Guidelines for Installation of:

Factory Fabricated Heavyweight > 0.64 mm (25 mil) Thickness Fabric-Supported Geomembranes

International Association of Geosynthetic Installers

www.iagi.org

*This installation guideline was developed in partnership with the **Fabricated Geomembrane Institute (FGI)** & the **International Association of Geosynthetic Installers (IAGI)**.*

FGI Fabricated Geomembrane Institute

www.fabricatedgeomembrane.com

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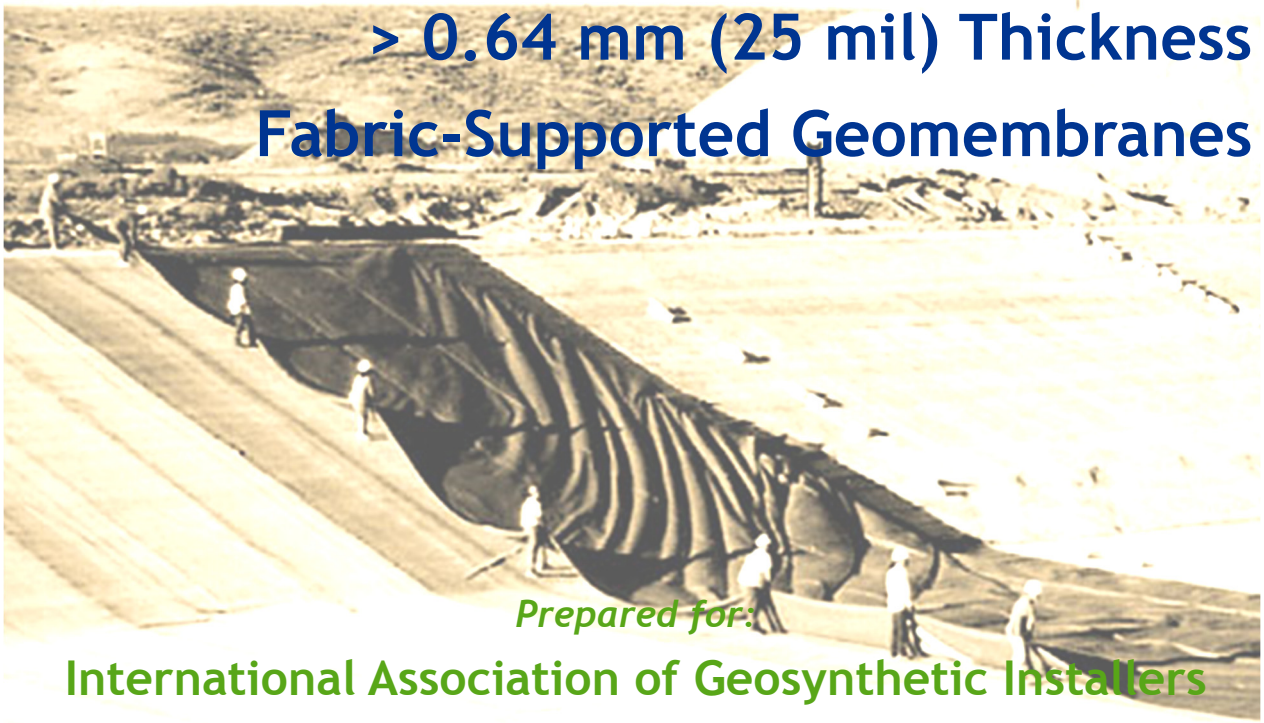

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Part 1 — GENERAL

1.01 Guideline Scope

A. This document is an installation guideline for **Factory Fabricated Fabric-Supported Heavyweight Geomembranes** (>0.64 mm or 25 mil in thickness as measured by ASTM D5199, D751 or D1777). The applicable product types are as outlined in Part 2 of this guideline. This guideline is designed to provide a minimum set of standards for site installation. However, depending on the complexity and project specific requirements, a qualified design engineering firm may be require different design and installation procedures for the geomembrane. All work shall be in accordance with the project drawings, specifications and QC requirements.

B. Applications

Typical applications for factory fabricated Fabric-Supported Heavyweight Geomembranes that are more than 0.64 mm (25 mil) in thickness include but are not limited to:

- Irrigation and canal liners
- Landfill liners
- Leach pad liners
- Moisture barriers and covers for athletic fields
- Golf course and decorative pond liners
- Soil remediation pads
- Interim and final landfill and Mine Reclamation cover systems
- Shale oil and gas development, e.g., drill pads and various liquid containment
- Oil and gas production, e.g., various secondary containment applications

- Mining leach pads and various liquid containment and transport applications
- Tailings ponds
- Water reservoirs and ponds
- Paved and unpaved roadways
- Subgrade protection
- Temporary erosion control
- Barriers, blankets, and curtains
- Rain sheets for Ore in Mining Applications
- Underslab vapor retarders

1.02 References

American Society for Testing and Materials (ASTM)

1. ASTM D4437. "Standard Practice for Non-destructive Testing (NDT) for Determining the Integrity of Seams Used in Joining Flexible Polymeric Sheet Geomembranes". ASTM International, West Conshohocken, PA..
2. ASTM D5199. "Standard Test Method for Measuring the Nominal Thickness of Geosynthetics". ASTM International, West Conshohocken, PA.
3. ASTM D751. "Standard Test Methods for Coated Fabrics". ASTM International, West Conshohocken, PA.
4. ASTM D1777. "Standard Test Method for Thickness of Textile Materials". ASTM International, West Conshohocken, PA.
5. ASTM D5641. "Standard Practice for Geomembrane Seam Evaluation by Vacuum Chamber". ASTM International, West Conshohocken, PA.

