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GRI - GM13 Standard Specification*

for

"Test Methods, Test Properties and Testing Frequency for
High Density Polyethylene (HDPE) Smooth and Textured Geomembranes" SM

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1. Scope

1.1 This specification covers high density polyethylene (HDPE) geomembranes with a formulated sheet density of 0.940 g/cc or higher, in the thickness range of 0.75 mm (30 mils) to 3.0 mm (120 mils). Both smooth and textured geomembrane surfaces are included, as shown in Figure 1.



Figure 1 – Photograph of GRI-GM13 HDPE Geomembrane Coupons

*This GRI standard specification 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 and it is kept current on the Institute's Website <<geosynthetic-institute.org>> **Copyright © 2017 Geosynthetic Institute - All Rights Reserved**

1.2 This specification sets forth a set of minimums, physical, mechanical and chemical properties that must be met, or exceeded by the geomembrane being manufactured. In a few cases a range is specified.

1.3 In the context of quality systems and management, this specification represents manufacturing quality control (MQC).

Note 1: 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.

1.4 This standard specification is intended to ensure good quality and performance of HDPE geomembranes in general applications, but is possibly not adequate for the complete specification in a specific situation. Additional tests, or more restrictive values for test indicated, may be necessary under conditions of a particular application.

Note 2: For information on installation techniques, users of this standard are referred to the geosynthetics literature, which is abundant on the subject.

2. Referenced Documents

2.1 ASTM Standards

D 792 Specific Gravity (Relative Density) and Density of Plastics by Displacement
D 1004 Test Method for Initial Tear Resistance of Plastics Film and Sheeting
D 1238 Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer
D 1505 Test Method for Density of Plastics by the Density-Gradient Technique
D 1603 Test Method for Carbon Black in Olefin Plastics
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 5199 Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes
D 5397 Procedure to Perform a Single Point Notched Constant Tensile Load – (SP-NCTL) Test: Appendix
D 5596 Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics
D 5721 Practice for Air-Oven Aging of Polyolefin Geomembranes
D 5885 Test method for Oxidative Induction Time of Polyolefin Geosynthetics by High Pressure Differential Scanning Calorimetry
D 5994 Test Method for Measuring the Core Thickness of Textured Geomembranes
D 6370 Standard Test Method for Rubber-Compositional Analysis by Thermogravimetry (TGA)

D 6693 Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes
D 7238 Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembrane Using Fluorescent UV Condensation Apparatus
D 7466 Test Method for Measuring the Asperity Height of Textured Geomembranes
D 8117 Standard Test Method for Oxidative Induction Time of Polyolefin Geosynthetics by Differential Scanning Calorimetry

22 GRI Standards

GM10 Specification for the Stress Crack Resistance of Geomembrane Sheet

23 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.

3. Definitions

3.1 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

3.2 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

3.3 Formulation - The mixture of a unique combination of ingredients identified by type, properties and quantity. For HDPE polyethylene geomembranes, a formulation is defined as the exact percentages and types of resin(s), additives and carbon black.

3.4 Nominal - Representative value of a measurable property determined under a set of conditions, by which a product may be described. Abbreviated as nom. in Tables 1 and 2.

4. Material Classification and Formulation

4.1 This specification covers high density polyethylene geomembranes with a formulated sheet density of 0.940 g/cc or higher. Density can be measured by ASTM D1505 or ASTM D792. If the latter, Method B is recommended.

4.2 The polyethylene resin from which the geomembrane is made will generally be in the density range of 0.932 g/cc or higher, and have a melt index value per ASTM D1238 of less than 1.0 g/10 min.

4.3 The resin shall be virgin material with no more than 10% rework. If rework is used, it must be a similar HDPE as the parent material.

4.4 No post-consumer resin (PCR) of any type shall be added to the formulation

5. Physical, Mechanical and Chemical Property Requirements

5.1 The geomembrane shall conform to the test property requirements prescribed in Tables 1 and 2. Table 1 is for smooth HDPE geomembranes and Table 2 is for single and double-sided textured HDPE geomembranes. Each of the tables are given in English and SI (metric) units. The conversion from English to SI (metric) is soft.

