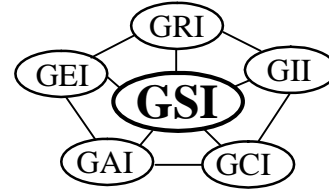


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Revision 6: Oct. 3, 2011
Revision schedule is on pg. 12

GRI Test Method GM19*

Standard Specification for

Seam Strength and Related Properties of Thermally Bonded Polyolefin 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 It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part.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 addresses the required seam strength and related properties of thermally bonded polyolefin geomembranes; in particular, high density polyethylene (HDPE), linear low density polyethylene both nonreinforced (LLDPE) and scrim reinforced (LLDPE-R) and flexible polypropylene both nonreinforced (fPP) and scrim reinforced (fPP-R).

1.2 Numeric values of seam strength and related properties are specified in both shear and peel modes.

Note 1: This specification does not address the test method details or specific testing procedures. It refers to the relevant ASTM test methods where applicable.

1.3 The thermal bonding methods focused upon are hot wedge (single and dual track) and extrusion fillet.

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

Note 2: 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.

- 1.4 This specification also suggests the distance between destructive seam samples to be taken in the field, i.e., the sampling interval. However, project-specific conditions will always prevail in this regard.
- 1.5 This specification is only applicable to laboratory testing.
- 1.6 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. Referenced Documents

2.1 ASTM Standards

D751 Standard Test Methods for Coated Fabrics
D6392 Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods

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

GM13 Test Properties and Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes
GM14 Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes
GM17 Test Properties and Testing Frequency for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes
GM18 Test Properties and Testing Frequency for Flexible Polypropylene (fPP and fPP-R) Geomembranes
GM20 Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using Control Charts
GM25 Test Property and Testing Frequency for Scrim Reinforced Linear Low Density Polyethylene Geomembranes

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 deprecated 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 polyolefin 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. The specification also provides guidance as to what spacing intervals the samples should be taken at typical field installation projects.

5. Sample and Specimen Preparation

- 5.1 The spacing for taking field seam samples for destructive testing is to be 1 per 500 feet (1 per 150 m) of seam length, or as by directed by the construction quality

assurance inspector. As the project continues and data is accumulated, however, this sampling interval should be varied according to the procedures set forth in either GRI-GM14 or GRI-GM20. Following this procedure three different situations can result.

- 5.1.1 Good seaming with fewer rejected test results than the preset historic average can result in a sequential increase in the spacing interval, i.e., one per greater than 500 ft. (one per greater than 150 m).
- 5.1.2 Poor seaming with more rejected test results than the preset historic average can result in a sequential decrease in the spacing interval, i.e., one per less than 500 ft. (one per less than 150 m).
- 5.1.3 Average seaming with approximately the same test results as the preset historic average will result in the spacing interval remaining the same, i.e., one per 500 ft. (one per 150 m).

Note 3: The method of attributes in GRI-GM14 or the method of control charts in GRI-GM20 are two of various statistical strategies that might be used to vary sampling frequency.

- 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 the referenced test method, i.e., ASTM D6392 for HDPE, LLDPE and fPP, and ASTM D751 (modified to a 150 mm + seam width gage length) for fPP-R. The specimens are to be conditioned prior to testing according to these same test methods and evaluated accordingly.

6. Assessment of Seam Test Results

- 6.1 HDPE seams – For HDPE seams (both smooth and textured), the strength of four out of five 1.0 inch (25 mm) wide strip specimens in shear should meet or exceed the values given in Tables 1(a) and 1(b). The fifth must meet or exceed 80% of the given values. In addition, the shear percent elongation, calculated as follows, should exceed the values given in Tables 1(a) and 1(b):

$$E = \frac{L}{L_o}(100) \quad (1)$$

where

E = elongation (%)

L = extension at end of test (in. or mm)

L_o = original average length (usually 1.0 in. or 25 mm)

Note 4: The assumed gage length is considered to be the unseamed sheet material on either side of the welded area. It generally

will be 1.0 in. (25 mm) from the edge of the seam to the grip face.

For HDPE seams (both smooth and textured), the strength of four out of five 1.0 in. (25 mm) wide strip specimens tested in peel should meet or exceed the values given in Tables 1(a) and 1(b). The fifth must meet or exceed 80% of the given values.

