabr & Valero (1995) reported solid particle density of 2 $\frac{g}{cm^3}$ for untreated waste 15-30 years old on the entire grain size distribution, and 2.4 $\frac{g}{cm^3}$ for fine fraction only (<No. 200 mesh). Density was determined according to ASTM D854-83 standard.

Reddy et al. (2009) published solid particle density of 0.85 $\frac{g}{cm^3}$ for untreated fresh MSW, and 0.97 $\frac{g}{cm^3}$ for untreated landfilled MSW 1.5-year-old.

Breitmeyer (2011) published solid particle density of 1.34 $\frac{g}{cm^3}$ for untreated, dry and shredded MSW. Author determined particle density according to ASTM D854 standard.

Petrovic et al. (2014) published solid particle density of 2.15 $\frac{g}{cm^3}$ determined according to ASTM D854-02 with maximum particle size of 4.75 mm.

Yesiller et al. (2014) determined specific gravity of 1.377 and 1.530 for as prepared/uncompacted and compacted manufactured wastes respectively, 1.072 and 1.258 for uncompacted and compacted fresh wastes respectively, and 2.201 for old wastes with water pycnometer method.

Sivakumar Babu et al. (2015) published solid particle density of 1.26 $\frac{g}{cm^3}$ for mechanically and biologically treated compost reject from a landfill site with bottle and pycnometer method.

Ramaiah & Ramana (2017) published solid particle density for untreated waste material from 1.90 to 2.15 $\frac{g}{cm^3}$ determined in accordance with ASTM D854-14 standard.

Based on the results obtained from various researchers it can be noticed that determined specific gravities lie in a wide range of values from very low as 0.85 and up to the highest value of 2.4 which is very close to the specific gravity of natural soils.

### 1.1 Scope of article

In this paper, authors presented results of basic geotechnical parameters (moisture content, organic matter content, particle size distribution, specific gravity of waste particles) obtained on unrecoverable fine fraction of MBT waste material suitable for landfill disposal. The waste samples were taken from the waste management center Mariscina, Istria, Croatia which utilizes aerobic biodrying process. The tested waste material is presented on Figure 1.


Figure 1. Fine fraction of pre-treated MBT waste material used in present research

In this work, the emphasis is placed on the usability of the Large water pycnometer (LWP) method for the determination of specific gravity of mechanically and biologically treated waste material.

## 2 MATERIALS AND METHODS

### 2.1 Waste composition

The representative samples were prepared by quartering method. Approximately 30 kilograms of waste material was mixed and then divided into four equal parts. Two diagonal parts were removed, while with other two parts the same mixing and splitting procedure was repeated until a representative sample of about 1 kg of waste material was obtained.

The obtained sample was manually sorted and weighed in order to determine the composition of the waste material (Table 1). Part of the waste that could not be identified or separated was placed into two "Unidentified" categories with particle size smaller and larger than 2 mm. The most frequent materials in the examined samples were Plastics, Paper/Cardboard, Metal and Glass.

Table 1. Component mass percentages of studied waste material

| Components | 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 |
| Unidentified | |
| Unidentified >2 mm | 42.48 |
| Unidentified <2 mm | 27.72 |
| Total | 100 |

### 2.2 Moisture content

Moisture content was determined immediately after the waste samples were delivered into the laboratory. For this purpose, ASTM D 2216 standard for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass was used. The drying temperature used was 60 °C to reduce decomposition of the organic material. Measured average moisture content was 9.60% respectively.

### 2.3 Organic matter content

The procedure for measuring organic matter content was adjusted and adopted from ASTM D 2974 standard for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils.

A representative sample of 50 g was prepared according to mass percentages of individual waste components presented in Table 1. The sample was placed into a ceramic vessel and burned in a muffle furnace at 440 °C until no further changes in mass were observed. Calculated organic matter content of studied material was 51.6%.

## 2.4 Particle size distribution

The procedure for particle size analysis was adopted from ASTM D 422 standard for Particle-Size Analysis of Soils. A series of sieves was used as follows: 31.5, 16, 8, 4, 2, 1 and 0.5 mm. A total of 25 samples were sieved. The mean value of particle size distribution curve is presented in Figure 2. The mean coefficient of curvature and mean uniformity coefficient for studied samples were $C_c = 0.86$ and $C_u = 15.8$ respectively. Therefore, the tested material can be considered as a coarse-grained and well-graded material.

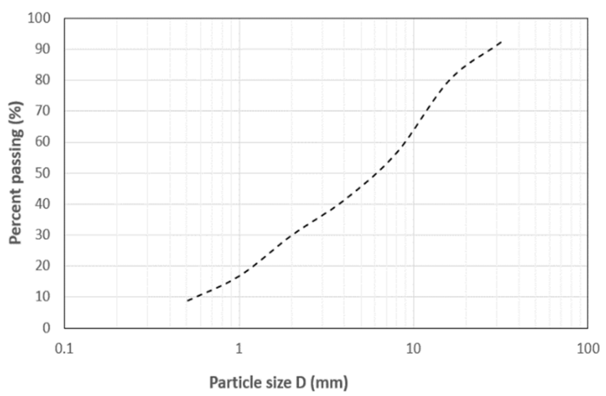


Figure 2. Particle size distribution curve of MBT material used in this research

## 2.5 Specific gravity

As defined in ASTM D 854 standard for Specific Gravity of Soil Solids by Water Pycnometer, specific gravity is the ratio of the mass of a unit volume of a soil solids to the mass of the same volume of gas-free distilled water at 20°C, Equation (1). This parameter can be used to calculate various physical and phase properties of waste material, e.g. density, void ratio, porosity and degree of saturation.

$$G_S = \frac{\rho_S}{\rho_W} \qquad (1)$$

Where $G_s$ is the specific gravity of material solids, $\rho_s$ is the density of material solids, and $\rho_w$ is the density of water.