Other References

1. USEPA. (1991). *Inspection Techniques For The*

Interesting Historical Fact:

Before Australia adopted the metric system, they used the term "thou" to mean thousandth of an inch instead of using the term "mil." So 30 mil geomembranes would be referred to as "30 thou." For clarification, the use of the term mil in this guideline means "thousandth of an inch."

Fabrication Of Geomembrane Field Seams. Cincinnati, Ohio 45268: U.S. Environmental Protection Agency.

2. Koerner, R. M. (2005). *Designing with Geosynthetics* (5 ed.). Upper Saddle River, NJ 07458: Pearson Education, Inc.
3. Geosynthetic Research Institute (2012). "Standard Specification for Test Methods, Required Properties and Testing Frequencies for Scrim Reinforced Polyethylene Geomembranes Used in Exposed Temporary Applications" GRI GM 22, Geosynthetic Institute, Folsom, PA.
4. Scheirs, J. (2009). *A Guide to Polymeric Geomembranes*. John Wiley & Sons. doi:10.1002/9780470748213.
5. GRI GM 14, Test Frequencies for Destructive Seam Testing Selecting, variable intervals for taking geomembrane destructive samples using the method of attributes.

1.03 Submittals

Documents to be included in a submittal to the owner/engineer for review or approval:

1. Example material warranty and Geomembrane installation warranty.
2. Sample of Geomembrane(s) to be installed including the technical data on the product.
3. Reports on the results of examinations and testing shall be prepared and submitted to the Owner's Representative.
4. Shop drawings/panel layout for Geomembranes with panel numbers, field seam locations and details, corresponding to shipping labels.

5. Submit resumes or qualifications of the installation supervisor and certified welding technicians.
6. Documentation of manufacturer's and installer's qualifications (see section 2.02 below). It is recommended that the welding technicians hold an International Association of Geosynthetic Installers (IAGI) Certified Welding Technician (CWT) certification in reinforced geomembranes
7. The installer shall submit a list of at least ten completed facilities. For each installation, provide: name and type of facility; its location; the date of installation; name and telephone number of contact at the facility; type and thickness of geomembrane and; surface area of the installed geomembrane.
8. The documentation to be submitted by the Fabricator to the Owner varies depending on the Owner's requirements. Documentation may include copies of tested seam results, certifications, or any other document related to the quality of the geomembranes and their installation.
9. Fabricator and Installer QC Manuals.

Additional submittals (at Completion)

1. Geomembrane installation warranty. The installer shall guarantee the geomembrane installation against defects in the installation and workmanship for one (1) year commencing with the date of final acceptance.
2. Compilation of pre-qualification test seam samples reports (see section 3.01.D.1 below).
3. Compilation of destructive and non-destructive field seam tests reports (See section 3.01.D below).

Part 2 — PRODUCTS

2.01 Geomembrane Materials

Geomembranes included

1. This Document is an installation guideline for Factory Fabricated Fabric-Supported Heavyweight Geomembranes that are more than 0.64 or mm 25 mil in thickness (as measured by ASTM D5199, D751 or D1777). The top and bottom coating material of the geomembranes included in this guideline may be comprised of a single layer or composite of the following Polymers (in alphabetical order).
    - Chlorosulfonated Polyethylene (CSPE)
    - Ethylene Interpolymer Alloy (EIA)
    - Low density polyethylene (LDPE)
    - Linear low density polyethylene (LLDPE)
    - High density polyethylene (HDPE)
    - Polyethylene (PE)
    - Polypropylene (PP)
    - Polyurethane (PU)
    - Polyvinyl Chloride (PVC)

Geomembranes that are included in this Guideline are the following:

- **Woven Coated Fabrics**: These materials are woven flat tapes coated with a polymeric layer on both sides to create a geomembrane. The geomembrane may include one or more layers or arrangements of flat tapes and as many polymeric layers as needed to create a low hydraulic conductivity (relatively impermeable) structure. The finished sheet shall be capable of being thermally heat welded, fused, or adhesively bonded to itself.
- **Woven Scrim Reinforced Geomembranes:** This geomembrane has an internal lightweight open weave reinforcement consisting of woven yarns in a square

pattern (i.e., 3.6 x 3.6 or 4 x 4 per sq. cm or 9 x 9 or 10 x 10 per sq. inch). The finished sheet shall be capable of being thermally heat welded, fused, or adhesively bonded to itself.

