

BENEFITS AND COST ADVANTAGES OF FABRICATED GEOMEMBRANES

Timothy D. Stark¹, Gary Kolbasuk², Stanford Slifer³, Duff Simbeck⁴, and Jeremiah Boorsma⁵

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Some geomembranes are flexible enough that they can be factory seamed into large panels, folded, transported, unfolded without creasing or damage, and field seamed and tested as necessary. These geomembranes are relatively thin, flexible, and are mainly produced by calendaring, lamination, and extrusion manufacturing processes. In short, calendaring uses a series of hard pressure rollers to form a thin sheet of plastic material, e.g., a geomembrane. Lamination involves constructing a geomembrane by uniting two or more layers of material, e.g., two plastic sheets with a fabric or scrim in the middle. Extrusion manufacturing is a process used to create a thin plastic sheet by forcing heated plastic through a die of the desired thickness.

If the geomembrane is not flexible, folding can crease the geomembrane which can result in a weakness that can be the location of possible cracking and/or accelerated aging. Figure 1 shows a factory seamed geomembrane being folded on a wooded pallet after factory seaming individual geomembrane rolls. Fabricated geomembranes can be accordion folded as shown in Figure 2(a) or rolled up to facilitate deployment and reduce double folds as shown in Figure 2(b).

Geomembranes that can be factory fabricated and folded reduce field seaming, installation time, cost, field testing and patching, thus improve overall quality. In addition, revised field testing procedures, e.g., air-channel testing (Stark et al., 2004), can reduce the number of destructive samples

¹ Professor of Civil and Environmental Engineering, University of Illinois, 205 N. Mathews Ave., Urbana, IL 61801, 217-333-7394, e-mail: tstark@illinois.edu

² Senior Product Development Engineer, Raven Industries, P.O. Box5107, Sioux Falls, SD57117, e-mail: gary.kolbasuk@ravenind.com

³ President, Watersaver, 5870 E. 56th Ave., Commerce City, CO 80022, e-mail: stan.slifer@watersaver.com

⁴ President, Simbeck and Associates, 38256 Highway 160, Mancos, CO 81238, e-mail: jsimbeck@velocitynetdsl.com

⁵ Project Manager, AccuGeo Liner Company, 321 Industrial St., Bakersfield, CA 93307, email: accugeo@aol.com

that are cut from the completed liner, saving time and cost. This can result in a completed liner that has fewer destructive samples and patches than a field assembled geomembrane liner. The reduction of installation time and testing is particularly important in harsh environments which can extend the “field installation season”. The installation season can be especially extended for projects in which the fabricated liner is large enough to line the entire area without having to perform any field seaming. These “drop-in” liners are less expensive than field assembled liners, have no patches due to field destructive sampling, and all of the seams are constructed in a clean and controlled environment.

Fabricated geomembranes also allow a more modular construction approach. In other words, the liner system is a module that is simply installed using several panels or modules and field seamed to create the desired containment system. Modular construction results in less resources having to be committed to one location for an extended period, e.g., deployment, welding, and testing equipment. Modular construction also adds more predictability to a project by reducing weather, transportation, site access, testing and data interpretation, and labor issues.

Figure 3 shows a fabricated geomembrane being unfolded and deployed while the first deployed geomembrane panel is ballasted in the background. The quick deployment of prefabricated panels allows large areas of the prepared subgrade to be covered quickly to prevent degradation due to weather and installation operations. Quick deployment of the prefabricated panels also allows large areas of a geosynthetic clay liner (GCL) to be covered quickly to prevent or limit premature hydration of the bentonite which can render the GCL unsuitable because of low shear strength and high compressibility of the hydrated bentonite. Commonly after completing only one field seam between two factory-fabricated panels, the area covered exceeds one acre in a short period of time.

