**SECTION 33 47 13.16**

POND AND RESERVOIR LINERS USING REINFORCED COMPOSITE GEOMEMBRANE

PART 1 GENERAL

* 1. SCOPE

The scope of work covered by this specification is for the manufacture, supply, and installation of a [24 | 30 | 40] mil polyethylene Reinforced Composite Geomembrane (RCG) for primary retention and/or containment applications.

* 1. REFERENCES
1. ASTM International
	1. D 751 Standard Test Methods for Coated Fabrics
	2. D 1204 Standard Test Method for Linear Dimensional Changes of Nonrigid Thermoplastic Sheeting or Film at Elevated Temperature
	3. D 2136 Standard Test Method for Coated Fabrics—Low-Temperature Bend Test
	4. D 4218 Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique
	5. D 4437 Standard Practice for Non-destructive Testing (NDT) for Determining the Integrity of Seams Used in Joining Flexible Polymeric Sheet Geomembranes
	6. D 4533 Standard Test Method for Trapezoid Tearing Strength of Geotextiles
	7. D 4833 Standard Test Method for Index Puncture Resistance of Geomembranes and Related Products
	8. D 5261 Standard Test Method for Measuring Mass per Unit Area of Geotextiles
	9. D 5641 Standard Practice for Geomembrane Seam Evaluation by Vacuum Chamber
	10. D 5884 Standard Test Method for Determining Tearing Strength of Internally Reinforced Geomembranes
	11. D 6241 Standard Test Method for Static Puncture Strength of Geotextiles and Geotextile-Related Products Using a 50-mm Probe
	12. D 7002 Standard Practice for Electrical Leak Location on Exposed Geomembranes Using the Water Puddle Method
	13. D 7003 Standard Test Method for Strip Tensile Properties of Reinforced Geomembranes
	14. D 7238 Standard Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembrane Using Fluorescent UV Condensation Apparatus
	15. D 7703 Standard Practice for Electrical Leak Location on Exposed Geomembranes Using the Water Lance Method
	16. D 7007Standard Practices for Electrical Methods for Locating Leaks in Geomembranes Covered with Water or Earthen Materials
	17. D 7747 Standard Test Method for Determining Integrity of Seams Produced Using Thermo-Fusion Methods for Reinforced Geomembranes by the Strip Tensile Method
	18. D 7953 Standard Practice for Electrical Leak Location on Exposed Geomembranes Using the Arc Testing Method
	19. E 96 Standard Test Methods for Water Vapor Transmission of Materials
	20. G 154 Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials
2. Geosynthetic Research Institute
	1. GRI GM-16 Observation of Surface Cracking of Geomembranes
	2. GRI GM-30 Test Methods, Test Properties and Testing Frequency for Coated Tape Polyethylene (cPE) Barriers
	3. SUBMITTALS
3. Pre-Installation Submittals
	1. The RCG manufacturer shall provide the owner / engineer a certificate stating the name of the RCG manufacturer, product name, style, polymer composition, and other pertinent information to fully describe the geomembrane.
	2. The RCG manufacturer shall provide the owner / engineer with a copy of quality control certificates issued by the resin supplier that resin meets the specifications, and that no recycled polymer is included within the resin.
	3. The RCG manufacturer is responsible for establishing and maintaining a Quality Control Program to assure compliance with the requirements of the specification. Documentation describing the quality control program shall be made available to the owner / engineer prior to the approval of the geomembrane for use on the project.
	4. The RCG manufacturer shall provide the owner / engineer with a Certificate of Compliance (COC) stating that the furnished geomembrane meets requirements of the specification as evaluated under the manufacturer’s quality control program. The certificate shall be attested to by a person having legal authority to bind the Manufacturer.
	5. The RCG manufacturer shall provide the owner / engineer with a sample of the geomembrane which meets the specifications herein, consisting of an intact (uncut) sheet measuring no less than four (4) feet of width oriented to the woven cross-direction, and no less than two (feet) of length oriented in the machine direction.
	6. The RCG manufacturer shall provide the owner / engineer with a comprehensive installation guide for the geomembrane, relative to a liner installation. The installation guide shall include all relevant procedures for site prep, deployment, welding, testing, and inspection of the RCG, along with pertinent forms for logging tests and other activities, as well as complete installation detail drawings.
	7. The RCG manufacturer shall provide the owner / engineer with a sample warranty, covering defects and workmanship of the geomembrane material.
	8. The installer shall provide the owner / engineer with shop drawings or panel diagrams, showing the location and orientation of proposed field and / or factory fabricated seams.
	9. The installer shall provide the owner / engineer with a certificate that the extrudate to be used is comprised of the same resin as the geomembrane
	10. The installer shall provide the owner / engineer with a list of welding devices with identification numbers
4. Installation / Completion Submittals
	1. The installer shall provide the owner / engineer with completed copies of the following installation verification forms (upon relevant stages of installation):
		1. Signed subgrade acceptance form
		2. Geomembrane deployment record
		3. Trial weld documentation
		4. Seaming / welding record
		5. Non-Destructive test log
		6. Destructive test log
		7. Geomembrane repair log
		8. Final walk-through documentation
	2. The installer shall provide the owner / engineer with a warranty covering the installation of the geomembrane, including the quality of welded field or factory fabricated primary seams.
	3. QUALIFICATIONS
5. Manufacturer
	1. The specified RCG shall be manufactured by:
		1. Owens Corning

