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PERMEABILITY OF DIFFERENT SIZE WASTE PARTICLES

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Abstract. The world and life style is changing, but the most popular disposal route for waste is landfill globally until now. We have to think about waste prevention and preparing for re-use or recycling firstly, according to the waste disposal hierarchy. Disposed waste to the landfill must be the last opportunity. In a landfill, during waste degradation processes leachate is formed that can potentially cause clogging of bottom drainage layers. To ensure stability of a landfill construction, the physical properties of its components have to be controlled. The hydrology of precipitation, evaporation, runoff and the hydraulic performance of the capping and liner materials are important controls of the moisture content. The water balance depends also on the waste characteristics and waste particle size distribution. The aim of this paper is to determine the hydraulic permeability in a landfill depending on the particle size distribution of municipal solid waste disposed. The lab experiment results were compared with the results calculated with DEGAS model. Samples were taken from a landfill operated for five years. The samples particle sizes are: >100 mm, 80 mm, 60 mm, 40 mm, 20 mm, 0.01 mm and <0.01 mm. The permeability test was conducted using the column test. The paper presents the results of experiment and DEGAS model water permeability with waste particle size.

Keywords: particle size, waste permeability, municipal solid waste, landfill, physical properties.

Introduction

*Object and aim of research***.** The world and life style is changing, but the most popular disposal route for waste is landfill globally up until now. We have to think about waste prevention and preparing for re-use or recycling firstly, according to the waste disposal hierarchy. Disposed waste to the landfill must be the last opportunity (Pepper *et al*. 2006). Municipal solid waste (MSW) is an important category of waste material which is sent to landfills. Many landfills are constructed as land raise features on top of the original ground surface. In this case the topography naturally restricts the inflow of surface- and ground- water into the landfill (Christensen 2011). Poorly controlled water inflow and landfill waste composition can cause faster degradation. Water inflow can cause an amount of the leachate. Increasing of leachate cost more money for leachate treatment. Leachate can potentially cause clogging with high organic content of leachate collection drainage layer.

It is important to gain an understanding of the factors governing the hydraulic properties of waste, and their impact on the flow of fluids within the waste mass (Powrie, Beaven 1999). To ensure stability of a construction, the physical properties of its components have to be well known (Dixon, Langer 2006). In a landfill, waste mass presents the largest structural element and often controls both the stability and integrity of the lining system. The hydrology of precipitation, evaporation, runoff and the hydraulic performance of the capping and liner materials are important to control the moisture content of the landfill. The water balance in landfill also depends on the waste characteristic. The waste characteristics are in relationship with waste composition in the landfill. Waste composition in landfill depends on waste sorting management. Waste sorting in Lithuania is relatively basic in comparison to more advanced techniques (Christensen 2011; Almut 2013).

The aim of this paper is to determine the hydraulic permeability in a landfill depending on the particle size distribution of municipal solid waste.

*Methodology and relevance of the research***.** Hydraulic permeability was determinated of different MSW particle size distribution. Research is based on the column test and analysis of the particle size distribution.

Powrie and Beaven (1999), Dixon and Langer (2006), White and Beaven (2011), Gomes (2013) and other authors provide extensive experimental evidence of physical (hydrological and mechanical) properties. In Lithuania, such experiments have not been conducted before. Lithuanian authors more specified on the leachate formation and the chemical characterization of the leachate. The leachate is formed from water, which has passed through the municipal solid waste. It is possible to control the cost of the leachate collection system treatment if they succeed to controll the water inflow to the municipal solid waste. There is less data on the Lithuanian landfills' physical properties, in particular for waste permeability.

Municipal solid waste permeability

The investigations of waste composition provide information for solving the problems of landfills. A clear perception of the problem or issue to be addressed is important in order to specify the purpose of the characterization and to identify the appropriate approach and methods to be used. The most important physical properties for MSW are waste permeability of MSW (Christensen 2010):

First of all it is important to understand water input and output in the landfill (Fig. 1). Water into landfill may permeate as a result of many processes. This study is a very wide one. We have to draw attention to weather conditions: snow, rain, storm, how many rain falls out, etc. in order to understand water inflow into the landfill.

