UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated January 2024
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GEOMEMBRANE WASTE CONTAINMENT

02/21

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USACE / NAVFAC / AFCEC | **UFGS-02 56 13.13 (February 2021)**

Preparing Activity: USACE | **Superseding without Revision UFGS-02 56 13 (February 2010)**

UNIFIED FACILITIES GUIDE SPECIFICATIONS

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SECTION 02 56 13.13

GEOMEMBRANE WASTE CONTAINMENT
02/21

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NOTE: This guide specification covers the requirements for geomembrane barrier for waste containment applications.

Adhere to UFC 1-300-02 Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable item(s) or insert appropriate information.

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR).

****

PART 1 GENERAL

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NOTE: This section is not to be used for POL systems. UFGS Section 33 56 19 FUEL IMPERMEABLE LINER SYSTEM for POL tank dike liners and Standard Design 078-24-27 for liners under POL tank bottoms.

Typical materials used in waste containment applications include linear low density polyethylene (LLDPE), high density polyethylene (HDPE), polyvinyl chloride (PVC), or polypropylene (PP). These materials are produced with both smooth and textured surfaces. The need for a textured versus a non textured material will be based on cover stability analyses. The drawings must clearly indicate the limits of placement for textured and non textured

geomembranes.

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1.1 MEASUREMENT AND PAYMENT

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NOTE: Delete this paragraph when lump sum bidding is used.

****

Measure the total surface area in square meters feet covered by geomembrane. Final quantities will be based on as-built conditions. Allowance will be made for geomembrane in anchor and drainage trenches; however, no allowance will be made for waste, overlap, repairs, or materials used for the convenience of the Contractor. Geomembrane installed and accepted by the Contracting Officer will be paid for at the respective contract unit price in the bidding schedule.

1.2 REFERENCES

****

NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a Reference Identifier (RID) outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.

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The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASTM INTERNATIONAL (ASTM)

ASTM D638	(2014) Standard Test Method for Tensile Properties of Plastics
ASTM D751	(2006; R 2011) Coated Fabrics
ASTM D792	(2013) Density and Specific Gravity (Relative Density) of Plastics by Displacement
ASTM D814	(1995; R 2020) Rubber Property - Vapor Transmission of Volatile Liquids

ASTM D882	(2012) Tensile Properties of Thin Plastic Sheeting
ASTM D1004	(2013) Initial Tear Resistance of Plastic Film and Sheeting
ASTM D1203	(2020) Standard Test Methods for Volatile Loss from Plastics Using Activated Carbon Methods
ASTM D1204	(2014; R 2020) Linear Dimensional Changes of Nonrigid Thermoplastic Sheeting or Film at Elevated Temperature
ASTM D1505	(2018) Standard Test Method for Density of Plastics by the Density-Gradient Technique
ASTM D1593	(2009) Standard Specification for Nonrigid Vinyl Chloride Plastic Film and Sheeting
ASTM D1603	(2020) Carbon Black Content in Olefin Plastics
ASTM D1790	(2014) Brittleness Temperature of Plastic Sheeting by Impact
ASTM D3895	(2014) Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry
ASTM D4218	(2020) Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique
ASTM D4833/D4833M	(2007; R 2020) Standard Test Method forIndex Puncture Resistance of Geomembranes and Related Products
ASTM D5199	(2012) Measuring Nominal Thickness of Geosynthetics
ASTM D5321/D5321M	(2020) Standard Test Method for Determining the Shear Strength of Soil-Geosynthetic and Geosynthetic-Geosynthetic Interfaces by Direct Shear
ASTM D5397	(2019a) Standard Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test
ASTM D5596	(2003; R 2016) Standard Test Method For Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics
ASTM D5721	(2008; R 2013) Air-Oven Aging of Polyolefin Geomembranes

ASTM D5885/D5885M	(2017) Standard Test Method for Oxidative Induction Time of Polyolefin Geosynthetics by High-Pressure Differential Scanning Calorimetry
ASTM D5994/D5994M	(2010; R 2015; E2015) Standard Test Method for Measuring Core Thickness of Textured Geomembranes
ASTM D6392	(2012; R 2018) Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods
ASTM D6497/D6497M	(2002; R 2015; E 2015)Standard Guide for Mechanical Attachment of Geomembrane to Penetrations or Structures
ASTM D7238	(2006; R 2012) Standard Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembrane Using Fluorescent UV Condensation Apparatus
ASTM D7466	(2010) Standard Test Method for Measuring Asperity Height of Textured Geomembranes

GEOSYNTHETIC INSTITUTE (GSI)

GSI GRI GM7	(1995) Accelerated Curing of Geomembrane Test Strip Seams Made by Chemical Fusion Methods
GSI GRI GM9	(1995; R 2013) Cold Weather Seaming of Geomembranes

1.3 PANEL LAYOUT

Submit geomembrane panel layout and penetration detail drawings, a minimum of [7] [_____] days prior to geomembrane placement.

1.4 SUBMITTALS

****

NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project. The Guide Specification technical editors have classified those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a “G” to an item, if the submittal is sufficiently important or complex in context of the project.

