

# Drop-In Specifications

GEOMEMBRANE



The following specification is a sample guideline to be customized by the engineer for preparing site specific specification. This information is provided for reference purposes only and is not intended as a warranty or guarantee. AGRU assumes no liability in connection with the use of this information.

## Part 1 GENERAL

### 1.1 SCOPE

This drop-in specification covers the technical requirements for the manufacturing and installation of HDPE and LLDPE Smooth Liner®, MicroSpike®, Super Gripnet®, MicroDrain® and DrainLiner® (GEOMEMBRANE). All materials meet or exceed the requirements of this specification, and all work will be performed in accordance with the procedures provided in these project specifications.

### 1.2 REFERENCES

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

1. D792 Method B, Density and Specific Gravity of Plastics by Displacement
2. D1004 Initial Tear Resistance of Plastic Film and Sheeting
3. D1238 Flow Rates of Thermoplastics by Extrusion Plastometer
4. D3895 Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry
5. D4218 Determination of Carbon Black in Polyethylene Compounds
6. D4833 Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products
7. D5199 Measuring Nominal Thickness of Geotextiles and Geomembranes
8. D5397 Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test
9. D5596 Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics
10. D5994 Measuring Core Thickness of Textured Geomembranes
11. D6392 Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods
12. D6693 Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes
13. D7466 Measuring Asperity Height of Textured Geomembranes

#### B. Geosynthetic Research Institute

1. GRI GM 13 Test Methods, Test Properties and Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes
2. GRI GM 17 Test Properties, Test Properties and Testing Frequency for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes

### 1.3 DEFINITIONS

- A. Lot - A quantity of resin (usually a rail car) used in the manufacture of geomembranes. Finished roll will be identified by a roll number traceable to the resin lot used.
- B. Construction Quality Assurance Consultant (CONSULTANT) - Party, independent from MANUFACTURER and INSTALLER that is responsible for observing and documenting activities related to quality assurance during the lining system construction.
- C. ENGINEER- The individual or firm responsible for the design and preparation of the project's Contract Drawings and Specifications.
- D. Geomembrane Manufacturer (MANUFACTURER) - The party responsible for manufacturing the geomembrane rolls.

- E. Geosynthetic Quality Assurance Laboratory (TESTING LABORATORY) - Party, independent from the OWNER, MANUFACTURER and INSTALLER, responsible for conducting laboratory tests on samples of geosynthetics obtained at the site or during manufacturing, usually under the direction of the OWNER.
- F. INSTALLER- Party responsible for field handling, transporting, storing, deploying, seaming and testing of the geomembrane seams.
- G. Panel - Area of a geomembrane that will be seamed in the field that is larger than 100 ft<sup>2</sup>.
- H. Patch - Area of a geomembrane that will be seamed in the field that is less than 100 ft<sup>2</sup>.
- I. Subgrade Surface - Soil layer surface which immediately underlies the geosynthetic material(s).

## 1.4 SUBMITTALS POST-AWARD

- A. Furnish the following product data, in writing, to ENGINEER prior to installation of the geomembrane material:
  - 1. Resin Data shall include the following.
    - a. Certification stating that the resin meets the specification requirements (see Table 2.1).
  - 2. Geomembrane Roll
    - a. Statement certifying no recycled polymer and no more than 10% rework of the same type of material is added to the resin (product run may be recycled).
- B. The INSTALLER shall furnish the following information to the ENGINEER and OWNER prior to installation:
  - 1. Installation layout drawings
    - a. Must show proposed panel layout including field seams and details
    - b. Must be approved prior to installing the geomembrane
  - 2. Approved drawings will be for concept only and actual panel placement will be determined by site conditions.
  - 3. Installer's Geosynthetic Field Installation Quality Assurance Plan
- C. The INSTALLER will submit the following to the ENGINEER upon completion of installation:
  - 1. Certificate stating the geomembrane has been installed in accordance with the Contract Documents
  - 2. Material and installation warranties
  - 3. As-built drawings showing actual geomembrane placement and seams including typical anchor trench detail and location of repairs.

## 1.5 QUALITY ASSURANCE

- A. Perform Work in accordance with these Specifications and the CQA Plan.
- B. Friction Angle Requirements and Testing
  - 1. The effective interface shear strength envelope at the interface between the geomembrane and the materials in direct contact with the geomembrane shall be verified by the CQA Officer by performing interface friction testing on representative materials to be used for construction of the liner system.
  - 2. The interface frictional resistance shall be determined by direct shear tests in general accordance with ASTM D5321.
  - 3. The interface frictional resistance for interfaces including GCLs shall be determined by direct shear tests in general accordance with ASTM D 6243.
  - 4. The interfaces and/or soil shall be tested saturated with water.
- C. The Manufacturer shall sample and test the HDPE geomembrane material, at minimum frequencies specified. General manufacturing procedures shall be performed in accordance with the Manufacturer's internal quality control guide and/or documents.

- D. All non-conductive geomembrane sheets shall be continuously spark tested during manufacturing.
1. The spark tester shall be capable of detecting defects or pinholes less than 10 mils in diameter.
  2. All necessary repairs to the geomembrane shall be made by the manufacturer at the factory before shipment.
  3. The manufacturer shall provide written certification to the Owner and/or Engineer that all the geomembrane rolls delivered to the project were continuously spark tested and do not contain pinhole defects.
- E. The Engineer shall examine the rolls upon delivery to the site and report any deviations from these Specifications to the Contractor.
- F. If a geomembrane sample fails to meet the quality control requirements of this Section, the Contractor and/or Engineer shall require that the Geomembrane Manufacturer sample and test each roll manufactured in the same lot or batch, or at the same time, as the failing roll. Additional sampling and testing shall be completed at no additional cost to the Owner. Sampling and testing of rolls shall continue until a pattern of acceptable test results is established.
- G. Any geomembrane sample that does not comply with this Section shall result in rejection of the roll from which the sample was obtained. The Contractor shall replace any rejected rolls at no additional cost to Owner. At the Geomembrane Manufacturer's discretion and expense, additional testing of individual rolls may be performed to more closely identify noncomplying rolls and to qualify individual rolls.

