# Geomembrane Interface Friction

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Interface friction angle between a Geomembrane and the adjacent material is a key design parameter in backfilled liner applications. This Tech Note discusses the friction properties of some geomembranes and introduces key design considerations for applications that include a soil cover.

Cover material over a geomembrane liner system can provide protection against ultraviolet degradation, oxidation, wrinkling, wind uplift, mechanical damage, and temperature fluctuations. A thin layer of soil about 0.3 – 1 m thick (1 – 3.3 ft) is typically used as a cover material. If improperly designed, this cover soil may slide down the slope due to its weight or other external factors such as increased pore pressure, mechanical loading, or differential settlement. Minor slides may often require less work and could be repaired by onsite staff, but major slides may lead to unwanted complications that may require high remedial costs.

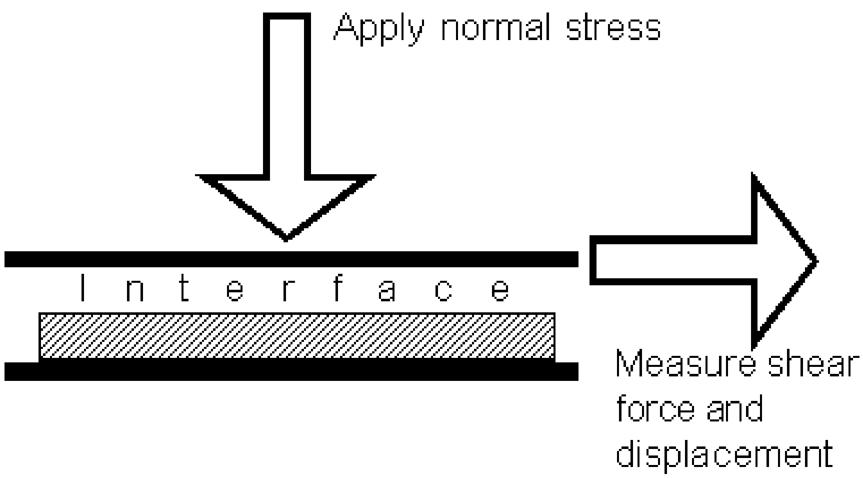


*Figure 1. Schematic showing a Typical Shear Box Test Procedure*

This Tech Note aims to provide some guidance on evaluating soil/geomembrane interface stability. The values used in this Tech Note are not meant to be used for designing a geomembrane-based system. In critical applications, Layfield strongly recommends that proper laboratory testing be carried out along with detailed slope stability assessment to ensure all potential stability issues have been individually and adequately evaluated.

## IMPORTANCE OF A CRITICAL INTERFACE

It is important to recognize the most critical interface when examining slope stability. Often in geomembrane systems, there is more than one interface that needs to be considered. For example, if a geotextile is used to cover a geomembrane prior to placing backfill the designer must consider not only the soil/geomembrane interface but also the geomembrane/geotextile and geotextile/soil veneer interfaces for failure. Each additional geosynthetic layer may introduce up to two interfaces that need independent evaluation.

## STABILITY ISSUES

The following is a list of the most common considerations facing the designer when addressing the stability of a soil veneer cover over a geomembrane liner system:

- cover geometry and anchorage
- geomembrane material
- design slope angle
- drainage conditions

Each consideration is briefly discussed below.

## COVER GEOMETRY AND ANCHORAGE

The geometry of the soil cover over the geomembrane and how it is anchored can also greatly influence stability. Figure 2 shows simplified design curves for a uniform thickness cover soil on membrane lined slopes. It is prominent from the figure that at larger slope angles, the required friction angle between the soil/geosynthetics is very high and often unachievable.

For such slopes, the designer may choose geometries such as a benched slope, a wedge to increase slope stability, or may need to rethink anchoring and ballasting. In most cases, benching or a buttress at the toe of the slope may add to the stability of the soil cover over the geomembrane. For cases where volume optimization is critical such as MSW landfills, out of the box type solutions such as using a GEOWEB® for confinement and retention of aggregates can also be considered.

In all cases, the anchor trench at the top of the slope should be designed to hold the geosynthetic layer (or layers) to a point where its strength is fully mobilized (i.e., at its tensile strength at yield, at supporting scrim break, or at an allowable strain). Refer to the Layfield Design Guide for typical geosynthetic anchor trench geometries.