One Owens Corning Parkway

Toledo, OH 43659

* + 1. An equivalent manufacturer as specified by the owner / engineer
	1. Any equivalent manufacturer of the RCG specified shall have at least five (5) years of continuous experience in the manufacture of such geomembrane. Equivalent manufacturer shall have produced at least 5,000,000 square feet of the specified type of geomembrane over the last five (5) years. The equivalent manufacturer shall provide the owner / engineer with documentation of such.
1. Fabricator (if applicable)
	1. The fabricator shall be a company approved by the manufacturer, or specializing in the fabrication of reinforced polyethylene geomembranes. The fabricator shall have at least five (5) years of continuous experience in the fabrication of such geomembrane. Fabricator shall have fabricated at least 5,000,000 square feet of the specified type of geomembrane over the last five (5) years. The fabricator shall provide the owner / engineer with documentation of such.
2. Installer
	1. The installer shall be the fabricator, approved fabricator's installer, or an installer/contractor approved by the owner, or the manufacturer on behalf of the owner. The installer shall have at least five (5) years of continuous experience in the installation of such geomembrane. The installer shall have installed at least 5,000,000 square feet of the specified type of geomembrane over the last five (5) years. The fabricator shall provide the owner / engineer with documentation of such.
	2. The installer shall provide the owner / engineer with the resumes or credentials of the “master welder” and other welding technicians to be used on the project. At a minimum, the “master welder” must hold an International Association of Geosynthetic Installers (IAGI) Certified Welding Technician (CWT) certification in reinforced geomembranes
	3. LABELING, DELIVERY, STORAGE, AND HANDLING
3. Each roll and/or panel of RCG shall be delivered to the site with appropriate labeling, to include:
	1. Original Manufacturer’s Name
	2. Fabricator’s Name (if applicable)
	3. Product Identification
	4. Date of Production and/or Fabrication (if applicable)
	5. Material Thickness
	6. Roll Length, Width, and Gross Weight
	7. Roll Number (or Panel Number, if fabricated)
	8. Instructions on Deployment Orientation / Direction (if fabricated)

Any RCG roll and/or panel delivered to the site without all of the labeling described above shall be rejected by the owner / engineer and /or installer

1. Each roll and/or panel of RCG shall be delivered to the site by appropriate means to prevent damage to the material and facilitate off-loading.
2. Off-loading and storage of the geomembrane is the responsibility of the installer. Any damage caused or observed during off-loading shall be immediately reported to the owner / engineer.
3. All damaged rolls must be separated from the undamaged rolls until the proper disposition of that material has been determined by the owner / engineer, who will be the final authority on determination of damage.
4. The geomembrane shall be stored so as to be protected from puncture, dirt, grease, water, moisture, mud, mechanical abrasions, excessive heat, or other damage. A sacrificial cover must be used to protect the geomembrane if stored on site more than six (6) months. The rolls shall be stored in such a manner as to avoid shifting, abrasion, or other adverse movements that can damage the geomembrane liner material.
5. The rolls shall be stored on a prepared surface (not wooden pallets) and should not be stacked more than three rolls high.
6. RCG shall be transported on the site with spreader bars and slings, or other equipment that prevents potential damage to the rolls or panels.
	1. WARRANTIES
7. The RCG manufacturer shall provide a written warranty directly to the owner, which warrants that the [ 24 | 30 | 40 ] mil geomembrane is free from defects in materials and/or workmanship for a period of [ 5 | 10 | 10 ] years in an exposed applications, and [ 10 | 20 | 20 ] years in a buried application.
8. The manufacturer’s warranty applies only to material defects, and does not cover welding or seaming, or any damages to the geomembrane once it has been delivered to the fabricator (if applicable) and/or the installer.
9. The fabricator and/or installer are responsible for negotiating specific welding and/or installation warranties directly with the owner.

PART 2 PRODUCTS

1. GEOMEMBRANE MATERIAL
2. The Basis of Design shall be the RhinoMat™ [ 500 | 750 | 1000 ] polyethylene Reinforced Composite Geomembrane manufactured by Owens Corning.
3. Any substitutions or variations from the Basis of Design shall be an equivalent product, requiring express written approval from the engineer of record on the project.
4. GEOMEMBRANE PROPERTIES [ choose one material ]

The [ 24 ] mil RCG shall have the following properties:

