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Filtration tests under confinement on geotextiles-tailings systems

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ABSTRACT: Non woven geotextiles have been commonly used in filtration and drainage of geotechnical engineering works. This paper presents a study on the use of such materials in drainage systems of tailings dams. Different combinations of tailings and geotextiles were submitted to gradient ratio tests under confinement in the laboratory with varying values of stress levels and hydraulic gradients. The dimensions of the tailings particles entrapped in the geotextile specimens and those that piped through the geotextile were also investigated. Geotextile specimens from the drainage system of a tailings dam were exhumed for analyses as part of the research programme. The results obtained showed that stress levels and the hydraulic gradients used in the tests influenced the behaviour of the system. Physical and microscopic analyses of the specimens tested in the laboratory and exhumed from the dam showed different levels of geotextile impregnation by the particles of the tailings. The overall performances of the geotextiles in the tests were satisfactory.

1 INTRODUCTION

Geotexiles have been increasingly used in several engineering works, particularly as drains and filters. Although very practical the use of such materials in drainage systems of tailings dams requires some particular investigations for a proper evaluation of their performances under the conditions found in such works, such as high stress levels, mechanical damage and chemical aggressiveness of the fluid.

The behaviour of fine cohesionless soils in filtration tests have been investigated by several researchers. Factors such as soil relative density, particle geometrical characteristics, shape of particle size distribution curves and hydraulic gradient have found to be factors that may identify internal instability of those soils. In addition, cementation of particles has also to be considered in fine grained soils. Regarding geotextiles, their hydraulic and physical properties can be significantly influenced by the stress level (Giroud 1996).

This paper describes a study on the influences of some mechanical and hydraulic factors on the performances of non woven geotextile filters as filters and drains for tailings.

2 BEHAVIOUR OF SOIL-GEOTEXTILE SYSTEMS IN FILTRATION TESTS

A geotextile has to present appropriate physical and hydraulic properties in order to function well as a filter. Its openings have to be large enough to allow unimpeded fluid flow and, simultaneously, small enough to retain base soil particles and guarantee the stability of the system. Migration of soil particles can occur, depending on soil characteristics and hydraulic conditions and this may cause clogging of the geotextile filter by blinding, blocking or internal clogging. Factors such as geotextile microstructure and stress level also influence the clogging mechanisms of a geotextile filter (Gardoni 2000).

The gradient ratio test (GRT) is commonly used for the study of the interaction between soils and geotextile filters (Fannin et al. 1994; Palmeira et al. 1996 and Gardoni 2000, for instance). In this test compatibility between soil and geotextile is evaluated based on the ratio between hydraulic gradients calculated at specific points along the system height. Figure 1 shows the geometrical characteristics of a test device which allows testing of soil-geotextile systems under confinement. The equipment also allows the verification of the influence of the total hydraulic gradient applied to the system. ASTM (1996) defines the gradient ratio (GR) as

$$GR_{25mm} = \frac{i_{9/12}}{i_{7/9}} \quad (1)$$

Where $i_{9/12}$ is the hydraulic gradient between ports P9 and P12 and $i_{7/9}$ is the hydraulic gradient between ports P7 and P9 in Figure 1.

Other researchers (Fannin *et al.* 1994 and Gardoni 2000) have introduced other definitions of GR attempting to capture the mechanisms of soil-filter interaction closer to the geotextile layer and to provide additional information for the interpretation of the test results. These definitions are

$$GR_{8mm} = \frac{i_{10/12}}{i_{7/9}} \quad (2)$$

and

$$GR_{3mm} = \frac{i_{11/12}}{i_{7/9}} \quad (3)$$

Where $i_{10/12}$ and $i_{11/12}$ are the hydraulic gradients between ports P10 and P12 and between ports P11 and P12 in Figure 1, respectively.

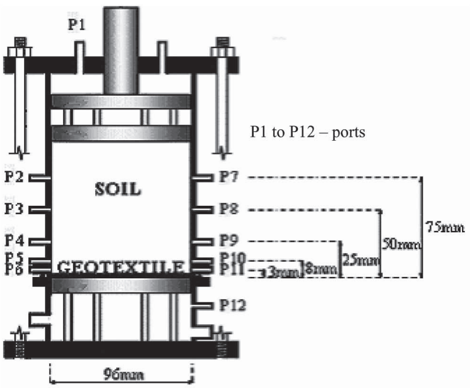

Figure 1. Geometrical characteristics of a GRT device for tests under confinement – (Bessa da Luz 2003).

