

Weathering: Degradation of Geomembranes

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EFFECTS OF WEATHERING

1. Geomembrane Vulnerability

Solar radiation, temperature, precipitation and other environmental contaminants all affect exposed geomembranes.

Ultraviolet radiation is particularly damaging to polymers, which can degrade through a photochemical reaction that works on a molecular level of the composite. The following factors indicate the performance has been jeopardized and the useful life of the polymer at the heart of the geomembrane is depleted, rendering it ineffective.

Initial indicator: Reduction in molecular weight

Implication: Weakens the geomembrane's physical and impact strength

Physical effects:

- Increased elongation
- Increased ductility
- Increased brittleness
- Discoloration
- Cracking
- Crazing
- Chalking

Physical properties reduced:

- Tensile strength
- Tear and puncture resistance

2. Linear Thermal Expansion

The coefficient of linear thermal expansion measures a material by how much it expands for each degree of temperature increase. This is important in design calculations, as the geomembrane will expand and contract throughout its working life, and intense temperature swings may lead to mechanical stress failures. The higher the linear coefficient of thermal expansion of the polymer, the greater the growth and contraction, resulting in potential thinning of the geomembrane.

In applications where the expansion and contraction of the geomembrane is critical, the combination of the lower coefficient of thermal expansion polymer with polyester-reinforced scrim is optimal, because polyester is a dimensionally stable polymer when exposed to heat and moisture. These features can be found in ethylene interpolymer alloy (EIA) geomembranes.

MOST COMMONLY USED GEOMEMBRANES

1. Polyethylene (PE) is a thermoplastic created by the polymerization of ethylene. Based on the branching, molecular weight, crystallinity and density of the polymer, it is classified as high density polyethylene (HDPE), linear low density polyethylene (LLDPE), or low density polyethylene (LDPE).

Threats:

- Temperature changes
- Installation/improper handling
- Overheating during welding
- Concentrated stress and differential in settlement
- Pinched wrinkles or waves in the material (I. Peggs).

HDPE susceptibilities (due to high crystallinity):

- Stress cracking: the result of the deformation of the geomembrane under low stress that causes the platelets of the PE to disentangle
- Environmental stress cracking (ESC): formation of macroscopic cracks that create a route for absorption of stress-cracking agents and moisture, causing the crack to expand. Data suggests that for every 7°C increase in temperature, the crack-growth rate is doubled (Lustiger).

Consideration: PE may have a high chemical resistance to a specific liquid environment, but under polyaxial stress (including stored stresses from extruding or molding), the material will suffer from ESC.

2. Thermoplastic Polyolefin (TPO) is the composite of polypropylene (PP) and ethylene-propylene (EP) rubber, which provides flexibility to the membrane. In the geomembrane market, TPO is typically referred to as polypropylene.

Threats: Ultraviolet light, heat and environmental exposure **Susceptibility:**

- Thermal degradation: molecular deterioration due to overheating
- Photo-oxidation: degradation on the polymer surface in the presence of oxygen

Consideration: Chemical additives help stabilize the polymers at ambient temperatures and inhibit molecular fracture to deter degradation of the membrane. However, degradation of PP in the field can result in degradation and scrim exposure. This leads to failure of the geomembrane as seen in the illustration below:



3. Polyvinyl Chloride (PVC)

Threats: Ultraviolet light, heat and environmental exposure

Susceptibility:

Degradation

Consideration: Chemical additives help stabilize the polymers at ambient temperatures and inhibit molecular fracture to deter degradation of the membrane. However, degradation of PP in the field can result in degradation and scrim exposure. This leads to failure of the geomembrane as seen in the illustration below:



4. Ethylene Interpolymer Alloy (EIA) geomembranes are based on an ethylene terpolymer, Trade-named XR-5®, which exhibits excellent thermal and chemical stability.

Benefits:

- Significantly longer lasting than crystalline products such as HDPE or liquid plasticized products such as PVC
- · Extremely low thermal expansion-contraction properties
- Allows for the use of a heavy reinforcing fabric while maintaining a light overall membrane package
- The reinforcement provides the strength rather than the polymer

The picture below illustrates the durability of the EIA membrane in an exposed application over 28 years:



POLYMER FAILURE

Degradation Process of the Polymer

Photo-oxidation and thermal degradation are significant weathering factors of polymers. The destructive effects of light are usually accelerated at elevated temperatures. The degradation process illustrated below occurs as a result of heat, light and/or oxygen absorbed by the polymer matrix.



