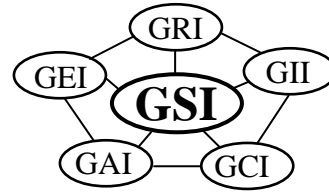


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GRI Test Method GM28**

Standard Specification for

“Test Methods, Test Properties and Testing Frequencies for Reinforced Chlorosulfonated Polyethylene (CSPE-R) Geomembranes”

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 It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part.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 reinforced chlorosulfonated polyethylene (CSPE-R) geomembranes in thicknesses of 0.91 mm (36 mils), 1.14 mm (45 mils) and 1.52 mm (60 mils).

Note 1: This specification covers only scrim reinforced CSPE geomembranes. On the rare occasion that it is non-reinforced, the closest GRI specification is for flexible polypropylene geomembranes which is GRI-GM18.

- 1.2 This specification sets forth a set of physical, mechanical and endurance properties that must be met or exceeded by the geomembrane being manufactured.
- 1.3 In the context of quality systems and management, this specification represents manufacturing quality control (MQC).

Note 2: Manufacturing quality control represents those actions taken by a manufacturer to ensure that the product represents the stated objective and properties set forth in this specification.

*This Registered 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 five-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 standard specification is intended to ensure good quality and performance of CSPE-R geomembranes in general applications, but may not be adequate for the complete specification of a specific situation. Additional tests, or more restrictive values for the tests indicated, may be necessary under conditions of a particular application.
- 1.5 This specification covers the final product of CSPE-R geomembranes, recognizing that the manufactured rolls have been fabricated into panels before shipment to the field. Fabrication, as such is not included in the specification.
- 1.6 This specification does not cover field installation considerations which are independent of the manufacturing of the geomembrane.

Note 3: For information on installation techniques, users of this standard are referred to the geosynthetics literature which is abundant on the subject, e.g., U.S. EPA and ASCE. In addition the DuPont Company (producers of CSPE resin) have an internal installation guide, i.e., SC5P.

2. Referenced Documents

2.1 ASTM Standards

- D 751 Test Methods for Coated Fabrics
- D1204 Test Method for Linear Dimensional Changes of Nonrigid Thermoplastic Sheeting or Film at Elevated Temperature
- D 1603 Test Method for Carbon Black in Olefin Plastics
- D 2136 Test Method for Coated Fabrics – Low Temperature Bend Test
- D 4218 Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique
- D 4833 Test Method for Index Puncture Resistance of Geotextiles, Geomembranes and Related Products
- D 4873 Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples
- 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 5884 Test Method for Determining the Tearing Strength of Internally Reinforced Geomembranes
- D 6636 Determination of Ply Adhesion Strength of Reinforced Geomembranes
- D 7004 Test Method for Garb Tensile Properties of Reinforced Geomembranes
- D 7238 Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembrane Using Fluorescent UV Condensation Apparatus
- D 7747 Test Method for Determining Integrity of Seams Produced Using Thermofusion Methods for Reinforced Geomembranes by the Strip Tensile Method

D 7865 Guide for Identification, Packaging, Handling, Storage and Deployment of Fabricated Geomembrane Panels

2.2 GRI Standards

- GM 7 Test Method for Accelerated Curing of Geomembrane Test Strip Seams Made by Chemical Fusion Methods
- GM 16 Test Method for Observation of Surface Cracking of Geomembranes
- GM 18 Specification for Test Methods, Test Properties and Testing Frequencies for Flexible Polypropylene Nonreinforced (fPP) and Reinforced (fPP-R) Geomembranes
- GM 19 Specification for Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes
- GM 23 Test Method for Laboratory and/or Field Observation of Surface Chalking of Flexible Polypropylene Geomembranes

2.3 duPont Co. Standard (depreciated)

- SC5P Flexible Geomembrane Liners: Installation, Inspection, and Testing (contact J. Guglielmetti at john.l.guglielmetti@usa.dupont.com for information)

2.4 Other References

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.

Daniel, D. E. and Koerner, R. M. (2007), "Waste Containment Facilities: Guidances for CQA and CQC of Liner and Cover Systems, ASCE, Reston, VA, 352 pgs.

3. Definitions (ref. EPA/600/R-93/182)

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.

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.

cont.

Construction Quality Control (CQC) - A planned system of inspections that is used directly to monitor and control the quality of a construction project. Construction quality control is normally performed by the geosynthetics installer or, for natural soil materials, by the earthwork contractor and is necessary to achieve quality in the constructed or installed system. 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.