## 1.6 QUALIFICATIONS

### A. MANUFACTURER

1. Geomembrane shall be manufactured by the following:
  - a. AGRU America, Inc.
  - b. approved equal
2. MANUFACTURER shall have manufactured a minimum of 10,000,000 square feet of polyethylene geomembrane during the last year.

### B. INSTALLER

1. INSTALLER shall have installed a minimum of 5,000,000 square feet of HDPE geomembrane during the 5 last years.
2. INSTALLER shall have worked in a similar capacity on at least 10 projects similar in complexity to the project described in the contract documents, and with at least 250,000 square feet of HDPE geomembrane installation on each project.
3. The Installation Supervisor shall have worked in a similar capacity on projects similar in size and complexity to the project described in the Contract Documents.
4. The INSTALLER shall provide a minimum of one Master Seamer for work on the project.
  - a. Must have completed a minimum of 1,000,000 square feet of geomembrane seaming work using the type of seaming apparatus proposed for the use on this Project.

## 1.7 MATERIAL LABELING, DELIVERY, STORAGE AND HANDLING

- A. Labeling - Each roll of geomembrane delivered to the site shall be labeled by the MANUFACTURER. The label will identify:
- a. manufacturer's name
  - b. product identification
  - c. thickness
  - d. length
  - e. width
  - f. roll number

B. Delivery- Rolls of liner will be prepared to ship by appropriate means to prevent damage to the material and to facilitate off-loading.

C. Storage- The on-site storage location for geomembrane material, provided by the CONTRACTOR to protect the geomembrane from punctures, abrasions and excessive dirt and moisture for should have the following characteristics:

- a. level (no wooden pallets)
- b. smooth
- c. dry
- d. protected from theft and vandalism
- e. adjacent to the area being lined

D. Handling- Materials are to be handled so as to prevent damage.

## 1.8 WARRANTY

A. Material shall be warranted, on a pro-rata basis against Manufacturer's defects for a period of 1 year from the date of geomembrane installation.

B. Installation shall be warranted against defects in workmanship for a period of 1 year from the date of geomembrane completion.

## Part 2 PRODUCTS

### 2.1 GEOMEMBRANE PROPERTIES

A. Material shall be smooth, textured or structured polyethylene geomembrane as shown on the drawings. Geomembrane shall be flat die-cast extruded.

B. Resin

1. Resin shall be new, first quality, compounded and manufactured specifically for producing geomembrane.
2. Natural resin (without carbon black) shall meet the following requirements:

Table 2.1: Raw Material Properties

Property	Test Method	HDPE	LLDPE
Density (g/cc)	ASTM D792, Method B	≥0.932	≥0.915
Melt Flow Index (g/10 min)	ASTM D 1238 (190/2.16)	≤1.0	≤1.0

C. Geomembrane Rolls

1. Do not exceed a combined maximum total of 1 percent by weight of additives other than carbon black.
2. Geomembrane shall be free of holes, pinholes as verified by on-line electrical detection, bubbles, blisters, excessive contamination by foreign matter, and nicks and cuts on roll edges.
3. Geomembrane material is to be supplied in roll form. Each roll is to be identified with labels indicating roll number, thickness, length, width and MANUFACTURER.
4. All liner sheets produced at the factory shall be inspected prior to shipment for compliance with the physical property requirements listed in section 2.1 D and be tested by an acceptable method of inspecting for pinholes.
5. All geomembrane shall contain edge markings which shall denote the name of the manufacturer, the product thickness,

the year of manufacture and the length of the roll. These marking shall occur at uniformly spaced intervals throughout the entire length of the roll.

D. Smooth surfaced geomembrane shall meet the requirements shown in the following data sheets below:

1. Table 2.2 for HDPE
2. Table 2.3 for LLDPE

Table 2.2: AGRU HDPE Smooth Liner®

Tested Property	Test Method	Frequency	Minimum Average Value				
			30 mil	40 mil	60 mil	80 mil	100 mil
Thickness, (minimum average) mil (mm) Lowest individual reading (-10%)	ASTM D5199	every roll	30 (0.75) 27 (0.69)	40 (1.00) 36 (0.91)	60 (1.50) 54 (1.40)	80 (2.00) 72 (1.80)	100 (2.50) 90 (2.30)
Density, g/cm <sup>3</sup>	ASTM D792, Method B	200,000 lb	0.94	0.94	0.94	0.94	0.94
Tensile Properties (each direction) Strength at Break, lb/in-width (N/mm) Strength at Yield, lb/in-width (N/mm) Elongation at Break, % Elongation at Yield, %	ASTM D6693, Type IV Dumbell, 2 ipm  G.L. 2.0 in (51 mm) G.L. 1.3 in (33 mm)	20,000 lb	120 (21) 66 (11) 700 12	160 (28) 88 (15) 700 12	240 (42) 132 (23) 700 12	320 (56) 176 (30) 700 12	400 (70) 220 (38) 700 12
Tear Resistance, lb (N)	ASTM D1004	45,000 lb	23 (102)	30 (133)	45 (200)	60 (267)	72 (320)
Puncture Resistance, lb (N)	ASTM D4833	45,000 lb	60 (267)	80 (356)	120 (534)	160 (712)	190 (845)
Carbon Black Content, % (Range)	ASTM D4218	20,000 lb	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D5596	45,000 lb	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>
Notched Constant Tensile Load, hr	ASTM D5397, Appendix	200,000 lb	500	500	500	500	500
Oxidative Induction Time, min	ASTM D3895, 200°C; O <sub>2</sub> , 1 atm	200,000 lb	>140	>140	>140	>140	>140

NOTES:

- <sup>(1)</sup>Dispersion only applies to near spherical agglomerates. 10 views shall be Category 1 or 2.
- All AGRU geomembranes have dimensional stability of ±2% when tested according to ASTM D 1204 and LTb of <-77° C when tested according to ASTM D 746.