The size of the fabricated panel is usually limited by shipping constraints. It is common to ship panels that weigh 1,816 kg (4,000 lbs) but panels as heavy as about 2,724 kg (6,000 lbs) have been frequently shipped (Stark et al., 2006). For rare applications and/or sites, panels as heavy as 4,086 kg (9,000 lbs) have been fabricated and shipped. Panels that weigh 2,724 kg (6,000 lbs) have areas that vary with the thickness of the geomembrane as shown in Table 1. For example, a 40 mil LLDPE geomembrane can be fabricated into panels that weigh 2,724 kg (6,000 lbs), have an area of 2,950m² (30,770 ft²), and dimensions of about 46.0m*62.5m/(150 ft*205 ft).



Figure 1 – Folding of 30 mil factory fabricated geomembrane panels



(a)



(b)

Figure 2 – Folded and rolled fabricated geomembranes



Figure 3 – Fabricated geomembrane panels being unfolded and deployed

Table 1 – Typical fabricated geomembrane panel areas and dimensions for a 2,724 kg (6,000 lbs) panel weight

<u>Geomembrane Material and Thickness</u>	<u>Weight per Area</u> <u>((Mg/m²)/(lbs/ft²))</u>	<u>Panel Area</u> <u>(m²/ft²)</u>	<u>Panel Dimensions</u> <u>(m/ft)</u>
40 mil LLDPE	0.95/0.195	2,950/30,770	45.8m*62.5m/ (150'*205')
30 mil PVC	0.92/0.189	2,955/31,745	45.8m*64.1m/ (150'*210')
30 mil Ethylene Interpolymer Alloy (EIA)	1.07/0.22	2,535/27,270	45.8m*54.9m/ (150'*180')
36 mil Reinforced Polypropylene	0.81/0.165	3,385/36,360	54.961.0180'*200'

Factory v. Field Seaming

Seaming of fabricated geomembranes is usually accomplished using thermal fusion for production seams and solvent or hand-held thermal equipment for patching depending on the type of geomembrane. Factory prepared seams are usually more consistent than field seams because of the problems that can develop with field seaming, such as wind, dirt, precipitation, temperature fluctuations, variable clouds, crew changes, subgrade conditions, etc. Factory seams result in fewer failed destructive tests and less patching because they exhibit more consistent shear and peel strengths. This results in a better completed liner because patches to repair locations where destructive samples were taken are difficult to make as good or leak free as the primary weld that was cut out for testing. Because of the consistent quality of factory seams, a lower testing frequency is recommended for factory seams than field seams, e.g., one per 153 m (500 feet) lineal feet for field seams, of a thermally welded seam. For example, the Fabricated Geomembrane Institute (www.fabricatedgeomembrane.com) prepared a guideline on testing frequency for factory seams which specifies the following requirements for qualification and production factory seams:

- **Pre- and Post-Qualification Seam Testing**

Trial seams shall be at least 2 m (6 ft) long using the same equipment, operator, and conditions anticipated during production welding. Trial seams will be tested in both shear and peel strength using either ASTM D 6392 (heat welded) or ASTM D 6214 (chemical welded).