Construction Quality Assurance (CQA) - A planned system of activities that provides the owner and permitting agency assurance that the facility was constructed as specified in the design. Construction quality assurance includes inspections, verifications, audits, and evaluations of materials and workmanship necessary to determine and document the quality of the constructed facility. 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.

4. Material Classification and Formulation

4.1 This specification covers reinforced chlorosulphonated polyethylene geomembranes which are scrim reinforced, hence the designation CSPE-R.

4.2 Formulation Details

4.2.1 The formulation used for the manufacturer of the geomembrane shall contain at least 45% CSPE and at most 60% CSPE. The formulation shall contain 5 to 36% by weight carbon black. Fillers (clay or calcium carbonate) may be included up to 25 to 35% by weight. Additives may also be included, e.g., magnesium oxide or magnesium hydroxide for potable water grade.

4.2.2 The blending, compounding, mixing and/or masticating equipment must be clean and completely purged from previously mixed materials of a different formulation. Before the formulation is extruded, it must be completely homogenized. Segregation, agglomeration, streaking, or discoloration that negatively affects the required physical or mechanical properties shall not be permitted.

4.3 The chlorosulphonated polyethylene resin shall be virgin material with no more than 10% rework. If rework is used, it must be an approved formulation similar to the parent material. The rework cannot contain any scrim material whatsoever.

- 4.4 No post-consumer resin (PCR) of any type shall be added to the formulation.
- 4.5 For reinforced chlorosulphonated polyethylene geomembranes, a fabric reinforcement (also called “scrim”) shall be sandwiched between plies of the parent resin so as to result in the desired specification values to be presented in the next section.

Note 4: The reinforcing fabric will be encapsulated between layers of CSPE geomembrane to create a single sheet of reinforced CSPE (CSPE-R). In the depreciated duPont standard they stipulated for three-ply construction, 10 × 10, 1000 denier polyester fabric with an open weave will be fully encapsulated between two sheets of CSPE geomembrane. In five-ply construction, two layers of 8 × 8, 25 denier polyester fabric will be encapsulated within three sheets of CSPE geomembrane. There are, however, other weave configurations and fiber strengths that are permitted provided they meet the specified properties in Table 1.

- 4.6 The CSPE-R geomembrane shall meet all of the requirements of Table 1. The scrim reinforcing fabric shall extend to within 12 mm (0.5 in.) of the sheet edge thus leaving 12 mm (0.5 in.) of selvage, which is CSPE ply directly on CSPE ply with no fabric between. A tolerance of 6 mm (0.25 in.) in either direction is permissible.

5. Physical, Mechanical and Endurance Property Requirements

- 5.1 The geomembrane shall conform to the test property requirements prescribed in Tables 1(a) and 1(b). Table 1(a) is in U. S. Standard units and Table 1(b) is in SI (metric) units. The conversion from U. S. Standard to SI (metric) units is soft. It is to be understood that the table refers to the latest revision of the referenced test methods and practices.

Note 5: There are several tests that could have been included in this specification which are omitted because it is felt that they are outdated, irrelevant, or generate information that is not necessary to evaluate the manufactured product on a routine MQC basis. The following tests have been purposely omitted:

• Volatile Loss	• Ozone Resistance
• Coef. of Linear Expansion	• Modulus of Elasticity
• Resistance to Soil Burial	• Hydrostatic Resistance
• Low Temperature Impact	• Tensile Impact
• Wide Width Tensile	• Field Seam Strength
• Water Vapor Transmission	• Mullen Burst
• Carbon Black Dispersion	• Various Toxicity Tests
• Water Absorption	• Oxidative Induction Time

Note 6: There is one incubation method which is included in this standard because it is relevant and important in the context of current manufacturing processes.

- Ultraviolet Resistance by UV Fluorescent Method

Note 7: There are other tests in this standard, focused on a particular property, which are updated from the original DuPont specification to current standards. The following are in this category:

- Tensile Strength Properties
- Mass per Unit Area
- Thickness
- Tear Resistance
- Puncture Resistance
- Ply Adhesion

Note 8: There are several GRI tests currently included in this standard. Since these topics are not covered in ASTM standards, this is necessary. They are the following:

- Surface Cracking
- Surface Chalking

5.2 Details of the endurance-related procedure, i.e., the UV Fluorescent Method per ASTM D7238 (mod. to 70°C) incubation procedure, are as follows:

This simulated weathering exposure device uses UV fluorescent tubes at 0.78 (W/(m²·nm)) with 340 nm wavelength bulbs (UVA-340) and measures the change in properties of the removed test specimens. The cycle is set to provide 24 hour cycles as follows: 20 hours UV cycle at 70°C followed by 4 hour condensation at 60°C. This procedure requires an initial and unexposed determination of the as-received properties, i.e., before incubation. The reinforced specimens are evaluated for their cracking and chalking behavior. If applicable, the nonreinforced specimens are evaluated for their retained strength and elongation behavior.

