Guideline for Desert Installation of Fabricated Geomembrane Panels

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August 12, 2021

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1. Introduction and Purpose

This guideline provides recommendations for installation and maintenance of fabricated geomembrane panels in desert mining applications, such as, deserts of the Andes Mountains and southwest of the United States. One such application is the use of fabricated geomembranes in solar evaporation pools to mine lithium in the Atacama desert or Salar de Atacama (see **Figure 1**). In this environment, the temperature fluctuates from -5^0C (23^0F) to 40^0C (104^0F), which creates challenging conditions for storing, installing, and maintaining geomembrane panels. Because of the large change in temperature, a light color is preferred for the geomembrane, e.g., grey.

In the lithium mining application in Chile, the geomembrane serves two main functions: (1) contain the brine that desiccates and yields lithium (see **Figure 1**), and (2) prevent the brine from reaching the underlying ground surface that contains mineral salts. Preventing the brine from soaking the underlying salts is important because the salts can dissolve, which can undermine the evaporation pond.

Figure 1. In-service evaporation pond for lithium mining (photo from Acevedo-Soriano and Cortes, 2021).

For a fabricated panel to be properly used it must be adequately identified and packaged. It must be handled and stored in such a way that its physical property values are not degraded. Failure to follow the best practices may result in the unnecessary failure of the fabricated panel in a properly designed application.

This guideline provides recommendations for the identification, packaging, handling, storage and deployment of fabricated geomembrane panels. It is not to be considered as an all-encompassing guideline for desert applications because each project involving fabricated geomembrane panels presents its own challenges and special conditions. Additional guidelines for identification, packaging, handling, storage, and deployment of fabricated geomembrane panels are included in ASTM D7865. Other geosynthetic products should use ASTM D4873 as their guideline. This guideline also presents best practices for field seaming and testing, if required, of the geomembrane panels. This guideline is NOT a guarantee of successful installation and performance of the fabricated geomembrane panels. In addition, use of any of the best practices herein is at the applicators own risk and expense.

2. Safety

This guideline does not purport to address all of the safety concerns, if any, associated with its use, especially in the hot and Ultraviolet Radiation (UV) intensive desert environment. It is the responsibility of the user of this guideline to establish appropriate safety. In desert environments, e.g., Chilean, Bolivian and Argentine deserts, winds, are so strong that work in the area is often interrupted. Appropriate safety measures should be implemented in strong winds.

3. General Best Practices for Installers

This section provides best practices for installer personnel:

i. Do not use equipment or tools that are sharp or bring sharp objects onto the deployed geomembrane panels.
ii. Smoking on the geomembrane is prohibited.
iii. Avoid shoes that can damage the geomembrane.
iv. No chemicals can be left on top of the geomembrane.
v. Whenever solvents are used, they must be capped immediately after use. While not in use, solvents should be stored in their original packaging and in a protected location.
vi. Geomembrane welding personnel must be informed of the risks of using a solvent and use appropriate personal protection equipment (PPE), such as gloves and masks during the operation.

4. Terminology

Some Terms from this guideline are defined within this section. Additional terms may also appear in ASTM D 4439.

***Fabricated panel*:** refers to a geomembrane panel fabricated at a manufacturing facility into a larger panel than the original roll stock material. A fabricated panel may be a larger rectangular panel of geomembrane or may be a specific fabricated shape or may contain special job-specific detail work.

***Rolled panel*:** refers to a fabricated panel that is rolled from one end or in some cases from both ends to the middle.

***Accordion-folded panel*:** refers to a fabricated panel where the material is folded back and forth in a "Z" formation in the same principal direction as the seams. This folding takes a wider panel of material and makes it into a narrow stack. For example, a 30 m by 30 m prefabricated panel could be accordion-folded into a 3 m wide stack of material 10 layers deep and 30 m long.

***Accordion-folded and rolled panel*:** refers to an accordion-folded fabricated panel that is first accordion-folded to the desired width and then rolled to form a finished, rolled bundle for transport.