Note 3: The tensile strength properties in this specification were originally based on ASTM D 638 which uses a laboratory testing temperature of 23°C ± 2°C. Since ASTM Committee D35 on Geosynthetics adopted ASTM D 6693 (in place of D 638), this GRI Specification followed accordingly. The difference is that D 6693 uses a testing temperature of 21°C ± 2°C. The numeric values of strength and elongation were not changed in this specification. If a dispute arises in this regard, the original temperature of 23°C ± 2°C should be utilized for testing purposes.

Note 4: There are several tests often included in other HDPE specifications which are omitted from this standard because they are outdated, irrelevant or generate information that is not necessary to evaluate on a routine MQC basis. The following tests have been purposely omitted:

- Volatile Loss
- Dimensional Stability
- Coeff. Of Linear Expansion
- Resistance to Soil Burial
- Low Temperature Impact
- ESCR Test (D1693)
- Wide Width Tensile
- Water Vapor Transmission
- Water absorption
- Ozone Resistance
- Modulus of Elasticity
- Hydrostatic Resistance
- Tensile Impact
- Field Seam Strength
- Multi-Axial Burst
- Various Toxicity Tests

Note 5: There are several tests which are included in this standard (that are not customarily required in other HDPE specifications) because they are relevant and important in the context of current manufacturing processes. The following tests have been purposely added:

- Oxidative Induction Time
- Oven Aging
- Ultraviolet Resistance
- Asperity Height of Textured Sheet - (see Note 6)

Note 6: The minimum average value of asperity height does not represent an expected value of interface shear strength. Shear Strength associated with geomembranes is both site-specific and product-specific and should be determined by direct shear testing using ASTM D5321/ASTM D6243 as prescribed. This testing should be included in the particular site's CQA conformance testing protocol for the geosynthetic materials involved, or formally waived by the Design Engineer, with concurrence from the Owner prior to the deployment of the geosynthetic materials.

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

- Thickness of Textured Sheet
- Puncture Resistance
- Stress Crack Resistance
- Carbon Black Dispersion (In the viewing and subsequent quantitative interpretation of ASTM D 5596 only near spherical agglomerates shall be included in the assessment).

5.2 The values listed in the tables of this specification are to be interpreted according to the designated test method. In this respect they are neither minimum average roll values (MARV) nor maximum average roll values (MaxARV).

5.3 The properties of the HDPE geomembrane shall be tested at the minimum frequencies shown in Tables 1 and 2. If the specific manufacturer's quality control guide is more stringent and is certified accordingly, it must be followed in like manner.

Note 8: 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.

6. Workmanship and Appearance

6.1 Smooth geomembrane shall have good appearance qualities. It shall be free from such defects that would affect the specified properties of the geomembrane.

6.2 Textured geomembrane shall generally have uniform texturing appearance. It shall be free from agglomerated texturing material and such defects that would affect the specified properties of the geomembrane. 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 Tables 1 and 2. If no sampling protocol is stipulated in the particular test method, then test specimens shall be taken evenly spaced across the entire roll width.

7.2 The number of tests shall be in accordance with the appropriate test methods listed in Tables 1 and 2.

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."

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 Marketing

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, unless otherwise specified in the contract or order.

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.

