New methodology for in-suspension filtration test

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ABSTRACT: The paper presents a new methodology for in-suspension filtration tests. The obtained results allow to estimate the unit step walk covered by particle for each confrontation, a required parameter for textile filters design by probabilistic theory and for the study of filters behaviour along time using simulation techniques. The parameter achievement is made by retro analysis of the results. The work also presents an evaluation of the geotextile filtration opening size obtained by in-suspension filtration tests and hydrodynamic sieving.

1 INTRODUCTION

During the last thirty years a rapid development of synthetic fabrics application in civil engineering has been observed. The good performance of geotextiles in filtration functions has been reported in practical engineering thus becoming one of the most popular geosynthetics applications in the world. In recent years, research has been conducted at several laboratories in order to obtain a better knowledge of mechanisms and parameters associated with filtration problems.

Designing with geotextiles for filtration is essentially the same as designing graded granular soil filters, both of them have similar structure, the geotextile has pores and filaments (or fibers) and the soil filter has voids and particles. However, with geotextiles, the geometric relationship between filaments and pores is generally more complex than in soil because of the shapes and compressibility of the porometric structure.

Usually the retention criteria used in filter designs are based on Terzaghi's proposition, empirically or semi empirically adapted by different authors. They consider that the greatest pore of the geotextile needs to be smaller than that determined by the soil particle diameter multiplied by a factor, and different solicitations and test parameters are considerate, without direct correlation. However, these procedures don't allow a complete understanding of the filtration phenomena. What make it difficult to calculate the filter thickness need to retain the soil particles.

Silveira (1965) proposed a probabilistic analysis to study the carrying of soil particles in a filter. This analysis gives us the granular filter thickness needed to retain certain soil particles, with an adopted reliability level. Until Urashima (1996) this theory had not been applied to textile filters because for this application it would be necessary to know the geotextile pore-size distribution curve and unit step walk covered by the particle for each confrontation.

Once these parameters are known, the filter design by probabilistic theory becomes possible. This is particularly important for environmental works, because it is the only one that allows to evaluate and to establish the reliability level of particle retention.

Once the thickness of the filter is established, the probability of each particle of the in-suspension material contained in a granulometric range to pass through the filter can be verified.

The knowledge of the value of the unit step walk still allows the study of the filtering systems behaviour along the time by means of simulation techniques. More details on the probabilistic design, calculation samples and study of the filters behaviour using simulation techniques are in Urashima & Vidal (1998, 2000).

Filtration characteristics and pore size distribution of geotextiles have been largely discussed in literature. The usual methods to analyse the filtration parameters of geotextiles are based on different conception and generally not applicable to obtain the geotextile pore size distribution.

The pore size distribution can be obtained by theoretical method, such as proposed by Gourc (1982) for needle-punched nonwoven geotextiles based on probabilistic analysis or by image analyse. Silveira (1993) suggested an experimental procedure to determine the pore size distribution by retro analysis, using in-suspension filtration test.

From the results of in-suspension filtration tests, conducted according to the probabilistic theory suppositions, and theoretical pore size distribution curve proposed by Gourc (1982), it is possible to estimate the unit step walk covered by the particle for each confrontation. Theses tests were conducted to evaluate the bigger particle passing across the filter on the first one seepage front, under severe flow conditions. Test had been done first in 150 mm diameter specimens and submitted to a special in-suspension filtration test described in Urashima & Vidal (1997, 1998).

2 CONCEPTION AND APPARATUS

2.1 *Conception*

Studies and analyses of the results obtained by traditional in-suspension filtration tests (Urashima & Vidal, 1997, 1998) shows that this methodology could not be extended for specimens of larger areas, as suggested by Silveira (1995), because the amount of necessary rate of flow would be huge. However, an augmentation in the specimen surface would allow an increase in the amount of passing base material, what would facilitate its analysis, also making possible the use of a standard soil instead of soil fractions.

