Investigation of municipal solid waste massif by method of multichannel analysis of surface waves

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ABSTRACT

Municipal solid waste is a specific type of a soil-like material. Waste landfills are always placed near urban settlements and occupy sizeable territories, which are irretrievably withdrawn from circulation. As a result of the permanent process of waste generation, landfill areas are steadily growing. There has been a tendency of a landfill capacity increase in waste storage types of 20 and more meters in height lately. This height increment is accompanied by both the increase of loads applied to the subsoil and stresses and deformations in a waste massif. As a result, the evaluation of stability becomes necessary, for which physical-mechanical properties of waste, as well as prediction of their changes in time are required. The application of modern nondestructive methods of field determination of mechanical properties of waste has significant advantages over the traditional approaches. One of these nondestructive methods is a multichannel analysis of surface waves (MASW). This method allows measurements in the weathering zone of the near-surface part of the profile during the field testing of soils and soil-like materials, when it is practically unrealizable to select and restore undisturbed samples. When applying the MASW-method, the data along the geological cross-section are usually obtained as mean values along the defined depth, which is suitable for the investigations of homogeneous massifs of municipal solid waste.

Keywords: municipal solid waste, multichannel analysis of surface waves

1 INTRODUCTION

Municipal solid waste (MSW) is a specific type of a soil-like material. As provided by the experimental results, the massif of MSW can be considered as a composite material consisting of two components. The basic component (the parent material) consisting of fine- and medium-grained particles (mostly soil-like) is characterized by its frictional behaviour. The second one, the reinforcing matrix, includes fibrous components of waste. In this case mixed MSW can be simulated like the soil reinforced by randomly oriented fibers (Kockel 1995).

Disposal tips are always arranged near human settlements. They occupy considerable areas, which are irretrievably taken out of economic circulation. In connection with the permanent process of waste formation, the areas occupied by landfills are constantly growing. The increase in the height of waste piling reduces involvement of new territories, but leads to the load increase on the subsoil and complicates the stress-strain behaviour of a waste pile. Estimation of physical-mechanical properties, stability of waste piles and their changes in time becomes actual.

Undisturbed sampling of waste material is practically impossible. It creates certain difficulties in defining their mechanical properties needed for calculations. Reliable mechanical properties of MSW can be obtained only by field methods. On the other hand, the spot definition of waste characteristics results in a wide scatter of investigation results. Besides, garbage refers to a special material, which demands strict safety measures when working with it. Moreover, sanitary-hygienic restrictions are imposed.

Application of modern nondestructive methods of field definition of mechanical properties of waste has essential advantages. One of them is the method of the multichannel analysis of surface waves (MASW) (Park et al. 2002). It allows measurements in a weathering zone of the near-surface part of the profile. It is the most efficient and rapid method, which does not demand well-drilling or any other disturbance and all measurements are made from the ground surface. It goes very well with the field research of soils and soil-like materials (MSW), when it is practically impossible to select and restore undisturbed samples.

When applying the MASW-method, the data along the geological cross-section are usually obtained as mean values along the defined depth, which is suitable for the investigations of homogeneous massifs of
municipal solid waste.

2 EQUIPMENT FOR MASW

Registration of surface waves was done by a telemetric 24-channel seismic exploration system, designed for shallow investigations with the use of different seismic sources and digital record of information in SEG-Y file. The system consists of seisphone cable assemblies, connected by field telemetric modules (Fig. 1). Each seismometer cable assembly of 8 m in length is equipped with 4 geophone cable sockets. It is very flexible, ultraportable, evacuable and user-friendly mountable-and-dismountable equipment.

![Geophone connected to cable assembly (upper) and telemetric field module (lower)](image1)

3 DESCRIPTION OF TEST AREA

Investigation of a waste pile profile was made on a landfill in the suburb of Perm. The area of 115×145 m in size and around 7.5 m in height on top of the aged MSW mass (3-7 years old) was selected (Fig. 2, 3).

According to the results of geological investigations the subsoil is represented by the low-plastic clay layer of 1.7 m in thickness, which is underlaid by the silty low-plastic loamy clay layer of 3.4 m in thickness. Soil characteristics are listed in Table 1.

Ground water level (top water type) was met at depths of 2.0 – 2.5 m.

![General view of the waste pile](image2)

![Topographic plan of the area with the contour of shooting configuration (scale adjusted, length of shooting line 115m)](image3)

Table 1: Soil characteristics

| Characteristic             | 1 layer | 2 layer |
|---------------------------|---------|---------|
| Name of soil              | low-plastic clay (CL) | silty low-plastic loamy clay (ML) |
| Depth                     | 1.7 m   | 3.4 m   |
| Density                   | 1.87 g/sm³ | 1.89 g/sm³ |
| Density of solids         | 2.74 g/sm³ | 2.70 g/sm³ |
| Moisture content          | 26.1 %  | 28.7 %  |
| Filtration coefficient    | 0.0066 m/day |         |
| Angle of internal friction| 16°     | 14°     |
| Cohesion                  | 52 KPa  | 19 KPa  |
4 RESEARCH METHODOLOGY

2-D in-line offset end-on spread geometry for the surface waves registration was applied. System quantity characteristics are listed in Table 2. General view from the first source point (SP-1) is shown in Fig. 4.