- **String Reinforced Geomembranes**: This geomembrane has a string reinforcement that has an open weave of greater than one-quarter inch (8 mm or ¼ inch) between fibers. The finished sheet shall be capable of being thermally heat welded, fused, or adhesively bonded to itself.

2.02 Quality Control

A. Manufacturer's Qualifications

The manufacturer of the specified geomembrane or similar product shall have at least five years of continuous experience in the manufacture of the geomembrane. Additionally, the Manufacturer shall have produced a minimum of 2,000,000 m^2 (21,527,820 square feet) of the specified geomembrane or similar product during the last 5 years.

B. Fabricators Qualifications

The fabricator of the geomembrane shall have fabricated a minimum of 500,000 m^2/year (5,381,955 ft^2/year) of the specified type or similar geomembranes.

C. Installer's Qualifications

The Geomembrane Installer shall be the Fabricator, approved Fabricator's Installer, or an installer/contractor approved by the Owner's Representative. The geomembrane installer shall have installed at least 10 projects involving a total of 500,000 m^2 (5,381,955 ft^2) using the specified geomembrane.

It is the responsibility of any of the aforementioned parties to select a Geomembrane Installer with the appropriate degree of experience, personnel, and equipment to accomplish the required quality standards.

2.03 Geomembrane Arrival at Project Site

A. Geomembrane Unloading

1. Inspect fabricated geomembrane panels prior to unloading from vehicle at project site (e.g. type of material, conditions, etc.). Make any claims for damage with the carrier prior to unloading or shortly after geomembrane unloading.
2. Materials delivered to site should be off-loaded (using forklift or similar equipment) in a location where minimum handling steps will be required.
3. While unloading or transferring the fabricated panels from one location to another, prevent damage to the wrapping and the fabricated panel itself.
4. Any damage during offloading and transferring should be documented by the contractor unloading the material and the installer.

B. Storage

1. Leave the panels packaged in UV protected wrap until the day that the panels are to be installed. If extremely hot or cold temperatures are present, keep the panels inside at a moderate temperature. This reduces the effort required to unfold the panels.
2. Fabricated panels, when possible, should be stored on pallets off the ground. The storage area should be dry, level, and with a firm base to facilitate lifting;

so the panels are not damaged, do not become dirty, and remain dry externally and internally.

Part 3 — EXECUTION

3.01 Installation

A. Subgrade Preparation

1. A pre-installation inspection shall be requested by the geomembrane installer and ALL interested parties before moving panels from the storage location to the placement area. If the subgrade is deemed to be inappropriate for any reason, e.g., roughness, moisture, rock, etc., it should be remediated prior to geomembrane movement and placement.
2. The geomembrane installer and owner's representative shall provide daily written acceptance for the surface to be covered by the geomembrane in that day's operations.
3. Subgrade surfaces should be free of loose rock fragments (>10 mm or 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.
4. No standing water, mud, vegetation, snow, frozen subgrade, or excessive moisture is allowed before geomembrane placement.
5. 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.

6. An anchor trench in the shape of a “U” or “V” can be used as a perimeter termination point for the geomembrane. Installation of the geomembrane shall be started from the anchor trench.

B. Unfolding and Deploying Prefabricated Panels

1. The geomembrane shall be supplied as a continuous, factory-seamed panel to reduce the amount of field seaming and testing.
2. The geomembrane shall be installed to the limits shown on the project drawings and essentially as shown on approved panel layout drawings.
3. Fabricated geomembrane panels are normally placed 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. Note accordion-folded and rolled panels will unroll in only one principal direction while double accordion-folded panels may unfold in either principal direction.
4. While unrolling and/or unfolding the geomembrane, inspect the fabricated panel for proper material type and thickness, damage, and/or defects. Repair any damage found.
5. Provide suitable wind uplift protection with sandbags (dirt) or other ballast (such as rolls of geotextile) after the geomembrane panel is unfolded.
6. Only material that is to be immediately welded, i.e., during that work-day, should be deployed.
7. Once the geomembrane is properly placed, the material should be seamed as soon as practical.

C. Field Seaming

1. A large advantage of factory fabricated geomembranes is that manufactured

rolls of material can be fabricated into large panels in a factory before shipment to the project site. This minimizes the amount of the field seaming and maximizes the amount of factory seaming which results in more high quality seams. In particular, the individual widths of the manufactured geomembrane rolls shall be assembled into large panels that are custom-designed for the specific project and correspond to the panel layout diagram. If factory seaming is maximized, field seaming can be reduced by 80 to 95 percent. In other words, only 5 to 20% of all seams need to be made in the field depending on the unit weight of the geomembrane material. This reduction in field seaming improves seam quality by seaming in controlled conditions, accelerates construction, minimizes or eliminates destructive field seam tests, reduces weather exposure issues, allows modular construction, and reduces project costs.