***Double accordion-folded panel*:** refers to an accordion-folded fabricated panel that is accordion-folded to the desired width and then accordion-folded in the length direction onto a pallet (or into a container). Double accordion-folded panels typically appear as a "cube" of material with square corners.

***Fabricator*:** the person or organization by whom the geomembrane material is fabricated into a fabricated panel.

5. Folding, Rolling, and Packaging Best Practices

This section presents to best practices for folding, rolling, and packaging factory fabricated geomembrane panels for use in a desert application.

i. The welding of multiple rolls of geomembrane into a fabricated panel results in a panel much wider than the initial roll widths. This wider panel can either be rolled "as is" (rolled panel), or accordion-folded and then rolled or double accordion folded for transport. Rolled panels are typically 10 m to 13 m wide because it is difficult to physically handle wider rolls without damaging them. Most fabricated panels are accordion-folded to a narrower width of between 1.7 to 4.0 m.

ii. An accordion folded and rolled panel is wound into a roll onto a sturdy core suitable for the weight of the panel. Accordion-folded and rolled panels are often placed on a pallet for transport. The panel should be folded such that the welded areas at not all lined up on each other because that will create a non-uniform thickness of the roll, i.e., thicker at the seams, and additional stress on the seams prior to deployment (see **Figure 2**).

Figure 2. Uneven rolled panel prior to deployment.

iii. For double accordion-folded panels the narrow, accordion-folded panel is folded once more lengthwise onto a sturdy pallet (or often into a cardboard container or crate). **Figure 3** shows the folding of an accordion-folded panel on a pallet for shipping. The resulting package is typically rectangular. Double accordion-folded panels are often sized to fit into transport trucks.

iv. When a pallet is used to support the fabricated geomembrane panel it should extend past the finished dimensions of the panel. One or two layers of geotextile or geomembrane should be placed on a pallet to protect the finished panel.

v. All pallets and crates should be inspected to make sure that there are no protruding fasteners that could damage the material. Pallets and crates should be in good condition.

vi. Packaging for fabricated geomembrane panels should be suitably weather resistant and protective for the storage conditions anticipated. Most importantly, the duration of exposure prior to deployment should be specified by the owner or the fabricator so appropriate packaging, is used because panels can be stored in the desert environment for a considerable time. The most common packaging is a wrap of a weather resistant material that protects the fabricated panel from UV damage and precipitation (see **Figure 4**). Double accordion-folded panels can be folded into a large cardboard box with a lid. The borders of the panel should be protected to prevent inadvertent puncture, such as, cardboard (see cardboard under straps in **Figure 3** or thick HDPE geomembrane).

(a) **(b)**

Figure 3. Photographs of: (a) factory fabricated geomembrane panel being accordion-folded onto a wood pallet for shipping and (b) accordion-folded panels wrapped for shipping.

(a) **(b)**

Figure 4. Rolled geomembrane panels wrapped for shipping and stored in the: (a) factory and (b) field.

vii. Slings, rope, or other handling and deployment aids are attached to the panel after the packaging is completed and often prior to the panel being placed on a pallet.

viii. The outside label is applied to the packaging and the unfolding markings are carefully checked and aligned on the packaged panel.

6. Transportation and Handling

i. Fabricated geomembrane panels should be transported directly to the project site and not transferred from truck to truck because damage can occur during transfer. If multiple handling is required, additional protection to the sides of the packaging is recommended to resist damage to the edges of the panel during transfers. If extensive handling is required during transit, use of a large cardboard box with a lid or a wooden crate is recommended.

ii. Equipment for unloading and handling of the geomembrane panels in the field must be evaluated and checked for compatibility with the packaging, configuration, dimensions, and weight of the panels before it is used. It will also be necessary to analyze the need for plastic straps to secure the panels during movement.

iii. If the fabricated panel is palletized or stored in a crate, a standard forklift with forks long enough to reach through the pallet or crate should be used.

iv. Slings may be used to carry relatively large-fabricated panels, provided that the slings do not cause damage to the panels. Do not drag the panels as damage may result.

v. Inspect fabricated panels at the time of delivery to the site and make any claims for damage with the carrier. The receiving inspection should verify the number and identity of each geomembrane panels, ensure that the packaging is intact, the panels are not damaged, and the labels and deployment markings are in place.

