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On the measurement of pore sizes for nonwoven polypropylene geotextiles

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ABSTRACT: The pore size distribution curves for 53 nonwoven polypropylene geotextiles were obtained according to the standards ASTM D4751, EN ISO 12956 and ASTM D6767. Comparisons were made between pore size values O_{95}, O_{90}, and O_{50} as measured according to each method. Significant differences, depending on test method, were observed between pore sizes. Pore size values obtained according to ASTM D6767 are in very good agreement with those obtained by EN ISO 12956 if the former are multiplied by a correction coefficient equal to 0.33. Pore sizes obtained byASTM D4751 are consistently larger than pore sizes obtained by EN ISO 12956 by 30% to 100%. Accordingly, there is a need to accept a unique methodology for determining the pore sizes of nonwoven geotextiles.

1 INTRODUCTION

The design of geotextile filters is strongly dependent on the quantification of the “maximum” pore size and the pore size distribution curve of the geotextiles. However, such efforts can be complicated when the applicability of certain design criteria depends on the use of results obtained by a specific testing method. Many methods have been used and propored for the determination of geotextile pore sizes. Results from such methods have been reviewed, compared and criticized (i.e. Fisher et al. 1996, Giroud 1996, Bhatia et al. 1996). Two such methods based on dry and wet sieving (ASTM D4751 and EN ISO 1256) have been standardized and are in wide use while a third one (ASTM D6767) has been recently introduced.

Available information (i.e. by Faure et al. 1990, Bhatia et al. 1994, Giroud 1996, Fisher et al. 1996, Bhatia et al. 1996, Tu et al. 2002, Aydilek et al. 2005) indicates, among other, that (a) laboratory determination of pore sizes depends on the method used, (b) application of ASTM D4751 is hampered by electrostatic phenomena and glass bead entrapment in the geotextile, (c) results obtained by EN ISO 12956 show less scatter than results obtained by ASTM D4751, (d) ASTM D4751 yields consistently higher pore size values than EN ISO 12936 and ASTM D6767 which may yield similar results and (e) pore channel constrictions can actually be measured by applying ASTM D6767.

Scope of this presentation is to supplement available information on comparative evaluation of results obtained according to standard methods and reinforce the concept of accepting a unique methodology for determining the pore size distribution of geotextiles.

2 MATERIALS AND TESTING

For the purposes of the experimental investigation reported herein, 52 large size samples (4 to 12 m^2) of nonwoven geotextiles were obtained from eight different manufacturers constituting nine product series with 4 to 7 grades per series. Only polypropylene geotextiles were tested since they are a strong majority of the manufactured nonwoven geotextiles and in order to minimize the effect of raw materials on test results. The geotextiles were needle-punched (83%) and heat-bonded (17%) and were made of staple yarns or continuous filaments. To avoid commercial names, a generic notation (M1 through M9) is used to identify products and manufacturers. The mass per unit area and the thickness of the geotextiles tested ranged from 70 to 640 g/m^2 and from 0.36 to 4.77 mm, respectively.

All geotextiles were tested according to ASTM D4751, EN ISO 12956 and ASTM D6767. In reporting pore sizes, the subscripts d, w and c are used herein to denote dry sieving, wet sieving and capillary flow method, respectively. The glass bead sizes used for dry sieving (ASTM D4751) were those specified by the Standard and the percentage of beads passing was used to plot an apparent pore size distribution curve. Glass beads with sizes from 0.02 mm to 1.00 mm were used to reproduce the gradation of granular material specified by EN ISO 12956.

To apply the capillary flow method (ASTM D6767) water (spec. D1193, type IV) was used as the wetting liquid and it was assumed that the pores are cylindrical and that the contact angle is equal to zero ($\cos\theta = 0$). Accordingly, pore sizes, O, were computed as $O = 4\gamma B/P$ where γ is the surface tension, P is the applied air pressure and B is a capillary constant which, according to the Standard, is equal to 0.715 when the pressure is in kPa. The results presented herein were obtained by setting B = 1 since the reason for introducing such a constant was not evident to the authors. Shown in Figure 1a is the laboratory equipment used for conducting all tests according to ASTM D6767. It includes a pressure regulator (1), the sample holder (2), pressure transducer (3), bubble point detector (4), fluid trap (5) and flowmeters (6). The sample holder (Figure 1b) supported the geotextile (1) on a metal screen with 2.0 mm openings and 0-rings (2) to prevent leaks.