|  |  |  |  |
| --- | --- | --- | --- |
| PROPERTY | TEST METHOD | TYPICAL VALUE | MARV |
|  |  |  |  |
| Weight | ASTM D5261 | 12.3 oz./yd2 | 12 oz./yd2 |
| Thickness | ASTM D751 | 25.8 mil | 25 mil |
| Strip Tensile Strength (MD) | ASTM D7003 | 265 lbf | 251 lbf |
| Strip Tensile Strength (CD) | ASTM D7003 | 229 lbf | 211 lbf |
| Strip Tensile Elongation (MD) | ASTM D7003 | 22% | 21% |
| Strip Tensile Elongation (CD) | ASTM D7003 | 21% | 20% |
| Tongue Tear (MD) | ASTM D5884 | 56 lbf | 50 lbf |
| Tongue Tear (CD) | ASTM D5884 | 56 lbf | 50 lbf |
| CBR Puncture | ASTM D6241 | 1237 lbf | 1181 lbf |
| Index Puncture Resistance | ASTM D4833 | 200 lbf | 184 lbf |
| Hydrostatic Resistance | ASTM D751 | 525 lb/in2 | 319 lb/in2 |
| Dimensional Stability3 | ASTM D1204 | 3.00% | N/A |
| Water Vapor Transmission3 | ASTM E96 | 0.14 g/m2-day | N/A |
| UV Resistance (Fluorescent Light Method)4 | ASTM D7238 |  |  |
| 1. Strength & Elongation retained after 10,000 light hours
 | ASTM D7003 | > 90% retained | > 90% retained |
| 1. Response to bending
 | GRI GM-16 | no cracking | no cracking |
| Grab Tensile Strength (MD) | ASTM D751 | 355 lbf | N/A |
| Grab Tensile Strength (CD) | ASTM D751 | 342 lbf | N/A |
| Trapezoidal Tear (MD) | ASTM D4533 | 63 lbf | N/A |
| Trapezoidal Tear (CD) | ASTM D4533 | 63 lbf | N/A |
| Seam Strength (Shear)5 | ASTM D7747 | 80 lbf | N/A |
| Seam Strength (Peel)6 | ASTM D7747 | 20 lbf | N/A |
| Hydraulic Conductivity | ASTM E96 (‘B’) | 1.0 x 10-14 cm/sec | N/A |
| Carbon Black Content | ASTM D4218 | > 2% | N/A |
| Accelerated UV Weathering7 | ASTM G154 | > 90% @ 10,000 hrs. | N/A |
| Low Temperature Brittleness | ASTM D2136 | Pass (@ -60°F) | N/A |

Notes:

1 Typical values represent an average test result for the sample size, with + 10% variance

2 Minimum Average Roll Values (MARV) are shown (unless otherwise noted), in accordance with GRI-GM30

3 Dimensional Stability and Water Vapor Transmission values shown are maximum test result values

4 Test samples were exposed to UV radiation using this method prior to evaluating changes in material properties

5 Test values reflect single-track wedge welding at approximately 750° F and 14 ft/sec

6 Test values reflect single-track wedge welding at approximately 750° F and 14 ft/sec

7 Test valued based on A-340 lamps, 8 hours UV @ 60° C, 4 hours condensation @ 40° C

The [ 30 ] mil RCG shall have the following properties:

|  |  |  |  |
| --- | --- | --- | --- |
| PROPERTY | TEST METHOD | TYPICAL VALUE | MARV |
|  |  |  |  |
| Weight | ASTM D5261 | 18 oz./yd2 | 17.1 oz./yd2 |
| Thickness | ASTM D751 | 33.5 mil | 30 mil |
| Strip Tensile Strength (MD) | ASTM D7003 | 246 lbf | 224 lbf |
| Strip Tensile Strength (CD) | ASTM D7003 | 272 lbf | 262 lbf |
| Strip Tensile Elongation (MD) | ASTM D7003 | 21% | 20% |
| Strip Tensile Elongation (CD) | ASTM D7003 | 21% | 20% |
| Tongue Tear (MD) | ASTM D5884 | 56 lbf | 50 lbf |
| Tongue Tear (CD) | ASTM D5884 | 56 lbf | 50 lbf |
| CBR Puncture | ASTM D6241 | 1348 lbf | 1301 lbf |
| Index Puncture Resistance | ASTM D4833 | 230 lbf | 199 lbf |
| Hydrostatic Resistance | ASTM D751 | 729 lb/in2 | 705 lb/in2 |
| Dimensional Stability3 | ASTM D1204 | 1.52% | N/A |
| Water Vapor Transmission3 | ASTM E96 | 0.09 g/m2-day | N/A |
| UV Resistance (Fluorescent Light Method)4 | ASTM D7238 |  |  |
| 1. Strength & Elongation retained after 10,000 light hours
 | ASTM D7003 | > 90% retained | > 90% retained |
| 1. Response to bending
 | GRI GM-16 | no cracking | no cracking |
| Grab Tensile Strength (MD) | ASTM D751 | 385 lbf | N/A |
| Grab Tensile Strength (CD) | ASTM D751 | 385 lbf | N/A |
| Trapezoidal Tear (MD) | ASTM D4533 | 66 lbf | N/A |
| Trapezoidal Tear (CD) | ASTM D4533 | 66 lbf | N/A |
| Seam Strength (Shear)5 | ASTM D7747 | 100 lbf | N/A |
| Seam Strength (Peel)6 | ASTM D7747 | 25 lbf | N/A |
| Hydraulic Conductivity | ASTM E96 (‘B’) | 1.0 x 10-14 cm/sec | N/A |
| Carbon Black Content | ASTM D4218 | > 2% | N/A |
| Accelerated UV Weathering7 | ASTM G154 | > 90% @ 10,000 hrs. | N/A |
| Low Temperature Brittleness | ASTM D2136 | Pass (@ -60°F) | N/A |

Notes:

1 Typical values represent an average test result for the sample size, with + 10% variance

2 Minimum Average Roll Values (MARV) are shown (unless otherwise noted), in accordance with GRI-GM30

3 Dimensional Stability and Water Vapor Transmission values shown are maximum test result values

4 Test samples were exposed to UV radiation using this method prior to evaluating changes in material properties

5 Test values reflect single-track wedge welding at approximately 750° F and 14 ft/sec

6 Test values reflect single-track wedge welding at approximately 750° F and 14 ft/sec

7 Test valued based on A-340 lamps, 8 hours UV @ 60° C, 4 hours condensation @ 40° C

The [ 40 ] mil RCG shall have the following properties:

|  |  |  |  |
| --- | --- | --- | --- |
| PROPERTY | TEST METHOD | TYPICAL VALUE | MARV |
|  |  |  |  |
| Weight | ASTM D5261 | 20.8 oz./yd2 | 20.3 oz./yd2 |
| Thickness | ASTM D751 | 40 mil | 36 mil |
| Strip Tensile Strength (MD) | ASTM D7003 | 303 lbf | 285 lbf |
| Strip Tensile Strength (CD) | ASTM D7003 | 265 lbf | 259 lbf |
| Strip Tensile Elongation (MD) | ASTM D7003 | 22% | 20% |
| Strip Tensile Elongation (CD) | ASTM D7003 | 22% | 20% |
| Tongue Tear (MD) | ASTM D5884 | 60 lbf | 50 lbf |
| Tongue Tear (CD) | ASTM D5884 | 62 lbf | 50 lbf |
| CBR Puncture | ASTM D6241 | 1400 lbf | 1360 lbf |
| Index Puncture Resistance | ASTM D4833 | 242 lbf | 220 lbf |
| Hydrostatic Resistance | ASTM D751 | 740 lb/in2 | 707 lb/in2 |
| Dimensional Stability3 | ASTM D1204 | 2.86% | N/A |
| Water Vapor Transmission3 | ASTM E96 | 0.08 g/m2-day | N/A |
| UV Resistance (Fluorescent Light Method)4 | ASTM D7238 |  |  |
| 1. Strength & Elongation retained after 10,000 light hours
 | ASTM D7003 | > 90% retained | > 90% retained |
| 1. Response to bending
 | GRI GM-16 | no cracking | no cracking |
| Grab Tensile Strength (MD) | ASTM D751 | 463 lbf | N/A |
| Grab Tensile Strength (CD) | ASTM D751 | 397 lbf | N/A |
| Trapezoidal Tear (MD) | ASTM D4533 | 73 lbf | N/A |
| Trapezoidal Tear (CD) | ASTM D4533 | 69 lbf | N/A |
| Seam Strength (Shear)5 | ASTM D7747 | 165 lbf | N/A |
| Seam Strength (Peel)6 | ASTM D7747 | 30 lbf | N/A |
| Hydraulic Conductivity | ASTM E96 (‘B’) | 1.0 x 10-14 cm/sec | N/A |
| Carbon Black Content | ASTM D4218 | > 2% | N/A |
| Accelerated UV Weathering7 | ASTM G154 | > 90% @ 10,000 hrs. | N/A |
| Low Temperature Brittleness | ASTM D2136 | Pass (@ -60°F) | N/A |

Notes:

1 Typical values represent an average test result for the sample size, with + 10% variance

2 Minimum Average Roll Values (MARV) are shown (unless otherwise noted), in accordance with GRI-GM30

3 Dimensional Stability and Water Vapor Transmission values shown are maximum test result values

4 Test samples were exposed to UV radiation using this method prior to evaluating changes in material properties

5 Test values reflect single-track wedge welding at approximately 750° F and 14 ft/sec

6 Test values reflect single-track wedge welding at approximately 750° F and 14 ft/sec

7 Test valued based on A-340 lamps, 8 hours UV @ 60° C, 4 hours condensation @ 40° C

1. OTHER PRODUCTS
2. Any extrusion welding performed on the geomembrane shall use an extrudate manufactured from the same base polymer(s) of the parent RCG.
3. Any boots, skirts, or sleeves fabricated for pipes or other penetrations shall be made from the same thickness parent material as the RCG liner.
4. Any batten strips used to connect the RCG to concrete (or other material) shall be manufactured using steel, aluminum, or other appropriate material as approved by the engineer of record. Fastening bolts shall be manufactured using steel, aluminum, or other corrosion-resistant material.
5. Any tape used on the RCG shall be GeoLap™ Adhesive Roll manufactured by Owens Corning, or approved equal. Tape shall not be used for any primary welding / seaming unless express written permission is provided by the engineer of record to the fabricator and/or installer.
6. Any cushioning material used below or above the RCG shall be approved by the engineer based on site conditions. At a minimum, the material shall be a needle-punched, non-woven polypropylene geotextile with a minimum average roll value mass per unit area no less than six (6) ounces per square yard.

