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Revision Schedule on pg. 18

# GRI -GM18 Standard Specification*

for

"Test Methods, Test Properties and Testing Frequencies for Flexible Polypropylene (fPP and fPP-R) Nonreinforced and Reinforced Geomembranes" 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 It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part.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 covers flexible polypropylene geomembranes which are nonreinforced (fPP) in thicknesses of 30 mils (0.75 mm), 40 mils (1.02 mm), 60 mils (1.52 mm) and also scrim reinforced (f PP-R) in thicknesses of 36 mils (0.91 mm ) and 45 mils (1.14 mm) and 60 mils (1.52 mm) as shown in Figure 1.

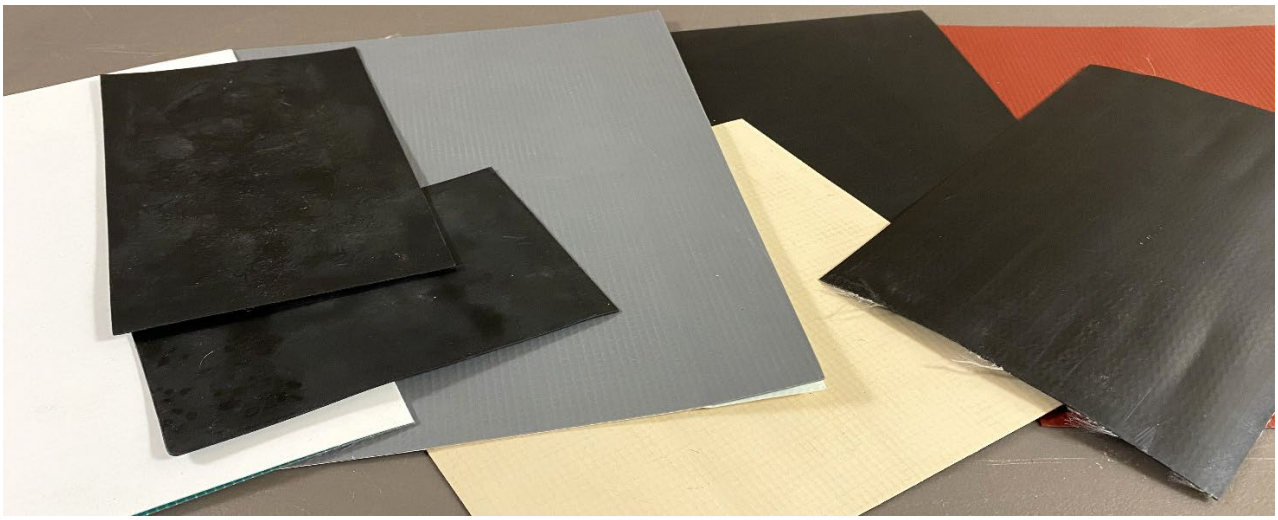

**Figure 1 – Photograph of GRI-GM18 FPP and FPP-R Geomembrane Coupons**

*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 two-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>>. 

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 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 fPP and fPP-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 does not cover installation considerations which are independent of the manufacturing of the geomembrane.

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 751 Test Methods for Coated Fabrics
D 1004 Test Method for Tear Resistance (Graves Tear) of Plastic Film and Sheeting
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 4439 Standard Terminology for Geosynthetics
D 4833 Test Method for Index Puncture Resistance of Geotextiles, Geomembranes and Related Products
D 4873 Guide for Identification, Storage and Handling 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 5323 Practice for Determination of 2% Secant Modulus for Polyethylene Geomembranes
D 5538 Standard Practice for Thermoplastic Elastomers – Terminology and Abbreviations
D 5617 Test Method for Multi-Axial Tensile Test for Geosynthetics

D 5884 Test Method for Determining the Tearing Strength of Internally Reinforced Geomembranes
D 6636 Determination of Ply Adhesion Strength of Reinforced Geomembranes
D 6693 Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes
D 7004 Test Method for Garb Tensile Properties of Reinforced Geomembranes D
D 7238 Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembrane Using Fluorescent UV Condensation Apparatus.

GRI Standards

GM 16 Test Method for Observation of Surface Cracking of Geomembranes
GM 23 Test Method for Observation of Surface Chalking of Geomembranes (draft)

2.2 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.

Koerner, R. M., Hsuan, Y. G. and Koerner, G. R. (2008), "Freshwater and Geosynthetics: A Perfect Marriage," Proc. 1st Pan American Geosynthetics Conference, March 2-5, 2008, Cancun, Mexico, IFAI Publisher, Roseville, MN (on CD).