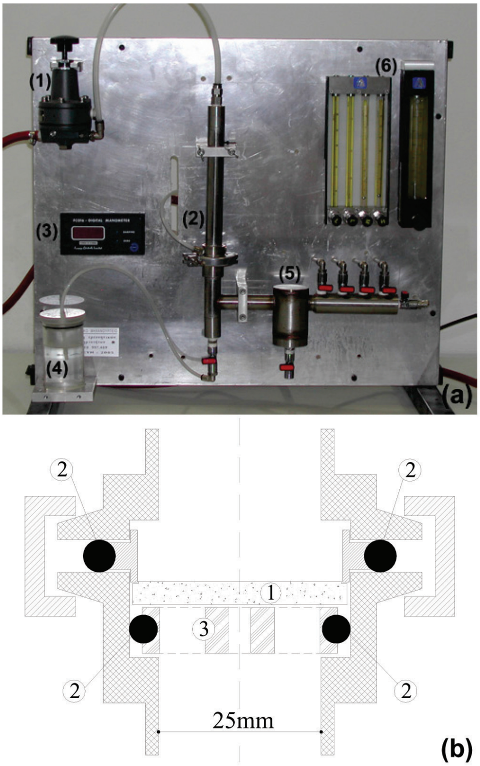

Figure 1. Laboratory equipment (a) and sample holder (b) for ASTM D6767.

3 RESULTS

The pore size distribution curves shown in Figure 2 are typical of the results obtained during this investigation. It was observed that, for all geotextiles tested, pore sizes determined according to the wet sieving method were smaller than those determined by the dry sieving and capillary flow methods and that the capillary flow method, as applied, yielded the larger values for pore sizes. Comparisons were made in terms of O_{95}, O_{90} and O_{50}. For simplicity, linear correlations of the form $y = A \cdot x$ were obtained per geotextile series as well as for the two groups (needle punched and heat bonded) and all of the geotextiles together. Results of such correlations for all geotextiles are shown in Figures 3 and 4. All results obtained are summarized in Tables 1 and 2.

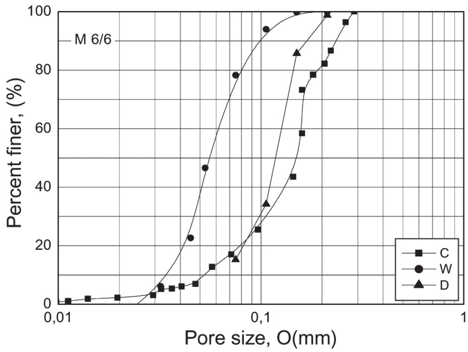

Figure 2. Typical pore sizes distribution curves.

Comparing pore sizes (O_{95}, O_{90}, O_{50}) measured by wet sieving with pore sizes measured by the capillary flow method and considering each of the nine geotextile series tested, it can be observed that the proportionality ratio $O_{95,w}/O_{95,c}$ ranges from 0.30 to 0.40 with an average of 0.34 which is the same as the ratio obtained when the complete group of all 52 geotextiles is considered as well as when considering needle-punched and heat bonded geotextiles separately. Similar observations can be made for the ratios $O_{90,w}/O_{90,c}$ and $O_{50,w}/O_{50,c}$ which have average values of 0.34 and 0.31, respectively.

Comparing the dry sieving and capillary flow methods and considering the nine geotextile series tested, the proportionality ratio $O_{95,d}/O_{95,c}$ ranges from 0.38 to 0.56 with an average of 0.46 which becomes 0.45 when the complete group of geotextiles is considered. The scatter of the proportionality ratio values is higher in this case.

Finally, it can easily be deduced that the dry sieving method yields pore sizes which are consistently larger than those obtained by the wet sieving method by an average of 30%, 35% and 100% when comparing O_{95}, O_{90} and O_{50} values, respectively.

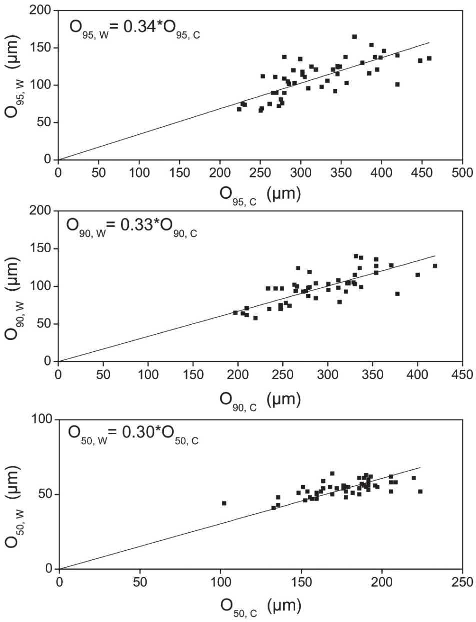

Figure 3. Comparison of results: ASTM D6767 vs. EN ISO 12956.

