Design of Drainage Geocomposites for Landfill Applications using the ASTM D7931

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What does ASTM stand for?

American Society of Testing Materials

ASTM International
How do you reference ASTM and what does the number at the end stand for?

Standard Guide for Specifying Drainage Geocomposites

Designation D7931-17

Guide D7931-17
Guide D7931-17

- Released in September 2017
- Provides guidelines for calculating several engineering properties related to Drainage Geocomposites:
  - Allowable flow rate;
  - Associated reduction factors; and
  - Shear strength properties.

Uniform Design Approach
What is a Drainage Geocomposite?

- Geonet or perforated mini-pipes sandwiched between two geotextiles (typically nonwoven)
  - Geonet can be bi-planar or tri-planar
- Design considerations:
  - Geotextile intrusion into geonet
  - Geonet crushing (creep)
  - Biological / chemical impacts
How are Drainage Geocomposites used?

- Erosion control
- Foundation wall drainage
- Pond leak detection
- Roadway and pavement drainage
- Subsurface drainage system applications
- Landfills
  - Leachate collection
  - Leak detection
  - Caps and closure
  - Methane gas collection
Guide D7931- 17

- Biaxial Geonet Geocomposite
- Triaxial Geonet Geocomposite
- Multilinear Drainage Geocomposite
- Structured Geomembrane System
- Sheet Drain Geocomposite
- Geocomposite Edge Drain
Biaxial Geonet Geocomposite

- Geonet consisting of an integrally connected parallel set of ribs overlying a similar set of ribs at typically opposite angles, typically heat laminated with nonwoven geotextiles on the top and bottom to form the geocomposite.
Triaxial Geonet Geocomposite

- Geonet consisting of an integrally connected parallel set of ribs, or forming an integrated web with a flow direction mainly oriented in the machine direction, typically head laminated with nonwoven geotextiles on the top and bottom to form the geocomposite.
Multilinear Drainage Geocomposite

A manufactured product composed of a series of parallel single drainage conduits regularly spaced across its width sandwiched between two or more geosynthetics.
Allowable Flow Rate for Drainage Geocomposites

\[ q_{\text{allow}} = q_{100} \frac{1}{RF_{CR} + RF_{CC} + RF_{BC} + RF_{GI}} \]

- \( q_{\text{allow}} \) = allowable flow rate for a drainage geocomposite
- \( q_{100} \) = initial flow rate determined under simulated conditions for 100-h duration
- \( RF_{CR} \) = reduction factor for creep to account for long-term behavior
- \( RF_{CC} \) = reduction factor for chemical clogging
- \( RF_{BC} \) = reduction factor for biological clogging
- \( RF_{GI} \) = reduction factor for geotextile intrusion past the initial 100-h seating time

Factor of Safety (FS) = \( \frac{q_{\text{allow}}}{q_{\text{reqd}}} \)

- \( q_{\text{reqd}} \) = required flow rate for a drainage geocomposite
5. Structure of the Guide

5.1 Basic Formulation – This guide is focused on determination of a “q_{allow}” value using the following formula:

\[
q_{\text{allow}} = q_{100} \left( \frac{1}{RF_{\text{CR}} \times RF_{\text{CC}} \times RF_{\text{BC}}} \right)
\]  

where

- \( q_{\text{allow}} \) = allowable flow rate
- \( q_{100} \) = initial flow rate determined under simulated conditions for 100-hour duration
- \( RF_{\text{CR}} \) = reduction factor for creep to account for long-term behavior
- \( RF_{\text{CC}} \) = reduction factor for chemical clogging
- \( RF_{\text{BC}} \) = reduction factor for biological clogging

Note 1: By simulating site-specific conditions (except for load duration beyond 100 hours and chemical/biological clogging), additional reduction factors such as intrusion need not be explicitly accounted for.

Note 2: The value of \( q_{\text{allow}} \) is typically used to determine the product-specific and site-specific flow rate factor of safety as follows:

\[
FS = \frac{q_{\text{allow}}}{q_{\text{load}}}
\]

The value of “\( q_{\text{load}} \)” is a design issue and is not addressed in this guide. Likewise, the numeric value of the factor-of-safety is not addressed in this guide. Suffice it to say that, depending on the duration and criticality of the situation, FS-values should be conservative unless experience allows otherwise.
Allowable Flow Rate for Drainage Geocomposites

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\[ \text{Factor of Safety (FS)} = \frac{q_{\text{allow}}}{q_{\text{reqd}}} \]

- \( q_{\text{reqd}} \) = required flow rate for a drainage geocomposite
What is/are the standard(s) for transmissivity testing of drainage geocomposites?