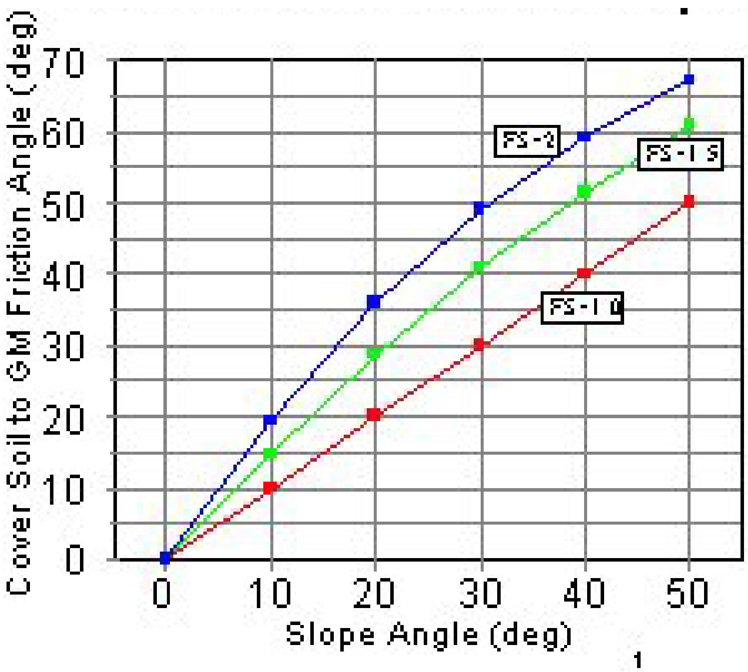


*Figure 2. Design Curves for Uniform Thickness Cover Soils on Membrane Lined Slopes*

## COVER SOIL TYPE

Particle size, moisture content, and transmissivity are three important characteristics to consider when examining the soil to be used against a geomembrane. Also, any angular stone, sticks, or other deleterious material in the soil may result in damage to the geomembrane. Refer to the Layfield Tech Note on Liner Backfill for more information on suitable materials to be used as backfill.

The designer may wish to consider using a reinforcement geosynthetic (such as a geogrid) to provide additional strength in the soil veneer over a geomembrane. Additionally, if drainage is required, a geotextile, porous soil layer, or a geocomposite could be added to minimize pore-water pressure.

## GEOMEMBRANE MATERIAL AND SURFACE TEXTURING

### HDPE and PVC

Table 1 summarizes the study reported by researchers at Syracuse University published by PGI (now FGI) Technical Bulletin in 1997. The study compared the interface friction properties of three different types of PVC geomembranes to two different types of HDPE geomembranes. The study showed that the interface friction properties are dependent on both the soil and geomembrane type.

*Table 1. Interface Friction Angle Values (degrees) for Various Interfaces at Peak and 10% Strain (PGI Technical Bulletin, March 1997)*

| Geomembrane Type (Friction angle at) | Material in Contact with Geomembrane | | | |
|---|---|---|---|---|
| | Fine Sand | Sandy Loam | Silty Clay | Non-Woven Geotextile |
| 30 mil Smooth PVC (10% strain/Peak) | 34.7/34.7 | 26.4/26.4 | 20.8/21.5 | 21.9/11.3 |
| 30 mil Textured PVC (10% strain/Peak) | 35.3/35.3 | 21.1/19.9 | 26.4/22.9 | 19.6/13.2 |
| 30 mil File-finish PVC (10% strain/Peak) | 30.9/30.9 | 28.1/28.1 | 26/27.7 | 17.3/11.4 |
| 60 mil Smooth HDPE (10% strain/Peak) | 21.1/23.6 | 18.2/25.2 | 17.0/25.8 | 14.2/15.1 |
| 60 mil Textured HDPE (10% strain/Peak) | 36.6/36.6 | 33.8/33.8 | 41.8/41.8 | 17.4/17.4 |

The test results in Table 1 show that the friction angle for softer geomembrane, PVC in this example, is higher than the stiffer HDPE material for otherwise similar test conditions. Texturing of the geomembrane surface improved the friction properties for soil covers however remained relatively lower against non-woven geotextiles.

### Layfield's Enviro Liner® (LLDPE)

Table 2 shows the test results with Layfield's Enviro Liner® high-performance geomembrane. The tests were conducted by independent commercial laboratories as per ASTM D5321 (*Standard Test Method for Determining the Shear Strength of Soil-Geosynthetic and Geosynthetic-Geosynthetic Interfaces by Direct Shear).* The soil/geomembrane interface friction was measured with a clayey sand and poorly graded gravel backfill that are typically used as geomembrane cover. A geotextile/geomembrane interface was also tested to evaluate the interface between two geosynthetics (Figure 3).