For Army projects, fill in the empty brackets following the "G" classification, with a code of up to three characters to indicate the approving

authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy and Air Force projects.

The "S" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.

Choose the first bracketed item for Navy and Air Force projects, or choose the second bracketed item for Army projects.

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Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are [for Contractor Quality Control approval.][for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Geomembrane Panel Layout

Penetrations

As-Built Drawings; G[, [_____]]

SD-03 Product Data

Materials; G[, [_____]]

Field Seaming; G[, [_____]]

Qualifications

SD-04 Samples

Samples

SD-06 Test Reports

Surface Preparation

Non-Destructive Field Seam Continuity Testing

Destructive Field Seam Testing

Destructive Seam Test Repairs

Interface Friction Testing

Tests

SD-07 Certificates

Samples

Materials

Surface Preparation

Destructive Field Seam Testing

Destructive Seam Test Repairs

Interface Friction Testing

Tests

1.5 QUALITY CONTROL

1.5.1 Qualifications

1.5.1.1 Manufacturer

Manufacturer will have produced the proposed geomembrane sheets for at least 5 completed projects having a total minimum area of [930,000] [_____] square meters [10] [_____] million square feet.

1.5.1.2 Fabricator

The fabricator is responsible for seaming geomembrane sheets into panels. Fabricator will have fabricated the proposed geomembrane panels for at least 5 completed projects having a total minimum area of [186,000] [_____] square meters [2] [_____] million square feet.

1.5.1.3 Installer

The installer is responsible for field handling, deploying, seaming, anchoring, and field Quality Control (QC) testing of the geomembrane. The installer will have installed the proposed geomembrane material for at least 5 completed projects having a total minimum area of [186,000] [_____] square meters [2] [_____] million square feet. At least one seamer will have experience seaming a minimum of [46,500] [_____] square meters [500,000] [_____] square feet of the proposed geomembrane using the same type of seaming equipment and geomembrane thickness specified for this project.

1.5.1.4 QC Inspector

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NOTE: A separate third party quality assurance (QA) contract should be considered based on the qualifications of the Government QA personnel, the size and importance of the project, and impacts of a geomembrane failure.

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The QC inspector is the person or corporation hired by the Contractor, who is responsible for monitoring and documenting activities related to the QC

of the geomembrane from manufacturing through installation. The QC inspector will have provided QC inspection during installation of the proposed geomembrane material for at least 5 completed projects having a total minimum area of [186,000] [_____] square meters [2] [_____] million square feet.

1.5.1.5 QC Laboratory

The QC laboratory will have provided QC and/or Quality Assurance (QA) testing of the proposed geomembrane and geomembrane seams for at least five completed projects having a total minimum area of [186,000] [_____] square meters [2] [_____] million square feet. The QC laboratory must be accredited via the Geosynthetic Accreditation Institute's Laboratory Accreditation Program (GAI-LAP) for the tests the QC laboratory will be required to perform.

1.5.2 Submittal Requirements

Submit manufacturer's, and fabricator's qualification statements, including resumes of key personnel involved in the project, a minimum of [7] [_____] days prior to geomembrane shipment. Also submit installer's, QC inspector's, and QC laboratory's qualification statements including resumes of key personnel involved in the project a minimum of [7] [_____] days prior to geomembrane placement. The submittal from the QC laboratory must include verification that the laboratory is accredited via the Geosynthetic Accreditation Institute's Laboratory Accreditation Program (GAI-LAP) for the tests the QC laboratory will be required to perform. Submit the following:

a. Manufacturer's and fabricator's QC manuals, a minimum of [7] [_____] days prior to geomembrane shipment. Installer's QC manual, a minimum of [7] [_____] days prior to geomembrane placement.

b. Geomembrane QA and QC samples.

c. Manufacturer's certified raw and sheet material test reports and a copy of the QC certificates, a minimum of [7] [_____] days prior to shipment of geomembrane to the site.

d. Certification from the QC inspector and installer of the acceptability of the surface on which the geomembrane is to be placed, immediately prior to geomembrane placement.

e. QC inspector certified test results on all field seams. Installer and certified QC laboratory test results on all destructively tested field seams. QC inspector certified test results on all repaired seams. Certified QC test results.

f. Certified laboratory interface friction test results including description of equipment and test method, a minimum of [7] [_____] days prior to geomembrane shipment.

1.6 DELIVERY, STORAGE AND HANDLING

1.6.1 Delivery

The QC inspector will be present during delivery and unloading of the geomembrane. Label each geomembrane roll/panel with the manufacturer's name, product identification number, roll/panel number, and roll dimensions.

1.6.2 Storage

Furnish temporary storage at the project site on a level surface, free of sharp objects where water cannot accumulate. Protect the geomembrane from puncture, abrasion, excessive heat or cold, material degradation, or other damaging circumstances. Do not crush the core of roll goods or flatten the rolls during storage. Do not store rolls more than two high. Store palleted materials on level surfaces and do not stack on top of one another. Cover ultraviolet sensitive materials (i.e., PVC) with a sacrificial opaque and waterproof covering or place in a temporary shelter. Remove damaged geomembrane from the site and replace with geomembrane that meets the specified requirements.

