

# POLYETHYLENE LINER DROP IN INSTALLATION

## SPECIFICATIONS

### **1. GENERAL REQUIREMENTS**

#### **1.1 Scope**

The following describes parameters for the manufacture, supply, and installation of Poly-Flex polyethylene geomembranes. All procedures, operations, and methods shall be in strict accordance with the engineer's specifications, plans, and drawings.

#### **1.2 Qualifications of Contractor Work Activities**

##### **1.2.1 Manufacturing**

The manufacturer shall have at least five (5) years continuous experience in manufacturing polyethylene geomembrane and/or experience totaling 10,000,000 square feet of manufactured polyethylene geomembrane.

##### **1.2.2 Installation**

The installation contractor shall be the manufacturer or a dealer trained to install the manufacturer's geomembrane.

Installation shall be performed under the constant direction of a field installation supervisor who shall remain on site and be responsible, throughout the liner installation, for liner layout, seaming, testing, repairs, and all other activities by the Installer. The field installation supervisor shall have installed or supervised the installation of a minimum of 1,000,000 square feet of polyethylene geomembrane. Seaming shall be performed under the direction of a master seamer (who may also be the field installation supervisor) who has seamed a minimum of 1,000,000 square feet of polyethylene geomembrane, using the same type of seaming apparatus specified for this project. The field installation supervisor and/or master seamer shall be present whenever seaming is performed.

#### **1.3 Submittals**

##### **1.3.1 Manufacturer**

The manufacturer shall provide the following information:

###### **A. Submittals with Bid Documents**

1. List of material properties.
2. Manufacturing quality control program.

###### **B. Submittals After Contract Award, Prior to Liner Installation**

1. Copy of quality control certificates issued by the resin supplier.
2. Copy of quality control certificates for the geomembranes in conformance with Section 2.4.3.

##### **1.3.2 Installation Contractor**

The installer shall provide the following written information:

###### **A. Submittals With Bid Documents**

A list of completed facilities, totaling a minimum of 1,000,000 square feet, for which the installer has installed polyethylene geomembrane. For each installation, the following information shall be provided:

- a. Name and purpose of facility, location, and date of installation.
- b. Name of owner, design engineer, manufacturer, and name and telephone number of contact at the facility who can discuss the project.
- c. Thickness and quantity of the installed geomembrane.

**B. Submittals by Successful Bidder Prior to Commencement of Installation**

1. Proposed installation panel layout.
2. Resume of the field installation supervisor and master seamer.

**1.4 Meeting**

A daily meeting shall be held at the work area just prior to commencement of the work to discuss work activities. The earthwork contractor, the liner installer and the inspector shall be present.

**1.5 Warranty**

A written Warranty shall be obtained from the manufacturer (for material) and the installation contractor (for workmanship). These documents shall warrant both the quality of the material and workmanship for a specified duration of time.

**2. MATERIAL SPECIFICATIONS**

**2.1 Materials**

1. The geomembrane shall be High-Density Polyethylene (HDPE) or Linear Low Density Polyethylene (LLDPE).
2. Gasket material shall be neoprene, closed cell medium, 1/4-inch thick, 2 inches wide with adhesive on one side, or other compatible gasket materials as required.
3. Metal battens or banding and hardware shall be stainless steel.
4. Water cut-off mastic shall be Neoprene Flashing Cement as supplied by Poly-Flex, Inc., or as required.
5. Sealant shall be General Electric Silicone, RTV 103, or equivalent.

**2.2 Geomembrane Raw Materials**

The geomembrane shall be manufactured of polyethylene resins produced in the United States and shall be compounded and manufactured specifically for the intended purpose. The resin manufacturer shall certify each lot for the following properties.

The natural polyethylene resin without the carbon black shall meet the following requirements:

Property	Test Method	HDPE	LLDPE
		Requirements	Requirements
Density, g/cc	ASTM D 1505 or ASTM D 792	0.935 - 0.940	0.915 - 0.926
Melt Index, g/10 min.	ASTM D 1238 Condition E	<0.4	<0.6

**2.3 Rolls**

The geomembrane shall be a minimum 23.0 ft seamless width, as manufactured by Poly-Flex, Inc. (2000 W. Marshall Dr., Grand Prairie, TX 75051, 888-765-9359). Carbon black shall be added to the resin if the resin is not compounded for ultra-violet resistance.

The surface of the smooth geomembrane shall not have striations, roughness, pinholes, or bubbles.

The geomembrane shall be supplied in rolls. Labels on each roll shall identify the thickness of the material, the length and width of the roll, lot and roll numbers, and name of manufacturer.