7. Storage

i. Fabricated panels should be stored on pallets off the ground. The storage area should be dry with a smooth and firm base that allows easy lifting and handling. The storage area must be free of objects that may cause puncture or other damage to the geomembrane.

ii. The packaging on each panel should remain in place and be suitable to protect the fabricated geomembrane panel from Ultraviolet Radiation (UV) and other expected weathering. Most importantly, the duration of exposure prior to deployment should be specified by the owner or the fabricator so appropriate packaging, is used because panels can be stored in the desert environment for a considerable time.

iii. The geomembrane panels can be stored at ambient temperature but the geomembrane panels should have a temperature between 10°C (50^0F) and 40°C (105^0F), which may require cooling or shade.

iv. Finally, follow all applicable site or project specifications and manufacturer's recommendations for handling and installation of fabricated panels.

8. Field Deployment and Installation

This section presents best practices for deployment and installation of the factory fabricated geomembrane panels in a desert application.

i. Before deploying a fabricated panel, verify its identification and its deployment location. If there is a panel layout diagram, match the panel identification marking to the panel layout diagram to confirm its proper location before transport to the location.

ii. Move the fabricated geomembrane panel with suitable lifting equipment to the deployment location following all site safety requirements (see **Figure 5**). Equipment for moving and deploying the panels must be previously evaluated and checked for compatibility with the packaging, configuration, dimensions, and weight of the panels before it is used.

iii. Fabricated geomembrane panels are normally placed at a starting point on one corner of the area to be covered. The deployment markings on the packaging or label indicate the direction the panel will unfold. Rolled panels and accordion-folded and rolled panels will only unroll in one principal direction while double accordion-folded panels may unfold in either principal direction.

iv. The area to be covered must be flat, continuous, firm, and free of rocks, stones, sticks, roots, sharp objects, or residues of any kind that could damage the geomembrane. If rocks and stones are present, they should be rounded and no larger than 9.5 mm (3/8") in diameter. There should be no standing water, mud, or excessive humidity in the area to be covered otherwise the geomembrane should not be deployed.

v. In South American evaporation ponds, the side slopes of the ponds are created using salt plates and stones that are usually between 5 to 10 cm in size and have sharp edges that can damage the geomembrane. As a result, the installer should carefully inspect the side slopes for sharp rocks, stones, plates, and other sharp objects that can damage the geomembrane. The ponds made on the salt plates, which in turn are over the brine, to form the slope, need soil from another location, since it is not possible to excavate. In this loan soil, salt stones (usually between 5 to 10 cm) and with highly cutting sides and ends often appear. The suggestion is a detailed check mainly in the region of the slopes, before any movement of the geomembrane on the ground. A typical side slope is 3H:1V.

vi. Before geomembrane deployment, the dimensions and slope inclinations of the area to be covered should be compared with project specification to ensure compliance with project design. The bottom of the pond should also be level so there is little tendency for the geomembrane to move on the abrasive salts on the ground surface. It is recommended to use survey equipment to verify the dimensions, slope inclinations, and levelness of the pond base. The use of survey equipment can also ensure proper and faster alignment of the fabricated panels, which reduces installation time.

vii. Before deployment, the depth to groundwater should be known and the cover area should be free of gas. If groundwater and/or gas is present near the ground surface, an underdrain system should be installed prior to deployment.

