By Anne Germain, Michael Houlihan, and Gregory Richardson

Exposed geomembrane covers: Part 3 – geomembrane restraint

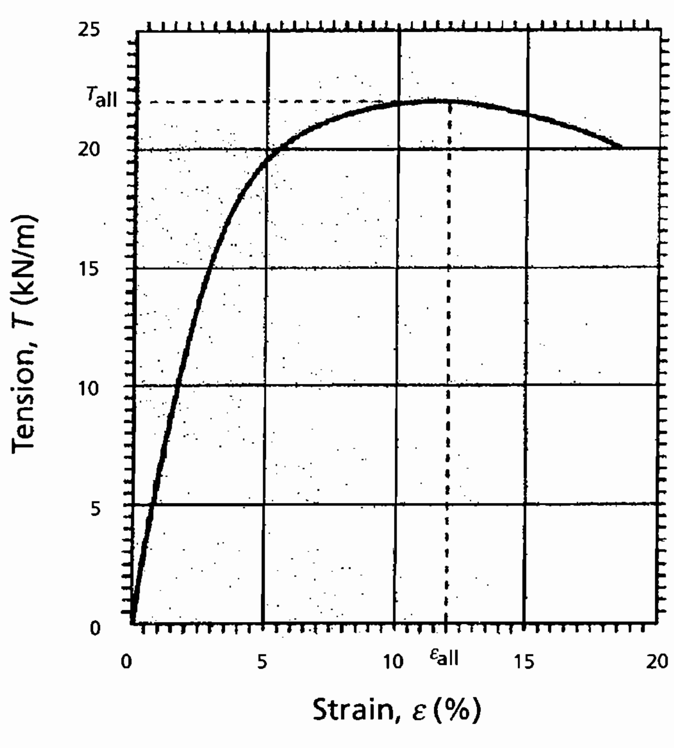
In the previous two Designer's Forums, methods for evaluating wind uplift tensions in geomembrane and anchorage considerations were presented. This final article in the EGC series will review selection criteria for the geomembrane itself. While historically an EGC provided only an interim solution that played no role in the final cover system, the advent of MSW bioreactor technology may view the EGC differently. This article will review the selection of interim EGCs as previously discussed by Chapman et al. (1993), Germain et al. (1996), and Gleason et al. (1998). Additionally, the article will discuss those EGCs that are intended to play a role in the final cover. The article provides no specific geomembrane recommendations, but does provide designers with the methodology to make that selection.

Geomembrane selection criteria

The geomembrane component of an EGC should be selected based on an evaluation of the following criteria:

- Resistance of the geomembrane to environmental factors, including ultraviolet radiation (UV) exposure, temperature extremes, and impact loads
- Resistance to wind-uplift related damage
- Resistance to down-slope creep caused by excessive thermal elongation and material creep
- Acceptable serviceability based on quality of seams and long-term ease of repair
- Compatibility with long-term final closure, if required
- Demonstrated performance history in exposed applications

Figure 1: Tension-strain curve of 40-mil HDPE geomembrane (from: *Geosynthetics International*, vol. 2, no. 6 (1995): p.922).



It is assumed that the selected geomembrane will be commercially available and acceptably priced based on project specific requirements.

Resistance to environmental factors

The geomembrane in an EGC system must not be adversely affected by repeated exposure to temperature extremes, exposure to UV radiation, or damage from common impact loads.

UV Radiation–Data is generally available for most geomembranes regarding UV resistance, based on either Zenon Arc Exposure (ASTM D4355) or Accelerated Weathering of Geomembranes Using a Fluorescent UVA Device (GRI-GM11). Such exposure is followed by OIT (standard or high- pressure) testing (ASTM D5885) and/or strength/elongation testing. The service life of the EGC must be considered when evaluating the required performance. The design exposed life of an EGC in a MSW landfill is usually about 5 to 10 years, whereas an EGC cover used for a mixed waste trench may be 30 years. While the interpretation and application of laboratory weathering data is subjective, an approximate prediction method is available from Hsuan and Koerner (1993). This process is greatly simplified if actual performance history data can be obtained for the geomembranes in question.