### **Applicable Test Methods**

#### American Society for Testing and Materials (ASTM)

ASTM D 792	Specific gravity (relative density) and density of plastics by displacement
ASTM D 1004	Initial tear resistance of plastic sheeting
ASTM D 1238	Flow rates of thermoplastics by extrusion plastometers
ASTM D 1505	Density of plastics by the Density-Gradient technique
ASTM D 1603	Carbon black in olefin plastics
ASTM D 1898	Sampling of plastics
ASTM D 3895	Test method for oxidative induction time of polyolefins by thermal analysis
ASTM D 4833	Index Puncture Resistance of geotextiles, geomembranes and related products
ASTM D 5199	Test method for measuring nominal thickness of geotextiles and geomembrane
ASTM D 5323	Determination of 2% secant modulus for polyethylene geomembranes
ASTM D 5397	Procedure to perform a single point notched constant tensile load - Appendix (SP-NCTL) test
ASTM D 5596	Test method for microscopic evaluation of the dispersion of carbon black in polyolefin geosynthetics
ASTM D 5617	Multi-axial tension test for geosynthetics
ASTM D 5721	Practice for air-oven aging of polyolefin geomembranes
ASTM D 5885	Test method for oxidative induction time of polyolefin geosynthetics by high pressure differential scanning calorimetry
ASTM D 5994	Test method for measuring the core thickness of textured geomembranes
ASTM D 6392	Determining the integrity of nonreinforced geomembrane seams produced using thermo-fusing methods
ASTM D 6693	Determining tensile properties of nonreinforced polyethylene and nonreinforced flexible polypropylene geomembranes

#### Geosynthetic Research Institute (GRI)

GRI GM 10	Specification for the stress crack resistance of geomembrane sheet
GRI GM 11	Accelerated weathering of geomembranes using a florescent UVA-condensation exposure device
GRI GM 12	Measurement of the asperity height of textured geomembranes using a depth gauge

The geomembrane rolls shall meet the following specifications:

## SMOOTH HDPE GEOMEMBRANE (ENGLISH UNITS)

Property	Test Method	<u>Minimum Average Values</u>				
		30 mil	40 mil	60 mil	80 mil	100 mil
Thickness, mils	ASTM D 5199					
minimum average		30	40	60	80	100
lowest individual reading		27	36	54	72	90
Sheet Density, g/cc	ASTM D 1505/D 792	0.940	0.940	0.940	0.940	0.940
Tensile Properties <sup>1</sup>	ASTM D 6693					
1. Yield Strength, lb/in		63	84	126	168	210
2. Break Strength, lb/in		114	152	228	304	380
3. Yield Elongation, %		12	12	12	12	12
4. Break Elongation, %		700	700	700	700	700
Tear Resistance, lb	ASTM D 1004	21	28	42	56	70
Puncture Resistance, lb	ASTM D 4833	54	72	108	144	180
Stress Crack Resistance <sup>2</sup> , hrs	ASTM D 5397 (App.)	300	300	300	300	300
Carbon Black Content <sup>3</sup> , %	ASTM D 1603	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D 5596	--Note 4--				
Oxidative Induction Time (OIT)						
Standard OIT, minutes	ASTM D 3895	100	100	100	100	100
Oven Aging at 85°C	ASTM D 5721					
Standard OIT - % retained after 90 days	ASTM D 3895	55	55	55	55	55
UV Resistance <sup>5</sup>	GRI GM11					
High Pressure OIT <sup>6</sup> - % retained after 1600 hrs	ASTM D 5885	50	50	50	50	50
Seam Properties	ASTM D 6392 (@ 2 in/min)					
1. Shear Strength, lb/in		57	80	120	160	200
2. Peel Strength, lb/in - Hot Wedge		45	60	91	121	151
- Extrusion Fillet		39	52	78	104	130
Roll Dimensions						
1. Width (feet):		23	23	23	23	23
2. Length (feet)		1000	750	500	375	300
3. Area (square feet):		23,000	17,250	11,500	8,625	6,900
4. Gross weight (pounds, approx.)		3,470	3,470	3,470	3,470	3,470

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 gauge length of 1.3 inches; Break elongation is calculated using a gauge length of 2.0 inches.

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

3 Other methods such as ASTM D 4218 or microwave methods are acceptable if an appropriate correlation can be established.

4 Carbon black dispersion for 10 different views: Nine in Categories 1 and 2 with one allowed in Category 3.

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

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

## SMOOTH HDPE GEOMEMBRANE (METRIC UNITS)

Property	Test Method	Minimum Average Values				
		0.75 mm	1.00 mm	1.50 mm	2.00 mm	2.50 mm
Thickness, microns	ASTM D 5199					
minimum average		750	1,000	1,500	2,000	2,500
lowest individual reading		675	900	1,350	1,800	2,250
Sheet Density, g/cc	ASTM D 1505/D 792	0.940	0.940	0.940	0.940	0.940
Tensile Properties <sup>1</sup>	ASTM D 6693					
1. Yield Strength, kN/m		11	15	22	29	37
2. Break Strength, kN/m		20	27	40	53	67
3. Yield Elongation, %		12	12	12	12	12
4. Break Elongation, %		700	700	700	700	700
Tear Resistance, N	ASTM D 1004	93	125	187	249	311
Puncture Resistance, N	ASTM D 4833	240	320	480	640	800
Stress Crack Resistance <sup>2</sup> , hrs	ASTM D 5397 (App.)	300	300	300	300	300
Carbon Black Content <sup>3</sup> , %	ASTM D 1603	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D 5596	--Note 4--				
Oxidative Induction Time (OIT)						
Standard OIT, minutes	ASTM D 3895	100	100	100	100	100
Oven Aging at 85°C	ASTM D 5721					
Standard OIT - % retained after 90 days	ASTM D 3895	55	55	55	55	55
UV Resistance <sup>5</sup>	GRI GM11					
High Pressure OIT <sup>6</sup> - % retained after 1600 hrs	ASTM D 5885	50	50	50	50	50
Seam Properties	ASTM D 6392 (@ 5 cm/min)					
1. Shear Strength, kN/m		10	14	21	28	35
2. Peel Strength, kN/m - Hot Wedge		7.9	10.5	15.9	21.2	26.4
- Extrusion Fillet		6.8	9.1	13.6	18.2	22.8
Roll Dimensions						
1. Width (meters):		7	7	7	7	7
2. Length (meters)		304.9	228.7	152.4	114.3	91.5
3. Area (square meters):		2,137	1,603	1,068	801	641
4. Gross weight (kilograms, approx.)		1,574	1,574	1,574	1,574	1,574

