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Standard Guide for Specifying Drainage Geocomposites[1]

This standard is issued under the fixed designation D7931; 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.

1. Scope

1.1 This guide presents a guideline specifying a drainage geocomposite product; it specifically provides recommendations to determine the 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.

1.2 This guide is intended to aid designers, purchasers, installers, contractors, owners, operators, and agencies in establishing minimum guidelines for drainage geocomposite materials. This guide is not to be used for manufacturer's quality control purposes, nor a construction quality assurance specification.

1.3 This guide does not address the required (or design) flow rate value, nor the subsequent factor of safety values, which are typically design specific.

1.4 The procedures recommended in this guide use ASTM test methods.

1.5 This 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 that provide drainage.

1.6 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.7 This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This guide cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this guide may be applicable in all circumstances. This guide is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this guide be applied without consideration of a project's many unique aspects. The word 'standard' in the title of this guide means only that the guide has been approved through the ASTM International consensus process.

1.8 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.9 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

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

D2990 Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics

D4354 Practice for Sampling of Geosynthetics and Rolled Erosion Control Products (RECPs) for Testing

D4439 Terminology for Geosynthetics

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

D4873/D4873M Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples

D5321/D5321M Test Method for Determining the Shear Strength of Soil-Geosynthetic and Geosynthetic-Geosynthetic Interfaces by Direct Shear

D5322 Practice for Laboratory Immersion Procedures for Evaluating the Chemical Resistance of Geosynthetics to Liquids

D6243/D6243M Test Method for Determining the Internal and Interface Shear Strength of Geosynthetic Clay Liner

[1] This guide 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.

by the Direct Shear Method
D6388 Practice for Tests to Evaluate the Chemical Resistance of Geonets to Liquids
D6389 Practice for Tests to Evaluate the Chemical Resistance of Geotextiles to Liquids
D6747 Guide for Selection of Techniques for Electrical Leak Location of Leaks in Geomembranes
D7001 Specification for Geocomposites for Pavement Edge Drains and Other High-Flow Applications
D7273/D7273M Guide for Acceptance Testing Requirements for Geonets and Geonet Drainage Geocomposites
D7361 Test Method for Accelerated Compressive Creep of Geosynthetic Materials Based on Time-Temperature Superposition Using the Stepped Isothermal Method
D7406 Test Method for Time-Dependent (Creep) Deformation Under Constant Pressure for Geosynthetic Drainage Products
D7852 Practice for Use of an Electrically Conductive Geotextile for Leak Location Surveys

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms related to geosynthetics, refer to Terminology D4439.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *agency, n*—in geosynthetics, the organization that reviews the permit application for compliance with the agency's regulation and all quality assurance documentation before and after construction.

3.2.2 *contractor, n*—in geosynthetics, the party or organization that has the responsibility for the construction of the man-made project, structure, or system.

3.2.3 *designer, n*—in geosynthetics, the person or organization that designs a man-made project, structure, or system that fulfills the owner/operator's requirements and meets or exceeds the minimum requirements of the agency.

3.2.4 *installer, n*—in geosynthetics, the party that installs, or facilitates installation of, any materials purchased from manufacturers or suppliers.

3.2.5 *operator, n*—in geosynthetics, the person or organization that operates the man-made project, structure, or system.

3.2.6 *owner, n*—in geosynthetics, the person or organization that owns the man-made project, structure, or system.

3.2.7 *purchaser, n*—in geosynthetics, the person, company, or organization that purchases any materials or work to be performed.

3.2.8 q_{100}, *n*—initial flow rate for a drainage geocomposite as determined under simulated conditions for 100-h duration.

3.2.9 q_{allow}, *n*—allowable flow rate for a drainage geocomposite.

4. Significance and Use

4.1 This guide is intended to aid designers, purchasers, installers, contractors, owners, operators, and agencies in establishing the minimum criteria to specify drainage geocomposites. Specifically, this guide presents a methodology for determining the 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.