- **Production Seam Testing**

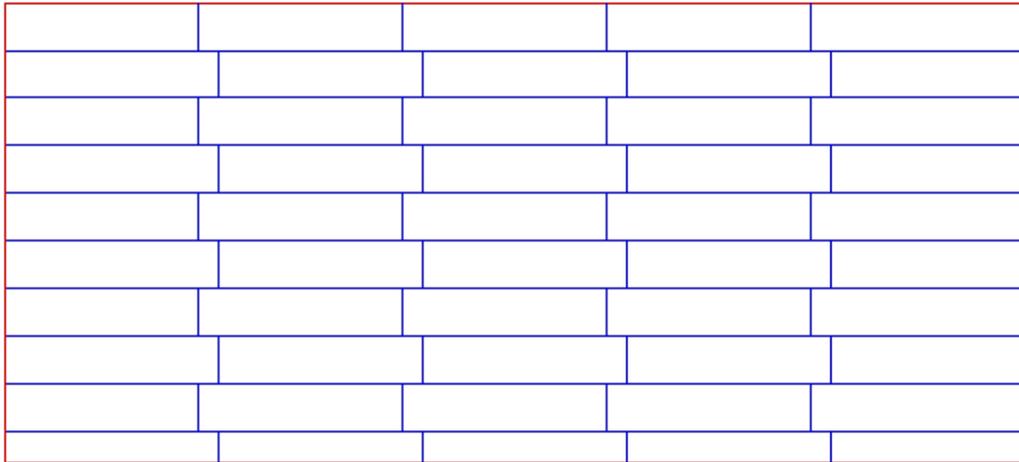
During production the testing frequency is once every shift change or every 4 hours of production, whichever is more frequent. Trial seams shall be at least 2 m (6 ft) long using the same equipment, operator, and conditions anticipated during production welding. Trial seams will be tested in both shear and peel strength using either ASTM D 6392 (heat welded) or ASTM D 6214 (chemical welded).

Review of the above factory seam testing frequency guideline reveals that a destructive sample from the middle of a production panel is not required. The rationale for this is that years of experience factory fabrication has shown that factory seams are more consistent than field seams probably due to the controlled, clean, favorable, and constant welding conditions in the factory. This allows welding equipment and settings to be used before and after seaming instead of during welding because the conditions are not changing significantly. As a result, the pre and post production seams are of similar

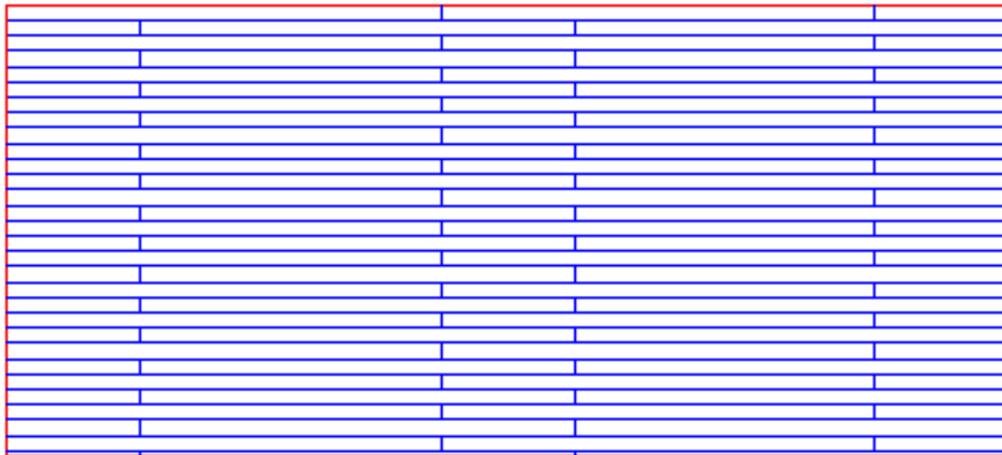
quality as the production panel seams which obviates the need to destructively sample the middle portion of the factory panels.

In a given liner area, the quantity of field seams required for a fabricated geomembrane may be up to 80% less than that required for a field assembled geomembrane. This reduces the potential problems associated with field seaming and the cost and duration of field installation. The panel layout diagrams in Figure 4 for a typical pond liner illustrate the reduction in field seams for factory fabricated panels. The pond area corresponds to 94,187.8 square meters (23.3 acres). Figure 4 shows that 50 panels of roughly 21.3 m x 91.5 m (70 ft x 300 ft) 30 mil factory fabricated geomembrane is required to cover the required 458.0 m x 205.7 m (1,500 ft x 675 ft) pond area. Alternatively, 75 rolls of 40 mil field assembled geomembrane with a standard width and length of 7.0 m and 198.2 m length (23 ft x 650 ft), respectively, are required to cover the 457.5 m x 205.9 m (1,500 ft x 675 ft) pond area. This results in about 65% less field seaming for the factory fabricated geomembrane than the field assembled geomembrane.

