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GRI Standard GC8*

Standard Guide for

Determination of the Allowable Flow Rate of a Drainage Geocomposite

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1. Scope

1.1 This guide presents a methodology for determining the allowable flow rate of a candidate drainage geocomposite. The resulting value can be used directly in a hydraulics-related design to arrive at a site-specific factor of safety.

1.2 The procedure is to first determine the candidate drainage composite's flow rate for 100-hours under site-specific conditions, and then modify this value by means of creep reduction and clogging reduction factors.

1.3 For aggressive liquids, a "go-no go" chemical resistance procedure is suggested. This is a product-specific verification test for both drainage core and geotextile covering.

1.4 The type of drainage geocomposites under consideration necessarily consists of a drainage core whose purpose it is to convey liquid within its manufactured plane. The drainage core can be a geonet, 3-D mesh, built-up columns, single or double cuspations, etc.

1.5 The drainage core usually consists of a geotextile on its upper and/or lower surface. In some cases, the drainage core is used by itself. The guide addresses all of these variations.

1.6 The guide is also applicable to thick nonwoven geotextiles when they are utilized for their drainage capability.

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1.7 All types of polymers are under consideration in this guide.

1.8 The guide does not address the required (or design) flow rate to which a comparison is made for the final factor of safety value. This is clearly a site-specific issue.

2. Referenced Documents

2.1 ASTM Standards

D1987 – "Test Method for Biological Clogging of Geotextile or Soil/Geotextile Filters"

D2240 – "The Method for Rubber Property – Durometer Hardness"

D4716 – "Test Method for Constant Head Hydraulic Transmissivity (In Plane Flow) of Geotextiles and Geotextile Related Products"

D5322 – "Standard Practice for Immersion Procedures for Evaluating the Chemical Resistance of Geosynthetics to Liquids"

D6364 – "Test Method for Determining the Short-Term Compression Behavior of Geosynthetics"

D6388 – "Standard Practice for Tests to Evaluate the Chemical Resistance of Geonets to Liquids"

D6389 – "Standard Practice for Tests to Evaluate the Chemical Resistance of Geotextiles to Liquids"

2.2 GRI Standards

GS4 – Test Method for Time Dependent (Creep) Deformation Under Normal Pressure

2.3 Literature

Giroud, J.-P., Zhao, A. and Richardson, G. N. (2000), "Effect of Thickness Reduction on Geosynthetic Hydraulic Transmissivity," Geosynthetics International, Vol. 7, Nos. 4-6, pp. 433-452.

Koerner, R. M. (2012), Designing with Geosynthetics, 6th Edition, Xlibris Publishing Co., 914 pgs.

3. Summary of Guide

3.1 This guide presents the necessary procedure to be used in obtaining an allowable flow rate of a candidate drainage geocomposite. The resulting value is then compared to a required (or design) flow rate for a product-specific and site-specific factor of safety. The guide does not address the required (or design) flow rate value, nor the subsequent factor of safety value.

3.2 The procedures recommended in this guide use either ASTM or GRI test methods.

3.3 The guide is applicable to all types of drainage geocomposites regardless of their core configuration or geotextile type. It can also be used to evaluate thick nonwoven geotextiles.

4. Significance and Use

4.1 The guide is meant to establish uniform test methods and procedures in order for a designer to determine the allowable flow rate of a candidate drainage geocomposite for site-specific conditions.

4.2 The guide requires communication between the designer, testing organization and manufacturer in setting site-specific control variables such as product orientation, stress level, stress duration, type of permeating liquid and materials below/above the geocomposite test specimen.

4.3 The guide is useful to testing laboratories in that a prescribed guide is at hand to provide appropriate data for both designer and manufacturer clients.

5. Structure of the Guide

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

$$q_{allow} = q_{100}\left[\frac{1}{RF_{CR} \times RF_{CC} \times RF_{BC}}\right] \tag{1}$$

where

q_{allow} = allowable flow rate
q_{100} = initial flow rate determined under simulated conditions for 100-hour 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

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_{allow} is typically used to determine the product-specific and site-specific flow rate factor of safety as follows:

$$FS = \frac{q_{allow}}{q_{reqd}} \tag{2}$$

The value of "q_{reqd}" 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.

5.2 Upon selecting the candidate drainage geocomposite product, one must obtain the 100-hour duration flow rate according to the ASTM D4716 transmissivity test. This establishes the base value to which drainage core creep beyond 100-hours and clogging from chemicals and biological matter must be accounted for.

