Concrete vs. Membrane: What's Best for Liquid Containment

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WHITEPAPER

When considering options for primary and secondary containment in the storage of water, fuels and industrial liquids, the design engineer may consider several options. This paper will compare and contrast the use of concrete with Reinforced Flexible Membrane Liners (rFMLs) in providing for liquid containment. Data is available from extensive studies completed by a variety of agencies and individuals dating back to 1984 (see appendix). Applications for consideration include: canals, secondary containment for fuel and industrial chemical storage, impoundments for storm water, water treatment facilities, and industrial process water.

Concrete, as a choice, provides several advantages. It is resistant to the elemental forces of nature including UV light, precipitation and variations in temperature. Concrete can provide a stable working platform resistant to traffic forces from heavy equipment used in operations and maintenance. Concrete also offers the advantage of being durable. In a study completed by Swihart and Haynes[1] for the Bureau of Reclamation, it was concluded that concrete containment systems could last as long as 40 to 60 years (page 203, Table 18, Canal Lining Demonstration Project, November 2002).

Concrete, however, falls short in its most important function as a containment system: it leaks. In the same study by Swihart and Haynes, it was found that concrete is only 70 percent effective as a containment medium. In a similar study completed by Korulla and Khan[2] (Geomembrane in Canals, Project Monitor, Minimol Korulla & Shabana Khan, May 2011) it was found that concrete containments can experience leakage rates as high as 30 percent. The leakage is primarily a function of cracking and inadequately treated expansion joints. Many agencies require that not just concrete joints but entire concrete surfaces be sealed. The federal guideline, UFC 3-460-01, for example in secondary containment for fuel storage, requires that entire concrete storage areas be sealed with UV-resistant, fuel-resistant coatings (UFC 3-460-01, 8/2010, pg. 146). Even with the sealant provision, the UFC 3-460-01 guideline requires a geomembrane to be used in conjunction with concrete in secondary containment applications.

Concrete is also subject to soil considerations in containment designs. Because it is a rigid medium, care must be taken to assure that subgrade conditions are acceptable. Expansive and chemically aggressive soils must be taken into account in concrete containment designs. Remediating poor soils prior to construction of concrete can add to project costs. Finally, concrete is an expensive option in any case. Prices for typical 4" reinforced concrete sections range from $6.00 to $7.00 per square foot installed (typical USACE cost).

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Reinforced Flexible Membrane Liners

Reinforced Flexible Membrane Liners (rFMLs) provide solutions that overcome the challenges presented by concrete in containment applications. rFMLs are relatively thin sheets of flexible thermoplastic polymeric materials reinforced with high-tenacity fabric. There are a variety of polymers used in the manufacturing of rFMLs (Figure 1) each with a variety of performance characteristics that provide an array of options for use on a site-by-site basis. A brief description of each is included in Figure 1.

Figure 1: Commonly Used Geomembrane Polymers

Polymer Type	Strengths	Limitations
Ethylene Interpolymer Alloy: reinforced (EIA-R)	• Chemical Resistance • UV Resistance • Flex Fatigue Resistance	• Aromatic Compounds in High Concentrations
Flexible Polypropylene: reinforced (fPP-R)	**UV Resistance**	**Chemical Resistance**
Chlorosulfonated polyethylene: reinforced (CSPE-R)	• UV Resistance • Flex Fatigue Resistance	• Chemical Resistance • Not Easily Repaired
Polyvinyl Chloride: reinforced (PVC-R)	• Durable when buried	• Chemical Resistance • UV Resistance • Flex Fatigue Resistance • Low Strength

A rFML installation is much quicker than concrete installation. rFML installers cite an average of **six acres of material installed per day!** To begin with, rFML sheets are factory fabricated into custom panels unique to each jobsite. Custom panels can be as large as 20,000 square feet. Factory fabrication of rFMLs results in two benefits:

- Field seams are minimized and replaced by much more reliable factory seams
- Construction speed is increased as the large panels can easily be deployed (Pictures 1a & 1b)

Picture 1a

Picture 1b

The individual panels are then heat-welded together. Welding is accomplished using either hot air welders (Picture 2a) or wedge welders (Picture 2b). rFML installation companies perform the installation and welding with trained crews. The liner installation companies are typically pre-certified as approved installers by the rFML manufacturers.

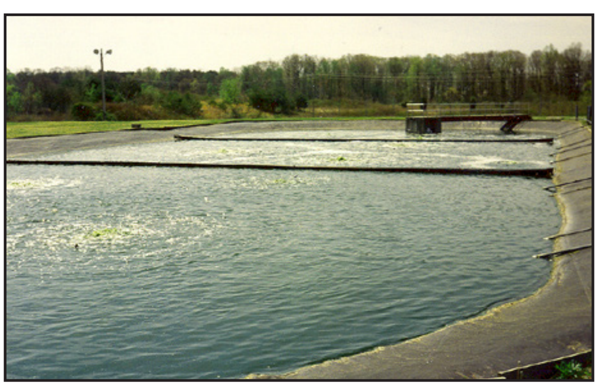
Picture 2a

Picture 2b

Field seams are tested destructively and non-destructively per project specifications. Destructive testing involves cutting test coupons of the seams periodically and testing weld integrity in a field tensiometer (see Fabricated Geomembrane Institute Guidelines). Non-destructive testing methods include air-lance and vacuum-box techniques (Picture 3).

