



Recent Advances in Geotextile Filtration Design: Pore Opening Size Measurement using a Porometer or an Optical Test
IGS Technical Committee on Hydraulics
April 26, 2022



Review of existing pore opening size measurement techniques, how reliable are ASTM D4751 and ISO 12956?

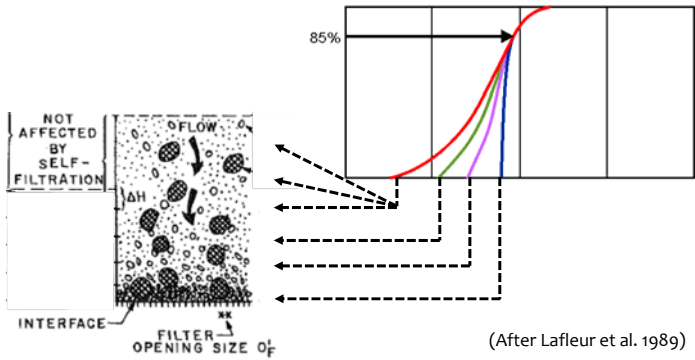
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Designing for Filtration

- * Retain soil particles
 - * Prevent piping
- * Permit circulation of water
 - * Prevent clogging



NOT AFFECTED BY SELF-FILTRATION

FLOW

ΔH


INTERFACE

FILTER OPENING SIZE O_F

(After Lafleur et al. 1989)

➔ The geotextile filter must facilitate the development of a 'self-filtering' structure in the soil

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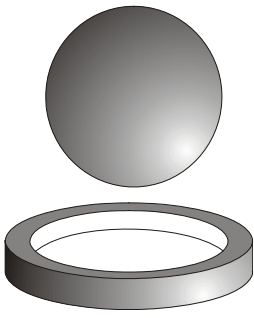
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Designing for Filtration

* Retention: $O_x(\text{geotextile}) < A \times d_x(\text{soil})$
 * Clogging: $O_y(\text{geotextile}) > B \times d_y(\text{soil})$

Determination of relevant opening sizes 'O_x' and 'O_y' of the geotextile??

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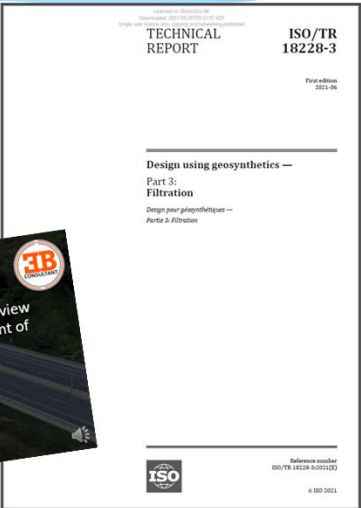
ISO Design Guide of geotextiles for filtration

Content of Technical Guide ISO 18228-3

- Chapter 4 Concepts and fundamental principles
- Chapter 5 Typical applications
- Chapter 6 Materials
- Chapter 7 Functional properties relevant to design
- Chapter 8 Principles of design
- Chapter 9 Testing the soil/geotextile filtration compatibility
- Chapter 10 Examples of material specifications and design guidance

Blond (2021): Designing Geotextiles for Filtration: A Review of the State of the Practice, Development of Design Standard ISO 18228-3; Proceedings of Geosynthetics'21, IFAI, 2021

<https://geosyntheticsconference.com/proceedings-archive/>

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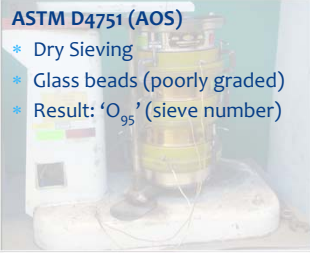
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Eric Blond - Review of existing pore opening size measurement techniques, how reliable are ASTM D4751 and ISO 12956?