The components shown include the following steps (Farquhar 1988):

- Precipitation (P) falls on the landfill and some of it becomes runoff (RO).
- Some of P infiltrates (I) the surface (uncovered refuse, intermediate cover, or final cover).
- Some of I evaporates (E) from the surface and (or) transpires (T) through the vegetative cover if it exists.
- Some of I may make up a deficiency in waste moisture storage (S) (the difference between field capacity (FC) and the existing moisture content (MC)).
- The remainder of I, after E, T, and S have been satisfied, moves downward forming percolate (PERC) arid eventually leachate (L) as it reaches the base of the landfill.
- PERC may be augmented by infiltration of groundwater (G). The procedure used to analyse these processes is referred to as a water balance (WB), various forms of which are commonly used for the simulation of surface water hydrology.

Waste physical parameters, like waste permeability, or hydrology, are a very wide topic. Analysis of how the particles of different size of MSW are thrown out by water filtration is an important part of understanding hydrology of landfill. Several experiments regarding the waste chemical characteristics or leachate composition in Lithuania were made, but it is important to understand the beginning of leachate formation. Quantity of leachate depends on quantity of water inflow and landfill waste composition.

Several Europe countries in recent years have prevented disposal of waste into the landfills, reducing the potential leachate leakage into the surrounding ground. In a conventional landfill, any attempt to control leachate levels requires an understanding of the hydraulic properties of the waste and how these may change with increasing effective stress (Powrie, Beaven 1999).

Powrie and Beaven (1999) performed an experimental investigation to determine the influence of vertical stress on hydraulic conductivity of household waste. The saturated hydraulic conductivity at different stresses is shown in Figure 2. The experimental results show that waste hydraulic conductivity is likely to decrease with depth growing.

They have found that the quantification of the hydraulic properties and geotechnical behaviour of the landfill waste is complex. This is partly because of the variable, deformable and degradable nature of its constituents, and partly because the material is often in an unsaturated state

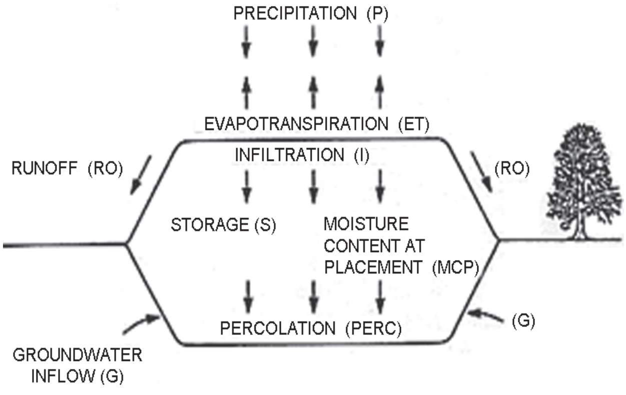

Fig. 1. Input and output of waste to the landfill (Farquhar 1988)

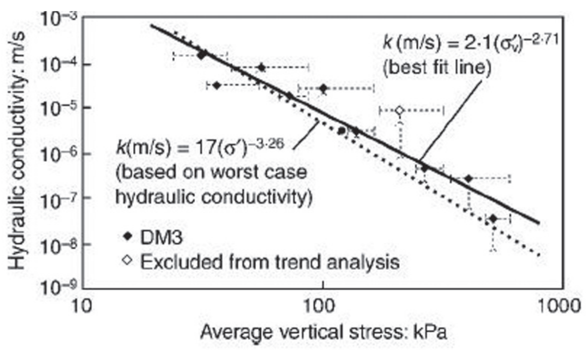

Fig. 2. Variation in saturated hydraulic conductivity with vertical effective stress for crude household waste (Powrie, Beaven 1999)