*Table 2. Interface Strength Properties for EnviroLiner/Soil and EnviroLiner/Geotextile measured as per ASTM D 5321.*

| Geomembrane Type | Disp. (cm) | Interface Strength | | |
|---|---|---|---|---|
| | | GP (USCS) | SC (USCS) | NW Geotextile |
| EL6040 Smooth | 2.5 | C = 19.2 kPa, ϕ = 23.7º | - | - |
| | 7 | C = 39.1 kPa, ϕ = 20º | - | - |
| EL6060 Smooth | 2.5 | C = 31.3 kPa, ϕ = 24.5º | - | - |
| | 7 | C = 38.6 kPa, ϕ = 23.9º | - | - |
| EL6140 Textured | 2.5 | C = 23.8 kPa, ϕ = 23.3º | C = 20 kPa, ϕ = 22.5º | - |
| | 7 | C = 23.8 kPa, ϕ = 24.4º | C = 31.9 kPa, ϕ = 21.6º | - |
| EL6260 Textured | Peak/residual | - | - | 34.5º/22.5º |

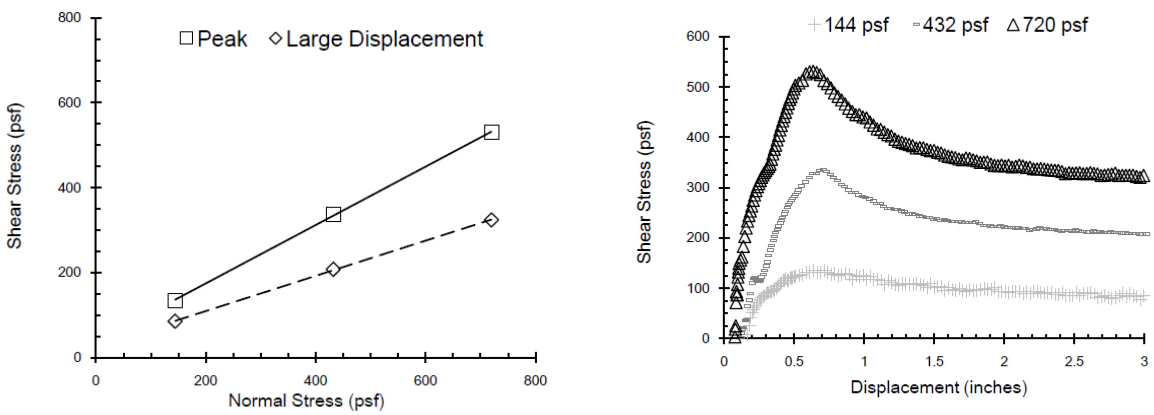


*Table 3. Results from Interface Shear Strength Measurement of Enviroliner 6260 and Non-Woven Geotextile by Direct Shear (according to ASTM D5321).*

Test results shown in Table 1, Table 2, and Figure 3 show that the softer, more flexible smooth PVC and LLDPE geomembranes have higher friction angles compared to stiffer smooth HDPE geomembrane, which can be attributed to:

- the softer material allowing the soil particles to easily embed themselves within the surface of the geomembrane,
- the ability of the more flexible material to better conform along the surface of the overlying and the underlying soil, and
- asperity height of the textured geomembrane.

## DESIGN SLOPE ANGLE

A 4:1 or 14 degrees is the maximum slope that is generally considered to be the most likely slope to maintain the stability of a soil veneer over most geomembranes. There are several archival articles detailing laboratory results of interface friction angles between geomembranes and various other surfaces, including the ones detailed in this technote. However, it is prudent to obtain site specific values through laboratory testing, especially for critical applications.

The designer should also note that geosynthetic properties are often proprietary and are subject to change. Geosynthetic materials generally must maintain a certain minimum specification; however, characteristics such as texturing can vary greatly between manufacturers. Given the variability and uncertainties, the site conditions will dictate stability in all circumstances.

## DRAINAGE CONDITIONS

Once a liquid is introduced to the soil/geomembrane interface, the stability of the soil veneer may be significantly affected. Proper drainage of the soil cover should be considered to ensure maximum performance. Drainage of the soil veneer may be accomplished using a transmissive geotextile, a sand layer, or a geonet such as HydraNet.

