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Standard Practice for Determining the Number of Constrictions "*m*" of Non-Woven Geotextiles as a Complementary Filtration Property[1]

This standard is issued under the fixed designation D7178; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ε[1] NOTE—A legend was added editorially to Eq X1.4 in X1.1.2.2 in July 2016.

1. Scope

1.1 This practice describes the procedure used along with existing test method to determine the number of constrictions *m* of mechanically bonded non-woven geotextiles, based on thickness, mass per unit area and fiber properties

1.2 The number of constrictions is a property of non-woven geotextiles, which is complementary to opening size to predict their filtration behavior. It can be used to differentiate non-woven geotextiles with similar opening sizes but different structures (thickness, weight, fiber diameter, etc.). However, more research is needed to assess its significance when comparing two products with different opening sizes.

1.3 Consideration of the number of constriction is relevant in filtration applications where piping or clogging concerns are to be controlled with a high level of confidence, that is, for filters applications in critical soils.

1.4 This standard is for design purposes only and is not intended for quality control purposes.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1577 Test Methods for Linear Density of Textile Fibers
D4439 Terminology for Geosynthetics
D4751 Test Method for Determining Apparent Opening Size of a Geotextile
D5199 Test Method for Measuring the Nominal Thickness of Geosynthetics
D5261 Test Method for Measuring Mass per Unit Area of Geotextiles
D6767 Test Method for Pore Size Characteristics of Geotextiles by Capillary Flow Test

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, refer to Terminology D4439.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *constriction*—in the non-woven geotextile, a "window" delimited by three or more fibers, through which soil particles could migrate.

3.2.2 *filtration paths*—under the forces induced by fluid flows, soil particles may travel in the geotextile filter along filtration paths. Each of these paths is composed of a sequence of constrictions of various size and shape.

3.2.3 *number of constrictions, m*—average number of constrictions for a filtration path.

3.2.4 *fiber count, T*—a measure of the linear density of the fiber expressed in tex, where 1 tex = 10^{-6} kg/m.

3.2.4.1 *Discussion*—The fiber count is sometime expressed in "Denier" (equivalent to the weight in grams of a theoretical 9000 meters long fiber). The value in "Tex" can be obtained from the value in Denier considering that 1 Denier = 9 Tex.

3.2.5 *opening size*—largest significant opening of a non-woven geotextile as measured using Test Method D6767.

NOTE 1—Although Test Method D4751 (Apparent Opening Size) is widely used to characterize geotextiles, it may often not be sufficient for advanced filtration investigations such as those requiring consideration of the number of constriction as a significant parameter. The "bubble-point" measurement technique proposed in Test Method D6767 shall thus be preferred to AOS per Test Method D4751.

4. Summary of Practice

4.1 The physical properties of the geotextile are evaluated according to specific procedures and the number of constriction *m* is determined based on Eq 1.

[1] This practice is under the jurisdiction of ASTM Committee D35 on Geosynthetics and is the direct responsibility of Subcommittee D35.03 on Permeability and Filtration.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

5. Significance and Use

5.1 This practice provides a calculation method for determining the number of constrictions *m* of a non-woven geotextile (or of a layer of a composite material). This standard is not applicable to woven geotextiles, knitted geotextiles, heat-bonded geotextiles or any other type of geosynthetic.

5.2 The number of constriction represents the number of "windows" delimited by three or more fibers, in which soil particles could migrate. In that regard, it can be basically defined by the following equation: $m = \frac{t}{d_c}$ where t is the thickness and d_c the average distance between two constrictions. This value has been found to be relevant to explain the different filtration behaviors of non-woven geotextiles with similar opening sizes but different structures for various soil conditions (see Appendix X1 for details).

5.3 This value will be used in filtration research to evaluate the prediction of filtration efficiency and effectiveness of various non-woven geotextiles with similar opening sizes (Test Method D6767).

5.4 Interpretation of the significance of *m* as calculated using this standard shall be done with care as some non-woven structures may not reflect the hypothesis used to establish the proposed equation (see Appendix X1 for details).

6. Procedure

6.1 Condition specimens at 23 ± 2°C and 65 % relative humidity for not less than 24 h.

6.2 Determine the mass per unit area and thickness of the geotextile according to Test Methods D5261 and D5199.

NOTE 2—Although the thickness of non-woven geotextiles is influenced by the normal load, the number of constriction shall be calculated considering the geotextile thickness under 2 kPa for standardization purpose. Practically, the number of constriction is not influenced by the thickness as it represents the structure of the non-woven (number of "windows" delimited by three or more fibers, in which soil particles could migrate as defined in 5.2), which does not depend on the normal load.

