Why 30 mil PVC is equivalent to 60 mil HDPE

A Discussion of Minimum Geomembrane Thickness

30 mil smooth polyvinyl chloride geomembrane is functionally equivalent to 60 mil textured high density polyethylene. ***F. P. Rohe***

"Minimum thickness" seems to imply that thicker is better… But in reality thickness is only one of many material properties affecting the ultimate performance and durability of any geomembrane. The discussion of minimum thickness focuses on ONE parameter and ignores all others, many of them equally as important factors. Here are some facts for you to consider… Let's explore the following items as they relate to the statement that "30 mil PVC is functionally equivalent to 60 mil HDPE" when it comes to geomembrane containment applications:

1. **Material type**
2. **Slope Stability**
3. **Manufacturing**
4. **Tensile Strength**
5. **Elongation at failure**
6. **Failure at Yield**
7. **Multi-axial Stress – Stress Cracking**
8. **Oxidation**
9. **Welding**
10. **Flexibility**
11. **Chemical Compatibility**
12. **Regulations**

Material:

Polyethylene is a crystalline plastic. PVC is an amorphous plastic. Amorphous means nebulous, fluid, unstructured… that is, it does NOT have a crystalline molecular structure like polyethylene.

This simple difference in the makeup of these two plastics creates significant differences in how they respond to many outside forces and situations in real world geosynthetic applications.

Slope Stability:

It has become the industry standard that on slopes steeper than about 6H/1V it is necessary to use textured HDPE for slope stability because smooth HDPE is unacceptable. This is in comparison to standard, smooth surface PVC geomembrane which is routinely installed on 3H/1V slopes every day. Textured polyethylene liners were originally developed in order to compete with the slope stability characteristics of smooth PVC, much the same as Low Density Polyethylene (LDPE) liners were developed to compete with the flexibility characteristics of PVC.   Smooth PVC geomembranes are inherently able to provide much higher residual friction angles and to provide stability with soils and other geosynthetics on much steeper slopes than smooth HDPE, and in many cases, textured HDPE. Research and individual project testing continues to show that smooth 30 mil PVC geomembrane has an equal or higher residual friction angle than textured 60 mil polyethylene.

Since the industry standard is to use textured HDPE on all slopes, it is only common sense to compare materials that would be used on a 3H/1V slope… that is 60 mil textured HDPE and 30 mil smooth PVC geomembranes.

Manufacturing Thickness Tolerance:

A mil, as used to describe a geomembrane, is defined as 1/1000th of an inch (0.001 inch). The methods of measurement of the thickness of smooth PVC and textured HDPE differ significantly. In order to fully understand this difference, read ASTM D-5199 for smooth geomembranes and ASTM D-5994 for textured geomembranes.

All PVC geomembrane material is manufactured to a thickness tolerance of +/- 5%. This means the minimum thickness of 30 mil PVC anywhere on the sheet cannot be less than 28.5 mils (specification thickness of 0.030 inches, minus 5% - 0.0015 inches = 0.0285 inches). So the thickness of PVC geomembrane can only vary below the minimum thickness a maximum of 1.5 mils measured anywhere on the membrane. For comparison, the clear PVC wrapper on the dry cleaning you picked up recently is about 1 mil thick.

HDPE on the other hand is manufactured to a thickness tolerance of +/- 10% which is measured using minimum average roll value (MARV) methods. This means the minimum thickness of 60 mil textured HDPE should not be less than 54 mils (specification thickness of 0.060 inches, minus 10% -0.006 inches = 0.054 inches) in 8 out of 10 measurements across the roll width. It should be noted that since minimum average roll value is used in calculating the thickness of the HDPE material, it is considered adequate for a thickness measurement of 51 mils (-15%) to be accepted for one or two of the measurements, as long as the minimum average of the measurements is above 0.054 inches.

A typical footnote for HDPE: "The combination of stress concentrations due to coextrusion texture geometry and the small specimen size results in large variation of test results. Therefore these tensile properties are minimum average values." PVC uses minimum values rather than "minimum average" values.

While the minimum thickness of 30 mil PVC is minus 5% (-1.5 mils)(0.0015") the minimum thickness for 60 mil textured HDPE is minus 15% (-9 mils) (0.0090"). PVC maintains much closer control of the thickness of the material in the manufacturing process.

Tensile Strength:

Tensile strength at break for 30 mil smooth PVC is 73 lbs/in (2400 psi). PVC is tested at a speed of 20 inches per minute.

Tensile strength at break for 60 mil textured HDPE is 90 lbs/in (1500 psi). HDPE is tested at a speed of 2 inches per minute.