A GR value of 1 indicates that the presence of the geotextile 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). A limit value of GR given by Equation 1 of 3 is commonly used for the acceptance or rejection of a candidate geotextile filter. However, field and experimental evidences have shown good long term performances of soil-geotextile systems presenting higher values of GR_{25mm} (Gardoni 2000), which suggests that limit may be rather conservative in some cases.

Tests results in the literature (Gardoni 2000, Palmeira et al. 2005) have shown that the values of GR_{8mm} and GR_{3mm} are more influenced by the test condition, particularly by increases in the stress level applied to the soil-geotextile system.

3 EXPERIMENTAL PROGRAMME

Three non woven geotextiles and three types of tailings were used for the evaluation of the compatibility between tailings and geotextile filters in gradient ratio tests. The apparatus used in the tests is shown in Figure 1. The systems tested and some properties of the materials studied are presented in Table 1. Two of the tailings were obtained from an iron mining and the third from a phosphate mining. A geotextile sample was also exhumed from a filter in a tailings (iron) dam (Germano Dam) as part of the research activities. A laser beam grain size analyser was used to measure the particle diameters of the tailings used as well as the diameters of the particles that passed through or were retained in the geotextile during the tests. Electronic scanning microscopy was also used in the studies of the materials tested.

The geotextiles tested were non woven materials, needle-punched, made of continuous filaments of polyester (Table 1). The geotextile filtration opening sizes (FOS) obtained in hydrodynamic tests were equal to 0.135 mm (geotextile G1), 0.11 mm (G2) and 0.06 mm (G3).

The normal stresses applied to the soil-geotextile systems varied between 0 and 2000 kPa. The high stress level is justified because large stresses can occur even in tailings dams of moderate height, depending on the tailings unit weight. Some of the tests were conducted with a constant system gradient ($i_{1/12}$ – gradient between ports 1 and 12 in Fig. 1) of 1. In other tests the hydraulic gradient was varied ($i_{1/12}$ = 1, 2.5, 5 and 10) during the first stage of the test (normal stress equal to 0) and then kept equal to 10 during the following loading stages. Readings taken during the tests included measurements of system compression, flow rates and variations of hydraulic heads at the different ports.

Samples of the soil particles that piped through the geotextile layer during the tests were collected for grain size analyses. The soil particles entrapped in the geotextile at the end of the tests were also subjected to grain size analyses.

4 RESULTS OBTAINED

4.1 *Tests with a system hydraulic gradient of 1*

Figures 2 to 4 shows the results obtained in the tests with a system hydraulic gradient ($i_{1/12}$ in Fig. 1) equal to 1 in terms of gradient ratio versus normal stress (σ_v) applied at the top of the soil-geotextile system. The values of GR_{25mm} obtained varied very little for the range of normal stresses employed. Values of

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Table 1. Soil-geotextile system tested.

System (7)	Tailing (1)	D_{10} (2)	D_{85} (2)	Cc (3)	Cu (4)	Geotextile	t_{GT} (5)	M_A (6)
SSG1						G1	2,0	200
SSG2	SS	0.028	0.125	1,0	2.6	G2	3,7	400
SSG2i						G2	3,7	400
SFG1						G1	2,0	200
SFG2	SF	0.006	0.112	0,8	9.2	G2	3,7	400
SFG2i						G2	3,7	400
FSG1						G1	2,0	200
FSG3	FS	0.043	0.281	0,9	3.7	G3	4,5	600
FSG1i						G1	2,0	200

Notes: (1) tailings: SS and SF – fine sandy tailings from iron mining, respectively, and FS – sandy tailings from phosphate rock; (2) diameter (D_i) for which i% of the particles have diameters smaller than that value (mm); (3) Coefficient of curvature ($D_{30}^2/D_{60}D_{10}$); (4) Coefficient of uniformity (D_{60}/D_{10}); (5) nominal thickness (mm); (6) mass per unit area (g/m^2); (7) SSG2i, SFG2i and FSG1i – systems for which the system hydraulic gradient ($i_{1/12}$) was varied during the test.