The basic hypothesis of the probabilistic theory applied to filters design (Silveira, 1965) considers unidirecional flow, in which the base material particle is carried throughout the filter, that can be retained or not. In order to satisfy this hypothesis the conceived test considers the following initial conditions:

- Reservoir with removable base, in a way that the flow is not disturbed;
- Specimen positioned over a support screen positioned at 2 cm of the removable base;
- Base material is sprinkled over the filled up water reservoir, in a homogeneous way and that each particle could not be blocked by other particle.

After the base material to settle down over the filter surface, a variable load flow is induced by means of the instantaneous base removal.

2.2 *Preliminary studies*

The possibility of a variable load test should be verified in order to allow the increasing of the tested area, instead of the constant load tests proposed by Silveira (1993). Comparative tests with fine geotextiles specimens, with $0.071m^2$ of tested area, were accomplished in an intermediate stage.

To verify the possibility of working with a continuous granulometric distribution soil, the tests performed at this stage they also consider this condition. The obtained results shown practically the same values obtained by the traditional test, confirming the be viability of the proposed changes.

2.3 *Apparatus*

The equipment proposed for the in-suspension filtration tests, with 0.61 m^2 area specimens, consists of an aluminium alloy rectangular reservoir (0.87 x 0.80 x 0.35 m); which bottom is fixed by electro magneto. The device assemblage is illustrated on Figure 1. The main components of the system can be divided in: main reservoir, specimen support screen made with a mesh of 1 cm^2 opened area, specimen clamp system, magnet and lower reservoir.

Although the new apparatus shown on this paper has dimension greater than the one described in Urashima & Vidal (1997, 1998) it is easily set up and handled.

The results obtained showed that the adopted methodology allows to evaluate the unit step walk on thin fabrics, but it doesn't work on the evaluation of thicker fabrics, because the amount of passing particles is very small to be analysed with the necessary accuracy.

The methodology presented in this paper was developed to satisfy Silveira (1993) hypothesis and to allow a better value of the unit step walk to fabrics with mass per unit area greater than 200 g/m^2.

The main differences between the new methodology and the other are: the specimen size, the hydraulic load (tests are made with variable loading instead of constant loading), and the base material preparation. Some results are presented and discussed to show the relevance of the adopted procedure.

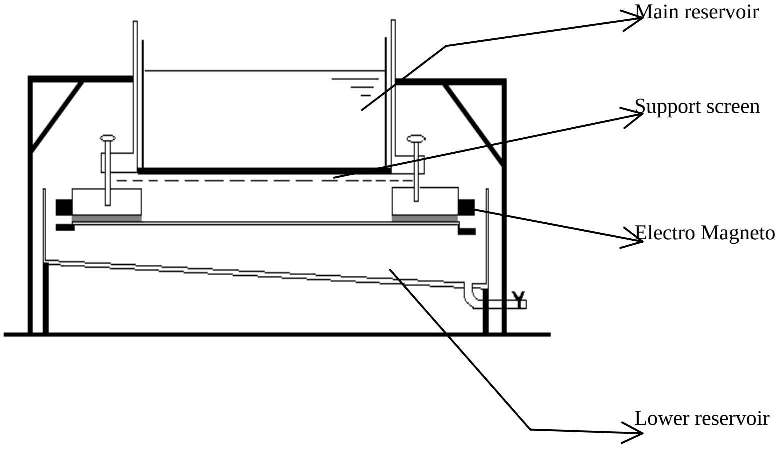


Figure 1. In-suspension filtration tests apparatus.

3 METHODOLOGY

The tests consists of the following procedure:

- The geotextile specimen should be weighed and then saturated. To facilitate saturation, water around 30^o C and a surfactant should be used;
- the main reservoir is filled out with water at a temperature over the room temperature condition until the level of the support screen to be reached;
- The saturated specimen should be positioned over the screen with the necessary cares to avoid the development of bubbles and it should be clamped with a secondary reservoir, eliminating eventual air bubbles that may appear;
- The reservoir will be filled out with water at a temperature over the room temperature condition until a hydraulic load of 20 cm to be applied on the specimen;
- The base material previously prepared is sprinkled over the water in a homogeneous way covering the whole specimen surface;

- After the base material to settle down over the specimen surface, the electro magneto are turned off and the reservoir bottom is instantaneously opened, without disturbing the flow condition.