> Note 3: It is recognized that the default duration listed in ASTM D4716 is 15-minutes. This guide purposely requires that the test conditions be maintained for 100-hours.

5.3 Reduction Factor for Creep – This is a long-term (typically 10,000 hours) compressive load test focused on the stability and/or deformation of the drainage core without the covering geotextiles. Stress orientation can be perpendicular or at an angle to the test specimen depending upon site-specific conditions.

5.4 Chemical and/or Biological Clogging – The issue of long term reduction factors to account for clogging within the core space is a site-specific issue. The issue is essentially impractical to simulate in the laboratory, hence a table is provided for consideration by the designer.

5.5 Chemical Resistance/Durability – This procedure results in a "go-no go" decision as to potential chemical reactions between the permeating liquid and the polymers comprising the drainage core and geotextiles. The issue will be addressed in this guide but is not a reduction factor, per se.

6. Determination of the Base Line Flow Rate (q_{100})

6.1 Using the ASTM D4716 transmissivity test with the conditions stated below (unless otherwise agreed upon by the parties involved), determine the 100-hour flow rate of the drainage geocomposite under consideration.

6.1.1 <u>The test specimen shall be the entire geocomposite</u>. If geotextiles are bonded to the drainage core, they shall not be removed and the entire geocomposite shall be tested as a unit. A minimum of three replicate samples in the site-specific orientation shall be tested and the results averaged for the reported value.

6.1.2 Specimen size shall be 300 × 300 mm (12 × 12 in.) within the stressed area.

6.1.3 The specimen orientation is to be agreed upon by the designer, testing laboratory and manufacturer. In this regard, it should be recognized that the specimen orientation during testing has to match the proposed installation orientation. Thus the site-specific design governs both the testing orientation and subsequent field installation orientation.

6.1.4 Specimen substratum shall be one of the following four options. The decision of which is made by the project designer, testing organization and manufacturer. The options are (i) rigid platen, (ii) foam, (iii) sand or (iv) site-specific soil or other material.

6.1.4.1 If a rigid platen is used the choices are usually wood, plastic or metal. The testing laboratory must identify the specifics of the material used.

6.1.4.2 If closed cell foam is used, it shall be 12 mm (0.5 in.) thick and a maximum durometer of 2.0 as measured in ASTM D2240, Type D.

6.1.4.3 If sand is used it shall be Ottawa test sand at a relative density of 85%, water content of 10% and compacted thickness of 25 mm (1.0 in.).

6.1.4.4 If site-specific soil or other material is used it must be carefully considered and agreed upon between the parties involved. Size, gradation, moisture content, density, etc., are all important considerations.

6.1.5 Specimen superstratum shall also be one of the four same options as mentioned in § 6.1.3 above. It need not be the same as the substratum.

6.1.6 The applied stress level is at the discretion of the designer, testing organization and manufacturer. Unless stated otherwise, the orientation shall be normal to the test specimen.

6.1.7 The duration of the loading shall be for 100 hours. A single site-specific data point is obtained at that time, i.e., it is not necessary to perform intermediate flow rate testing, unless otherwise specified by the various parties involved.

6.1.8 The hydraulic gradient at which the above data point is taken (or a range of hydraulic gradients) is at the discretion of the designer, testing organization and manufacturer.

6.1.9 The permeating liquid is to be tap water, unless agreed upon otherwise by the designer, testing organization, and manufacturer.

6.1.10 Calculations

$$Q = kiA \tag{3}$$

$$Q = ki(Wt)$$

$$Q/W = \theta i \tag{4}$$

$$q = \theta i \tag{5}$$

where

Q = flow rate per unit time (m^3/sec)
k = permeability (m/sec)
i = hydraulic gradient (= H/L)
H = head loss across specimen (m)
L = length of specimen (m)
A = cross sectional area of specimen (m^2)
W = width of specimen (m)
t = thickness of specimen (m)
θ = transmissivity (m^3/sec-m or m^2/sec)
q = flow rate per unit width (m^2/sec)

The results can be presented as flow rate per unit width (Q/W), or as transmissivity (θ), as agreed upon by the parties involved.

7. Reduction Factor for Creep

7.1 Using the GRI GS4 test method or ASTM D6364 (mod.) for time dependent (creep) deformation, the candidate drainage core is placed under compressive stress and its decrease in thickness (deformation) is monitored over time.