Opening Size Measurement

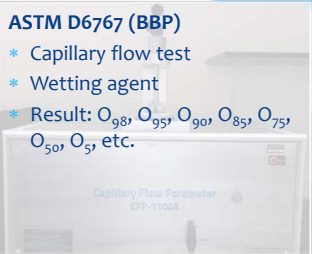
ASTM D4751 (AOS)

- * Dry Sieving
- * Glass beads (poorly graded)
- * Result: 'O₉₅' (sieve number)



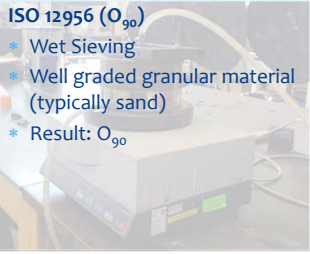
ASTM D6767 (BBP)

- * Capillary flow test
- * Wetting agent
- * Result: O₉₈, O₉₅, O₉₀, O₈₅, O₇₅, O₅₀, O₅, etc.



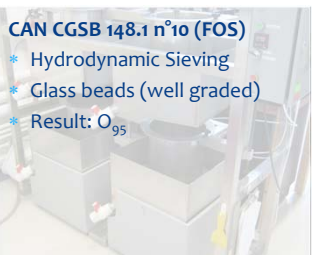
ISO 12956 (O₉₀)

- * Wet Sieving
- * Well graded granular material (typically sand)
- * Result: O₉₀



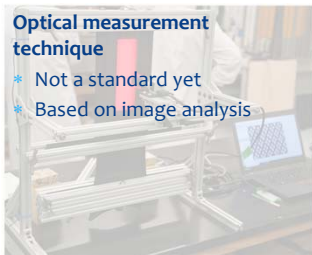
CAN CGSB 148.1 n°10 (FOS)

- * Hydrodynamic Sieving
- * Glass beads (well graded)
- * Result: O₉₅



Optical measurement technique

- * Not a standard yet
- * Based on image analysis





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ASTM D4751 – AOS

- * Standard soil shaker, designed for soil analysis
 - * Low shaking frequency
 - * Impact energy
- * Management of static electricity
 - * Anti-static spray
 - * Beads preparation
 - * Grounded sieves?
 - * Other creative solutions?
- * Specimen preparation
 - * Wash / Dry in distilled water
- * Granular material
 - * Uniform glass bead sizes



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ASTM D4751 – AOS

- * Some factors affecting the results:
 - * Impact energy: not well defined in the standard
 - * Glass beads preparation
 - * Relative Humidity (static electricity)





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ASTM D4751 – AOS

Some factors affecting the results:

<ul style="list-style-type: none"> * Precision of the glass beads? <ul style="list-style-type: none"> * Preparation by sieving is unrealistic (sieves clog) * Wash and check (re-used) glass beads for fractured beads * Inherent variability of the sieves? 	<p>Solution: purchasing glass beads separated using a sedimentation process. Cost: ~100\$ / lb</p>
<ul style="list-style-type: none"> * Re-use of previously tested specimens? <ul style="list-style-type: none"> * High risk of contamination 	<p>Solution: Reduce the number of time glass beads are recycled. >> Impact on testing cost??</p> <p>Solution: purchasing glass beads separated using a sedimentation process. Cost: ~100\$ / lb</p> <p>Solution: Do NOT re-use test specimens. >> Impact of the variability of the product??</p>

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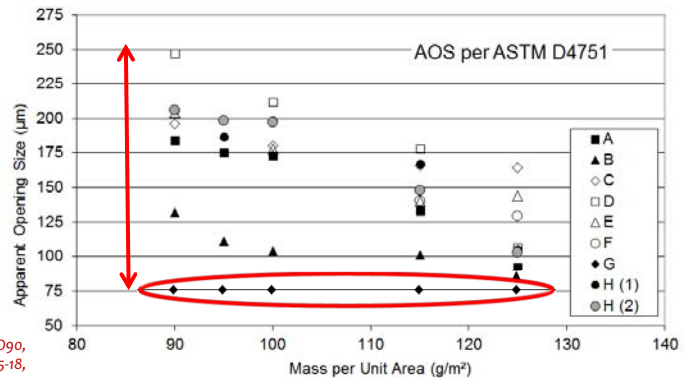
ASTM D4751 – AOS : Accuracy??

Study conducted on a series of heat bonded geotextile

- * 5 products with different mass per unit area
- * 8 different laboratories
- * 'blind' requests (not a round robin!)