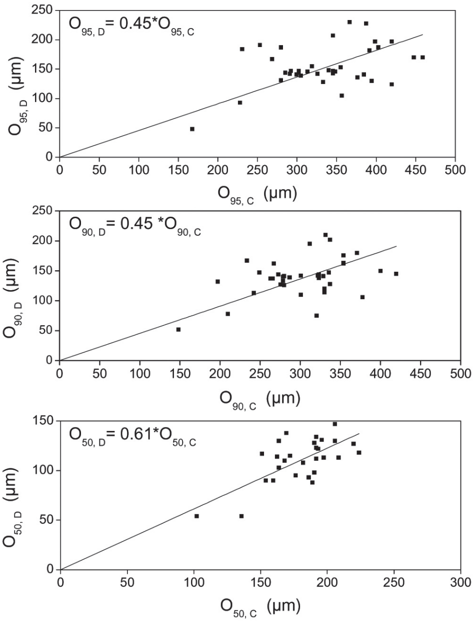

Figure 4. Comparison of results: ASTM D6767 vs. ASTM D4751.

Table 1. Comparison of results obtained by wet sieving and capillary flow methods.

GTX series	$\frac{O_{95,w}}{O_{95,c}}$	$\frac{O_{90,w}}{O_{90,c}}$	$\frac{O_{50,w}}{O_{50,c}}$
M1 (7)	0,31	0,31	0,30
M2 (7)	0,35	0,33	0,30
M3 (7)	0,32	0,32	0,30
M4 (5)	0,30	0,31	0,28
M5 (6)	0,36	0,35	0,31
M6 (6)	0,35	0,35	0,33
M7 (5)	0,40	0,39	0,28
M8 (5)	0,38	0,37	0,37
M9 (4)	0,32	0,32	0,32
Needle-punched	0,33	0,33	0,30
Heat bonded	0,34	0,35	0,34
All	0,34	0,33	0,30

( ): number of geotextile grades

Table 2. Comparison of results obtained by dry sieving and capillary flow methods.

GTX series	$\frac{O_{95,d}}{O_{95,c}}$	$\frac{O_{90,d}}{O_{90,c}}$	$\frac{O_{50,d}}{O_{50,c}}$
M1 (7)	0,39	0,39	–
M2 (7)	0,48	0,49	0,61
M3 (7)	0,38	0,38	0,56
M4 (5)	0,39	0,37	0,59
M5 (6)	0,45	0,46	0,55
M6 (6)	0,55	0,56	0,68
M7 (5)	0,45	0,52	0,62
M8 (5)	0,56	0,55	0,69
M9 (4)	0,46	0,45	0,53
Needle-punched	0,44	0,45	0,61
Heat bonded	0,45	0,52	0,64
All	0,45	0,45	0,61

( ): number of geotextile grades

4 DISCUSSION

The significant difference in pore sizes obtained according to the wet sieving and the capillary flow methods (ratio of 1:3) is in disagreement with observations in available literature that these methods may yield similar results. Even if the coefficient B, with a constant value of 0.715 when pressure is in kPa, was introduced in the processing of raw data, the discrepancy in values obtained from the two methods would have been reduced to a ratio of 1:2 approximately. It should be noted that (a) the reference provided in ASTM D6767 for the nature and value of the parameter B (Bechhold 1908) includes no such constant but recommends the use of a correction coefficient with values between 0.1 and 1.0 and (b) in part of the available literature on the capillary flow method (i.e. Vermeersch and Mlynarek 1996, Bhatia and Smith 1994, Tu et al. 2002) the parameter B is not included in the equation for pore size determination. It should also be noted that the results obtained are strongly influenced by the assumptions that the contact angle is zero and that the pores have a circular cross-section. Using $\theta \neq 0$ and other cross-section shapes, it can easily be concluded that pore sizes are computed with on error of perhaps up to +100%. Accordingly, it can be postulated that the value of parameter B introduced in the computation of pore sizes by ASTM D6767 is not constant and depends on equipment used, wetting liquid, geotextile raw materials and pore shape. If it is accepted that the wet sieving and capillary flow methods should yield similar results, then all pore size distribution curves obtained by the capillary flow method during the investigation reported herein should be shifted by applying a multiplier equal to 0.33 on pore sizes.

5 CONCLUSIONS

Based on the results of the experimental investigation presented herein, the following conclusions may be advanced:

1. Available standard methods (ASTM D4751, EN ISO 12956 and ASTM D6767) for measuring pore sizes of nonwoven geotextiles yield significantly different results by as much as 50% to 100%.
2. The use of a “capillary constant”, B, with a universal value for computing pore sizes according to the capillary flow method can not be justified. It appears that B has a “case specific” value which depends on equipment used, wetting liquid, geotextile raw materials and pore shape.
3. Application of a multiplier equal to 0.33 on pore sizes obtained by the capillary flow method and eliminating the “capillary constant”, B, yields results very similar to those obtained by wet sieving in this investigation.
4. Pore sizes obtained by dry sieving are larger than those obtained by wet sieving by at least 30% and this may be attributed to glass bead entrapment as well as electrostatic phenomena that are known to affect results obtained by dry sieving.

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