For the purpose of this research the reference value of waste solid particle density $\rho_s$ was established using gas pycnometer method. Due to the strong heterogeneity of tested samples the established values varied from 1.691 to 2.188 $\frac{g}{cm^3}$, with arithmetic mean value of 1.88 $\frac{g}{cm^3}$.

The mean value of $\rho_s$ obtained with gas pycnometer was taken as a reference value for comparison purposes with results obtained from the LWP method.

## 2.6 LWP method

The water pycnometer procedure was adapted from BS 1377: Part 2: 1990 standard for determination of solid particle density with a Large pycnometer method. The glass pycnometer volume was 1 $dm^3$, which was considered sufficiently large since the largest particle size of tested waste material was less than 25 mm. To prevent floating of the light mass components (plastics, Styrofoam, cardboard), a mechanical bridging (aluminum screen) was placed into the bottom of a conical screw cap (Figure 3), as suggested by Breitmeyer (2011).

Figure 3. Large water pycnometer (1$dm^3$ volume) with aluminum screen for the light mass components

### 2.6.1 LWP method testing procedure

a) Cleaning and weighing an empty pycnometer with lid and mesh (establishing mass $m_1$).

b) A portion of the waste sample was placed in a pycnometer and the mass of the sample and pycnometer with a lid and mesh was weighed (establishing mass $m_2$).

c) Deaerated water at room temperature is added to about half of the pycnometer height. The sample and water were then stirred with a glass rod to remove air bubbles in the sample. The pycnometer was then closed so that the previously marked marker on the lid coincides with the marker on the pycnometer.

d) After closing, the pycnometer was shaken and rolled on a solid surface. The opening on the pycnometer lid was kept closed with a finger, allowing air to come out of the pycnometer and the foam to dissolve. The pycnometer was left for a minimum of 24 hours at room temperature, which must be constant with a tolerance of ± 2 °C. Additionally, the air was sucked out from the waste sample with use of a vacuum pump before filling the pycnometer to the top.

e) The pycnometer was then filled to the top of the lid with deaerated water, leaving no air bubbles under the lid.

f) The mass of the pycnometer was then measured (to the nearest of 0.5 g) (establishing mass $m_3$).

g) After that, the pycnometer was emptied, washed and filled to the top of the lid with deaerated water at room temperature. Special attention was paid to remove air bubbles and keep the water at the top of the lid (not to spill the water from the pycnometer). The pycnometer was then dried on the outside and the mass of the pycnometer filled with deaerated water was weighed (establishing mass $m_4$).

Solid particle density was then calculated according to Equation (2).

$$\rho_s = \frac{m_2 - m_1}{(m_4 - m_1) - (m_3 - m_2)} \left[\frac{g}{cm^3}\right] \quad (2)$$

After the solid particle densities of all specimens were calculated using Equation (2), corresponding specific gravities were then calculated by dividing measured solid particle density with density of water at 4 °C (1 $\frac{g}{cm^3}$) (see Table 2).

2.6.2 LWP method accuracy

In order to establish the accuracy of the LWP method, four consecutive tests on uniform sand samples (0-1 mm fraction) with known solid particle density of 2.63 $\frac{g}{cm^3}$ were made. The mean value of solid particle density obtained using the LWP method was 2.718 $\frac{g}{cm^3}$. Therefore, the results obtained with LWP method was 3.3% higher than the reference value. Thus, in order to confirm the applicability of LWP method on waste specimens it is anticipated that, by following the same testing procedure, the solid particle density of waste specimens established with LWP method should also not differ more than 3.3% from the reference value of the tested waste material.

## 3 RESULTS

The water pycnometer set-up is shown in Figure 4, while the obtained results are provided in Table 2.

Figure 4. LWP, vacuum pump and desiccator

Table 2. Calculated specific gravity of studied waste material

| Mass of the specimen [g] | Specific Gravity $G_s$ |
|---|---|
| 57.9 | 1.350 |
| 56.4 | 1.372 |
| 102.7 | 1.768 |
| 87.6 | 1.631 |
| 58.3 | 1.465 |
| 47.8 | 1.547 |
| 55.2 | 1.614 |
| 61.9 | 1.423 |
| 71.3 | 1.540 |
| 128.5 | 1.660 |
| 75.6 | 1.490 |
| 77 | 1.590 |

As can be seen from results presented in Table 2, specimens masses used in tests were in the range of 47.8 g to 128.5 g, while specific gravity varied from 1.350 to 1.768, with mean value equal to 1.538.

Presented results reveal that regardless of the applied method, in comparison with soils, the scatter of data obtained on waste samples is much more significant due to a more pronounced heterogeneity. Therefore, as opposite to soils, the specific gravity of waste material cannot be assumed. The measurement of specific gravity of waste material has to be carried out on a much larger number of representative samples and then averaged.

With respect to the LWP method, it can be seen that LWP method produced specific gravity which was 18.19% smaller than the reference value. The obtained results clearly indicate that Large water pycnometer method, in spite its simplicity, might not be appropriate for the determination of specific gravity of MBT waste samples.

## 3 CONCLUSIONS

In this work, basic geotechnical parameters of biodryed fine waste MBT fraction was presented. A special emphasis was placed on the applicability of the LWP method for measuring specific density of MBT waste.

Obtained results showed significant discrepancy between specific gravity values obtained with LWP and the reference method.

Preliminary results show that light and floating particles might have significant influence on the measurement results. Therefore, use of Large water pycnometer method for determination of specific gravity of waste samples requires special care and considerations from the operator. However, in order to obtain a more final conclusion, further research is necessary.

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