

GRI-GCL-3

STANDARD SPECIFICATION FOR TEST METHODS, REQUIRED PROPERTIES AND TESTING FREQUENCIES OF GCLs

The Geosynthetic Research Institute has developed a specification on geosynthetic clay liners (GCLs) for general use by the public. CETCO encourages designers to use this specification and modify it, as needed, on a project-by-project basis using their engineering judgment.

There are many different types of GCLs and thus the specification has a table in the back that is subdivided into reinforced and non-reinforced, each of which is further subdivided into three subgroups:

- Geotextile-only GCLs
- Geotextile encased GCLs with a polymer coating
- GCLs with geomembrane or geofilm (may be geotextile encased or not)

CETCO products can be cross-referenced by the following listing.

	Reinforced GCL			Non-reinforced GCL		
	GT-related	GT polymer coated	GM-GF related	GT-related	GT polymer coated	GM-GF related
Bentomat ST	X					
Bentomat DN	X					
Bentomat CL			X			
Bentomat CLT			X			
Bentomat 200R				X		

GT – geotextile GM – geomembrane GF – geofilm

The complexity of the specification warrants further explanation of the property sections.

Clay

Swell index and fluid loss of the clay is tested prior to fabrication of the GCL or from the GCL if the bentonite is modified in any way during manufacture.

Geotextiles

There are two layers of geotextiles, a cap fabric and a carrier fabric. This relates to the orientation during manufacturing; cap on top and carrier below the bentonite. **Note: It does not specify orientation during installation. Orientation during installation should be determined from interface shear testing.**

For CETCO GCLs, the cap and carrier fabrics are as follows:

Geotextile	Bentomat ST	Bentomat DN	Bentomat CL	Bentomat CLT	Bentomat 200R
cap fabric (nonwoven)	X	X	X	X	X
cap fabric (woven)					
carrier fabric (nonwoven)		X			
carrier fabric (woven)	X		X	X	X

Footnote (2) states that: “For both cap and carrier fabrics for nonwoven reinforced GCLs: one, or the other, must contain a scrim component of mass >2.9 oz/yd² for dimensional stability. This only applies to GM/GCL composites which are exposed to the atmosphere for several months or longer so as to mitigate panel separation”. Bentomat DN does not contain a scrim component. However, Bentomat DN is suitable for projects where dimensional stability is not a concern. Even for projects where the geomembrane will be left exposed for months or years, Bentomat DN is still suitable if reasonable preventative measures are taken, such as either of the following (as discussed in TR-338):

- Increase the overlap of the GCL to account for the potential of panel separation.
- Heat-tack weld the GCL seams with a quick application of a flame torch followed immediately by light pressure.

Geomembrane/Geofilm

Bentomat CL has a geofilm and Bentomat CLT has a geomembrane.

GCL (as manufactured)

Note that the specification lists two new test methods; ASTM D6768 for tensile strength and ASTM D6496 for peel strength. These test methods differ from the ASTM test method D4632 used in ASTM D5889 Standard Guide for Manufacturing Quality Control of GCLs. Engineers should read the new test methods and CETCO TR-334 to acquaint themselves with the differences in testing and calculating values.

Also, note that the flux is listed in units of ‘cm³/cm²-sec’. This differs by two orders of magnitude from the units of ‘m³/m²-sec’ that are listed by CETCO in its Certified Properties sheets. The conversion is as follows:

- $1 \times 10^{-6} \text{ cm}^3/\text{cm}^2\text{-sec} = 1 \times 10^{-8} \text{ m}^3/\text{m}^2\text{-sec}$, and
- $1 \times 10^{-7} \text{ cm}^3/\text{cm}^2\text{-sec} = 1 \times 10^{-9} \text{ m}^3/\text{m}^2\text{-sec}$.

GCL permeability

These tests actually represent *bentonite durability* of the GCL permeated with a 0.1M CaCl₂ solution. The tests are to run only **once a year** for the geotextile-related products under the two test conditions listed:

- ASTM D6766 Scenario 1, prehydrated with distilled deionized water and tested at 5 psi maximum effective confining pressure, and
- Modified ASTM D6766 Scenario 1, prehydrated with distilled deionized water and tested at 70 psi maximum effective confining pressure.

