The behaviour of non-woven geotextiles in tailings dams drainage systems

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ABSTRACT: Geotextiles have been used as drains and filters in geotechnical and environmental protection works. One of the disposal techniques is the desiccation process. The evaluation of geotextiles clogging mechanisms and the retention capacity of the disposal structure different combinations of tailings and geotextiles were submitted to gradient ratio tests under confinement in the laboratory with varying values of stress levels. The results obtained showed that the effect of confining stresses and the presence of entrapped waste particles have a marked effect on drainage and filter performance. The compressibility and the pore sizes of the geotextile are significantly reduced by the presence of the waste particles with implications to current filter criteria for non-woven geotextiles. The results of the present study emphasizes the need for further investigation on long term behaviour of geotextile filters and their performances under conditions as close as possible to those found in the field.

1 INTRODUCTION

Nonwoven geotextiles have been commonly used in many drainage applications of geotechnical and environmental protection engineering works such as tailings dams.

The utilization of geotextiles filter systems in mining projects is interesting due to a better quality control when compared to natural granular materials, quick to install even in difficult ground conditions, cost effectiveness, etc. Nevertheless, due to the complexity involved in the drainage and filtration mechanisms in tailing-geotextiles systems, the application of geotextiles filters has been limited mainly to large tailing dams.

This paper describes and discusses the results of a series of GR and HCT tests performed on systems consisting of tailings iron and nonwoven geotextiles on the Germano dam, in Minas Gerais state, Brazil. The fine grained tailing slurry is disposed in drying bays (300 m x 300 m) for dewatering under the initial concentration of 20 % of solids. Figure 1 shows a cross-section of the drying bays of the Germano dam. The drainage is provided by 10m high vertical drainage systems consisting of wells made of gabions enveloped by a nonwoven geotextile filter. After 6 years of operation a severe clogging occurred and the system was substituted by another.

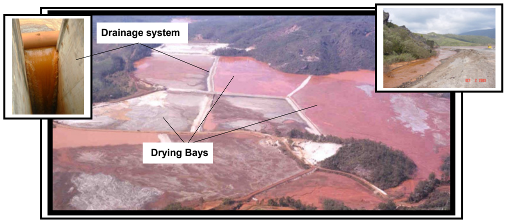

Figure 1. General view of drying bays - Germano tailings dam.

2 TESTING METHODOLOGY

2.1. Gradient Ratio test (GRT)

One of the methods to evaluate the compatibility between a geotextile filter and a granular base material is to use the Gradient Ratio test (GRT) (ASTM, 1992). This test evaluates this compatibility based on the ratio calculated at specific points along the permeameter height. In the present work, the tailing-geotextile compatibility tests were performed using a new filtration apparatus which permeameter cell is 300 mm height. The Figure 2 presents a schematic view of the apparatus.

Generally, the value of the Gradient Ratio can be defined as:

$$GR = \frac{i_{7/10}}{i_{5/7}}$$

Where $i_{7/10}$ is the hydraulic gradient between ports P_7 and P_{10} and $i_{7/9}$ is the hydraulic gradient between ports P_5 and P_7 in Figure 1.

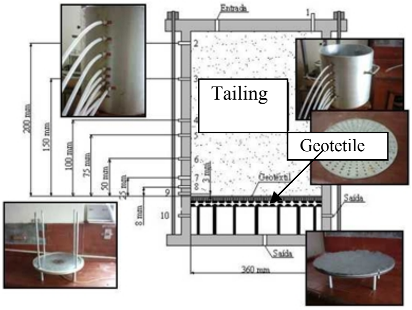

Figure 2. Gradient ratio equipment.

Other researchers (Fannin et al., 1994, Gardoni, 2000 and Fannin et al, 2008) have presented different definitions of GR attempting to pick up the mechanisms of base soil-geotextile filter in a region close to the geotextile layer.

Fannin et al. (1994) defined a Modified Gradient Ratio, GR_{Mod} (GR_{8mm}) using a port located 8 mm above the geotextile layer. Gardoni (2000) proposed a definition of gradient ratio named GR_{3mm} using a port 3mm above the geotextile filter. A limit value of given by Equation 1 indicates that the presence of geotextiles does not affect the flow conditions. A value of GR greater than 2 is an indication of some level of clogging, whereas GR values below 0,5 indicates soil piping (Lafleur et al., 2002). However, field and experimental evidences have shown good long term performances of soil geotextiles systems presenting higher values of GR_{25mm} (Gardoni, 2000, Palmeira et al., 2005 and Araujo, 2005) which suggests that the limit way be rather conservative in some cases.

2.2. HCT tests

The (HCT) test with flow pump is employed for determination of the compressibility and consolidation of fine soils or tailings. In this test, the characteristics of compressibility and permeability of the fine tailings were evaluated based on the relations of void ratio versus effective stress and permeability (Araújo, 2005). Figure 3 shows the test device which allows testing of soil-geotextile systems under confinement up to 1000 kPa.