Figure 5. Suitable equipment for moving and unrolling a rolled geomembrane panel.

viii. The installer should conduct a visual inspection should be performed over the entire cover area before deployment. If the installer finds any non-conformity, it should be corrected, and registered in the workbook or CQA documents. The deployment should only proceed if the non-conformity has been eliminated.

ix. The Project Owner and the installer must analyze the climatic information before scheduling the installation to avoid damage due to low temperatures during the day,

possible rain, hail storms, and/or wind. Hail is especially problematic when the geomembrane is already installed and not yet covered with brine.

x. The geomembrane will not be deployed during rain or excessive winds occur. Do not deploy panels if winds are above site safety specifications or above the manufacturer's (or fabricator's) recommended wind speed, e.g., typically 5 km/hour (3 mph), for deployment. In no cases should the geomembrane be deployed with a wind speed of 30 km/hour (18 mph) or greater. In addition, the unbonded flap of the geomembrane seams should be in the same direction as the wind (see **Figure 6**).

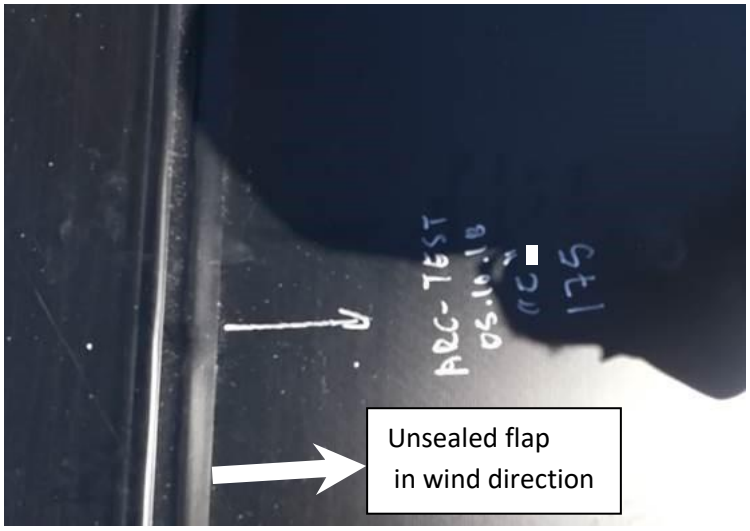

Figure 6. Photograph showing unbonded geomembrane flap in wind direction.

xi. The geomembrane panels should be deployed when the ambient and geomembrane temperatures are between 10°C (50^0F) and 40°C (105^0F). The extreme range of maximum ambient and geomembrane temperature that a geomembrane can be deployed at is 5°C (40^0F) and 50°C (120^0F). The temperature at the center of a rolled or folded panel can be 10°C different than at the edge of the panel. As a result, it is recommended to unroll or unfolded ONLY 100 m at a time and allow the panel temperature to equilibrate with the ambient temperature before exposing more geomembrane. After the first 100 m of geomembrane is acclimated, another 100 m is exposed and allowed to acclimate. This is 100 m at a time deployment is continued until the entire panel is unrolled or unfolded. Fore example, if the panel is 300 m long by 11 m wide or wider, this process will require three (3) pauses in the unrolling and unfolding of the geomembrane. Any panel size can be installed with a similar pause to allow the geomembrane to acclimate to the weather conditions.

xii. Remove packaging prior to deployment. Verify the unrolling direction of the rolled and accordion-folded and rolled panels and adjust the starting point if necessary. The method of opening the geomembrane for deployment must be described in the project specifications.

xiii. The embossed side of the geomembrane should be in contact with the subgrade or cushion geomembrane or geotextile to increase interface strength and reduce the potential for slippage.

xiv. Unroll and/or unfold the fabricated panel into the area to be covered starting at the highest point.

xv. While unrolling and/or unfolding, inspect the fabricated panel for damage or defects. Repair any damage or defects found.

xvi. After unrolling and/or unfolding, flap the panel up and down to allow air to enter beneath the panel so it can be pulled into the proper location (see **Figure 7**).

xvii. After moving the panel into the desired location, remove any geomembrane tension between the side slope and the flat portion of the pond before backfilling the anchor trench, which is discussed in the next section.