The permeability of geofilm- and geomembrane-related products is no longer required due to the extremely low permeability of the geofilm/geomembrane component, which prevents sufficient flow to reach equilibrium.

ASTM D6766 requires relative equilibrium (+/- 10%) between the influent and effluent electrical conductivity. However, it can be difficult to achieve this equilibrium in some cases, including GCLs tested at 70 psi maximum effective confining pressure, due to the low permeability at high confining pressure. For this reason, GRI-GCL-3 states that the termination criteria at 70 psi will be outflow electrical conductivity within 25% of the influent electrical conductivity.

Component Durability

Geotextile and reinforcing yarn

These tests are to be run **once a year** per fabric to evaluate the component durability by testing the material for tensile strength before and after exposure in a forced air oven @ 60°C for 50 days. Until test data is available in March of each year, CETCO will provide data from the previous year.

Geomembrane

Bentomat CLT has a high-density polyethylene geomembrane. The geomembrane supplier shall provide information on the durability per GRI GM 13.

Geofilm/polymer treated

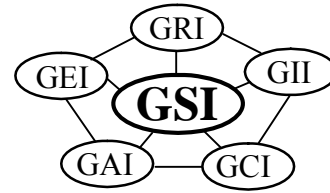
These tests are to be run **once a year** per fabric to evaluate the component durability by testing the material for tensile strength before and after exposure in a forced air oven @ 60°C for 50 days. Until test data is available in March of each year, CETCO will provide data from the previous year.

Workmanship and Appearance

There must be continuous needle detection and removal used during the manufacture of GCL products (see TR-335 for a description of CETCO's needle detection and removal procedures). Needle-punched GCL shall be essentially free of broken needles and fragments. The specification acknowledges that some needle fragments will inevitably reach the final product. The specification does not specify that GCL be needle-free.

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GRI-GCL3*

Standard Specification for

“Test Methods, Required Properties, and Testing Frequencies of Geosynthetic Clay Liners (GCLs)”

This specification was developed by the Geosynthetic Research Institute (GRI), with the cooperation of the member organizations for general use by the public. It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part. Neither GRI, the Geosynthetic Institute, nor any of its related institutes, warrant or indemnifies any materials produced according to this specification either at this time or in the future.

1. Scope

- 1.1 This specification covers the manufacturing quality control (MQC) of geosynthetic clay liners (GCLs), describing types of tests, the proper test methods, minimum and sometimes maximum values, and the minimum testing frequencies.

Note 1: Geosynthetic Clay Liners (GCLs) are also called Clay Geosynthetics Barriers (GBR-Cs).

- 1.2 There are two general categories of GCLs covered in this specification: reinforced and nonreinforced. Within each category there are geotextile, polymer coated geotextiles, and geomembrane/geofilm related types.
- 1.3 This specification is intended to aid manufacturers, suppliers, purchasers and users of GCLs in establishing an acceptable level of effort for manufacturing quality control.

*This GRI standard is developed by the Geosynthetic Research Institute through consultation and review by the member organizations. This specification will be reviewed at least every 2-years, or on an as-required basis. In this regard it is subject to change at any time. The most recent revision date is the effective version.

- 1.4 This specification does not address manufacturing quality assurance (MQA), product acceptance testing, or conformance testing. These are independent activities taken by organizations other than the GCL manufacturer.
- 1.5 The values stated in SI (metric) units are to be regarded as the standard. The U.S. (English) units are calculated values using a “soft” conversion accuracy.
- 1.6 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

