Analysis of the influence of the grain size variation of a waste rock dump on the resistance parameters of the waste rock-geomembrane Interface through the Direct Shear Test

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Resumo

Mine waste rock dump are formed by the provision of waste rock, according to the standard, to ensure long term stability. The use of geomembranes in mining structures is very strong at the moment due to its environmental characteristics; a relevant case is the use in mine waste rock dump, with the objective of sealing these areas is one of the very current applications in fields such as mining, as an example direct. In order for the applications to take place properly, it is vital to know the resistance parameters of the waste rock-geomembrane interface and how these vary in relation to the other parameters. The aim of this paper is to analyze the effect of the granulometry variation, using the original granulometry curve as the reference, and the others were structured by the correlations of the granulometry with a consistency of 50%, in the interface resistance parameters, in order to direct the appropriate dimensioning of structures with inclusion of this material. During the experimental program, samples obtained from physical characterization tests adequate to the current norms were used. The analyzes were based on small direct shear tests with rigid base, made at the interfaces of membranes of PEAD liner with waste rock of an iron mine of the state of Minas Gerais, Brazil. Nevertheless, the evaluation of the grain size effect at this interface can contribute to minimize the risks of physical stability, thus considerably lower environmental impacts.

Keywords: Direct interface shear, Soil-Geomembrane Interface, Geosynthetic.

1 INTRODUCTION

Geosynthetic is a solution with many applications in the last decades because of the versatility of its material that comes into contact with the soil directly and applied in the field of engineering in one-dimensional (strip), two-dimensional or three-dimensional structural form characteristics that vary depending on the need, being the main function of surface waterproofing, erosion control and soil reinforcement when used correctly (Pilarczky, 2000; Vertematti, 2004, 2015; Sieira, 2006). The continuous study of geosynthetic has led mainly to the knowledge of soil interfaces with geosynthetic, and how they absorb and redistribute the stresses of the soil matrix, what is the stress behavior in direct shear tests, but an incorrect choice of stresses (generally low) to be used can be reflected in errors and results contrary to reality in the field (Koutsourais et al., 1991, Girard et al. 1990; Giroud et al. 1990; Gourc et al. 1996).

Many studies regarding the use of the direct shear test have been performed to determine the best results concerning the geosynthetic structure and to obtain the value of the interface strength, to know the influence of the effects of grains on geosynthetics related to mechanical damage (Mousavi, 2017; Punethaet al., 2017; Ghazizadeh et Bareither, I, II, 2018; Pinho-Lopes et Lopes, 2018; Sudarsanan et al., 2018;).

The waterproofing of the material placed in the controlled deposits is an important step, and the use of geomembranes is one of the most common solutions making a relevant interface between the materials, so it is necessary to obtain the resistance parameters in this interface to avoid the occurrence of some kind of corrosion. the waterproofing process of a mine waste rock pile fails. Direct shear tests were performed with a relative compactness of 50% for the interface, as the mine waste rock has a mechanical and mechanical characterization record. Aiming to compare the results in both cases to ensure a good sizing based on a correct selection of resistance parameters, reducing safety risks and economic losses

2 METHODOLOGY

A campaign composed by direct shear tests was carried out aiming to reach the resistance properties of the iron miner geomembrane-mine waste rock interphase, knowing the properties of the mine waste rock deformed samples with a known compactness in order to be able to test the mine waste rock with values certain (Martínez et al., 2011; Frost et al., 2012). In general, mine waste rock materials can be evaluated by analyzing the behavior of sandy soils, the lower concentration of fine plastics and the compactness effect in both materials has justified the adoption of evaluation techniques, similar test methodologies those used for properly sandy soils (Belly, 2015).

2.1 Geotechnical characterization of mine waste rock samples

Technological Characterization

According to Barriga (2015) the samples were artificially reproduced with a variation of the size of the mine waste rock. An opposite procedure was performed for particle size analysis according to ASTM D6913 / D6913M, because graphically, it was possible to critically obtain the values of accumulated percentages, and then to achieve analytically the values of accumulated and partial retained percentages, reaching In the end, the necessary weights of the parcels are obtained. The percentages obtained, represented by the curves already presented, are shown in Figure 1 and described in Table 1.

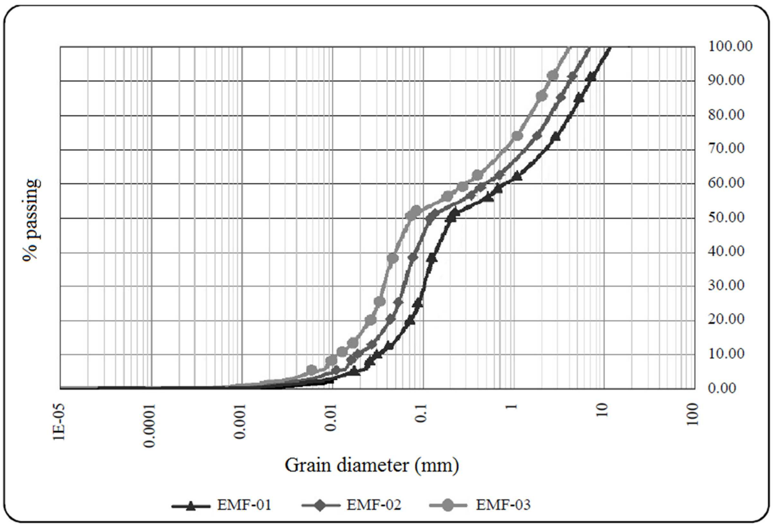

Figure 1: Particle size curves of artificially structured mine waste rock samples (Barriga, 2015)