1.6.3 Handling

Do not drag, lift by one end, or drop rolls/panels. Use a pipe or solid bar, of sufficient strength to support the full weight of a roll without significant bending, for all handling activities. The diameter of the pipe or solid bar must be small enough to be easily inserted through the core of the roll. Use chains to link the ends of the pipe or bar to the ends of a spreader bar. The spreader bar must be wide enough to prevent the chains from rubbing against the ends of the roll. Alternatively, a stinger bar protruding from the end of a forklift or other equipment may be used. The stinger bar must be at least three-fourths the length of the core and also must be capable of supporting the full weight of the roll without significant bending. If recommended by the manufacturer, a sling handling method utilizing appropriate loading straps may be used.

1.7 AMBIENT CONDITIONS

Do not deploy or field-seam geomembrane in the presence of excess moisture (i.e., rain, fog, dew), in areas of ponded water, or in the presence of excess wind. Unless authorized by the Contracting Officer, do not place or seam at ambient temperatures below 0 degrees C 32 degrees F or above 40 degrees C 104 degrees F. Measure ambient temperature at a height less than 150 mm 6 inches above the ground or geomembrane surface. If seaming is allowed below 0 degrees C 32 degrees F, follow the procedures outlined in GSI GRI GM9. In marginal conditions, cease seaming unless destructive field seam tests, conducted by the QC laboratory, confirm that seam properties meet the requirements listed in Table [3] [5]. Conduct tests in accordance with paragraph Destructive Field Seam Testing.

PART 2 PRODUCTS

2.1 MATERIALS

2.1.1 Raw Materials

In manufacturing geomembrane sheets, use resin made of virgin uncontaminated ingredients. Use no more than [10] [_____] percent regrind, reworked, or trim material in the form of chips or edge strips to manufacture the geomembrane sheets. All regrind, reworked, or trim materials must be from the same manufacturer and exactly the same formulation as the geomembrane sheet being produced. Do not use post consumer materials or water-soluble ingredients to produce the geomembrane. For geomembranes with plasticizers, use only primary plasticizers that are resistant to migration. Submit a copy of the test reports and QC certificates for materials used in the manufacturing of the

geomembrane shipped to the site.

2.1.2 Sheet Materials

NOTE: USACE practice on landfill cover systems has been to use a minimum nominal geomembrane thickness of 1 mm 40 mils. This criterion is based on survivability. USACE practice for landfill liner systems has been to use a minimum nominal geomembrane thickness of 1.5 mm 60 mils. Site-specific analyses should be conducted to determine the appropriate thickness for both landfill liners and covers. Reinforced geomembranes are generally not recommended where geomembrane elongation properties are critical (i.e., landfill covers) but may be suitable for other applications such as liquid surface impoundments. The property values listed in Tables 1, 2, and 4 are based on industry agreed upon Manufacturing Quality Control (MQC) values for 40 mil smooth and textured HDPE and 40 mil smooth PVC. These values are provided as examples only. Refer to GRI Test Method GM-13 when specifying MQC values for other thicknesses of HDPE.

Tables 1 and 2 can also be used for LLDPE geomembranes. Refer to GSI GRI GM17 when specifying MQC property requirements for LLDPE. If LLDPE geomembrane is being specified, omit property requirements for stress crack resistance (ASTM D5397), yield strength (ASTM D882), and yield elongation (ASTM D882).

Include property requirements for multi-axial tensile strength (ASTM D5617). Property requirements for multi-axial tensile tests simulate a void beneath the geomembrane or differential settlement which may stress the geomembrane beyond its multi-axial strain limit. Multi-axial tensile tests are typically specified for HDPE geomembranes only when the geomembrane is likely to be subjected to significant multi-axial stresses. If multi-axial testing will be performed on an HDPE geomembrane, tests should be performed in accordance with ASTM D5617. A minimum multi-axial tensile strain at rupture of 20 percent is typically specified for smooth HDPE geomembranes. For textured HDPE geomembranes, the specified minimum multi-axial tensile strain at rupture should be 15 percent.

Refer to the PVC Geomembrane Institute's PGI 1197 when specifying MQC values for other thicknesses of PVC. For other material types, evaluate at least three current manufacturer's property sheets for each acceptable material type before specifying property test values.

Provide geomembrane sheets that are [unreinforced] [reinforced] and

manufactured as wide as possible to minimize factory and field seams. Provide geomembrane sheets that are uniform in color, thickness, and surface texture. For slopes greater than or equal to 1V on [_____] H, provide sheets that are textured on [the upper face] [the lower face] [both faces]. The textured surface features consist of raw materials identical to that of the parent sheet material and are uniform over the entire face of the geomembrane. Provide sheets that are free of and resistant to fungal or bacterial attack and free of cuts, abrasions, holes, blisters, contaminants and other imperfections. Geomembrane sheets and factory seams mut conform to the requirements listed in Table [1] [2] [3] [4] and [5] for Manufacturing Quality Control (MQC).