- D 638 Test Method for Tensile Properties of Plastics
- D 792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
- D 882 Test Method for Tensile Properties of Thin Plastic Sheeting
- D 1141 Practice for Preparation of Substitute Ocean Water
- D 1505 Test Method for Density of Plastics by the Density-Gradient Method
- D 4354 Practice for Sampling of Geosynthetics for Testing
- D 4439 Terminology for Geosynthetics
- D 4632 Test Method for Grab Breaking Load and Elongation of Geotextiles
- D 4759 Practice for Determining the Specification Conformance of Geosynthetics
- D 5199 Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes
- D 5261 Test Method for Measuring Mass per Unit Area of Geotextiles
- D 5721 Practice for Air-Oven Aging of Polyolefin Geomembranes
- D 5887 Test Method for Measurement of Index Flux Through Saturated Geosynthetic Clay Liner Specimens Using Flexible Wall Permeameter
- D 5888 Practice for Storage and Handling of Geosynthetic Clay Liners
- D 5889 Practice for Quality Control of Geosynthetic Clay Liners
- D 5890 Test Method for Swell Index of Clay Mineral Component of Geosynthetic Clay Liners
- D 5891 Test Method for Fluid Loss of Clay Component of Geosynthetic Clay Liners
- D 5993 Test Method for Measuring the Mass Per Unit Area of Geosynthetic Clay Liners
- D 5994 Test Method for Measuring the Core Thickness of Textured Geomembrane
- D 6102 Guide for Installation of Geosynthetic Clay Liners
- D 6141 Guide for Screening the Clay Portion of a GCL for Chemical Compatibility to Liquids

- D 6243 Method for Determining the Internal and Interface Shear Resistance of Geosynthetic Clay Liner by the Direct Shear Method
- D 6495 Guide for Acceptance Testing Requirements for Geosynthetic Clay Liners
- D 6496 Test Method for Determining Average Bonding Peel Strength Between the Top and Bottom Layers of Needle-Punched Geosynthetic Clay Liners
- D 6693 Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes
- D 6766 Test Method for Evaluation of Hydraulic Properties of Geosynthetic Clay Liners Permeated with Potentially Incompatible Liquids
- D 6768 Test Method for Tensile Strength of Geosynthetic Clay Liners

2.2 GRI Standards

- GM13 Test Properties, Testing Frequency and Recommended Warrant for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes
- GM17 Test Properties, Testing Frequency and Recommended Warranty for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes
- GM18 Test Properties, Testing Frequency and Recommended Warrant for Flexible Polypropylene (fPP and fPP-R) Nonreinforced and Reinforced Geomembranes (Presently suspended as of May 3, 2004)

2.3 Government Document:

U.S. Environmental Protection Agency Technical Guidance Document “Quality Control Assurance and Quality Control for Waste Containment Facilities,” EPA/600/R-93/182, September 1993, 305 pgs.

3. Terminology

3.1 Definition

3.1.1 Geosynthetic Definitions:

- 3.1.1.1 geotextile, n—a permeability geosynthetic comprised solely of textiles. (ASTM D 4439)
- 3.1.1.2 geomembrane, n—an essentially impermeable geosynthetic barrier composed of one or more synthetic sheets. (ASTM D 4439)
- 3.1.1.3 geofilm, n—a thin polymeric film which is essentially impermeable having a thickness no greater than 0.25 mm (10 mils).
- 3.1.1.4 geotextile-polymer, n—a geotextile which has been coated with, or impregnated by, a polymer such as polypropylene

- 3.1.1.5 geosynthetic clay liner, n—a manufactured hydraulic barrier consisting of clay bonded to a layer or layers of geosynthetic materials. (ASTM D 4439). Also recall Note 1.

Note 2: Geotextile Related GCL is one in which two geotextiles are used respectively as cap and carrier to the bentonite. Cap and carrier designations in this standard refer to respective orientations during manufacturing. This may or may not be the as-placed orientation in the field. It can be internally reinforced by needle punching or stitching, or be nonreinforced.

Geotextile Polymer Coated GCL is one in which two geotextiles are used respectively as cap and carrier to the encased bentonite, however, one of the geotextiles has been polymer coated in a manner that the permeability and flux are decreased. Within this context a bitumen coated geotextile can be considered as being a polymer. Cap and carrier designations refer to the as manufactured product and not necessarily to the as-placed orientation. It can be internally reinforced by needle punching or stitching, or be nonreinforced.

Geomembrane/Geofilm Related GCL is one in which a geomembrane or geofilm is included in the cross section either above or below the cap geotextile. It can be internally reinforced needle punching or be nonreinforced. Also in the nonreinforced category is bentonite adhesively bonded to a geomembrane.