PART 3 EXECUTION

1. VERIFICATION
2. The area to be covered with RCG must be depicted on an engineering drawing signed and sealed by a registered professional engineer. This drawing should provide detailed information regarding the coverage area location, dimensions, and any special provisions for the installation of geomembrane materials. The installer shall have this drawing readily available on the site at all times.
3. It is recommended that RCG be fabricated in a controlled environment prior to delivery to the site. Fabrication can result in higher quality seams by minimizing field seaming in adverse conditions. Fabrication can also save time and labor through creation of large panels that can be deployed on site with minimal field seaming.
4. The fabricator is responsible for the creation of a panel diagram based on the engineering drawing. The owner / engineer and installer must approve this panel diagram in writing, prior to any fabrication of welded panels.
5. The installer shall schedule a pre-installation meeting on the site no than 24 hours prior to deployment of the first roll or panel of RCG. It will be the responsibility of the installer to schedule the meeting with enough advance notice to ensure that a representative of the owner, engineer, fabricator (if applicable), and any other pertinent stakeholders in the project are able to attend.
6. SUBGRADE PREPARATION AND ACCEPTANCE
7. Prior to RCG installation, the subgrade shall be prepared by clearing, grading, and compacting the underlying soil to the specifications of the project construction documents.
8. Subgrade surface should be free of loose rock fragments (>0.4 inches), sticks, sharp objects, or debris of any kind. The surface should provide a smooth, flat, firm, unyielding foundation for the geomembrane with no sudden, sharp or abrupt changes or break in grade that can tear or damage the geomembrane. The owner / engineer shall direct the installer to use a minimum of a 6-8 oz. / SY needle-punched non-woven geotextile directly atop the subgrade to protect the RCG in cases where rocks or debris are prevalent.
9. No standing water, mud, vegetation, snow, frozen subgrade, or excessive moisture is allowed during geomembrane placement.
10. All pipes, drains, fitting, etc., which are to be installed beneath the geomembrane, should be in place, backfilled, and ready to be covered with the geomembrane before panel deployment.
11. When applicable, an anchor trench, excavated in accordance with the approved construction documents, should be used as a perimeter termination point for the geomembrane. Installation of the geomembrane shall be started from the anchor trench.
12. Before any geomembrane deployment, the installer is responsible for inspecting the subgrade and approving its condition upon each day of RCG installation. This subgrade approval shall be certified in writing and provided to the project owner.
13. If the subgrade is deemed to be inappropriate for any reason by the installer, it is the installer’s responsibility to require remediation prior to geomembrane placement.
14. GEOMEMBRANE DEPLOYMENT AND PLACEMENT
15. The geomembrane shall be installed to the limits shown on the engineering drawing and/or approved panel diagram.
16. No geomembrane material shall be unrolled and deployed if the sheet temperatures are lower than 32°F unless otherwise approved by the engineer.
17. Typically, only the quantity of geomembrane (rolls or panels) that will be properly anchored and welded together in one day should be deployed.
18. No vehicular traffic shall travel on the geomembrane other than an approved low ground pressure vehicles weighing 500 pounds or less.
19. Sand bags or equivalent ballast shall be used as necessary to temporarily hold the geomembrane material in position under the average seasonal wind conditions. Sand bag material shall be sufficient to resist UV degradation for the duration of geomembrane installation.
20. Geomembrane placement shall not be done if moisture prevents proper subgrade preparation, roll / panel placement, or welding.
21. Fabricated geomembrane panels should be placed in accordance with the panel diagram, at a starting point on one corner of the area to be lined. The deployment markings on the packaging or label indicate which direction the panel will unfold.
	1. Note that accordion-folded and rolled panels will unroll in only one principal direction while double accordion-folded panels may unfold in either principal direction.
	2. Once the geomembrane is properly placed, the panels should be field seamed in accordance with the panel diagram as soon as practical.
22. RCG that has not been fabricated must be deployed in individual rolls.
	1. Rolls should be suspended from a spreader bar and pulled in the direction of deployment, or they can be unrolled manually by holding the roll end and deploying the bulk roll.
	2. In either case, the rolls should be deployed so that the seams will be parallel to the direction of the maximum slope.
	3. In corners and odd shaped geometric locations, the total length of field seams shall be minimized.
	4. Seams shall not be located at low points in the subgrade unless geometry requires seaming at such locations, and approved by the engineer.
23. The geomembrane shall not be allowed to “bridge over” voids or low areas in the subgrade. The geomembrane shall rest in intimate contact with the subgrade.
24. Wrinkles caused by panel placement or thermal expansion should be minimized prior to welding or further roll / panel deployment.
25. Rolls or panels shall be overlapped prior to seaming in a “shingled” direction specified in the engineering drawing and / or panel diagram. Overlap shall be no less than four (4) inches, but no greater than six (6) inches, unless otherwise directed by the engineer.
26. Rolls and panels should be marked, by the installer, to identify their placement and location with respect to the engineering drawing and panel diagram. The installer is responsible for logging the deployment in accordance with Section 1.03B of this specification.
27. GEOMEMBRANE SEAMING
28. Seaming of RCG is performed to create a single functional film by combining roll / panel edges together via thermal fusion welding. Special care must be taken to ensure the formation of a robust film bond without compromising the scrim reinforcement of the product. Failure to do so may result in failure of the product.
29. A single-track thermal fusion wedge welder configured with solid rubber rollers and a minimum of 2-inch-wide solid wedge should be used as the primary RCG seaming device.
30. Welding is to be undertaken only by persons that have been trained and qualified in the use of the equipment. It is required that all welding equipment be setup to the standards of the welding machine manufacturer by a trained operator.
31. Sheet Conditioning and Seam Preparation
32. Prior to performing any welding operation, ensure both geomembrane sheets are clean and dry at the weld interface, using clean, soft rags no more than 30 minutes prior to the welding. The wedge should be cleaned and clear of any residual material buildup from previous use.
33. Allow geomembrane roll edges to be welded to relax after unfolding or unrolling and equilibrate to the ambient temperature.
34. Set correct overlap through placement of adjacent geomembranes sheets or panels. The overlap should be between 4-6 inches to prevent wrinkles/bunching and ensure a full width seal will occur along the length of the seam.
35. Trial Welding
36. Prior to any seam welding of RCG, a trial weld process should be successfully completed. This ensures that the equipment is in proper working order, and that speed and temperature setpoints are sufficient for quality welded seams.
37. Trial welding is required if or when any of the following events / conditions occur:
	1. At the beginning of wedge welding (i.e., new project, new day of welding)
	2. Every four (4) hours of wedge welding
	3. Every 3,000 lineal feet of field seam per machine (or more frequently, if specified by the owner / engineer)
	4. After the machine has been turned off and restarted
	5. After the machine has undergone power interruptions.
	6. After any machine setting changes have been made.
	7. At the time of any welding personnel changes.
	8. After drastic changes in conditions that significantly alter the geomembrane temperature.
38. Trial welds should be performed on scraps of RCG that are no less than 4 feet long and at least 12 inches wide. Trial welding should be performed in the same manner and conditions as anticipated field welding.
39. Once the trial weld is complete, a total of ten (10) test specimens of 1” wide should be extracted from the last 12 inches of the weld. Five (5) specimens are to be used for shear testing, and the other five (5) used for peel testing in accordance with ASTM D7747, Method ‘A’. Testing should be performed by the installer (or fabricator) using a field tensiometer with a valid calibration performed no more than one year prior to the testing. Trial welded seams specimens should have peel and shear strength values no less than: [ choose one ]