TABLE 1 - SMOOTH HDPE GEOMEMBRANE PROPERTIES

PROPERTY	TEST VALUE	MQC TESTING FREQUENCY (MIN.)	TEST METHOD
Thickness (min ave)	[1] [_____] mm [40] [_____] mils	per roll	ASTM D5199
Lowest individual of 10 values	-10 percent	per roll	ASTM D5199
Density (min)	0.940 g/cc	per 90,000 kg per 200,000 lb	ASTM D1505
Tensile Properties(1)(min ave)		per 9,000 kg per 20,000 lb	ASTM D638 Type IV
yield stress	[15] [_____] kN/m [84] [_____] lb/in		
break stress	[27] [_____] kN/m [152] [_____] lb/in		
yield elong	[12] [_____] percent		
break elong	[700] [_____] percent		
Tear Resistance (min ave)	[125] [_____] N [28] [_____] lb	per 20,000 kg per 45,000 lb	ASTM D1004
Puncture Resistance(min ave)	[320] [_____] N [72] [_____] lb	per 20,000 kg per 45,000 lb	ASTM D4833/D4833M
Stress Crack Resistance (2)	[200] [_____] hr	per 90,000 kg per 200,000 lb	ASTM D5397 (Appendix)
Carbon Black Content	2.0-3.0 percent	per 9,000 kg per 20,000 lb	ASTM D1603 (3)
Carbon Black Dispersion	Note (4)	per 20,000 kg per 45,000 lb	ASTM D5596
Oxidative Induction Time (OIT)(min ave)(5)		per 90,000 kg per 200,000 lb	

TABLE 1 - SMOOTH HDPE GEOMEMBRANE PROPERTIES			
PROPERTY	TEST VALUE	MQC TESTING FREQUENCY (MIN.)	TEST METHOD
-Std OIT	100 min		ASTM D3895
-High Pres OIT	400 min		ASTM D5885/D5885M
Oven Aging at 85 deg C 185 deg F (min ave) (5), (6)		per year and change in formulation	ASTM D5721
Std OIT	55 percent at 90 days		ASTM D3895
or High Pres OIT	80 percent at 90 days		ASTM D5885/D5885M
UV Resistance (min ave) (7)		per year and change in formulation	ASTM D7238
High Pres OIT(8)(9)	50 percent at 1600 hours		ASTM D5885/D5885M

TABLE 2 - TEXTURED HDPE GEOMEMBRANE PROPERTIES			
PROPERTY	TEST VALUE	MQC TESTING FREQUENCY (MIN.)	TEST METHOD
Nominal Thickness	[1] [_____] mm [40] [_____] mils		
Thickness (min ave)	-5 percent of nominal	per roll	ASTM D5994/D5994M
Lowest individual for 8 out of 10 values	-10 percent of nominal	per roll	ASTM D5994/D5994M
Lowest individual of 10 values	-15 percent of nominal	per roll	ASTM D5994/D5994M
Asperity Height (min ave) (10)	0.25 mm10 mils	every second roll	ASTM D7466 (11)
Density (min)	0.940 g/cc	per 90,000 kg per 200,000 lb	ASTM D1505
Tensile Properties(1)(min ave)		per 9,000 kgper 20,000 lb	ASTM D638 Type IV

TABLE 2 - TEXTURED HDPE GEOMEMBRANE PROPERTIES			
PROPERTY	TEST VALUE	MQC TESTING FREQUENCY (MIN.)	TEST METHOD
yield stress	[15] [_____] kN/m [84] [_____] lb/in		
break stress	[11] [_____] kN/m [60] [_____] lb/in		
yield elongation	[12] [_____] percent		
break elongation	[100] [_____] percent		
Tear Resistance (min ave)	[125] [_____] N [28] [_____] lb	per 20,000 kg per 45,000 lb	ASTM D1004
Puncture Resistance(min ave)	[267] [_____] N [60] [_____] lb	per 20,000 kg per 45,000 lb	ASTM D4833/D4833M
Stress Crack Resistance (2)	[200] [_____] hr	per 90,000 kg per 200,000 lb	ASTM D5397 (Appendix)
Carbon Black Content	2.0-3.0 percent	per 9,000 kgper 20,000 lb	ASTM D1603 (3)
Carbon Black Dispersion	Note (4)	per 20,000 kg per 45,000 lb	ASTM D5596
Oxidative Induction Time (OIT)(min ave)(5)		per 90,000 kg per 200,000 lb	
Std OIT	100 min		ASTM D3895
or High Pres OIT	400 min		ASTM D5885/D5885M
Oven Aging at 85 deg C 185 deg F (min ave) (5), (6)		per year and change in formulation	ASTM D5721
Std OIT	55 percent at 90 days		ASTM D3895
or High Pres OIT	80 percent at 90 days		ASTM D5885/D5885M
UV Resistance (min ave) (7)		per year and change in formulation	ASTM D7238
High Pres OIT(8)(9)	50 percent at 1600 hours		ASTM D5885/D5885M