- 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 gauge length of 33 mm; Break elongation is calculated using a gauge length of 50 mm.
- 2 The yield stress used to calculate the applied load for the SP-NCTL test should be the mean value via MQC testing.
- 3 Other methods such as ASTM D 4218 or microwave methods are acceptable if an appropriate correlation can be established.
- 4 Carbon black dispersion for 10 different views: Nine in Categories 1 and 2 with one allowed in Category 3.
- 5 The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
- 6 UV resistance is based on percent retained value regardless of the original HP-OIT value.

## TEXTURED HDPE GEOMEMBRANE (ENGLISH UNITS)

Property	Test Method	Minimum Average Values			
		40 mil	60 mil	80 mil	100 mil
Thickness, mils	ASTM D 5994				
minimum average		38	57	76	95
lowest individual of 8 of 10 readings		36	54	72	90
lowest individual of 10 readings		34	51	68	85
Asperity Height <sup>1</sup> , mils	GRI GM12	10	10	10	10
Sheet Density, g/cc	ASTM D 1505/D 792	0.940	0.940	0.940	0.940
Tensile Properties <sup>2</sup>	ASTM D 6693				
1. Yield Strength, lb/in		84	126	168	210
2. Break Strength, lb/in		60	90	120	150
3. Yield Elongation, %		12	12	12	12
4. Break Elongation, %		100	100	100	100
Tear Resistance, lb	ASTM D 1004	28	42	56	70
Puncture Resistance, lb	ASTM D 4833	60	90	120	150
Stress Crack Resistance <sup>3</sup> , hrs	ASTM D 5397 (App.)	300	300	300	300
Carbon Black Content <sup>4</sup> , %	ASTM D 1603	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D 5596	--Note 5--			
Oxidative Induction Time (OIT)					
Standard OIT, minutes	ASTM D 3895	100	100	100	100
Oven Aging at 85°C	ASTM D 5721				
Standard OIT - % retained after 90 days	ASTM D 3895	55	55	55	55
UV Resistance <sup>6</sup>	GRI GM11				
High Pressure OIT <sup>7</sup> - % retained after 1600 hrs	ASTM D 5885	50	50	50	50
Seam Properties	ASTM D 6392 (@ 2 in/min)				
1. Shear Strength, lb/in		80	120	160	200
2. Peel Strength, lb/in - Hot Wedge		60	91	121	151
- Extrusion Fillet		52	78	104	130
Roll Dimensions					
1. Width (feet):		23	23	23	23
2. Length (feet)		750	500	375	300
3. Area (square feet):		17,250	11,500	8,625	6,900
4. Gross weight (pounds, approx.)		3,500	3,500	3,470	3,470

1 Of the 10 readings; 8 must be  $\geq 7$  mils and lowest individual reading must be  $\geq 5$  mils.

2 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 gauge length of 1.3 inches; Break elongation is calculated using a gauge length of 2.0 inches.

3 The yield stress used to calculate the applied load for the SP-NCTL test should be the mean value via MQC testing.

4 Other methods such as ASTM D 4218 or microwave methods are acceptable if an appropriate correlation can be established.

5 Carbon black dispersion for 10 different views: Nine in Categories 1 and 2 with one allowed in Category 3.

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

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

## TEXTURED HDPE GEOMEMBRANE (METRIC UNITS)

Property	Test Method	Minimum Average Values			
		1.00 mm	1.50 mm	2.00 mm	2.50 mm
Thickness, microns	ASTM D 5994				
minimum average		950	1,425	1,900	2,375
lowest individual of 8 of 10 readings		900	1,350	1,800	2,250
lowest individual of 10 readings		850	1,275	1,700	2,125
Asperity Height <sup>1</sup> , microns	GRI GM12	250	250	250	250
Sheet Density, g/cc	ASTM D 1505/D 792	0.940	0.940	0.940	0.940
Tensile Properties <sup>2</sup>	ASTM D 6693				
1. Yield Strength, kN/m		15	22	29	37
2. Break Strength, kN/m		11	16	21	26
3. Yield Elongation, %		12	12	12	12
4. Break Elongation, %		100	100	100	100
Tear Resistance, N	ASTM D 1004	125	187	249	311
Puncture Resistance, N	ASTM D 4833	267	400	534	667
Stress Crack Resistance <sup>3</sup> , hrs	ASTM D 5397 (App.)	300	300	300	300
Carbon Black Content <sup>4</sup> , %	ASTM D 1603	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D 5596	--Note 5--			
Oxidative Induction Time (OIT)					
Standard OIT, minutes	ASTM D 3895	100	100	100	100
Oven Aging at 85°C	ASTM D 5721				
Standard OIT - % retained after 90 days	ASTM D 3895	55	55	55	55
UV Resistance <sup>6</sup>	GRI GM11				
High Pressure OIT <sup>7</sup> - % retained after 1600 hrs	ASTM D 5885	50	50	50	50
Seam Properties	ASTM D 6392 (@ 5 cm/min)				
1. Shear Strength, kN/m		14	24	28	35
2. Peel Strength, kN/m - Hot Wedge		10.5	15.9	21.2	26.4
- Extrusion Fillet		9.1	13.6	18.2	22.8
Roll Dimensions					
1. Width (meters):		7	7	7	7
2. Length (meters):		228.7	152.4	114.3	91.5
3. Area (square meters):		1,603	1,068	801	641
4. Gross weight (kilograms, approx):		1,588	1,588	1,574	1,574

