Geotextile performance as barriers for erosion control

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Keywords: Geotextiles, Erosion Control, Filtration, Fine Fraction Filtration Tests, Gradent, Ratio Test

ABSTRACT: This paper presents the results of a research programme to evaluate the performance of light non woven geotextiles as barriers for erosion control. To understand the interaction between soil and geotextiles, a modified version of the Fine Fraction Filtration test (f^3) was developed and a test series with different combinations of soils and geotextiles was conducted. Gradient Ratio Tests were also conducted. The performance of the soil-geotextile systems depended on the soil grain size distribution and on the geotextile characteristics. The maximum diameter of the soil particles that passed through the geotextile layer was considerably smaller than what would be expected from data on geotextile filtration opening size. The results also showed the potentials of the use of light and low cost non woven geotextiles as barriers for erosion control.

1 INTRODUCTION

As large cities grow, serious and numerous problems related to soil erosion may be caused depending on the soil characteristics and on the lack of city expansion planning. In the Federal District, where the country capital (Brasilia) is located, the soils are very sensitive to erosion. Lack of concern regarding this fact have caused the occurrence of large gullies (some of them above 25 m high) that have threatened or caused damages to existing constructions. Figure 1 shows an example of a large gully, close to Taguatinga, a city 25 km from Brasilia. Because of the number and dimensions of these gullies, effective low cost solutions are required to control the erosion process and to help to accelerate the remedy of the degraded area.

This paper presents the investigation on the compatibility between available low mass per unit area geotextiles and soils from erosions in the Federal District by means of laboratory tests, as described below.

2 EQUIPMENT AND MATERIALS

Figure 2 shows the Fine Fraction Filtration Test equipment developed as part of the research programme. Figure 3 shows a general view of the test apparatus during a test. The equipment is based on a model similar to the one presented by Sansone and Koerner (1992), with some modifications to favour research purposes. Basically, the test consists in inducing the flow of water with soil particles in suspension towards the geotextile specimen, which is fixed inside a cylindrical cell (Fig. 2). Parts of the equipment were made of perspex tubes, to allow the visualisation of the retention or piping mechanisms during the tests. Piezometers were installed close to the geotextile specimen to assess water head losses in that region. Discharge valves at different levels allow the gradient of flow to be varied.

It was also one of the objectives of the research to measure the dimensions of the particles that were able to pass though the geotextile layer during the test. All the material that piped though the geotextile was collected after the tests in the sedimentation chamber below the geotextile specimen and along the tubes of the apparatus (Fig. 2). The control of the amount of soils in suspension in the discharge water that left the apparatus was also performed. Due to the small amount of soil piped in the tests, a Malvern Mastersizer laser beam grain size analyser was used to obtain the grain size distribution curve of the soil that passed through the geotextile. The grain size analyser is capable of measuring particle diameters in the range 0.5 to 900 μm.

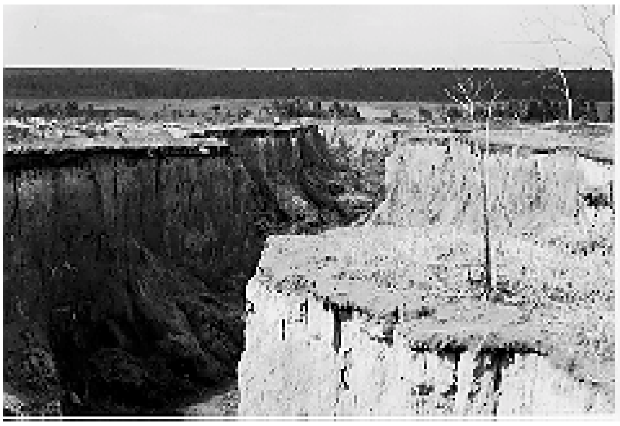

Figure 1. Large gully close to the city of Taguatinga.

The piezometers installed in the cell of the f^3 test apparatus also allowed the execution of gradient ratio tests, as described in ASTM D5101-90 (ASTM, 1996).

Permeability tests on the geotextile specimens after the modified f^3 tests were also performed to assess the loss of geotextile normal permeability. In this case a permeameter based on ASTM D4491-89 (ASTM, 1996) was used for these tests.