U.S. (Standard) Units

Table 1(a) – High Density Polyethylene (HDPE) Geomembrane -Smooth

Properties	Test Method	Test Value							Testing Frequency (minimum)
		30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils	
Thickness (min. ave.) - mils	D5199	nom.	nom.	nom.	nom.	nom.	nom.	nom.	per roll
• lowest individual of 10 values - %		-10	-10	-10	-10	-10	-10	-10	
Formulated Density (min. ave.) - g/cc	D 1505/D 792	0.940	0.940	0.940	0.940	0.940	0.940	0.940	200,000 lb
Tensile Properties *(1)* (min. ave.)	D 6693								20,000 lb
• yield strength - lb/in.	Type IV	63	84	105	126	168	210	252	
• break strength - lb/in.		114	152	190	228	304	380	456	
• yield elongation - %		12	12	12	12	12	12	12	
• break elongation - %		700	700	700	700	700	700	700	
Tear Resistance (min. ave.) - lb	D 1004	21	28	35	42	56	70	84	45,000 lb
Puncture Resistance (min. ave.) - lb	D 4833	54	72	90	108	144	180	216	45,000 lb
Stress Crack Resistance *(2)* - hr.	D5397 (App.)	500	500	500	500	500	500	500	per GRI-GM10
Carbon Black Content (range) - %	D 4218 *(3)*	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	20,000 lb
Carbon Black Dispersion	D 5596	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	45,000 lb
Oxidative Induction Time (OIT) (min. ave.) *(5)*									200,000 lb
(a) Standard OIT - min.	D 8117	100	100	100	100	100	100	100	
— or —									
(b) High Pressure OIT - min.	D 5885	400	400	400	400	400	400	400	
Oven Aging at 85°C *(5), (6)*	D 5721								
(a) Standard OIT (min. ave.) - % retained after 90 days	D 8117	55	55	55	55	55	55	55	per each formulation
— or —									
(b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5885	80	80	80	80	80	80	80	
UV Resistance *(7)*	D 7238								
(a) Standard OIT (min. ave.)	D 8117	N.R. *(8)*	N.R. *(8)*	N.R. *(8)*	N.R. *(8)*	N.R. *(8)*	N.R. *(8)*	N.R. *(8)*	per each formulation
— or —									
(b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(9)*	D 5885	50	50	50	50	50	50	50	

(1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
Yield elongation is calculated using a gage length of 1.3 inches
Break elongation is calculated using a gage length of 2.0 in.

(2) The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.

(3) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.

(4) Carbon black dispersion (only near spherical agglomerates) for 10 different views: 9 in Categories 1 or 2 and 1 in Category 3

(5) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(6) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(7) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(8) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

S.I. (Metric) Units

Table 1(b) – High Density Polyethylene (HPDE) Geomembrane - Smooth

Properties	Test Method	Test Value							Testing Frequency (minimum)
		0.75 mm	1.00 mm	1.25 mm	1.50 mm	2.00 mm	2.50 mm	3.00 mm	
Thickness - (min. ave.) - mm	D5199	nom.	nom.	nom.	nom.	nom.	nom.	nom.	per roll
• lowest individual of 10 values - %		-10	-10	-10	-10	-10	-10	-10	
Formulated Density (min. ave.) - g/cc	D 1505/D 792	0.940	0.940	0.940	0.940	0.940	0.940	0.940	90,000 kg
Tensile Properties *(1)* (min. ave.)	D 6693								9,000 kg
• yield strength - kN/m	Type IV	11	15	18	22	29	37	44	
• break strength - kN/m		20	27	33	40	53	67	80	
• yield elongation - %		12	12	12	12	12	12	12	
• break elongation - %		700	700	700	700	700	700	700	
Tear Resistance (min. ave.) - N	D 1004	93	125	156	187	249	311	374	20,000 kg
Puncture Resistance (min. ave.) - N	D 4833	240	320	400	480	640	800	960	20,000 kg
Stress Crack Resistance *(2)* - hr.	D 5397 (App.)	500	500	500	500	500	500	500	per GRI GM-10
Carbon Black Content (range) - %	D 4218 *(3)*	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	9,000 kg
Carbon Black Dispersion	D 5596	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	20,000 kg
Oxidative Induction Time (OIT) (min. ave.) *(5)*									90,000 kg
(a) Standard OIT - min.	D 8117	100	100	100	100	100	100	100	
— or —									
(b) High Pressure OIT - min.	D 5885	400	400	400	400	400	400	400	
Oven Aging at 85°C *(5), (6)*	D 5721								
(a) Standard OIT (min. ave.) - % retained after 90 days	D 8117	55	55	55	55	55	55	55	per each formulation
— or —									
(b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5885	80	80	80	80	80	80	80	
UV Resistance *(7)*	D 7238								
(a) Standard OIT (min. ave.)	D 8117	N. R. *(8)*	N.R. *(8)*	N.R. *(8)*	N.R. *(8)*	N.R. *(8)*	N.R. *(8)*	N.R. *(8)*	per each formulation
— or —									
(b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(9)*	D 5885	50	50	50	50	50	50	50	

