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3.0 GEOMEMBRANE LINER EVALUATION

This section presents general procedures, quality control testing requirements, and construction specifications for geomembrane liner construction. Unless otherwise designed, the composite liner system will generally include the following components above the minimum 2-foot thick compacted soil liner:

- 60-mil high density polyethylene (HDPE) geomembrane
- A geosynthetic drainage layer composed of a geonet and filter geotextile (or equivalent geocomposite)
- 2-foot protective cover

Chimney drains will be provided in the protective cover to allow leachate to readily drain to the leachate collection system. The geomembrane and the geocomposite drainage layer may be replaced with an alternate material that incorporates both components (e.g., Super Gripnet® by Agru America) provided material equivalency in terms of barrier and flow characteristic is demonstrated.

3.1 Pre-installation Material Evaluation

3.1.1 Manufacturer's Quality Control Certificates

Prior to the installation of any geomembrane, the manufacturer or installer shall provide the POR with quality control certificates signed by a responsible party employed by the manufacturer. Each quality control certificate shall include roll identification numbers, testing procedures, and results of quality control tests. The quality control tests shall be performed in the manufacturing plant using the test methods and frequencies listed in the most recent version of the Geosynthetic Research Institute (GRI) test method GM13. The owner may require more frequent testing at his/her discretion.

The POR shall review the test results prior to accepting the geomembrane to assure that the certified minimum properties meet the minimum values for smooth and textured geomembranes, as determined by the most recent GRI test method GM13, "Test Methods, Test Properties and Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes," included in Appendix III-3F-1. The owner may require more frequent testing at his/her discretion.

The rolls delivered to the site shall be inventoried, recording the manufacturer's name and product identification, and the roll thickness, number, and dimensions. Manufacturer's certificates should be cross-referenced to rolls delivered on-site.

Resumes of the installer's supervisor(s) or Master Seamer(s) shall be obtained to verify that adequate seaming experience will be utilized on the project. The installer's supervisor or Master Seamer shall have had experience totaling a minimum of 2,000,000 square feet of geomembrane installation.

Upon delivery of geosynthetic materials, storage and handling procedures shall also be documented. Rolls of geosynthetic materials shall be handled and stored in such a way as not to damage the material. As a general rule, rolls of geosynthetic materials should not be stacked more than four rolls high.

In addition to the manufacturer's quality control certificates, samples of the geomembrane will be obtained either at the manufacturing facility or upon delivery to the site for conformance testing. The test samples shall be obtained for conformance testing in accordance with the testing schedule shown in Table III-3F-3. <u>Conformance testing shall be provided by a third party.</u>

The POR shall review the test results to ensure that they meet the values presented in Table III-3F-3. The POR shall compare measured shear strength values to those used in the stability analyses included in Appendix III-3C. If the measured interface shear strengths are less than the values used in the analyses, the stability of the liner system shall be reassessed and revised calculations shall be included in the GLER.

TABLE III-3F-3: Geomembrane Conformance Test Schedule

TEST	METHOD[1]	FREQUENCY
Thickness (laboratory measurement)	ASTM D5199 (Smooth) or ASTM D5994 (Textured)	Not less than 1 test per 100,000 ft^2 with not less than 1 per resin lot
Density	ASTM D1505 or D792	
Carbon black content<u>[5]</u>	ASTM D4218	
Carbon black dispersion	ASTM D5596	
Tensile properties	ASTM D6693, Type IV	
Direct shear[2][3][4]	ASTM D5321	Per geomembrane/adjoining material interface

Notes:

1. Updated ASTM or GRI methods may be implemented based on a review by the POR.
2. Soak interface and apply normal stresses of 200, 1000, and 5000 psf for at least one hour prior to shearing at a displacement rate of 0.04 in/min.
3. The POR shall confirm that the interface shear strengths exceed the values used in the stability calculations presented in Appendix III-3C. If the measured interface shear strengths are less than the values used in the analyses, the stability of the liner system shall be reassessed and revised calculations shall be included in the GLER.

<u>4.</u> Test results from materials used during one construction event may be used in subsequent events provided the materials used are the same and approved by the POR.