The weight of the soil particles entrapped in the geotextile was also measured after the end of each f^3 test.

Six types of soils were tested and their main characteristics are presented in Table 1 and Figure 4. The soil samples were collected from the following sites: University of Brasilia Geotechnical Engineering Experimental Site (soil code SG-12, in Table 1), one erosion close to the city of Taguatinga (code ErTa, see Fig. 1), one erosion in the city of Ceilandia (30 km from Brasilia, code ErCe) and two sandy soils (codes AFB and AMFA). Additionally, a mixture of soils ErTa and AFB (soil code S1Fb) was also tested.

Six types of non woven needle-punched geotextiles made of continuous polyester fibers were used in the tests. Their relevant characteristics are presented in Table 2. The mass per unit area of the geotextiles varied between 76 and 250 g/cm^2.

The geotextile specimen was saturated prior to the tests by water jetting and vacuum. The soil samples were first dried, broken into their individual particles with the help of a rubber-tipped pestle and then sieved. Only the soil particles below 2 mm diameter were used in the tests. Specific values of soil mass (2 to 16 grams) were mixed with water in different containers, saturated by boiling and left to rest for 24 hours.

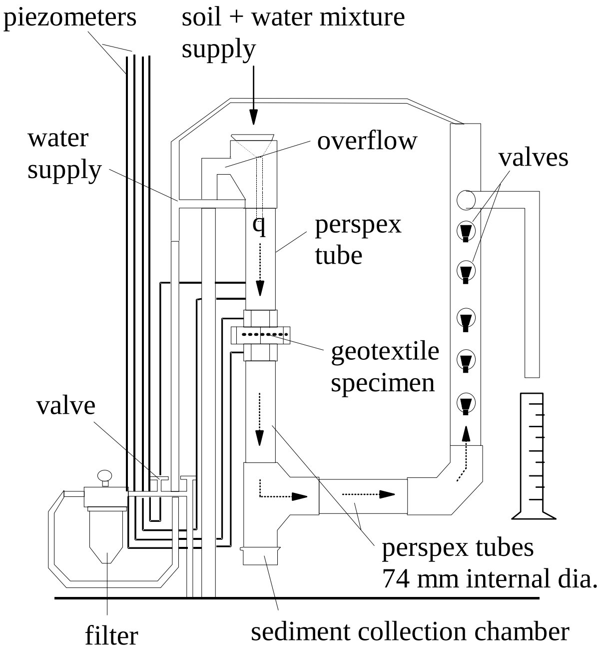

Figure 2. Equipment used in the tests.

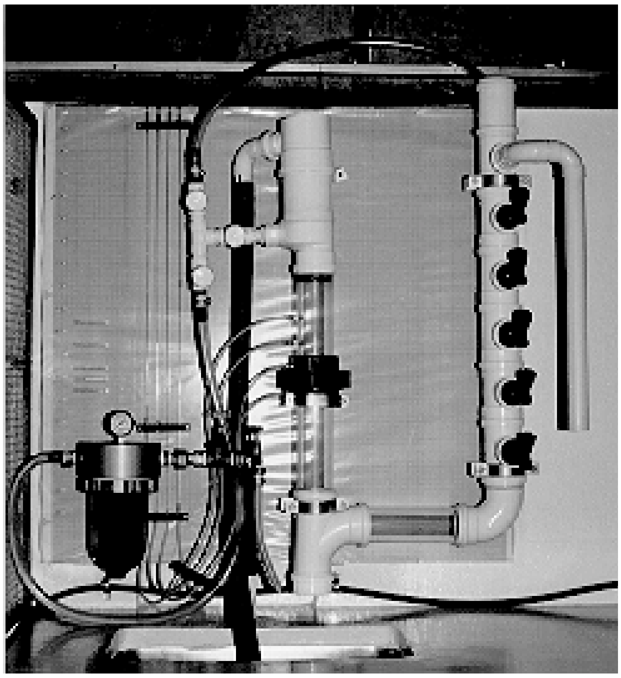

Figure 3. General view of the equipment

Table 1. Characteristics of the soil used.