GR_{25mm} close to 0.5 were observed for the system FSG1, suggesting piping, although the system remained stable throughout the entire test duration.

The values of GR_{3mm} and GR_{8mm} were consistent with those of GR_{ASTM}. In tests on systems SSG2 and SFG2 (Figs. 2 and 3) most of the variations in GR_{3mm} and GR_{8mm} occurred for normal stresses below 400 kPa. Very low values of these gradient ratios were also observed in the test with system FSG1 (Fig. 4). However, GR_{3mm} and GR_{8mm} started to increase for normal stresses greater than 500 kPa, which indicates the increase in the system stability, in spite of the initial piping mechanism.

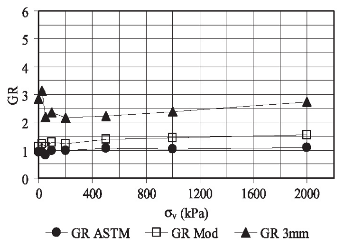


Figure 2. GR versus σ_v for system SSG2.

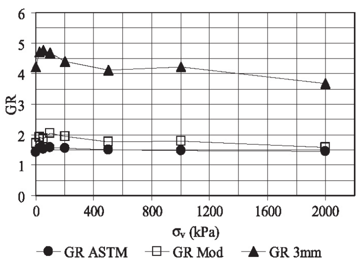


Figure 3. GR versus σ_v for system SFG2.

4.2 *Tests with $i_{1/12}$ varying between 1 and 10*

In these tests the system hydraulic gradient ($i_{1/12}$) was varied between 1 and 10 during the first stage of

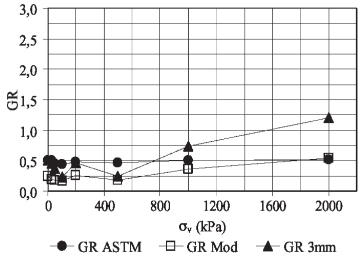


Figure 4. GR versus σ_v for system FSG1.

the test (no vertical stress on the sample). Afterwards, the total hydraulic gradient was kept constant and equal to 10 during the other loading stages (σ_v between 0 and 2000 kPa). Figures 5 and 6 show the results obtained in the test on system SLG2i (Table 1) with varying total hydraulic gradient.

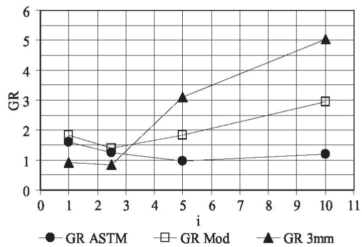


Figure 5. GR versus $i_{1/12}$ for system SLG2i.

Figure 5 presents the variations of gradient ratios with the system hydraulic gradient during the first stage of the test (no vertical stress). GR_{25mm} varied between 1.6 and 1.2 during this entire stage, while GR_{3mm} and GR_{8mm} started to present marked increases for values of $i_{1/12}$ greater than 2.5. This behaviour indicates changes in the interaction between soil and geotextile in the vicinities of the latter. Figure 6 shows that with the increase of the normal stress on the sample top GR_{3mm} and GR_{8mm} decreased significantly in value, while the value of GR_{25mm} remained rather

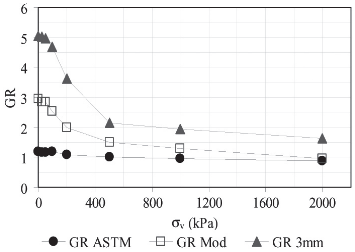
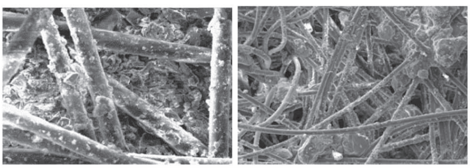


Figure 6. GR versus σ_v for system SLG2i.

stable. The reduction in the values of GR_{3mm} and GR_{8mm} with increasing stress levels can be attributed to changes closer to the soil-geotextile interface. Increasing stress levels are likely to cause rearrangements of particles at the soil-geotextile interface and displacement or expelling of particles entrapped in the geotextile (Palmeira et al. 2005).