3.1.2 Material Definitions

- 3.1.2.1 bentonite—a distinct type of fine-grained clay soil typically containing not less than 80% montmorillonite clay, usually characterized by high swelling upon wetting.
- 3.1.2.2 Formulation, n - The mixture of a unique combination of ingredients identified by type, properties and quantity. For geosynthetic materials, a formulation refers to the exact percentages of resin, additives, carbon black and/or other additives. It does not necessarily refer to individual suppliers of each ingredient. The individual suppliers must meet the manufacturer's internal quality control specification.

3.1.3 Organizational Definitions:

- 3.1.3.1 installer, n—the party who installs, or facilitates installation of, any materials purchased from manufacturers or suppliers.
- 3.1.3.2 manufacturer, n—the group, corporation, partnership, or individual that manufactures a product.
- 3.1.3.3 purchaser, n—the person, company, or organization that purchases any materials or work to be performed.

3.1.3.4 supplier, n—the party who supplies material or services.

3.1.4 Quality Definitions:

3.1.4.1 Manufacturing Quality Control (MQC) - A planned system of inspections that is used to directly monitor and control the manufacture of a material which is factory originated. MQC is normally performed by the manufacturer of geosynthetic materials and is necessary to ensure minimum (or maximum) specified values in the manufactured product. MQC refers to measures taken by the manufacturer to determine compliance with the requirements for materials and workmanship as stated in certification documents and contract specifications, ref. EPA/600/R-93/182

3.1.4.2 Manufacturing Quality Assurance (MQA) - A planned system of activities that provides assurance that the materials were constructed as specified in the certification documents and contract specifications. MQA includes manufacturing facility inspections, verifications, audits and evaluation of the raw materials (resins and additives) and geosynthetic products to assess the quality of the manufactured materials. MQA refers to measures taken by the MQA organization to determine if the manufacturer is in compliance with the product certification and contract specifications for the project, ref. EPA/600/R-93/182

3.1.4.3 Construction Quality Control (CQC) - A planned system of inspections that are used to directly monitor and control the quality of a construction project. Construction quality control is normally performed by the geosynthetics manufacturer or installer, or for natural soil materials by the earthwork contractor, and is necessary to achieve quality in the constructed or installed system. Construction quality control (CQC) refers to measures taken by the installer or contractor to determine compliance with the requirements for materials and workmanship as stated in the plans and specifications for the project, ref. EPA/600/R-93/182

3.1.4.4 Construction Quality Assurance (CQA) - A planned system of activities that provide assurance that the facility was constructed as specified in the design. Construction quality assurance includes inspections, verification, audits, and evaluations of materials and workmanship necessary to determine and document the quality of the constructed facility. Construction quality assurance (CQA) refers to measures taken by the CQA organization to assess if the installer or contractor is in compliance with the plans and specifications for a project, ref. EPA.600/R-93/182

4. Significance and Use

- 4.1 GCLs must be properly manufactured in a manner consistent with a minimum level of quality control as determined by in-house testing of the final product. This specification presents the types of tests, standard methods of the testing, required (usually minimum) test values, and minimum testing frequencies which should be embodied in the manufacturer's quality control documents. The quoted tests, test methods and test values in Table 1 must appear in the MQC plan and the MQC report.
- 4.2 It should be clearly recognized that manufacturers may perform additional tests or at greater frequency than required in this specification, or both. In this case, the manufacturer's quality control plan will then take precedence over this specification.
- 4.3 It should also be recognized that purchasers and installers of GCLs may require additional tests or at a great frequency than called for in this specification, or both. The organization(s) producing such project specific specification or quality assurance plan should recognize that such requirements are beyond the current state-of-the-practice. If such a request is made by purchasers or installers, they should clearly communicate the requirements to the manufacturer or supplier during the contract decisions in order that disputes do not arise at a subsequent time.

5. Procedure

- 5.1 The procedures embodied in this specification are contained in the respective test methods given in Table 1.
 - 5.1.1 The minimum recommended quality control tests for the manufacture of GCLs are given in Table 1. Specific tests are performed on the bentonite, the geosynthetic component materials, and the finished GCL. Table 1(a) is in S.I. (Metric) units and Table 1(b) is in U.S. (English) units.