Table 1: Particle size distribution according to ASTM

Scale		Diameter (mm)	EMF-01 (%)	EMF-02 (%)	EMF-03 (%)
Grave		60 - 4,75	-	-	-
	Coarse	4,75 - 2	31,15	23,93	14,38
Sand	Medium	2 - 0,425	13,82	16,71	22,51
	Fine	0,425 - 0,075	34,44	22,16	12,89
Silt		0,075 - 0,005	18,6	34,42	45,74
Clay		0,005 - 0,001	1,67	2,23	3,38
Colloid		0,001 >	0,32	0,55	1,1

According to Esposito (2000), the specific mass of iron ore tailings grains tends to be high, since they are formed by hematite (from 10 to 15% of solids), whose specific grain mass (ρs) is in around 5.25 g/cm³, the remainder being quartz (ρs between 2.65 to

2.70 g/cm³). In the case of the studied iron ore barren, the high specific gravity of the grains is influenced by the amount of iron particles that are present in the material, values are justified by the high iron content present.

According to ASTM D4253−00, they highlight the obtaining of the maximum and minimum specific masses of granular materials, knowing the specific grain mass of the material to obtain the minimum and maximum void indices. For the determination of the minimum dry specific mass, the mine waste rock is poured well loose into a tube, later the tube is raised (extracted) and the material fills the cylinder in an extremely fluffy compactness. And to calculate the minimum, it was vibrated reaching the minimum value of voids. With both values it can be achieve and natural when placed a value for the relative compactness, which for this study was 50%.

Geotechnical Characterization

For the direct shear test, a compact equipment was used when compared to the traditional equipment used in soil mechanics, servo-controlled, for testing 100 x 100 mm specimens, with a system that allows the control, control and digital monitoring of loading, displacement and travel speed, which is controlled by the operating software on a computer or by commands on the human machine interface screen (Barriga, 2015).

According to Head (1994) the process depends on the type of soil and the condition under which it will be tested. The maximum particle size present in significant quantities shall not exceed one tenth of the sample height. For a 20 mm or 25 mm high sample, particles trapped in a 2.0 mm sieve should be removed. The soil should not contain a significant amount of fine material (passing through at 63μm). This avoids the segregation of fine particles if dry, and ensures that the drainage free condition is maintained if saturated. The author also recommends that in the densification phase of a granular soil, from a vertical displacement curve versus time root, t_{100} was calculated from the extension of the initial rectilinear interval to the horizontal axis, equivalent to the final interval (stabilization of volumetric variations). The intersection point gives the root of t_{100} in minutes. The value of t_{100} was used to define the shear rate. The shear rate data for the samples gave a value of 0.15 mm/min, considered in previous tests.

The iron ore mine waste rock with zero moisture content was mechanically mixed with all the percentages of particle size requested to form the sample to be tested. To evaluate the shear strength at the interface, the geomembrane was fixed to a block of wood that is positioned on the underside of the direct shear box and then the prepared soil sample was placed in the shear box. To determine interface shear strength and the effect of reinforcement on shear strength, the Geosynthetic occupied half of the shear box as shown in Figure 2.

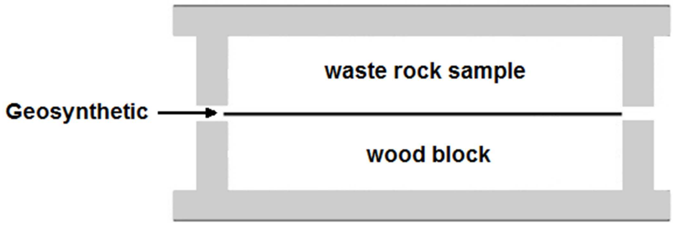

Figure 2: Geosynthetic shear box arrangement at the soil-geosynthetic interface.

The direct shear tests were performed according to ASTM D3080-04, contributing to evaluate the effect of the interface zone on the shear strength mobilized in the test sample, to perform the direct shear test 9 samples artificially assembled mine waste rock sets The deformed iron mining operations were sheared in a 100 mm square box under normal effective stresses of 200 kPa, 400 kPa and 800 kPa. The assembled shear box was placed in an automated direct shear apparatus (Figure 3) with an applied shear rate of 0.15 mm/min.

Figure 3: Details of compact conventional direct shear equipment

Geomembrane

Smooth HDPE geomembranes were fabricated from polyethylene with a high density of 0.94 g / cm3 and a thickness of 1.50 mm, with a tensile strength at break of 40 kN / m and elongation at break 700%. The geomembrane has excellent durability because the material is additive with thermo stabilizers, carbon black and antioxidants.