Remark:

- * Heat bonded have less tendency to trap beads within their thickness



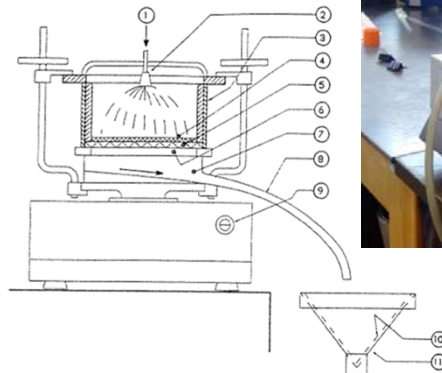
Blond E, Veermersch O, Diederich R (2015): A Comprehensive Analysis of the Measurement Techniques used to Determine Geotextile Opening Size: AOS, FOS, O₉₀, and 'Bubble Point'. Proceedings of the Geosynthetics 2015 Conference, February 15-18, Portland, Oregon

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ISO 12956 – O₉₀

- * Vibrating Table
 - * 50-60 Hz frequency, 1.5 mm amplitude
- * Water flow rate
 - * No water head on the specimen
- * Specimen preparation
 - * Wetting agent
- * Granular material
 - * Silty sand mixture
 - * Glass beads tolerated



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ISO 12956 – O₉₀ : Accuracy??

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Diederich R et al, "Variation in test results between laboratories from different parts of the world", Proceedings of EuroGeo 2012, Valencia, p.139-143, 2012



Item	Laboratory A (□)	Laboratory B (▲)	Laboratory C (×)	Laboratory D (●)	Laboratory E (○)	Laboratory F (+)	Laboratory G (◇)	Laboratory H (—)	Laboratory I (◆)
1	75	130	70	115	165	115	115	200	115
2	70	130	65	85	110	85	85	200	90
3	65	125	60	85	110	85	85	200	110
4	60	85	60	85	110	85	85	185	85
5	65	85	55	85	85	85	85	200	85

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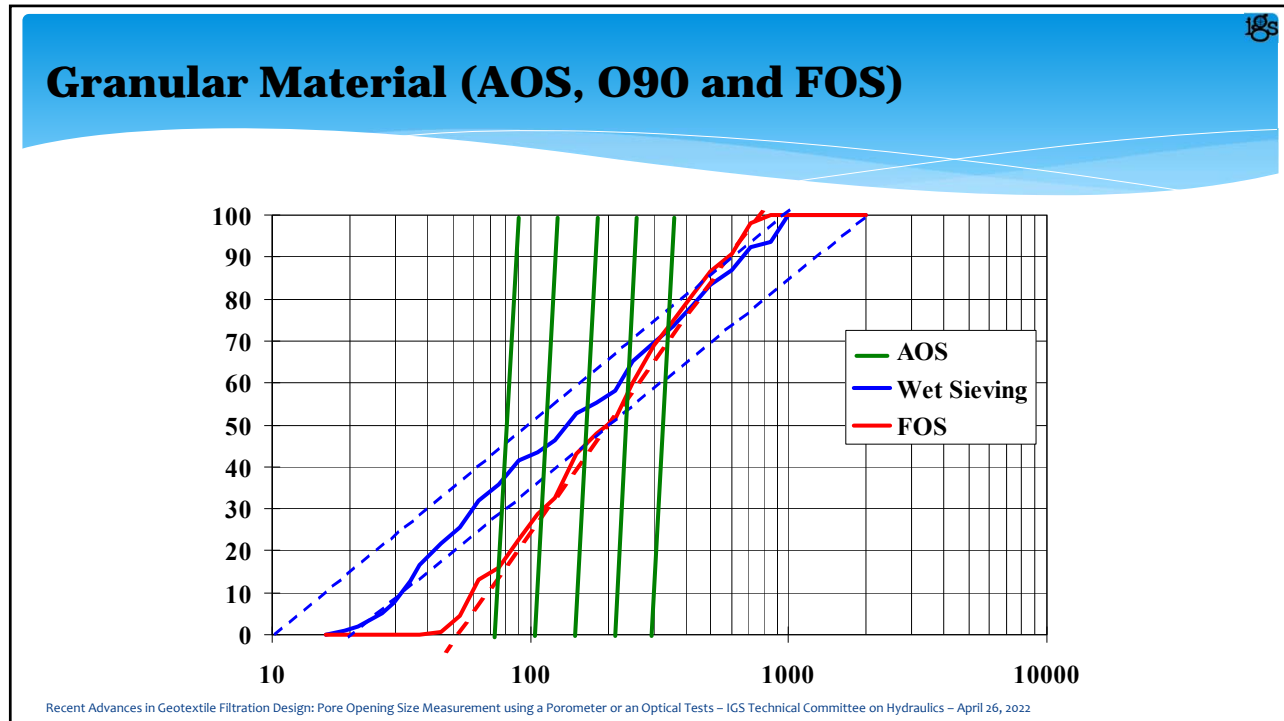
CGSB 148.1 n°10 – FOS