Note 3: The conversion from S.I. units into U.S. units is soft.
 - 5.1.2 The individual properties in Table 1 are minimum values; except fluid loss, moisture content, and permeability (or flux). They are maximum values. The manner of taking specimens is described in the appropriate test method. When an average value is indicated, it is listed in the table as "min. ave.", or "max. ave."
- 5.2 Bentonite (as received)

Two tests are required; swell index and fluid loss. The latter is a maximum value. These tests should be performed on the bentonite prior to fabrication into a GCL

or on bentonite taken from the manufactured product if the bentonite is modified in any way during manufacturing, e.g., if an adhesive is added.

5.3 Geotextile (as received)

Mass per unit area is required on the as-manufactured cap and carrier fabrics, with different values depending on the fabric being nonwoven or woven.

Note 4: These tests are to be performed on the geotextiles before manufacturing into the final GCL. Removal of the geotextiles from the manufactured product and subsequent testing will give erroneous values and is not an acceptable practice. The exception is polymer coated GCLs where the geotextile must be removed to determine its mass per unit area.

5.4 Geomembrane/Geofilm (as received)

The following tests are required; thickness, density, and tensile strength at break. All are minimum required values. Tensile strength at break is the lowest of machine direction and cross machine direction.

Note 5: These tests are to be performed on the geomembrane or geofilm before manufacturing into the final GCL. Removal of the geomembrane or geofilm from the manufactured product and subsequent testing will give erroneous values and is not an accepted practice.

5.5 GCL (as manufactured)

Six tests are required on the as-manufactured GCL with one having an alternative, i.e., hydraulic conductivity or flux. All are minimum values, with the exception of moisture content and hydraulic conductivity or flux.

5.6 GCL (long-term)

The purpose of these long-term or endurance tests is to provide confidence in the continuing acceptable performance of the bentonite and geosynthetic components of the installed GCL.

5.6.1 The durability of the bentonite is evaluated using a permeant consisting of 0.1 M calcium chloride solution. See ASTM D 6141 which is a guide for this particular aspect of the specification. The GCL is to be hydrated with distilled dionized water prior to conducting the tests with the calcium chloride solution. In this regard, ASTM D6766 Scenario 1 and Method C is the procedure to be used. Furthermore, this test is conducted twice at two different normal pressures, i.e., 35 and 500 kPa. The termination criterion at 500 kPa of two pore volumes does not apply and now becomes an outflow-to-inflow hydraulic conductivity within 25%. The maximum allowable values are listed in Table 1.

- 5.6.2 The geotextiles in their as-received condition are evaluated by incubation in a forced air oven per ASTM D5721 set at 60°C for 50 days. The minimum percent in tensile strength retained at break, as measured by ASTM D6768, is 65%. If individual yarns are used in reinforcing GCLs, they must also meet this same endurance criterion.
- 5.6.3 The geomembrane in its as-received condition is evaluated for durability via the appropriate GRI Specification. For high density polyethylene (HDPE), the specification is GRI GM13. For linear low density polyethylene (LLDPE), the specification is GRI GM17. For flexible polypropylene (fPP), the specification is GRI GM18.
- 5.6.4 The geofilm in its as-received condition is evaluated by incubation in a forced air oven per ASTM D5721 set at 60°C for 50 days. The minimum percent tensile strength retained at break for either MD or XMD, as measured by ASTM D882, is reported accordingly and must meet or exceed the specification value.

Note 6: It should be recognized that the above durability criterion for geofilms is not as stringent as the criteria for geomembranes stated in Section 5.6.3.

6. Workmanship and Appearance

- 6.1 Waterproof ink overlap lines should be printed on both edges of one of the surfaces (geotextile or geomembrane) of the manufactured GCL.

Note 7: The overlap lines are minimally 150 mm (6.0 in.) from the edges of the GCL. Other design-related situations may require greater overlap distances to be printed on the GCLs, e.g., when not backfilled in a timely manner.