Temperature Extremes–In addition to temperature-induced strains, extreme temperatures can significantly impact the strength of many geomembranes. Giroud et al. (1995) presents an excellent discussion of the impact of temperature on the modulus and elongation limits of nonreinforced geomembranes as applicable to wind-uplift design. **Figure** 1 shows the tension-strain curve for a smooth 40-mil (1mm) HDPE geomembrane obtained at 20°C using the ASTM D4885 "Standard Test Method for Determining the Performance Strength of Geomembranes by the Wide Strip Tensile Method." Note that T_{yield} = 20 kN/m and ε_{yield} = 11%. At a temperature of -20°C, T_{yield} = 26 kN/m and ε_{yield} = 8.5%. At a temperature of 40°C,

T_{yield} = 16 kN/m and ε_{yield} = 12%. Since the allowable wind uplift is related to the yield stress (see Part 1 of series), the allowable wind velocity over a given HDPE EGC increases as the temperature decreases.

The combination of temperature extremes and the high thermal expansion of most non-reinforced geomembranes can produce cyclic tension-relaxation of the geomembrane that can lead to environmental stress cracking. The designer should use ASTM D5397 "Evaluation of Stress Crack Resistance of Polyolefin Geomembrane Using Notched Constant Tensile Load Test." The failure time of the polymer should be compared to industry standards. HDPE should have a failure time of more than 600 hours for the single-point test.

Impact Loads–The EGC will be subject to impact loads from hail and various dropped objects during its service life. The week following Thanksgiving generally brings the strange sight of birds dropping turkey carcasses on exposed geomembranes to break up the bones. Seagulls are also very adept at determining new applications for geosynthetics. The ability of a geomembrane to resist cross-plane impact has been studied by Koerner et al. (1986), using the swinging pendulum mass Elmendorf tear test, ASTM D1424. A summary of this test series is also available in Koerner's book *Designing with Geosynthetics*. This test is not commonly performed, so the designer may be limited to using the results of ASTM D4833 "Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products." While this test is not dynamic in nature, it does apply forces across the plane of the geomembrane, and data is readily available for all geomembranes.

Resistance to wind-uplift damage

Part 1 of this series presented equations for calculating the tension in geomembranes under given wind-uplift conditions. The ability of a given geomembrane to resist uplift was related to its tensile stiffness, *J*. The tensile stiffness is defined as the slope of the load-elongation curves as shown on **Figure 1.** In general, fabric-reinforced geomembranes have a high tensile stiffness and therefore are able to resist higher wind speeds.

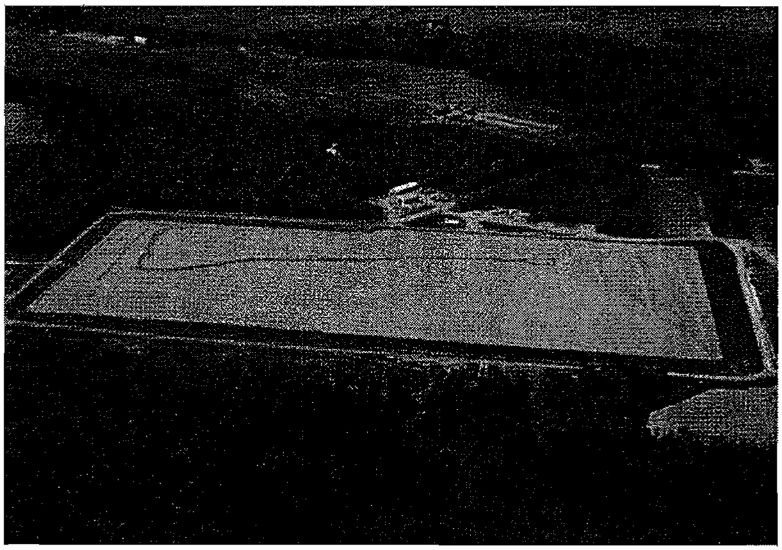


Photo 1: EGC over Cells 1 and 2 of the DSWA's southern facility.

A secondary concern as the geomembrane is tensioned by wind uplift is the tear resistance of the geomembrane at defects. Thus, the tear resistance of non-reinforced geomembranes, as measured by ASTM D1004, should be evaluated as an index to this property.

Resistance to down-slope creep

The combination of gravity and thermal expansion/contraction acting on a geomembrane placed on a slope can lead to down-slope creep movement of the geomembrane. This tendency is reduced with decreased thermal wave action, increased interface friction and geomembrane tensile modulus. Thermally induced waves are minimized by a geomembrane with a light surface color or low bending modulus. Note, however, that lighter colors have lower UV resistance than dark for a given polymer. The combination of high tensile modulus and low bending modulus favors a scrim-reinforced geomembrane. However, such geomembranes may lack adequate seam strength (both shear and peel are important) and interface friction for incorporation into the long-term final closure of many side slopes.