- * Specimen fixed in the bottom of a cylinder + container
- * 300 mm diameter specimens
- * Hydrodynamic sieving :
 - * 10 cm water head (upward / downward)
 - * Water drags particles through the geotextile

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ASTM D6767 – BBP / O₉₈

- * Well known, broadly used technique in other industries to measure small to very small pore sizes
 - * Stone, ceramics...
- * Ongoing work since the 90's to adapt the technique (and equipment) to geotextiles = to 'large' pore sizes
 - * See next presentation by Sam Allen

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ASTM D6767 – BBP / O₉₈

* Permits determination of the complete range of pore openings

- 1- Wet test
- 2- Dry test

$$\% \text{ smaller} = \left[1 - \frac{\text{wet flow rate}}{\text{dry flow rate}} \right] \times 100$$

$$\text{Diameter} = \frac{\text{Constant}}{\text{Pressure}}$$

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Correlation between BBP and AOS (or FOS)?

Observations made by SAGEOS / historical data:

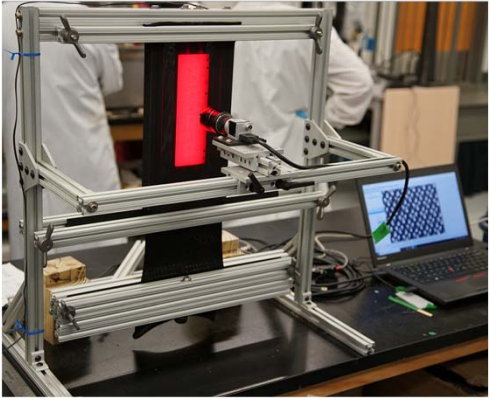
- * No mathematical correlation between AOS (ASTM D4751) and any of the other opening sizes
- * O₉₀ (ISO 12956) often 'close to' FOS (CGSB 148.1 n°10)
- * Relation between 'Bubble Point' (ASTM D6767) and FOS (CGSB 148.1 n°10) was demonstrated by Vermeersch et Al. for non-woven geotextiles (1996)

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Optical measurement

- * POA specified for woven geotextiles since the ~80's
 - * U.S. Army Corps of Engineers, 1986, Geotextiles Used as Filters, Civil Works Construction Guide Specification, CW-02215
- * Opportunity for measuring the opening size of thin geotextiles:
 - * Circular knits
 - * Light weight Heat-bonded
 - * Woven?
 - * ~~Non-woven~~ (no!)
- * Work in progress! (see next presentation)
 - * ASTM D35 project – WK80720 – Pore Characterization of Geotextiles by Image Analysis




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Summary

- * ASTM D4751 (AOS): despite its apparent simplicity, very challenging test in the laboratory, **very poor repeatability**
- * ISO 12956 (O_{90}): less challenging, with still a **relatively high dispersion of the results**
- * CGSB 148.1 n°10 (FOS): **not enough laboratories** performing the test to assess its repeatability. However, it **best reflects the mechanism of particles transport prevailing in the field**
- * ASTM D6767 (BBP): **very promising technique**. However, it involves the circulation of fluids instead of solid particles. Requires adequate **equipment and expertise** to generate quality data
- * WK80720 (Image Analysis): **very promising technique**. A draft standard is being submitted to ASTM D35 for review by the Society



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Further presentations	
Introduction	Eric Blond Sam Allen
Review of existing pore opening size measurement techniques, how reliable are ASTM D4751 and ISO 12956?	Eric Blond
Innovative technique #1: porometer	
1. Benefits of PSD and the porometer test for AOS determination	Sam Allen
2. Experimental correlation between porometer and AOS tests	Melissa Medlin (TenCate)
Innovative technique #2: optical measurement	
1. Assessment of the pore opening size of knitted geotextiles by image analysis	Eric Blond
2. Application of optical measurements for MQC of heat-bonded geotextiles	A-L Backes (Dupont)
Q&A	

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