In addition, the peel separation (or incursion) should not exceed the values given in Tables 1(a) and 1(b). The value shall be based on the proportion of area of separated bond to the area of the original bonding as follows:

$$S = \frac{A}{A_0}(100) \quad (2)$$

where

S = separation (%)

A = average area of separation, or incursion (in² or mm²)

A₀ = original bonding area (in² or mm²)

Note 5: 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

Exception: AD-WLD (unless strength is achieved)

Note 6: 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.

6.2 LLDPE seams – For LLDPE seams (smooth, textured and scrim reinforced), the strength of four out of five 1.0 in. (25 mm) wide strip specimens in shear should meet or exceed the values given in Tables 2(a) through 2(d). The fifth must meet or exceed 80% of the given values. Note that the unreinforced specimens are 1.0 in. (25 mm) wide strips and the scrim reinforced specimens are 4.0 in. (100 mm) wide

grab tests. In addition, the shear percent elongation, calculated as follows, should exceed the values given in Tables 2(a) through 2(d).

$$E = \frac{L}{L_o}(100) \quad (1)$$

where

E = elongation (%)

L = extension at end of test (in. or mm)

L_o = original average length (usually 1.0 in. or 25 mm)

Note 4: The assumed gage length is considered to be the unseamed sheet material on either side of the welded area. It generally will be 1.0 in. (25 mm) from the edge of the seam to the grip face.

Shear elongation is not relevant to scrim reinforced geomembranes and as such is listed as “not applicable” in Tables 2 (c) and (d).

For LLDPE seams (smooth, textured and scrim reinforced), the strength of four out of five 1.0 in. (25 mm) wide strip specimens tested in peel should meet or exceed the values given in Tables 2(a) through 2(d). The fifth must meet or exceed 80% of the given values.

In addition, the peel separation (or incursion) should not exceed the values given in Tables 2(a) through 2(d). The value shall be based on the proportion of area of separated bond to the area of the original bonding as follows:

$$S = \frac{A}{A_o}(100) \quad (2)$$

where

S = separation (%)

A = average depth of separation, or incursion (in.² or mm²)

A₀ = original bonding distance (in.² or mm²)

Note 5: 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
Exception: AD-WLD (unless strength is achieved)

Note 6: 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.

6.3 fPP Seams – For fPP seams (both nonreinforced and scrim reinforced), the strength of four out of five specimens in shear should meet or exceed the values given in Tables 3(a) and 3(b). The fifth must meet or exceed 80% of the given values. Note that the unreinforced specimens are 1.0 in. (25 mm) wide strips and the scrim reinforced specimens are 4.0 in. (100 mm) wide grab tests. In addition, the shear percent elongation on the unreinforced specimens, calculated as follows, should exceed the values given in Tables 3(a) and 3(b).

$$E = \frac{L}{L_o}(100) \quad (1)$$

where

E = elongation (%)

L = extension at end of test (in. or mm)

L_o = original gauge length (usually 1.0 in. or 25 mm)

Note 4: The assumed gage length is considered to be the unseamed sheet material on either side of the welded area. It generally will be 1.0 in. (25 mm) from the edge of the seam to the grip face.

Shear elongation is not relevant to scrim reinforced geomembranes and as such is listed as “not applicable” in Tables 3(a) and 3(b).

For fPP seams (both nonreinforced and scrim reinforced), the strength of four out of five specimens in peel should meet or exceed the values given in Tables 3(a) and 3(b). The fifth must meet or exceed 80% of the given values. Note that the unreinforced specimens are 1.0 in. (25 mm) wide strips and the scrim reinforced specimens are grab tests. In addition, the peel percent separation (or incursion) should not exceed the values given in Tables 3(a) and 3(b). The values should be based on the proportion of area of separated bond to the area of the original bonding as follows.

$$S = \frac{A}{A_o}(100) \quad (2)$$

where

S = separation in (%)

A = average depth of separation, or incursion (in.² or mm²)

A_o = original bonding distance (in.² or mm²)

Note 5: 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

Exception: AD-WLD (unless strength is achieved)

Note 6: 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.

