CASE HISTORY OF A 22-YEAR OLD GEOMEMBREANE LINER AT A DOMESTIC WASTE LANDFILL

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ABSTRACT

This paper presents a case history of an exhumed geomembrane beneath a landfill in New Jersey in the U.S.A. The geomembrane taken from the landfill has been in service for the past 22 years. The liner was exhumed due to a lateral expansion at the site. The owner plans to tie into the existing liner system along with the new cell's construction. Hence the opportunity arose to exhume a section of textured 1.5 mm (60 mil) HDPE geomembrane that was in service and experiencing actual field conditions of compression, temperature and leachate exposure since its installation.

Most durability research has been laboratory work making use of accelerated aging tests. Rarely are we presented the opportunity to access actual geomembranes that have undergone field exposed conditions. Samples were exhumed at the site of both the sheet material and the seams. Fortunately, quality assurance testing of the geomembrane during installation was very rigorous and used ASTM Standards still currently used. Thus with this new data, a direct comparison was made of the as-manufactured test results versus current test results after exposure to MSW long-term field conditions at the site. Original property values are contrasted to the aged material values and also to the current GRI-GM13 specification values. Test results indicate that density has increased (thus stress crack resistance has decreased about 25%) and oxidative induction time has decreased by about 15% (thus there are considerable antioxidants remaining in the material). All other physical and mechanical properties have remained essentially unchanged and well above current specification values. There are no visible indications of geomembrane degradation and the material's performance has met the project's expectations.

1 INTRODUCTION

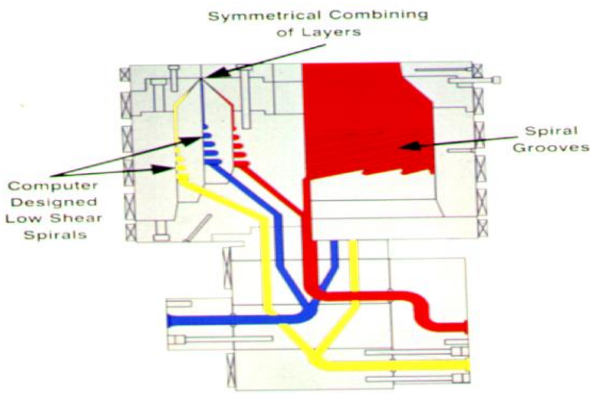
Research into the durability, i.e., lifetime, of geomembranes has focused to date on buried conditions for a number of applications such as landfill liners and covers, among others (Koerner, et al. 1990) and (Koerner, et al. 2005). Most of the research has been laboratory work making use of accelerated aging tests. Rarely are we presented the opportunity to access actual

Geomembranes that have undergone field exposed conditions. Research into degradation and lifetime prediction of exposed geomembranes follows existing polymer durability studies using laboratory weatherometers of which the literature is voluminous. These devices attempt to simulate field and utilize Arenius modeling to arrive at a lifetime. Koerner, et al. (2005) presents such data on a number of commercially available geomembranes. While such laboratory studies are important, the actual site-specific behavior for feed-back as to validity of simulated laboratory exposure studies is critical. This paper presents such a case history on an 25-year old high density polyethylene (HDPE) geomembrane liner at a landfill in Pennsylvania, USA.

2 BACKGROUND AND SITE CONDITIONS

A schematic diagram of the blown film die and process is shown respectively in Figure 1 (a) and 1(b). In this process, an extruder is used to melt and forward molten resin into an annular film die. Air is injected into the center of the annular die to inflate the polymer bubble. The bubble is cooled by an air ring that blows air on the surface of the bubble to lower its temperature until it becomes solidified. Above the die, a stabilizing cage may be used to minimize movement of the bubble as it is collapsed in the collapsing frame to make a flat film. This film is then pulled over nip rolls and fed into a film winder to make the finished film roll. A key part of this process is the blown film die shown in Figure 1 (a). The blown film die takes the polymer melt from the extruder and shapes it into a tubular geometry to form the film bubble. This bubble must be uniform in thickness and temperature in order to form a uniform bubble.

There are different types of annular blown film dies that can be used in polymer processing. The one used to make the geomembrane for this project was a spiral mandrel feed by three different extruders. For our case, the “A” and “C” extruders are supplemented with nitrogen which creates the textured affect as the material exits the die. In a spiral mandrel die, the cylindrical surface of the inner mandrel is spirally cut with grooves that become shallower as you progress down the channel. In order to make a multilayer blown film structure using spiral mandrel technology, a separate die manifold must be made for each layer. The individual annular flow streams are formed and then joined together near the exit of the die with complete continuity of the layers.