The radicals join with polymers on a molecular level, split, continue to generate free radicals, and the reaction of polymer degradation continues. The reaction of different free radicals with each other can occur; polymeric chains react with each other, referred to as cross-linking, resulting in embrittlement of the polymer.

Polymer Stabilization

To ensure long-term performance, the polymer coating must be properly protected from exposure by:

- Blocking or filtering harmful wavelengths so they cannot generate free radicals
- Interfering with the reaction of free radicals if they have already been generated

Pigments such as carbon black, TiO2, or others, can be incorporated into the polymer to block, reflect or absorb UV radiation. UV absorbers such as benzophenones, benzotriazoles, or triazines, preferentially absorb UV radiation to reduce free radical generation.

Light stabilizers, such as hindered amines, phenols and to some extent, carbon black, interfere with the reactions of free radicals that have been generated by UV or high-temperature exposure. UV absorbers are often used in combination with light stabilizers.

In polymers that are susceptible to oxidation at high temperatures, antioxidants are added to prevent polymer degradation, a common problem during the molding and extruding operation. Over time, some additives are vulnerable to environmental degradation.

ARTIFICIAL SIMULATION OF WEATHERING

Artificial weathering gives a correlation of long-term performance of the geomembrane to natural exposures. Typical test procedures expose the geomembrane to a specific amount of energy at various wavelengths, over a specific length of time. Environmental conditions such as freezing and thawing, contaminates, and acid rain are not taken into consideration during testing.

Solar Degradation Testing

- Application
- Methodology: Two artificial light sources are usually used to evaluate solar degradation.
 - 1. **The xenon arc tester** with daylight filters, in accordance with ASTM G155 Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials, duplicates the entire spectrum of solar radiation. The irradiance and temperature is controlled; humidity and water spray are available.
 - Fluorescent UV-A340 bulbs have excellent correlation in the UV wavelength range of 295nm-370nm and offer humidity as a moisture source, in addition to temperature control. These light source devices are in compliance with ASTM G154 Standard. dation.

Oxidation Induction Time (OIT)

- Application: In PP and PE polymer systems where oxidation stability is critical to the long-term performance of the geomembrane. This test is not used to determine life expectancy of the material, but to give an indication of polymer stability by the addition of additives at the time of manufacture.
- Methodology: Testing is performed to ASTM D5885 Standard Test Method for Oxidative Induction Time of Polyolefin Geosynthetics by High-Pressure Differential Scanning Calorimetry.

Thermal Degradation Testing

- Application: Evaluates the degradation as a result of heat and does not take other degradation mechanisms into account.
- Methodology: Subjects the geomembrane material to high temperature over an extended period; this is typically referenced to as "oven aging." Field correlation testing is required to determine equivalency to outdoor exposure. In addition, deadload testing (static load) on the seams at elevated temperatures is performed in a standard laboratory air-circulating oven. This test is a good indication of seam integrity in an exposed environment, under load at elevated temperatures, and can be found in ASTM D751 Standard Test Methods for Coated Fabrics.

POINTS TO CONSIDER IN EXPOSED APPLICATIONS

At the start of the selection process, determine the strength, stability, and chemical resistance required for the specific project. In addition, consider the following to provide for a

long-term high-performance geomembrane in an exposed environment:

1. Application

- Sloped or flat-different angles of installation can increase UV exposure
- Select geomembrane with superior UV resistance
- Drainage and anchoring issues associated with high thermal expansion/contraction
- Dead load critical on factory and field seams

2. Long-term performance history of the specific geomembrane environmental contaminates

- Superior chemical resistance and performance is important
- Not all membrane suppliers use the same formula, additives, processing, etc. Choose a proven formulation/process from a reputable supplier

3. Case histories of long-term performance in comparable environmental conditions

Select a geomembrane with a proven performance record

4. Artificial Weathering

- Product specification must represent mode of failure for geomembrane
- Artificial exposure relationship to geomembrane degradation in field
- Sensitivity of polymer degradation to UV, OIT, moisture, etc.
- Thermal expansion/contraction due to thermal swings induced by UV exposure

CONCLUSION

There are many variables to consider when specifying an exposed geomembrane. Solar radiation is the main factor that will affect the performance. Each polymer is spectrally susceptible to specific wavelengths, in addition to environmental factors.

Laboratory tests help ensure long-term field performance in a variety of environmental conditions, but these tests do not take into consideration all the elements that could affect the geomembrane in the field.

The best option is to make selections based on the performance history of products in similar exposure conditions. For an exposed environmental application that requires a long-term, high-performance geomembrane liner or cover, contact a technical expert at Seaman Corporation. Call (800) 927-8578 for an in-depth consultation, or visit www.XRGeomembranes.com.

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