Forensic Study of an HDPE Liner after 10 Years of Exposure

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ABSTRACT

This is a detailed forensic study of high density polyethylene (HDPE) geomembrane material that was installed Ohio, USA. Specifically, 40 mil (1.0 mm) HDPE smooth geomembrane was used to line a wastewater pre-treatment facility that contained water from a fruit concentrate processing plant. Upon removal of the geomembrane from the installation site, samples were re-evaluated for physical property integrity. The results show minimal property degradation after over 10 years in active service.

BACKGROUND

An HDPE geomembrane was chosen to serve as a containment barrier at a food processing plant. The lagoon was approximately 161,135 square feet (14,970 square meters) in area. Side slope angles for the project were 3:1 and the total depth of the pond was eight feet. Liner installation took nine days beginning on 1 May, 1988.

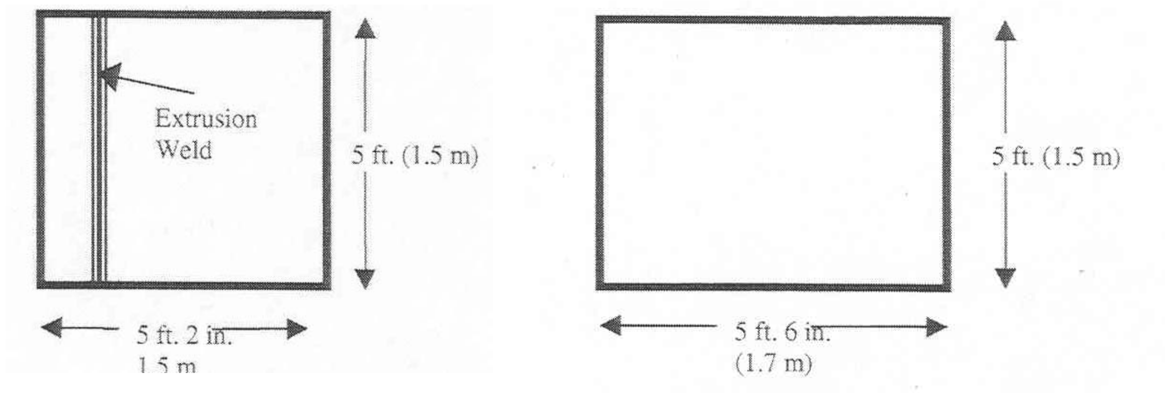
The geomembrane material was used to line the bottom and the sides of three contact tanks (lagoons) in the wastewater treatment system at this plant. A 6 oz/yd^2
(200 g/m^2) non-woven polypropylene geotextile was placed under the liner for added protection from any sharp rocks or protruding objects that may have been present in the subgrade.

While in service, significant portions of the liner were exposed but the majority of the geomembrane was underwater. The pH levels in the lagoon were typically 5 to 8, and some neutralization of the wastewater was required before discharging into the city's water system.

Over a decade later the wastewater lagoons were permanently emptied and samples of the geomembrane liner, including welds, were re-tested and evaluated for physical property characterization. Sampling occurred in March, 1999. One of the samples tested was taken from the top panel of a panel (which was exposed) and one sample was taken from the bottom panel of the same panel (which was typically under 8 feet (2.5 m) of water). Dimensions of the samples are shown in Figure 1.

Approximately five feet (1.5 m) of extrusion welded panels was obtained from the wastewater treatment site (see Figure 3). This weld was removed from the top of the lagoon -it experienced exposure to ultraviolet radiation from the sun.

Figure 1: Sample Dimensions



Top Panel
(Exposed)

foundation Panel
(Unexposed)