4.2 It is recognized that there are other products that may achieve the same performance requirements but are not listed in this document. Manufacturers of such products are invited to implement this standard guide with the appropriate information.

4.3 It should be recognized that parties, organizations, or representatives may perform additional tests other than those required in this guide. In this case, the more stringent project-specific tests will then take precedence.

4.4 By simulating site-specific conditions (inclusive of site-specific liquids and temperatures except for load duration beyond 100 h, chemical/biological clogging, and geotextile intrusion), additional reduction factors need not be explicitly accounted for in certain products.

5. Classification

5.1 *General*—This guide covers geocomposite drainage products or structures intended for blanket subsurface drainage applications. Five distinctly different product designs are included in this guide as geocomposite drainage products:

5.2 *Biaxial Geonet Geocomposite*—A 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. Note that single-sided biaxial geonet geocomposites are available in the marketplace as well; in that particular case, only one side of the geonet will be heat laminated with a nonwoven geotextile.

5.3 *Triaxial Geonet Geocomposite*—A 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 heat laminated with nonwoven geotextiles on the top and bottom to form the geonet geocomposite. It should be noted that single-sided triaxial geonet geocomposites are available in the marketplace as well; in that particular case, only one side of the geonet will be heat laminated with a nonwoven geotextile.

5.4 *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.

5.5 *Structured Geomembrane System*—A geomembrane with integrated drainage nubs, spikes, or both. The drainage nubs, when overlain or heat laminated by a filter fabric (heat burnished on one side), will form the structured geomembrane drainage geocomposite.

5.6 *Sheet Drain Geocomposite*—A three-dimensional structured core consisting of integrally connected voids, typically heat laminated with a nonwoven geotextile or monofilament filter either on the top or bottom (or both) to form the drainage geocomposite. It should be noted that single-sided sheet drain geocomposites are available in the marketplace as well; in that particular case, only one side of the structure will be laminated with a nonwoven geotextile or monofilament filter geotextile.

5.7 *Geocomposite Edge Drain*—A geotextile wrapped around a structural polymer drainage core used for subsurface drainage applications in highway, turf, and environmental applications. The product is typically 1 in. (25 mm) thick and available in 6 in. (150 mm), 12 in. (300 mm), 18 in. (450 mm), 24 in. (600 mm), 30 in. (750 mm), and 36 in. (900 mm) widths.

6. Determination of the q_{allow} of a Candidate Drainage Geocomposite

6.1 *Basic Formulation*[3]—This guide is focused on determination of a q_{allow} value using the following formula:

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

where:

q_{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, and
RF_{GI} = reduction factor for geotextile intrusion past the initial 100-h seating time.

NOTE 1—The value of q_{allow} is typically used to determine the product-specific and site-specific flow rate factor of safety as follows:

$$FS = \frac{q_{allow}}{q_{reqd}} \quad (2)$$

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.

6.2 Upon selecting the candidate drainage geocomposite product, one must obtain the 100-h duration flow rate according to the Test Method D4716/D4716M transmissivity test or other appropriate transmissivity test method such as Specification D7001, which is more appropriate for high-flow applications. (See 6.2.2 for more background on which transmissivity test method to select.) This establishes the base value to which drainage core creep beyond 100 h, clogging from chemicals and biological matter, and geotextile intrusion must be accounted for.

6.2.1 It is recognized that the default duration listed in Test Method D4716/D4716M is 15 min. This guide purposely requires that the test conditions be maintained for 100 h, and simulating site-specific loading and boundary conditions.

6.2.2 While Test Method D4716/D4716M has historically been the "default" transmissivity test for geosynthetic drainage geocomposites, this transmissivity test method is limited to the size of the specimen being tested. Zimmel et al. (2011) identified that specimen size can significantly affect transmissivity tests performed in accordance with Test Method D4716/D4716M; however, recent research has shown that Test Method D4716/D4716M typically underestimates the actual flow rates at a certain hydraulic gradient (tested with a large-scale transmissivimeter), at least for unidirectional drainage geocomposites, and as a result Test Method D4716/D4716M transmissivity results are typically conservative.