Three critical items necessary to consider when examining a drainage layer include (but are not limited to): flow rate (or transmissivity), normal stress over the drainage layer, and the hydraulic gradient along the drainage layer. It is also important to note that if the drainage layer is in intimate contact with the geomembrane, this interface must be examined along with the other interfaces critical to slope stability. A collection system at the base of the slope should also be incorporated into the drainage design, for example, a perforated subdrain at the toe of the slope could act as a header to collect the runoff from the drainage system and safely drain the collected water away from the slope.

## CONSTRUCTION QA/QC AND SEQUENCING

Construction Quality Assurance and Quality Control (QA/QC) and sequencing need to be properly specified and implemented to follow the design assumptions. Refer to the Tech Note on Backfilling Geomembrane and a technical paper by Koerner and Soong (1998) for additional guidance on construction sequencing.

## SIMPLIFIED DESIGN EXAMPLE

**Problem:** What type of cover soil and geomembrane combination would work on a 3H:1V slope using a factor of safety of 1.5?
**Solution:** $\text{Tan}^{-1}$ (1/3) =18.4 deg. Using Figure 2 and interpolating the FS = 1.5 curve to yield a required friction angle of 28 deg. From Table 1 and Table 2, we find that all of the materials would be suitable in this application, but the selection of the material will depend on the material in contact, texturing of the geomembrane, consideration of adhesion in design etc. Additionally, factors such as design life, exposure, construction sequencing, material availability etc. should also be considered.

## LABORATORY TESTING

It has been emphasized before in this Tech Note that the geomembrane friction angles are sensitive to site-specific variables and that laboratory testing is always recommended to identify critical failure plane. It is also important that the designer identifies the field conditions and specifies the test parameters appropriately.

Some site-specific critical testing parameters are as follows:

- geomembrane material type
- type and gradation of the soil
- soil density and moisture content
- moisture condition of the soil during the test
- normal stress to be applied

- strain rate to be applied during shear
- total strain to be evaluated during the test

## AVAILABLE TEST METHODS

There are five test methods available to the designer, they include:

- Direct Shear Box (ASTM D3080),
- Large Scale Shear Box (ASTM D5321),
- Tilt Table (no ASTM standard),
- Torsional Ring Shear Device (no ASTM standard), and
- Double Interface Shear Device (no ASTM standard).

The two most common are the Direct Shear Box test (ASTM D3080) and Large Scale Shear Box test (ASTM D5321).

The decision on which test should be used is left to the design engineer considering site specific conditions. The Direct Shear Box test method has the advantages of being inexpensive, simple, and has a large experience base. The Large-Scale Direct Shear Box (300mm x 300mm box size) test method allows for larger displacements of the interface being tested, which helps to minimize boundary effects experienced in the direct shear, which has a smaller box size (100mm x 100mm). Disadvantages of this test include the fact that the sample changes in area as it is being tested, a correction factor should be applied. Also, this test is usually more expensive than the direct shear.

## YOUR OBLIGATION TO TEST

It is the responsibility of the owner or owner’s representative to determine the suitability of the geomembrane in the environment in which it will be used. Layfield recommends that in all applications where friction angle will be an important part of the design that a test be performed. This test should include the actual subgrade and backfill materials planned for use at the site and the actual geosynthetics proposed for the project. Layfield can assist the designer by providing geosynthetic samples for testing and can recommend suitable testing labs in your area. A typical direct shear box test is usually under $1,000. In relation to the cost of failure, an interface friction test is invaluable. In cases where there are multiple layers of geosynthetics, it is very difficult to predict where the failure plane will occur. Layfield strongly recommends that a friction angle test be performed on all multiple layer geosynthetics projects.

As noted previously, the purpose of this TechNote is to provide guidance on predicting soil/geomembrane interface stability. Since every project is most likely to have a different set of conditions, this TechNote should not be used in the final design of a geomembrane system. In critical applications, proper laboratory testing must be carried out along with detailed analysis to ensure all stability issues have been properly addressed.

Additional manufacturer’s test data can be made available by Layfield. If you have any additional questions on friction angles of geomembranes, please do not hesitate to contact your local representative. Our technical service group can also help you design your next project.

## REFERENCES

*Analysis and Design of Veneer Cover, Dr. R.M. Koerner & T-Y Soong, 1998 Sixth International Conference on Geosynthetics.*

*Soils Designing with Geosynthetics 3rd Edition, Dr. R.M. Koerner, Ph.D., P.E., 1994.*

*PGI Technical Bulletin, March 1997.*

*Interface Friction/Direct Shear Testing & Slope Stability Issues Short Course Notes, Dr. Gilbert & Sam Allan, April 27, 1999, Geosynthetics 1999 Conference, Boston, MA.*

*Layfield archives.*