Table 2.3: AGRU LLDPE Smooth Liner®

Tested Property	Test Method	Frequency	Minimum Average Value			
			40 mil	60 mil	80 mil	100 mil
Thickness, (minimum average) mil (mm) Lowest individual reading (-10%)	ASTM D5199	every roll	40 (1.00) 36 (0.91)	60 (1.50) 54 (1.40)	80 (2.00) 72 (1.80)	100 (2.50) 90 (2.25)
Density, g/cm <sup>3</sup> (maximum)	ASTM D792 Method B	200,000 lb	0.939	0.939	0.939	0.939
Tensile Properties (each direction) Strength at Break, lb/in-width (N/mm) Elongation at Break, %	ASTM D6693, Type IV Dumbbell, 2 ipm G.L. 2.0 in (51 mm)	20,000 lb	160 (28) 800	240 (42) 800	320 (56) 800	400 (70) 800
Tear Resistance, lb (N)	ASTM D1004	45,000 lb	25 (111)	37 (165)	48 (214)	62 (276)
Puncture Resistance, lb (N)	ASTM D4833	45,000 lb	60 (267)	90 (400)	120 (534)	150 (667)
Carbon Black Content, % (Range)	ASTM D4218	20,000 lb	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0
Carbon Black Dispersion	ASTM D5596	45,000 lb	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>
Oxidative Induction Time, min	ASTM D3895, 200° C; O <sub>2</sub> , 1 atm	200,000 lb	>140	>140	>140	>140

NOTES:

- <sup>(1)</sup>Dispersion only applies to near spherical agglomerates. 10 views shall be Category 1 or 2.
- All AGRU geomembranes have dimensional stability of ±2% when tested according to ASTM D 1204 and LTB of <-77° C when tested according to ASTM D 746.

E. Textured surface and structured surface geomembrane shall contain a smooth surface on each edge. Otherwise, texturing shall be uniform from edge to edge and roll to roll. Textured geomembrane shall be manufactured with an embossed surface to ensure uniformity of texture. Textured and/or structured geomembrane shall meet the requirements shown in the following tables:

1. Table 2.4 for HDPE AGRU MicroSpike®
2. Table 2.5 for HDPE AGRU Super Gripnet Liner
3. Table 2.6 for HDPE AGRU Drain Liner
4. Table 2.7 for LLDPE AGRU MicroDrain
5. Table 2.8 for LLDPE AGRU MicroSpike®
6. Table 2.9 for LLDPE AGRU Super GripNet Liner
7. Table 2.10 for LLDPE AGRU MicroDrain
8. Table 2.11 for LLDPE AGRU Drain Liner

Table 2.4: AGRU HDPE MicroSpike® Textured geomembrane

Tested Property	Test Method	Frequency	Minimum Average Value				
			30 mil	40 mil	60 mil	80 mil	100 mil
Thickness, (min. average) mil (mm) Lowest individual reading (-10%)	ASTM D5994	every roll	30 (0.75) 27 (0.68)	40 (1.0) 36 (0.90)	60 (1.5) 54 (1.35)	80 (2.0) 72 (1.8)	100 (2.5) 90 (2.25)
Density, g/cm <sup>3</sup>	ASTM D792 Method B	200,000 lb	0.94	0.94	0.94	0.94	0.94
Tensile Properties (each direction) Strength at Break, lb/in-width (N/mm) Strength at Yield, lb/in-width (N/mm) Elongation at Break, % Elongation at Yield, %	ASTM D6693, Type IV Dumbbell, 2 ipm  G.L. 2.0 in (51 mm) G.L. 1.3 in (33 mm)	20,000 lb	66 (11) 66 (11) 350 12	88 (15) 88 (15) 350 12	132 (23) 132 (23) 350 12	176 (31) 176 (31) 350 12	220 (38) 220 (38) 350 12
Tear Resistance, lb (N)	ASTM D1004	45,000 lb	23 (102)	30 (133)	45 (200)	60 (267)	72 (320)
Puncture Resistance, lb (N)	ASTM D4833	45,000 lb	60 (267)	90 (400)	120 (534)	150 (667)	180 (801)
Carbon Black Content, % (Range)	ASTM D4218	20,000 lb	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D5596	45,000 lb	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>
Asperity Height, mil (mm)	ASTM D7466	second roll	20 (0.5)	20 (0.5)	20 (0.5)	18 (0.45)	18 (0.45)
Notched Constant Tensile Load, hr	ASTM D5397, App.	200,000 lb	500	500	500	500	500
Oxidative Induction Time, min	ASTM D 3895, 200° C; O <sub>2</sub> , 1 atm	200,000 lb	>140	>140	>140	>140	>140

NOTES:

- <sup>(1)</sup>Dispersion only applies to near spherical agglomerates. 10 views shall be Category 1 or 2.
- All AGRU geomembranes have dimensional stability of ±2% when tested according to ASTM D 1204 and LTB of <-77° C when tested according to ASTM D 746.