TABLE 1 AND TABLE 2 NOTES	
MQC	Manufacturing Quality Control
Note (1)	Base minimum average machine direction and minimum average cross machine direction values on 5 test specimens in each direction. For HDPE geomembrane, yield elongation is calculated using a gauge length of 33 mm 1.3 inches. For HDPE geomembrane, break elongation is calculated using a gauge length of 50 mm 2.0 inches. For LLDPE geomembrane, break elongation is calculated using a gage length of 50 mm 2.0 inches at 50 mm/min 2 inches/min.
Note (2)	For HDPE geomembrane, the yield stress used to calculate the applied load for test method ASTM D5397 (Appendix), is the manufacturer's mean value. ASTM D5397 does not need to be run on LLDPE geomembrane.
Note (3)	Other methods such as ASTM D4218 or microwave methods are acceptable if an appropriate correlation to ASTM D1603 can be established.
Note (4)	Carbon black dispersion for 10 different views: - minimum 8 of 10 in Categories 1 or 2 - all 10 in Categories 1,2, or 3
Note (5)	The manufacturer has the option to select either one of the OIT methods to evaluate the antioxidant content.
Note (6)	Evaluate samples at 30 and 60 days and compare with the 90 day response.
Note (7)	The condition of the test is a 20 hour UV cycle at 75 degrees C 167 degrees F followed by a 4 hour condensation cycle at 60 degrees C 140 degrees F.
Note (8)	Do not use the standard OIT test (ASTM D3895) in determining UV resistance.
Note (9)	UV resistance is based on percent retained value regardless of the original HP-OIT value.
Note (10)	Textured Geomembrane Only: Of 10 readings; 8 out of 10 must be 0.18 mm 7 mil, and lowest individual reading must be 0.13 mm 5 mil.
Note (11)	Textured Geomembrane Only: Alternate the measurement side for double sided textured sheet.

TABLE 3 - HDPE SEAM PROPERTIES		
PROPERTY	TEST VALUE	TEST METHOD
Seam Shear Strength (min) (1)	[14.0] [_____] kN/m[80] [_____] lb/in	ASTM D6392
Seam Peel Strength (min) (1) (2)	[8.4] [_____] kN/m[48] [_____] lb/in	ASTM D6392
Note (1): Seam tests for peel and shear must fail in the Film Tear Bond mode. This is a failure in the ductile mode of one of the bonded sheets by tearing or breaking prior to complete separation of the bonded area.		

TABLE 3 - HDPE SEAM PROPERTIES		
PROPERTY	TEST VALUE	TEST METHOD
Note (2): Where applicable, test both tracks of a double hot wedge seam for peel adhesion.		

TABLE 4 - SMOOTH PVC GEOMEMBRANE PROPERTIES		
PROPERTY	TEST VALUE	TEST METHOD
Thickness (nominal)	[1] [_____] mm[40] [_____] mils	ASTM D1593
Thickness (min)	[0.95] [_____] mm[38] [_____] mils	ASTM D1593
Specific Gravity (min)	1.2 g/ml	ASTM D792
Tensile Properties (min)		ASTM D882, Method A
break strength (Machine direction (MD) and Transvers direction (TD))	[17.0] [_____] kN/m[97] [_____] lb/in	
elongation @ break (MD and TD)	[400] [_____] percent	
modulus @ 100 percent (MD and TD)	[7.2] [_____] kN/m[41] [_____] lb/in	
Tear Resistance (min)	[46.7] [_____] kN/m[10.5] [_____] lb/in	ASTM D1004, Die C
Low Temperature, pass	-29 degrees C-20 degrees F	ASTM D1790
Dimensional Stability (max)(MD and TD)	[3] [_____] percent	ASTM D1204
Water Extraction (max)	[0.2] [_____] percent loss	See Note 1
Volatile Loss (max)	[0.5] [_____] percent loss	ASTM D1203 (A)
Resistance to Soil Burial		See Note 1
breaking factor	+/- 5 percent	
elongation @ break	+/- 20 percent	
100 percent modulus	+/- 20 percent	
Water Vapor	.00000000005 m/sec	ASTM D814
Hydrostatic Resistance (min)	[827] [_____] kN/sq m[120] [_____] lb/sq in	ASTM D751 (A)

TABLE 4 - SMOOTH PVC GEOMEMBRANE PROPERTIES		
PROPERTY	TEST VALUE	TEST METHOD
NOTE 1: Perform Water Extraction and Resistance to Soil Burial testing in accordance with manufacturer's approved procedures.		

TABLE 5 - PVC SEAM PROPERTIES		
PROPERTY	TEST VALUE	TEST METHOD
Seam Shear Strength (min)	[13.5] [_____] kN/m[77] [_____] lb/in	Installers approved procedure
Seam Peel Strength (min) (1)	[2.6] [_____] kN/m[15] [_____] lb/in	Installers approved procedure
Note (1): Where applicable, test both tracks of a double hot wedge seam for peel adhesion.		