ASTM D4716/D4716M – Standard Test Method for Determining the (In-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head

**$q_{100}$ or the Required Transmissivity**

- Manufacturer specified flow rate or transmissivity, or other required transmissivity.
- Test Method D4716/D4716M transmissivity test, or other appropriate transmissivity test method, such as Specification D7001.
  - Test duration = 100 hours (default is 15 minutes).
  - Simulate site-specific loading and boundary conditions.
q_{100} or the Required Transmissivity

- Research has shown that this Test Method typically underestimates the actual flow rate at certain hydraulic gradients.
  - Transmissivity is only valid for laminar flow conditions and while according to Darcy’s law, it should be constant-it is not when testing drainage geocomposites.
  - Transmissivity decreases as hydraulic gradient increases because of the development of turbulent flow conditions within the water gradients used in transmissivity tests.
- Water flow rate of drainage geocomposites can be better expressed as a discharge (i.e., flow rate) at a given hydraulic loss rather than as a transmissivity.
Allowable Flow Rate for Drainage Geocomposites

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Reduction Factor of Creep, $RF_{CR}$

- The drainage core of the geocomposite might creep, which leads to a reduction of its in-plane flow capacity.
Reduction Factor of Creep, $RF_{CR}$

- However, products like multilinear drainage geocomposites, may not be sensitive to creep when confined into a soil matrix because of their core structures.
Reduction Factor of Creep, $RF_{CR}$

- Can be obtained by running a long-term transmissivity test (1,000 hour minimum) under site-specific conditions
  - Test Method D7406 - core is placed under compressive stress and the decrease in thickness (deformation) is monitored over time.

- However, the reduction in thickness of the core does not have a linear relationship to a reduction of transmissivity of the geocomposite
allowable flow rate for drainage geocomposites

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Reduction Factor for Chemical and Biological Clogging, $RF_{CC}$ and $RF_{BC}$

- Chemical clogging within the drainage core space can occur with precipitates deposited from high alkalinity soils, typically calcium and magnesium.

- Biological clogging can occur by the growth of biological organisms, or by roots growing through the overlying soil and extending downward through the geotextile filter and into the drainage core.

- Contact product manufacturer for reduction factors as they are geotextile and core dependent.

- Likely to vary tremendously from one application to the other (i.e., landfill versus drainage of an embankment).
Allowable Flow Rate for Drainage Geocomposites

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Reduction Factor of Geotextile Intrusion into Core, $R_{FGI}$

- Intrusion of the covering geotextile or geomembranes, or both, into the large open spaces in some drainage cores (goenets, structured geomembranes, or sheet drains).
- Major variables are the spacing of geonet ribs, nubs, or columns, stiffness of the covering geotextiles or geomembranes, and magnitude, orientation, and duration of the stresses applied during service.
Reduction Factors- should you use published values or can they be evaluated in a laboratory setting?

Both will work.

Perform tests under design loading conditions with the proposed materials and extended testing time frame (100 hours).

Consider specialty materials - those specifically made to combat reduction effects [e.g., biological clogging and creep]].
What are the steps to select a drainage geocomposite for the leachate collection system?

1. Calculate the estimated amount of leachate to be generated for each operational scenario.
2. Calculate the design transmissivity for the leachate generated and the cell configuration.
3. Calculate the required transmissivity based on reduction factors and an overall factor of safety.
a. Geosynthetic drainage layers must comply with the following:

1. Any geosynthetic drainage layers designed for use in a groundwater suppression system or a leachate collection and removal system must meet the structural and hydraulic transmissivity design requirements using actual boundary conditions at the maximum adjusted design load for a minimum period of 100 hours, modified to take into consideration the long-term conditions for creep representative of site conditions, and other reduction factors.
   i. For hydraulic flow capacity calculations, the design engineer must use a factor of safety of at least three, and consider the reduction in transmissivity due to creep, biological clogging, and chemical clogging.
   ii. The chemical and physical resistance of the geosynthetic drainage material must be adequate so that its hydraulic transmissivity is not adversely affected by waste placement or leachate.