While the thickness of 30 mil PVC is 50% less, the tensile strength at break is only 18% less than the 60 mil textured HDPE. Doubling the thickness from 30 mil to 60 mil for HDPE provides only slightly higher tensile strength than 30 mil PVC.

Elongation at Break:

The minimum elongation at break for 30 mil smooth PVC geomembrane is 380%.

The minimum elongation at break for 60 mil textured HDPE geomembrane is only 100%.

While the thickness of the HDPE is double that of the PVC, the elongation at break of the 60 mil textured HDPE is 60% lower than the 30 mil PVC.

Polyethylene proponents may quickly point out that SMOOTH HDPE has a minimum elongation at break of 700%... but remember, smooth HDPE is NEVER used on a slope, so the value is not relevant in the comparison of geomembranes in actual use.

Failure at Yield Elongation:

Minimum elongation at break for 30 mil PVC is 380%. PVC does not have a yield point when elongated.

The minimum yield elongation for 60 mil textured HDPE is 12% (GRI GM-13). This is the point at which the HDPE fails.

Since PVC is an amorphous material, it does not have a yield failure point like crystalline materials. PVC is an elastic material. It remains elastic throughout its elongation all the way up to the break point. Therefore, the failure elongation for PVC is the break point, which is 380% for 30 mil PVC.

HDPE is also elastic, but only through elongation up to it's yield point, at about 12%. Then the material becomes plastic. When the yield point is exceeded, HDPE is no longer the same material. It is no longer elastic and changes to a plastic state. Once the HDPE material has elongated beyond the 12% yield point, it can no longer function as a geomembrane.

Engineers can safely design using strain limits two or three times higher by using PVC geomembrane.

Stress Cracking:

Since PVC geomembrane is an amorphous material, it is not subject to environmental stress cracking. Nor does PVC geomembrane stress crack when exposed to multi-axial stresses.

Polyethylene geomembranes are crystalline plastic and ARE subject to environmental stress cracking. The higher the density of the resin, the more likely the sheet is to stress crack.

Stress cracking of HDPE can be compared to the cracking of an automobile windshield. A windshield is installed with a neoprene or rubber gasket around the perimeter to isolate it from the vehicles metal frame, and cushion it from being twisted or subjected to unequal stresses. A minuscule stone chip or tiny scratch is all it takes to initiate a crack in a windshield when a small amount of stress is applied (a bump at the car wash, a sudden change in temperature…). Crystalline plastics like HDPE behave in much the same way.

HDPE geomembrane must not be subjected to unequal stresses in order to minimize stress cracking. An example is that HDPE geomembranes require a neoprene gasket when attaching it to a solid structure such as a concrete wall or steel support. This will hopefully delay cracking of the HDPE material beyond the service life of the installation. PVC on the other hand, is not crystalline, is not subject to stress cracking, so therefore does not require the use of neoprene, rubber, or any other cushioning gasket when attaching PVC to concrete or steel structures.

Polyethylene manufacturers test their material for environmental stress cracking. However it is interesting to read the footnotes. For instance, one typical note: "NCTL for HD Textured is conducted on representative smooth membrane samples". So this means stress crack testing is never actually performed on textured 60 mil HDPE.

Oxidation:

30 mil PVC geomembrane materials do not oxidize on the surface. When repairs are required or when patches are necessitated by removal of destructive samples, welding can be accomplished by simply cleaning the surface of the PVC of any dirt or moisture. Mechanical or chemical preparation is not required. Joining can be done by thermal, chemical or adhesive seaming. Abrading the surface of PVC geomembrane is not required.

In order to thermally join textured 60 mil HDPE panels for repairs it is necessary to remove the surface oxidation from each of the polyethylene sheets before extrusion welding. This process is done using hand held electric grinders using heavy grit sanding disks. Welding specifications limit the amount of surface grinding to a maximum of 10% of the sheet thickness (6 mils in the case of 60 mil textured HDPE). (For comparison, 5 mils is the thickness of a sheet of stationary paper). This means a technician with a hand grinder operating at 1200 rpm using 80 or 100 grit sanding disks is limited to a tolerance of 0.006 inches when grinding the surface of a 51 mil thick textured HDPE liner. (51 mils is the minimum thickness to still be called 60 mil textured HDPE). Considering he never exceeds (?) the 0.006" limit, at the point of each repair weld on a 60 mil textured HDPE liner, the material can be 45 mils thick and still qualify as 60 mil. This is a reduction in thickness of 15 mils, a full 25% of the original thickness. This is compared with the 30 mil PVC with a 5% tolerance of only 1.5 mils.