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, n - The mixture of a specific combination of ingredients identified by type, properties and quantity. For flexible polypropylene geomembranes a formulation is defined as the exact percentages and types of resin(s), additives, and carbon black or colorants.

Note 3: The geomembrane focused upon in this standard specification shall be formulated from virgin flexible polypropylene, in amounts greater than 85% by weight of the total polymer content. The remaining 15% shall be comprised of compatible polymers and/or pigments, stabilizers, and colorants that are suitably compounded to satisfy the physical, mechanical and endurance requirements in the specification; see ASTM Practice D 5538 for definitions. The formulations shall not contain fillers (such as talc or calcium carbonate) postconsumer (PCR) plastics, or any other ingredients that could interfere with the long-term durability of the geomembrane. No more than 10% rework resin is allowed for the production of the geomembrane and, if used, it shall be fully compatible with the parent material.

3.4 Flexible Polypropylene, n. [per ASTM D4439] – a material having a 2% secant modulus of less than 300 MPa (40,000 lb/in.$^2$) as determined by ASTM D5323 produced by polymerization of propylene with or without other alpha olefin monomers.

3.5 Rework, n - Polymer which has been converted into a geosynthetic material and then ground into chips for reintroduction into the extruder without leaving the plant, e.g., edge trim, out-of-spec thickness material, etc.

3.6 Chalking, n. – Formation of powdery deposit on the surface of a coating that has been exposed to some form of degradation. It is commonly found on coatings that have been exposed outdoors to sun and rain. The powder is in fact the pigment and extender that remains after the binder has been destroyed by weathering. (BS 3900-H6: ISO 4628/6)

Note 4: In addition to the coatings referred to above, chalking is also found in geomembranes when exposed outdoors and in geomembranes when incubated in laboratory weatherometers.

3.7 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 de tail. For a full field project, however, m any 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.

## 4. Material Classification and Formulation

4.1 This specification covers flexible polypropylene geomembranes which are nonreinforced (fPP) and scrim reinforced, hence the designation fPP-R.

4.2 The flexible polypropylene resin from which the geomembrane is made shall conform to the definition presented in Section 3.

4.3 The flexible polypropylene 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.

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

4.5 For reinforced flexible polypropylene, the fabric reinforcement (also called the "scrim") shall be present so as to give the desired specification values to be presented in the next section.

Note 5: Fabric scrims are sometimes 1000 denier in either a 9 × 9 weft- inserted or a 10 × 10 basket pattern (i.e., 9 or 10 yarns per inch of width in both machine and cross-machine directions). They are usually made from high tenacity polyester resin. Other patterns and polymers are also possible. Reinforced geomembranes are sometimes referred to as "supported" geomembranes.

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 6: The tensile strength properties of unreinforced fPP geomembranes 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 follows 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 7: 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 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
- Wide Width Tensile
- Water Vapor Transmission
- Carbon Black Dispersion
- Water Absorption
- Ozone Resistance
- Modulus of Elasticity
- Hydrostatic Resistance
- Tensile Impact
- Field Seam Strength
- Mullen Burst
- Various Toxicity Tests
- Oxidative Induction Time (Standard and High Pressure)

Note 8: There are several tests which are included in this standard because they are relevant and important in the context of current manufacturing processes. The following incubation methods and subsequent test methods have been purposely added:

- Ultraviolet Resistance by UV Fluorescent Method
- Multi-Axial Burst

Note 9: There are other tests in this standard, focused on a particular property, which are updated to current standards. The following are in this category:

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

Note 10: 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 ($W/(m^2 \cdot nm)$ with 340 nm wavelength bulbs (UVA-340) and measures the change in properties of the removed test specimens. The cycle cam 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 nonreinforced specimens are

evaluated for their retained strength and elongation behavior. The reinforced specimens are evaluated for their cracking and chalking behavior.

Note 11: Earlier versions of this specification had the endurance criteria (oven aging and UV weathering) based on reduction of oxidative inductive time (OIT) from the as -received value. This was subsequently found to be not fully reliable so this reinstated specification is now based completely on UV weathering using the fluorescent tube method (ASTM D 7238). The 20,000 light hour exposure time is admittedly long, however, is felt to be in keeping with both nonexposed and exposed applications of fPP and fPP-R geomembranes.