The apparatus assembled as described above is presented on Figure 2.

The following procedure is taken to analyse the passing material:

- After the necessary time to the passing particles to settle down, the clean water above the settled material is took out by a siphon, in order to reduce the passing material volume to be treated;
- The remaining material is drained to a smaller reservoir, the whole flow is sieved by a 0.037 mm mesh sieve;
- The settle down process and drainage are repeated until the remaining volume could be taken to a oven for drying;
- The particle size distribution curve of the total passing material is plotted ;
- The specimen should be carefully taken out of the equipment and then taken into a oven for drying;
- The oven dried out specimen should be weighted to obtain the amount of retained material.

All those measured values are compared to verify the soil losses during the process.

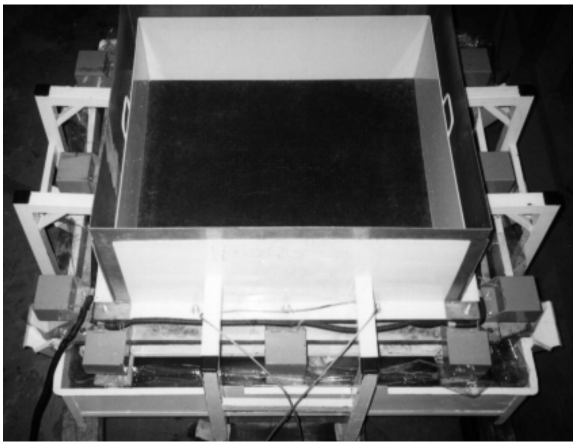


Figure 2. Test apparatus.

4 MATERIALS

4.1 *Filter*

Needle punched continuous filaments and staple fibers nonwoven geotextiles, composed by polyester and polypropylene were used as filter material.

The physical properties of the geotextiles employed in the research were mass per unit area and nominal thickness, obtained in agreement with NBR 12568 (1992) (ISO 9864, 1990) and NBR 12569 (1992) (ISO 9863, 1990) standards, fifteen specimens were prepared according to NBR 12593 (1992) (ISO 9862, 1990).Table 1 presents the summary of the obtained results.

4.2 *Base material*

The granular base material chosen was a stone powder of 27 kN/m^3 solid unit weight, with high strength particles. Table 2 presents the fractions used to compose the standard soil for the proposal methodology.

Table 1. Physical characteristics of the geotextiles.

type	d_f[1] (mm)	t_{GT}[2] (mm)	M_A[3] (g/m^2)	η_{GT}[4] (%)
AA	0.022	1.33	158	91.4
AB	0.022	1.55	181	91.5
B	0.030	1.94	210	87.9
C	0.022	2.10	240	87.3

[1]fiber diameter
[n]nominal thickness
[3]mass per unit area
[4]porosity

Table 2. Fractions used to compose the standard

sieve	(mm)	Mass (g)
140 / 170	0.105 / 0.088	30
170 / 200	0.088 / 0.075	30
20 / 230	0.075 / 0.066	30
230 / 270	0.066 / 0.053	30
270 / 325	0.053 / 0.044	30
325 / 400	0.044 / 0.037	30
d < 400	< 0.037	30

5 RESULTS

5.1 *Preliminary analysis*

Table 3 compares the values of filtration opening size (O_{95}) obtained by the in suspension filtration tests under hydraulic constant load (Urashima, 1996) to the values obtained in the variable load tests carried out during the preliminary studies and also the values obtained by hydrodynamic sieving (NF G 38017, 1986) are presented.

5.2 *Tests with the developed equipment*

Table 4 summarises the values of filtration opening size (O_{95}) and the unit step walk obtained by retro analysis of the results obtained from the pore distribution curves (Gourc, 1982) as proposed by Urashima (1996) (Urashima & Vidal, 1998), based on Silveira (1993) proposal. A 98% reliability level was adopted.

Figure 3 shows the particle size distribution curve of the base material passing throughout the geotextile filter.

Table 3. Filtration opening size obtained by different test methodologies.