Soil Code	D_{10} (μm)	D_{15} (μm)	D_{60} (μm)	C_u (1)	γ_s (2)
SG-12	-	-	35	-	26.98
ErTa	-	-	64	-	26.34
ErCe	2.9	3.2	35	12.1	26.57
AFB	60	80	180	3.0	26.10
AMFA	100	140	280	2.5	27.02
SlFb	2	15	160	7.5	25.83

(1) Soil coefficient of unformity (D_{60}/D_{10})
(2) Soil particle unit weight (kN/m^3)

Table 2. Geotextile characteristics.

Geotextile	t_{GT} (1) (mm)	M_A (2) (g/m^2)	FOS (3) (μm)	ψ (4) (s^{-1})
VP-75	0.80	76	153	5.0
IR-11	1.40	113	159	2.8
OP-15	1.50	150	150	2.5
OP-20	2.00	200	130	2.0
XT-04	1.80	180	140	2.2
XT-06	2.30	250	120	1.7

Notes: (1) t_{GT} = geotextile thickness under 2 kPa., (2) M_A = mass per unit area, (3) FOS = filtration opening size (AFNOR G38017, CFG 1986); (4) ψ = geotextile permittivity (s^{-1})

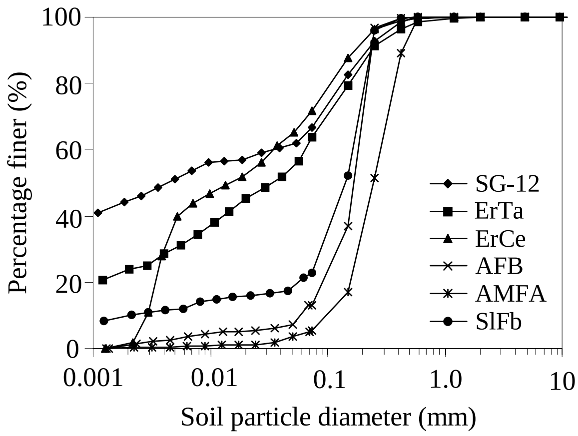

Figure 4. Grain size distribution curves.

After the water flow had been established in the apparatus the soil and water solution (2g of soil per 200 ml of water) was added in 2 minutes intervals up to a total of 50 grams. During each 2 minutes time interval, after feeding the system with the soil and water solution, samples of water percolating through the geotextile and measurements of flow rate were taken. After a total mass of

50 grams has been added to the system, greater concentrations of soil and water mixtures (4, 6, 8, 10 and 16 grams per 200 ml of water) started to be added. For these larger concentrations water samples and flow rate measurements were taken after 4, 6, 8, 10 and 16 minutes respectively.

After the feeding stages have been completed, the water flow was interrupted and the system was left to rest to allow the sedimentation of particles in suspension. The apparatus was the disassembled to allow the collection of the soil mass that passed through the geotextile for grain size measurements.

For the gradient ratio tests the soil samples were prepared following the recommendations presented in Kuerbis and Vaid (1988) and Vaid and Negussey (1988).

Additional information on materials, equipment and testing procedures can be found in Farias (1999).

4 RESULTS OBTAINED

Figures 5 and 6 show the test results obtained in tests with geotextiles VP-75 and IR-11, respectively, in terms of variation of flow rate per unit area of the geotextile specimen versus the amount of soil mass added to the system. The results in Figures 5 and 6 lead to the following conclusions:

