Retention analysis of nonwoven geotextile filters during filtration of suspended solids

Urashima, D.C.
Department of Civil Engineering – CEFET-MG, Minas Gerais, Brazil.
Vidal, D.
Geotechnical Department, ITA, São Paulo, Brazil.

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ABSTRACT: The present paper describes a model for analyses of nonwoven geotextile filters during filtration of suspended fine particles and discusses the influence of the fibre/filament ability to retain the particles. This was carried out by computer techniques to simulate scenarios regarding dynamics of filtering systems. Simulations allow potential users of these products to research the subject and to perform analyses under different conditions. This brings about a situation where engineers may test their hypotheses and systems, and their applicability, for any given period of time, and relating to any specific environmental condition. The simulation allows considering flow type and intensity, the base material and the geotextile porometric structure. The system retention capacity is evaluated considering these parameters and the fibre/filament retention level that is adopted from laboratory tests. Variable hydraulic head filtration tests were taken into consideration to evaluate the retention level to be adopted for a fine uniform granular base material.

1 INTRODUCTION

Geotextiles filters have been extensively used in conventional geotechnical works all over the world. Its application have been widespread to a growing number of environmental protection work, in permanent filters and in-suspension particles filtration cases that need substitution or periodic wash of the filter along the lifetime of the system (Faure et al. 2006, Aydilek 2006).

In the last ten years several specific laboratory tests have been proposed to evaluate the geotextile performance during in-suspension particles filtration, trying to improve the specifications and the quality of the applied products (Moo-Young et al. 2002, Liao & Bhatia 2006, Muthukumaran & Ilamparuthi 2006).

Also several theoretical and probabilistic models to analyse the geotextile retention in-suspension filtration applications have been proposed, as discussed by Faure et al. (2006), Urashima & Vidal (2002).

The possibility to evaluate the retention reliability level or the retention probability solves only a part of the in-suspension particles retention problem, because it is still necessary to know the behaviour of the filter during its lifetime, evaluating the permeability of the system throughout time and the filter changing or washing period. This problem becomes extremely serious in the case of very fine particles filtration (clay or silt). The consequence of fine particles accumulation in the geotextile is a progressive increase of the water head loss in the system (Faure et al. 2006) that could reduce the system hydraulic conductivity and to demand a frequent maintenance. Simulation techniques can solve this problem when it is known the flow conditions and the filter and base material properties.

Urashima & Vidal present in 2002 a proposition to simulate nonwoven geotextiles retention for in-suspension particles filtration. In 2006 Aydilek presents a study based on simulation techniques specific for woven geotextiles filters.

Urashima & Vidal (2002) consider that:

- the flow type and intensity are analyzed through mathematical formulations,
- the base materials fabric are analyzed through statistical analysis of the particles arrival and
- the geotextile fabric is considered from microscope image analysis verifying the existence of filaments or fibres that can retain the particles present in the base material.

This technique eliminates the problem of establishing the pores shape and size in nonwoven geotextiles, but the algorithm needs to account for the influence of the fibre/filament ability to retain the particles as a retention level percentage.

The aim of this work is to discuss the retention level concept to nonwoven geotextile filters during filtration of suspended fine particles, and the factors that could affect nonwoven synthetic filters performance by simulation.

To understand the retention phenomena involved, the results of laboratory in-suspension filtration tests were compared to the results of computer simulations considering the same boundary condition.

2 MATERIALS

2.1 *Soil tested*

A non friable granular material – a crushed stone powder – was selected, with solids unit weight of 2.72 g/cm^3 and an uniformity coefficient of 1.6. Table 1 shows the uniform single fractions adopted to the simulations and employed in the variable hydraulic head filtration tests.

Table 1. Soil characteristic diameters.

d_{10} (mm)	d_{16} (mm)	d_{84} (mm)	d_{90} (mm)
0.0035	0.038	0.058	0.105

2.2 *Geotextile tested*

A continuous filament needlepunched nonwoven geotextile with characteristics presented in Table 2 was selected to this research.

Table 2. Geotextile properties.

Properties	Value
Filament diameter	0.022 mm
Thickness (NBR 12569)	1.33 mm
Mass per unit area (NBR 12568)	158 g/m^2
Porosity	91.4 %
Characteristic opening size (ISO12.956)	90 μm
Number of confronts	4

3 TEST METHOD AND ANALYSES

3.1 *Variable hydraulic head filtration test*

The developed equipment for the variable hydraulic head filtration tests, with 0.61 m^2 area specimens, consists of a rectangular reservoir (0.87 × 0.80 × 0.35 m), which bottom is fixed by an electro-magnet system. The device assemblage is illustrated in Figure 1. Urashima & Vidal (2000) describe the equipment and the test procedure.

