The tensile strength of soils built-in landfill mineral sealing layers

La résistance à la traction du sol intégré dans des couches d'étanchéité décharges minèrales

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ABSTRACT: The basic role of landfill sealing layers is to reduce the negative effect of leakage from landfill into the environment. To determine soil suitability for earth structures, its parameters should be measured. Waste or ground settlement results in the formation of tensile stress in the mineral barrier and leads to its damage. Laboratory tests on fly ash, fly ash with bentonite addition and medium clay as materials for sealing layers were conducted. Research was carried out by the indirect method. Materials were compacted at different moisture content w_{opt}±3% by the Standard Proctor method. Fly ash and fly ash with bentonite addition were tested directly after compaction as well as after 7 and 28 days of curing. Tensile stress values in reference to the strain of the sample are presented. It was found that an addition of bentonite affects tensile strength. Curing time also impacts tensile stress. As far as medium clay is concerned, moisture content has relevance for obtaining maximum tensile strength and deformation measurement.

1 INTRODUCTION

Mineral sealing layers ensure a reduction of negative impact of waste on the environment. Their main function is to prevent ground and groundwater contamination caused by leakage. This protection is provided when the layer is continuous, tight and devoid of cracks. Therefore, liner and cover material requires sufficient properties such as low hydraulic conductivity (less than 10^{-9} m/s), high compressive and tensile strength. Stress in a barrier, caused by ground or waste settlement, leads to rupture of its continuity. Hence, the maximum tensile strength should be defined as a measure of the maximum elongation that a sealing layer can bear without suffering fracture.

The aim of the study is to present the indirect tensile strength test results of fly ash and fly ash and bentonite mixtures in comparison to medium clay as materials appropriate for usage as a landfill liner.

2 MATERIALS AND TEST METHOD

2 .1 *Materials*

Tensile tests were carried out on fly ash (FA) and fly ash with sodium bentonite addition (FA+B). Additionally, tests on sandy medium clay were conducted. Fly ash, whose grain-size distribution curve corresponds to sandy silt – saSi, was obtained as a hard-coal combustion product from Bialystok Thermal Power Plant. The material was taken from a dry disposal site. The addition of sodium bentonite to fly ash mixtures amounted to 5, 10 and 15% of bentonite in the dry weight of the sample. In order to provide a comparison to fly ash and its mixtures with bentonite, sandy medium clay – saMCl (EN ISO 14688-2 2004) samples were investigated.

Samples were compacted by the Standard Proctor (SP) method at the optimum moisture content or w_{opt}±3%. Tests were carried out directly after compaction as well as after 7 and 28 days of curing in humidity chamber. Bentonite was added to fly ash directly before compaction, material was mixed thoroughly and then compacted. Parameters of tested materials are shown in Table 1.

Table 1. Parameters of tested materials.

Tested material	ρ_s (Mg/m^3)	*Compaction parameters*	
		w_{opt} (%)	$\rho_{d\,max}$ (Mg/m^3)
FA	2.18	40.0	1.073
FA+5%B	2.18	39.0	1.100
FA+10%B	2.22	36.3	1.118
FA+15%B	2.24	33.0	1.134
saMCl	2.68	14.0	1.950

2 .2 *Test method*

Tensile strength was tested by the indirect method called Brazilian test. In this type of test the cylindrical or disc sample is subjected to two opposing forces at the disc periphery (Mollamahmutoğlu and Yilmaz 2001, Araki et al. 2016, Li and Wong 2013). According to ASTM D3967-08 (2008), the thickness-to-diameter ratio of the sample (*H*/*D*) should be between 0.2 and 0.75. Additionally, the specimen diameter should be at least 10 times greater than the largest grain of the material. A disc sample with diameter of *D*=65 mm and thickness of *H*=20mm meets these criteria. The disc specimens were formed by compaction in a two-part mold designed for sample preparation for oedometric tests.

The splitting tensile strength in Brazilian method was calculated as follows (see Eq. 1):

$$\sigma = \frac{2F}{\pi HD} \tag{1}$$

where: *F* is the maximum applied load at failure, *H* is the thickness of the disc sample and *D* is its diameter.

Research was carried out at the Faculty of Mechanical Engineering at Bialystok University of Technology using the MTS Insight electromechanical testing machine. The samples were subjected to compressive load with test ratio of 0.02 mm/s. The load was continuously increasing until failure of the sample occurred. The tensile force action causes sample cracking, which is initiated by reaching the maximum load on the disc sample during the tensile test, as shown in Figure 1.

The direct method of testing the tensile strength of the materials described above was also conducted, and the results were presented by Zabielska-Adamska and Wasil (2017).

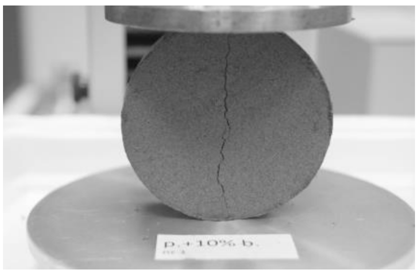

Figure 1. The mixture sample during the indirect tensile strength test.

3 TEST RESULTS

Figure 2 shows tensile strength measurements using the Brazilian test for disc samples with various bentonite content and time of curing. All samples were compacted at w_{opt}.