Fabricated geomembranes are especially advantageous for smaller projects because the field work can usually be completed in one day. For example, a 0.81 hectares (2 acre) pond can be completely installed (with 2 to 3 field seams), tested, patched, and certified in one day. The savings on a small project include a smaller crew being required compared to a field assembled geomembrane, which equals a smaller mobilization cost, less equipment, and less detail work because the panels are formed to model the area that is to be lined than is required for a field assembled geomembrane project. Generally a field assembled geomembrane will require a second day of work to complete the testing and detail work. Thus, smaller projects tend to accentuate the advantages of fabricated geomembranes compared to field assembled geomembranes.



(a)



(b)

Figure 4 – Possible layout for (a) 30 mil factory fabricated geomembrane panels and (b) 40 mil field assembled geomembrane rolls for a 457.5 m x 205.9 m (1,500 ft x 675 ft) pond area.

Estimated Installation Cost

The following project illustrates the difference in installation costs for factory fabricated material versus field assembled geomembranes. In general, field assembled geomembrane material is frequently the same or less expensive than geomembranes that can be fabricated. However, the installed cost is usually higher for field assembled geomembranes because of the greater installation time and field testing costs. This is illustrated using a 610,000 square meter (two million square foot) canal liner (see Figure 5) near San Lucas, California. The pricing was developed for the canal that has

a width and length of 14.6 m (48 feet) 10.7 km (6.3 miles), respectively. The canal sideslopes are 4H:1V. The two products considered for the project are a factory fabricated 30 mil reinforced LLDPE geomembrane and a field assembled 40 mil unreinforced HDPE geomembrane but other materials could have been used. This project is only used to illustrate the relative installed costs and not for current pricing of these materials. By utilizing a fabricated geomembrane for this project, the end user was able to save approximately \$0.13 per square meter (\$0.04 cents per square foot) because of the reduced length of field seaming and subsequent reduced number of days on the project for the Installation Contractor. The costs are based on 40 mil geomembrane rolls that are 6.9 m (22.5 feet) in width which would have required 21,804 lineal meters (71,488 lineal feet) of field seams. This large amount of field seaming would increase exposure of the project to weather and require that all seams be made in the canal prism exposing the seams to dirt, water, and other contaminants.



Figure 5 – Canal lined with a factory fabricated geomembrane

The fabricated geomembrane panels were assumed to be delivered to the project in custom sized panels fabricated for the variable dimensions of the canal. The canal dimension is 14.6 m (48 ft) wide which necessitated a 17.4 m (57 ft) wide by 91.5 m (300 ft) long panel. By utilizing this custom panel size, the field seams for the project totaled only about 1,617 lineal meters (5,300 lineal feet). With this reduction in the quantity of field seams, the overall cost for installation, which does not include the

material cost difference between the 30 mil and 40 mil geomembranes being considered, was about \$100,000 less for installation of the fabricated geomembrane option. More importantly, the challenging geometry of the canal, see “S” turn in Figure 5, was easily accommodated using prefabricated panels instead of having to line the turns with partial rolls of rolled material.

Estimated CQA/CQC Cost

The following project illustrates the difference in CQA/CQC costs required for factory fabricated material versus a field assembled geomembrane. This project involves a 305,000 square meter (one million square foot) MSW landfill final cover system in the Midwest. Table 2 presents a comparison of the field seam lengths for this project. A large cost saving was derived using a fabricated geomembrane via the reduction of third party Construction Quality Assurance (CQA) and Construction Quality Control (CQC) costs. Only 10 destructive seam tests are required for the factory fabricated geomembrane based on the traditional field destructive seam test frequency of one every 152.5 m (500 lineal feet) of field seam and a field seam length of 4,697 lineal meters (15,400 lineal feet) (see Table 3). It is anticipated that 95 destructive seam tests would be required for the factory fabricated geomembrane based on the traditional field destructive seam test frequency of one every 152.5 m (500 lineal feet) of field seam and a field seam length of 4,697 lineal meters (15,400 lineal feet).