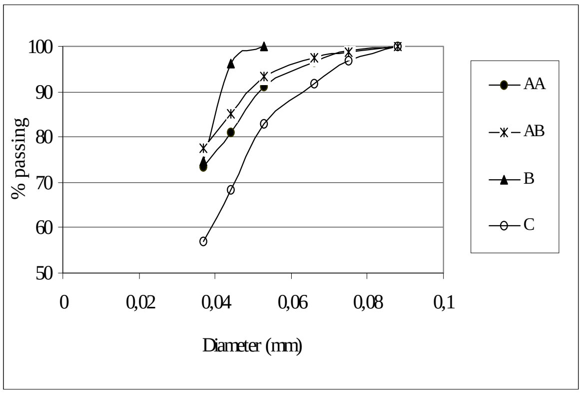
Type	$O_{95,H}$ (mm)	O_{95} S_1 (mm)	O_{95} S_2 (mm)
AA	0.210	0.070	0.069
AB	0.170	0.059	0.058

[1]constant load
[2]variable load

Table 4. Filtration opening size and unit step walk obtained through the new methodology.

	AA	AB	B	C
O_{95} (mm)	0.061	0.056	0.043	0.071
s (mm)	0.359	0.410	0.289	1.078

Figure 3. Particle size distribution curves obtained by the new in suspension filtration tests.



The results presented the expected behaviour, as it could be observed for the group A tested specimens. The particle size distribution curve would shift to the left side if there was an increment of thickness to the same geotextiles group.

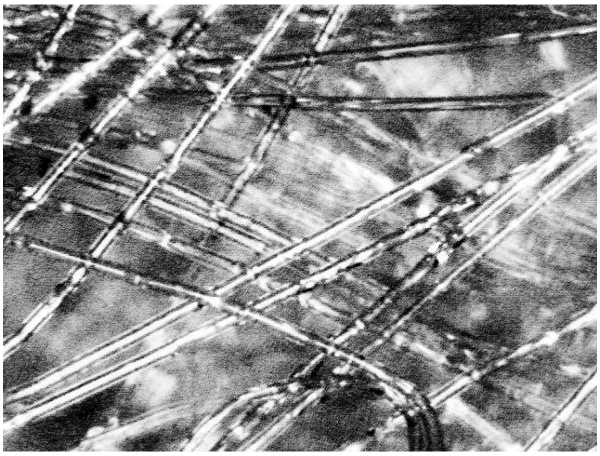
Figure 4 presents the geotextile porometric fabric before and after the in suspension filtration tests. The images were acquired by a 50 X zoom CCD video camera coupled to a 300 X enlargement microscope, and visualised in real time in a digital monitor, connected to a computer that allows the images caption.

6 COMMENTS

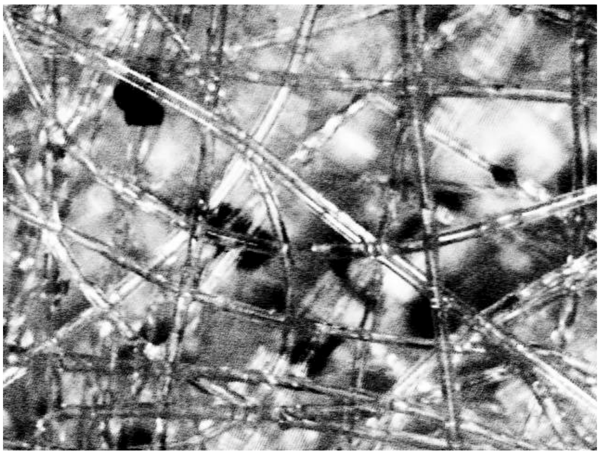
The method proposed allows to analyse geotextiles specimen of higher dimension, obtaining a larger amount of passing material, making possible a better analyses of the particle size distribution of the passing material.

The new proposal takes to a test method whose handling and analysis are much less complex than the traditional in suspension filtration tests, with an easy reproducibility and standardisation.

The simplicity of the test accomplishment and their possible standardisation are a major step in filter design by probabilistic theory, once the largest difficulty for the application of this theory is the unit step walk determination.



(a)



(b)

Figure 4. Geotextile B porometric fabric before the in suspension filtration tests (a) and after tests (b)

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