Table 2.5: AGRU HDPE Super Gripnet® Liner

Tested Property	Test Method	Frequency	Minimum Average Value			
			50 mil	60 mil	80 mil	100 mil
Thickness, (Nominal) mil (mm) Thickness, (average) mil (mm) Lowest individual reading 8 of 10 (-10%) Lowest Individual 2 of 10	ASTM D5994	every roll	50 (1.25) 47.5 (1.18) 45 (1.12) 42.5 (1.06)	60 (1.5) 57 (1.43) 54 (1.35) 51 (1.28)	80 (2.0) 76 (1.9) 72 (1.8) 68 (1.7)	100 (2.5) 95 (2.4) 90 (2.3) 85 (2.1)
Drainage Stud Height, mil (mm)	ASTM D7466	second roll	130 (3.3)	130 (3.3)	130 (3.3)	130 (3.3)
Friction Stud Height, mil (mm)	ASTM D7466	second roll	175 (4.45)	175 (4.45)	175 (4.45)	175 (4.45)
Density, g/cm <sup>3</sup>	ASTM D792, Method B	200,000 lb	0.94	0.94	0.94	0.94



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Tensile Properties (each direction) Strength at Break, lb/in-width (N/mm) Strength at Yield, lb/in-width (N/mm) Elongation at Break, % Elongation at Yield, %	ASTM D6693, Type IV Dumbbell, 2 ipm  G.L. 2.0 in (51 mm) G.L. 1.3 in (33 mm)	20,000 lb	110 (19) 110 (19) 200 12	132 (23) 132 (23) 200 12	176 (30) 176 (30) 200 12	220 (38) 220 (38) 200 12
Tear Resistance, lb (N)	ASTM D1004	45,000 lb	38 (169)	42 (187)	56 (249)	70 (312)
Puncture Resistance, lb (N)	ASTM D4833	45,000 lb	80 (356)	90 (400)	120 (534)	150 (667)
Carbon Black Content, % (Range)	ASTM D4218	20,000 lb	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D5596	45,000 lb	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>
Notched Constant Tensile Load, hr	ASTM D5397, Appendix	200,000 lb	500	500	500	500
Oxidative Induction Time, min	ASTM D3895, 200°C; O <sub>2</sub> , 1 atm	200,000 lb	>140	>140	>140	>140

NOTES:

- <sup>(1)</sup>Dispersion only applies to near spherical agglomerates. 10 views shall be Category 1 or 2.
- All AGRU geomembranes have dimensional stability of ±2% when tested according to ASTM D 1204 and LTB of <-77° C when tested according to ASTM D 746.

Table 2.6: AGRU HDPE Drain Liner®

Tested Property	Test Method	Frequency	Minimum Average Value			
			50 mil	60 mil	80 mil	100 mil
Thickness, (Nominal) mil (mm) Thickness, (average) mil (mm) Lowest individual reading 8 of 10 (-10%) Lowest Individual 2 of 10	ASTM D5994	every roll	50 (1.25)	60 (1.5)	80 (2.0)	100 (2.5)
47.5 (1.18)			57 (1.43)	76 (1.9)	95 (2.4)	
45 (1.12)			54 (1.35)	72 (1.8)	90 (2.3)	
42.5 (1.06)			51 (1.28)	68 (1.7)	85 (2.1)	
Drainage Stud Height, mil (mm)	ASTM D7466	second roll	130 (3.3)	130 (3.3)	130 (3.3)	130 (3.3)
Density, g/cm <sup>3</sup>	ASTM D792, Method B	200,000 lb	0.94	0.94	0.94	0.94
Tensile Properties (each direction) Strength at Break, lb/in-width (N/mm) Strength at Yield, lb/in-width (N/mm) Elongation at Break, % Elongation at Yield, %	ASTM D6693, Type IV Dumbbell, 2 ipm  G.L. 2.0 in (51 mm) G.L. 1.3 in (33 mm)	20,000 lb	110 (19) 110 (19) 300 12	132 (23) 132 (23) 300 12	176 (30) 176 (30) 300 12	220 (38) 220 (38) 300 12
Tear Resistance, lb (N)	ASTM D1004	45,000 lb	38 (169)	42 (200)	56 (267)	70 (300)
Puncture Resistance, lb (N)	ASTM D4833	45,000 lb	80 (356)	95 (422)	126 (560)	158 (703)
Carbon Black Content, % (Range)	ASTM D4218	20,000 lb	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D5596	45,000 lb	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>
Notched Constant Tensile Load, hr	ASTM D5397, Appendix	200,000 lb	500	500	500	500
Oxidative Induction Time, min	ASTM D3895, 200°C; O <sub>2</sub> , 1 atm	200,000 lb	>140	>140	>140	>140

NOTES:

- <sup>(1)</sup>Dispersion only applies to near spherical agglomerates. 10 views shall be Category 1 or 2.

- All AGRU geomembranes have dimensional stability of  $\pm 2\%$  when tested according to ASTM D 1204 and LTB of  $< -77^\circ \text{C}$  when tested according to ASTM D 746.