- For all the combinations of soil-geotextile tested the greater amount of particles piped after the first addition of 2 g of soil to the system. The exceptions to this pattern were verified for tests with the sandy soil AMFA, due to the coarser nature of this soil, and to soil AFB, for which washing of fines were observed during most of the test duration.
- For all the combinations of soil and geotextile tested a severe drop in the flow rate and velocity was also observed after the addition of the first 2g of soil. At this stage the most severe drop in flow rate was observed for the combination geotextile VP-75/soil ErTa (Fig. 5), for which the addition of the first 2g of soil reduced the flow by a factor of 4. The smallest flow rate reduction was observed for the combination VP-75/AMFA.
- Permeability tests performed on the geotextile specimens after the f^3 tests showed little reduction in the geotextile permeability after the tests. The greater reductions (≅ 50% reduction) geotextile permeability occurred in tests with soil ErCe.
- A severe flow rate drop was observed for the combinations VP-75/ErCe and IR-11/ErCe after the addition of 48g and 18g of soil to the systems, respectively (Figs. 5 and 6). Indeed this type of behaviour was observed for all the tests with soil ErCe. It should be should be noted the significant non uniformity (CU = 12.1) of the grain size distribution curve (Fig. 4) for this soil, with rather uniform particle sizes for diameters between 0.002 and 0.005 mm (40% of the soil mass). Therefore, the finer 40% of the soil mass is very uniform. These results suggest that a severe reduction in the flow rate might be anticipated in real works involving the use of those materials. In this case the consequences of such a drop in the flow rate and the possibility of overtopping of the sediment retention system in real works must be carefully considered.

Figures 7 and 8 present the grain size distribution curves for the soil particles passing through the geotextiles in tests with geotextiles VP-75 and IR-11, respectively. The largest diameter of the particle passing through the geotextile is usually considered as the diameter corresponding to 95% passing (D_{95}) obtained in curves such as the ones presented in Figures 7 and 8. The smallest value of D_{95} (= 30 μm) for geotextile VP-75 occurred for the test with soil AMFA. This value is approximately 20% of the filtration opening size value for that geotextile (Table 2). The largest value of D_{95} (= 70 μm) for geotextile VP-75 was observed for the test with soil S1Fb, which in this case corresponds to 46% of the filtration opening size of that geotextile.