Note 12: At an irradiance level of 0.78 W/($m^2$·nm) and at 340 nm wavelength, the radiant exposure (RE) of a successful geomembrane passing 20,000 light hours is as follows:

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

Note 13: Earlier versions of this specification had the endurance criteria based on black versus other colors. This version does not distinguish on the basis of color and all colors must meet the criteria given.

5.3 As noted in the adoption and revision schedule included on Page 10, this specification was suspended in 2004 and then withdrawn in 2007. During this time and up to its reinstatement in 2009 considerable research on the durability criterion has been undertaken by the institute. This effort resulted in the 20,000 light hour requirement per ASTM D7238 at 70°C; see Koerner, et al. (2008). Related research activities are given in the following notes:

Note 14: There have been field reports that imposed tensile stresses have caused premature failures in both fPP and fPP-R geomembranes. At the institute we have evaluated two types of such stresses (wide width and over rollers) and not found issues in products that passed 20,000 light hours of incubation. That said, further research might still be considered.

Note 15: There have been field reports that abrupt corners in the products during factory folding have caused premature failures in both fPP and fPP-R geomembranes. At the institute we have evaluated 90°, 180°, and corner (or dead) folds in numerous aggressive solutions at 50°C for 1000 hours and not found issues in products that passed 20,000 light hours of incubation. That said, further research might still be considered.

Note 16: There have been field reports that chlorine and chloride compounds (even in minute quantities) have caused premature failures in both

fPP and fPP-R geomembranes. At the institute we have evaluated a number of chemical solutions (tap water, 1% sulfuric acid, 10 M calcium chloride, 10% Igepal, 10 M lime 10% hydrogen peroxide and 10% bleach solution) at 50°C for 1000 hours and not found issue in products that passed 20,000 light hours of incubation. That said, further research might still be considered.

5.4 The various properties of the fPP and fPP-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 17: 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 fPP geomembrane shall have good and uniform appearance qualities. It shall be free from such defects that would affect the specified properties of the geomembrane.

6.2 Scrim reinforced fPP-R geomembrane shall generally have a uniform undulating appearance. It shall be free from irregular yarns, yarns that are bunched together, yarns crossing over one another, and such defects that would affect the specified properties of the geomembrane.

6.3 For fPP-R geomembranes there is to be no exposed scrim except for roll ends. A $0.375 \pm 0.25$ in. ($10 \pm 6$ mm) edge encapsulation on each side is required.

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 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 3 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, unless otherwise specified in the contract or order.

9.2 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.

Note 18: 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 19: The authentication and certification of the test methods, procedures, and resulting values of any or all properties in Table 1 should be communicated between th e parties involved. This can be between any, or all, of the following; manufacturer, specifier, purchaser, owner, and/or regulator.

Note 20: 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 Note 3.