20 lbf (peel) and 150 lbf (shear) [ 40 mil ]

15 lbf (peel) and 120 lbf (shear) [ 30 mil ]

15 lbf (peel) and 100 lbf (shear) [ 24 mil ]

1. If more than one (1) specimen in each testing group (shear and peel) does not meet or exceed the values shown above, then the welding machine should be inspected, temperature and/or speed settings adjusted, and the trial weld performed and tested again. If specimens do not pass after a third (3rd) trial weld test, then the welding machine used to perform the trial weld must be taken out of operation, inspected, and repaired before being used again.
2. Tested trial weld specimens and a 12-inch remaining piece of the trial weld should be saved and marked with date, time, machine / operator identification, settings, and test results, and logged in accordance with Section 1.03B of this specification.
3. Welding should begin and end at the roll or panel ends of the geomembrane sheet and performed as a continuous process. Should the seam be interrupted for any reason, the area should be marked and inspected with any damage remedied through specified patching and repair practice.
4. To prevent subgrade inference with the welding equipment, a piece of liner scrap (i.e., “rub sheet”) should be pulled along underneath the geomembrane to maintain an optimal welding surface.
5. The welding operator must visually inspect the weld exiting the machine to ensure that the weld is even, without sharp edge lines. Visual detection of an asymmetric weld profile is in indication that the equipment needs adjusting before any further use.
6. A record of all wedge welded seams and/or panels should be recorded and logged as described in Section 1.03 B of this specification. Testing of welded seams is described in Section 3.07 of this specification.
7. GEOMEMBRANE PATCHING AND REPAIRS
8. A repair patch must consist of the [ 24 | 30 | 40 ] mil RCG material, with scrim yarns oriented in the same direction as the parent [ 24 | 30 | 40 ] mil RCG being repaired. The patch (or cap, for long linear seam repair) must extend a minimum of six (6) inches in all directions beyond the edge of the hole or defect.
9. For holes, rips, or tears with jagged edges, exceeding approximately 0.5 inches in width or diameter, a clean extraction of material extending at least six (6) inches from the edge of the hole or defect should be removed. The patch should then extend a minimum of six (6) inches in all directions beyond the edge of the extraction.

[ choose one ]

1. [ 30 | 40 ] mil RCG should have a patch thermally fused using a hot air welder. Constant, even pressure should be applied to the top sheet during the welding using a rubber roller. The two materials should be heated until softened, but not overheated.

1. Once hot air welded, patch edges should be reinforced with an extrusion fillet weld with a single extruded bead, using welding rod made from the same resin class as the parent RCG. Extrusion welding should be performed similarly to wedge welding (Section 3.04 of this specification), including the use of the trial welding procedure (Section 3.04 E of this specification).
2. Edges of newly installed [ 30 | 40 ] mil RCG should not be grinded prior to extrusion welding. For repairs of [ 30 | 40 ] mil RCG that have been installed for six (6) months or longer, the surfaces to be repair welded (patch and parent material) should be lightly grinded with a fine grit sandpaper (an electric grinder is not recommended) to gently roughen the surface. Grinding should only be done approximately 1/4 inch from the edges of the overlapping materials.
3. A record of all repairs to the RCG should be recorded and logged as described in Section 1.03 B of this specification. Testing of repair welds is described in Section 3.07 of this specification.