6.2.3 Furthermore, standard engineering practice identifies that the transmissivity is only valid for laminar flow conditions, specifically when Darcy's law is valid, and then the transmissivity is an intrinsic property of the product and not dependent on external conditions such as the hydraulic gradient. According to Darcy's law, transmissivity should be a constant. However, transmissivity testing of drainage geocomposites has shown that transmissivity is not a constant, but is associated not only with the normal load but also with the hydraulic gradient and selected boundary conditions. In fact, transmissivity decreases as the hydraulic gradient increases, because of the development of turbulent flow conditions within the water path of the product being tested. Typically, for hydraulic gradients used in transmissivity tests (greater than 0.1), the flow is non-laminar for drainage geonets or drainage geonet geocomposites (Giroud et al., 2012). Therefore, the water flow rate of a drainage geocomposite can be better expressed as a discharge (flow rate) at a given hydraulic loss (van der Sluys and Dierickx, 1987) than as a transmissivity.[4]

6.3 *Reduction Factor for Creep*—This is a long-term (typically 10 000 h) compressive load test focused on the stability or deformation (or both) 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.

6.4 *Chemical/Biological Clogging*—The issue of long-term reduction factors to account for clogging within the core space is a site-specific issue.

6.5 *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.

7. Determination of the q_{100}

7.1 Using the Test Method D4716/D4716M transmissivity test under simulated field conditions, as stated below (unless otherwise agreed upon by the parties involved, such as potentially using Specification D7001 for appropriate high-flow applications), determine the q_{100} flow rate of the drainage geocomposite under consideration.

[3] This guide is updated and modified from GRI-GC 8 "Determination of the Allowable Flow Rate of a Drainage Geocomposite" to reflect different products in the marketplace today. For referenced GRI standards, visit the GSI website, http://www.geosyntheticinstitute.org/, or contact GSI Customer Service at (610) 522-8440. GRI standards are developed by the Geosynthetics Research Institute through consultation and review by the member organizations.

[4] Bourges-Gastaud, S., Blond, E., Touze-Foltz, N., "Multiscale Transmissivity Study of Drain-Tube Planar Geocomposites: Effect of Experimental Device on Test Representativeness," *Geosynthetics International*, Vol 20, No. 3, 2013, pp. 119–128.

7.1.1 The test specimen shall be the entire geocomposite or system as installed in the field. If geotextiles are bonded to the drainage core, they shall not be removed and the entire geocomposite shall be tested as a unit; vice versa, if the geotextile is overlain the structured geomembrane, it should be tested as installed in the field. A minimum of three replicate samples in the site-specific orientation shall be tested and the results averaged for the reported value.

7.1.2 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.

7.1.3 Determining the base transmissivity of the candidate drainage geocomposite per Test Method D4716/D4716M (or approved alternate test method) involves specifying a set of site-specific parameters: specimen boundary conditions, applied stress level, hydraulic gradient, seating or loading time, temperature, and the permeating liquid.

7.1.3.1 Typically, specimen boundary conditions shall be one of the following options: (*1*) rigid platen, (*2*) standardized sand, or (*3*) site-specific or other earth material which is typically based on what will most closely simulate field conditions.

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

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

(3) If site-specific soil or other material is used, it must be carefully considered and agreed upon between the parties involved. Compaction, moisture content, water content, etc., are all important considerations but should simulate anticipated conditions in the field.

7.1.3.2 The applied stress level is at the discretion of the designer, testing organization, and manufacturer. Unless otherwise stated, the orientation shall be normal to the test specimen. Typically, the selected applied stress level will be based on the maximum anticipated stress that the drainage geocomposite will undergo in the field, inclusive of a factor of safety.

7.1.3.3 The hydraulic gradient at which the above data is taken (or a range of hydraulic gradients) is at the discretion of the designer, testing organization, and manufacturer. But typically, the hydraulic gradient is selected based on the slope gradient that the drainage geocomposite will be placed in the field.