The total CQA/CQC cost for the factory fabricated geomembrane landfill cover is \$9,990 (Table 3) versus \$25,350 (Table 4) for the field assembled geomembrane which is about a 60% reduction. The increased CQA/CQC cost for the field assembled geomembrane is mainly due to the greater number of days required for the additional destructive field seam tests and time associated with the accompanying patching.

Table 2 – Installation details and field seam lengths for 305,000 square meter (one million square foot) landfill final cover

	<u>Fabricated</u>	<u>Field Assembly</u>
Installation	23 panels	29 rolls
Field Seam Length	4,697 lineal meters (15,400 lineal feet)	14,274 lineal meters (46,800 lineal feet)

Table 3 – Factory Fabricated Geomembrane Third Party CQA/CQC

	<u>Quantity</u>	<u>Unit Price</u>	<u>Total Cost</u>
Destructive Seam Tests	30 Tests	\$30/each	\$ 900
3rd Party Site Inspection	6 days	\$1,500/day	\$ 9,000

Total Factory Fabricated Geomembrane QA/QC Costs = \$9,990

Table 4 – Field Assembled Geomembrane Third Party QA/QC

	<u>Quantity</u>	<u>Unit Price</u>	<u>Total Cost</u>
Destructive Seam Tests	95 Tests	\$30/each	\$ 2,850
3rd Party Site Inspection	15 days	\$1,500/day	\$22,500

Total Field Assembled Geomembrane QA/QC Costs = \$25,350

Uses of Factory Fabricated Geomembranes

Because fabricated geomembranes are flexible, installed quickly, can be resistant to UV exposure and hydrocarbons, etc., they can be used for a variety of challenging projects. Table 5 below provides a summary of the range of applications in which fabricated geomembranes can be used.

Summary

The use of fabricated geomembranes can facilitate installation of a containment system, closure cell, final cover system, sports turf barrier, floating cover, e.g., over a leachate pond to reduce precipitation and leachate volume, pond liners, e.g., stormwater or leachate, and gas collection systems because of the large reduction in field seams and installation time. In addition, the use of prefabricated panels and fewer field seams results in the liners being completed with fewer destructive sample patches than if geomembrane rolls of 7 m width are used.

Fabricated geomembranes also result in lower installation and CQA/CQC costs because of the use of large factory fabricated panels that reduce the amount of field personnel time and excavation contractor costs. Finally, fabricated geomembranes have more consistent seams than field assembled geomembranes because the majority of the seams are created in a controlled temperature, cleaner, and low moisture environment, and fewer field seams result in fewer destructive samples and fewer potential leak paths.

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Table 5 – Geomembranes most commonly found in these applications

Geomembrane Type	Aquaculture	Baffle Curtain	Canals	Decorative Ponds	Golf Course Lakes	Harsh Environments	Irrigation Reservoirs	Landfill Covers	Landfill Liners	Mine Tailing Ponds	Hydrocarbon	Fertilizer Containment	Sewage Lagoons	Sports Field Under Liner	Tank Liners	UV-Stable Liners	Wastewater Lagoons
EPDM	X	X	X	X	X		X					X				X	X
Ethylene Interpolymer Alloy		X				X		X	X	X	X	X			X	X	
HDPE	X		X		X	X	X	X	X	X	X	X	X			X	X
Hypalon – CSPE	X	X	X			X	X									X	X
LLDPE	X		X	X	X	X	X	X		X	X		X	X		X	X
PVC	X		X	X	X		X	X	X	X		X	X	X	X		X
Reinforced LLDPE	X	X	X	X	X	X	X	X		X	X	X	X		X	X	X
Reinforced PP	X	X	X		X		X	X				X	X		X	X	X