1 Of the 10 readings; 8 must be  $\geq$  180 microns and lowest individual reading must be  $\geq$  130 microns.

2 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 gauge length of 33 mm; Break elongation is calculated using a gauge length of 50 mm.

3 The yield stress used to calculate the applied load for the SP-NCTL test should be the mean value via MQC testing.

4 Other methods such as ASTM D 4218 or microwave methods are acceptable if an appropriate correlation can be established.

5 Carbon black dispersion for 10 different views: Nine in Categories 1 and 2 with one allowed in Category 3.

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

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

## SMOOTH LLDPE GEOMEMBRANE (ENGLISH UNITS)

Property	Test Method	Minimum Average Values			
		30 mil	40 mil	60 mil	80 mil
Thickness, mils	ASTM D 5199				
minimum average		30	40	60	80
lowest individual reading		27	36	54	72
Sheet Density, g/cc (max.)	ASTM D 1505/D 792	0.939	0.939	0.939	0.939
Tensile Properties <sup>1</sup>	ASTM D 6693				
1. Break Strength, lb/in		114	152	228	304
2. Break Elongation, %		800	800	800	800
2% Modulus, lb/in <sup>2</sup> (max.)	ASTM D 5323	60,000	60,000	60,000	60,000
Tear Resistance, lb	ASTM D 1004	16	22	33	44
Puncture Resistance, lb	ASTM D 4833	42	56	84	112
Axi-Symmetric Break Strain, %	ASTM D 5617	30	30	30	30
Carbon Black Content <sup>2</sup> , %	ASTM D 1603	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D 5596	--Note 3--			
Oxidative Induction Time (OIT)					
Standard OIT, minutes	ASTM D 3895	100	100	100	100
Oven Aging at 85°C	ASTM D 5721				
Standard OIT - % retained after 90 days	ASTM D 3895	35	35	35	35
UV Resistance <sup>4</sup>	GRI GM11				
High Pressure OIT <sup>5</sup> - % retained after 1600 hrs	ASTM D 5885	35	35	35	35
Seam Properties	ASTM D 6392 (@ 2 in/min)				
1. Shear Strength, lb/in		45	60	90	120
2. Peel Strength, lb/in - Hot Wedge		38	50	75	100
- Extrusion Fillet		34	44	66	88
Roll Dimensions					
1. Width (feet):		23	23	23	23
2. Length (feet):		1,000	750	500	375
3. Area (square feet):		23,000	17,250	11,500	8,625
4. Gross weight (pounds, approx.):		3,435	3,435	3,435	3,435

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

2 Other methods such as ASTM D 4218 or microwave methods are acceptable if an appropriate correlation can be established.

3 Carbon black dispersion for 10 different views: Nine in Categories 1 and 2 with one allowed in Category 3.

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

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

## SMOOTH LLDPE GEOMEMBRANE (METRIC UNITS)

Property	Test Method	Minimum Average Values			
		0.75 mm	1.00 mm	1.50 mm	2.00 mm
Thickness, microns	ASTM D 5199				
minimum average		750	1,000	1,500	2,000
lowest individual reading		675	900	1,350	1,800
Sheet Density, g/cc (max.)	ASTM D 1505/D 792	0.939	0.939	0.939	0.939
Tensile Properties <sup>1</sup>	ASTM D 6693				
1. Break Strength, kN/m		20	27	40	53
2. Break Elongation, %		800	800	800	800
2% Modulus, MPa (max.)	ASTM D 5323	414	414	414	414
Tear Resistance, N	ASTM D 1004	70	100	150	200
Puncture Resistance, N	ASTM D 4833	190	250	370	500
Axi-Symmetric Break Strain, %	ASTM D 5617	30	30	30	30
Carbon Black Content <sup>2</sup> , %	ASTM D 1603	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D 5596	--Note 3--			
Oxidative Induction Time (OIT)					
Standard OIT, minutes	ASTM D 3895	100	100	100	100
Oven Aging at 85°C	ASTM D 5721				
Standard OIT - % retained after 90 days	ASTM D 3895	35	35	35	35
UV Resistance <sup>4</sup>	GRI GM11				
High Pressure OIT <sup>5</sup> - % retained after 1600 hrs	ASTM D 5885	35	35	35	35
Seam Properties	ASTM D 6392 (@ 5 cm/min)				
1. Shear Strength, kN/m		7.9	10.5	15.8	21.0
2. Peel Strength, kN/m - Hot Wedge		6.6	8.7	13.1	17.5
- Extrusion Fillet		5.9	7.7	11.5	15.4
Roll Dimensions					
1. Width (meters):		7	7	7	7
2. Length (meters):		304.9	228.7	152.4	114.3
3. Area (square meters):		2,137	1,603	1,068	801
4. Gross weight (kilograms, approx.):		1,558	1,558	1,558	1,558

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

2 Other methods such as ASTM D 4218 or microwave methods are acceptable if an appropriate correlation can be established.