Figure 7. Photographs of unfolding geomembrane panel and allowing air under panel to pull it into proper location.

xviii. After unrolling and/or unfolding the fabricated geomembrane panel, provide suitable wind uplift protection with sandbags or other ballast. Due to the high winds in a desert environment, the deployed geomembrane must be anchored with temporary weights to avoid movement. Plastic bags filled with sand (20 kg) can be used and spaced as needed (see **Figure 8**).

xix. Placement of the geomembrane panels should be verified to ensure compliance with the panel layout diagram and contract specification. Surveyor monitoring and locating of the deployed panels is recommended. The use of survey equipment will ensure proper and faster alignment of the fabricated panels, which reduces installation time.

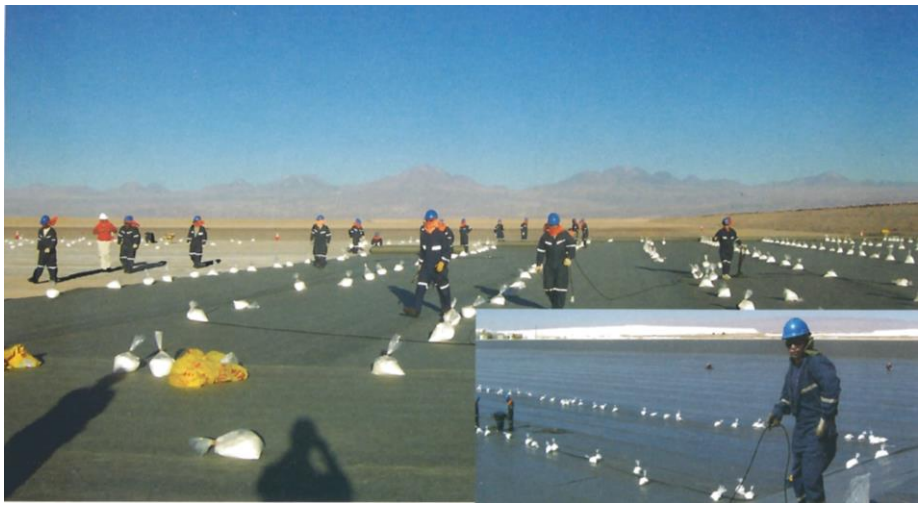

Figure 8. Deployed geomembrane panel being ballasted with sandbags (photo from Berube et al., 2007).

9. Anchor Trench Design and Installation

i. The anchor trench must conform with project specifications and dimensions.

ii. Typical dimensions for an anchor trench are 0.6 m (2 ft) deep and wide with a minimum runout distance from the slope create to the anchor trench of 1.0 m (3 ft). The FGI anchor trench design calculator can be downloaded free using the following link: https://www.fabricatedgeomembrane.com/protected/anchor-trench-calculator. This calculator can be used to calculate either the required runout distance or depth and width of the anchor trench.

iii. Unroll and/or unfold the fabricated panel into the area to be covered starting at the highest point. The upper portion of the panel should be placed in the anchor trench and ballasted (see **Figure 9**).

iv. The anchor trench should be free of rocks, stones, sticks, roots, sharp objects, or residues of any kind that could damage the geomembrane. The anchor trench shown in **Figure 10** is not acceptable or protected from the rocky subgrade material.

v. To protect the geomembrane against damage at the edge of the anchor trench (see yellow arrow in **Figure 8**), a sacrificial piece of similar geomembrane or geotextile may be needed UNDER the geomembrane at the edge of the anchor trench and at the change in slope. The decision to place a cushion geomembrane or geotextiles under and/or above the geomembrane is a design decision. If the designer decides not to place a cushion geomembrane or geotextile the geomembrane can be damaged because the salt in the existing ground is hard with the strength of concrete and can have sharp edges.

vi. Because of the extreme temperatures and Ultraviolet Radiation (UV), a sacrificial piece of

geomembrane or geotextile may be needed OVER the geomembrane from the anchor trench down the slope until the geomembrane panel will always be covered by liquid or solid to reduce UV exposure. This must conform with project specifications and dimensions.

vii. After all geosynthetics have been placed in the anchor trench, the trench should be backfilled with material that conforms with project specifications, properties, and is rock and object free.