Table 2: Characteristics of end-on offset spread geometry

| № | Symbol | Characteristic | Value |
|---|--------|----------------|-------|
| 1 | N      | Multiplicity   | 4     |
| 2 | D      | Receiver spread length (m) | 46 |
| 3 | NC     | Number of channels | 24 |
| 4 | Xmin   | Minimum distance of receiver point from source point (m) | 10 |
| 5 | Xmax   | Maximum distance of receiver point from source point (m) | 56 |
| 6 | SI     | Source interval (m) | 8 |
| 7 | RI     | Receiver interval (spacing) (m) | 2 |
| 8 | R      | Offset (m) | 10 |
| 9 | ND     | Density of source points per 1 km | 125 |

Consequently, seismic signals were registered and recorded in the operating personal computer. Primary data processing and seismogram summation using the operating software were done directly during the measurements. The initial seismogram obtained at the first shot point is presented in Fig. 5.

Fig. 4 General view of shooting configuration at the first source point

Data were recorded in 6 modes with the sampling time of 0.5 ms, 1.0 ms and the record length of 1,024, 2,048 and 4,096 readings. 4-fold stacking was applied due to the low level of the ambient noise. External synchronization was provided by short circuit under the sensitivity equal to 1. A start-record signal was sent to the computer via the Wi-Fi interface by a wireless synchronization system.

The seismic system, as well as seismic cables, were tested at every source point by operational software before the beginning of field measurements. The complete seismic system test included control of the main seismic channel parameters, such as noise, a nonlinear distortion factor, geophone sensitivity and phase variation, crosstalk, in-phase rejection. The seismic cables test included a nonlinear distortion factor, a number of geophones connected to one channel, geophone resistance.

After the survey and data record completion at each shot point, all the system, including the 24-channel receiver spread and the shot point, was carried to the distance of 8 m.

Further processing and material interpretation were carried out with the use of a specialized software package. Loading of the initial SEG-Y files, data reading, geometry assignment, database record and visualization were performed at the first stage in the program module ‘Loading of data and geometry assignment’. Visualized seismograms at shot points SP-1 – SP-4 are presented in Fig. 6.

A dispersive analysis was performed at the second stage of processing. For every seismogram a dispersive image was calculated. A dispersive curved line was “extracted” from each image by means of image picking to the maximum of amplitudes. The dispersive image received for source point SP-1 in the sampling period of 0.5 ms and the record length of 2,048 readings is presented in Fig. 7. After the image at SP-1 had been picked out, the images at other source points were processed in the same way. Then all picked curves were exposed to the inversion procedure.
If we are given the velocity of shear waves $V_s$, it is possible to calculate the initial shear modulus of the waste $G_{0\text{MSW}}$ using the known formula (Timoshenko & Goodier 1970):

$$G_{0\text{MSW}} = V_s^2 \times \rho = 110^2 \times 0.887 = 10732 \text{ KPa}$$

(1)

where, $\rho = 0.887 \text{ t/m}^3$ is MSW density.

Then, using the known values of the shear modulus under small strains and the Poisson's ratio, it is possible to calculate the Young's modulus and the oedometric modulus.

6 CONCLUSION

The method of the multichannel analysis of surface waves (MASW) is the most inexpensive and fast way of field testing of soils and soil-like materials, the selection and restoration of undisturbed samples of which are impossible. MSW attributes to these types of material.

The MASW method is nondestructive. It does not demand well-drilling (all measurements are carried out from the surface) and goes very well with the study of the homogeneous masses of municipal solid waste. All field works done by this method are carried out by the group of 2 people. The complete equipment package weighs no more than 40 kg and is easily delivered manually to any point of observation (Fig. 9). The outcome of the research is a wave velocity profile which can be used for the soil profile estimation.

5 ANALYSIS OF WAVE VELOCITY PROFILE

In Fig. 8 there are three clearly visible layers, the top of which is the mass of waste. The upper layer of the landfill base consisting of low-plastic clay is located under the waste, and the third layer is silty low-plastic loamy clay. The average velocity of shear waves in the first layer from the surface (waste) was 110 m/s, in the second (clay) – 150 m/s and in the third (loamy clay) – 260 m/s.

REFERENCES

1). Kockel, R. (1995): Scherfestigkeit von Mischabfällen in Hinblick auf die Standsicherheit von Deponien. Dissertation, Schriftenreihe des Instituts für Grundbau, Ruhr-Universität, Bochum, Germany, Heft 24.

2). Park C.B., Muller R.D., Miura H. (2002): Optimum field parameters of an MASW survey. Japanese Society of Exploration Geophysicists (SEG-I) Extended Abstracts, Tokyo, Japan, 22–23 May 2002.

3). Timoshenko, S., Goodier, J.N. (1970): Theory of elasticity. ISBN-13: 978-0070647206, McGraw-Hill College.