3 Carbon black dispersion for 10 different views: Nine in Categories 1 and 2 with one allowed in Category 3.

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

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

## TEXTURED LLDPE GEOMEMBRANE (ENGLISH UNITS)

Property	Test Method	Minimum Average Values		
		40 mil	60 mil	80 mil
Thickness, mils	ASTM D 5994			
minimum average		38	57	76
lowest individual of 8 of 10 readings		36	54	72
lowest individual of 10 readings		34	51	68
Asperity Height <sup>1</sup> , mils	GRI GM12	10	10	10
Sheet Density, g/cc (max.)	ASTM D 1505/D 792	0.939	0.939	0.939
Tensile Properties <sup>2</sup>	ASTM D 6693			
1. Break Strength, lb/in		60	90	120
2. Break Elongation, %		250	250	250
2% Modulus, lb/in <sup>2</sup> (max.)	ASTM D 5323	60,000	60,000	60,000
Tear Resistance, lb	ASTM D 1004	22	33	44
Puncture Resistance, lb	ASTM D 4833	44	66	88
Axi-Symmetric Break Strain, %	ASTM D 5617	30	30	30
Carbon Black Content <sup>3</sup> , %	ASTM D 1603	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion <sup>4</sup>	ASTM D 5596		--Note 4--	
Oxidative Induction Time (OIT)				
Standard OIT, minutes	ASTM D 3895	100	100	100
Oven Aging at 85°C	ASTM D 5721			
Standard OIT - % retained after 90 days	ASTM D □3895	35	35	35
UV Resistance <sup>5</sup>	GRI GM11			
High Pressure OIT <sup>6</sup> - % retained after 1600 hrs	ASTM D 5885	35	35	35
Seam Properties	ASTM D 6392 (@ 2 in/min)			
1. Shear Strength, lb/in		60	90	120
2. Peel Strength, lb/in - Hot Wedge		50	75	100
- Extrusion Fillet		44	66	88
Roll Dimensions				
1. Width (feet):		23	23	23
2. Length (feet):		750	500	375
3. Area (square feet):		17,250	11,500	8,625
4. Gross weight (pounds, approx.):		3,465	3,465	3,435

1 Of the 10 readings; 8 must be  $\geq 7$  mils and lowest individual reading must be  $\geq 5$  mils.

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

3 Other methods such as ASTM D 4218 or microwave methods are acceptable if an appropriate correlation can be established.

4 Carbon black dispersion for 10 different views: Nine in Categories 1 and 2 with one allowed in Category 3.

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

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

Property	Test Method	Minimum Average Values		
		1.00 mm	1.50 mm	2.00 mm
Thickness, microns	ASTM D 5994			
minimum average		950	1,425	1,900
lowest individual of 8 of 10 readings		900	1,350	1,800
lowest individual of 10 readings		850	1,275	1,700
Asperity Height <sup>1</sup> , microns	GRI GM12	250	250	250
Sheet Density, g/cc (max.)	ASTM D 1505/D 792	0.939	0.939	0.939
Tensile Properties <sup>2</sup>	ASTM D 6693			
1. Break Strength, kN/m		11	16	21
2. Break Elongation, %		250	250	250
2% Modulus, MPa (max.)	ASTM D 5323	414	414	414
Tear Resistance, N	ASTM D 1004	100	150	200
Puncture Resistance, N	ASTM D 4833	200	300	400
Axi-Symmetric Break Strain, %	ASTM D 5617	30	30	30
Carbon Black Content <sup>3</sup> , %	ASTM D 1603	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion <sup>4</sup>	ASTM D 5596		--Note 4--	
Oxidative Induction Time (OIT)				
Standard OIT, minutes	ASTM D 3895	100	100	100
Oven Aging at 85°C	ASTM D 5721			
Standard OIT - % retained after 90 days	ASTM D □3895	35	35	35
UV Resistance <sup>5</sup>	GRI GM11			
High Pressure OIT <sup>6</sup> - % retained after 1600 hrs	ASTM D 5885	35	35	35
Seam Properties	ASTM D 6392 (@ 5 cm/min)			
1. Shear Strength, kN/m		10.5	15.8	21.0
2. Peel Strength, kN/m - Hot Wedge		8.7	13.1	17.5
- Extrusion Fillet		5.9	7.7	11.5
Roll Dimensions				
1. Width (meters):		7	7	7
2. Length (meters):		228.7	152.4	114.3
3. Area (square meters):		1,603	1,068	801
4. Gross weight (kilograms, approx.):		1,572	1,572	1,558

1 Of the 10 readings; 8 must be  $\geq$  180 microns and lowest individual reading must be  $\geq$  130 microns.

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

3 Other methods such as ASTM D 4218 or microwave methods are acceptable if an appropriate correlation can be established.