The method proposed allows analyzing geotextile specimen of higher dimension, obtaining a larger amount of passing material. It makes possible a better analysis of the particle size distribution of the passing material and allows evaluating the bigger particle passing across the filter on the first one seepage front, under severe flow conditions.

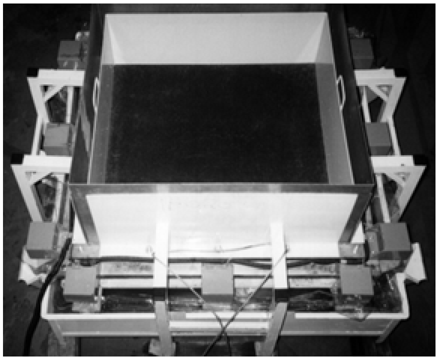


Figure 1. Equipment utilized in the variable hydraulic head filtration tests.

3.2 *Retention simulation technique*

The simulation of filtration systems based on Logic - mathematical models representing the dynamics of the system permits to evaluate the long time filtering behaviour considering porous media or in-suspension particles flow. The simulation also allows evaluate the hydraulic head development on time due to the soil retention by the filtering system.

The proposed model considers a statistical distribution from the given set of the base materials particles that will be filtered. These particles present several diameters that can be randomly generated by statistical distribution. The geotextile fabric is represented from image analysis.

To simulate the behaviour of the textile filters it is necessary to define the statistics of particles arrival. The base material can be represented by a probabilistic distribution curve - the choice of the distribution to be used depends on the existent data. Whenever the base material is well graded, the particle diameter can be generated randomly considering a normal distribution with the average μ and the variance σ^2, defined from the characteristics diameters: d_{16}, d_{50} e d_{84}. The generated diameters are limited by [d_0, d_{100}].

When the base material presents a uniform grain size distribution curve, the particle diameter can be generated randomly using a uniform distribution defined between [d_0, d_{100}]. In case of a poorly graded grain size distribution, no statistical distribution can be considered and the diameters are randomly generated between [d_0, d_{100}].

Due to the difficulty to evaluate d_0 and d_{100} from the particle size distribution curve obtained in laboratory tests, to obtain the limit characteristic diameters, an analysis of the material curve should be done to define the most reliable values.

To evaluate the retention capacity of the textile filters by simulation techniques, it is also necessary to analyse the geotextile fabric. The geotextile porometric structure images can be taken from pictures generated by a video camera connected to a microscope and connected to a computer that allows capturing the images.

In order to minimize the shadow effects associated to material three-dimensionality and to enable distinct pores and filaments that constitute the first confrontation front of the filter material, digital images processing techniques are employed (Urashima & Vidal 2002).

In the model adopted here, the system structure is represented by pixels. White pixels refer to retention area and black pixel to free area (pores). Each generated particle is confronted to an image randomly chosen from a group of binary images representative of the universe of the studied geotextile. If the particle projected area only confront pixels related to the free area, the particle pass. If the particle projected area confronts retention pixels, the percentage of the particle area retained is calculated and compared to the retention level adopted. If the calculated percentage is equal or superior to the adopted value, the particle is considered retained and its projection is incorporated to the system as white pixels (see Figure 4).

3.3 *Simulation Analysis*

Table 3 presents the boundary conditions employed in this work to simulate a variable hydraulic head filtration test.

Simulation analysis considering different retention level for the same boundary conditions of the laboratory tests: flow velocity, concentration, test time and base materials conditions were conducted. To generate the base material, the limits of the grain size distribution curve were considered as the values of d_{10} and d_{90}.

For each retention level adopted, ten simulations were realized to obtain representative results of average and standard deviation of passing particles.

Table 3. Boundary Conditions

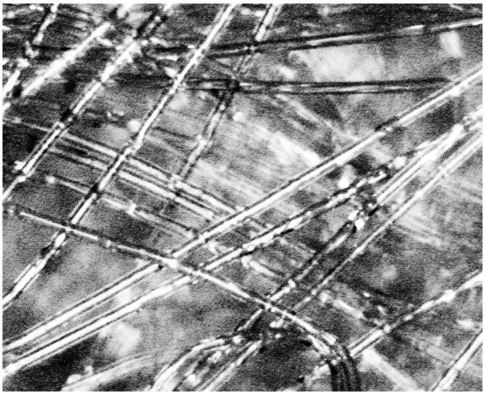
Conditions	Value
Velocity	4 cm/s
Concentration	1.57 g/l
Time	3s