~~4~~<u>5. Other methods such as D1603 (tube furnace) or D6370 (TGA) are acceptable if an appropriate correlation to D4218 (muffle furnace) can be established.</u>

3.2 Installation Procedures

3.2.1 Geomembrane Liner Subgrade Preparation and Acceptance

Prior to geomembrane installation over a soil liner, the top of the soil liner shall be checked for irregularities, protrusions, sharp stones, stones larger than 3/8 inch in size, loose soil, and abrupt changes in grade. The soil liner surface shall be prepared by rolling with a smooth-drum roller to minimize the roughness and to press down protruding soil or rock particles prior to geomembrane deployment. Loose rocks and/or dry soil

4.0 GEOMEMBRANE LINER EVALUATION

This section presents general procedures, quality control testing requirements, and construction specifications for geomembrane liner construction. Unless otherwise designed, the composite liner system will generally include the following components above the geosynthetic clay liner:

The proposed liner and leachate collection system for the overliner area consists of, from top to bottom:

- 60-mil linear low-density polyethylene (LLDPE) geomembrane liner, textured on both sides
- A geocomposite drainage layer composed of a geonet and filter geotextiles heat-bonded to both sides
- 2-foot protective cover soil

The geomembrane and the geocomposite drainage layer may be replaced with an alternate material that incorporates both components (e.g., Super Gripnet® by Agru America) provided material equivalency in terms of barrier and flow characteristic is demonstrated.

4.1 Pre-installation Material Evaluation

4.1.1 Manufacturer's Quality Control Certificates

Prior to the installation of any geomembrane, the manufacturer or installer shall provide the POR with quality control certificates signed by a responsible party employed by the manufacturer. Each quality control certificate shall include roll identification numbers, testing procedures, and results of quality control tests. The quality control tests shall be performed in the manufacturing plant using the test methods and frequencies listed in the most recent version of the Geosynthetic Research Institute (GRI) test method GM17. The owner may require more frequent testing at his/her discretion.

The POR shall review the test results prior to accepting the geomembrane to assure that the certified minimum properties meet the minimum values for smooth and textured geomembranes as determined by the most recent GRI test method GM17, "Test Methods, Test Properties and Testing Frequency for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes," included in Appendix III-3H-1. The owner may require more frequent testing at his/her discretion.

The rolls delivered to the site shall be inventoried, recording the manufacturer's name and product identification, and the roll thickness, number, and dimensions. Manufacturer's certificates should be cross-referenced to rolls delivered on-site.

Resumes of the installer's supervisor(s) or Master Seamer(s) shall be obtained to verify that adequate seaming experience will be utilized on the project. The installer's supervisor or Master Seamer shall have had experience totaling a minimum of 2,000,000 square feet of geomembrane installation.

Upon delivery of geosynthetic materials, storage and handling procedures shall also be documented. Rolls of geosynthetic materials shall be handled and stored in such a way as not to damage the material. As a general rule, rolls of geosynthetic materials should not be stacked more than four rolls high.

In addition to the manufacturer's quality control certificates, samples of the geomembrane will be obtained either at the manufacturing facility or upon delivery to the site for conformance testing. The test samples shall be obtained for conformance testing in accordance with the testing schedule shown in Table III-3H-3.

Table III-3H-3: Geomembrane Conformance Test Schedule

TEST	METHOD(1)	FREQUENCY
Thickness (laboratory measurement)	ASTM D5994 (Textured)	Not less than 1 test per 100,000 ft^2 with not less than one per resin lot
Density	ASTM D1505 or D792	
Carbon black content(2)	ASTM D4218	
Carbon black dispersion	ASTM D5596	
Tensile properties	ASTM D6693, Type IV	

Notes:

1. Updated ASTM or GRI methods may be implemented based on a review by the POR.
2. Other methods such as D1603 (tube furnace) or D6370 (TGA) are acceptable if an appropriate correlation to D4218 (muffle furnace) can be established.

~~1.~~

4.2 Installation Procedures

4.2.1 Geomembrane Deployment

The geomembrane shall be installed in direct and uniform contact with the GCL. The geomembrane shall not be placed during inclement weather such as high winds or rain.