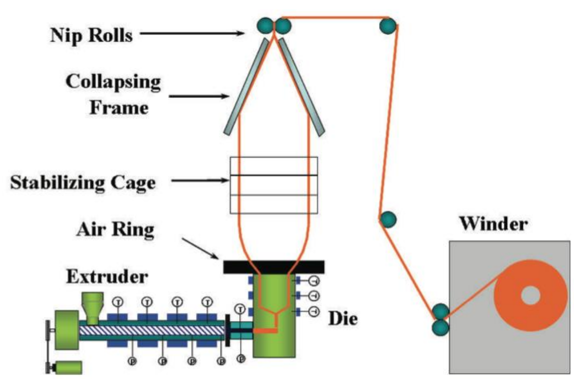


Figure 1(a) . Blown Film Die Figure 1(b) Schematic Diagram of the blown film extrusion process

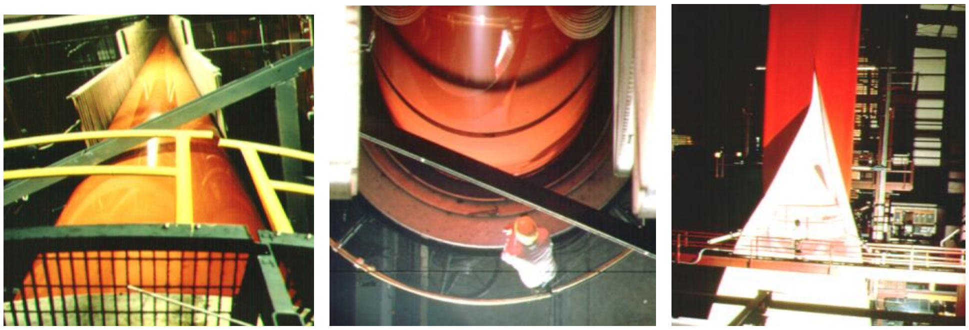


Figure 2. Photographs of the blown film extrusion process

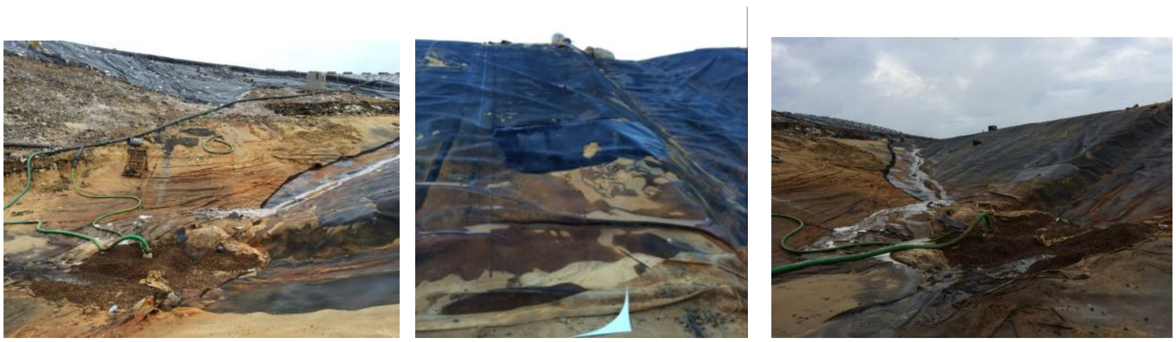


Figure 3, Overview Photograph of the excavation showing sump and sample area

In the Summer of 1994, a GSE Environmental provided a 1.5 mm thick textured both sides black HDPE geomembrane for a Subtitle D landfill liner in Cumberland County, NJ. While there was no indication of any type of geomembrane degradation, the opportunity of sampling both the geomembrane and its seam presented itself in the Summer of 2016, approximately 22-years after installation. Figure 4 shows a sheet sample and Figure 5 shows seam sample being taken from the site. Quality assurance testing of the geomembrane during installation was very rigorous and used ASTM Standards still current presently. Thus, a direct comparison can be made of the as-manufactured test results versus current test results.