[ OR ]

1. 24 mil RCG should have a patch thermally fused using a hot air welder. Constant, even pressure should be applied to the top sheet during the welding using a rubber roller. The two materials should be heated until softened, but not overheated.
2. Once hot air welded, patch edges should be reinforced with approved tape (in accordance with Section 2.04 D of this specification). Extrusion welding is not to be performed on 24 mil RCG.
3. GEOMEMBRANE PENETRATIONS AND CONNECTIONS
4. It is the responsibility of the installer to correctly install connections and penetrations to the RCG in accordance with the detail drawings.
5. All pipes, drains, fittings, etc., to be installed beneath the geomembrane, should be in place and covered during geomembrane deployment.
6. Pipes
	1. Pipe boots shall generally consist of a prefabricated skirt attached to the underlying RCG, with a prefabricated sleeve attached to the skirt.

[ choose one ]

* 1. [ 30 | 40 ] mil RCG should have skirts / sleeves prefabricated from identical [ 30 | 40 ] mil material from the same manufacturer

[ OR ]

24 mil RCG should have skirts / sleeves prefabricated from 30 or 40 mil RCG from the same manufacturer

[ choose one ]

* 1. [ 30 | 40 ] mil RCG boot assemblies should be attached using a combination of hot air and extrusion welding. The skirt to liner connection should be made using both methods, while the sleeve to skirt connection should be made only through hot air welding.

[ OR ]

24 mil RCG boot assemblies should be attached using hot air welding only. Extrusion welding is not to be performed on 24 mil RCG

* 1. The pipe boot sleeve should be attached to the pipe using a double-sided butyl adhesive between the pipe and boot and two stainless steel band clamps. Approved tape (in accordance with Section 2.04 D of this specification) should be used to reinforce boot assembly connections.
1. Batten Strips
	1. Batten strips shall be at least 1.25 inches wide and 0.25 inches thick, and made of steel, aluminum, or other appropriate material as approved by the engineer of record.
	2. Fastening bolts will be no less than 0.375 inches in diameter on 12 inch centers, and made of steel, aluminum, or other appropriate material as approved by the engineer of record.
	3. Double-sided butyl adhesive shall be placed between concrete and RCG, and a chemically compatible (silicone or equivalent) sealant be placed between the RCG and batten strip.
	4. Geomembrane welds should only be allowed to pass perpendicularly under the batten strips.
2. Drains or inlets within the geomembrane coverage area require that RCG be mechanically fastened to a concrete base or collar around the drainage structure, using the batten strip procedures described above.
3. RCG installed in lagoons with aerators should include protection (e.g., ballasting, concrete pad, etc.) to support the aerator when the water level is lowered.
4. Vents can be installed (if directed by the owner / engineer) near the top of slope of a lined facility, well above the maximum high water level. A one (1) inch square area should be extracted from the geomembrane, and covered with a patch welded on three sides, with the fourth side left open towards the contained area.
5. QUALITY ASSURANCE / QUALITY CONTROL
6. Panels and seams should be visually inspected by the installer (and/or fabricator) during and after all panel or roll deployment to identify defects, holes, blisters, or subgrade protrusions. Suspect locations, whether on a seam or the liner, shall be marked and non-destructively tested. Any non-destructive test failures will require subsequent repair.
7. Non-Destructive Seam Testing
	1. Non-Destructive Testing (NDT) shall be performed by the installer on all welded seams (both field and fabricated) in accordance with the Air Lance Test method (ASTM D4437).
	2. Check all wedge welded seams using a minimum 50 psi air supply directed through a 3⁄16 in. nozzle, held not more than 2 in. from the seam edge and directed at the seam edge. Any areas that are deemed to be unbonded, or poorly bonded, must be immediately repaired and retested.
	3. The installer is responsible for recording NDT (including pass/ fail designation, location of seams tested, date and time of test, and tester identification) logged in accordance with Section 1.03B of this specification.
8. Destructive Seam Testing
	1. Destructive Testing (DST) shall be performed by the installer on all welded seams (both field and fabricated) in accordance with ASTM D 7747, Method ‘A’.
	2. The default interval for DST sampling is every 500 lineal feet of welded seam, however it is strongly recommended that these samples be extracted from areas close to the edges of rolls or panels that are outside of containment areas (i.e., above normal high water levels). It is not recommended that DST samples be taken from welded seams within the containment area, particularly on the bottom of the pond or holding area.
	3. For projects where the total length of welded seams is 10,000 lineal feet or more, or the average seam length exceeds 500 lineal feet then the Geosynthetic Research Institute (GRI) GM14 standard can be employed by the installer for DST frequencies, if approved in writing by the engineer of record.
	4. DST sample size shall be 12 inches wide by 39 inches long with the seam centered lengthwise. The sample shall be cut into three equal sections and distributed as follows: one section given to the owner (or designated representative) as an archive sample; one section supplied to the owner for laboratory testing; and one section retained by the installer for field testing.
	5. Field testing should be performed by the installer using a field tensiometer with a valid calibration performed no more than one year prior to the testing. The installer shall cut and test five specimens for seam shear strength and five for seam peel strength in accordance with ASTM D7747, Method ‘A’. Wedge welded DST specimens should have peel and shear strength values no less than: [ choose one ]

20 lbf (peel) and 150 lbf (shear) [ 40 mil ]

15 lbf (peel) and 120 lbf (shear) [ 30 mil ]

15 lbf (peel) and 100 lbf (shear) [ 24 mil ]