> Note 4: This is not a flow rate test, although the test specimen can be immersed in a liquid to be agreed upon by the designer, testing organization, and manufacturer. However, it is usually a test conducted without liquid.

7.1.1 The test specimen shall be the drainage core only. If geotextiles are bonded to the drainage core they should be carefully removed. Alternatively, a sample of the drainage core can be obtained from the manufacturer before the geotextiles are attached. A minimum of three replicate tests shall be performed and the results averaged for the reported value.

7.1.2 Specimen size should be 150 × 150 mm (6.0 × 6.0 in.) and placed in a rigid box made from a steel base and sides. The steel load plate above the test specimen shall be used to transmit a constant stress over time. Deformation of the upper plate is measured by at least two dial gauges and the results averaged accordingly.

> Note 5: For high stress conditions requiring a large size and number of weights with respect to laboratory testing and safety, the specimen size can be reduced to 100 × 100 mm (4.0 × 4.0 in.).

7.1.3 Specimen substratum and superstratum shall be rigid platens. Alternatively, a 1.5 mm (60 mil) thick HDPE geomembrane can be placed against the drainage core with the steel plates as back-ups.

7.1.4 The test specimen shall be dry unless water or a simulated or site-specific leachate is agreed upon by the parties involved.

7.1.5 The normal stress magnitude(s) shall be the same as applied in the transmissivity test described in Section 6.0. Alternatively, it can be as agreed upon by the designer, testing organization, and manufacturer.

7.1.6 The load inclination shall be normal to the test specimen. If there exists a tendency for the core structure to deform laterally, separate tests at the agreed upon load inclinations shall also be performed at the discretion of the parties involved.

7.1.7 The dwell time shall be 10,000 hours. If, however, this is a confirmation test (or if a substantial data base exists on similar products of the same type), the dwell time can be reduced to 1000 hours. This decision must be made with agreement between the designer, testing organization, and manufacturer.

> Note 6: Alternative procedures to arrive at an acceptable value for the creep reduction factor based on shorter test times (e.g., the use of time-temperature superposition or stepped isothermal method) may be acceptable if agreed upon by the various parties involved.

7.1.8 The above process results in a set of creep curves similar to Figure 1(a). The curves are to be interpreted as shown in Figure 1(b). The reduction factor for creep of the core is interpreted according to the following formulas, after Giroud, Zhao and Richardson (2000).

$$RF_{CR} = \left[\frac{(t_{CO} / t_{original}) - (1 - n_{original})}{(t_{CR} / t_{original}) - (1 - n_{original})} \right]^3 \qquad (6)$$

where

RF_{CR} = reduction factor for creep
$t_{original}$ = original thickness (m)
t_{CO} = thickness at 100-hours (m)
t_{CR} = thickness at >>100-hours, e.g., at 10,000 hours (m)
$n_{original}$ = original porosity (see Equation 7)

$$n_{original} = 1 - \frac{\mu}{\rho t_{original}} \qquad (7)$$

where

μ = mass per unit area (kg/m^2)
ρ = density of the formulation (kg/m^3)

7.1.9 The above illustrated numeric procedure is not applicable to drainage geocomposites which include geotextiles. It is for the drainage core only.

Example: A HDPE geonet has the following properties: mass per unit area μ = 1216 g/m^2 (or 1.216 kg/m^2); density ρ = 950 kg/m^2 and original thickness of 8.55 mm.

Test specimens were evaluated according to ASTM D4716 for 100 hours and the average thickness decreased to 7.14 mm. A 10,000 hour creep test was then performed on a representative specimen according to GRI-GS4 and the resulting thickness further decreased to 6.30 mm. Thus Δy in Figure 1(b) is 7.14 – 6.30 = 0.84 mm. Determine the creep reduction factor "RF_{CR}".

Solution: The porosity n, is calculated according to Eq. (7) as follows

$$n_{original} = 1 - \frac{\mu}{\rho t_{original}}$$

$$= 1 - \frac{1.216}{(950)(0.00855)}$$

$$= 1 - 0.150$$

$$n_{original} = 0.850$$

The reduction factor for creep is calculated according to Eq. (6) as follows:

$$RF_{CR} = \left[\frac{(t_{CO} / t_{original}) - (1 - n_{original})}{(t_{CR} / t_{original}) - (1 - n_{original})}\right]^3$$

$$= \left[\frac{(7.14 / 8.55) - (1 - 0.850)}{(6.30 / 8.55) - (1 - 0.850)}\right]^3$$

$$= \left[\frac{0.835 - 0.150}{0.737 - 0.150}\right]^3$$

$$= \left[\frac{0.685}{0.587}\right]^3$$

$$RF_{CR} = 1.59$$

Note 7: Other calculation methods to arrive at the above numeric value of creep reduction factor may be considered if agreed upon by the various parties involved.