Table 2.7: AGRU HDPE MicroDrain® Liner

Tested Property	Test Method	Frequency	Minimum Average Value				
			50 mil	60 mil	80 mil	100 mil	
Thickness, (Nominal) mil (mm)	ASTM D5994	every roll	50 (1.25)	60 (1.5)	80 (2.0)	100 (2.5)	
Thickness, (average) mil (mm)			47.5 (1.18)	57 (1.43)	76 (1.9)	95 (2.4)	
Lowest individual reading 8 of 10 (-10%)			45 (1.12)	54 (1.35)	72 (1.8)	90 (2.3)	
Lowest Individual 2 of 10			42.5 (1.06)	51 (1.28)	68 (1.7)	85 (2.1)	
Drainage Stud Height, mil (mm)	ASTM D7466	second roll	130 (3.3)	130 (3.3)	130 (3.3)	130 (3.3)	
MicroSpike® Asperity Height, mil (mm)	ASTM D7466	second roll	20 (0.51)	20 (0.51)	18 (0.46)	18 (0.46)	
Density, g/cm <sup>3</sup>	ASTM D792, Method B	200,000 lb	0.94	0.94	0.94	0.94	
Tensile Properties (each direction)	ASTM D6693, Type IV Dumbbell, 2 ipm	20,000 lb					
Strength at Break, lb/in-width (N/mm)			110 (19)	132 (23)	176 (30)	220 (38)	
Strength at Yield, lb/in-width (N/mm)			110 (19)	132 (23)	176 (30)	220 (38)	
Elongation at Break, %			G.L. 2.0 in (51 mm)	300	300	300	300
Elongation at Yield, %			G.L. 1.3 in (33 mm)	12	12	12	12
Tear Resistance, lb (N)	ASTM D1004	45,000 lb	38 (169)	42 (200)	56 (267)	70 (300)	
Puncture Resistance, lb (N)	ASTM D4833	45,000 lb	80 (356)	95 (422)	126 (560)	158 (703)	
Carbon Black Content, % (Range)	ASTM D4218	20,000 lb	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	
Carbon Black Dispersion	ASTM D5596	45,000 lb	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>	
Notched Constant Tensile Load, hr	ASTM D5397, Appendix	200,000 lb	500	500	500	500	
Oxidative Induction Time, min	ASTM D3895, 200°C; O <sub>2</sub> , 1 atm	200,000 lb	>140	>140	>140	>140	

NOTES:

- <sup>(1)</sup>Dispersion only applies to near spherical agglomerates. 10 views shall be Category 1 or 2.
- All AGRU geomembranes have dimensional stability of  $\pm 2\%$  when tested according to ASTM D 1204 and LTB of  $< -77^\circ \text{C}$  when tested according to ASTM D 746.

Table 2.8: AGRU LLDPE MicroSpike® Textured Geomembrane

Tested Property	Test Method	Frequency	Minimum Average Value			
			40 mil	60 mil	80 mil	100 mil
Thickness, (min. average) mil (mm)	ASTM D5994	every roll	40 (1.0)	60 (1.5)	80 (2.0)	100 (2.5)
Lowest individual reading (-10%)			36 (0.9)	54 (1.35)	72 (1.8)	90 (2.25)
Density, g/cm <sup>3</sup> – maximum	ASTM D792 Method B	200,000 lb	0.939	0.939	0.939	0.939

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Tensile Properties (each direction) Strength at Break, lb/in-width (N/mm) Elongation at Break, %	ASTM D6693, Type IV Dumbell, 2 ipm G.L. 2.0 in (51 mm)	20,000 lb	112 (20) 400	168 (29) 400	224 (39) 400	280 (49) 400
Tear Resistance, lb (N)	ASTM D1004	45,000 lb	25 (111)	36 (160)	50 (222)	60 (267)
Puncture Resistance, lb (N)	ASTM D4833	45,000 lb	50 (222)	70 (310)	90 (400)	115 (512)
Carbon Black Content, % (Range)	ASTM D421 8	20,000 lb	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0
Carbon Black Dispersion	ASTM D5596	45,000 lb	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>
Asperity Height, mil (mm)	ASTM D7466	second roll	20 (0.5)	20 (0.5)	18 (0.45)	18 (0.45)
Oxidative Induction Time, min	ASTM D3895, 200° C; O <sub>2</sub> , 1 atm	200,000 lb	>140	>140	>140	>140

NOTES:

- <sup>(1)</sup>Dispersion only applies to near spherical agglomerates. 10 views shall be Category 1 or 2.
- All AGRU geomembranes have dimensional stability of ±2% when tested according to ASTM D 1204 and LTB of <-77° C when tested according to ASTM D 746.

Table 2.9: AGRU LLDPE Super Gripnet® Liner

Tested Property	Test Method	Frequency	Minimum Average Value			
			50 mil	60 mil	80 mil	100 mil
Thickness, (Nominal) mil (mm)	ASTM D5994	every roll	50 (1.25)	60 (1.5)	80 (2.0)	100 (2.5)
Thickness, (average) mil (mm)			47.5 (1.18)	57 (1.43)	76 (1.9)	95 (2.4)
Lowest individual reading 8 of 10 (-10%)			45 (1.12)	54 (1.35)	72 (1.8)	90 (2.3)
Lowest Individual 2 of 10			42.5 (1.06)	51 (1.28)	68 (1.7)	85 (2.1)
Drainage Stud Height, mil (mm)	ASTM D7466	second roll	130 (3.3)	130 (3.3)	130 (3.3)	130 (3.3)
Friction Stud Height, mil (mm)	ASTM D7466	second roll	175 (4.45)	175 (4.45)	175 (4.45)	175 (4.45)
Density, g/cm <sup>3</sup> – maximum	ASTM D792, Method B	200,000 lb	0.939	0.939	0.939	0.939
Tensile Properties (each direction) Strength at Break, lb/in-width (N/mm) Elongation at Break, %	ASTM D6693, Type IV Dumbell, 2 ipm G.L. 2.0 in (51 mm)	20,000 lb	105 (18) 300	126 (22) 300	168 (29) 300	210 (36) 300
Tear Resistance, lb (N)	ASTM D1004	45,000 lb	30 (133)	40 (178)	53 (236)	65 (285)
Puncture Resistance, lb (N)	ASTM D4833	45,000 lb	55 (245)	70 (311)	90 (400)	110 (489)
Carbon Black Content, % (Range)	ASTM D4218	20,000 lb	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D5596	45,000 lb	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>
Oxidative Induction Time, min	ASTM D3895, 200°C; O <sub>2</sub> , 1 atm	200,000 lb	>140	>140	>140	>140