* 1. Upon verifying that all specimens pass the requirements above, the remaining DST samples can be sent to the owner for laboratory testing in accordance with instructions and requirements set forth by the engineer of record.
	2. DST samples that fail, either in the field or laboratory, are subject to further testing. New DST samples must be cut on both sides of the failed sample, approximately 10 feet from the sample. These new samples must be tested in similar fashion and recorded. These two samples must pass (as described above) before repair patching of the seam between the samples. Failure of one or both of the new DST samples will require the original welded seam (in entirety) to be extracted and rewelded.
	3. Bounding of sample failures require that the subject welding machine and operator cease welding immediately until the cause of failure is determined (i.e., welder malfunction, operator error, etc.). The last weld with the defective operator/welder combination is to be marked, and tracked back to where the combination began welding (coinciding with the applicable trial weld), or to the last passing DST. All welded seams between these boundaries require extraction of the seam and reweld.
	4. The installer is responsible for recording DST (date, time, machine / operator identification, settings, and test results) logged in accordance with Section 1.03B of this specification.
1. Non-Destructive Repair / Non-Seam Area Testing
2. Vacuum Box testing (in accordance with ASTM D5641) should be used for all extrusion repairs, patches affixed using hot air welding or extrusion fillet welding, and caps attached with extrusion fillet welds.
3. A minimum pressure of 4 psi should be applied within the vacuum box, and held for at least ten (10) seconds without the presence of bubbles. Should bubbles appear, they should be marked and the area be repaired before testing again. The installer is responsible for recording repair NDT (date, time, machine / operator identification, settings, and test results) logged in accordance with Section 1.03B of this specification.
4. Destructive Repair / Non-Seam Area Testing
5. DST should only be performed on a repaired area per the written request of the owner and/or engineer of record. If a DST sample is requested for testing, it should be extracted, marked, tested, and logged in accordance with the procedures described for welded seams and logged in accordance with Section 1.03B of this specification.
6. Electrical Leak Location Survey
7. Electrical Leak Location (ELL) should be performed on the completed RCG installation if specifically required by the owner or engineer of record. In this case, the installer shall be responsible for facilitating the survey, using a qualified ELL professional or company to perform the test in strict accordance with accepted procedures.
8. Exposed RCG should utilize the following ELL methods if required by the owner / engineer:
	* 1. Water Puddle Method (ASTM D7002)
		2. Water Lance Method (ASTM D7703)
		3. Arc Testing Method (ASTM D7953)
9. Any leaks discovered in the ELL process (before project close-out) should be marked and repaired by the installer using procedures outlined in Section 3.05 of this specification. Repairs should be made and tested prior to any placement of cover soil, or filling with water.
10. Buried or submerged RCG (surveyed after project close-out) should utilize the following ELL methods if required by the owner / engineer:
	* 1. Dipole Method (ASTM D7707)
11. Any leaks discovered in the ELL process (after project close-out) is the responsibility of the owner to facilitate identification and marking. This may require excavation of cover soils, removal of other debris, or extraction of water from the containment area. Once the leak or breach has been identified and marked, the owner is responsible for notifying the installer and complying with any provisions of their warranty. The leak or breach should be repaired by the installer using procedures outlined in Section 3.05 of this specification.
12. PROJECT CLOSE-OUT
13. On completion of installation, excess material shall be cut from the anchor trench areas and all scrap, sandbags, and debris shall be removed. The installer shall dispose of all waste and scrap material in a location provided and approved by the owner. No scrap material shall be left on the completed surface of the geomembrane.
14. The installer should remove all equipment used in connection with the work herein, and shall leave the premises in a neat and acceptable manner.
15. The installer, owner / engineer, and other participating representatives shall conduct a thorough walk through and visual inspection of the complete geomembrane surface, checking for any remaining defects requiring additional repairs.
16. The Geomembrane will be accepted by the owner when all of the following have been completed:
	1. the entire installation, or agreed upon subsections of the installation are finished, with aforementioned walk through and visual inspection completed;
	2. all of the installer’s testing documentation is complete and submitted to the owner, and;
	3. verification of the adequacy of all field seams and repairs and associated geomembrane testing is complete.
17. Upon completion of walk-through and visual inspection, the installer shall submit documentation in accordance with Section 1.03B of this specification.
18. COVER MATERIALS
19. No cover material should be placed atop any section of geomembrane that has yet to be completed, documented, and certified by the installer, and accepted by the owner.
20. Cover material shall consist of 0.5-inch maximum diameter (minus particles), clean rounded soils or gravels free of sharp edges, sticks, metal, rubbish, and debris or foreign materials. Site specific materials or sizes may be acceptable as approved by the engineer.
21. The cover material shall be placed as soon as practical, in conjunction with or upon completion of the geomembrane installation or as the installation progresses to minimize traffic on the geomembrane and damage.
22. Cover soils should be dumped and leveled over the geomembrane and not pushed from one end to the other to minimize rolling and wrinkling of the geomembrane beneath the soils.
23. Cover soil should always be placed from the bottom to the top of slopes to avoid stressing the geomembrane and slope stability problems.
24. Equipment should be turned in long sweeping turns and not spun quickly to eliminate the chance of tires digging down to the geomembrane through the cover soil and wrinkling or stretching the geomembrane. Sudden starts and stops should also be avoided.
25. At no time will construction equipment be allowed to operate or drive directly on the geomembranes.

\*\*\* END OF SECTION \*\*\*