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 1(a) – Seam Strength and Related Properties of Thermally Bonded **Smooth and Textured** High Density Polyethylene (HDPE) Geomembranes (**English Units**)

Geomembrane Nominal Thickness	30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils
Hot Wedge Seams⁽¹⁾							
shear strength ⁽²⁾ , lb/in.	57	80	100	120	160	200	240
shear elongation at break ⁽³⁾ , %	50	50	50	50	50	50	50
peel strength ⁽²⁾ , lb/in.	45	60	76	91	121	151	181
peel separation, %	25	25	25	25	25	25	25
Extrusion Fillet Seams							
shear strength ⁽²⁾ , lb/in.	57	80	100	120	160	200	240
shear elongation at break ⁽³⁾ , %	50	50	50	50	50	50	50
peel strength ⁽²⁾ , lb/in.	39	52	65	78	104	130	156
peel separation, %	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. Value listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values
3. Elongation measurements should be omitted for field testing

Table 1(b) – Seam Strength and Related Properties of Thermally Bonded **Smooth and Textured** High Density Polyethylene (HDPE) Geomembranes (**S.I. Units**)

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 ⁽²⁾ , N/25 mm.	250	350	438	525	701	876	1050
shear elongation at break ⁽³⁾ , %	50	50	50	50	50	50	50
peel strength ⁽²⁾ , N/25 mm	197	263	333	398	530	661	793
peel separation, %	25	25	25	25	25	25	25
Extrusion Fillet Seams							
shear strength ⁽²⁾ , N/25 mm	250	350	438	525	701	876	1050
shear elongation at break ⁽³⁾ , %	50	50	50	50	50	50	50
peel strength ⁽²⁾ , N/25 mm	170	225	285	340	455	570	680
peel separation, %	25	25	25	25	25	25	25

Table 2(a) – Seam Strength and Related Properties of Thermally Bonded **Smooth and Textured** Linear Low Density Polyethylene (LLDPE) Geomembranes (English Units)

Geomembrane Nominal Thickness	20 mils	30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils
Hot Wedge Seams⁽¹⁾								
shear strength ⁽²⁾ , lb/in.	30	45	60	75	90	120	150	180
shear elongation ⁽³⁾ , %	50	50	50	50	50	50	50	50
peel strength ⁽²⁾ , lb/in.	25	38	50	63	75	100	125	150
peel separation, %	25	25	25	25	25	25	25	25
Extrusion Fillet Seams								
shear strength ⁽²⁾ , lb/in.	30	45	60	75	90	120	150	180
shear elongation ⁽³⁾ , %	50	50	50	50	50	50	50	50
peel strength ⁽²⁾ , lb/in.	22	34	44	57	66	88	114	136
peel separation, %	25	25	25	25	25	25	25	25

Notes for Tables 2(a) and 2(b):

1. Also for hot air and ultrasonic seaming methods
2. Values listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values
3. Elongation measurements should be omitted for field testing

Table 2(b) – Seam Strength and Related Properties of Thermally Bonded **Smooth and Textured** Linear Low Density Polyethylene (LLDPE) Geomembranes (S.I. Units)

Geomembrane Nominal Thickness	0.50 mm	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 ⁽²⁾ , N/25 mm	131	197	263	328	394	525	657	788
shear elongation ⁽³⁾ , %	50	50	50	50	50	50	50	50
peel strength ⁽²⁾ , N/25 mm	109	166	219	276	328	438	547	657
peel separation, %	25	25	25	25	25	25	25	25
Extrusion Fillet Seams								
shear strength ⁽²⁾ , N/25 mm	131	197	263	328	394	525	657	788
shear elongation ⁽³⁾ , %	50	50	50	50	50	50	50	50
peel strength ⁽²⁾ , N/25 mm	95	150	190	250	290	385	500	595
peel separation, %	25	25	25	25	25	25	25	25

Table 2(c) – Seam Strength and Related Properties of Thermally Bonded **Scrim Reinforced** Linear Low Density Polyethylene (LLDPE-R) Geomembranes (English Units)

Geomembrane Nominal Thickness	36 mil ⁽⁴⁾	45 mil ⁽⁴⁾
Hot Wedge Seams ⁽¹⁾		
shear strength ⁽²⁾ , lb	200	200
shear elongation ⁽³⁾ , %	n/a	n/a
peel strength ⁽²⁾ , lb	20	20
peel separation, %	n/a	n/a
Extrusion Fillet Seams		
shear strength ⁽²⁾ , lb	200	200
shear elongation ⁽³⁾ , %	n/a	n/a
peel strength ⁽²⁾ , lb	20	20
peel separation, %	n/a	n/a

1. Also for hot air and ultrasonic seaming methods
2. Values listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values
3. Elongation measurements should be omitted for field testing
4. Values are based on grab tensile strength and elongation per D751 for laboratory tested specimens

Table 2(d) – Seam Strength and Related Properties of Thermally Bonded **Scrim Reinforced** Linear Low Density Polyethylene (LLDPE-R) Geomembranes (S.I. Units)