2.1.3 Factory Seams

****

NOTE: Polyethylene geomembranes are not usually factory seamed. Delete this paragraph when factory seaming is not applicable.

****

Factory seam geomembrane sheets into maximum sized panels to minimize field seaming. Factory seaming must be by methods approved by the geomembrane manufacturer. Seams must meet the minimum shear and peel strength requirements shown in Table [3] [5]. Factory seams must extend to the end of the sheet so that no unbonded edges greater than 3.2 mm 1/8 inch wide are present.

2.2 TESTS, INSPECTIONS, AND VERIFICATIONS

2.2.1 Interface Friction Testing

****

NOTE: Interface friction testing should be conducted on all potential slip interfaces. The rate of displacement and normal stresses used for interface friction testing are dependent on the materials being tested and anticipated site conditions. Normal stresses specified should cover the range of anticipated field loads. Selection of peak versus residual values should be based on anticipated interface displacements taking into account seismic activities and long term conditions.

The number of interface friction tests must be determined on a site specific basis considering regulator input and the potential for damage due to a shear failure. This testing should be completed

during design or by the Contractor prior to the start of construction.

A method sometimes used to model saturated conditions at the shear interface is to wet these surfaces prior to shearing.

****

Conduct laboratory interface friction tests on the following interfaces: [_____]. The frequency of testing for each interface is [1 per [_____] acres of geomembrane placed] [[_____] per project]. Conduct tests in accordance with ASTM D5321/D5321M. Use normal stresses of [_____], [_____], and [_____] kPa psi along with a displacement rate of [1.0] [5.0] [_____] mm [0.04] [0.2] [_____] inches per minute. Test [wet] [dry] interfaces. Use the same soil components that are used for full scale construction and compact to the same moisture-density requirements specified for full scale field placement. Provide geosynthetics that are the same materials as those proposed for use during full scale construction. Orient geosynthetics such that the shear force is parallel to the down slope orientation of these components in the field. A minimum [peak] [residual] interface friction angle of [_____] degrees is required for all interfaces.

2.2.2 Manufacturing, Sampling, and Testing

2.2.2.1 Raw Materials

Test raw materials in accordance with the approved MQC manual. Do not use any raw material which fails to meet the geomembrane manufacturer's specified physical properties in manufacturing the sheet. Manufacture seaming rods and pellets using materials which are essentially identical to that used in the geomembrane sheet. Test seaming rods and pellets for density, melt index and carbon black content in accordance with the approved MQC manual. Do not use seaming rods and pellets which fail to meet the corresponding property values required for the sheet material for seaming.

2.2.2.2 Sheet Material

Test geomembrane sheets in accordance with the approved MQC manual. As a minimum, conduct MQC testing at the frequencies shown in Table 1. Do not send sheets not meeting the minimum requirements specified in Table 1 to the site.

2.3 EQUIPMENT

Use the geomembrane manufacturer's recommended equipment to perform the work and maintain equipment in satisfactory working condition.

PART 3 EXECUTION

3.1 PREPARATION

3.1.1 Surface Preparation

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NOTE: Ensure other sections of the specification package adequately address compaction requirements for soil subgrade layers.

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Perform surface preparation in accordance with Section 31 00 00 EARTHWORK. Remove rocks larger than [13] [_____] mm [1/2] [_____] inch in diameter and any other material which could damage the geomembrane from the surface to be covered with the geomembrane. Construction equipment tire or track deformations beneath the geomembrane greater than 25 mm 1.0 inch in depth is prohibited. Each day during placement of geomembrane, the [QC Inspector] [Contracting Officer] and installer must inspect the surface on which geomembrane is to be placed and certify in writing that the surface is acceptable. Perform repairs to the subgrade at no additional cost to the Government.

3.1.2 Anchor Trenches

Where an anchor trench is required, place it [610] [_____] mm [24] [_____] inches back from the edge of the slope to be covered. Provide an anchor trench [610] [_____] mm [24] [_____] inches deep and [460] [_____] mm [18] [_____] inches wide. If the anchor trench is excavated in cohesive soil susceptible to desiccation, excavate only the amount of anchor trench required for placement of geomembrane in a single day. Remove ponded water from the anchor trench while the trench is open. Slightly round trench corners to avoid sharp bends in the geomembrane. Remove loose soil, rocks larger than [13] [_____] mm [1/2] [_____] inch in diameter, and any other material which could damage the geomembrane from the surfaces of the trench. Extend the geomembrane down the front wall and across the bottom of the anchor trench. Perform backfilling and compaction of the anchor trench in accordance with Section 31 00 00 EARTHWORK.