Geomembrane seaming should generally not take place when ambient temperatures are below 32 degrees Fahrenheit (°F), unless preheating is used. For extrusion welding, preheating will be required if the temperature is below 32°F. For fusion welding, preheating may be waived if the installer demonstrates that quality welds may be obtained without preheating. Seaming shall not be permitted at ambient temperatures above 104°F, unless the installer can demonstrate that seam quality is not compromised.

In general, only low ground pressure rubber-tired support equipment approved by the POR may be allowed on the geomembrane. If the POR observes any potential damage done to the liner by the support equipment, use of the equipment will cease and the damage will be repaired. Personnel working on the geomembrane shall not smoke, wear damaging shoes, or engage in any other activity likely to damage the geomembrane. Only those sections that are to be placed and seamed in one day should be unrolled. Panels left unseamed should be anchored with sandbags or other suitable weights. In general, seams should be oriented parallel to the line of maximum slope (i.e., oriented up and down, not across the slope). In corners and odd-shaped geometric locations, the number of field seams should be minimized.

Upon delivery of geosynthetic materials, storage and handling procedures shall also be documented. Rolls of geosynthetic materials shall be handled and stored in such a way as not to damage the material. As a general rule, rolls of geosynthetic materials should not be stacked more than four rolls high.

In addition to the manufacturer's quality control certificates, samples of the delivered rolls of geomembrane will be obtained either at the manufacturing facility or upon delivery to the site for conformance testing. The test samples shall be obtained for conformance testing in accordance with the testing schedule shown in Table III-7A-3.

Table III-7A-3: Geomembrane Conformance Test Schedule

TEST	METHOD(1)	FREQUENCY
Thickness (laboratory measurement)	ASTM D5199 (Smooth) or ASTM D5994 (Textured)	Not less than 1 test per 100,000 ft^2 with not less than 1 per resin lot
Density	ASTM D1505 or D792	
Carbon black content(5)	ASTM D4218	
Carbon black dispersion	ASTM D5596	
Tensile properties	ASTM D6693, Type IV	
Direct shear(2)(3)(4)	ASTM D5321	Per geomembrane/adjoining material interface

Notes:
1. Updated ASTM or GRI methods may be implemented based on a review by the POR.
2. Soak interface and apply normal stresses of 100, 200, and 400 psf for at least one hour prior to shearing at a displacement rate of 0.04 in/min.
3. The POR shall confirm that the interface shear strengths exceed the values used in the stability calculations presented in Appendix III-3C-5. If the measured interface shear strengths are less than the values used in the analyses, the stability of the liner system shall be reassessed and revised calculations shall be included in the FCSER.
4. Test results from materials used during one construction event may be used in subsequent events provided the materials used are the same and approved by the POR.
5. ~~4.~~ Other methods such as D1603 (tube furnace) or D6370 (TGA) are acceptable if an appropriate correlation to D4218 (muffle furnace) can be established.

3.2 Installation Procedures

3.2.1 Geomembrane Liner Subgrade Preparation and Acceptance

Prior to geomembrane installation over a cohesive soil cover, the top of the cohesive soil cover shall be checked for irregularities, protrusions, sharp stones, stones larger than 3/8 inch in size, loose soil, and abrupt changes in grade. The cohesive soil cover surface shall be prepared by rolling with a smooth-drum roller to minimize the roughness and to press down protruding soil or rock particles prior to geomembrane deployment. Loose rocks and/or dry soil particles that could damage the geomembrane shall be removed. Excessive voids or dimples shall be filled in with a soil-bentonite mixture. The surface shall not exhibit excessive desiccation prior to geomembrane deployment. The geomembrane subgrade acceptance shall be documented.

monitor being present. Fishmouths, or wrinkles at the seam overlap, shall be cut along the ridge of the wrinkle to achieve a flat overlap. The cut shall be seamed and/or patched. Seams shall extend to the outside edge of panels placed in the anchor trench.

Panel layout and field seams shall be given an identification code, mapped, and logged to record relevant installation information. Inspection and testing records shall be logged as well as repair and retest data.