4 Carbon black dispersion for 10 different views: Nine in Categories 1 and 2 with one allowed in Category 3.

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

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

## **2.4 Quality Control Specifications**

### **2.4.1 Raw Materials**

#### **A. Resin**

All resins for use in geomembrane must pass a candidate pre-approval process before being eligible for use. Each incoming railcar shall be sampled by compartment with the following testing performed and compared to the manufacturer's specifications:

1. Density: ASTM D 1505.
2. Melt Index: ASTM D 1238.
3. Oxidative Induction Time (OIT): ASTM D 3895.

#### **B. Additives**

All incoming materials are to be tested and approved prior to use with the following testing performed and compared to the manufacturer's specifications:

1. Carbon Black Content: ASTM D 1603.
2. Oxidative Induction Time (OIT): ASTM D 3895.

### **2.4.2 Finished Product: During Production**

#### **A. Inspection**

Performed on each roll during manufacturing.

##### **1. Appearance**

Sheet surface appearance shall be monitored for flaws.

##### **2. Thickness**

A full width sample shall be cut from the end of each roll for thickness measurement.

#### **B. Roll Identification**

Four tags per roll shall be used.

1. Outside the core.
2. On the core plug.
3. On the roll surface.
4. On the production roll sample.

#### **C. Out-of-Spec. Material**

Any roll not meeting the specification for any of the above inspections shall be separated from other rolls and placed on hold.

### **2.4.3 Manufacturer's Quality Control & Quality Assurance Testing**

#### **A. Sampling**

Full width samples shall be taken as retains from the end of each roll to the manufacturer's laboratory.

## B. Testing

The geomembrane quality control testing shall meet the following frequency requirements:

Property	Test Method	Testing Frequency (min.)
Thickness (smooth sheet) (textured sheet)	ASTM D 5199 ASTM D 5994	per roll
Asperity Height (textured sheet only) Alternate the measurement side for double-sided textured sheet.	GRI GM12	every second roll
Sheet Density	ASTM D 1505/D 792	200,000 lb (90,000 kg)
Tensile Properties 1. Yield Strength (HDPE only) 2. Break Strength 3. Yield Elongation (HDPE only) 4. Break Elongation	ASTM D 6693	20,000 lb (9,000 kg)
2% Modulus (LLDPE only)	ASTM D 5323	per each formulation
Tear Resistance	ASTM D 1004	45,000 lb (20,000 kg)
Puncture Resistance	ASTM D 4833	45,000 lb (20,000 kg)
Axi-Symetric Break Strain (LLDPE only)	ASTM D 5617	per each formulation
Stress Crack Resistance (HDPE only)	ASTM D 5397 (App.)	per GRI GM10
Carbon Black Content	ASTM D 1603	20,000 lb (9,000 kg)
Carbon Black Dispersion	ASTM D 5596	45,000 lb (20,000 kg)
Oxidative Induction Time (OIT) Standard OIT	ASTM D 3895	200,000 lb (90,000 kg)
Oven Aging at 85°C Standard OIT	ASTM D 5721 ASTM D 3895	per each formulation
UV Resistance	GRI GM11	
High Pressure OIT	ASTM D 5885	per each formulation

## C. Welding Rod

A sample of welding rod shall be tested at the frequency of once per 25 rolls of welding rod. The following tests shall be performed on the sample:

1. Diameter ASTM D 5199
2. Density ASTM D 1505
3. Melt Index ASTM D 1238
4. Carbon Black Content ASTM D 1603

#### **D. Reporting**

Results from the testing shall be reviewed by the quality control manager. Material that does not meet specifications shall be identified and placed on hold. The test data shall then be transferred to the product data file for roll certification.

### **3. GEOMEMBRANE INSTALLATION**

#### **3.1 Materials Logistics**

##### **3.1.1 Transportation and On-site Storage**

The geomembrane rolls shall be shipped by flatbed trailer to the job site. The geomembrane shall be stored so as to be protected from puncture, dirt, grease, moisture and excessive heat. Damaged material shall be stored separately for repair or replacement. The rolls shall be stored on a prepared smooth surface (not wooden pallets) and should not be stacked more than two rolls high.

#### **3.2 Earthwork**

##### **3.2.1 General**

The owner or his representative (soil quality assurance inspector) shall inspect the subgrade preparation. Prior to liner installation the subgrade shall be compacted in accordance with the project specifications. Weak or compressible areas which cannot be satisfactorily compacted should be removed and replaced with properly compacted fill. All surfaces to be lined shall be smooth, free of all foreign and organic material, sharp objects, or debris of any kind. The subgrade shall provide a firm, unyielding foundation with no sharp changes or abrupt breaks in grade. Standing water or excessive moisture shall not be allowed.

The installer, on a daily basis, shall approve the surface on which the geomembrane will be installed. After the supporting soil surface has been approved, it shall be the installer's responsibility to indicate to the inspector any changes to its condition that may require repair work.

