SECTION 02 56 13.13

GEOMEMBRANE

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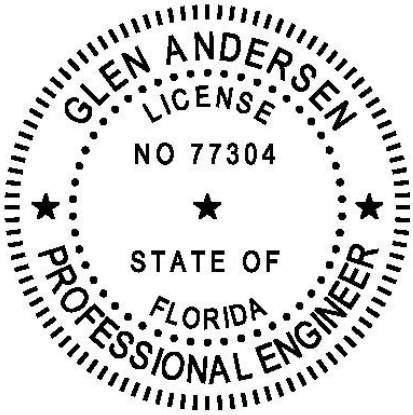
Engineer's Seal



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GLEN ANDERSEN P.E., STATE OF FLORIDA, PROFESSIONAL ENGINEER, LICENSE NO. 77304.

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PART 1 GENERAL

1.2 REFERENCES

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 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 for Index 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 drawings, a minimum of 7 days prior to geomembrane placement.

1.4 SUBMITTALS

Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

- Geomembrane Panel Layout
- As-Built Drawings

SD-03 Product Data

- Materials
- Field Seaming
- 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

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 shall have produced the proposed geomembrane sheets for at least 5 completed projects having a total minimum area of 10 million square feet.

1.5.1.2 Fabricator

The fabricator is responsible for seaming geomembrane sheets into panels. Fabricator shall have fabricated the proposed geomembrane panels for at least 5 completed projects having a total minimum area of 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 shall have installed the proposed geomembrane material using the same techniques as required for this project for at least 2 completed projects having a total minimum area of 15,000 square feet. At least one seamer shall have experience seaming a minimum of 15,000 square feet of the proposed geomembrane under similar conditions using the same type of seaming equipment and geomembrane thickness specified for this project.

1.5.1.4 QC Inspector

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 using the same techniques as required for this project. The QC inspector shall have provided QC inspection during installation of the proposed geomembrane material for at least 2 completed projects having a total minimum area of 15,000 square feet.

1.5.1.5 QC Laboratory

The QC laboratory shall have provided QC and/or Quality Assurance (QA) testing of the proposed geomembrane and geomembrane seams for at least 5 completed projects having a total minimum area of 15,000 square feet each. The QC laboratory shall 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 shall 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. The following shall also be submitted:

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 shall be present during delivery and unloading of the geomembrane. Each geomembrane roll/panel shall be labeled with the manufacturer's name, product identification number, roll/panel number, and roll dimensions.

1.6.2 Storage

Temporary storage at the project site shall be on a level surface, free of sharp objects where water cannot accumulate. The geomembrane shall be protected from puncture, abrasion, excessive heat or cold, material degradation, or other damaging circumstances. Storage shall not result in crushing the core of roll goods or flattening of the rolls. Rolls shall not be stored more than two high. Palleted materials shall be stored on level surfaces and shall not be stacked on top of one another. Ultraviolet sensitive materials (i.e., PVC) shall be covered with a sacrificial opaque and waterproof covering or placed in a temporary shelter. Damaged geomembrane shall be removed from the site and replaced with geomembrane that meets the specified requirements.

1.6.3 Handling

Rolls/panels shall not be dragged, lifted by one end, or dropped. A pipe or solid bar, of sufficient strength to support the full weight of a roll without significant bending, shall be used for all handling activities. The diameter of the pipe or solid bar shall be small enough to be easily inserted through the core of the roll. Chains shall be used to link the ends of the pipe or bar to the ends of a spreader bar. The spreader bar shall 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 shall 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.

PART 2 PRODUCTS

2.1 MATERIALS

2.1.1 Raw Materials

Resin used in manufacturing geomembrane sheets shall be made of virgin uncontaminated ingredients. No more than 10 percent regrind, reworked, or trim material in the form of chips or edge strips shall be used to manufacture the geomembrane sheets. All regrind, reworked, or trim materials shall be from the same manufacturer and exactly the same formulation as the geomembrane sheet being produced. No post-consumer materials or water-soluble ingredients shall be used to produce the geomembrane. For geomembranes with plasticizers, only primary plasticizers that are resistant to migration shall be used. 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

Geomembrane sheets shall be reinforced and manufactured as wide as possible to minimize factory and field seams. Geomembrane sheets shall be uniform in color, thickness, and surface texture. The sheets shall be 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 shall conform to the requirements listed in Table 1 for Manufacturing Quality Control (MQC).