NOTES:

- <sup>(1)</sup>Dispersion only applies to near spherical agglomerates. 10 views shall be Category 1 or 2.
- All AGRU geomembranes have dimensional stability of ±2% when tested according to ASTM D 1204 and LTB of <-77° C when tested according to ASTM D 746.

Table 2.10: AGRU LLDPE MicroDrain® Liner

Tested Property	Test Method	Frequency	Minimum Average Value			
			50 mil	60 mil	80 mil	100 mil
Thickness, (Nominal) mil (mm)	ASTM D5994	every roll	50 (1.25)	60 (1.5)	80 (2.0)	100 (2.5)
Thickness, (average) mil (mm)			47.5 (1.18)	57 (1.43)	76 (1.9)	95 (2.4)
Lowest individual reading 8 of 10 (-10%)			45 (1.12)	54 (1.35)	72 (1.8)	90 (2.3)
Lowest Individual 2 of 10			42.5 (1.06)	51 (1.28)	68 (1.7)	85 (2.1)
Drainage Stud Height, mil (mm)	ASTM D7466	second roll	130 (3.3)	130 (3.3)	130 (3.3)	130 (3.3)
MicroSpike® Asperity Height, mil (mm)	ASTM D7466	second roll	20 (0.51)	20 (0.51)	18 (0.46)	18 (0.46)
Density, g/cm <sup>3</sup> – maximum	ASTM D792, Method B	200,000 lb	0.939	0.939	0.939	0.939
Tensile Properties (each direction)	ASTM D6693, Type IV Dumbell, 2 ipm G.L. 2.0 in (51 mm)	20,000 lb				
Strength at Break, lb/in-width (N/mm)			105 (18)	126 (22)	168 (29)	210 (36)
Elongation at Break, %			300	300	300	300
Tear Resistance, lb (N)	ASTM D1004	45,000 lb	30 (133)	40 (178)	53 (236)	67 (298)
Puncture Resistance, lb (N)	ASTM D4833	45,000 lb	55 (245)	70 (311)	90 (400)	110 (489)
Carbon Black Content, % (Range)	ASTM D4218	20,000 lb	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D5596	45,000 lb	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>
Oxidative Induction Time, min	ASTM D3895, 200°C; O <sub>2</sub> , 1 atm	200,000 lb	>140	>140	>140	>140

NOTES:

- <sup>(1)</sup>Dispersion only applies to near spherical agglomerates. 10 views shall be Category 1 or 2.
- All AGRU geomembranes have dimensional stability of ±2% when tested according to ASTM D 1204 and LTb of <-77° C when tested according to ASTM D 746.

Table 2.11: AGRU LLDPE Drain Liner®

Tested Property	Test Method	Frequency	Minimum Average Value			
			50 mil	60 mil	80 mil	100 mil
Thickness, (Nominal) mil (mm)	ASTM D5994	every roll	50 (1.25)	60 (1.5)	80 (2.0)	100 (2.5)
Thickness, (average) mil (mm)			47.5 (1.18)	57 (1.43)	76 (1.9)	95 (2.4)
Lowest individual reading 8 of 10 (-10%)			45 (1.12)	54 (1.35)	72 (1.8)	90 (2.3)
Lowest Individual 2 of 10			42.5 (1.06)	51 (1.28)	68 (1.7)	85 (2.1)
Drainage Stud Height, mil (mm)	ASTM D7466	second roll	130 (3.3)	130 (3.3)	130 (3.3)	130 (3.3)
Density, g/cm <sup>3</sup> – maximum	ASTM D792, Method B	200,000 lb	0.939	0.939	0.939	0.939
Tensile Properties (each direction)	ASTM D6693, Type IV Dumbell, 2 ipm G.L. 2.0 in (51 mm)	20,000 lb				
Strength at Break, lb/in-width (N/mm)			105 (18)	126 (22)	168 (29)	210 (36)
Elongation at Break, %			300	300	300	300
Tear Resistance, lb (N)	ASTM D1004	45,000 lb	30 (133)	40 (178)	53 (236)	67 (298)

Puncture Resistance, lb (N)	ASTM D4833	45,000 lb	55 (245)	70 (311)	90 (400)	110 (489)
Carbon Black Content, % (Range)	ASTM D4218	20,000 lb	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D5596	45,000 lb	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>	Note <sup>(1)</sup>
Oxidative Induction Time, min	ASTM D3895, 200°C; O <sub>2</sub> , 1 atm	200,000 lb	>140	>140	>140	>140

NOTES:

- <sup>(1)</sup>Dispersion only applies to near spherical agglomerates. 10 views shall be Category 1 or 2.
- All AGRU geomembranes have dimensional stability of  $\pm 2\%$  when tested according to ASTM D 1204 and LTB of  $< -77^\circ \text{C}$  when tested according to ASTM D 746.

F. Extrudate Rod or Bead

1. Extrudate material shall be made from same type resin as the geomembrane.
2. Additives shall be thoroughly dispersed.
3. Materials shall be free of contamination by moisture or foreign matter.