##### **3.2.2 Anchor Trench**

The anchor trench shall be excavated to the line, grade, and width shown on the project construction drawings, prior to liner system placement. Slightly rounded corners shall be provided in the trench to avoid sharp bends in the geomembrane.

#### **3.3 Method of Placement**

The rolls shall be deployed using a spreader bar assembly attached to a loader bucket or by other methods approved by the project engineer.

The installer shall be responsible for the following:

1. Equipment or tools shall not damage the geomembrane during handling, transportation and deployment.
2. Personnel working on the geomembrane shall not smoke or wear damaging shoes.
3. The method used to unroll the panels shall not cause scratches or crimps in the geomembrane and shall not damage the supporting soil.
4. Adequate loading (e.g., sand bags or similar items that will not damage the geomembrane) shall be placed to prevent uplift by wind (in case of high winds, continuous loading is recommended along edges of panels to minimize risk of wind flow under the panels).

### 3.3.1 Weather Conditions

Geomembrane deployment shall proceed between ambient temperatures of 32° F and 104° F. Placement can precede below 32° F only after it has been verified by the inspector that the material can be seamed according to the specification. Geomembrane placement shall not be done during any precipitation, in the presence of excessive moisture (e.g., fog, rain, dew) or in the presence of excessive winds, as determined by the installation supervisor.

## 3.4 Field Seaming

Approved seaming processes are fusion and extrusion welding. On side slopes, seams shall be oriented in the general direction of maximum slope, i.e., oriented down, not across the slope. In corners and odd-shaped geometric locations, the number of field seams shall be minimized.

No base T-seam shall be closer than 5 feet from the toe of the slope. Seams shall be aligned with the least possible number of wrinkles and “fishmouths”. If a fishmouth or wrinkle is found, it shall be relieved and cap-stripped.

### 3.4.1 Seam Overlap

Geomembrane panels must have a finished minimum overlap of 4 inches for fusion welding and 6 inches for extrusion welding.

Cleaning solvents may not be used unless the product is approved by the liner manufacturer.

### 3.4.2 Test Seams

Field test seams shall be conducted on the liner to verify that seaming conditions are satisfactory. Test seams shall be conducted at the beginning of each seaming period and at least once every 4 hours, for each seaming apparatus and personnel used that day.

All test seams shall be made in contact with the subgrade. Welding rod used for extrusion welding shall have the same properties as the resin used to manufacture the geomembrane. The test seam samples shall be 10 feet long for fusion welding and 3 feet long for extrusion welding with the seam centered lengthwise. Three specimens shall be cut from each end of the test seams by the inspector. The inspector shall use a tensiometer to test 3 specimens for shear and 3 specimens for peel. Each specimen shall be one inch wide with a grip separation of 4 inches plus the width of the seam. The seam shall be centered between the clamps. The rate of grip separation shall be 2 inches per minute.

### 3.4.3 Assessment of Seam Test Results

For both smooth and textured seams the strength of two out of three 1.0 inch (25 mm) wide strip specimens should meet or exceed values given in this specification. The third must meet or exceed 80% of the given values. The shear percent elongation should exceed 50%. The assumed gauge length is considered to be the unseamed sheet material on either side of the welded area. Elongation measurements should be omitted for field testing. In addition, the peel separation should not exceed 25% based on the proportion of area of separated bond to the area of the original bonding. 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 the ASTM D 6392. In this regard, SIP is an acceptable break code.

#### Unacceptable Break Codes

Hot Wedge: AD and AD-BRK > 25%

Extrusion Fillet: AD1, AD2 and AD-Weld (unless strength is achieved)

### **3.4.4 Non-Destructive Seam Testing**

The installer shall non-destructively test all field seams over their full length.

#### **A. Vacuum Box Testing**

Equipment for testing extrusion seams shall be comprised of the following:

1. A vacuum box assembly consisting of a rigid housing, a transparent viewing window, a soft rubber gasket attached to the bottom, port hole or valve assembly, and a vacuum gauge.
2. Soapy solution in a plastic bucket with a mop.

The following procedures shall be followed by the installer:

1. Excess sheet overlap shall be trimmed away.
2. Wet a strip of geomembrane approximately 12 inches wide by the length of box with the soapy solution.
3. Place the box over the wetted area and compress.
4. Create a vacuum of 3 - 5 psi.
5. Ensure that a leak tight seal is created.
6. For a period of approximately 10 seconds, examine the geomembrane through the viewing window for the presence of animated soap bubbles.
7. If no animated bubbles appear after 10 seconds, close the vacuum valve and open the bleed valve, move the box over the next adjoining area with a minimum 3 inches overlap and repeat the process.
8. All areas where animated soap bubbles appear shall be marked, repaired and then retested.

The following procedures shall apply to locations where seams cannot be non-destructively tested.

1. If the seam is accessible to testing equipment prior to final installation, the seam shall be non-destructively tested prior to final installation.
2. If the seam cannot be tested prior to final installation, the seams shall be spark tested according to the spark tester manufacturer's procedures.

#### **B. Air Pressure Testing (For Double Fusion Seams Only)**

Equipment for testing double fusion seams shall be comprised of the following:

1. An air pump equipped with pressure gauge capable of generating and sustaining a pressure between 25 and 30 psi.
2. A pressure gauge equipped with a sharp hollow needle.