TABLE 1 - SMOOTH PVC GEOMEMBRANE PROPERTIES

PROPERTY	TEST VALUE	MQC TESTING FREQUENCY (MIN.)	TEST METHOD
Thickness (minimum ave)	60 mils	per roll	ASTM D1593
Thickness (min)	56 mils	per roll	ASTM D1593
Specific Gravity (min)	1.2 g/ml	once	ASTM D792
Tensile Properties (min)			ASTM D882, Method A
Break strength (Machine direction (MD) and Transvers direction (TD))	97 lb/in	once	

TABLE 1 - SMOOTH PVC GEOMEMBRANE PROPERTIES			
PROPERTY	TEST VALUE	MQC TESTING FREQUENCY (MIN.)	TEST METHOD
elongation @ break (MD and TD)	400 percent	once	
modulus @ 100 percent (MD and TD)	41 lb/in	once	
Tear Resistance (min)	10.5 lb/in	once	ASTM D1004, Die C
Low Temperature, pass	-20 degrees F	once	ASTM D1790
Dimensional Stability (max) (MD and TD)	3 percent	once	ASTM D1204
Water Extraction (max)	0.2 percent loss	once	See Note 1
Volatile Loss (max)	0.5 percent loss	once	ASTM D1203 (A)
Resistance to Soil Burial			See Note 1
breaking factor	+/- 5 percent	once	
elongation @ break	+/- 20 percent	once	
100 percent modulus	+/- 20 percent	once	
Water Vapor	.00000000005 m/sec	once	ASTM D814
Hydrostatic Resistance (min)	120 lb/sq in	once	ASTM D751 (A)
NOTE 1: Water Extraction and Resistance to Soil Burial testing shall be performed in accordance with manufacturer's approved procedures.			

TABLE 2 - PVC SEAM PROPERTIES		
PROPERTY	TEST VALUE	TEST METHOD
Seam Shear Strength (min)	77 lb/in	Installers approved procedure
Seam Peel Strength (min) (1)	15 lb/in	Installers approved procedure
Note (1): Where applicable, both tracks of a double hot wedge seam shall be tested for peel adhesion.		

2.1.3 Factory Seams

Geomembrane sheets shall be factory seamed into maximum sized panels to minimize field seaming. Factory seaming shall be by methods approved by the geomembrane manufacturer. Seams shall meet the minimum shear and peel strength requirements shown in Table 2. Factory seams shall extend to the end of the sheet so that no unbonded edges greater than 1/8 inch wide are present.

2.2 TESTS, INSPECTIONS, AND VERIFICATIONS

2.2.1 Manufacturing, Sampling, and Testing

2.2.1.1 Raw Materials

Raw materials shall be tested in accordance with the approved MQC manual. Any raw material which fails to meet the geomembrane manufacturer's specified physical properties shall not be used in manufacturing the sheet. Seaming rods and pellets shall be manufactured of materials which are essentially identical to that used in the geomembrane sheet. Seaming rods and pellets shall be tested for density, melt index and carbon black content in accordance with the approved MQC manual. Seaming rods and pellets which fail to meet the corresponding property values required for the sheet material, shall not be used for seaming.

2.2.1.2 Sheet Material

Geomembrane sheets shall be tested in accordance with the approved MQC manual. As a minimum, MQC testing shall be conducted at the frequencies shown in Table 1. Sheets not meeting the minimum requirements specified in Table 1 shall not be sent to the site.

2.3 EQUIPMENT

Equipment used in performance of the work shall be in accordance with the geomembrane manufacturer's recommendations and shall be maintained in satisfactory working condition.