8. Reduction Factors for Core Clogging

There are two general types of core clogging that might occur over a long time period. They are chemical clogging and biological clogging. Both are site-specific and both are essentially impractical to simulate in the laboratory.

8.1 Chemical clogging within the drainage core space can occur with precipitates deposited from high alkalinity soils, typically calcium and magnesium. Other precipitates can also be envisioned such as fines from turbid liquids although this is less likely since the turbid liquid must typically pass through a geotextile filter. It is obviously a site-specific situation.

8.2 Biological clogging within the drainage core space 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. It is a site-specific situation and depends on the local, or anticipated, vegetation, cover soil, hydrology, etc.

8.3 Default tables for the above two potential clogging mechanisms (chemical and biological) are very subjective and by necessity broad in their upper and lower limits. The following table is offered as a guide.

Range of Clogging Reduction Factors (modified from Koerner, 1998)

Application	Chemical Clogging (RF_{CC})	Biological Clogging (RF_{BC})
Sport fields	1.0 to 1.2	1.1 to 1.3
Capillary breaks	1.0 to 1.2	1.1 to 1.3
Roof and plaza decks	1.0 to 1.2	1.1 to 1.3
Retaining walls, seeping rock and soil slopes	1.1 to 1.5	1.0 to 1.2
Drainage blankets	1.0 to 1.2	1.0 to 1.2
Landfill caps	1.0 to 1.2	1.2 to 3.5
Landfill leak detection	1.1 to 1.5	1.1 to 1.3
Landfill leachate collection	1.5 to 2.0	1.1 to 1.3

9. Polymer Degradation

9.1 Degradation of the materials from which the drainage geocomposite are made, with respect to the site-specific liquid being transmitted, is a polymer issue. Most geocomposite drainage cores are made from polyethylene, polypropylene, polyamide or polystyrene. Most geotextile filter/separators covering the drainage cores are made from polypropylene, polyester or polyethylene.

> Note 8: It is completely inappropriate to strip the factory bonded geotextile off of the drainage core and then test one or the other component. The properties of both the geotextile and drainage core will be altered in the lamination process from their original values.

9.2 If polymer degradation testing is recommended, the drainage core and the geotextile should be tested separately in their as-received condition before lamination and bonding.

9.3 The incubation of the drainage cores and/or geotextile coupons is to be done according to the ASTM D5322 immersion procedure.

9.4 The testing of the incubated drainage cores is to be done according to ASTM D6388 which stipulates various test methods for evaluation of incubated geonets.

> Note 9: For drainage cores other than geonets, e.g., columnar, cuspated, meshes, etc., it may be necessary to conduct additional tests than appear in ASTM D6388. These tests, and their procedures, should be discussed and agreed upon by the project designer, testing organization, and manufacturer.

9.5 The testing of the incubated geotextiles is to be done according to ASTM D6389 which stipulates various test methods for evaluation of incubated geotextiles.

Note 10: The information obtained in testing the drainage core (Section 9.4) and the geotextile (Section 9.5) result in a "go-no go" situation and not in a reduction factor, per se. If an adverse chemical reaction is indicated, one must select a different type of geocomposite material (drainage core and/or geotextile).