The following procedures shall be followed by the installer:

1. Seal one end of the seam to be tested.
2. Insert needle or other approved pressure feed device through the sealed end of the channel created by the double wedge fusion weld.
3. Energize the air pump to verify the unobstructed passage of air through the channel.
4. Seal the other end of the channel.
5. Energize the air pump to a pressure between 25 and 30 psi, close valve, allow 2 minutes for the injected air to come to equilibrium in the channel, and sustain pressure for approximately 5 minutes.
6. If loss of pressure exceeds 4 psi, or pressure does not stabilize, locate faulty area, repair and retest.

7. If pressure does not drop below the acceptable value after five minutes, cut the air channel open at the opposite end from the pressure gauge. The air channel should deflate immediately indicating that the entire length of the seam has been tested.

### **3.4.5 Destructive Seam Testing**

Destructive seam testing should be minimized to preserve the integrity of the liner. The installer shall provide the inspector with one destructive test sample per project specifications (usually once per 500 feet of seam length) from a location specified by the inspector.

#### **A. Sampling Procedure**

In order to obtain test results prior to completion of liner installation, samples shall be cut by the installer as the seaming progresses. The installer shall also record the date, location, and pass or fail description. All holes in the geomembrane resulting from obtaining the seam samples shall be immediately patched and vacuum tested.

#### **B. Size and Disposition of Samples**

The samples shall be 12 inches wide by 36 inches long with the seam centered lengthwise. The sample shall be cut into three equal-length pieces, one to be given to the inspector, one to be given to the owner and one to the installer.

#### **C. Field Laboratory Testing**

The inspector shall test ten 1-inch wide specimens from his sample, five specimens for shear strength and five for peel strength.

#### **D. Independent Laboratory Testing**

The owner, at his discretion and expense, may send seam samples to a laboratory for testing. The test method and procedures to be used by the independent laboratory shall be the same as used in field testing.

#### **E. Procedures for Destructive Test Failure**

The following procedures shall apply whenever a sample fails the field destructive test:

1. The installer shall cap strip the seam between the failed location and any passed test locations.
2. The installer can retrace the welding path to an intermediate location (usually 10 feet from the location of the failed test), and take a sample for an additional field test. If this test passes, then the seam shall be cap stripped between that location and the original failed location. If the test fails, then the process is repeated.
3. Over the length of seam failure, the installer shall either cut out the old seam, reposition the panel and reseam, or add a cap strip.

### **3.4.6 Defects and Repairs**

All seams and non-seam areas of the geomembrane shall be inspected by the inspector for defects, holes, blisters, undispersed raw materials, and any sign of contamination by foreign matter. The surface of the geomembrane shall be clean at the time of inspection.

#### **A. Evaluation**

Each suspect location in seam and non-seam areas shall be non-destructively tested as appropriate in the presence of the inspector. Each location that fails the non-destructive testing shall be marked by the inspector, and repaired accordingly.

## **B. Repair Procedures**

1. Defective seams shall be cap stripped or replaced.
2. Small holes shall be repaired by extrusion welding a bead of extrudate over the hole. If the hole is larger than 1/4 inch, it shall be patched.
3. Tears shall be repaired by patching. If the tear is on a slope or an area susceptible to stress and has a sharp end it must be rounded prior to patching.
4. Blisters, large cuts and undispersed raw materials shall be repaired by patches.
5. Patches shall be completed by extrusion welding. The weld area shall be ground no more than 10 minutes prior to welding. No more than 10% of the thickness shall be removed by grinding. Welding shall commence where the grinding started and must overlap the previous seam by at least 2 inches. Reseaming over an existing seam without regrinding shall not be permitted. The welding shall restart by grinding the existing seam and rewelding a new seam.

Patches shall be round or oval in shape, made of the same geomembrane, and extend a minimum of 6 inches beyond the edge of defects.

## **C. Verification of Repairs**

Each repair shall be non-destructively tested. Repairs that pass the non-destructive test shall be taken as an indication of an adequate repair. Failed tests indicate that the repair shall be repeated and retested until passing test results are achieved.

The inspector shall keep daily documentation of all non-destructive and destructive testing. This documentation shall identify all seams that initially failed the test and include evidence that these seams were repaired and successfully retested.

## **3.5 Cover Material and Backfilling of Anchor Trench**

The geomembrane shall be covered as soon as possible. The covering operation shall not damage the geomembrane. The cover soil material shall be free of foreign and organic material, sharp objects, or debris of any kind, which could potentially damage the geomembrane. No construction equipment or machinery shall operate directly on the geomembrane. The use of lightweight machinery (i.e., generator, etc.) with low ground pressure is allowed.

The anchor trench shall be backfilled by the earthwork contractor. Trench backfill material shall be placed and compacted in accordance with the project specifications.

Care shall be taken when backfilling the trenches to prevent any damage to the geomembrane. If damage occurs, it shall be repaired prior to backfilling.

## **3.6 Geomembrane Acceptance**

The installer shall retain all ownership and responsibility for the geomembrane until accepted by the owner.

Final acceptance is when all of the following conditions are met:

1. Installation is finished.
2. Verification of the adequacy of all field seams and repairs, including associated testing, is complete.