3.3 Installation Monitoring and Testing

3.3.1 Trial Seams

Each day prior to commencing field seaming, trial seams shall be made on pieces of geomembrane material to verify that conditions are adequate for production seaming. Trial seams shall be made at the beginning of each seaming period and shift (generally, at least twice each day) for each combination of production seaming machine and operator to be used that day. The trial test seam shall be at least 3 feet long by 1 foot wide (after seaming) with the seam centered lengthwise. Four 1-inch wide specimens shall be die-cut from the trial seam sample. Two specimens shall be tested in the field for shear and two for peel (test both inner and outer welds for dual track fusion welding) and shall be compared to the minimum seam strength requirements specified in the most current version of the GRI Test Method GM19. The current versions of the GRI test methods are included in Appendix III-3F-1.

If any of the trial seam specimens fail, the entire trial seam operation shall be repeated. If an additional specimen fails during the second trial seam, the seaming machine and seamer shall not be used for seaming until the deficiencies are corrected and two consecutive successful trial seams are achieved. Additional trial seams shall be performed if frequent field seaming problems are experienced or if power to the seaming machines is interrupted sufficiently long to require rewarming. Additional trial seams shall be made at each occurrence of significantly different environmental conditions, including, but not limited to, temperature, humidity, and dust, and after any machine is turned off for more than 30 minutes.

3.3.2 Non-Destructive Testing

Continuous, non-destructive testing shall be performed on all seams by the installer. All leaks must be isolated and repaired by following the procedures described in this LQCP.

> Air Pressure Testing – ASTM D5820. The ends of the air channel of the dual-track fusion weld must be sealed and pressured to approximately 30 pounds per square inch (psi), if possible. The air pump must then be shut off and the air pressure observed after 2 minutes. A loss of less than 3 psi is acceptable if it is determined that the air channel is not blocked between the sealed ends. A loss greater or equal to 3 psi indicates the presence of a seam leak that must then be isolated and repaired by following the procedures described in this LQCP. The POR or his/her qualified representative must observe and record all pressure gauge readings.
>
> Vacuum-Box Testing – ASTM D5641. Apply a vacuum of approximately 4 to 8 psi to all extrusion welded seams that can be tested in this manner. The seam must be observed for

Panels should be overlapped as recommended by the manufacturer as appropriate for the type of seam welding to be performed; however, overlapping shall be no less than 2 inches. Field seaming shall only be performed by the method or methods approved by the manufacturer, either by extrusion welding or double-tracked fusion welding. No seaming shall take place without the installer's supervisor or Master Seamer and CQA monitor being present. Fishmouths or wrinkles at the seam overlap shall be cut along the ridge of the wrinkle in order to achieve a flat overlap. The cut shall be seamed and/or patched. Seams shall extend to the outside edge of panels placed in the anchor trench.

Panel layout and field seams shall be given an identification code, mapped, and logged to record relevant installation information. Inspection and testing records shall be logged as well as repair and retest data.

4.3 Installation Monitoring and Testing

4.3.1 Trial Seams

Each day prior to commencing field seaming, trial seams shall be made on pieces of geomembrane material to verify that conditions are adequate for production seaming. Trial seams shall be made at the beginning of each seaming period and shift (generally, at least twice each day) for each combination of production seaming machine and operator to be used that day. The trial test seam shall be at least 3 feet long by 1 foot wide (after seaming) with the seam centered lengthwise. Four 1-inch wide specimens shall be die-cut from the trial seam sample. Two specimens shall be tested in the field for shear and two for peel (test both inner and outer welds for dual track fusion welding) and shall be compared to the minimum seam strength requirements specified in the most current version of the GRI Test Method GM19. The current versions of the GRI test methods are included in Appendix III-3H-1.

If any of the trial seam specimens fail, the entire trial seam operation shall be repeated. If an additional specimen fails during the second trial seam, the seaming machine and seamer shall not be used for seaming until the deficiencies are corrected and two consecutive successful trial seams are achieved. Additional trial seams shall be made at each occurrence of significantly different environmental conditions, including, but not limited to, temperature, humidity, and dust, and after any machine is turned off for more than 30 minutes.

4.3.2 Non-Destructive Testing

Continuous, non-destructive testing shall be performed on all seams by the installer. All leaks must be isolated and repaired by following the procedures described in this OQCP.