3. EXPERIMENTAL PROGRAMME

Three types (G_1, G_3 and G_4) of nonwoven, needle-punched geotextiles made of continuous fibres of polyester produced by the same manufacturer were tested (Table 1). The geotextile filtration sizes (FOS) obtained in hydrodynamic tests were equal to 0,130 mm (geotextile G_1), 0,120 mm (G_2) and 0,09 mm (G_3). The mass per unit area of the geotextiles tested vary between 150 g/m^2 and 400 g/m^2.

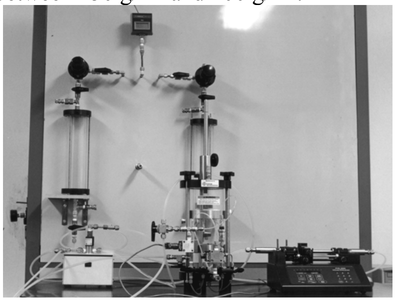

Figure 3. HCT equipment with flow pump.

The tailing samples were collected from five different points (P_1 to P_5) along the drying bays on the Germano dam for the evaluation of compressibility and permeability. The Table 1 presents some characteristics of these tailings and the geotextiles. The soil particles entrapped in the geotextile at the end of thes tests were also subjected to grain size analyses. Eletronic Scanning microscopy was employed for the study of the interaction between geotextile filter and tailings in the filtration tests.

Table 1. Soil-geotextile system tested

Systems	Tailing (1)	D_{85} (2)	C_U (3)	Geotextile	M_A (4)
P_1G_1/P_1G_3/ P_1G_4	P_1			G_1	150
P_2G_1/P_2G_3/ P_2G_4	P_2				
P_3G_1/P_3G_3/ P_3G_4	P_3	0,09	12	G_2	250
P_4G_1/P_4G_3/ P_4G_4	P_4				
P_5G_1/P_5G_3/ P_5G_4	P_5			G_3	400

Notes: (1) –fine tailings samples, (2) – diameter for which 85% of the particles have diameter smaller than that value (mm), (3) Coefficient of uniformity (D_{60}/D_{10}), (4) - mass per unit area (g/m^2)

4. RESULTS OBTAINED

Results of grain size analysis showed that the soil has approximately 75% of the mass finer than 0,074 and large value of C_U and Cc, which makes it potentially internally unstable (Beirigo et al., 2006).

Figures 4 and 5 show the results obtained in the GR tests with a system hydraulic gradient equal to 1 for the system P_1-G_4 (Table 1). The value of $GR_{25\ mm}$ was rather constant and greater than 3 thought the test, whereas $GR_{3\ mm}$ increased more markedly. At the early stages of the test values up to 10 were observed. The results are in accordance with previous works (Gardoni, 2000 and Palmeira et al., 2005).

The values of $GR_{3\ mm}$ and GR_{Mod} were consistent with those of GR_{ASTM}. However, $GR_{3\ mm}$ started to increase after 4000 min of test, which indicates changes in the interaction between tailings and geotextile in the vicinities of the filter. It is important to point out that the original geotextile filter layer of the vertical drainage system of the drying bays of the Germano dam was clogged after approximately 6 years of operation.

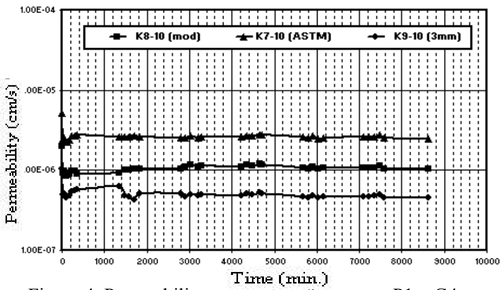

Figure 4. Permeability versus time for system P1 – G4.

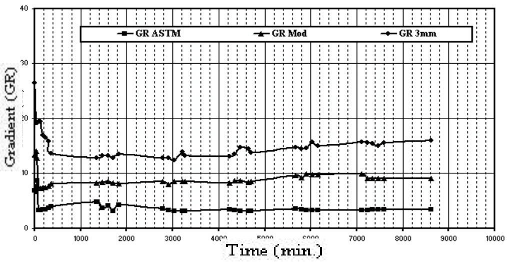

Figure 5. GR versus time for system P1 – G4.

HCT tests were carried out on tailings considering the influence of geotextile or not. The results for this test have been processed using a computer programme named Seepage Induced Consolidation test analysis (SICTA), (Araújo, 2005). The results of compressibility and permeability obtained for tailings only show that the behaviour is similar to those of the literature (Vick, 1983). A gradual reduction of permeability (due to reduction of void ratio) with increase of the effective stress was observed on the samples collected in different points along the drying bay.