6.3 Determine the fiber count of the fibers per Test Methods D1577 using the data available from MQA or suppliers certificate. Report values by classes of average fiber count associated to the type of polymer as well as the percentage of each class found in the geotextile sample (that is, respective percentages of polypropylene / xx tex, polypropylene / yy tex, polyester / zz tex, etc.).

6.3.1 Calculate the number of constrictions *m* of the geotextile using Eq 1 (dimensionless value). Result must be rounded to the closest unit.

$$m_i = \frac{1}{2} \times \sqrt{\pi \cdot \mu_i \cdot t_i} \times \sum_k p_k \cdot \sqrt{\frac{1}{T_k}} \quad (1)$$

where:

i = specimen number,
m_i = number of constriction for the geotextile specimen i,
μ_i = mass per unit area of the geotextile specimen i (g/m^2) as measured in 6.2,
t_i = thickness of the geotextile specimen i (mm) as measured in 6.2,
k = class of fibers with a given fiber count and type of polymer,
p_k = percentage (in decimal unit, that is, 10 % = 0.1) of fibers from a class of fibers k, and
T_k = fiber count (tex) associated to a class of fibers k as measured in 6.3.

NOTE 3—If the fiber count T_k is available in Denier, divide the available value by 9 to obtain the value in Tex.

7. Report

7.1 Report the following information:

7.1.1 State that the number of constriction was calculated as directed in Practice D7178;

7.1.2 Complete geotextile identification;

7.1.3 Statement of conditioning;

7.1.4 Thickness and mass per unit area of the geotextile: individual values and average;

7.1.5 Fiber count distribution / polymer as evaluated in 6.3. If it was assumed that only one type of polymer was used to manufacture the geotextile, state this on report;

7.1.6 Number of constriction as calculated in 6.3.1; and

7.1.7 Report any deviation from the described standard practice.

8. Precision and Bias

8.1 Precision and bias has not been established yet.

9. Keywords

9.1 clogging; constriction; filtration; geotextile; mechanically bonded; non-woven; number of constrictions; opening size; piping

APPENDIX

(Nonmandatory Information)

X1. PHYSICAL SIGNIFICANCE OF THE NUMBER OF CONSTRICTION

X1.1 Alternate Equations Describing the Number of Constriction

X1.1.1 The number of constriction represents the number of "windows" delimited by three or more fibers, in which soil particles could migrate. In that regard, it can be basically defined by the following equation:

$$m = \frac{t}{d_c} \quad \text{(X1.1)}$$

where:

t = the geotextile thickness, and
d_c = the average distance between two constrictions.

X1.1.2 Given that the average distance between two constrictions can be expressed by the following equation (**1**):[3]

$$d_c = \frac{d_f}{\sqrt{1-n}} \quad \text{(X1.2)}$$

X1.1.2.1 The porosity of the non-woven geotextile by:

$$n = 1 - \frac{\mu}{\rho \cdot t} \quad \text{(X1.3)}$$

where:

μ = the mass per unit area,
t = the thickness of the non-woven geotextile, and
ρ = the polymer specific gravity.

X1.1.2.2 Another expression of the number of constriction of non-woven geotextiles is as follows:

$$m = \sqrt{\frac{\mu \cdot t}{\rho \cdot {d_F}^2}} \quad \text{(X1.4)}$$

where:

d_F = fiber diameter.

X1.1.3 Fiber count expressed as $T = \left(\frac{\pi \cdot {d_F}^2}{4}\right) \cdot \rho$, it is also possible to define the number of constriction of non-woven geotextiles as follows:

$$m = \sqrt{\frac{\pi \cdot \mu \cdot t}{4T}} \quad \text{(X1.5)}$$

where:

π = 3.14,
μ = mass per unit area,
t = thickness, and
T = fiber count.

X1.2 Constrictions and Filtration Opening Size Distributions

X1.2.1 A conceptual definition of the constrictions and filtration opening size distributions of all the filtration paths of a geotextile is presented in Fig. X1.1 (**2**). Given that the filtration openings are defined as the smallest constrictions of the filtration paths, their distribution in size will be proportionally smaller than the constrictions one. By definition, the smallest opening size (O_0) could not be smaller than the smallest constriction (C_0).

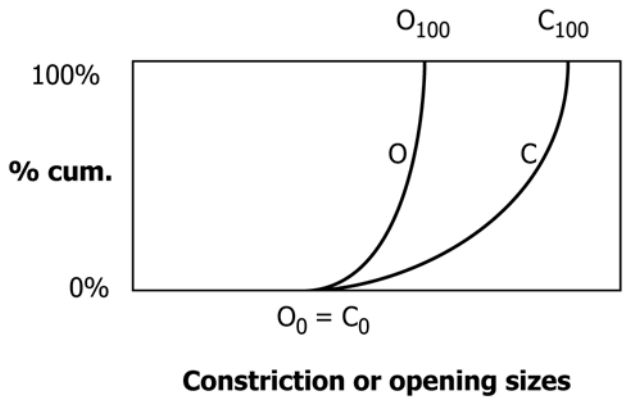
X1.3 Significance of the Number of Constrictions with Regard to Opening Size Distribution and Soil Filtration

X1.3.1 Non-woven geotextiles filters having similar Filtration Opening Size (which may be considered equal to O_{100}) but different constriction numbers may exhibit significantly different filtration behavior for specific situations.