- 6.2 Needle punched and stitch bonded GCLs shall be essentially free of broken needle and fragments that would negatively effect the performance of the final product. There must be continuous needle detection and removal devices, e.g., metal detectors and magnets, used during manufacture of GCL products.
- 6.3 The manufactured GCL shall have good appearance qualities. It shall be free from such defects that would affect the specified properties and integrity of the product.
- 6.4 General manufacturing procedures shall be performed in accordance with the manufacturer's internal quality control guide and/or documents. ASTM D5888 and D5889 should be followed in this regard.

7. MQC Sampling

- 7.1 Sampling shall be in accordance with the specific test methods listed in Table 1. If no sampling protocol is stipulated in the particular test method, then test specimens shall be taken evenly spaced across the entire roll width, see ASTM D 4354.
- 7.2 The number of tests shall be in accordance with the appropriate test methods listed in Table 1.
- 7.3 The average of the test results should be calculated per the particular standard cited and compared to the minimum value listed in these tables, hence the values listed are the minimum average values and are designated as "min. ave.". When the property is a maximum value, the designation is "max. ave.".

8. MQC Retest and Rejection

- 8.1 If the results of any test do not conform to the requirements of this specification, retesting to determine conformance or rejection should be done in accordance with the manufacturing protocol as set forth in the manufacturer's quality manual.

9. Packaging and Marking

- 9.1 The GCL shall be rolled onto a substantial core, clearly labeled, and enclosed in a waterproof wrapper. Packaging must be adequate for safe transportation to the point of delivery.
- 9.2 The label should include manufacturer, style, lot and/or roll number, weight, length and width.

10. Conformance and Certification

- 10.1 Conformance of the manufactured GCL to this specification, or agreed-upon variation thereof, shall be performed by the MQA organization or designated by the purchaser/owner. ASTM D 4759 can be used as a general guide, but individual test methods must be clearly stipulated and communicated to the parties involved.
- 10.2 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

Adoption and Revision Schedule
for

GCL Specification for GRI-GCL3

“Test Methods, Required Properties, and Testing Frequencies of
Geosynthetic Clay Liners (GCLs)”

Adopted: May 16, 2005

Revision #1: March 30, 2009: Removed permeability testing requirement for GM back, GF backed, and polymer treated GCLs. Various editorial modifications.

Revision #2: July 26, 2010: (i) Increased cap fabric weights for nonreinforced GCL's to 100 g/m² (3.0 oz/yd²); (ii) Included a maximum value for initial moisture content of 35%; (iii) Termination criterion for D6766 test was modified per Section 5.6.1; and (iv) Added to Footnote #2, “This only applies to GM/GCL composites which are exposed to the atmosphere for months or longer so as to mitigate panel separation”.

Table 1(a) – Specification for Geosynthetic Clay Liners (GCLs)