We believe the EPA was very aware of the welding repair issues when making recommendations concerning the 30 mil minimum for an FML, but increasing the thickness to 60 mil when using polyethylene. Some European countries require minimum 100 mil thickness for HDPE with zero strain allowed.

Welding:

30 mil PVC is now routinely welded using dual track hot air equipment, allowing for air channel testing of all field welds. This process is virtually identical to the process of welding 60 mil textured HDPE. The exception is that 30 mil PVC can also be tested for peel strength along the full length of any field seam using simple, proven air channel methods.

30 mil PVC field welding quality control is actually now superior to that of textured 60 mil HDPE. Coupled with an electronic leak location survey, it is now possible to test the strength and integrity of the entire length of all PVC field welds, and the integrity of the entire surface of a 30 mil PVC liner installation.

Flexibility:

PVC is very flexible due to the addition of plasticizers that make the material ideal for geomembrane applications. Flexibility = Durability. Forensic analysis of PVC in application after application shows that PVC will effectively do the job year after year in buried geosynthetic liquid containment applications.

PVC material has been exhumed by many different researchers, including The Bureau of Reclamation (http://www.usbr.gov/main/index.html).

In addition, continuous research is being done to insure plasticizer retention in PVC geomembranes for many future generations.

Flexibility also impacts how a geomembrane can be affected by folds, wrinkles or waves in the material. Textured 60 mil HDPE requires management of waves and wrinkles during installation to prevent any folds in the material. Folds and wrinkles are not allowed ever in textured 60 mil HDPE. Folds in textured HDPE will cause stress cracking in the material. Forensic analysis has also shown that buried waves in HDPE are likely to remain in place throughout the life of the installation and can serve as conduits for liquid flow above or below an HDPE geomembrane.

30 mil PVC on the other hand is extremely flexible due to its amorphous makeup. Also, PVC has a 60% lower coefficient of thermal expansion (70 x 10^{-6} cm/cm/ºC) than textured HDPE. PVC geomembrane is NOT subject to the formation of waves by changes in ambient temperature during the day as is HDPE. In addition, there has been testing on the effects of folds and wrinkles by the Bureau of Reclamation and forensic analysis of actual exhumed PVC geomembrane material to show conclusively that folds and wrinkles have no adverse effect on the long term durability of 30 mil PVC geomembrane.

Chemical Compatibility:

30 mil PVC geomembrane has been successfully used for many years for waste containment applications, including municipal landfills, waste water treatment,

and animal waste containment. EPA 9090 testing has been performed countless times on PVC geomembrane.

PVC has been proven to perform effectively in applications requiring resistance to a wide range of chemicals, including municipal solid waste landfills, anaerobic waste treatment ponds, and oxidation ponds.

Regulations:

Subtitle D regulations determine the thickness of geomembrane used in waste containment applications in the United States of America.

Many people involved in the business of waste containment believe that US Government regulations require a minimum of 60 mil thick HDPE for a liner in a municipal waste containment application. This is just NOT accurate! The fact is that US Government Subtitle D regulations and all state regulations which use Subtitle D as their guide, require a minimum 30 mil thick flexible membrane liner. This 30 mil liner is used in conjunction with a compacted clay base or some other form of composite liner system. The 30 mil liner can be PVC, CPE, or CSPE. What is true though, is that Subtitle D and all of those individual State Regulations require that if the bottom liner used is polyethylene, then (specifically because it is polyethylene) the HDPE can NOT be 30 mil, but is REQUIRED by REGULATION a to be MINIMUM of 60 mils thick.

The bottom line is that 30 mil PVC has already been approved by Subtitle D regulations. Choosing to use polyethylene requires the use of a minimum of 60 mil thick HDPE.

This is an excerpt from the regulation:

40 CFR Ch. I (7–§ 258.29 1–02 Edition)

Subpart D—Design Criteria

§ 258.40 Design criteria.

(b) For purposes of this section, *composite liner* means a system consisting of two components; the upper component must consist of a minimum 30-mil flexible membrane liner (FML), and the lower component must consist of at least a two-foot layer of compacted soil with a hydraulic conductivity of no more than $1x10^{-7}$ cm/sec. FML components consisting of high density polyethylene (HDPE) shall be at least 60- mil thick.

Conclusion:

30 mil smooth polyvinyl chloride geomembrane is functionally equivalent to 60 mil textured high density polyethylene.

The combination of physical properties possessed by 30 mil PVC geomembrane gives it the performance characteristics that make it functionally equivalent to polyethylene geomembranes that are twice as thick. PVC has proven itself to be an ideal solution for long term containment applications.