3.2 GEOMEMBRANE DEPLOYMENT

Do not elongate, wrinkle, scratch, or otherwise damage the geomembrane, other geosynthetic layers, or the underlying subgrade. Replace or repair geomembrane damaged during installation at the [QC inspector's] [Contracting Officer's] discretion. Only deploy geomembrane panels that can be anchored and seamed together the same day. Place adequate ballast (i.e., sand bags) on the geomembrane, without damaging the geomembrane, to prevent uplift by wind. Do not operate equipment on the top surface of the geomembrane without permission from the Contracting Officer. Orient seams parallel to the line of maximum slope. Where seams can only be oriented across the slope, lap the upper panel over the lower panel. Minimize wrinkles and tensile stresses in the geomembrane. Provide adequate slack to prevent the creation of tensile stress. Wrinkle height to width ratio for installed geomembrane exceeding 0.5 is unacceptable. In addition, geomembrane wrinkles exceeding 150 m 6 inches in height is prohibited. Cut out and repair wrinkles that do not meet the above criteria in accordance with the installer's approved QC manual.

3.3 FIELD SEAMING

3.3.1 Trial Seams

Make trial seams under field conditions on strips of excess geomembrane. Make trial seams each day prior to production seaming, whenever there is a change in seaming personnel or seaming equipment and at least once every four hours, by each seamer and each piece of seaming equipment used that day. Collect and test trial seam samples in accordance with ASTM D6392. Obtain one sample from each trial seam. This sample must be at least 920

mm long by 305 mm wide 36 inches long by 12 inches wide with the seam centered lengthwise. Cut ten random specimens 25.4 mm 1 inch wide from the sample. Field test five seam specimens for shear strength and field test 5 seam specimens for peel adhesion using an approved quantitative tensiometer. Where necessary, conduct accelerated curing of trial seams made by chemical methods in accordance with GSI GRI GM7. To be acceptable, 4 out of 5 replicate test specimens must meet seam strength requirements specified in Table [3] [5]. If the field tests fail to meet these requirements, repeat the entire operation. If the additional trial seam fails, do not use the seaming apparatus or seamer until the deficiencies are corrected by the installer and 2 consecutive successful trial seams are achieved.

3.3.2 Field Seams

Seam panels in accordance with the geomembrane manufacturer's recommendations. In sumps, corners and odd-shaped geometric locations, minimize the number of field seams. Extend seaming to the outside edge of panels. Soft subgrades must be compacted and approved prior to seaming. Provide a seam area that is free of moisture, dust, dirt, and foreign material at the time of seaming. Repair fish mouths in seam.

3.3.2.1 Polyethylene Seams

Seam polyethylene geomembranes by thermal fusion methods. Only use extrusion welding for patching and seaming in locations where thermal fusion methods are not feasible. Ground seam overlaps that are to be attached using extrusion welds prior to welding. Orient grinding marks perpendicular to the seam direction and do not extend marks beyond the extrudate after placement. Begin extrusion welding within 10 minutes after grinding. Where extrusion welds are temporarily terminated long enough to cool, ground prior to applying new extrudate over the existing seam. The total depth of the grinding marks greater than 10 percent of the sheet thickness is unacceptable.

3.3.2.2 Non-Polyethylene Seams

Seam non-polyethylene geomembranes by methods as recommended by the geomembrane manufacturer. Store seaming adhesives, solvents, or chemical cleaning agents away from the geomembrane and only use spill-resistant containers while working on the geomembrane. If low temperatures slow the curing process of chemically fused seams and delay seam testing, use GSI GRI GM7 to accelerate sample curing.

3.4 SAMPLES

Obtain one QC sample, 500 mm 18 inches in length, for the entire width of a roll, for every 9,000 square meters 100,000 square feet of material delivered to the site. Do not obtain samples from the first three feet of the roll. For accordion folded geomembranes, collect samples of equivalent size from approved locations. Identify the samples by manufacturer's name, product identification, lot and roll/panel number. Also, note the date, a unique sample number, and the machine direction. In addition, collect and label a [305 by 305 mm] [_____] [12 inch by 12 inch] [_____] QA sample, and submit to the Contracting Officer each time QC samples are collected.

3.5 TESTS

Provide all QC samples to the QC laboratory to determine density, thickness, tensile strength at break, and elongation at break in accordance with the methods specified in Table [1] [2] [4]. Samples not meeting the specified requirements will result in the rejection of applicable rolls/panels. As a minimum, test rolls/panels produced immediately prior to and immediately after the failed roll/panel for the same failed parameter. Continue testing until a minimum of three successive rolls/panels on both sides of the original failing roll/panel pass the failed parameter.

3.5.1 Non-Destructive Field Seam Continuity Testing

Non-destructively test field seams for continuity over their full length in accordance with the installer's approved QC manual. Perform seam testing as the seaming work progresses, not at the completion of field seaming. Document and repair any seams which fail in accordance with the installer's approved QC manual.