Property	ASTM Test Method	Reinforced GCL			Non-Reinforced GCL			Testing Frequency
		GT-Related	GT Polymer Coated	GM-GF Related	GT-Related	GT Polymer Coated	GM-GF Related	
<u>Clay (as received)</u>								
swell index (ml/2g)	D5890	24	24	24	24	24	24	50 tonnes
fluid loss (ml) ⁽¹⁾	D5891	18	18	18	18	18	18	50 tonnes
<u>Geotextiles (as received)</u>								
cap fabric (nonwoven) - mass/unit area (g/m ²) ⁽²⁾	D5261	200	200	200	100	100	n/a/100	20,000 m ²
cap fabric -(woven) - mass/unit area (g/m ²)	D5261	100	100	100	100	100	100	20,000 m ²
carrier fabric (nonwoven composite) - mass/(g/m ²) ⁽²⁾	D5261	240	240	240	100	100	n/a/100	20,000 m ²
carrier fabric (woven) - mass/unit area (g/m ²)	D5261	100	100	100	-	-	-	20,000 m ²
coating - mass/unit area (g/m ²) ⁽³⁾	D5261	n/a	100	n/a	n/a	100	n/a	4,000 m ²
<u>Geomembrane/Geofilm (as received)</u>								
thickness ⁽⁴⁾ (mm)	D5199/D5994	n/a	n/a	0.40/0.50/0.10	n/a	n/a	0.40/0.75/0.10	20,000 m ²
density (g/cc)	D1505/D792	n/a	n/a	0.92	n/a	n/a	0.92	20,000 m ²
break tensile strength, MD&XMD (kN/m)	D6693	n/a	n/a	n/a	n/a	n/a	6.0	20,000 m ²
break tensile strength, MD (kN/m)	D882	n/a	n/a	2.5	n/a	n/a	2.5	20,000 m ²
<u>GCL (as manufactured)</u>								
mass of GCL (g/m ²) ⁽⁵⁾	D5993	4000	4050	4100	4000	4050	4100	4,000 m ²
mass of bentonite (g/m ²) ⁽⁵⁾	D5993	3700	3700	3700	3700	3700	3700	4,000 m ²
moisture content ⁽¹⁾ (%)	D5993	35	35	35	35	35	35	4,000 m ²
tensile str., MD (kN/m)	D6768	4.0	4.0	4.0	4.0	4.0	4.0	20,000 m ²
peel strength (N/m)	D6496	360	360	360	n/a	n/a	n/a	4,000 m ²
permeability ⁽¹⁾ (m/sec), “or”	D5887	5×10^{-11}	n/a	n/a	5×10^{-11}	n/a	n/a	25,000 m ²
flux ⁽¹⁾ (m ³ /sec-m ²),	D5887	1×10^{-8}	n/a	n/a	1×10^{-8}	n/a	n/a	25,000 m ²
GCL permeability ^{(1),(6)} (m/sec) (max. at 35 kPa)	D6766	1×10^{-8}	n/a	n/a	1×10^{-8}	n/a	n/a	yearly
GCL permeability ^{(1),(6)} (m/sec) (max. at 500 kPa)	D6766 mod.	5×10^{-10}	n/a	n/a	5×10^{-10}	n/a	n/a	yearly
<u>Component Durability</u>								
geotextile and reinforcing yarns ⁽⁷⁾ (% strength retained)	See § 5.6.2	65	65	n/a	65	65	n/a	yearly
geomembrane	See § 5.6.3	n/a	n/a	GM Spec ⁽⁸⁾	n/a	n/a	GM Spec ⁽⁸⁾	yearly
geofilm/polymer treated ⁽⁷⁾ (% strength retained)	See § 5.6.4	n/a	85	80	n/a	85	80	yearly

n/a = not applicable with respect to this property :

(1) These values are maximum (all others are minimum)

(2) For both cap and carrier fabrics for nonwoven reinforced GCLs; one, or the other, must contain a scrim component of mass ≥ 100 g/m² for dimensional stability. This only applies to GM/GCL composites which are exposed to the atmosphere for several months or longer so as to mitigate panel separation.

(3) Calculated value obtained from difference of coated fabric to as-received fabric

(4) First value is for smooth geomembrane; second for textured geomembrane; third for geofilm

(5) Mass of the GCL and bentonite is measured after oven drying per the stated test method

(6) Value represents GCL permeability after permeation with a 0.1 M calcium chloride solution (11.1 g CaCl₂ in 1-liter water); for termination criterion see § 5.6.1

(7) Value represents the minimum percent strength retained from the as-manufactured value after oven aging at 60°C for 50 days

(8) Durability criteria should follow the appropriate specification for the geomembrane type used; i.e., GRI GM-13 for HDPE, GRI GM-17 for LLDPE or GRI GM-18 for fPP

Table 1(b) – Specification for Geosynthetic Clay Liners (GCLs)