(1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction
Yield elongation is calculated using a gage length of 33 mm
Break elongation is calculated using a gage length of 50 mm

(2) The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.

(3) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.

(4) Carbon black dispersion (only near spherical agglomerates) for 10 different
views: 9 in Categories 1 or 2 and 1 in Category 3

(5) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(6) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(7) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(8) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

U.S. (Standard) Units

Table 2(a) – High Density Polyethylene (HDPE) Geomembrane - Textured

Properties	Test Method	Test Value							Testing Frequency (minimum)
		30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils	
Thickness for Textured Area of Sheet (min. ave.) - mils	D 5994	nom. -5%	nom. -5%	nom. -5%	nom. -5%	nom. -5%	nom. -5%	nom. -5%	per roll
• lowest individual for 8 out of 10 values - %		-10	-10	-10	-10	-10	-10	-10	
• lowest individual for any of the 10 values - %		-15	-15	-15	-15	-15	-15	-15	
Thickness for weld edges (if applicable) (min. individual specimen) *(1)*	D 5199 modified	nom -10%	nom -10%	nom -10%	nom -10%	nom -10%	nom -10%	nom -10%	per roll
Asperity Height mils (min. ave.) - mils	D 7466	16	16	16	16	16	16	16	every 2nd roll *(2)*
Formulated Density (min. ave.) - g/cc	D 1505/D 792	0.940	0.940	0.940	0.940	0.940	0.940	0.940	200,000 lb
Tensile Properties (min. ave.) *(3)*	D 6693 Type IV								20,000 lb
• yield strength - lb/in.		63	84	105	126	168	210	252	
• break strength - lb/in.		45	60	75	90	120	150	180	
• yield elongation - %		12	12	12	12	12	12	12	
• break elongation - %		100	100	100	100	100	100	100	
Tear Resistance (min. ave.) - lb	D 1004	21	28	35	42	56	70	84	45,000 lb
Puncture Resistance (min. ave.) - lb	D 4833	45	60	75	90	120	150	180	45,000 lb
Stress Crack Resistance *(4)* - hr.	D 5397 (App.)	500	500	500	500	500	500	500	per GRI GM10
Carbon Black Content (range) - %	D 4218 *(5)*	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	20,000 lb
Carbon Black Dispersion	D 5596	note *(6)*	note *(6)*	note *(6)*	note *(6)*	note *(6)*	note *(6)*	note *(6)*	45,000 lb
Oxidative Induction Time (OIT) (min. ave.) *(7)*									200,000 lb
(a) Standard OIT - min.	D 8117	100	100	100	100	100	100	100	
— or —									
(b) High Pressure OIT - min.	D 5885	400	400	400	400	400	400	400	
Oven Aging at 85°C *(7), (8)*	D 5721								
(a) Standard OIT (min. ave.) - % retained after 90 days	D 8117	55	55	55	55	55	55	55	per each formulation
— or —									
(b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5885	80	80	80	80	80	80	80	
UV Resistance *(9)*	D 7238								
(a) Standard OIT (min. ave.)	D 8117	N.R. *(10)*	N.R. *(10)*	N.R. *(10)*	N.R. *(10)*	N.R. *(10)*	N.R. *(10)*	N.R. *(10)*	per each formulation
— or —									
(b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(11)*	D 5885	50	50	50	50	50	50	50	

(1) For textured geomembrane with a smooth weld edge, one specimen should be taken from each edge within 6" or 150mm of the edge of the geomembrane sheet. These individual specimen values should be reported separately from the textured geomembrane sheet thickness

(2) Alternate the measurement side for double sided textured sheet

(3) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
Yield elongation is calculated using a gage length of 1.3 inches
Break elongation is calculated using a gage length of 2.0 inches

(4) SP-NCTL per ASTM D5397 Appendix, is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials.
The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.