2. Field Cleaning of Seams

a. After the panels are initially placed in the proper position, remove as many wrinkles as practical. If possible, allow the panels to "relax" by allowing the panel to warm in the sun before seaming. The edges to be seamed need to be smooth and free of wrinkles to ensure good field seams and no "fish mouths".

b. A minimum overlap of 100 mm to 150 mm (4 - 6 inches) for all field seams types, e.g., thermal fusion, tape, chemical fusion, etc., must be cleaned of all dust, dirt, water, and foreign debris no more than 30 minutes prior to the seaming operation. Only clean, soft rags should be used for cleaning the areas to be seamed.

c. The seaming operation requires a solid, dry, smooth subsurface (see section 3.01 A Subgrade Preparation).

d. During the cleaning operation, the Geomembrane sheets will be inspected for proper type, thickness, and defective areas which must be removed and/or repaired prior to seaming.

3. Field Seaming:

a. Reinforced Factory Fabricated Heavyweight Geomembrane Panels can be field seamed by one or more of the following methods:

i. Thermal Fusion Welding

ii. Extrusion Welding

iii. Chemical Fusion Welding

iv. Adhesive Bonding

v. Field Tape Seaming

4. Thermal Fusion Welding:

a. Wedge welding is performed with a hot wedge welding machine, which uses a heated element to melt the geomembranes to be welded and then presses the two melted sheets together to form a fusion bond. When performed properly, wedge welders produce high quality and consistent seams.

b. The wedge in a hot wedge welder can be heated with hot air (hot air method), or with electric resistance heating (hot wedge method). It is common to weld fabric supported material with a hot air wedge welder. All wedge welders employ a set point controller to accurately maintain the welding temperature within the most efficient welding temperature for the material. The pressure wheels are normally adjustable to allow for good material bonding after heating.

c. Only single or solid wedge arrangement is available for factory and field welding of Reinforced Heavyweight Geomembranes. Only single or solid wedge welding should be used for factory and field welding because of the

presence of scrim or tape exposures in the completed seams. These exposures can result in false pressure drops in completed seams that make a resulting air-channel test unreliable. The single (or solid) wedge arrangement produces a continuous bonded weld not less than 25 mm (1" inch) width. A double (or split) wedge produces two welds with an un-bonded channel between them. This channel is intended for use in non-destructive air pressure testing; however, air lance and pick tests may also be used on split wedge welded seams as well (See Section 3.01.D below). However, difficulties may be encountered air pressure testing as noted above so only single or solid wedge welding should be used for factory and field welding.

d. Seaming with a wedge welder is to be undertaken only by persons that have been trained and qualified in the use of the equipment (see section 2.02C above). Repairs, maintenance, adjustments, and modifications are to be performed only by trained personnel.

e. Temperature controllers on the thermal welding device should be set according to type of geomembrane, thickness, ambient temperature, type of heating (air v. wedge), rate of seaming, and location of thermocouple within the device.

f. It is necessary for the operator to keep constant visual contact with the temperature controls, as well as the completed seam exiting the welder to ensure adequate welding is occurring. It is not recommended to adjust welding parameters without first constructing and testing a trial seam. If the trail seam meets minimum acceptable values, the adjustments can be used on the field seam (See section 3.01.D.1 below).

g. Pre-heating of the geomembrane in the seaming area is optional. The amount or type of preheating and its timing preceding the actual seaming is at the option of the installer.

h. Properly functioning portable electric generators must be available within

close proximity of the seaming region and with adequate extension cords to complete the entire seam. These generators should be of sufficient size or number to handle all seaming electrical requirements. The generator must have rubber tires, or be placed on a smooth plate such that it is completely stable and it does not damage the geomembrane. Fuel (gasoline or diesel) for the generator must be stored away from the geomembrane, and if accidentally spilled on the geomembrane it must be removed immediately. The areas should be inspected for damage to the geomembrane and repaired if necessary.

5. Extrusion Welding

a. In extrusion welding, a fusion joint is created by applying a bead of heated and softened plastic on top of, (fillet seaming) or in between (flat seaming) the overlapped edges of the geomembrane panels to be seamed.

b. Historically, extrusion welding has not been recommended for panel to panel production seams however some geomembranes such as reinforced LLDPE can be extrusion welded. Typically extrusion welding is used only on minor detail work, repairs and work around penetrations (see section 3.01.E) and cut scrim edges.

c. Extrusion welding is not recommended for geomembranes thinner than 0.762 mm (30 mils).

d. All exposed cut scrim or fabric edges shall be encapsulated with an extrusion bead of the same polymer as the geomembrane.

e. Extrusion welding is applicable to the following materials: EIA, HDPE, LLDPE, PE, PP, PU geomembranes.

f. The minimum overlap for extrusion welding should be about 50 mm (2 inches).

g. It is appropriate to grind the surfaces to be seamed prior to the application of the softened plastic bead. The roughened surface should be slightly narrower than the seam width.
h. Grinding dust and grit should be cleaned prior to extrusion welding.
i. Grinding should not remove more than 10% of geomembrane thickness.
j. The quality of extrusion welding seams is affected by welding temperature, welding speed, applied preheat, bead thickness, and operator's skills