2. Any geosynthetic drainage layers designed for use in a final cover system for either drainage or gas venting must meet the transmissivity design requirements using actual boundary conditions at the maximum adjusted design load for a minimum period of 100 hours, and appropriate reduction factors and must consider any proposed landfill end use structures.
   i. For hydraulic flow capacity calculations, the design engineer must use a factor safety of at least three.
   ii. The hydraulic design of the geosynthetic drainage layer should be performed using the saturated hydraulic conductivity of the barrier protection layer.
a. **Double composite liner system.**

3. The liner system must include a primary leachate collection and removal system that is designed to maintain no more than 12 inches of leachate depth (head) above the primary liner, except during 24-hour, 25-year storm events and except in sump areas. The leachate collection and removal system must be designed to function with proper maintenance throughout the active life, post-closure period, and custodial care period of the landfill.
   
i. The primary leachate collection and removal system must be a minimum of two feet thick.
   
ii. On slopes less than or equal to 10 percent, the 24 inches of primary leachate collection and removal system must have a hydraulic conductivity of 1.0 centimeter per second or greater. Alternatively, the upper 12 inches of primary leachate collection and removal system may have a hydraulic conductivity of 0.1 centimeter per second or greater if the lower 12 inches has a hydraulic conductivity of 1 centimeter per second or greater.
   
iii. On slopes greater than 10 percent, the entire 24 inch thickness of the primary leachate collection and removal system must have a hydraulic conductivity of 0.1 centimeter per second or greater.

4. The liner system must include a secondary leachate collection and removal system placed between the primary and secondary liners with a design capacity of at least 1,000 gallons per acre per day and a maximum detection time of 24 hours using steady state flow calculations in a saturated medium.
   
i. On slopes less than or equal to 10 percent, the secondary leachate collection and removal system must include a geosynthetic drainage layer and a minimum of 1 foot of soil drainage media with a hydraulic conductivity of 0.1 centimeter per second or greater, and a maximum leachate depth (head) of 1 inch.
   
ii. On all slopes greater than 10 percent, the secondary leachate collection system may be constructed of a geosynthetic drainage layer system designed to meet the hydraulic and mechanical needs of the landfill with a head that does not exceed the thickness of the confined drainage layer.
Example Calculation- Leachate Collection

\[ q_{\text{allow}} = q_{\text{reqd}} \times \text{Factor of Safety (FS)} \]

\[ q_{\text{reqd}} = \text{required flow rate for a drainage geocomposite} \]
\[ = \text{required flow rate for a drainage geocomposite based on the liquid supply rate (i.e., leachate impingement rate)} \]

\[ q_{\text{reqd}} = \frac{q_i \times L}{\sin \beta} \]

where:
\[ q_i = \text{leachate impingement rate (ft/day)} \]
\[ L = \text{maximum sideslope length (ft)} \]
\[ \beta = \text{maximum slope inclination (degrees)} \]

\[ \text{FS} = 3.0 \text{ (from NYDEC regs)} \]
Leachate Impingement Rate

- Quantity of liquid drained by the LCS

![Diagram showing water access over time with different stages: construction, operation, with a cover. The diagram indicates water access over waste thickness and time, with labels for evaporation, runoff, etc., and infiltration.]
Leachate Impingement Rate

- USEPA’s Hydraulic Evaluation of Landfill Performance (HELP) model
  - Calculates leachate generation rate, as average annual leachate generation rate \( \frac{\text{ft}^3}{\text{acre-day}} \)
  - Converted to impingement rate \( \frac{\text{ft}}{\text{day}} \)
Example Calculation - Leachate Collection

\[ q_{\text{allow}} = q_{\text{reqd}} \times \text{Factor of Safety (FS)} \]

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FS = 3.0 (from NYDEC regs)
Allowable Flow Rate for Drainage Geocomposites

\[ q_{\text{allow}} \leq \frac{q_{100}}{1 \times (RF_{CR} + RF_{CC} + RF_{BC} + RF_{GI})} \]

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## Reduction Factors

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<td>Geonet</td>
<td>1.0 to 1.5</td>
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* In cases when using DRAINTUBE® ACB, which contains a non-leachable, silver based biocide treatment

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Take Aways

- Guide D931-17 provides a standard for specifying drainage geocomposites for any application to aid designers, purchasers, installers, contactors, owners, operators, and agencies in establishing minimum guidelines for drainage geocomposite materials.

- The guide is applicable to all types of drainage geocomposites regardless of their core configuration or geotextile type.
Thank you!

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