(5) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D4218 (muffle furnace) can be established.

(6) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3

(7) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(8) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(9) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(10) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(11) UV resistance is based on percent retained value regardless of the original HP-OIT value.

S.I. (Metric) Units

Table 2(b) – High Density Polyethylene (HDPE) Geomembrane - Textured

Properties	Test Method	Test Value							Testing Frequency (minimum)
		0.75 mm	1.00 mm	1.25 mm	1.50 mm	2.00 mm	2.50 mm	3.00 mm	
Thickness for Textured Area of Sheet (min. ave.) - mm	D 5994	nom. -5%	nom. -5%	nom. -5%	nom. -5%	nom. -5%	nom. -5%	nom. -5%	per roll
• lowest individual for 8 out of 10 values - %		-10	-10	-10	-10	-10	-10	-10	
• lowest individual for any of the 10 values - %		-15	-15	-15	-15	-15	-15	-15	
Thickness for weld edges (if applicable) (min. individual specimen *(1)*	D 5199 modified	nom. -10%	nom. -10%	nom. -10%	nom. -10%	nom. -10%	nom. -10%	nom. -10%	per roll
Asperity Height mils (min. ave.) - mm	D 7466	0.40	0.40	0.40	0.40	0.40	0.40	0.40	every 2nd roll *(2)*
Formulated Density (min. ave.) - g/cc	D 1505/D792	0.940	0.940	0.940	0.940	0.940	0.940	0.940	90,000 kg
Tensile Properties (min. ave.) *(3)*	D 6693								9,000 kg
• yield strength - kN/m	Type IV	11	15	18	22	29	37	44	
• break strength - kN/m		8	10	13	16	21	26	32	
• yield elongation - %		12	12	12	12	12	12	12	
• break elongation - %		100	100	100	100	100	100	100	
Tear Resistance (min. ave.) - N	D 1004	93	125	156	187	249	311	374	20,000 kg
Puncture Resistance (min. ave.) - N	D 4833	200	267	333	400	534	667	800	20,000 kg
Stress Crack Resistance *(4)* - hr.	D 5397 (App.)	500	500	500	500	500	500	500	per GRI GM10
Carbon Black Content (range) - %	D 4218 *(5*	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	9,000 kg
Carbon Black Dispersion	D 5596	note *(6)*	note *(6)*	note *(6)*	note *(6)*	note *(6)*	note *(6)*	note *(6)*	20,000 kg
Oxidative Induction Time (OIT) (min. ave.)*(7)*									90,000 kg
(a) Standard OIT - min.	D 8117	100	100	100	100	100	100	100	
— or —									
(b) High Pressure OIT - min.	D 5885	400	400	400	400	400	400	400	
Oven Aging at 85°C *(7), (8)*	D 5721								
(a) Standard OIT (min. ave.) - % retained after 90 days	D 8117	55	55	55	55	55	55	55	per each formulation
— or —									
(b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5885	80	80	80	80	80	80	80	
UV Resistance *(9)*	D 7238								
(a) Standard OIT (min. ave.)	D 8117	N.R. *(10)*	N.R. *(10)*	N.R. *(10)*	N.R. *(10)*	N.R. *(10)*	N.R. *(10)*	N.R. *(10)*	per each formulation
— or —									
(b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(11)*	D 5885	50	50	50	50	50	50	50	

(1) For textured geomembrane with a smooth weld edge, one specimen should be taken from each edge within 6" or 150mm of the edge of the geomembrane sheet. These individual specimen values should be reported separately from the textured geomembrane sheet thickness

(2) Alternate the measurement side for double sided textured sheet

(3) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
Yield elongation is calculated using a gage length of 33 mm
Break elongation is calculated using a gage length of 50 mm

(4) The SP-NCTL test is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials.
The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.