6. Chemical Fusion Welding

a. The materials described in this guideline (see section 1.01.A) applicable to chemical welding include: EIA, CSPE, and PVC geomembranes.
b. Chemical fusion welding consists of the application of a chemical substance (Seam bonding solvents) at the surface of the strip of the geomembrane sheets that are going to be seamed. This chemical softens the geomembranes in contact and creates a viscous interface which is later subject to pressure to create a bond between the two geomembranes in contact.
c. All field seams should overlap a minimum of 150 mm (6 inches) wide. A sufficient amount of chemical fusion agent should be applied that, upon compressing the seam surfaces together, a thin excess of chemical fusion agent is forced out of the seam. Enough time should be provided to make the chemical soften the surfaces of the geomembranes in contact before pressing them together.
d. A high durometer rubber, nylon, or hand steel roller can be used to compress the seam surfaces together releasing any air bubbles until a bond is formed.
e. Bodied chemical fusion is a special type of chemical welding, where a small quantity of the lining material (about 10%) is dissolved in the solvent to help reduce the amount of solvent used, to increase the viscosity of the chemical,

and to speed evaporation of the solvent.

f. Chemical solvents are designed to produce adhesive welds in compatible plastic films. Contact the geomembranes representative to determine the optimum bonding agent for the geomembrane being installed.

g. A minimum overlap of 150 mm (6 inches) should be provided for chemical welding.

h. Chemical seaming is a time dependent process. Enough time should be allowed prior to the execution of non-destructive testing.

7. Adhesive Bonding

a. As with chemical welding, the materials described in this guideline (see section 1.01.A) applicable to adhesive welding include: EIA, CSPE, and PVC geomembranes.

b. Adhesive seams also consist of the application of a chemical substance. However, in adhesive seams, the chemical acts as a cementing material and does not soften the geomembrane sheets.

c. A minimum overlap of 150 mm (6 inches) should be provided for adhesive seaming.

d. Similar to chemical seaming, adhesive seaming is also a time dependent process and requires enough time to set up prior to the execution of the non-destructive testing.

8. Field Tape Seaming

a. Some Factory Fabricated Fabric-Supported Heavyweight Geomembranes can be seamed using field tape seaming methods. Tape seaming is limited to 0.6 mm (24 mil) and 0.76 mm (30 mil) woven coated or string reinforced geomembranes.

b. Prepared tapes such as mastics, putties, asphalt, and butyl tapes can be used

to seam some geomembranes. Selection of the tape depends on the material being seamed and the fluid being contained.

c. Immediately after creating a tape seam, it should be loaded or secured to facilitate bonding. The preferred method for securing prepared tape joints is to backfill the geomembrane with a suitable soil cover so tensile stresses do not develop. The backfill creates a pressure seal between the geomembrane panels and tape which is usually effective.

d. An alternative method of creating strength in a tape seam is to sew the seam first and then use prepared tapes to waterproof the joint. Even with a sewn seam; the recommended practice is to backfill the geomembrane to prevent shifting of the seam and to help adhere or bond the tapes.

e. Ambient conditions for prepared tape seaming should be in accordance to manufacturer's directions. Snow accumulations must be removed prior to seaming because tapes may not adhere or stick in the presence of frost or dew.

f. To create a tape seam, place one or two continuous lines of prepared tape between the sheet overlap. Press the sheet materials together to compress the tape using a rubber, *nylon, or steel hand* roller or similar tool. In areas where wrinkles cannot be removed, use tapes on all sides of the wrinkle to form a waterproof seal.

g. Visually inspect the completed seam to ensure intimate contact between the tapes and the upper and lower sheet surfaces. Repair discontinuities by placing a patch over the damaged area with a prepared tape seal around the perimeter. The patch must be round, oval, or contain rounded corners and extend 150 mm (6 inches) around the defect.

h. Supervise the backfilling of the seam area to prevent the seam from being placed in tension and pulled apart. Backfill should proceed in a direction that

does not tend to pull the seams apart or create a shear or tensile stress in the seam. (See section 3.01G Cover Materials below).

D. Field Seaming Test Requirements

1. Test Seams (Trial Seams)
   a. Test seams shall be prepared and tested by the Geomembrane Installer to verify that the seaming parameters meet accepted seam values at the start of each welding session or at the beginning of each working day.
   b. Test seams also may be made whenever personnel or equipment are changed and when climatic conditions reflect wide changes in geomembrane temperature or other conditions that could affect seam quality.
   c. A minimum of one test strip per seaming apparatus shall be conducted at the start of each welding session during a day and at least every 4 hours or 915 lineal meters (3000 lineal feet) of field seam per machine, whichever is more frequent.
   d. Field test seams shall be made using "scrap" material from the same lot as the geomembrane being welded in the field because the geomembrane is pre-fabricated into panels in a factory. This requirement is necessary to ensure that the installed geomembrane panels are not damaged prior to the onset of the field welding process because no destructive seam tests shall be conducted on factory fabricated seams to preserve integrity of the fabricated panels (See section 3.01.D.2.a below).
   e. Test seaming shall be conducted under ambient conditions and with the same equipment, geomembrane, and operator as field seaming on the fabricated panels. The test seams shall be at least 1.8 meter (6 feet) long for all types of field seams.