7.1.4 Seating or loading time is 100 h, while it is not necessary to perform intermediate flow rate testing, unless otherwise specified by the various parties involved.

7.1.5 The permeating liquid is typically tap water, unless site-specific fluids need to be used, which should be agreed upon by the designer, testing organization, and manufacturer.

7.1.6 The resulting allowable transmissivity value shall then be compared to a required (or design) transmissivity (flow rate) for a product-specific and site-specific factor of safety. This guide does not address the required (or design) transmissivity (flow rate) value, nor the subsequent reduction factors and the overall product safety value, which is highly project specific and should be risk based.

8. Reduction Factor of Creep

8.1 Depending on the site-specific situation and applied stresses, the drainage core of the geocomposite might creep, which leads to a reduction of its in-plan flow capacity. The creep phenomenon is core dependent. Some products, like multilinear drainage geocomposites, may not be sensitive to creep when confined into a soil matrix because of their core structures.

8.2 The creep reduction factor can be obtained by running a long-term transmissivity test (1000 h minimum) under site-specific conditions (boundaries, load, etc.). In that case, the obtained reduction factor will take into account creep and geotextile intrusion into core.

8.3 For geonets, structured geomembranes, and sheet drain cores, the factor for creep can be estimated with Test Method D7406. The candidate drainage core is placed under compressive stress and its decrease in thickness (deformation) is monitored over time. 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.

8.4 The obtained reduction in thickness of the core itself does not give the reduction of transmissivity of the geocomposite. The relationship between hydraulic transmissivity reduction and thickness reduction is not linear and product specific. Interpretation must be done based on the type of product.

8.5 Normal stress magnitude(s) shall be the same as applied in the transmissivity test described in Section 7. Alternatively, it can be as agreed upon by the designer, testing organization, and manufacturer.

8.6 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. Contact the manufacturers for reduction factors for creep as they are product and core dependent.

8.7 The seating time shall be a minimum of 1000 h with up to 10 000 h. If, however, this is a confirmation test (or if a substantial database exists on similar products of the same type), the seating time can be reduced to 1000 h rather than the full 10 000 h. This decision must be made with agreement among the designer, testing organization, and manufacturer.

NOTE 2—Creep properties of the geonet core can be evaluated using the stepped isothermal method (SIM, Test Method D7361). SIM testing was developed using the time-temperature superposition (TTS) principle by utilizing temperatures to accelerate the creep deformation and therefore, to significantly shorten the long creep dwell time on the geonet core. Furthermore, a single test specimen is exposed to a series of temperature steps instead of multiple specimens, as in TTS, eliminating the influence of material variability. This accelerated creep test, SIM, has been used in research applications to evaluate creep behavior of HDPE geonets (Thornton et al., 2000; Narejo and Allen, 2004; Allen, 2005). The single largest advantage of the SIM method is that the creep behavior of the geonet core can be derived in a very short time period (days) versus the recommended dwell time of 1000 to 10 000 h, which has resulted in limited test being completed with Test Method D7406 (Lawrence, 1987). Creep reduction factors derived either via Test Method D7406 or D7361 might not be directly comparable given the limited data set derived with Test Method D7406; if creep reduction factor needs to be verified during a construction quality assurance (CQA) program, the creep testing method should be as agreed upon by the designer, testing organization, and manufacturer.

8.8 If it is desired to extrapolate creep deformation response to future, potentially longer time frames such as 100 years or longer, there are a number of different techniques for analyzing time-dependent deformation and essentially "creep" which will model that behavior (for example, Appendix X5 of Test Methods D2990 for prediction of long-term properties, the three-element model, curve extrapolation, and so forth). As they are beyond the scope of this method, it is always necessary to include the raw data in the final report. See WSDOT Standard Practice T9255 for further details in this regard.

9. Reduction Values for Chemical and Biological Clogging

9.1 There are two general types of core clogging that might occur over a long time period. They are chemical clogging and biological clogging. 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.