(5) Other methods such as D1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D4218 (muffle furnace) can be established.

(6) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3

(7) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(8) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(9) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(10) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(11) UV resistance is based on percent retained value regardless of the original HP-OIT value

APPENDIX

"Seam Strength and Related Properties of Thermally Bonded HDPE Geomembranes Covered Under GRI-GM 13 Specification" SM

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 addresses the required strength and related properties of thermally bonded nonreinforced, high-density polyethylene (HDPE) seams.

1.2 It must be clearly stated that the geomembrane installer is responsible for seam requirements contained within the appendix to this specification. Furthermore, there are no implications or impacts towards the geomembrane manufacturer as a result of this appendix.

1.3 Numeric values of seam strength and related properties are specified in both shear and peel modes per ASTM D6392.

1.4 The thermal bonding methods focused upon are hot wedge (single and dual track) and extrusion fillet. Other acceptable, but less frequently used, methods of seaming are hot air and ultrasonic methods. They are inferred as being a subcategory of hot wedge seaming.

1.5 This specification does not suggest a specific distance between destructive seam samples to be taken in the field, i.e., the sampling interval. Two separate GRI Standard Practices are focused on this issue, see GRI-GM14 and GRI-GM20.

1.6 This specification is only applicable to laboratory, not field testing, where environmental controls are within ASTM D6392 tolerances.

1.7 This specification 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. Reference Documents

2.1 ASTM Standards

D6392 Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods

2.2 GRI Standards

GM13 Test Properties and Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes

GM14 Guide for Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes

GM20 Guide for Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using Control Charts

2.3 Other References

EPA 600/2.88/052 (NTIS PB-89-129670)
Lining of Waste Containment and Other Containment Facilities

3. Definitions

3.1 Geomembrane, n – An essentially impermeable geosynthetic composed of one or more synthetic sheets used for the purpose of liquid, gas or solid containment.

3.2 Hot Wedge Seaming – A thermal technique which melts the two opposing geomembrane surfaces to be seamed by running a hot metal wedge or knife between them. Pressure is applied to the top or bottom geomembrane, or both, to form a continuous bond. Seams of this type can be made with dual bond tracks separated by a nonbonded gap. These seams are referred to as dual hot wedge seams or double- track seams.

3.3 Hot Air Seaming – This seaming technique introduces high-temperature air or gas between two geomembrane surfaces to facilitate localized surface melting. Pressure is applied to the top or bottom geomembrane, forcing together the two surfaces to form a continuous bond.

3.4 Ultrasonic Seaming - A thermal technique which melts the two opposing geomembrane surfaces to be seamed by running a ultrasonically vibrated metal wedge or knife between them. Pressure is applied to the top or bottom geomembrane, or both, to form a continuous bond. Some seams of this type are made with dual bond tracks separated by a nonbonded gap. These seams are referred to as dual-track seams or double-track seams.

3.5 Extrusion Fillet Seaming – This seaming technique involves extruding molten resin at the edge of an overlapped geomembrane on another to form a continuous bond. A depreciated method called “extrusion flat” seaming extrudes the molten resin between

the two overlapped sheets. In all types of extrusion seaming the surfaces upon which the molten resin is applied must be suitably prepared, usually by a slight grinding or buffing.

4. Significance and Use

4.1 The various methods of field fabrication into homogeneous, nonreinforced, HDPE geomembrane seams are covered in existing ASTM standards mentioned in the referenced document section. What is not covered in those documents is the numeric values of strength and related properties that the completed seam must meet, or exceed. This specification provides this information insofar as minimum, or maximum, property values are concerned when the field fabricated seams are sampled and laboratory tested in shear and peel.