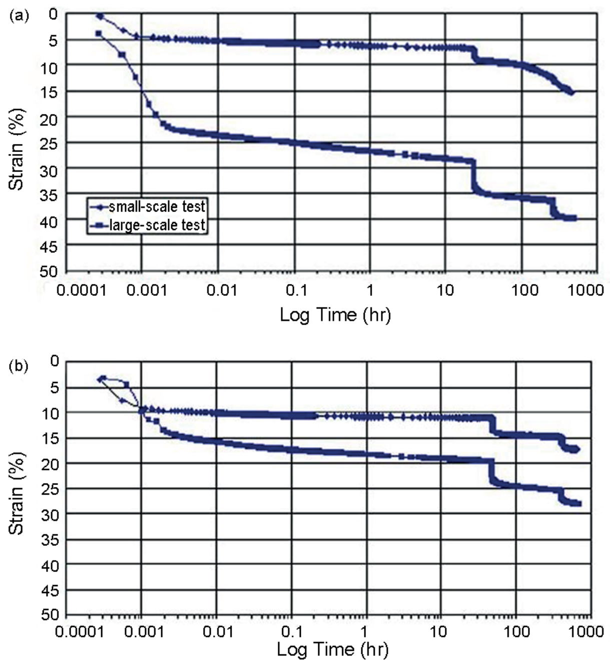

Fig. 3. Strain versus log-time plots in small- and large-scale tests at different moisture contents: a) at original moisture content; b) at field capacity

with gaseous, liquid and solid phases present. The field capacity of the refuse, which is defined as the equilibrium water content (mass of water to mass of dry solids) at the certain vertical stress under conditions of free vertical drainage, represents a useful reference state.

Durmusoglu *et al.* (2006) performed some experiments to evaluate the permeability and compression characteristics of landfill's MSW samples. While the two series of tests were conducted using a conventional small-scale consolidometer, the two others were conducted in a large-scale consolidometer. In each consolidometer, the MSW samples were tested at two different moisture contents, i.e. original moisture content and field capacity (Fig. 3).

Results of the compression tests indicate that the compressibility of MSW depends to some extent on moisture content. Specimens with lower moisture content (e.g., at original moisture content) generally exhibited a higher compressibility than specimens with higher moisture content (e.g., at field capacity). The rate is significantly less of secondary compression observed in the small-scale consolidometer, where solid particles were small, than the rate of secondary compression observed in the large-scale consolidometer.

DEGAS model

According to Beaven and White (2011) DEGAS is a degradation and settlement model based on particle size distribution. For this model particle size is important to search for differences between their physical properties, for example, water permeability. The main aims of the DEGAS model are:

- to show relationship between waste particle geometry and pore space geometry when particle geometry is changing or deforming due to:
  - changes in effective stress (causing particle compression and or deformation, and changes in dry density)
  - Particle crushing (in response to the need to accommodate dry density changes)
  - Particle biodegradation in the organic content.
- to relate the pore space geometry to the permeability of waste in order to further understand the mechanics of the flow of gas and liquids through waste.

Figure 4 shows how gas or liquid goes through the MSW, according to the different particle size distribution, degradation or crushing. Other important thing is to know biodegradable level of different MSW age. These parameters help to understand that water permeability depend on different particle size. Decrease of particle size distribution can cause slower water permeability through the particles of different size. When waste age are about 1 month or 1 year, water permeability must be bigger, because waste absorb area is so high and biodegradable processes may not have started yet.

Figure 5 helps to understand impact on particle size distribution according to some parameters such as compression, deformation, bio-degradation, and crushing. The unsieved waste mass has the highest impact on biodegradable process, compared with sieved waste after drying. The red line (Fig. 5) shows that crushing process always starts when waste age is from 1 month to 1 year. The crushing process depends on municipal solid waste type. The crushing process stops when waste particle size is about 8 mm. Biodegradation process starts after crushing, which reduces particle size to a minimum (Beaven, White 2011).