## Part 3 EXECUTION

### 3.1 EQUIPMENT

A. Welding equipment and accessories shall meet the following requirements:

1. Gauges showing temperatures in apparatus such as extrusion welder or fusion welder shall be present.
2. An adequate number of welding apparatus shall be available to avoid delaying work.
3. Power source must be capable of providing constant voltage under combined line load.

### 3.2 DEPLOYMENT

A. Assign each panel a simple and logical identifying code. The coding system shall be subject to approval and shall be determined at the job site.

B. Visually inspect the geomembrane during deployment for imperfections and mark faulty or suspect areas.

C. Deployment of geomembrane panels shall be performed in a manner that will comply with the following guidelines:

1. Geomembranes shall be installed according to site-specific specifications.
2. Unroll geomembrane using methods that will not damage geomembrane and will protect underlying surface from damage (spreader bar, protected equipment bucket).
3. Place ballast (commonly sandbags) on geomembrane which will not damage geomembrane to prevent wind uplift.
4. Personnel walking on geomembrane shall not engage in activities or wear shoes that could damage it. Smoking will not be permitted on the geomembrane.
5. Do not allow heavy vehicular traffic directly on geomembrane. Low ground pressure, rubber-tired vehicles are acceptable.
6. Protect geomembrane in areas of heavy traffic by placing protective cover over the geomembrane.

D. Sufficient material (slack) shall be provided to allow for thermal expansion and contraction of the material.

### 3.3 FIELD SEAMING

A. Seams shall meet the following requirements:

1. To the maximum extent possible, orient seams parallel to line of slope, i.e., down and not across slope.
2. Minimize number of field seams in corners, odd-shaped geometric locations and outside corners.
3. Slope seams (panels) shall extend a minimum of five-feet beyond the grade break into the flat area.
4. Use a sequential seam numbering system compatible with panel numbering system that is agreeable to the CONSULTANT and INSTALLER.
5. Align seam overlaps consistent with the requirements of the welding equipment being used. A 6-inch overlap is commonly suggested.

B. During Welding Operations

1. Provide at least one Master Seamer who shall provide direct supervision over other welders as necessary.

C. Extrusion Welding

1. Hot-air tack adjacent pieces together using procedures that do not damage the geomembrane.
2. Clean geomembrane surfaces by disc grinder or equivalent.
3. Purge welding apparatus of heat-degraded extrudate before welding.
4. On materials 80 mil and thicker, bevel the top edge of liner to be welded to avoid air pockets.

D. Hot Wedge Welding

1. Welding apparatus shall be a self-propelled device equipped with an electronic controller which displays applicable temperatures.
2. Clean seam area of dust, mud, moisture and debris immediately ahead of hot wedge welder.
3. Protect against moisture build-up between sheets.

E. Trial Welds

1. Perform trial welds on geomembrane samples to verify welding equipment is operating properly.
2. Make trial welds under the same surface and environmental conditions as the production welds, i.e., in contact with sub-grade and similar ambient temperature.
3. Minimum of two trial welds per day, per welding apparatus, one made prior to the start of work and one completed at mid shift.
4. Cut four, one-inch wide by six-inch long test strips from the trial weld.
5. Quantitatively test specimens for peel adhesion, and then for shear strength.
6. Trial weld specimens shall pass when the results shown in the following tables for HDPE and LLDPE are achieved in both peel and shear test.

Table 2.12.A: Minimum Weld Values for HDPE Geomembranes

Property	Test Method	30 (0.75)	40 (1.0)	60 (1.5)	80 (2.0)	100 (2.5)	120 (3.0)
Peel Strength (fusion), ppi (kN/m)	ASTM D 6392	45 (197)	60 (263)	91 (398)	121 (530)	151 (661)	181 (793)
Peel Strength (extrusion), ppi (kN/m)	ASTM D 6392	39 (170)	52 (225)	78 (340)	104 (445)	130 (570)	156 (680)
Shear Strength (fusion & ext.), ppi (kN/m)	ASTM D 6392	57 (250)	80 (350)	120 (525)	160 (701)	200 (876)	240 (1050)

Table 2.12.B: Minimum Weld Values for LLDPE Geomembranes

Property	Test Method	30 (0.75)	40 (1.0)	60 (1.5)	80 (2.0)	100 (2.5)
Peel Strength (extrusion), ppi (kN/m)	ASTM D 6392	38 (166)	50 (219)	75 (328)	100 (438)	125 (547)
Peel Strength (fusion), ppi (kN/m)	ASTM D 6392	34 (150)	44 (190)	66 (290)	88 (385)	114 (500)
Shear Strength (fusion & ext.), ppi (kN/m)	ASTM D 6392	45 (197)	60 (263)	90 (394)	120 (525)	150 (657)

a. The break, when peel testing, occurs in the liner material itself, not through peel separation (FTB).

b. The break is ductile.

7. Repeat the trial weld, in its entirety, when any of the trial weld samples fail in either peel or shear.
8. No welding equipment or welder shall be allowed to perform production welds until equipment and welders have successfully completed trial weld.
9. Seaming shall not proceed when ambient air temperature or adverse weather conditions jeopardize the integrity of the liner installation. INSTALLER shall demonstrate that acceptable seaming can be performed by completing acceptable trial welds.

G. Defects and Repairs

1. Examine all seams and non-seam areas of the geomembrane for defects, holes, blisters, undispersed raw materials, and any sign of contamination by foreign matter.
2. Repair and non-destructively test each suspect location in both seam and non-seam areas. Do not cover geomembrane at locations that have been repaired until test results with passing values are available.