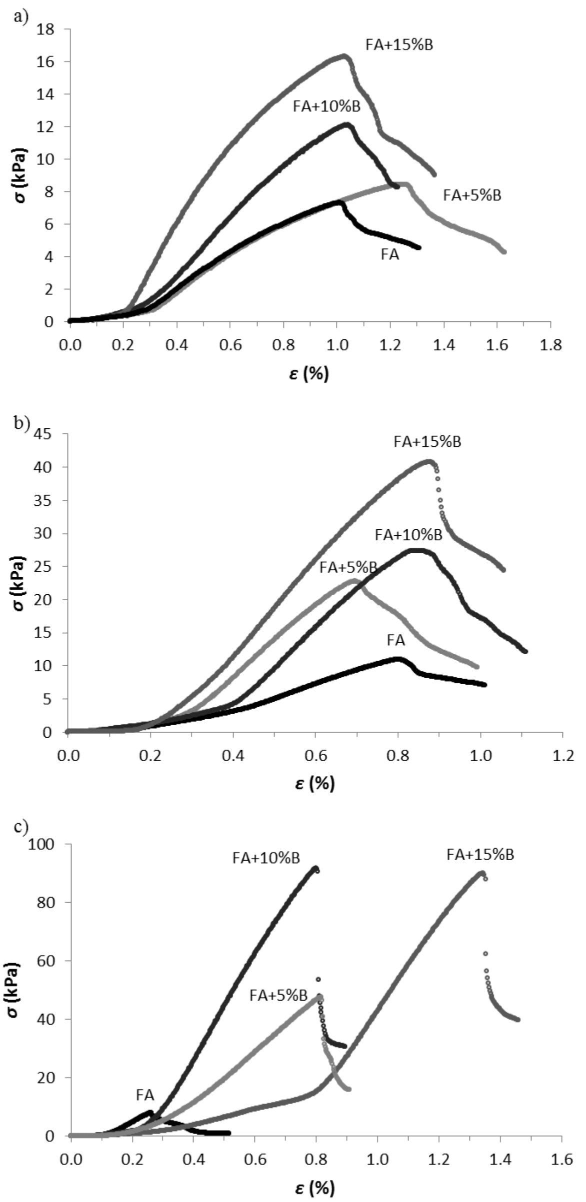

Figure 2. Tensile strength of fly ash samples with various bentonite content, tested: a) directly after compaction, b) after 7 days of curing, c) after 28 days of curing.

The tensile strength increased with the percentage value of bentonite addition. Tensile strength tested directly after compaction for fly ash and fly ash and bentonite samples increased from 7.3 kPa to 16.3 kPa. After 7 and 28 days of curing, the obtained values were respectively from 11.0 kPa to 40.8 kPa and from 8.1 kPa to 91.7 kPa.

In the case of clay samples (Fig. 3) at w_{opt}±3%, the values of tensile strength were from 33.7 kPa to 98.0 kPa. For fly ash tested at different moisture contents directly after compaction, the values of tensile strength varied slightly and averaged at about 7.0 kPa. During tests, fly ash samples fractured after reaching the maximum load. On clay samples cracks appeared at the moment of peak compressive force, but the samples did not break apart.

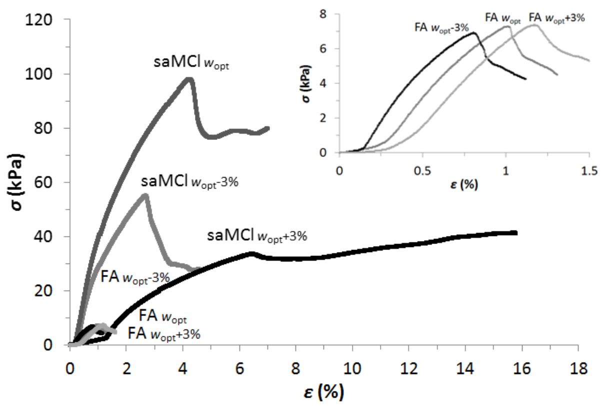

Figure 3. Tensile strength of medium clay and fly ash disc samples with various water content and fragment of fly ash graph on different scale.

4 CONCLUSIONS

The addition of bentonite has an impact on the tensile strength of fly ash. An increase in the percentage content of bentonite in specimens results in higher tensile strength values. Additionally, curing time affected the maximum applied load which a sample could support. Directly after compaction, the values of tensile strength were from 7.3 kPa to 16.3 kPa, while after 28 days of curing, the tensile strength increased to 8.1 – 90.0 kPa. The highest value of strain during fracture was obtained for a fly ash sample with 15% of bentonite addition after 28 days of curing, which was approximately 1.4%.

For medium clay samples, moisture content significantly affects the tensile strength and deformation results. The sample at w_{opt} obtained the tensile strength value of 98.0 kPa, which is 2.9 times greater than the sample at w_{opt}+3%. Additionally, saMCl reached the strain at about 6.5%, which is 1.5 times greater than the maximum strain of saMCl at w_{opt}. Results of deformation are much higher than the elongations gained in direct test (Zabielska-Adamska and Wasil 2017).

For fly ash at w_{opt}±3% strain gained values from 0.8 to 1.16 – moisture content slightly affects both the tensile strength and deformation that increase with moisture content.

3 ACKNOWLEDGEMENTS

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