f. If there is no area or equipment on site to provide for these seam requirements, seam strength can be verified for production using trial welds sent to an independent testing laboratory to verify quality.

g. If a test seam fails, an additional test seam shall be immediately completed. If the additional test seam fails, the seaming apparatus shall be rejected and not used until the deficiencies are corrected and a successful full test seam is produced.

h. Each test seam shall be labeled with date, geomembrane temperature, weather conditions, number of seaming unit, panel identification, seam number or test location, technician performing the test seam, and a pass or fail description.

i. Pre-qualification seams for tape seams shall be in accordance with ASTM D7272.

j. There is a variance in the ASTM seam testing utilized for the geomembranes specified in this document. The Design Engineer should include the specific ASTM test methods that are relevant to the specified material.

2. Non-Destructive Testing (NDT) of Seam Testing

   a. ALL FIELD SEAMS shall be non-destructively tested by the Geomembrane Installer over the full length of the seams before the seam is covered. Each seam shall be numbered or otherwise designated. The location, date, test unit, name of the technician, name of QC person, and outcome of all NDT shall be recorded and submitted to the Owner's Representative.

   b. Testing should be performed as the seaming progresses, not at the completion of all field seaming, unless agreed to in advance by the Owner's Representative. All defects found should be repaired, re-tested, and remarked to indicate acceptable completion of repair.

c. NDT of field seams shall be performed using one or more of the following methods:

3. Air Lance Testing (*ASTM D 4437)*
   a. The Geomembrane Installer shall provide an air compressor, air hose, and air lance wand with a pressure gauge capable of measuring air flow to the tip. The testing shall be performed by experienced technicians familiar with this testing procedure.
   b. This non-destructive test involves placing the air lance wand 6 to 12 mm (¼ to ½ inch), but not more than 50 mm (2 inches), from the edge of a completed seam and closely monitoring the backside of the sheet for any air penetration through the seam, loose edges, riffles, and/or noise. If air penetrates the seam area, the technician will either see this visibly or hear it audibly and the area shall be marked for repair.

4. Vacuum Box Testing (ASTM D5641)

   NOTE: Vacuum box testing is not appropriate for all flexible products. Some flexible materials will pull up or adhere to the screen of the vacuum box and false values can result. Contact the material manufacturer for guidance on whether you should vacuum box test the geomembrane being used.

   a. Vacuum box testing is preferable for extrusion welding.
   b. Apply soapy solution to seam area to be tested.
   c. Place vacuum box with clean viewing glass along seam.
   d. Ensure sealing foam around bottom of box is well seated and provides a good seal.
   e. It may be necessary to “work” the box into place and to use some wet rags to get a good seal.
   f. Apply a minimum pressure in the box of about 27.6 kPa (4 psi) to test the seams.

g. Monitor the seam for soap bubbles for at least 5 seconds.

h. Mark any locations where bubbles indicate leaks for repairs.

i. If no bubbles occur after 5 seconds, relieve vacuum and move to next seam section.

j. An overlap of about 75 mm (3 inches) should be tested between two consecutive testing sections along the field seam being tested.

k. With thinner products it may be beneficial to install a rigid mesh over the bottom of the box to prevent the geomembrane from being sucked or pulled into the vacuum box. Avoid rough edges that might damage the geomembrane.

5. Destructive Field Seam Testing

a. One destructive test sample per 150 lineal meters (492 linear feet) of field seam length or another predetermined length in accordance with GRI GM 14 shall be obtained by the Geomembrane Installer from a location specified by the Owner's Representative. The Geomembrane Installer shall not be informed in advance of the sample location. Testing should be arranged such

NOTE: Historically, destructive seam testing has been conducted every 150 lineal meters. (approximately 500 lineal feet). There is a movement toward doing less destructive testing mid field seam. The rationale behind this change is that when a hole is cut from a seam, it is repaired with a seam that is not as good as the original. There are several methods used within the industry to reduce the amount of destructive seam sampling done. One method involves the use of both destructive and non-destructive methods for testing seam integrity. First, the seam must be made with split-wedge welder and successfully air channel tested. Also a destructive seam sample is taken from the anchor trench and tested. If both tests are successful, then no destructive seams are taken from the field seam. If either test fails, then destructive sampling is conducted on the field seam. A second method is detailed in GRI's GM 14 guideline "Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes." A simplified explanation of this method is that good seaming performance is rewarded by extending the destructive sampling interval. Poor seaming performance is penalized.

that test results are provided prior to completion of geomembrane installation. Samples shall be cut by the Geomembrane Installer as directed by the Owner's Representative as seaming progresses.