10. Summary

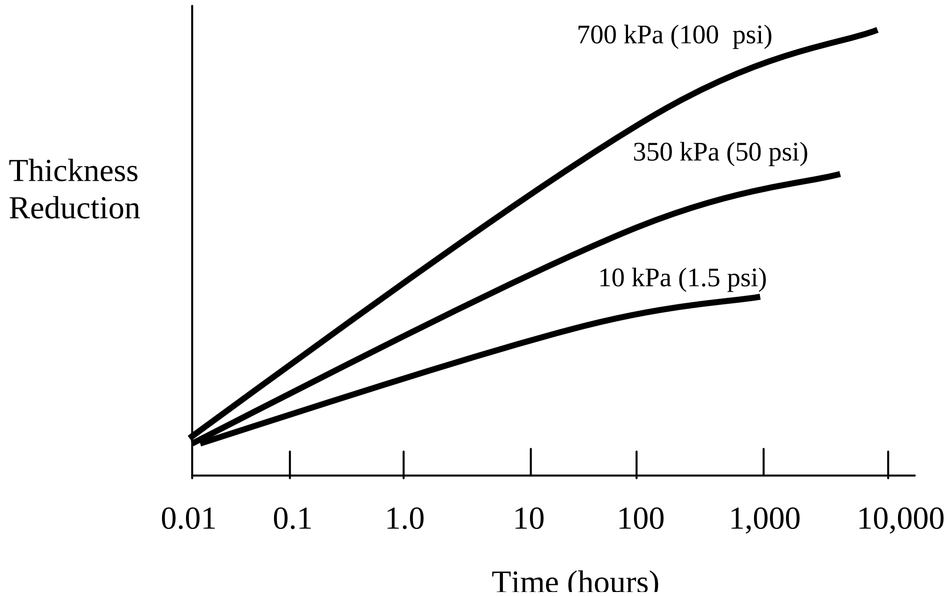
10.1 For a candidate drainage geocomposite, the 100-hour flow rate behavior under the site-specific set of variables, e.g., specimen orientation, stress level, hydraulic gradient, and permeating liquid is to be obtained per ASTM D4716 following procedures of Section 6.0.

10.2 A reduction factor for long term creep of the drainage core following Section 7.0 per GRI GS4 or ASTM D6364 (mod.) is then obtained. The result is usually a unique value for a given set of conditions.

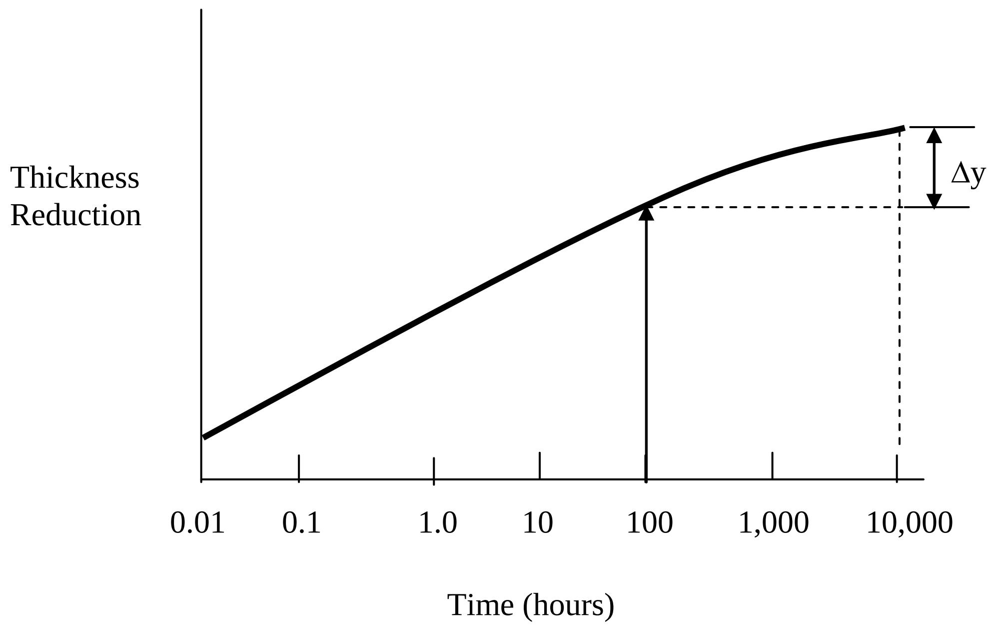
10.3 A reduction factor for chemical and/or biological clogging, as discussed in Section 8.0 can be included. It is very much a site-specific situation at the discretion of the parties involved.

10.4 Polymer degradation to aggressive liquids is covered in separate immersion and test protocols, e.g., ASTM D5322 (immersion), ASTM D6388 (geonets) and ASTM D6389 (geotextiles) as discussed in Section 9.0. The procedure does not result in a reduction factor, rather in a "go-no go" decision with the product under consideration.

10.5 Other possible flow rate reductions and/or concerns such as flow in overlap regions, effect of high or low temperatures, etc., are site-specific and cannot readily be generalized in a guide such as this.



(a) Hypothetical data from creep testing illustrating effect of normal load magnitude



(b) Interpretation of project specific normal load curve to obtain creep reduction factor

Figure 1 – Hypothetical example of creep test data and data interpretation to obtain creep reduction factor