5. Sample and Specimen Preparation

5.1 The spacings for taking field seam samples for destructive testing can be a fixed, or variable, interval or can be statistically related as provided in GRI-GM14 and GRI-GM20. These statistical processes describe a progression from the most restrictive interval of 1 per 500 feet (1 per 150 m) to the complete use and reliance of the electrical leak location survey (ELLS) method. Intermediate between these extremes are variations depending upon the installers experience and performance.

Note 1: The job-specific spacing is decided upon the design engineer or CQA organization.

5.2 The size of field seam samples is to be according to the referenced test method, e.g., ASTM D6392 or site-specific CQA plan.

5.3 The individual test specimens taken from the field seam samples are to be tested according to ASTM D6392. The specimens are to be conditioned prior to testing according to these same test methods and evaluated accordingly to the specification.

6. Assessment of Seam Test Results

6.1 All geomembrane seam should exhibit a ductile failure when tested in shear and peel modes via ASTM D6392. This ductile failure mode is characterized by a slow, gradual tearing of the material at the seam before it completely separates. This contrasts with brittle failure, where the seam breaks suddenly without much deformation. Brittle failures are often associated with conditions like excessive grinding or overheating of the geomembrane during seam preparation or welding. When geomembrane seams fail with ductility, they exhibit a Film tearing bond (FTB). This refers to the requirement that the seam bond is stronger than the parent material, and the geomembrane itself fails in a ductile manner before the seam separates.

6.2 HDPE seams – For HDPE seams (both smooth and textured), the strength of all five out of five 1.0 inch (25 mm) wide strip specimens in shear should meet or exceed the

values given in Tables 3(a) and 3(b). In addition, all five specimens should meet the shear percent elongation values given in Tables 3(a) and 3(b) as calculated by ASTM D6392. For HDPE seams (both smooth and textured), the strength of all five out of five 1.0 in. (25 mm) wide strip specimens tested in peel should meet or exceed the values given in Tables 3(a) and 3(b).

In addition, the peel separation (or incursion) should not exceed the values given in Tables 3(a) and 3(b) for all five out of five specimens. The value shall be based on the proportion of area of separated bond to the area of the original bonding as described in ASTM D6392.

> Note 2: The area of peel separation can occur in a number of nonuniform patterns across the seam width. The estimated dimensions of this separated area is visual and must be done with care and concern. The area must not include squeeze-out which is part of the welding process.

Regarding the locus-of-break patterns of the different seaming methods in shear and peel, the following are unacceptable break codes per their description in ASTM D6392 (in this regard, SIP is an acceptable break code);

Hot Wedge: AD and AD-Brk > 25%
Extrusion Fillet: AD1, AD2 and AD-WLD

> Note 3: Separation-in-plane (SIP) is a locus-of-break where the failure surface propagates within one of the seamed sheets during destructive testing (usually in the peel mode). It is not merely a surface skin effect producing a few ductile fibrils (sometimes called ductile drawdown). SIP is acceptable if the required strength, shear elongation and peel separation criteria are met.

In this regard, five out of five specimens shall result in acceptable break patterns.

7. Retest and Rejection

7.1 If the results of the testing of a sample do not conform to the requirements of this specification, retesting to determine conformance or rejection should be done in accordance with the construction quality control or construction quality assurance plan for the particular site under construction.

8. Certification

8.1 Upon request of the construction quality assurance officer or certification engineer, an installer's certification that the geomembrane was installed and tested in accordance with this specification, together with a report of the test results, shall be furnished at the completion of the installation.

U.S. (Standard) Units

Table 3(a) – Seam Strength and Related Properties of Thermally Bonded Smooth and Textured High Density Polyethylene (HDPE) Geomembranes

Geomembrane Nominal Thickness	30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils
Hot Wedge Seams[1]							
shear strength, lb/in. (minimum)	57	80	100	120	160	200	240
shear elongation at break[2], % (minimum)	50	50	50	50	50	50	50
peel strength, lb/in. (minimum)	45	60	76	91	121	151	181
peel separation, % (maximum)	25	25	25	25	25	25	25
Extrusion Fillet Seams							
shear strength, lb/in.(minimum)	57	80	100	120	160	200	240
shear elongation at break[2], % (minimum)	50	50	50	50	50	50	50
peel strength, lb/in. (minimum)	39	52	65	78	104	130	156
peel separation, % (maximum)	25	25	25	25	25	25	25