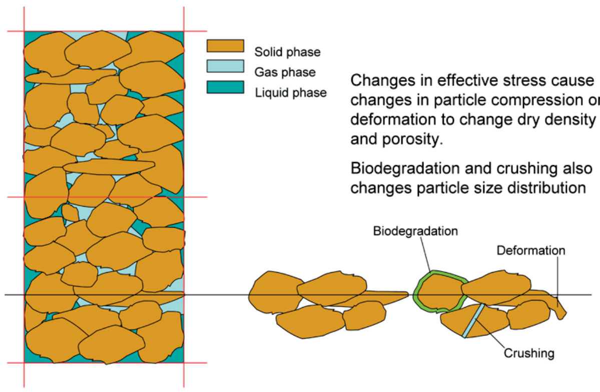

Fig. 4. Illustration of ways in which particle geometry can change (Beaven, White 2011)

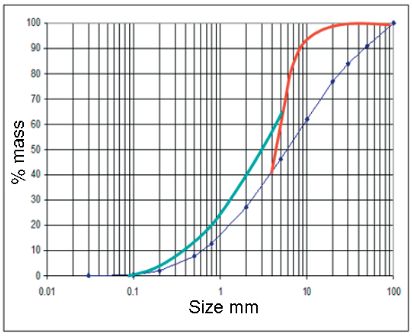

Fig. 5. Particle size distribution and impact of biodegradation and crushing (Beaven, White 2011)

This model can estimate many important parameters of the waste, according to therelationship between particle geometry and space geometry (pore).

This research had tested how water permeability in the waste mass may change according to the particle size and pore size. When the solid waste age changes, the pore size changes also. If pore size is becoming smaller, it shows that biodegradable process in waste mass has been started (Beaven, White 2011).

Methodology

For municipal solid waste permeability experiment was used the same municipal solid waste sample like in particle size distribution experiment and moisture content. The municipal solid waste particle size of the sample's are so high and it cannot show municipal solid small particle waste permeability. For that reason, in this experiment some waste was crashed, according to literature, to get particles of small size. This crashing process simulates real process in the landfill. This process goes with degradation process for non-biodegradable MSW. For water permeability experiment it is important to find what is the water permeability for particles of different size, not only of big particles, but also of small ones. For this experiment particles' sizes were: 0.15 mm, 0.3 mm, 0.6 mm, 1 mm, 5 mm, 10 mm, 20 mm, 30 mm, 40 mm, 50 mm, 60 mm, 80 mm, and lastly 100 mm.

The particle size distribution through the fractions was calculated according to the second experiment. It was calculated according to the particle size distribution. Also there was not a small diameter sieving, like as 0.15 mm, 0.3 mm, 0.6 mm or 1 mm, because in the particle size distribution experiment mechanical sieving was used. Respectively the particle sizes were selected according to the passing through fractions.

For the laboratory experiment it is needed to use columns. These columns have to be filled with MSW. The diameter of the column can be no less than 25 cm. According to the column diameters and quantity of MSW different amount of water is needed. This parameter shows L/S ratio. This test was carried out at a temperature of (20±5) °C.

The column was filled with the waste from municipal landfill. All portions are included according to the particle size after the sieve shaking (>20 mm, 20–12 mm, 12–7 mm, 7–5 mm and <5 mm). All columns were filled until about 17 cm. After the filling of the column all waste was compressed, like in landfills.

The column was saturated with water either by using the pump or by hydrostatic pressure. When the pump is stopped or the hydrostatic pressure is taken away, the material in the column is completely saturated, but the outlet hose remains empty. The saturated material was left for a period of at least two days, in order to equilibrate the system. After the equilibration period, the pump started to pump again and the flow rate was set such that the linear velocity would be approximately (15±2) cm/day through the empty column (LST CEN 21268-3).

Results

According to Figure 6 larger particles were used for this experiment. Small particles were also included. The particle size of landfill waste was bigger during the experiment then when calculating according the DAGAS model,. It is important to look how water goes through the particles of different size.

Figure 7 shows MSW permeability changes according to particle size. MSW permeability is highest if particle size increases. The permeability of water through MSW decreases, if particle size of waste decreases. Waste permeability of municipal solid waste is higher when waste particle size (PZ) is bigger.