Properly installed rFMLs will provide decades of reliable service. In the Swihart and Haynes study, cited above, it was concluded that rFMLs (geomembranes) can provide 10 to 25 years of service life. Anecdotal evidence supports this service life expectation. For example, at the Great Onyx Job Corps Center, located on the grounds of Mammoth Cave National Park in Kentucky, an rFML was used to line an aeration pond for the facility's wastewater treatment plant. The installation was completed in 1984 (Picture 4a). The pond is exposed to year-around sunshine and ambient temperatures ranging from below freezing to greater than 100˚F. In a recent site visit, the facility manager stated that the liner continues to perform well and shows no sign of deterioration (Picture 4b).

Picture 3



Picture 4a

Picture 4b

In 1991, the Pacific Division of The Naval Facilities Engineering Command in Pearl Harbor, Hawaii performed a value engineering study[3] (Oil Spill Prevention Facilities P-072 Value Engineering Report, 11/8/91). The report concluded that the Navy would benefit by using an rFML in place of concrete as a secondary containment liner in the bermed tank farm (Picture 5). The rFML continues to perform well 24 years after the initial installation.


Picture 5

Cost Advantages

The Pearl Harbor report further stated that the Navy would save $1,690,000 (1991 dollars) by using an rFML in place of a concrete liner. The savings were to be realized in the initial cost of the liner, the maintenance costs, and the anticipated replacement costs.

Again, lower cost is another advantage that rFMLs offer against concrete in liner applications. Installed rFML costs range from $.50/sf to $1.75/sf depending on the nature of the polymer type required and the complexity of the job site. This compares favorably with concrete at $6.00/sf to $7.00/sf for a 4" reinforced section as in most secondary containment applications. Concrete costs rise with the addition of sealants.

Subgrade Considerations

The use of rFMLs also minimizes the need to consider subgrade conditions in containment designs. Because they are flexible, they are able to accommodate expansion in clayey soils. Soft subgrades are also less of a concern with rFMLs because liners are able to accommodate soil deformations. Freeze/thaw dynamics have little influence on rFMLs. This was one consideration driving the Bureau of Reclamation's decision to choose an rFML over concrete to line a canal in Horseshoe Bend, Idaho (Picture 6).


Picture 6

The presence of sulfates in subgrades can also be a cause of concern when using concrete. This is especially true of applications involving waste or seawater. Because the polymers used in rFMLs are chemically inert, there is no additional design or expense required when using liners over soils with high sulfate content. Finally, rFMLs have very good mechanical properties and are able to resist puncture and tear. In the Pulau Semakau4 landfill project, off the shore of Singapore, rFMLs were deployed over wet subgrades with large potentials for deformation (Picture 7). This landfill was created by joining three off-shore islands with rock bunds to create a completely enclosed containment area.

Nearly half of the liner used on this project was installed underwater prior to dewatering the site. In another example, for a project in the Dominican Republic, an rFML was deployed over rocky subgrades for the Barcelo Distilleries' process water pond.
The pond was dug by hand with shovels, as was the trench that led to it from the distillery (Picture 8). The rFML liner was deployed over the rough subgrade with no additional protection. Where necessary, rFMLs can lessen concerns regarding subgrade conditions.

Picture 7

Picture 8

Chemical Resistance

Concrete is susceptible to chemical attack from a variety of substances. Degradation from acids, sulfates, and leaching are common concerns. Admixtures can be used to enhance concrete resistance to chemical attack but at added expense. As stated above, the polymers used in rFMLs are generally inert and can be chosen to resist a broad range of chemical environments at no extra cost. The chart below lists some compatibility ratings (Figure 2): rFMLs are frequently chosen over concrete to contain strong acids, caustic substances, hydrocarbons, commercial process chemicals, and more.

Figure 2: Chemical Compatibilities

	EIA-R	fPP-R	CSPE-R	PVC-R
Kerosene	A	C	C	C
Diesel Fuel	A	C	C	C
Acids (General)	A	A	B	A
Naphtha	A	C	B	C
Jet Fuels	A	C	B	C
Saltwater, 160°F	A	A	B	C
Crude Oil	A	C	B	C
Gasoline	B	C	C	C

Environmental Extremes

Like concrete, rFMLs can be used in extremes of weather. Examples can be seen in both very cold climates and very hot climates. Picture 9 shows a rFML being used on a National Science Institute facility in Antarctica:

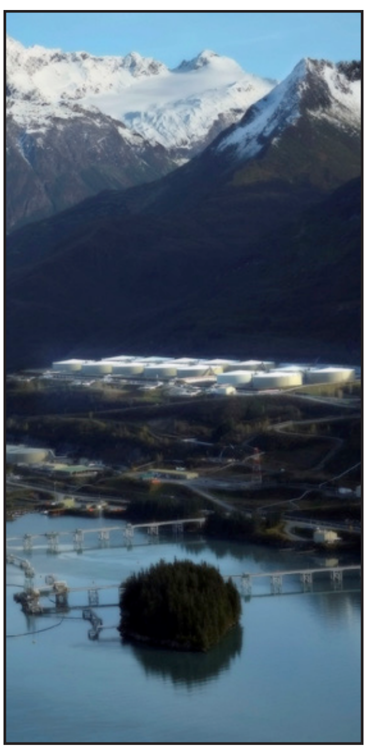
Picture 9

The Lowell Point Wastewater Treatment Plant in Seward, Alaska is another example of an rFML being used in cold weather. In this case, liner is used for an aerated sewage lagoon application (Pictures 10a and 10b). There was concern that the ice forming on top of the pond would abrade or puncture the liner as the primary containment system. Installed in 1991, the liner on this project continues to perform well to this day.

Picture 10a

Picture 10b

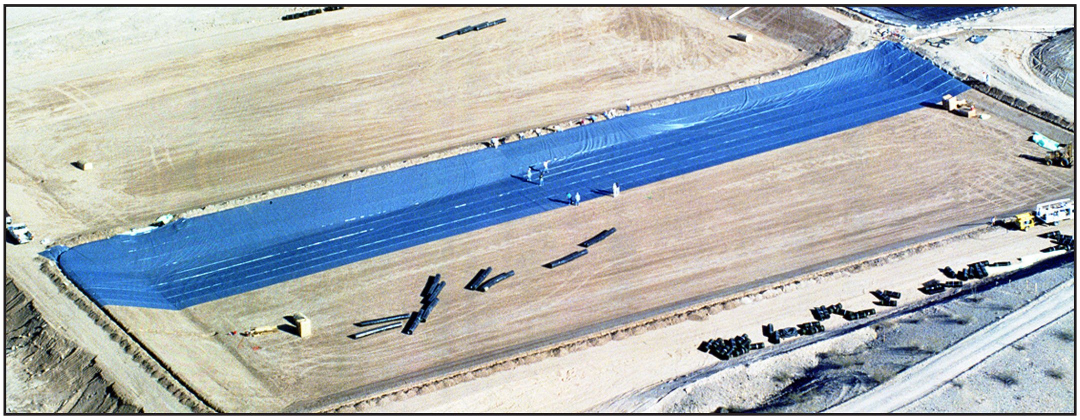
In a third cold weather example, the Alaska Pipeline Service Company (APSC) made use of rFMLs at its Alyeska facility in Valdez, Alaska (Picture 11). APSC stores 7.1 million barrels of crude oil on the site. The wide range of temperatures makes Valdez an environmentally challenging area; the temperature swings range from -30°F to 100°F. Reinforced liners were chosen because of their very low coefficient of thermal expansion. The liner on this project was installed in 1995 and is still in service.



Picture 11

rFMLs have seen use in very hot, UV-intense environments as well. Southern California Gas made use of a liner for the evaporation ponds at their Mohave Desert facility (Picture 12). These lagoons were constructed in 1991 and saw service until the plant was decommissioned in 2006. The original liners provided reliable service for the life of project.

In another heat and UV-intense application, RAI Oil Field Services (an Oil & Gas firm based in UAE) chose an rFML for its use in creating an oily water lagoon for a tank farm in Libya (Picture 13). The ability to fabricate very large panels of material helped the construction process in two ways. First, by making it faster to deploy the material once shipped to the remote site.



Picture 12

Picture 13

Secondly, by reducing the number of field seams required on the site. This again sped installation and reduced the time and number of welding crews required on the job site. rFMLs can be relied upon to deliver containment performance in any climate.

Subsurface Cutoff Walls

Cutoff walls have long been a reliable means of preventing the subsurface migration of contaminated materials. Cementitious or clay slurry products have been the traditional choice for the construction of cutoff walls. rFMLs have gained acceptance as a low-cost, and more effective means of creating a cutoff wall. A chemical manufacturing facility in Grimbergen, Belgium[5] was closed in 1990. The site was purchased by WATCO, a company specializing in the treatment of contaminated soils. Remediation began in 2001. The decision was made to use an rFML in the cutoff wall construction (Picture 14). The site was also capped by an rFML. An added benefit of this approach was that the cutoff wall liner could be welded to the cap liner to completely seal the contained area.

Picture 14

Off-site monitoring wells, piezometers and groundwater levels across the site profile are used to verify the success of the project. To date, the rFML alternative has proved to be a financial and technical improvement over the originally proposed project using other materials.

Conclusion

In conclusion, reinforced flexible membrane liners offer superior performance to concrete in containment applications. rFMLs are less expensive than concrete. The flexibility inherent in rFMLs means they are more easily and quickly transported and deployed than concrete treatments. They require less subgrade preparation and so can be more readily deployed on existing subgrades. They are inert and so inherently more resistant to a broad range of chemicals. They are environmentally stable and, therefore, can be used in a wide range of temperatures while exposed to extreme UV light. rFMLs should be the design engineer's first choice for primary or secondary containment.

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