4.3 *Grain size and microscopic analyses*

The evaluation of the impregnation level of the geotextile specimen exhumed from the filter of the tailings dam yielded values of impregnation levels (ratio between masses per unit area of entrapped particles and geotextile fibres) between 2 and 10.2. Figure 7(a) depicts an image obtained by electronic microscopy of this specimen showing the impregnation of the geotextile by tailings particles. Figure 7(b) shows an image of geotextile G2 after a test on system SLG2i. In the gradient ratio tests the lower the geotextile mass per unit area the greater the impregnation level obtained at the end of the test.



(a) Specimen exhumed (b) Specimen of test on SLG2i

Figure 7. Microscopic images of geotextile specimens.

Figure 8 presents the grain size distribution curves of the particles that passed through or were retained in the geotextile in the test on system SFG2i. In this figure the code SF.LG stands for the grain size distribution curves of the tailings, SFG2.OG for the particles on the surface of the geotextile, SFG2.IG for the particles inside the geotextile and SFG2.BF and SG2.AF for the particles that piped through the geotextile during sample preparation and at the end of the test, respectively. The results show that the particles that piped during sample preparation and that were retained in the geotextile were those from the coarser fraction of the tailings. This may be in part due to the vibration used for soil densification during sample preparation, which may favour the

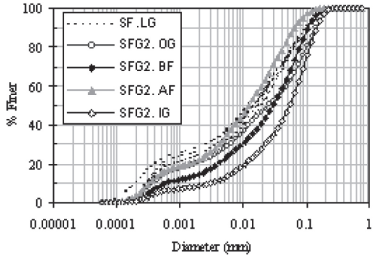


Figure 8. Grain size distribution curves of the particles that piped through the geotextile in the test on system SFG2i.

intrusion of large particles in the geotextile. The presence of large particles inside the geotextile was confirmed in microscopic analyses.

5 CONCLUSIONS

The results obtained in the research programme described in this paper showed that the gradient ratio test is a useful tool for the study of soil-geotextile compatibility in filtration. For unconfined tests an important influence of the total hydraulic gradient on the values of GR_{3mm} and GR_{8mm} was observed. These values were also significantly affected by the stress level. The values of GR_{ASTM} were little affected by the total gradient or by the stress levels used in the tests.

The soil-geotextile systems investigated presented stable behaviours during the tests. However, the system FSG1 presented low values of gradient ratios, suggesting the occurrence of important piping mechanisms, despite a stable condition being observed throughout the test duration.

REFERENCES

ASTM 1996. Standard test method for measuring the soil-geotextile clogging potential by the gradient ratio (D5101-96). *Annual Book of ASTM Standards*, Philadelpia, USA.

Fannin, R.J., Vaid, Y.P and Shi, Y.C. 1994. A critical evaluation of the gradient ratio test. *Geotechnical Testing Journal* 17(1): 35-42.

Gardoni, M.G. 2000. A study on the drainage and filtration behaviour of geosynthetics under compression. *PhD. Thesis*, University of Brasilia, Brasilia, DF, Brazil, 313 p.

Giroud, J.P. 1996. Granular filters and geotextiles filters. *Proc. of Geofilters'96*, Montreal, Canadá, 1: 565-680.

Lafleur, J., Francoeur, J. and Faure, Y. 2002. Piping, bridging and blinding of geotextiles as evaluated from the gradient ratio test. *Proc. 7th International Conference on Geosynthetics*, Nice, France, (2): 1069-1074.

Palmeira, E.M., Fannin, R.J. and Vaid, Y.P. 1996. A study on the behaviour of soil-geotextile systems in filtration tests. *Canadian Geotechnical Journal*, 33: 899-912.

Palmeira, E.M. Gardoni, M.G. and Bessa-da-Luz, D.W. 2005. Soil-geotextile filter Interaction under High Stress Levels in the gradient ratio test. *Geosynthetics International* 12(4): 162-175.