**U. S. Standard Units**

## Table 1(a) – Flexible Polypropylene Nonreinforced (fPP) and Reinforced (fPP-R) Geomembranes

| Property | Test Method ASTM or GRI | fPP 30 mils | fPP 40 mils | fPP 60 mil | fPP-R 36 mils | fPP-R 45 mils | fPP-R 60 mil | Testing Frequency (minimum) |
|---|---|---|---|---|---|---|---|---|
| Mass per Unit Area – lb/ft$^2$ (min. ave.) | D5261 | 0.12 | 0.16 | 0.20 | 0.15 | 0.18 | 0.24 | 15,000 lb |
| Thickness | D5199 | | | | | | | |
| • Nominal (mils) | | 30 | 40 | 60 | 36 | 45 | 60 | per roll |
| • min. ave. (mils) | | 27 | 36 | 54 | 32 | 40 | 54 | |
| Tensile Strength | | | | | | | | |
| • dumbbell[(1)] – lb/in. (min. ave.) | D6693-IV | 60 | 72 | 96 | - | - | - | 15,000 lb |
| • grab[(1)] – lb (min. ave.) | D7004 | - | - | - | 200 | 250 | 300 | 15,000 lb |
| Tensile Elongation | | | | | | | | |
| • dumbbell[(1,2)] - % (min. ave.) | D6693-IV | 700 | 700 | 700 | - | - | - | 15,000 lb |
| • grab[(1)] - % (min. ave.) | D7004 | - | - | - | 22 | 22 | 22 | 15,000 lb |
| Multiaxial Elongation - % | D5617 | 120 | 120 | 120 | - | - | - | formulation |
| Tear Resistance | | | | | | | | |
| • nonreinforced[(1)] – lb (min. ave.) | D1004 | 10 | 12 | 18 | - | - | - | 15,000 lb |
| • reinforced[(1)] – lb (min. ave.) | D5884 | - | - | - | 55 | 55 | 55 | 15,000 lb |
| Puncture Resistance – lb (min. ave.) | D4833 | 25 | 30 | 40 | 75 | 85 | 100 | 15,000 lb |
| Ply Adhesion – lb/in. (min. ave.) | D6636 | - | - | - | 15 | 15 | 15 | 15,00 lb |
| Low Temperature Flexibility - °F | D2136[(3)] | -40 | -40 | -40 | -40 | -40 | -40 | formulation |
| Carbon Black Content[(4)] - % | D4218 | 2-15 | 2-15 | 2-15 | 2-15 | 2-15 | 2-15 | 45,000 lb |
| Ultraviolet Light Resistance[(5,6)] | D7238 @ 70°C | | | | | | | per formulation |
| (a) % strength retained after 20,000 light hrs. | D6693-IV | | ≥ 50 | | | ≥ 50 | | |
| - or - | | | | | | | | |
| (b) % elongation retained after 20,000 light hrs. | D6693-IV | | ≥ 50 | | | ≥ 50 | | |
| - and - | | | | | | | | |
| (c) Surface Cracking Observation after 20,000 light hrs. | GM16 | | none | | | none | | |
| (d) Surface Chalking (or Powdering) after 20,000 light hrs. | GM23 | | minor | | | minor | | |

(1) Test methods modified to 20 in./min. for unreinforced and 12 in./min. for reinforced
(2) Calculation based on a 2.0 in. gage length
(3) Using 1/8 in. mandrel for 4-hours.
(4) Applicable only to black geomembranes. Also D1603 is an acceptable method to determine carbon black content.
(5) The conditions of the UV Fluorescent exposure method should be 20 hr. UV cycle at 70°C followed by 4 hr. condensation at 60°C.
(6) See Section 5.2 for fPP-R geomembranes.

**SI (METRIC) UNITS**

## Table 1(b) – Flexible Polypropylene Nonreinforced (fPP) and Reinforced (fPP-R) Geomembranes

| Property | Test Method ASTM or GRI | fPP 0.76 mm | fPP 1.02 mm | fPP 1.52 mm | fPP-R 0.91 mm | fPP-R 1.14 mm | fPP-R 1.52 mm | Testing Frequency (minimum) |
|---|---|---|---|---|---|---|---|---|
| Mass per Unit Area – kg/m$^2$ (min. ave.) | D5261 | 0.59 | 0.78 | 0.98 | 0.73 | 0.88 | 1.17 | 7500 kg |
| Thickness | D5199 | | | | | | | |
| • Nominal (mils) | | 0.76 | 1.02 | 1.52 | 0.91 | 1.14 | 1.52 | per roll |
| • min. ave. (mils) | | 0.68 | .92 | 1.37 | 0.82 | 1.03 | 1.37 | |
| Tensile Strength | | | | | | | | |
| • dumbbell(1) – kN/m (min. ave.) | D6693-IV | 11 | 13 | 17 | - | - | - | 7500 kg |
| • grab(1) – N (min. ave.) | D7004 | - | - | - | 890 | 1110 | 1340 | 7500 kg |
| Tensile Elongation | | | | | | | | |
| • dumbbell(1,2) - % (min. ave.) | D6693-IV | 700 | 700 | 700 | - | - | - | 7500 kg |
| • grab(1) - % (min. ave.) | D7004 | - | - | - | 22 | 22 | 22 | 7500 kg |
| Multiaxial Elongation - % | D5617 | 120 | 120 | 120 | - | - | - | formulation |
| Tear Resistance | | | | | | | | |
| • nonreinforced(1) – N (min. ave.) | D1004 | 45 | 53 | 80 | - | - | - | 7500 kg |
| • reinforced(1) – N (min. ave.) | D5884 | - | - | - | 245 | 245 | 245 | 7500 kg |
| Puncture Resistance – N (min. ave.) | D4833 | 110 | 130 | 180 | 330 | 380 | 440 | 7500 kg |
| Ply Adhesion – kN/m (min. ave.) | D6636 | - | - | - | 2.6 | 2.6 | 2.6 | 7500 kg |
| Low Temperature Flexibility - °C | D2136(3) | -40 | -40 | -40 | -40 | -40 | -40 | formulation |
| Carbon Black Content(4) - % | D4218 | 2-15 | 2-15 | 2-15 | 2-15 | 2-15 | 2-15 | 22,000 kg |
| Ultraviolet Light Resistance(5,6) | D7238 @ 70°C | | | | | | | per formulation |
| (a) % strength retained after 20,000 light hrs. | D6693-IV | ≥ 50 | | | ≥ 50 | | | |
| - or - | | | | | | | | |
| (b) % elongation retained after 20,000 light hrs. | D6693-IV | ≥ 50 | | | ≥ 50 | | | |
| - and - | | | | | | | | |
| (c) Surface Cracking Observation after 20,000 light hrs. | GM16 | none | | | none | | | |
| (d) Surface Chalking (or Powdering) after 20,000 light hrs. | GM23 | minor | | | minor | | | |