3 RESULTS AND ANALYSIS

Table 2 presents, from the particle size analyzes performed on the samples, the values of the characteristic diameters D_{10}, D_{30} and D_{60} and the value of the coefficient of uniformity (Cu) and curvature (Cc). These values were obtained to verify how the particle size of the samples, based on the characteristic diameters, interferes with the friction angle.

Table 2: Summary of Sample Particle Size Characteristics

Sample	D_{60}	D_{30}	D_{10}	Cu	Cc
EMF-01	0,79	0,100	0,030	26,3	0,4
EMF-02	0,47	0,061	0,020	23,5	0,4
EMF-03	0,28	0,036	0,012	23,3	0,4

According to Barriga (2015) noted that Cu for all samples is greater than 15, featuring materials with well-depleted particle size curves, occupying a wider region with different diameters, typical behavior of non-uniform materials. Although classical classifications attribute granular soils as having Cc between 1 and 3, the studied mine waste rocks have a reasonable gradation. Although the value of D_{30} is relatively close to D_{10}. After all, we tried to work with a well distributed grain size, which presented a distribution proportionally equivalent to the original sample.

The void index is known for each sample in the condition of medium compactness and the specific gravity of the grains, it was possible to obtain the values of the dry specific mass, the values are shown in Table 3.

Table 3: Specific dry masses of each sample for CR = 50%

Sample	e_{max}	e_{min}	e	ρ_s g/cm^3	ρ_d g/cm^3
EMF-1	0,90	0,25	0,57	3,960	2,516
EMF-2	0,86	0,24	0,55	3,952	2,549
EMF-3	1,00	0,32	0,66	4,096	2,467

The molding of the sample depended on the values presented in the previous table, since, based on the knowledge of the dry specific mass value and the mold volume, the value of the mass used for each shear box was calculated for the three samples (Barriga, 2015).

Table 4: Effective Friction Angle Values (φ')

	Friction Angle (φ') – (°)	
Sample	Mine waste rock	Mine waste rock geomembrane interface
EMF-01	42,38	27,19
EMF-02	41,95	26,45
EMF-03	40,36	25,93

The friction angles obtained from the tests are shown in Table 4, and the mine waste rock values show a linear growth trend of the friction angle for the three samples, in all correlated diameters. Although all curves are systematically parallel, the presence of fines can influence the shear strength, compromising the interlocking of grains, as shown in Figure 4. In this figure are shown the differences between floating and non-floating states. Coarse particles floating in a fine particle matrix do not significantly modify the strength and deformation characteristics of the mixture, therefore a model containing larger particles can be represented by a sample containing only smaller particles completely modifying the soil behavior. (Fragaszy et al., 1992).

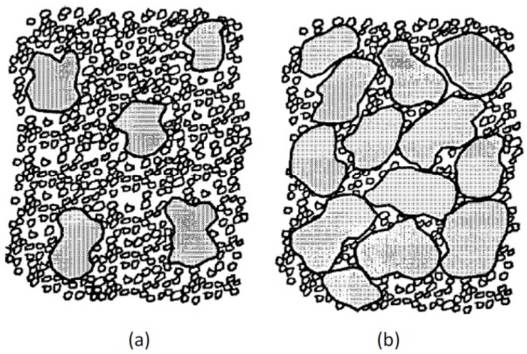

Figure 4: (a) floating state: fine particle matrix; (b) non-floating state: fine particles occupying coarse particle voids (Fragaszy et al., 1992)

4 CONCLUSIONS

The study aimed to analyze the response of the mine waste rock-geomembrane interface where the sample matrix was based on fines. For this purpose, direct shear tests were performed using HDPE smooth geomembranes and samples with 50% compactness, through the obtained results, it is observed that:

In general, the use of smooth surface geomembranes affects the breaking strength, decreasing the values up to 36% of the natural value of the iron ore barren. The influence of the variation of the granulometry of this work in the determination of the mine waste rock friction angle, reason of this research, offered no doubt, either in the natural test or in obtaining results in the interface. For both cases the dependence between the size of the mine waste rock samples and the shear strength of the mine waste rock was noticed by the tendency of the friction angle decrease with the reduction of the particles diameter.

Although reducing the friction angle is not the most convenient when working with structures, the results presented may be useful for the correct sizing of waterproofing layers in areas for specifically iron ore waste disposal. The conformance and reproducing quality of the results for the various samples, with different particle sizes, stated with conviction and verified the matching of the quality of the projected and performed moldings. Likewise for the mine waste rock geomembrane interface the properties measured the quality.

Finally, it is noteworthy that for proper design geotechnical analysis, studies of this nature are very important, since many structures are dimensioned from tests performed with reduced particle size when compared to those present in situ and related to geosynthetics. In general, when this is done, the project outcome is safe as they are based on conservative parameters. However, looking for a study of the effect of scale, structures that involve smaller areas of arrangement may be suggested.

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