Notes for Tables 1(a) and 1(b):

1. Also for hot air and ultrasonic seaming methods
2. Elongation measurements should be omitted for field testing

S.I (Metric) Units

Table 3(b) – Seam Strength and Related Properties of Thermally Bonded Smooth and Textured High Density Polyethylene (HDPE) Geomembranes

Geomembrane Nominal Thickness	0.75 mm	1.0 mm	1.25 mm	1.5 mm	2.0 mm	2.5 mm	3.0 mm
Hot Wedge Seams[1]							
shear strength, N/25 mm. (minimum)	250	350	438	525	701	876	1050
shear elongation at break[2], % (minimum)	50	50	50	50	50	50	50
peel strength, N/25 mm (minimum)	197	263	333	398	530	661	793
peel separation, % (maximum)	25	25	25	25	25	25	25
Extrusion Fillet Seams							
shear strength, N/25 mm (minimum)	250	350	438	525	701	876	1050
shear elongation at break[2], % (minimum)	50	50	50	50	50	50	50
peel strength, N/25 mm (minimum)	170	225	285	340	455	570	680
peel separation, % (maximum)	25	25	25	25	25	25	25

Adoption and Revision Schedule for HDPE Specification GRI-GM13

"Test Methods, Test Properties, Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes"

Adopted:	June 17, 1997
Revision 1:	November 20, 1998; changed CB dispersion from allowing 2 views to be in Category 3 to requiring all 10 views to be in Category 1 or 2. Also reduced UV percent retained from 60% to 50%.
Revision 2:	April 29, 1999: added to Note 5 after the listing of Carbon Black Dispersion the following: "(In the viewing and subsequent quantitative interpretation of ASTM D5596 only near spherical agglomerates shall be included in the assessment)" and to Note (4) in the property tables.
Revision 3:	June 28, 2000: added a new Section 5.2 that the numeric table values are neither MARV or MaxARV. They are to be interpreted per the designated test method.
Revision 4:	December 13, 2000: added one Category 3 is allowed for carbon black dispersion. Also, unified terminology to "strength" and "elongation".
Revision 5:	May 15, 2003: Increased minimum acceptable stress crack resistance time from 200 hrs to 300 hrs.
Revision 6:	June 23, 2003: Adopted ASTM D 6693, in place of ASTM D 638, for tensile strength testing. Also, added Note 2.
Revision 7:	February 20, 2006: Added Note 6 on Asperity Height clarification with respect to shear strength.
Revision 8:	Removed recommended warranty from specification.
Revision 9:	June 1, 2009: Replaced GRI-GM12 test for asperity height of textured geomembranes with ASTM D 7466.
Revision 10	April 11, 2011: Added alternative carbon black content test Methods.
Revision 11	December 13, 2012: Replaced GRI-GM11 with the equivalent ASTM D 7238.
Revision 12	November 14, 2014: Increased minimum acceptable stress crack resistance time from 300 to 500 hours. Also, increased asperity height of textured sheet from 10 to 16 mils (0.25 to 0.40 mm).
Revision 13	November 4, 2015: Removed Footnote (1) on asperity height from tables.
Revision 14	January 6, 2016: Removed Trouser Tear from Note 5.
Revision 15:	September 9, 2019: Editorial update to harmonize tables.

Revision 16: March 17, 2021: Updated Standard OIT Test from ASTM D3895 D8117.

Revision 17: July 17, 2023: Included thickness requirements for weld edge oftextured geomembrane in Note 8.

Revision 18: April 3, 2024 Removed Note 8 and clarified weld edge characterization of textured geomembrane in Tables 2a and 2b.

Revision 19: June 11, 2025 Added HDPE Seam Specifications to Appendix in lieu of GRI-GM19.