> Air Pressure Testing – ASTM D5820. The ends of the air channel of the dual-track fusion weld must be sealed and pressured to approximately 30 pounds per square inch (psi), if possible. The air pump must then be shut off and the air pressure observed after 2 minutes. A loss of less than 3 psi is acceptable if it is determined that the air channel is not blocked between the sealed ends. A loss greater or equal to 3 psi indicates the presence of a seam leak that must

3.2.2 Geomembrane Deployment

The geomembrane shall be installed in direct and uniform contact with the compacted cohesive soil cover. The geomembrane shall not be placed during inclement weather such as high winds or rain.

Geomembrane seaming should generally not take place when ambient temperatures are below 32 degrees Fahrenheit (°F), unless preheating is used. For extrusion welding, preheating will be required if the temperature is below 32°F. For fusion welding, preheating may be waived if the installer demonstrates that quality welds may be obtained without preheating. Seaming shall not be permitted at ambient temperatures above 104°F, unless the installer can demonstrate that seam quality is not compromised.

In general, only low ground pressure rubber-tired support equipment approved by the POR may be allowed on the geomembrane. If the POR observes any potential damage done to the liner by the support equipment, use of the equipment will cease and the damage will be repaired. Personnel working on the geomembrane shall not smoke, wear damaging shoes, or engage in any other activity likely to damage the geomembrane. Only those sections that are to be placed and seamed in one day should be unrolled. Panels left unseamed should be anchored with sandbags or other suitable weights. In general, seams should be oriented parallel to the line of maximum slope (i.e., oriented up and down, not across the slope). In corners and odd-shaped geometric locations, the number of field seams should be minimized.

Panels should be overlapped as recommended by the manufacturer as appropriate for the type of seam welding to be performed; however, overlapping shall be no less than 2 inches. Field seaming shall only be performed by the method(s) approved by the manufacturer, either by extrusion welding or double-tracked fusion welding. No seaming shall take place without the installer's supervisor or Master Seamer and CQA monitor being present. Fishmouths or wrinkles at the seam overlap shall be cut along the ridge of the wrinkle to achieve a flat overlap. The cut shall be seamed and/or patched. Seams shall extend to the outside edge of panels placed in the anchor trench.

Panel layout and field seams shall be given an identification code, mapped, and logged to record relevant installation information. Inspection and testing records shall be logged as well as repair and retest data.

3.3 Installation Monitoring and Testing

3.3.1 Trial Seams

Each day prior to commencing field seaming, trial seams shall be made on pieces of geomembrane material to verify that conditions are adequate for production seaming. Trial seams shall be made at the beginning of each seaming period and shift (generally, at least twice each day) for each combination of production seaming machine and operator to be used that day. The trial test seam shall be at least 3 feet long by 1 foot wide (after seaming) with the seam centered lengthwise. Four 1-inch wide specimens shall be die-cut from the trial seam sample. Two specimens shall be tested in the field for shear and two for peel (test both inner and outer welds for dual track fusion welding) and shall be compared to the minimum seam strength requirements specified in the most current version of the GRI Test Method GM19. The current versions of the GRI test methods are included in Appendix III-7A-1.

If any of the trial seam specimens fail, the entire trial seam operation shall be repeated. If an additional specimen fails during the second trial seam, the seaming machine and seamer shall not be used for seaming until the deficiencies are corrected and two consecutive successful trial seams are achieved. Additional trial seams shall be made at each occurrence of significantly different environmental conditions, including, but not limited to, temperature, humidity, and dust, and after any machine is turned off for more than 30 minutes.

3.3.2 Non-Destructive Testing

Continuous, non-destructive testing shall be performed on all seams by the installer. All leaks must be isolated and repaired by following the procedures described in this FCQCP.