9.2 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.

9.3 Contact the product manufacturers for reduction factors for chemical and biological clogging as they are product, geotextile, and core dependent. RF_{CC} and RF_{BC} are also likely to vary tremendously from one application to the other (that is, in a landfill or for drainage of an embankment). In the absence of relevant information, test methods such as D1987 may be useful for assessing the sensitivity of a particular geotextile filter to biological or chemical clogging in particular environmental conditions, in a direction perpendicular to the plane of the geotextile. There were no test methods available to assess the influence of a particular environment on the transmissivity of a drainage geocomposite at the time this standard was prepared. If such an assessment is needed, the appropriate procedure should be agreed on by the end user and the manufacturer, considering existing literature and experience.

10. Reduction Factor of Geotextile Intrusion into Core

10.1 Considering the large open spaces in some drainage cores (geonets, structured geomembranes, or sheet drains), the intrusion of the covering geotextiles or geomembranes, or both, represents a meaningful reduction factor. 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.

10.2 For geocomposites that exhibit geotextile intrusion into the drainage core, a table is offered as a guide in Koerner (2005), last revised in 2012.

10.3 For geocomposites that do not suffer from geotextile intrusion and the q_{100} incorporates the appropriate geotextile intrusion, the RF_{GI} value will be taken equal to 1.0.

11. Polymer Degradation

11.1 Degradation of the materials from which the drainage geocomposites 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 filters/separators covering the drainage cores are made from polypropylene, polyester, or polyethylene.

NOTE 3—It is 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. Testing for polymer degradation should thus be performed on unbonded locations of the geocomposite, that is, on specimens sampled on the edges, or samples of both core and geotextile taken in the plant before lamination.

11.2 Polymer degradation testing is recommended for applications where operating conditions involve harsh, potentially incompatible environments or where products are anticipated to perform over very long service lives, or both.

11.3 The incubation of the drainage geocomposite or its individual geosynthetic (or both) is to be done according to the Practice D5322 immersion procedure.

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

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

11.6 The information obtained in polymer degradation testing of the drainage geocomposite and potentially its individual components (11.2 – 11.5) results in a "go/no-go" regarding use of the drainage geocomposite for that particular application with its site-specific liquid and not in a reduction factor, per se. So in summary, either the selected product is compatible with the site conditions or it is not.

12. Determination of System Shear Strengths

12.1 Determine both peak and residual shear strengths for all possible shear surfaces in a geosynthetic liner system (base and final cover system) using direct shear testing in the laboratory (Test Method D5321/D5321M or D6243/D6243M) at relevant normal stresses and boundary conditions. The post-peak shear strength corresponding to the 3-in. shear displacement is considered the residual shear strength (that is, it is not the steady-state shear strength at large displacements).

12.2 Establish the peak and residual shear strengths for the liner system (not necessarily the same as the lowest residual

Guide D7273/D7273M, but individual test methods must be clearly stipulated and communicated to the parties involved. For the multilinear, structured geomembranes and sheet drain drainage geocomposites, the manufacturer specification sheets and test methods might be used as a guide.

17.1.1 Typically at the time of shipment, the purchaser of the drainage geocomposite shall be furnished with a manufacturer's certification that the materials were manufactured and tested in accordance with the design specification.

17.2 Additional acceptance tests may be required depending on the application. For example, in applications in which shear strength is critical, direct shear tests of the interfaces adjacent to the drainage geocomposite (Test Method D5321/D5321M) shall to be tested. In addition, when leachate is the permeating fluid, specific biological clogging tests as specified in Test Method D1987 should be considered to ensure that the filtration geotextile is an adequate filter for this type of fluid.

18. Keywords

18.1 biaxial geonet geocomposites; draintube; geocomposite edge drains; geosynthetics; geotextiles; multilinear drainage geocomposites; sheet drain deocomposites; structured geomembranes; testing; triaxial geonet geocomposites