4 RESULTS

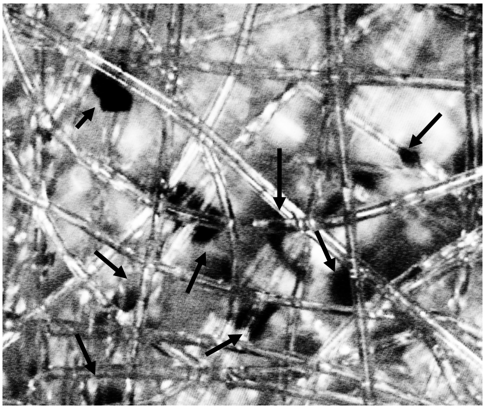
4.1 *Variable hydraulic head filtration tests*

Figure 2 presents the filter structure observed before (Fig.2a) and after (Fig.2b) one of the variable hydraulic head filtration tests. The images obtained with a video camera coupled to a microscope are 50 times bigger than the original.

The three tests result in an average value of 19% for the retained mass, with a standard deviation of 0.2.



(a)



(b)

Figure 2. Geotextile microscopic image: (a) before the test, (b) after the test (x50).

4.2 *Simulations*

Table 4 and Figure 3 demonstrate the results obtained for the different retention level, considering the boundary conditions presented in Table 3.

Table 4. Resume of the simulation results.

	Retention level (%)		
Parameters	55	60	65
Retained mass (%)	32.1	19.8	12.1
Standard deviation	0.9	1.2	1.1
Tests number	10	10	10

Figure 4 shows the first confrontation front of the filter material before the test (Fig.4a) and this confrontation front after the simulation, with the retained particles (Fig.4b), for one of the simulation tests considering a retention level of 60 %.

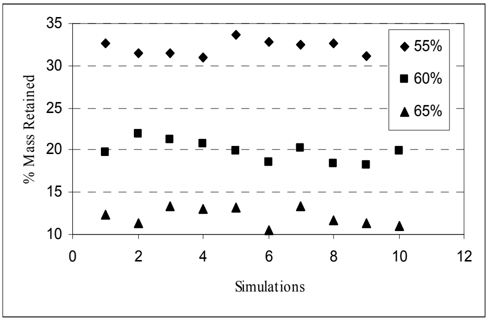
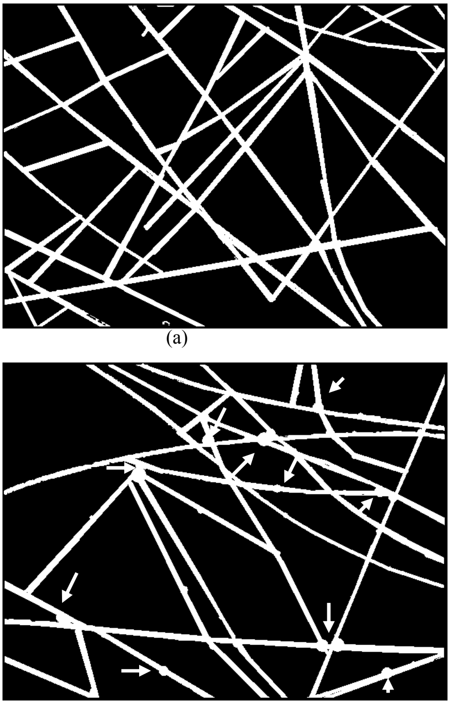


Figure 3. Simulation results.



(a)

(b)

Figure 4. First confrontation front with 60% of retention level: (a) before simulation, (b) after simulation.

5 DISCUSSION AND CONCLUSION

The simulation technique for analyses of geotextile filters during filtration of suspended fine particles is a versatile tool. It allows analyzing the most different situations, accounting for fabric peculiarities and various flow and base material conditions.

For a base material uniform and fine as the tested material, it could be expected a high retention level as indicated by the results obtained for the studied case.

As discussed, the simulation technique eliminates the problem of establishing the pores shape and size in nonwoven geotextiles, but it is still necessary to analyze the influence of the fibre/filament ability to retain the particles.

The main factors that influence the retention capacity of the system are the base material (texture, rounded and roughness), the fibre/filament characteristics and the flow conditions.

This study adopted a constant value for the fibre/filament retention level, considering that the base material is uniform. However, for a non uniform base material, a retention level depending on the grain size distribution curve should be considered. The particle retention is function of the particle diameter and the retention level should be inversely proportional to this diameter.

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