The highest water permeability is estimated when PZ is from 50 to 70 mm and further. Water permeability is 0.0177 m/hour – 0.0326 m/hour. Water permeability of small PZ is very poor. It may happen because of small pores

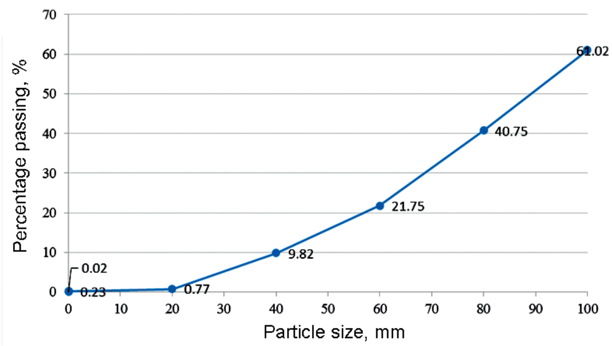

Fig. 6. Waste fraction passing through mesh in experiment

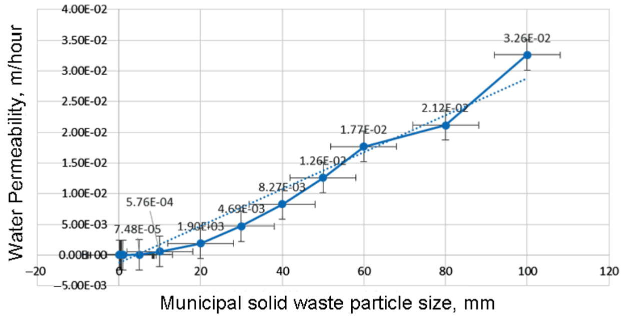

Fig. 7. Municipal solid waste permeability according to different particle size

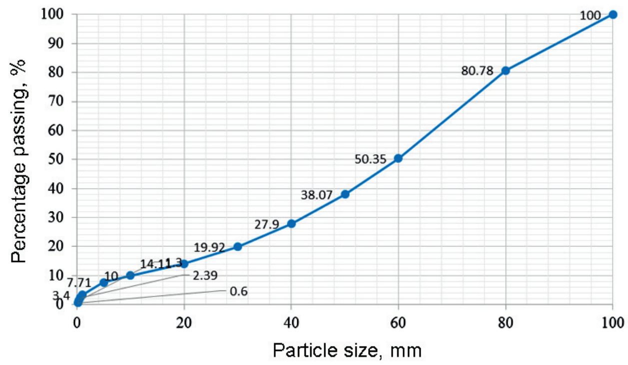

Fig. 8. Particle size and fraction passing for experiment in DEGAS model

between the particles. So water could experience difficulties going through MSW. Figure 7 shows a high difference of water permeability through small and large particles. The water permeability is 0.0000748 m/hour and when the particles are larger, the water permeability is 0.0326 m/hour. Largest particles leach more water and absorb a small amount of water. Small particles of MSW absorb all water.

All experiments were checked with DEGAS model. The most important input for DEGAS model is particle size distribution of MSW. DEGAS model has been used already existing particle size distribution of MSW. These results are shown in Figure 8. Particle size and their percentage were calculated when sieving waste through the mesh of different size. Water permeability through MSW could be found according to particle size distribution of MSW.

The porosity of 0.5 was chosen. This number was chosen according to the recommendations of the authors Beaven and White (2011). Authors have chosen this porosity, because it is calculated at the landfill of municipal solid waste. The porosity is spaces in the mass of municipal solid waste through which gas and water may flow without restrictions. Porosity is higher when in the municipal solid waste there are less of small size particles. Porosity is inferior when in the municipal solid waste there are more small size particles.