Property	ASTM Test Method	Reinforced GCL			Non-Reinforced GCL			Testing Frequency
		GT-Related	GT Polymer Coated	GM-GF Related	GT-Related	GT Polymer Coated	GM-GF Related	
<u>Clay (as received)</u>								
swell index (ml/2g)	D5890	24	24	24	24	24	24	50 tonnes
fluid loss (ml) ⁽¹⁾	D5891	18	18	18	18	18	18	50 tonnes
<u>Geotextiles (as received)</u>								
cap fabric (nonwoven) - mass/unit area (oz/yd ²) ⁽²⁾	D5261	5.8	5.8	5.8	3.0	3.0	n/a/3.0	25,000 yd ²
cap fabric (woven) - mass/unit area (oz/yd ²)	D5261	3.0	3.0	3.0	3.0	3.0	3.0	25,000 yd ²
carrier fabric (nonwoven composite) - mass/(oz/yd ²) ⁽²⁾	D5261	5.9	5.9	5.9	3.0	3.0	n/a/3.0	25,000 yd ²
carrier fabric (woven) - mass/unit area (oz/yd ²)	D5261	3.0	3.0	3.0	-	-	-	25,000 yd ²
coating - mass/unit area (oz/yd ²) ⁽³⁾	D5261	n/a	2.9	n/a	n/a	2.9	n/a	5,000 yd ²
<u>Geomembrane/Geofilm (as received)</u>								
thickness ⁽⁴⁾ (mils)	D5199/D5994	n/a	n/a	15/20/4	n/a	n/a	15/30/4	25,000 yd ²
density (g/cc)	D1505/D792	n/a	n/a	0.92	n/a	n/a	0.92	25,000 yd ²
break tensile strength, MD&XMD (lb/in.)	D6693	n/a	n/a	n/a	n/a	n/a	34	25,000 yd ²
break tensile strength, MD & XMD (lb/in.)	D882	n/a	n/a	14	n/a	n/a	14	25,000 yd ²
<u>GCL (as manufactured)</u>								
mass of GCL (lb/ft ²) ⁽⁵⁾	D5993	0.81	0.83	0.84	0.81	0.83	0.84	5,000 yd ²
mass of bentonite (lb/ft ²) ⁽⁵⁾	D5993	0.75	0.75	0.75	0.75	0.75	0.75	5,000 yd ²
moisture content ⁽¹⁾ (%)	D5993	35	35	35	35	35	35	5,000 yd ²
tensile str., MD (lb/in.)	D6768	23	23	23	23	23	23	25,000 yd ²
peel strength (lb/in.)	D6496	2.1	2.1	2.1	1.0	1.0	1.0	5,000 yd ²
permeability ⁽¹⁾ (cm/sec), “or”	D5887	5×10^{-9}	n/a	n/a	5×10^{-9}	n/a	n/a	30,000 yd ²
flux ⁽¹⁾ (cm ³ /sec-cm ²),	D5887	1×10^{-6}	n/a	n/a	1×10^{-6}	n/a	n/a	30,000 yd ²
GCL permeability ^{(1),(6)} (cm/sec) (max. at 5 lb/in. ²)	D6766	1×10^{-6}	n/a	n/a	1×10^{-6}	n/a	n/a	yearly
GCL permeability ^{(1),(6)} (cm/sec) (max. at 70 lb/in. ²)	D6766 mod.	5×10^{-8}	n/a	n/a	5×10^{-8}	n/a	n/a	yearly
<u>Component Durability</u>								
geotextile and reinforcing yarns ⁽⁷⁾ (% strength retained)	See § 5.6.2	65	65	n/a	65	65	n/a	yearly
geomembrane	See § 5.6.3	n/a	n/a	GM Spec ⁽⁸⁾	n/a	n/a	GM Spec ⁽⁸⁾	yearly
geofilm/polymer treated ⁽⁷⁾ (% strength retained)	See § 5.6.4	n/a	85	80	n/a	85	80	yearly

n/a = not applicable with respect to this property :

(1) These values are maximum (all others are minimum)

 (2) For both cap and carrier fabrics for nonwoven reinforced GCLs; one, or the other, must contain a scrim component of mass > 2.9 oz/yd² for dimensional stability. This only applies to GM/GCL composites which are exposed to the atmosphere for several months or longer so as to mitigate panel separation.

(3) Calculated value obtained from difference of coated fabric to as-received fabric

(4) First value is for smooth geomembrane; second for textured geomembrane; third for geofilm

(5) Mass of the GCL and bentonite is measured after oven drying per the stated test method

 (6) Value represents GCL permeability after permeation with a 0.1 M calcium chloride solution (11.1 g CaCl₂ in 1-liter water); termination criterion see § 5.6.1.

(7) Value represents the minimum percent strength retained from the as-manufactured value after oven aging at 60°C for 50 days

(8) Durability criteria should follow the appropriate specification for the geomembrane used; i.e., GRI GM-13 for HDPE, GRI GM-17 for LLDPE or GRI GM-18 for fPP