PART 3 EXECUTION

3.1 PREPARATION

3.1.1 Surface Preparation

Rocks and concrete spoil and any other material which could damage the geomembrane shall be removed from the surface to be covered with the geomembrane. The concrete surface or gravel layer beneath the geomembrane shall not have asperities greater than 1.0 inch in depth. Each day during placement of geomembrane, the QC Inspector and installer shall inspect the surface on which geomembrane is to be placed and certify in writing that the surface is acceptable. Repairs to the subgrade shall be performed at no additional cost to the County.

3.2 GEOMEMBRANE DEPLOYMENT

The procedures and equipment used shall not elongate, wrinkle, scratch, or otherwise damage the geomembrane, other geosynthetic layers, or the underlying subgrade. The methods used to place steel and reinforced concrete over the geomembrane shall minimize wrinkles and tensile stresses in the geomembrane. The geomembrane shall have adequate slack to prevent the creation of tensile stress. The wrinkle height to width ratio for installed geomembrane shall not exceed 0.5. In addition, geomembrane wrinkles shall not exceed 6 inches in height. Wrinkles that do not meet the above criteria shall be cut out and repaired in accordance with the installer's approved QC manual. Geomembrane damaged during installation shall be replaced or repaired at no additional cost to the County.

3.3 FIELD SEAMING

3.3.1 Trial Seams

Trial seams shall be made under field conditions on strips of excess geomembrane. Trial seams shall be made 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. Trial seam samples shall be collected and tested in accordance with ASTM D6392. One sample shall be obtained from each trial seam. This sample shall be at least 36 inches long by 12 inches wide with the seam centered lengthwise. Ten random specimens 1 inch wide shall be cut from the sample. Five seam specimens shall be field tested for shear strength and 5 seam specimens shall be field tested for peel adhesion using an approved quantitative tensiometer. Where necessary, accelerated curing of trial seams made by chemical methods shall be conducted in accordance with GSI GRI GM7. To be acceptable, 4 out of 5 replicate test specimens shall meet seam strength requirements specified in Table [3] [5]. If the field tests fail to meet these requirements, the entire operation shall be repeated. If the additional trial seam fails, the seaming apparatus or seamer shall not be used until the deficiencies are corrected by the installer and 2 consecutive successful trial seams are achieved.

3.3.2 Field Seams

Panels shall be seamed in accordance with the geomembrane manufacturer's recommendations. In sumps, corners and odd-shaped geometric locations, the number of field seams shall be minimized. Seaming shall extend to the outside edge of panels. Soft subgrades shall be compacted and approved prior to seaming. The seam area shall be free of moisture, dust, dirt, and foreign material at the time of seaming. Fish mouths in seams shall be repaired.

3.3.2.1 Polyethylene Seams

Polyethylene geomembranes shall be seamed by thermal fusion methods. Extrusion welding shall only be used for patching and seaming in locations where thermal fusion methods are not feasible. Seam overlaps that are to be attached using extrusion welds shall be ground prior to welding. Grinding marks shall be oriented perpendicular to the seam direction and no marks shall extend beyond the extrudate after placement. Extrusion welding shall begin within 10 minutes after grinding. Where extrusion welds are temporarily terminated long enough to cool, they shall be

ground prior to applying new extrudate over the existing seam. The total depth of the grinding marks shall be no greater than 10 percent of the sheet thickness.

3.3.2.2 Non-Polyethylene Seams

Non-polyethylene geomembranes shall be seamed by methods as recommended by the geomembrane manufacturer. Seaming adhesives, solvents, or chemical cleaning agents shall be stored away from the geomembrane and only spill-resistant containers shall be used while working on the geomembrane. If low temperatures slow the curing process of chemically fused seams and delay seam testing, GSI GRI GM7 shall be used to accelerate sample curing.