b. All field samples shall be marked with their sample number and seam number. The sample number, date, time, location, and seam number shall be recorded. The Geomembrane Installer shall repair all of the holes in the geomembrane created during the seam sampling process. All patches shall be vacuum box tested or spark tested to ensure no leakage. If a patch cannot be permanently installed over the test location the same day of sample collection, a temporary patch shall be tack welded or hot air welded over the opening until a permanent patch can be affixed.

c. The destructive sample size shall be 300 mm (12 inches) wide by 1 m (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's Representative as an archive sample; one section given to the Owner's Representative for laboratory testing as specified in paragraph (e) below; and one section retained by the Geomembrane Installer for field testing as specified in paragraph (d) below.

d. For field testing, the Geomembrane Installer shall cut replicate specimens from his sample in accordance with the ASTM test method appropriate to the geomembrane being installed. The Geomembrane Installer shall test five specimens for seam shear strength and five for seam peel strength. Peel tests will be performed on both inside and outside weld tracks. To be acceptable, 4 of 5 test specimens must pass the specified Geomembrane Manufacturer’s strength criteria with less than 25% separation. If 4 of 5 specimens pass, the sample qualifies for testing by the testing laboratory if required.

e. Standard ASTM non-destructive test (NDT) methods shall be used to evaluate seams. The Engineer shall designate the appropriate standard NDT method

dependent on the type of geomembrane to be installed.

f. Reports of the results of examinations and testing shall be prepared and submitted to the Owner's Representative.

g. For field seams, if a laboratory test fails, that shall be considered as an indicator of the possible inadequacy of the entire seamed length corresponding to the test sample. Additional destructive test portions shall then be taken by the Geomembrane Installer at locations indicated by the Engineer; typically 3 m (10 feet) on either side of the failed sample.

h. On either side of the failed sample and laboratory seam tests shall be performed. Passing tests shall be an indicator of adequate seams. Failing tests shall be an indicator of non-adequate seams and all seams represented by the destructive test location shall be repaired with a cap-strip extrusion welded to all sides of the capped area. All cap-strip seams shall be non-destructively vacuum box tested until adequacy of the seams is achieved. Cap strip seams exceeding 50 m (164 feet) shall be destructively tested.

i. Destructive field seaming tests for tape seams (see section 3.01.C.3.f above) shall be in accordance with ASTM D7272.

6. Identification of Defects

   a. Seams shall be inspected by the geomembrane installer and the owner’s representative before, during, and after field seaming to identify all dirty and wrinkled areas and any defects.

7. Evaluation of Defects

   a. Each suspect location (both in geomembrane seam and non-seam areas) shall be non-destructively tested. Each location which fails non-destructive testing shall be marked, numbered, measured, and posted on the daily installation drawings and subsequently repaired.

b. Defective seams, tears or holes shall be repaired by capping or cutting out the defective seam and re-seaming. Single seams in excess of 20% of their length requiring repair should be entirely removed and re-welded.
c. Each patch or capping shall extend a minimum of 150 mm (6 inches) in all directions beyond the defect.
d. All repairs shall be located, measured, non-destructively tested, and recorded.

E. Geomembrane Penetrations

Any structure or containment area built from man-made materials (metal, concrete, etc.) shall not allow protrusions, pinch points, or movement of the supporting structure that might damage the geomembrane and adversely affect the ability of the geomembrane to perform its containment function. All pipes, drains, fitting, etc., which are to be installed beneath the geomembrane, should be in place and ready to be covered with the geomembrane before geomembrane deployment. If possible, avoid cutting the geomembrane at details by using factory fabricated pipe boots that can be seamed to panels in the field. The following directions provide additional details for handling geomembrane penetrations:

1. Pipes
    a. Whenever possible, avoid slitting geomembrane panels for piping details until a prefabricated pipe boot is ready for immediate installation. Cuts made in the geomembrane for clearance over penetrations should always be made as small as possible to minimize patch work. Generally, it is preferred to let the geomembrane straddle a relatively small protrusion (for later detail work) provided that a rag or towel is taped over the pipe to avoid damage to the geomembrane.
    b. Factory prepared pipe boots should fit snugly but not require excessive force to pull over a pipe. If a pipe boot feels overly snug but workable, try applying

either talc powder or using compressed air with a nozzle to float the boot sleeve over and along the pipe.

c. Pipe boots should never be used if the force required to install them stresses or weakens the boot. When properly installed, the pipe boot will lay flat against grade surrounding pipe without leaving pockets that may become stressed during or after placement of backfill.

d. Pipe boot aprons should be seamed to the parent geomembrane using one of the repair techniques described in the Seaming Section above (see 3.01C Field Seaming).

e. Proper leak-proof sealing of pipe boots should be verified by non-destructive methods (see section 3.01 D). The pipe boot sleeve should be attached to the pipe using butyl tape between the pipe and boot and two stainless steel clamps.

f. When cover materials are not used (see section 3.01.F below), splash pads or additional geomembrane layers shall be used for all inflow pipes to prevent long term wear and damage to the geomembrane caused by the direct impact of the inflow on the geomembrane panels. The pads should be welded on top of the geomembrane panels and tested according to sections 3.01.C and D, respectively. Common splash panel sizes are 1.2 to 1.8 m (4 to 6 ft) in all directions. However, larger sizes may be required depending on the amount of inflow pipes and the height to the discharge point.