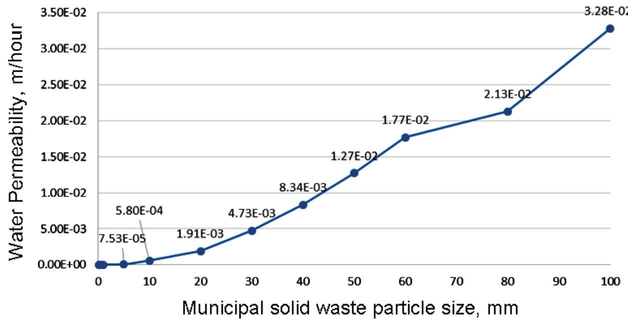

Fig. 9. Municipal solid waste permeability according to different particle size in DEGAS model

All experiments were compared with DEGAS model results and the comparisoncan show an error of the experiment. This data is shown in Figure 9. It shows error of 5%. The results show similarly situation like in water permeability experiment. The highest water permeability is when particle size is higher then 100 mm. Water permeability near this values is 0.0284 m/hour. The smallest water permeability is when particle size is about 5 mm. This water permeability is 0.0000753 m/hour.

The both experiments showed that the water permeability was inferior when the smaller size particles were investigated. There is visible break in both experiments near the particles size from 60 to 80 mm.

Difference between both experiments on water permeability could be according to fraction passing. Fraction passing in DEGAS model is more accurate calculated then in the experiment.

In conclusion, increase of particle size increases water permeability. Small size particlecould absorb more water. Small size particles almost always are in biodegradable waste, which moisture content is very high. Without bieodegradable waste water faster goes through waste to the leachate collection system. When there are no small size particles, water has no barriers to flow without restrictions.

Conclusions

MSW permeability is higher if particle size increases. Decrease of particle size cause decrease of water permeability through MSW. Waste permeability of MSW is higher if the waste particle size is bigger. The highest increase of the water permeability through the particles of different size is when particle size ranges from 50 to 70 mm.

The highest water permeability in experiment is estimated when the particles are bigger than 100 mm. Water permeability near these values is 0.0326 m/hour. The smallest water permeability is estimated when particle size is about 5 mm. This value is equal to 0.0000748 m/hour.

The highest water permeability in DEGAS model is estimated when particle is bigger than 100 mm. Water permeability near these values is 0.0284 m/hour. The smallest water permeability is estimated when particle size is about 5 mm. This value is 0.0000753 m/hour.

Difference between the laboratory experiment and mathematic model DEGAS of water permeability through the particles of different size was found equal to 5%.

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SKIRTINGO DYDŽIO ATLIEKŲ DALELIŲ LAIDUMAS DRĖGMEI

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Santrauka

Gyvenimo būdas kiekvieną dieną keičiasi, bet vienas populiariausių būdų šalinti atliekas yra sąvartynai. Pagal atliekų šalinimo hierarchiją pirmiausia, jas šalindami, turėtumėme galvoti apie tai, kaip išvengti atliekų ir paruošti jas naudoti dar kartą. Šalinti atliekas sąvartynuose turėtų būti paskutinė galimybė. Sąvartyne vykstant biodegradacijai susiformuoja filtratas, kuris dėl sudėtingos sudėties lemia filtrato surinkimo sistemų kolmataciją. Siekdami užtikrinti stabilumą sąvartyne, turime smulkinti ar suslėgti atliekas. Kritulių, garavimo kontroliavimas yra svarbus, užtikrinant tam tikrą komunalinių atliekų drėgnumą. Vandens balansas atliekų masėje taip pat priklauso nuo atliekų savybių ir atliekų dalelių dydžio. Šio darbo tikslas yra nustatyti vandens laidumą sąvartyne priklausomai nuo komunalinių atliekų dalelių dydžio pasiskirstymo. Laboratorinio eksperimento metu gauti rezultatai buvo palyginti su DEGAS modeliu gautais rezultatais. Tyrimui mėginiai buvo paimti iš sąvartyno, kurio amžius yra penkeri metai. Mėginių dalelių dydžiai yra: >100 mm, 80 mm, 60 mm, 40 mm, 20 mm, 0,01 mm ir <0,01 mm. Laidumo tyrimas buvo atliktas taikant kolonėlės testą. Straipsnyje pateikiami eksperimento metu ir taikant DEGAS modelį apskaičiuoti vandens laidumo rezultatai, esant skirtingo dydžio atliekų dalelėms.

Reikšminiai žodžiai: dalelių dydis, atliekų laidumas vandeniui, komunalinės atliekos, komunalinių atliekų fizikinės savybės.