Note 9: The 20,000 light hour exposure time (24,000 total hours = 2.74 years) is admittedly long, however, is felt to be in keeping with both nonexposed and exposed applications of fPP and fPP-R geomembranes.

Note 10: At an irradiance level of 0.78 W/(m²·nm) and at 340 nm wavelength, the radiant exposure (RE) of a successful geomembrane passing 20,000 light hours is as follows:

$$\begin{aligned} RE &= 0.78 \times 20,000 (60 \times 60) \times (1/1000) \\ &= 56,160 \text{ kJ}/(\text{m}^2 \cdot \text{nm}) \text{ at } 340 \text{ nm} \end{aligned}$$

- 5.3 The various properties of the CSPE-R geomembranes shall be tested at the minimum frequencies shown in Table 1. If the specific manufacturer's quality control guide is more stringent and is certified accordingly, it must be followed in like manner.

Note 11: This specification is focused on manufacturing quality control (MQC). Conformance testing and manufacturing quality assurance (MQA) testing are at the discretion of the purchaser and/or quality assurance engineer, respectively.

- 5.4 Minimum Average, n. - Many index test methods, such as thickness, mass, puncture, tear, etc., require a number of test readings to be taken across an individual roll or panel immediately after it is manufactured and then averaged accordingly. The particular standard calls out this practice in detail. For a field project, however, many rolls or panels are required and the minimum average is the minimum of all the specific average values of the individual rolls or panels. In this regard, "minimum average" is invariably lower than the "average of the average" values which has sometimes been reported in the past.

6. Workmanship and Appearance

- 6.1 The geomembrane shall be free of holes, blisters, scratches, bubbles and other surface blemishes, undispersed raw materials, or any sign of contamination by foreign matter that would adversely lead to physical or mechanical properties not meeting the specification values of Table 1. There shall be no pinholes, and this shall be confirmed by a pinhole test at the factory by the manufacturer before shipment to the fabricator or field.
- 6.2 There shall be no exposed fabric or indication of delamination. The uniform pattern of the reinforcing fabric shall be reflected on both sides. There will be no knots, gathering of yarns, crossover of yarns, or any other sign of non-uniform or deformed reinforcement.
- 6.3 The geomembrane shall have uniform color, gloss, and surface texture.
- 6.4 General manufacturing procedures shall be performed in accordance with the manufacturer's internal quality control guide and/or documents.

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 or panel width.

- 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. For the entire lot, or complete field project, of rolls or panels the values listed are the minimum average values and are designated as "min. ave." (See Section 5.4 for definition)
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 acceptance 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 geomembrane shall be rolled onto a substantial core or core segments and held firm by dedicated straps/slings, or other suitable means. The rolls must be adequate for safe transportation to the point of delivery which is usually a fabricator of large panels unless otherwise specified in the contract or order. See ASTM D7865 in this regard.
- 9.2 In addition to the above, the geomembrane can also be folded in an accordion manner and placed on a wooden pallet. The entire package is to be protected by a cardboard enclosure and the entire assembly banded together with plastic strapping.
- 9.3 Identify the product per ASTM D4873, which also includes information on storage and handling. Each roll shall have permanently affixed, both inside and outside of the unit, the following information: name of manufacturer, date of manufacture, product information, thickness of the material, roll number, roll length and roll width. Similar information shall be supplied by the fabricator as is appropriate for the situation.
- Note 12: It is considered to be good practice to archive samples of the final geomembrane. At the least, the manufacturer and owner should retain samples along with the "cut sheets" of original physical, mechanical, and endurance testing values. The samples should be stored in a sealed zip-locked polyethylene bag and properly labeled and dated.
10. Certification
- 10.1 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.

Note 13: The authentication that the precise formulation of the material shipped to the job site is the same as that originally tested should be communicated between the parties involved. By precise formulation is meant the type and amount of resin(s), as well as the types and amounts of all additives; recall Section 4.2.1.

Note 14: The authentication and certification of the test methods, procedures, and resulting values of any or all properties in Table 1 should be communicated between the parties involved. This can be between any, or all, of the following; manufacturer, fabricator, specifier, purchaser, owner, and/or regulator.