X1.3.2 Fig. X1.2 (**2**) presents the constrictions and openings sizes distributions of two geotextiles having an identical opening size (O_{100}), but where the number of constrictions of filter A is smaller than the one of filter B. As a consequence, the maximum constriction size C_{100} of filter A is also smaller than the one of filter B.

X1.3.3 Using the constriction and opening size distribution curves, it is possible to estimate the probability that a given soil particle will be retained in or on the geotextile, or be piped:

X1.3.3.1 For a soil particle diameter d_2 larger than the filter opening size O_{100}, the probability to be trapped into the geotextile increases as the number of constrictions increases. So filter B is more likely to trap soil particles with a diameter d_2, while these particles will be retained on the surface of filter A. If the particle particles with a diameter d_2 is part of the soil skeleton, this skeleton will not be stable, the particles closer to the filter being likely to move downward into the geotextile structure. For two geotextiles presenting the same opening size but different numbers of constrictions used to filter a soil made of a skeleton and movable particles, the geotextile presenting a high number of constrictions could thus lead to an unstable



C: constrictions
O: openings

FIG. X1.1 Constriction and Filtration Size Distribution Curves (2)

[3] The boldface numbers in parentheses refer to the list of references at the end of this standard.

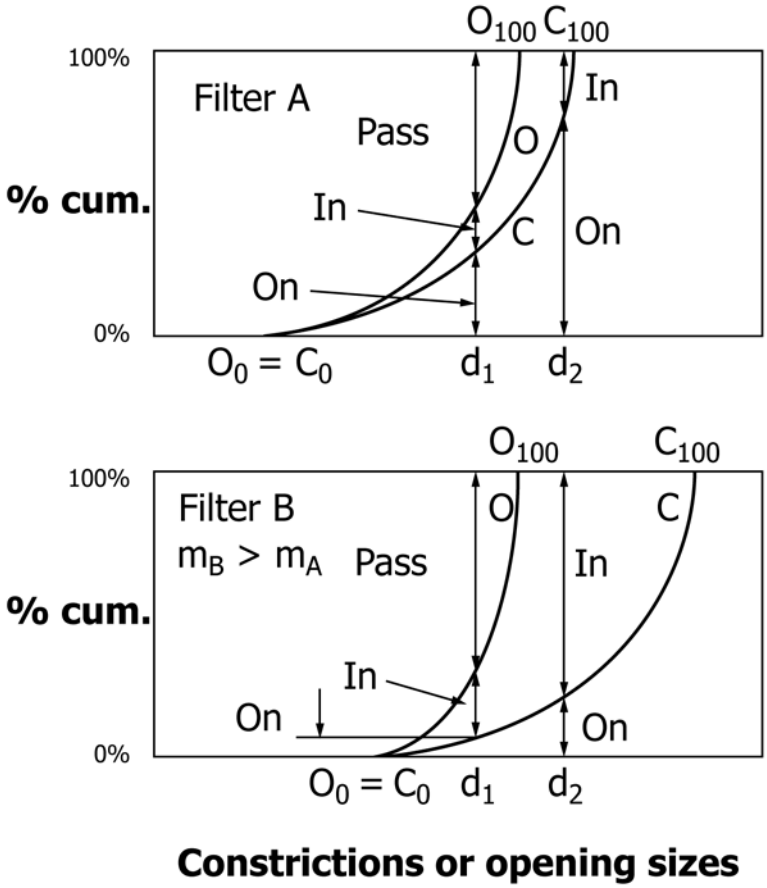


FIG. X1.2 Influence of the Number of Constrictions on the Filtration Behavior of Non-Woven Geotextiles (2)

behavior of the soil, the soil skeleton integrity being not properly supported in critical situations and/or soil / geotextile combinations.

X1.3.3.2 For a soil particle diameter d_1 lower than the geotextile opening size O_{100}, the probability to be washed out through the geotextile increases as the *m* value increases. On the other hand, this increased probability to be retained on a low *m* geotextile compared to a high *m* geotextile could eventually lead to the development of the blinding mechanism in critical situations and/or soil / geotextile combinations.

X1.3.4 At the time of preparation of this standard, there was no general agreement regarding the limits that shall be considered for filtration design.

REFERENCES

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