Figure 2: Sample after 10 years in application

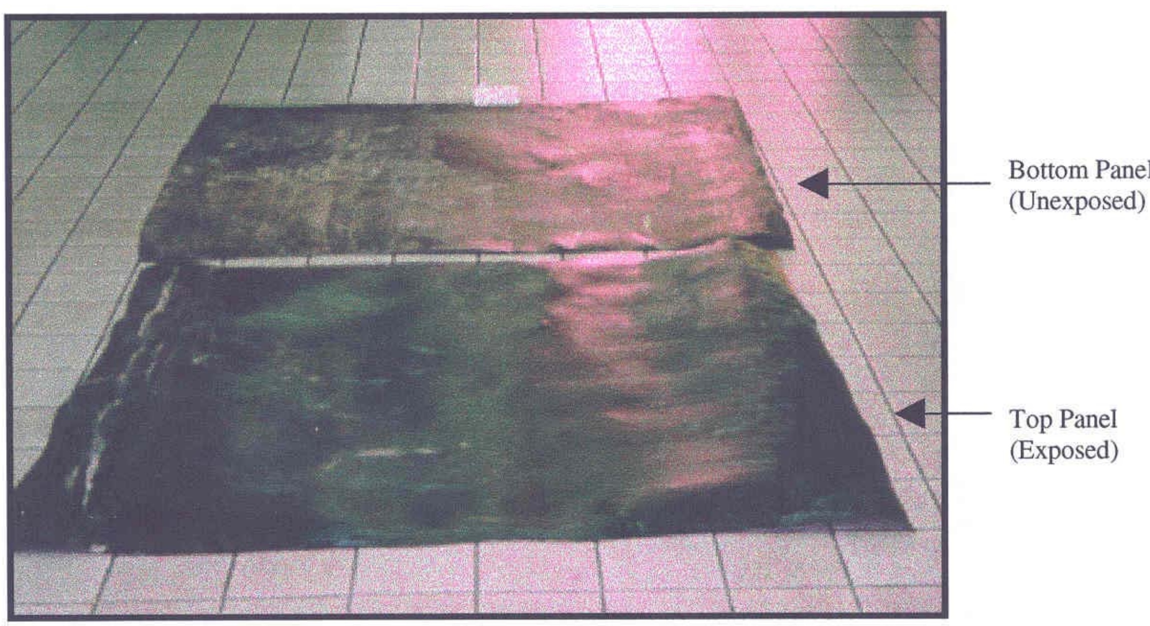
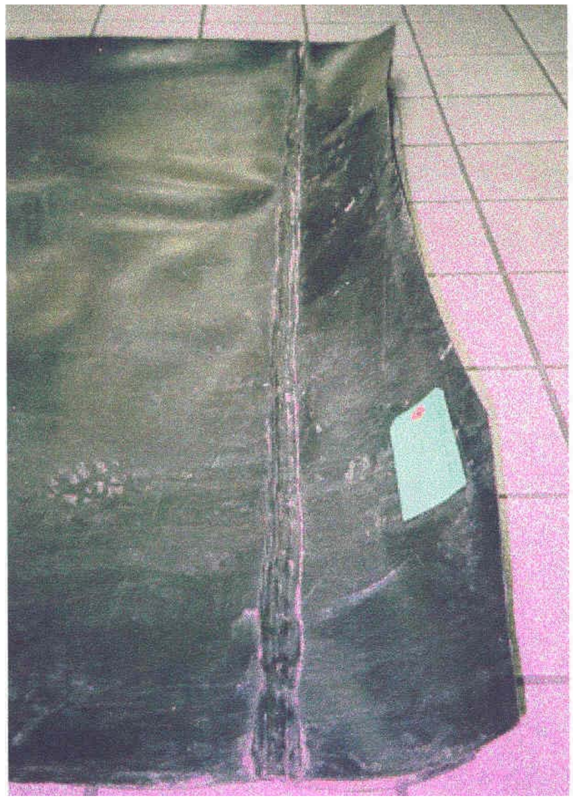


Figure 3: Welded Seam on Top Panel



PERFORMANCE

The geomembrane was manufactured in April, 1988. At that time, the following tests were performed:

Thickness	ASTM D 1593
Density	ASTM D 1505
Melt flow index	ASTM D 1238, Condition 190/2.16
Tensile strength	ASTM D 638, Type IV, 2ipm (51 mm/rnin)
Tensile elongation	ASTM D 638. Type IV
Carbon black content	ASTM D 1603
Weld seam strength	ASTM D 638. Type IV, 2 ipm (51 mm/min)

In March 1999, the samples (Figure 2 and 3) were removed from the wastewater lagoons and the physical testing listed above was repeated. In addition, oxidative induction time (OIT) and single-point notched constant tensile load (SP-NCTL) testing was performed. These tests were performed since they provide useful information regarding aging. Finally, a comparison of seam strength (both peel and shear) of the initial and current weld values was made. The results are summarized below.