U. S. Standard Units

Table 1(a) – Reinforced Chlorosulphonated Polyethylene (CSPE-R) Geomembranes

Property	Test Method ASTM or GRI	CSPE-R 36 mils	CSPE-R 45 mils	CSPE-R 60 mil	Testing Frequency (minimum)
Mass per Unit Area – lb/ft ² (min. ave.)	D5261	0.15	0.18	0.24	15,000 lb
Thickness – mils (min. ave.) • lowest individual specimen – mils, nominal – 10%	D5199	36 32	45 40	60 54	per roll or panel
Tensile Strength ⁽¹⁾ • grab ⁽¹⁾ – lb (min. ave.)	D7004	200	250	300	15,000 lb
Tensile Elongation ⁽²⁾ • grab - % (min. ave.)	D751-A	15	15	15	15,000 lb
Tear Resistance ⁽¹⁾ • reinforced – lb (min. ave.)	D5884	70	70	70	15,000 lb
Puncture Resistance – lb (min. ave.)	D4833	75	85	100	15,000 lb
Ply Adhesion – lb (min. ave.)	D6636	15	15	15	15,00 lb
Low Temperature Flexibility - °F	D2136 ⁽³⁾	-40	-40	-40	per formulation
Dimensional Stability - % change max.	D1204 ⁽⁴⁾	2	2	2	per formulation
Carbon Black Content ⁽⁵⁾ - %	D4218	5-36	5-36	5-36	45,000 lb
Ultraviolet Light Resistance ^(5,6) (a) Surface Cracking Observation after 20,000 light hrs. (b) Surface Chalking (or Powdering) after 20,000 light hrs. } Reinforced (c) % strength retained after 20,000 light hrs. - or - (d) % elongation retained after 20,000 light hrs. } Non-Reinforced	D7238 GM16 GM23 D6693-IV D6693-IV	none minor ≥ 50 ≥ 50			per formulation

(1) Test methods modified to 12 in./min. for reinforced material

(2) Calculation based on a 3.0 in. gage length

(3) Using 1/8 in. mandrel for 4-hours.

(4) Incubated at 100°C ± 1°C for one hour.

(5) Applicable only to black geomembranes. Also D1603 is an acceptable method to determine carbon black content.

(6) The conditions of the UV Fluorescent exposure method should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(7) See Section 5.2 for fPP-R geomembranes.

Table 1(b) – Reinforced Chlorosulphonated Polyethylene (CSPE-R) Geomembranes

Property	Test Method ASTM or GRI	CSPE-R 0.91 mm	CSPE-R 1.14 mm	CSPE-R 1.52 mm	Testing Frequency (minimum)
Mass per Unit Area – kg/m ² (min. ave.)	D5261	0.73	0.88	1.17	7500 kg
Thickness – mils (min. ave.) • lowest individual specimen – mils, (nominal – 10%)	D5199	0.91 0.82	1.14 1.03	1.52 1.37	per roll or panel
Tensile Strength • grab ⁽¹⁾ – N (min. ave.)	D7004	890	1110	1340	7500 kg
Tensile Elongation • grab ⁽¹⁾ - % (min. ave.)	D751-A	15	15	15	7500 kg
Tear Resistance • reinforced ⁽¹⁾ – N (min. ave.)	D5884	315	315	315	7500 kg
Puncture Resistance – N (min. ave.)	D4833	330	380	440	7500 kg
Ply Adhesion – N (min. ave.)	D6636	65	65	65	7500 kg
Low Temperature Flexibility - °C	D2136 ⁽³⁾	-40	-40	-40	per formulation
Dimensional stability - % change max.	D1204 ⁽⁴⁾	2	2	2	per formulation
Carbon Black Content ⁽⁵⁾ - %	D4218	5-36	5-36	5-36	22,000 kg
Ultraviolet Light Resistance ^(5,6) (a) Surface Cracking Observation after 20,000 light hrs. (b) Surface Chalking (or Powdering) after 20,000 light hrs. (c) % strength retained after 20,000 light hrs. - or - (d) % elongation retained after 20,000 light hrs.	D7238 GM16 GM23 D6693-IV D6693-IV	none minor ≥ 50 ≥ 50			per formulation

(1) Test methods modified to 500 mm/min. for unreinforced and 12 in./min. for reinforced material

(2) Calculation based on a 50 mm gage length

(3) Using 32 mm mandrel for 4-hours.

(4) Incubated at 100°C ± 1°C for one hour.

(5) Applicable only to black geomembranes. Also D1603 is an acceptable method to determine carbon black content.

(6) The conditions of the UV Fluorescent exposure method should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(7) See Section 5.2 for fPP-R geomembranes.

Adoption and Revision Schedule
for
CSPE-R Specification per GRI-GM28

“Test Properties, Testing Frequency and Recommended Warrant for Chlorosulphonated Polyethylene (CSPE-R) Reinforced Geomembranes”

Adopted: September 16, 2013