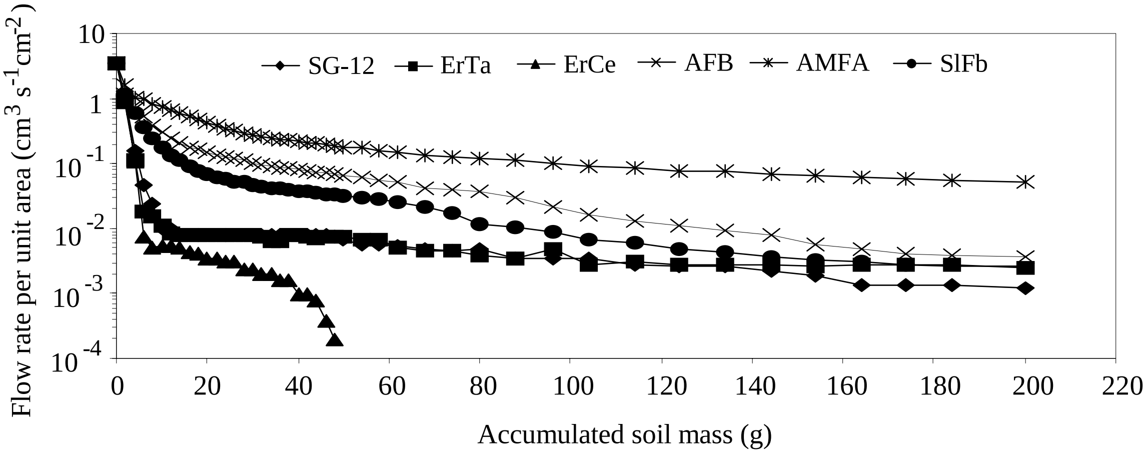

Figure 5. Test results for the geotextile VP- 75

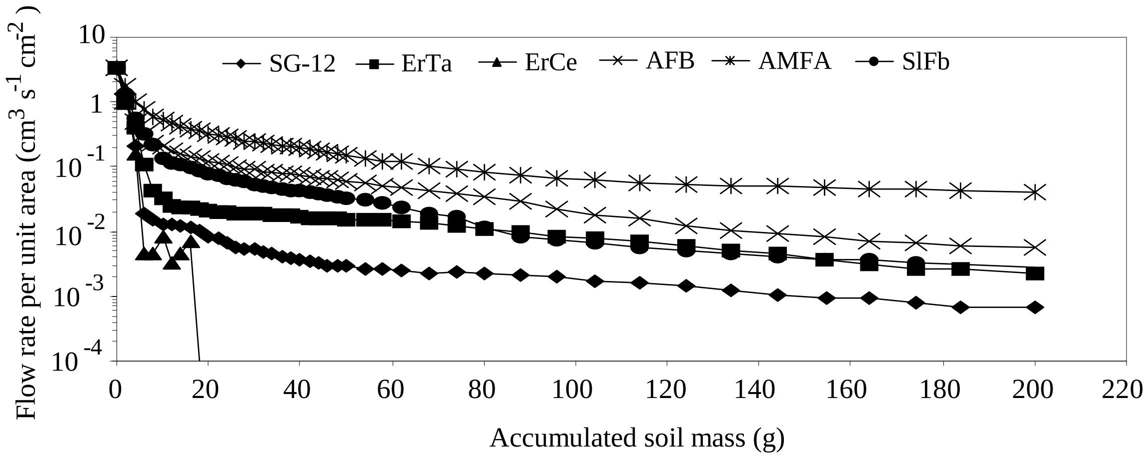

Figure 6. Test results for the geotextile IR-11

Figure 9 presents the comparisons between measured values of D_{95} and geotextile filtration opening sizes (O_{95}) for all the combinations soil/geotextile tested. It can be observed that for most of the tests the ratio between D_{95} and O_{95} varied between 0.20 and 0.75. In 63% of the tests performed the ratio D_{95}/O_{95} varied between 0.20 and 0.5, which suggests that the evaluation of geotextile retention capability based in traditional filter criteria and on the geotextile filtration opening size can be considerably conservative. It should be pointed out that in the field other factors not accounted for in the laboratory tests may affect the performance of the geotextile as a barrier, such as turbulent flow conditions, a broader grain size distribution of the soil particles carried by the water and debris.

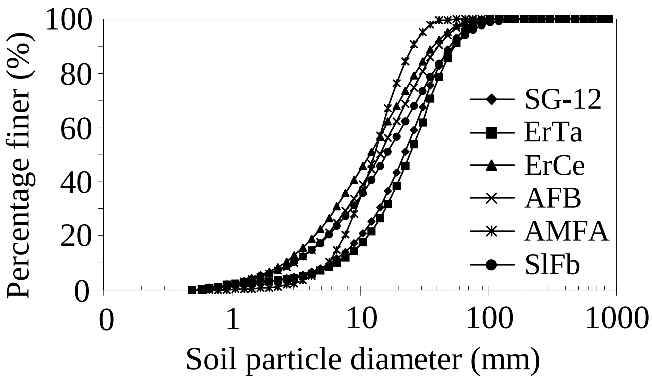

Figure 7. Grain size distribution curves for the soils passing through geotextile VP-75.

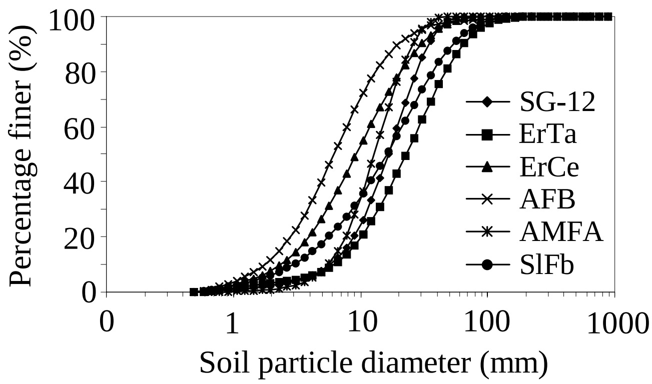

Figure 8. Grain size distribution curves for the soils passing through geotextile IR-11.

Figure 10 shows the variation of the Geotextile Entrapment Ratio T_p (Faure et al, 1999) versus the geotextile Filtration Opening Size, FOS. The Entrapment Ratio is defined as the percentage of the geotextile pore space that is occupied by the soil particles. The value of T_p varied typically between 2 and 15%, with the highest value occurring for the lighter geotextile (VP-15, FOS = 153 μm). Soils with similar grain size distributions curves yielded similar variations of T_p versus FOS.