The results obtained for the same tests on tailings (Point 1)with geotextile G_4 are despicted in Figures 6 and 7. The series of tests which take into account the influence of the geotextiles were performed in a similar way to the procedure for tailings only (Araújo, 2005).The results show that the compressibility depends directly on the mass per unit area of geotextiles. Thus, a lower compressibility has been observed for the lower mass per unit area. The decrease of void ratio with the effective stress is more uniform than the one for tailings without geotextile.

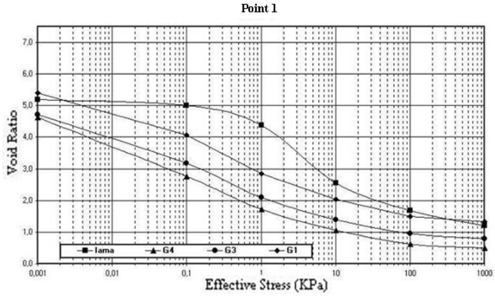

Figure 6. Ccompressibility of P_1G_4 system.

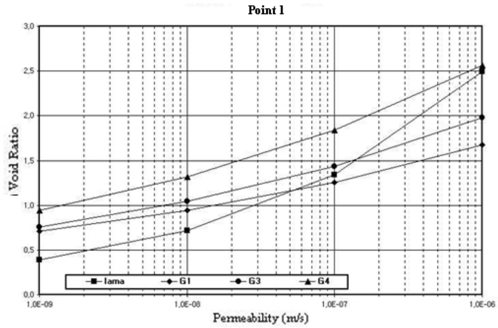

Figure 7. Permeability of P_1G_4 system

The geotextile specimen from GR tests were subjected to microscopic investigations and the particles retained in the geotextile filter were subjected to grain size analyses. Figure 8 presents an image obtained of the specimen from P_1G_4 system, where it can be observed the geotextile voids heavily impregnated by small tailings particles (Figure 8c and d). However, an impregnation by coarser particles is also noticed (Figure 8a and b) and the average diameters has varied from 63 to 500 µm. Beirigo et al. (2007) and Palmeira et al. (2009) obtained similar results for a geotextile specimen exhumed from the filter of tailing dam.

Figure 9 presents the grain size distribution curves of particles of tailings piped through geotextile in the GR tests. These particles were the fine fraction of tailings, which is consistent with the grain size distribution of tailings specimens P_1, P_3 and P_4 and it was confirmed in microscopic analyses. The variation of grain size curves is an indication of the unstable conditions of the tailings structure at the geotextile interface.

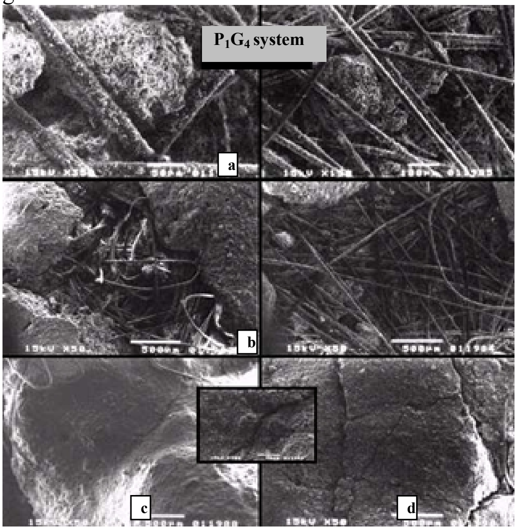

Figure 8. Microscopic images of geotextiles of the P1 – G4 system.

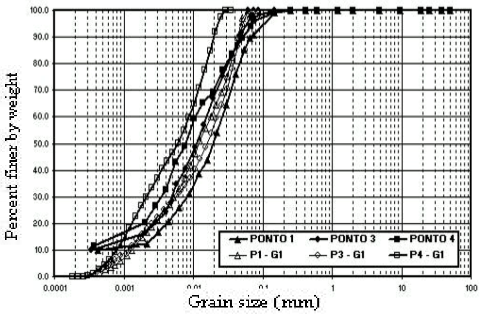

Figure 9. Grain size distribution curves of the particles that piped through the geotextile in the test on P_1-G_1, P_3-G_1, P_4–G_1systems.

5. CONCLUSIONS

The main conclusions are summarised below:

- The results obtained in the research programme showed that the Gradient Ratio test is a useful tool for the study of soil-geotextile compatibility. The GR_{ASTM} were little affected by the total gradient. The piping mechanism occurred in the vicinity of the tailing-geotextile interface was more clearly picked up by the GR_{Mod} and $GR_{3\ mm}$ Particularly at the Germano dam tailings identified as potencially internally unstable material.
- The HCT test is a new proposal for fine tailings and the results obtained show that the test is very sensitive to a interaction tailing-geotextile.It can be noted that the influence of geotextile on the permeability behaviour of tailing-geotextile system was substantially higher for samples closer to the spreading area than the others samples. This can attributed to some local migration of fines during the tailing spreading yielding to increases of void ratio in this region and consequently increasing the values of permeability

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