(1) Test methods modified to 500 mm/min. for unreinforced and 12 in./min. for reinforced
(2) Calculation based on a 50 mm gage length
(3) Using 32 mm mandrel for 4-hours.
(4) Applicable only to black geomembranes. Also D1603 is an acceptable method to determine carbon black content.
(5) The conditions of the UV Fluorescent exposure method should be 20 hr. UV cycle at 70°C followed by 4 hr. condensation at 60°C.
(6) See Section 5.2 for fPP-R geomembranes.

## APPENDIX

## "Seam Strength and Related Properties of Thermally Bonded Flexible Polypropylene (fPP and fPP-R) Nonreinforced and Reinforced Covered Under GRI-GM 18 Specification" SM

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### 1. Scope

1.1 This specification addresses the required strength and related properties of thermally bonded homogeneous, nonreinforced, flexible polyethylene (fPP) geomembrane 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 and D7747. This specification does not address the test method details or specific testing procedures. It refers to the relevant ASTM test methods where applicable.

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 applicable to laboratory where environmental controls are within ASTM 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

D7747 Standard Test Method for Determining Integrity of Seams Produced Using Thermo-Fusion Methods for Reinforced Geomembranes by the Strip Tensile Method

2.2 EPA Standards

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

2.3 GRI Standards

GM14 Guide for Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes
GM18 Test Properties and Testing Frequency for Flexible Polypropylene (fPP and fPP-R) Geomembranes
GM20 Guide for Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using Control Charts

## 3. Definition

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 of seams in homogeneous or nonreinforced geomembranes 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. Separate GRI standards, GM14 and GM20, provide guidance as to the spacing that destructive samples should be taken in typical filed installation projects.

## 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 ASTM test method, 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 For fPP Seams – For nonreinforced fPP seam strengths all five out of five specimens in shear and peel should meet or exceed the values given in Tables 3(a) and 3(b). Note that the specimens are 1.0 in. (25 mm) wide strips. In addition, the shear percent elongation on the specimens should exceed the values given in Tables 3(a) and 3(b). All five out of five peel separation specimens should not exceed the values given in Tables 3(a) and 3(b).

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.

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.

6.2 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.

6.3 For fPP-R seams - For reinforced fPP seam strengths of all five out of five specimens in shear and peel mode should meet or exceed the values given in Tables 4(a) and 4(b). Note that the unreinforced specimens are 1.0 in. (25 mm) wide strips.

## 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.

**Table 3(a) – Seam Strength and Related Properties of Thermally Bonded Nonreinforced Flexible Polypropylene (fPP) Geomembranes (English Units)**

| Geomembrane Nominal Thickness | Test Method | 30 mil | 40 mil |
|---|---|---|---|
| Hot Wedge Seams[1] | | | |
| shear strength, lb/in., (minimum) | ASTM D6392 | 25 | 30 |
| shear elongation[2], %, (minimum) | | 50 | 50 |
| peel strength, lb/in., (minimum) | | 20 | 25 |
| peel separation, %, (maximum) | | 25 | 25 |
| Extrusion Fillet Seams | | | |
| shear strength, lb/in., (minimum) | ASTM D6392 | 25 | 30 |
| shear elongation[2], %, (minimum) | | 50 | 50 |
| peel strength, lb/in., (minimum) | | 20 | 25 |
| peel separation, %, (maximum) | | 25 | 25 |