Table 1: Physical Property Comparison of 1988 and 1999 Samples

Property	Test Method	Units	Original (1988)	Aged (1999 exposed)	Aged (1999 unexposed)
Thickness	ASTM D 1593	mils	38	38	38
Density	ASTM D 1505	g/cc	0.951	0.951	0.951
Tensile Properties	ASTM D 638				
Strength at Yield	Type IV coupon	ppi	111	121	122
Strength at Break	2 in/min	ppi	163	169	184
Elongation at Yield		%	13	17	18
Elongation at Break	2.5" gage length	%	734	579	630
Carbon Black	ASTM D 1603	%	2.9	2.6	2.8
Melt Flow Index	ASTM D I268,E	g/10min	0.14	0.11	0.11

The original weld testing in 1988 was performed using the ASTM D 638 test method (Type IV specimen, 2 ipm). The test method that is commonly used today for measuring weld strength is ASTM D 4437 (Standard Test Method for Determining the Integrity of Field Seams in Geomembranes).

Table 2: Weld Strength Comparison of 1988 and 1999 Samples

Property	Test Method	Units	Original 1988	Aged 1999 exposed
Seam Strength- Shear	ASTM D 638, Type IV coupon, 2 ipm	ppi	129	149
Seam Strength- Peel	ASTM D 638, Type IV coupon, 2 ipm	ppi	85	137
Seam Strength- Shear	ASTM D 4437	ppi	Not available	109
Seam Strength- Peel	ASTM D 4437	ppi	Not available	89

Table 3: Additional Physical Property Testing on Aged Samples

Property	Test Method	Units	Aged Exposed	Aged Unexposed
Tear Resistance	ASTM D 1004	lbs	37	39
Puncture Resistance	FTMS 101 / 2065	lbs	91	89
Dimensional Stability	ASTM D 1204	% change	0.75	0.60
Oxidative Inductive Time	ASTM D 3865	minutes	43	38
Single Point Notched Constant Tensile Load	ASTM D 5397	hours	>668	>668

ANALYSIS

Thickness

There were no measurable changes in material thickness. This is expected since polyethylene does not change dimensions in the conditions experienced by the material.

Density

There were no measurable changes in the density. Again, this is expected for polyethylene exposed the conditions of this application.

Tensile Values

The Strength at Yield and Strength at Break exhibited small changes. However, these changes are not significant since all results fall within the same statistical range of newly manufactured material.

The elongation at yield and elongation at break however, did demonstrate statically valid changes. The elongation at yield showed an increase for both the exposed and unexposed material. This is indicative of cross-linking of the polymer chains as a result of exposure to ultraviolet radiation. (This is further evidenced by the decrease in melt index.) Such cross-linking is expected over a 10-year period with the chemical stabilizers used in polyethylene geomembranes in 1988. The decrease in the elongation at break is also attributed to cross-linking of the material.

Carbon Black Content

There were no notable changes in carbon black content. This is expected since carbon black cannot be extracted out of polyethylene except by pyrolysis (burning).

Melt Index

There is a decrease in the melt flow index of the material. This is most likely attributed to cross-linking. This is the most probable reason in light of the change in tensile elongation properties mentioned above.

Weld Strength Values

The shear and peel properties increased over the 10-year period of exposure. This is in contradiction to the behavior observed with the tensile strength of the sheet. This discrepancy is not explainable. However, it is significant to note that the weld has not lost any strength during exposure.

Oxidative Inductive Time Test Results

OIT testing was performed on both the top panel, which was exposed to sunlight, and the bottom panel, which was underwater and therefore not directly exposed to natural sunlight. No significant difference in OIT is indicated between the exposed and unexposed samples. Actually, the exposed material has a higher OIT than the unexposed material. This difference is probably due to the difference in statistical variation that would normally be seen among different samples from the same material. This indicates that any additive depletion occurring, as a result of sunlight exposure is immeasurable in this case.

SUMMARY

High density polyethylene exposed for 10 years to ultraviolet radiation and wastewater was studied. The material was 40 mils (1 mm) thick and installed in April, 1988 in Ohio, USA.

No significant change in physical properties (tensile, tear, puncture and carbon black) was observed with the exception of tensile elongation. Both yield and break tensile elongations were higher. This is attributed to cross-linking of the material. This theory is substantiated by the decrease in melt index, which is also an indication of cross-linking.

OIT testing indicates that the variation between samples that were exposed and unexposed to natural sunlight is not larger that the variation that is commonly seen from sample to sample.

It is therefore demonstrated that the material is serving the intended purpose and will do so. Materials manufactured today are expected to perform better and function longer, primarily due to technological improvements in resin stabilization and sheet manufacturing techniques.