

ESCR - Environmental Stress Crack Resistance of HDPE

Introduction

High Density Polyethylene (HDPE) sheet can be susceptible to a phenomenon known as Environmental Stress Cracking (ESC). ESC is a brittle failure that occurs when the HDPE sheet is in tension at a constant tensile stress that is lower than the yield stress at which failure would be expected. ESC does not occur when HDPE is in compression. It is particularly significant as HDPE is used to manufacture a wide range of products such as geomembranes, geocellular webs, pipes, etc. ESC is a fundamental phenomenon of HDPE which does not occur in MDPE or LLDPE. All potentially affected ABG products use Environmental Stress Crack Resistant (ESCR) grade HDPE.

Table 1: Polyethylene Grades

Grade	Abbreviation	Weight
High Density Polyethylene	HDPE	>940 kg/m ³
Medium Density Polyethylene	MDPE	926-940 kg/m ³
Linear Low Density Polyethylene	LLDPE	915-925 kg/m ³

Background

HDPE is used to manufacture geomembranes, geocellular webs, pipes, etc. ESC was first identified as a problem in HDPE in the 1970's in gas pipes, and then in HDPE geomembranes in the 1980's. Since then, the problem has been researched and is now fully understood such that ESC can be avoided.

Environmental Stress Cracking

Due to its high density, HDPE is a crystalline material and when a high tensile stress is applied, the material will stretch and yield before ductile failure but at low tensile stress, the material will fail suddenly with a smooth break typical of brittle failure. This is known as environmental stress cracking. All such failures in geomembranes occurred when the geomembrane had been exposed to continuous processes of UV light, high temperature oxidation, and/or low temperature contraction.

Environmental Stress Cracking (ESC) can be avoided if the HDPE is not subjected to environments or installations that place the sheet in tension. However, that is not a really practical proposition in many cases and therefore the best solution is to use a polyethylene (PE) that is more resistant to ESC. One of the key parameters affecting ESC is chain branching of the polymer. Generally speaking, as branching increases, density decreases, and resistance to ESC improves. So lower density polymers offer better resistance to ESC. Hence the simplest solution is to use a lower density grade of PE. There are several commercially available grades of polyethylene that are at the upper density of Medium Density Polyethylene (MDPE) with a density of 930 kg/m³ which do not suffer from ESC. After the addition of carbon black (required for UV resistance) the density of the manufactured polyethylene sheet is 940 kg/m³. Such polyethylene sheets are known as Environmental Stress Crack Resistant grade (ESCR grade) polyethylene, and their datasheets have test values of ESCR performance.

Development of ESCR Testing

ASTM D1693 – Bent Strip Method

The earliest test method to measure Environmental Stress Crack Resistance (ESCR) was ASTM D1693 – Bent Strip Method. This test is now discredited and many experts recommend that this test should be discontinued because it does not reliably indicate ESCR. The test takes a

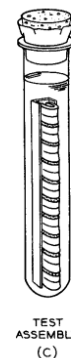


Figure 1: ASTM D1693 Test Setup

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small specimen of HDPE, bent unto a U shape inside a test tube which is then placed in a wetting agent at 50°C. The length of time in hours until the specimen cracks is recorded. Bending the specimen into a U shape causes tensile stress on the outer radius of the bend but stress relaxation over time reduces the tensile stress and after approximately 100 hours, the specimen is no longer in tension. The problem with this test is that ESC only occurs when HDPE is in tension and so, if the specimen does not fail in less than 100 hours, this test cannot distinguish true ESCR. Datasheet values of 3000 to 5000 hours ESCR to ASTM D1693 are therefore meaningless.

ASTM D5397 – Single Point Notched Constant Tension Load Test

A more reliable test is ASTM D5397 Appendix X1 – Single Point Notched Constant Tension Load test (SP-NCTL). This test places a dumbbell shaped test specimen of HDPE with a central notch under a constant tensile load (30% of the yield strength) in a wetting agent at 50°C. This is a more stringent test. The specimen is kept in tension throughout the test. The Geosynthetic Research Institute (GRI) has an internationally recognised specification for HDPE geomembranes (Geosynthetic-institute.org, 2016), in which the ESCR value tested to ASTM D5397 must be greater than 500 hours.

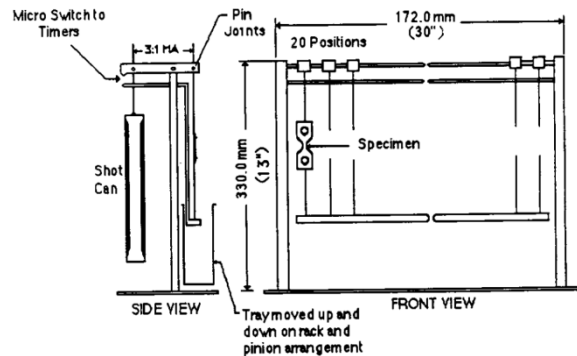


Figure 2: ASTM D5397 Test Setup

Conclusion

ABG recommends that in any project where an HDPE geomembrane is in tension, the specifier should require testing in accordance with ASTM D5397. Any test results submitted based on ASTM D1693 should be rejected.

Relevance of Environmental Stress Cracking to ABG Products

The most relevant ABG products with respect to environmental stress cracking are **Webwall** and **Alphaline**. **Webwall** is a geocell retaining wall product manufactured by ABG from ultrasonic welded HDPE, and **Alphaline** is an impermeable HDPE geomembrane. Both these products are partially under tension once installed and so are manufactured with ESCR grade HDPE. ABG drainage geocomposites such as **Pozidrain**, **Deckdrain** and **Fildrain** are produced from standard grade HDPE because these products are used in compression, and environmental stress cracking does not occur under compressive loads.

References

ASTM D1693-15, *Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics*. ASTM International, West Conshohocken, PA, 2015, www.astm.org

ASTM D5397-07(2012), *Standard Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test*. ASTM International, West Conshohocken, PA, 2012, www.astm.org

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Geosynthetic-institute.org. (2016) *Test Methods, Test Properties and Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes, Revision 14*. [online] Available at: <http://www.geosynthetic-institute.org/grispecs/gm13.pdf> [Accessed 12 Apr. 2018].