Acceptable serviceability

It is assumed that the EGC will have minor localized damage during its service life. Such damage may consist of minor defects caused by hail or major tears related to excessive wind events for example. The biggest problem for the EGC at the Delaware Solid Waste Authority (DSWA) has been birds picking at the exposed scrim. The geomembrane polymer must lend itself to reliable repair throughout the service life of the EGC. For example, polyolefins such as polyethylene and polypropylene are readily patched with thermal welds. While this does require the service of an experienced welder, most facilities have access to local welders on a daily rental basis. At DSWA, the liner manufacturer trained landfill staff to perform the welds. Training was done during installation, at no cost to DSWA.

Non-polyolefin geomembranes should be evaluated to determine the manufacturer's recommendations for patching aged sheet. If solvent seams are used during initial installation of the geomembrane, verify whether this same solvent will be suitable after years of exposure. Historically, the industry has seen polymers that cross-linked with age so that the suitable "solvent" changed with age.

Compatibility with long-term closure

The long-term function of the geomembrane after its service as an EGC may be a critical factor in the selection of a geomembrane.

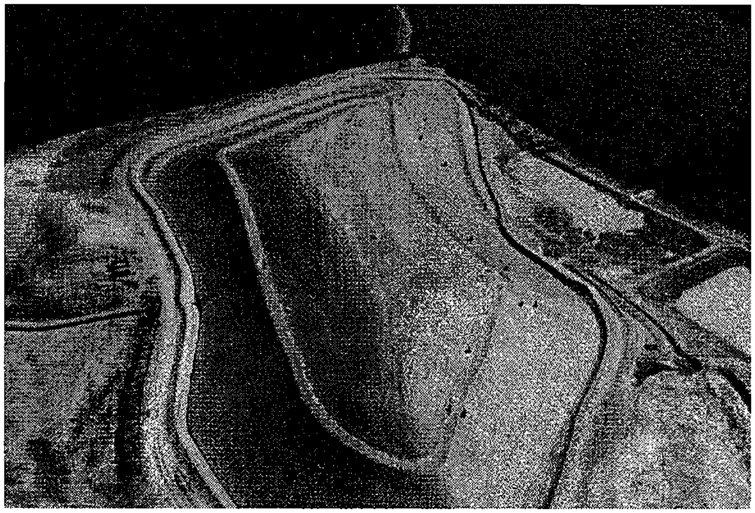


Photo 2: A 16-acre EGC placed over MSW landfill in Louisiana.

Photo 1 shows the EGC placed over Cells 1 and 2 at the DSWA's southern facility. This EGC is placed over 5% to 4H:1V slopes. This EGC will be removed to allow potential mining of the in-place waste and placement of additional waste into the cells. A 0.9 mm green polypropylene geomembrane with a polyester scrim reinforcement was used. In this application, the interface friction required of the geomembrane is defined by the swale anchorage structures (see discussion in Part 2 of this series).

Photo 2 shows a 16-acre EGC placed over a MSW landfill in Louisiana. This EGC benefits from the suction of an active gas collection system to resist wind uplift. The EGC may be incorporated in a conventional final cover system after subsidence of the side slopes has slowed. This means that the interface friction provided by the EGC geomembrane must be adequate to support a lateral drainage system and vegetative layer placed at some time in the future. Because of this need for long-term high interface friction, a 60-mil (1.5mm) textured HDPE geomembrane was used. This particular geomembrane used a coextruded texturing with a green exposed surface face.

Demonstrated performance history

Geomembranes commonly have been used in exposed applications for surface impoundments and floating covers. Such applications provide the designer with a direct analog to the EGC application in terms of geomembrane and seaming survivability. Manufacturers must be encouraged to perform forensic studies of such historic applications to provide the designer with confidence that the EGC will survive. The recent study by Adams and Wagner (2000) is a good example of the type of forensic studies needed. The study verified that no statistically significant change had occurred in the physical properties of a 40-mil smooth black HDPE geomembrane over an 11-year service in a wastewater lagoon. Lacking such studies on a specific geomembrane, the designer should at least verify that the geomembrane being evaluated has been used historically in similar exposed applications. Also, remember that lighter colors of a given polymer have less UV resistance than dark colors of the same polymer.

Summary

Properly selected, an EGC geomembrane can be an integral part of a long-term closure that follows the EGC phase. Each application has unique site characteristics and long-term requirements for the geomembrane. However, it is readily observed that today's commercially-available geomembranes can service most EGC applications. GFR

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