3.4 SAMPLES

One QC sample, 18 inches in length, for the entire width of a roll, shall be obtained for every 100,000 square feet of material delivered to the site. Samples shall not be obtained from the first three feet of the roll. For accordion folded geomembranes, samples of equivalent size shall be collected from approved locations. The samples shall be identified by manufacturer's name, product identification, lot and roll/panel number. The date, a unique sample number, and the machine direction shall also be noted. In addition, a 12 inch by 12 inch QA sample shall be collected, labeled, and submitted to the Engineer 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 Tables 1 and 2. Samples not meeting the specified requirements shall result in the rejection of applicable rolls/panels. As a minimum, rolls/panels produced immediately prior to and immediately after the failed roll/panel shall be tested for the same failed parameter. Testing shall continue 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

Field seams shall be non-destructively tested for continuity over their full length in accordance with the installer's approved QC manual. Seam testing shall be performed as the seaming work progresses, not at the completion of field seaming. Any seams which fail shall be documented and repaired in accordance with the installer's approved QC manual.

3.5.2 Destructive Field Seam Testing

A minimum of one destructive test sample per 500 feet of field seam shall be obtained at locations specified by the QC Inspector in consultation with the Engineer. Sample locations shall not be identified prior to seaming. Samples shall be a minimum of 12 inches wide by 42 inches long with the seam centered lengthwise. Each sample shall be cut 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 Engineer for QA testing and/or permanent record. Each sample shall be numbered and cross referenced to a field log which identifies: (1) panel number; (2) seam number; (3) date and time cut; (4) ambient temperature within 6 inches above the geomembrane; (5) seaming unit designation; (6) name of seamer; and (7) seaming apparatus temperature and pressures (where applicable). Ten 1-inch wide

replicate specimens shall be cut from the installer's sample. Five specimens shall be tested for shear strength and 5 for peel adhesion using an approved field quantitative tensiometer. Jaw separation speed shall be in accordance with the approved QC manual. To be acceptable, 4 out of 5 replicate test specimens shall meet the seam strength requirements specified in Table 2. If the field tests pass, 5 specimens shall be tested 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 shall meet the seam strength requirements specified in Table 2. If the field or laboratory tests fail, the seam shall be repaired in accordance with paragraph Destructive Seam Test Repairs. Holes for destructive seam samples shall be repaired 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, the seaming path shall be retraced to an intermediate location a minimum of 10 feet on each side of the failed seam location. At each location a 12 by 18 inch minimum size seam sample shall be taken for 2 additional shear strength and 2 additional peel adhesion tests using an approved quantitative field tensiometer. If these tests pass, then the remaining seam sample portion shall be sent 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, then the seam shall be cap stripped or repaired using other approved methods between that location and the original failed location. If field or laboratory tests fail, the process shall be repeated. After repairs are completed, the repaired seam shall be non-destructively tested in accordance with paragraph Non-Destructive Field Seam Continuity Testing.

3.6.2 Patches

Tears, holes, blisters and other defects shall be repaired with patches. Patches shall have rounded corners, be made of the same geomembrane, and extend a minimum of 6 inches beyond the edge of defects. Minor localized flaws shall be repaired by spot welding or seaming as determined by the QC inspector. Repairs shall be non-destructively tested. The Engineer may also elect to perform destructive seam tests on suspect areas.

3.7 VISUAL INSPECTION AND EVALUATION

Immediately prior to placing underwater, the geomembrane, seams, and non-seam areas shall be visually inspected by the Engineer of Record or designee for defects, holes, or damage due to weather conditions or construction activities. At the Engineer’s or the QC Inspector's discretion, the surface of the geomembrane shall 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. Each suspect location shall be non-destructively tested in accordance with paragraph Non-Destructive Field Seam Continuity Testing. Each location that fails non-destructive testing shall be repaired in accordance with paragraph Patches and non-destructively retested.

After placement underwater but before covering, Contractor shall perform visual diver inspections and produce daily field reports with photographs documenting proper installation procedures have been followed in accordance with the approved shop drawings.

3.8 PROTECTION AND BACKFILLING/COVERING

The deployed and seamed geomembrane shall be covered with the specified material within 5 calendar days of acceptance. Wrinkles in the geomembrane shall be prevented from folding over during placement of cover materials. Cover materials shall not be dropped onto the geomembrane from a height greater than 3 feet.

-- End of Section --