> Air Pressure Testing – ASTM D5820. The ends of the air channel of the dual-track fusion weld must be sealed and pressured to approximately 30 pounds per square inch (psi), if possible. The air pump must then be shut off and the air pressure observed after 2 minutes. A loss of less than 4 psi is acceptable if it is determined that the air channel is not blocked between the sealed ends. A loss greater or equal to 4 psi indicates the presence of a seam leak that must then be isolated and repaired by following the procedures described in this FCQCP. The POR or his/her qualified representative must observe and record all pressure gauge readings.
>
> Vacuum-Box Testing – ASTM D5641. Apply a vacuum of approximately 4 to 8 psi to all extrusion welded seams that can be tested in this manner. The seam must be observed for leaks for at least 10 seconds while subjected to this vacuum. The POR or his/her qualified representative must observe 100 percent of this testing.
>
> Other Testing. Other non-destructive testing must have prior written approval from the TCEQ.

3.3.3 Destructive Seam Testing

Destructive samples shall be taken at a minimum frequency of one test location, selected randomly, within each 500 linear feet of seam length, inclusive of both primary longitudinal and cross seams, cap strips, and repairs 20 square feet in total area or larger. Each test sample should be of sufficient length and 12 inches wide with the seam located in the middle. Test specimens, approximately 1 inch wide, shall be cut from both ends of the sample for field testing (peel and shear). The remaining sample should be cut into three parts (one for quality assurance laboratory testing, one for installer quality control laboratory testing, and one for archive storage to be maintained at a location selected by the owner).

The field tests shall be conducted on a certified calibrated tensiometer capable of maintaining a constant extension rate of 2 inches per minute. If one of the field test specimens from the ends of the destructive sample fails, then the seam will be considered to have failed, and repairs shall be initiated, as described below. If both specimens pass, then a sample for laboratory testing will be sent to the quality assurance particles that could damage the geomembrane shall be removed. Excessive voids or dimples shall be filled in with a soil-bentonite mixture. The surface shall not exhibit excessive desiccation prior to geomembrane deployment. The geomembrane subgrade acceptance shall be documented.

3.2.2 Anchor Trench Construction

The anchor trench shall be constructed according to the project plans and specifications, and the excavation and backfilling operations shall be documented. If the anchor trench is excavated in a clay material susceptible to desiccation, the amount of anchor trench open at any time should be minimized. The inside edge of the trench shall be rounded so as to avoid stresses from sharp bends in the geomembrane. Excessive amounts of loose soil shall not be allowed underneath the geomembrane in the anchor trench, and the anchor trench shall be adequately drained to prevent ponding or softening of adjacent soils while the trench is open. The anchor trench shall be backfilled and compacted according to the project plans and specifications; however, backfilling shall be performed, at a minimum, with ordinary compaction as deemed suitable by the POR. <u>The anchor trench backfill is compacted to at least 90% of the maximum dry density as determined by the moisture/density compaction relationship.</u>

3.2.3 Geomembrane Deployment

The geomembrane shall be installed in direct and uniform contact with the compacted soil liner. The geomembrane shall not be placed during inclement weather, such as high winds or rain.

Geomembrane seaming should generally not take place when ambient temperatures are below 32 degrees Fahrenheit (°F), unless preheating is used. For extrusion welding, preheating will be required if the temperature is below 32°F. For fusion welding, preheating may be waived if the installer demonstrates that quality welds may be obtained without preheating. Seaming shall not be permitted at ambient temperatures above 104°F, unless the installer can demonstrate that seam quality is not compromised.

In general, only low ground pressure rubber-tired support equipment approved by the POR may be allowed on the geomembrane. If the POR observes any potential damage done to the liner by the support equipment, use of the equipment will cease and the damage will be repaired. Personnel working on the geomembrane shall not smoke, wear damaging shoes, or engage in any other activity likely to damage the geomembrane. Only those sections that are to be placed and seamed in one day should be unrolled. Panels left unseamed should be anchored with sandbags or other suitable weights. In general, seams should be oriented parallel to the line of maximum slope (i.e., oriented up and down, not across the slope). In corners and odd-shaped geometric locations, the number of field seams should be minimized.

Panels should be overlapped, as recommended by the manufacturer, as appropriate for the type of seam welding to be performed; however, overlapping shall be no less than 2 inches. Field seaming shall only be performed by the method(s) approved by the manufacturer, either by extrusion welding or double-tracked fusion welding. No seaming shall take place without the installer's supervisor or Master Seamer and CQA