Table 3 present the results of Gradient Ratio tests for geotextiles VP-15 and IR-11. Very low or very large values of the gradient ratio (GR) can be observed, depending on the combination geotextile/soil tested. For the combination VP-15/ErTa there was piping in the region close to the geotextile layer (GR = 0.3), while substantial clogging occurred for the combination IR-11/AFB (GR = 8). However, these combinations presented stable results in the f ^{3} tests (Figs. 5 and 6). These disagreements indicates the influence of the different flow regimes and clogging mechanisms in those types of tests.

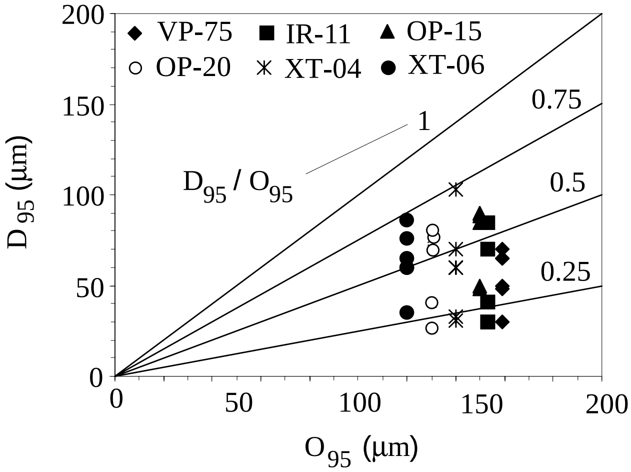

Figure 9. Comparison between O_{95} and D_{95}

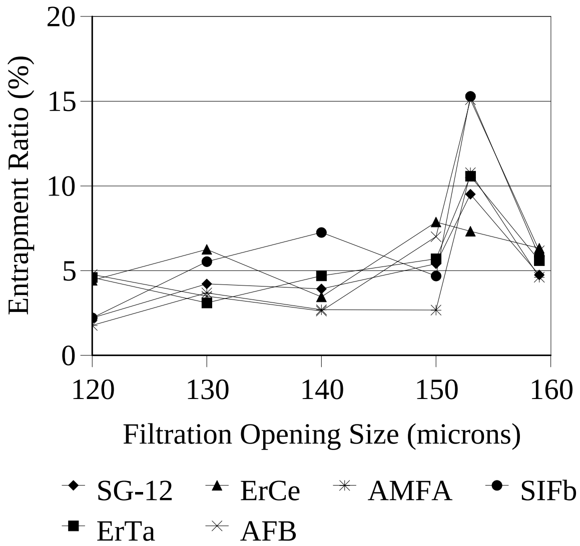

Figure 10. Entrapment Ratio versus FOS.

Table 3. Values of GR.

Geotextile	Soil	GR
VP-75	ErTa	0.3
	AFB	4
	SIFb	1.2
IR-11	ErTa	4
	AFB	8
	SIFb	2

Note: GR defined in ASTM (1996) for a hydraulic gradient equal to 3.

5 CONCLUSIONS

This paper presents a study on the evaluation of the performance of light non woven geotextiles as barriers by means of laboratory tests. The main conclusions are summarised below:

- The modified version of the f test equipment performed well and can be used as an index test for the evaluation of retention capability of geotextiles for erosion control works.
- For most of the combinations geotextile/soil tested the pattern of behaviour was similar with a significant drop in the flow rate in the early stages of the test followed by stabilization. For the soil ErCe a significant reduction of flow rate was observed for all the geotextiles tested. This behaviour can be attributed to the grain size distribution for this soil.
- Soil particles larger than the geotextile filtration opening size can form a stable structure that accelerates the stabilisation of the flow conditions. This structure can retain or not finer soil particles that may pass through or be retained by the geotextile. A similar behaviour was observed by Sansone and Koerner (1992).
- The maximum diameter of the particles passing through the geotextile were considerably smaller than the geotextile filtration opening size. This suggests that the use of current retention criteria can be conservative for the flow conditions present in this type of test.

ACKNOWLEDGEMENTS

The authors are indebted to the following institutions for their support to this research: University of Brasilia, CNPq-Brazilian Research Council, CAPES-Brazilian Ministry of Education, FAP/DF-Foundation for the Research Support in the Federal District and Bidim-BBA Nonwoven Geotextiles.

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