3.5.2 Destructive Field Seam Testing

Obtain a minimum of one destructive test sample per [230] [_____] m [750] [_____] feet of field seam at locations specified by the [QC inspector] [Contracting Officer]. Do not identify sample locations prior to seaming. Provide samples that are a minimum of 305 mm 12 inches wide by 1.1 m 42 inches long with the seam centered lengthwise. Cut each sample into 3 equal pieces, with one piece retained by the installer, one piece given to the QC laboratory, and the remaining piece given to the Contracting Officer for QA testing and/or permanent record. Number and cross reerence each sample to a field log which identifies: (1) panel number; (2) seam number; (3) date and time cut; (4) ambient temperature within 150 mm 6 inches above the geomembrane; (5) seaming unit designation; (6) name of seamer; and (7) seaming apparatus temperature and pressures (where applicable). Cut ten 25 mm 1 inch wide replicate specimens from the installer's sample. Test five specimens for shear strength and 5 for peel adhesion using an approved field quantitative tensiometer. Jaw separation speed must be in accordance with the approved QC manual. To be acceptable, 4 out of 5 replicate test specimens must meet the seam strength requirements specified in Table [3][5]. If the field tests pass, test 5 specimens at the QC laboratory for shear strength and 5 for peel adhesion in accordance with the QC laboratory's approved procedures. To be acceptable, 4 out of 5 replicate test specimens must meet the seam strength requirements specified in Table [3][5]. If the field or laboratory tests fail, repair the seam in accordance with paragraph Destructive Seam Test Repairs. Repair holes for destructive seam samples the same day they are cut.

3.6 DEFECTS AND REPAIRS

3.6.1 Destructive Seam Test Repairs

Seams that fail destructive seam testing may be overlaid with a strip of new material and seamed (cap stripped). Alternatively, retrace the seaming path to an intermediate location a minimum of 3 m 10 feet on each side of the failed seam location. At each location, take a 305 by 460 mm 12 by 18 inch minimum size seam sample for 2 additional shear strength and 2 additional peel adhesion tests using an approved quantitative field tensiometer. If these tests pass, send the remaining seam sample portion

to the QC laboratory for 5 shear strength and 5 peel adhesion tests in accordance with the QC laboratory's approved procedures. To be acceptable, 4 out of 5 replicate test specimens must meet specified seam strength requirements. If these laboratory tests pass, cap strip or repair the seam using other approved methods between that location and the original failed location. If field or laboratory tests fail, repeat the process. After repairs are completed, non-destructively test the repaired seam in accordance with paragraph Non-Destructive Field Seam Continuity Testing.

3.6.2 Patches

Repair tears, holes, blisters and other defects with patches. Provide patches that have rounded corners, are made of the same geomembrane, and extend a minimum of 150 mm 6 inches beyond the edge of defects. Repair minor localized flaws by spot welding or seaming as determined by the QC inspector. Non-destructively test repairs. The Contracting Officer or the QC inspector may also elect to perform destructive seam tests on suspect areas.

3.7 VISUAL INSPECTION AND EVALUATION

Immediately prior to covering, the QC inspector and Contracting Officer will visually inspect the geomembrane, seams, and non-seam areas for defects, holes, or damage due to weather conditions or construction activities. At the Contracting Officer's or the QC inspector's discretion, the surface of the geomembrane must be brushed, blown, or washed by the installer if the amount of dust, mud, or foreign material inhibits inspection or functioning of the overlying material. Non-destructively test each suspect location in accordance with paragraph Non-Destructive Field Seam Continuity Testing. Repair each location that fails non-destructive testing in accordance with paragraph Patches and non-destructively retested.

3.8 PENETRATIONS

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NOTE: Minimize the number of penetrations and show their locations on the drawings. Referencing the manufacturer's typical penetration details is generally acceptable.

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Provide geomembrane penetration details [as indicated] [in accordance with ASTM D6497/D6497M or as recommended by the geomembrane manufacturer]. Use factory fabricated boots wherever possible. Non-destructively test field seams for penetrations in accordance with the installer's approved QC manual. Repair seams that fail non-destructive testing in accordance with the installer's approved QC manual and non-destructively tested prior to acceptance.

3.9 PROTECTION AND BACKFILLING

Cover the deployed and seamed geomembrane with the specified material within [5] [14] [_____] calendar days of acceptance. Prevent wrinkles in the geomembrane from folding over during placement of cover materials. Do not drop cover soil onto the geomembrane or overlying geosynthetics from a height greater than 1 m 3 feet. Push the soil out over the geomembrane or overlying geosynthetics in an upward tumbling motion. Place soil from the

bottom of the slope upward. Provide an initial loose soil lift thickness of [350] [_____] mm [12] [_____] inches. Use equipment with ground pressures less than 50 kPa 7 psi to place the first lift over the geomembrane. Maintain a minimum of [460] [610] [915] [_____] mm [18] [24] [36] [_____] inches of soil between construction equipment with ground pressures greater than 50 kPa 7 psi and the geomembrane. Cover soil compaction and testing requirements are described in Section 31 00 00 EARTHWORK. Equipment placing cover soil that stops abruptly, makes sharp turns, spin their wheels, or travels at speeds exceeding [2.2] [_____] m/s [5] [_____] mph is prohibited.

3.10 As-Built drawings

Submit final as-built drawings of the geomembrane installation. Include panel numbers, seam numbers, location of repairs, destructive seam samples, and penetrations in these drawings.

-- End of Section --