2. Concrete

a. Where bonding a geomembrane to concrete (or masonry) is required, the concrete surface should be smooth, clean, dry, and free of any sharp protrusions or rock in the backfill. Geomembrane to concrete seals shall be accomplished with mechanical anchors (e.g. fasteners, termination bars). An approved sealant is placed between the geomembrane and the concrete surface to ensure sealing.

b. The geomembrane fixed to a concrete structure must be on firm soil subgrade that will not deform and stretch the geomembrane. Compacting of the soil subgrade around such structures must be performed with particular care so excessive differential movement between the concrete and soil subgrade does not occur.

3. Drains
   a. The geomembrane shall be mechanically fastened to the concrete structure at the location of water discharge. This detail requires the installation of a concrete base or structure at the location of the drain.
   b. Where water enters or exits the geomembrane area, e.g., ponds, reservoirs, and canals, this point must have proper geomembrane termination so as not to damage the geomembrane. The area of inflow must be anchored or attached to a structure as designed by the Project Engineer or Design Professional. The geomembrane is installed and then anchored to the concrete prior to the covering with soil.
4. Aerators
   a. Geomembrane design in lagoons with aerators should require ballast, e.g. precast concrete slab, on the geomembrane to prevent uplift and to provide a pad to support the aerator when the water level is lowered. Many examples exist of geomembrane damage due to an aerator settling on the geomembrane or where the geomembrane was lifted into the aerator. Other aerator damage is frequently evidenced as cuts in the geomembrane along a specific elevation on the side slope where the aerators have been pulled to shore for maintenance. Geomembrane sheets are easily damaged by the sharp edges of a 6 mm (0.25 inch) thick stainless steel plate of an aerator.

F. Cover Materials

1. When placing cover material or initially filling the containment area, it is important to ballast the geomembrane into the perimeter anchor trench before covering or filling. The anchor trench or perimeter shelf area should be the last area covered to complete the cover process.
2. Under all operating conditions, protection of the geomembrane will be required. Care should be taken when covering the geomembrane to prevent any damage. At no time will construction equipment be allowed to operate or drive directly on the geomembranes.
3. Any damage to the geomembrane should be repaired prior to proceeding with cover material placement. Costs associated with repairs are the general contractor's responsibility.
4. 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.
5. Access roads for clean soil cover should be maintained to provide 0.45 m (18 inch) minimum and for heavier equipment on haul roads a minimum of 0.90 m (36 inch) preferable between the excavation equipment and geomembrane at all times. Cover soil requirements should be verified before placement with the Design Professional and geomembrane installer.
6. Additionally, a protection geotextile layer may be needed in rougher soil conditions between the geomembrane and the cover materials. The use of a protection layer should be verified with the Design Professional and geomembrane fabricator.
7. Cover material shall consist of 12 mm (0.5 inch) 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. It is recommended

that the contractor receive prior written approval of acceptance of the cover materials from a geomembrane representative and/or Design Professional before covering the geomembrane.

8. 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. Cover soil should always be placed from the bottom to the top of slopes to avoid stressing the geomembrane and slope stability problems.
9. Equipment should be turned in long sweeping turns and not spun quickly to eliminate the chance of tires digging down to the geomembrane thru the cover soil and wrinkling or stretching the geomembrane.
    a. If geomembrane damage does occur during construction, cover placement, and/or filling, DO NOT COVER IT UP. Advise the foreman and CQA personnel so repair can be made and documented which will make doing the repair a lot easier than after cover soil placement or filling.

G. Field Acceptance

1. The Geomembrane will be accepted by the Owner's Representative when all of the following have been completed:
    a. The entire installation is finished or on agreed upon subsections of the installation are finished (3.01 A through 3.01F).
    b. All Installer's QC documentation is complete and submitted to the Owner.
    c. Verification of the adequacy of all field seams and repairs and associated geomembrane testing is complete.

H. Site Clean Up and Demobilization

1. On completion of installation, the geomembrane installer shall dispose of all waste and scrap material in a location provided and approved by the owner. The installer should also remove all equipment used in connection with the work herein, and shall leave the premises in a neat and acceptable manner. No scrap material shall be left on the completed surface of the geomembrane.
2. Excess material shall be cut from the anchor trench areas and all scrap, sand bags, and debris, shall be removed just prior to final backfill of anchor trench with select cover soil.

Part 4 — MEASUREMENT AND PAYMENT

4.01 Measurement & Payment

As per project specifications.

Thank you to Mr. Ronald Frobel for reviewing and commenting on this document.

Acknowledgments:

This document was prepared by graduate student Rafael Villarreal and Professor Timothy D. Stark of the University of Illinois at Urbana-Champaign.