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

**Table 3(b) – Seam Strength and Related Properties of Thermally Bonded Nonreinforced Flexible Polypropylene (fPP) Geomembranes (S.I. Units)**

| Geomembrane Nominal Thickness | Test Method | 0.75 mm | 1.0 mm |
|---|---|---|---|
| Hot Wedge Seams[1] | | | |
| shear strength, N/25 mm, (minimum) | ASTM D6392 | 110 | 130 |
| shear elongation [2], %, (minimum) | | 50 | 50 |
| peel strength, N/25 mm, (minimum) | | 85 | 110 |
| peel separation, %, (maximum) | | 25 | 25 |
| Extrusion Fillet Seams | | | |
| shear strength, N/25 mm, (minimum) | ASTM D6392 | 110 | 130 |
| shear elongation [2], %, (minimum) | | 50 | 50 |
| peel strength, N/25 mm, (minimum) | | 85 | 110 |
| peel separation, %, (maximum) | | 25 | 25 |

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

**Table 4(a) – Seam Strength of Thermally Bonded Reinforced Flexible Polypropylene (fPP-R) Geomembranes Made According to GRI-GM18[2] (English Units)**

| Property | Test Method | Min. Value | Min. Value | Min. Value |
|---|---|---|---|---|
| Sheet Thickness<br>• nominal (mils) | ASTM D5199<br>(Method A) | <br>36 | <br>45 | <br>60 |
| Hot Wedge/Air Seams[1]<br>• shear strength (lb)<br>• peel strength (lb) | ASTM D7747 | <br>50<br>25 | <br>60<br>25 | <br>70<br>25 |
| Other Seam Types<br>• shear strength (lb)<br>• peel strength (lb) | ASTM D7747 | <br>50<br>25 | <br>60<br>25 | <br>70<br>25 |

(1) Also for other possible seaming methods, e.g., ultrasonic
(2) Values are based on 1.0 in. (25 mm) wide strip tensile strength per D7747 for laboratory tested specimens

**Table 4(b) – Seam Strength of Thermally Bonded Reinforced Flexible Polypropylene (fPP-R) Geomembranes Made According to GRI-GM18[2] (S.I. Units)**

| Property | Test Method | Min. Value | Min. Value | Min. Value |
|---|---|---|---|---|
| Sheet Thickness<br>• nominal (mm) | ASTM D5199<br>(Method A) | <br>0.91 | <br>1.14 | <br>1.52 |
| Hot Wedge/Air Seams[1]<br>• shear strength (N)<br>• peel strength (N) | ASTM D7747 | <br>220<br>110 | <br>270<br>110 | <br>310<br>110 |
| Other Seam Types<br>• shear strength (N)<br>• peel strength (N) | ASTM D7747 | <br>220<br>110 | <br>270<br>110 | <br>310<br>110 |

(1) Also for other possible seaming methods, e.g., ultrasonic
(2) Values are based on 25 mm (1.0 in.) wide strip tensile strength per D7747 for laboratory tested specimens

**Adoption and Revision Schedule for FPP and FPP-R Specification GRI-GM18**

"Test Properties, Testing Frequency and Recommended Warrant for Flexible Polypropylene (fPP and fPP-R) Nonreinforced and Reinforced Geomembranes"

Adopted: February 18, 2002

Revision 1: June 23, 2003: Adopted ASTM D 6693, in place of ASTM D 638 for tensile strength testing. Also added Note 5.

Revision 2: August 12, 2003: S.I. conversion errors in mass corrected

Suspended: May 3, 2004

Withdrawn: January 22, 2007

Revision 3: March 20, 2009: Changed endurance criteria from OIT testing to 50% percent strength and elongation retained (for nonreinforced fPP) and no cracking or chalking (for reinforced fPP-R) after 20,000 light hours of UV-fluorescent exposure per ASTM D 7238 at 70°C. Numerous notes have been added as well as editorial corrections. Also removed recommended warranty from the specification.

Revision 4: June 18, 2009: Corrected calculation for radiant exposure (RE).

Revision 5: February 1, 2011: Added 60 mil (1.52 mm) fPP and fPP-R to the specification.

Revision 6: December 17, 2012: Editorial changes.

Revision 7: August 4, 2014: Reviewed range of C.B. Content from 2-3% to 2-15% recognizing that thermoset resins can be added up to 15% per Note 3.

Revision 8: September 10, 2015: Changed thickness description from "lowest individual specimen" to "minimum average" in Tables 1a and 1b.

Revision 9: June 12, 2025 Added Seam Specifications to Appendix in lieu of GRI GM 19a and 19b.