### 3.4 FIELD QUALITY ASSURANCE

A. MANUFACTURER and INSTALLER shall participate in and conform to all terms and requirements of the Owner's quality assurance program. CONTRACTOR shall be responsible for assuring this participation.

B. Quality assurance requirements are as specified in this Section and in the Field Installation Quality Assurance Manual if it is included in the contract.

C. Field Testing

1. Non-destructive testing may be carried out as the seaming progresses or at completion of all field seaming.
  - a. Vacuum Testing
    - 1) Shall be performed in accordance with ASTM D 5641, Standard Practice for Geomembrane Seam Evaluation by Vacuum Chamber.
  - b. Air Pressure Testing
    - 1) Shall be performed in accordance with ASTM D 5820, Standard Practice for Pressurized Air Channel Evaluation of Dual Seamed Geomembranes.
  - c. Other approved methods.
2. Destructive Testing (performed by CONSULTANT with assistance from INSTALLER)
  - a. Location and Frequency of Testing
    - 1) Collect destructive test samples at a frequency of one per every 500 lineal feet of seam length.
    - 2) Test locations will be determined after seaming.
    - 3) Exercise Method of Attributes as described by GRI GM-14 (Geosynthetic Research Institute, <http://www.geosynthetic-institute.org>) to minimize test samples taken.
  - b. Sampling Procedures are performed as follows:
    - 1) INSTALLER shall cut samples at locations designated by the CONSULTANT as the seaming progresses in order to obtain field laboratory test results before the geomembrane is covered.

- 2) CONSULTANT will number each sample, and the location will be noted on the installation as-built.
  - 3) Samples shall be twelve (12) inches wide by minimal length with the seam centered lengthwise.
  - 4) Cut a 2-inch wide strip from each end of the sample for field-testing.
  - 5) Cut the remaining sample into two parts for distribution as follows:
    - a) One portion for INSTALLER, 12-inches by 12 inches
    - b) One portion for the Third Party laboratory, 12-inches by 18-inches
    - c) Additional samples may be archived if required.
      - 6) Destructive testing shall be performed in accordance with ASTM D6392, Standard Test Method for Determining the Integrity of Non-Reinforced Geomembrane Seams Produced Using Thermo-Fusion Methods.
      - 7) INSTALLER shall repair all holes in the geomembrane resulting from destructive sampling.
      - 8) Repair and test the continuity of the repair in accordance with these Specifications.
      - 9) CQA activities should not to be more than one day behind deployment.
3. Failed Seam Procedures
- a) If the seam fails, INSTALLER shall follow one of two options:
    - 1) Reconstruct the seam between any two passed test locations.
    - 2) Trace the weld to intermediate location at least 10 feet minimum or where the seam ends in both directions from the location of the failed test.
  - b) The next seam welded using the same welding device is required to obtain an additional sample
  - c) If sample passes, then the seam shall be reconstructed or capped between the test sample locations.
  - d) If any sample fails, the process shall be repeated to establish the zone in which the seam shall be reconstructed.

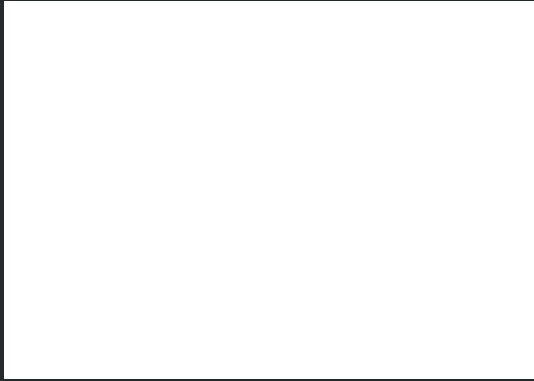
### 3.5 REPAIR PROCEDURES

- A. Remove damaged geomembrane and replace with acceptable geomembrane materials if damage cannot be satisfactorily repaired.
- B. Repair any portion of unsatisfactory geomembrane or seam area failing a destructive or non-destructive test.
- C. INSTALLER shall be responsible for repair of defective areas.
- D. Agreement upon the appropriate repair method shall be decided between CONSULTANT and INSTALLER by using one of the following repair methods:
  1. Patching- Used to repair large holes, tears, undispersed raw materials and contamination by foreign matter.
  2. Abrading and Re-welding- Used to repair short section of a seam.
  3. Spot Welding- Used to repair pinholes or other minor, localized flaws or where geomembrane thickness has been reduced.
  4. Capping- Used to repair long lengths of failed seams.
  5. Remove the unacceptable seam and replace with new material.
- E. The following procedures shall be observed when a repair method is used:
  1. All geomembrane surfaces shall be clean and dry at the time of repair.
  2. Surfaces of the polyethylene which are to be repaired by extrusion welds shall be lightly abraded to assure cleanliness.
  3. Extend patches or caps at least 6 inches for extrusion welds and 4 inches for wedge welds beyond the edge of the defect, and around all corners of patch material.
- F. Repair Verification
  1. Number and log each patch repair (performed by CONSULTANT).
  2. Non-destructively test each repair using methods specified in this Specification.



## Part 4 MEASUREMENT AND PAYMENT

- A. Payment for geomembrane installation will be as per contract unit price per square foot, including designed anchor trench material and is based upon net lined area.
- B. Net lined area is defined to be the true area of all surfaces to be lined plus designed burial in all anchor trenches, rubsheets, and sacrificial layers.
- C. Prices shall include full compensation for furnishing all labor, material, tools, equipment, and incidentals.
- D. Prices also include doing all the work involved in performing geomembrane installation completely as shown on the drawing, as specified herein, and as directed by the ENGINEER.



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