Geomembrane Nominal Thickness	36 mil ⁽⁴⁾	45 mil ⁽⁴⁾
Hot Wedge Seams ⁽¹⁾		
shear strength ⁽²⁾ , N	890	890
shear elongation ⁽³⁾ , %	n/a	n/a
peel strength ⁽²⁾ , N	90	90
peel separation, %	n/a	n/a
Extrusion Fillet Seams		
shear strength ⁽²⁾ , N	890	890
shear elongation ⁽³⁾ , %	n/a	n/a
peel strength ⁽²⁾ , N	90	90
peel separation, %	n/a	n/a

1. Also for hot air and ultrasonic seaming methods
2. Values listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values
3. Elongation measurements should be omitted for field testing
4. Values are based on grab tensile strength and elongation per D751 for laboratory tested specimens

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

Geomembrane Nominal Thickness	30 mil-NR	40 mil-NR	36 mil-R ⁽⁴⁾	45 mil-R ⁽⁴⁾
Hot Wedge Seams⁽¹⁾				
shear strength ⁽²⁾ , lb/in. (NR); lb (R)	25	30	200	200
shear elongation ⁽³⁾ , %	50	50	n/a	n/a
peel strength ⁽²⁾ , lb/in. (NR); lb (R)	20	25	20	20
peel separation, %	25	25	n/a	n/a
Extrusion Fillet Seams				
shear strength ⁽²⁾ , lb/in. (NR); lb (R)	25	30	200	200
shear elongation ⁽³⁾ , %	50	50	n/a	n/a
peel strength ⁽²⁾ , lb/in. (NR); lb (R)	20	25	20	20
peel separation, %	25	25	n/a	n/a

1. Also for hot air and ultrasonic seaming methods
2. Values listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values
3. Elongation measurements should be omitted for field testing
4. Values are based on grab tensile strength and elongation per D751 for laboratory tested specimens

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

Geomembrane Nominal Thickness	0.75 mm-NR	1.0 mm-NR	0.91 mm-R ⁽⁴⁾	1.14 mm-R ⁽⁴⁾
Hot Wedge Seams⁽¹⁾				
shear strength ⁽²⁾ , N/25 mm (NR); N (R)	110	130	890	890
shear elongation ⁽³⁾ , %	50	50	n/a	n/a
peel strength ⁽²⁾ , N/25 mm (NR); N (R)	85	110	90	90
peel separation, %	25	25	n/a	n/a
Extrusion Fillet Seams				
shear strength ⁽²⁾ , N/25 mm (NR); N (R)	110	130	890	890
shear elongation ⁽³⁾ , %	50	50	n/a	n/a
peel strength ⁽²⁾ , N/25 mm (NR); N (R)	85	110	90	90
peel separation, %	25	25	n/a	n/a

1. Also for hot air and ultrasonic seaming methods
2. Values listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values
3. Elongation measurements should be omitted for field testing
4. Values are based on grab tensile strength and elongation per D751 for laboratory tested specimens

Adoption and Revision Schedule

for

Seam Specification per GRI-GM19

“Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes”

Adopted: February 18, 2002

Revision 1: May 15, 2003; Increased selected shear and peel test requirements, per the following:

Material	Test	Seam Type	Current GM19	Proposed GM19	Difference
HDPE	Shear	Hot Wedge Extrusion	95% yield 95% yield	95% yield 95% yield	no change no change
	Peel	Hot Wedge Extrusion	62% yield 62% yield	72% yield 62% yield	16% increase no change
LLDPE	Shear	Hot Wedge Extrusion	1300 psi break 1300 psi break	1500 psi break 1500 psi break	15% increase 15% increase
	Peel	Hot Wedge Extrusion	1100 psi break 1100 psi break	1250 psi break 1100 psi break	14% increase no change

Revision 2: January 28, 2005; added Note 6 (in three locations) stating that incursion is measured on an area basis and not depth as in ASTM D6392.

Revision 3: June 4, 2010; Removed Note 6 on peel incursion since ASTM D6392 (2008) now uses area of incursion whereas previously they used linear length of incursion. Thus ASTM is now in agreement with GM19 in this regard.

Revision 4: November 15, 2010; Added Note 6 (in three locations) stating what separation-in-plane (SIP) is, and is not, and that it is acceptable if the required strength, shear elongation and peel separation criteria are met.

Revision 5: July 12, 2011; AD1 and AD2 breaks are now unacceptable even if strength is achieved.

Revision 6: October 3, 2011; Added LLDPE-R to the various geomembrane types, in particular, Tables 2(c) and 2(d) and made editorial changes.