Figure 9. Upper edge of deployed panel inserted and ballasted in anchor trench.

Figure 10. Excavated anchor trench in rocky material prior to geomembrane placement.

10. Field Welding of Panels

This section presents best practices for field welding of the geomembrane panels. These activities and practices should be performed before starting to weld the panels:

i. The surface of the geomembrane panels that are to be welded must be completely dry and clean. If the welder operator cannot completely dry and/or clean the geomembrane surface with a cloth, they must notify the inspector and request a decision on how to proceed.

ii. The welder operator should completely clean the hot wedge area and the pressure rollers. If a hot air welding machine is used, the air outlet of the welder should be completely cleaned.

iii. The temperature of the hot wedge should be physically measured by contact thermometer and compared with the temperature indicated on the device readout LED. If the temperatures are not in agreement, this should be documented so the temperature contacting the geomembrane can be determined. In the case of a hot air welding machine, the air outlet temperature and the temperature indicated on the readout LED should be compared. If the temperatures are not in agreement, this should be documented so the temperature contacting the geomembrane can be determined.

iv. Before starting to weld the actual geomembrane panels every day, the welder operator and their machine should make at least two (2) practice welds on similar geomembrane material

that is available for this purpose to ensure consistency. The resulting welds should be tested using a tensiometer to determine if the seam shear strength and peel strength meet project specifications.

v. The unbonded flap of the geomembrane seams should be in the same direction as the wind (see **Figure 6**).

vi. At noon or a hotter time during the day, the welder operator and their machine should make at least two (2) practice welds on similar geomembrane material that is available to set new welder conditions because the geomembrane is softer due to the higher temperature than at the start of welding.

vii. Before starting to weld the actual geomembrane panels every day, the welder operator should have available on the project site a repair kit recommended by the machine manufacturer.

viii. Before starting to weld the actual geomembrane panels every day, the welder operator should have available adequate electricity for welding and compress air for testing in all areas where the geomembrane panels are to be placed.

ix. All welds must pass an air test. If an air channel is created during the welding process, i.e., a dual-track weld, an air channel test should be performed in accordance with ASTM D7177. If a single-track weld is used, an air lance test should be performed in accordance with ASTM D4437.

x. If the owner/client is going to use a "spark-test" to verify field welds, the maximum voltage that will be used because excessive voltage can damage the geomembrane and result in holes. The maximum voltage should be conveyed to the geomembrane manufacturer and fabricator to make sure it will not damage the geomembrane before testing.

xi. For all field welds, the panel numbers or identification information should be recorded for the panels being welded together, welding machine number, welder operator, date and time of the welding, and weathering conditions.

xii. If a field weld involves three of more panels, a patch must be placed and sealed above the field weld to ensure containment.

xiii. Procedures for repairing non-passing welds and any defects or holes must be determined by the owner and installer to avoid problems during field welding. The benefit of using factory fabricated panels is the amount of field welding is small so the potential for problems is small compared to a completely field welded geomembrane.

Figure 11 shows a completed liner system after deployment and field welding of geomembrane panels for an evaporation pond in a desert environment. This photograph shows the intimate contact, i.e., few wrinkles, between the geomembrane and subgrade due to the geomembrane flexibility. This will minimize

leakage if a geomembrane defect is present. The left side of the geomembrane is in the backfilled anchor trench with a worker checking the edge of the geomembrane.

Figure 11. Completed liner system after deployment and field welding of geomembrane panels in desert environment.

11. References

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