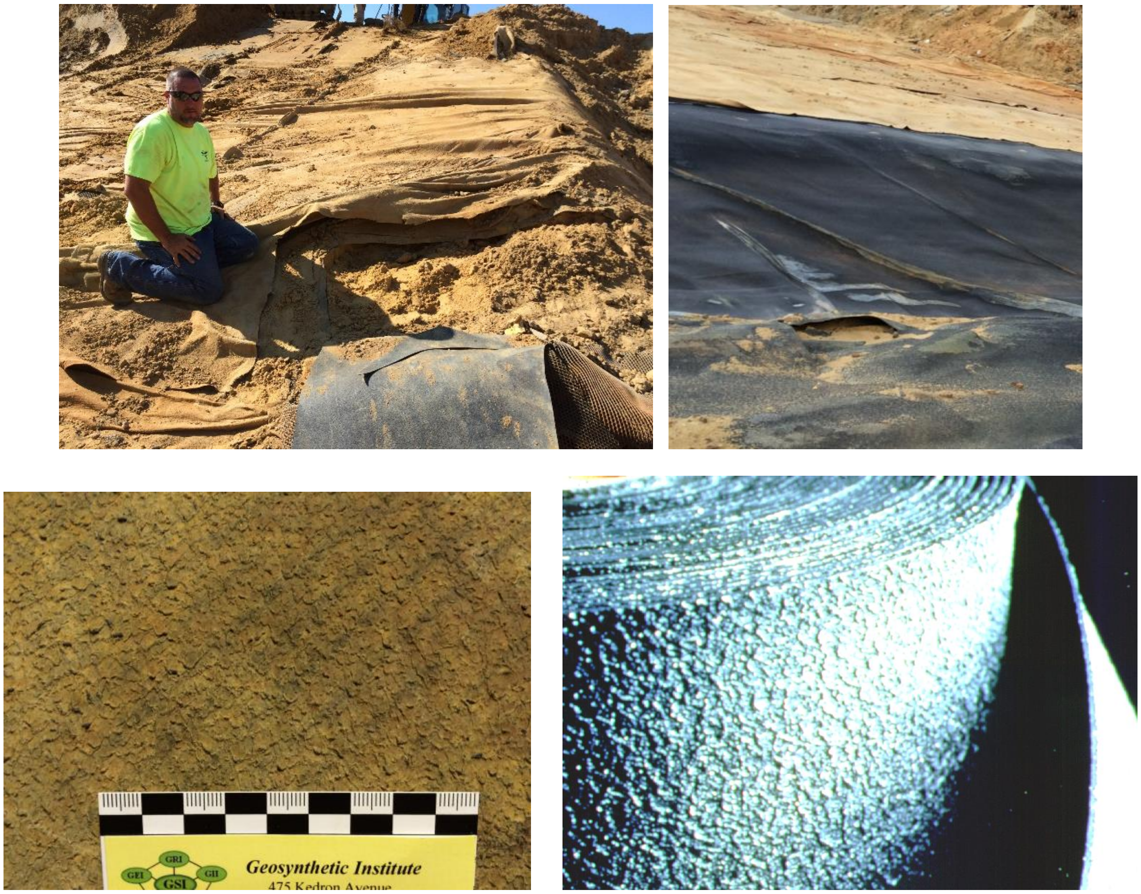


Figure 4. Field sampling of geomembrane

Figure 5, Field sampling of dual track hot wedge fusion seam and fillet extrusion seam

In 1994 GM13 Specification for HDPE was new and the manufacturer was fully involved in the development process of this specification. Thus, the present specification values will be used for comparison purposes. Also, the GRI-GM19 Specification for field seams will be used for comparison to the as-installed and current seam values.

3.0 COMPARISON OF TEST RESULTS

The original and aged test results, as well as the current GRI-GM13 specification values are all based on ASTM standards. The results are given in Table 1.

Table 1. Test result comparison of CCIA textured HDPE sheet material

Property	ASTM Test Method	Units	GM13 Values	Original Values	Sample 1 Primary Sump	Sample 2 Primary Wet-Dry	Sample 3 Primary Crest
Thickness Core	D5994	mm	1.35	1.59	1.57	1.59	1.58
Thickness Asperity	D7466	mm	0.4	0.6	0.71	0.70	0.73
Density	D792	g/cc	0.940	0.946	0.947	0.946	0.947
Tensile Properties	Type IV						
• yield stress	D6693	kN/m	29	30	33	29	30
• break stress	D6693	kN/m	26	28	30	32	33
• yield elongation	D6693	%	12	15	15	16	15
• break elongation	D6693	%	100	127	147	162	153

Tear Resistance	D1004	N	187	231	237	240	248
Puncture Re-sistance	D4833	N	481	641	586	665	591
Stress Crack Re-sistance	D5397 (App.)	hr.	200	>300	339	426	411
CB Content	D1603	%	2.0-3.0	2.3	2.2	2.4	2.3
CB Black Disper-sion	D5596	Cat.	1 or 2	1	1	1	1
Oxidative Time OIT by STD DSC	D3895	min.	100	104	157	118	166

Comments on the comparison of values follow:

- original and aged thicknesses are similar and both are above the specification value,
- density of the aged material has increased over the original values, however, both are above the specification value,
- original and aged tensile properties (yield and break stress, and yield and break elongation) are similar and above specification values,
- original and aged tear resistances are similar and above the specification value,
- original and aged puncture resistances are similar and above
- the specification value,
- stress crack resistance has decreased from the original value by 35% and is now below the initial specification value of 200 hours. (Note that the specification value was increased in 2003 to 300 hours. Thus, the original resin used in this formulation would not have met the current specification value and a different, i.e., better stress crack resistance, resin would have had to been used.)
- original and aged carbon black contents are similar and meet the specification range of valu

- original and aged carbon black dispersion categories are similar and meet the specification value, and
- oxidative induction time has decreased from the original value by 28% and is currently less than the specification value. (Note that the high pressure OIT may result in a different conclusion, but we are unsure of the type of antioxidants used in the formulation.)

Of all of the values, the most revealing are the density (coupled with stress crack resistance, or SCR) and the oxidative induction time (OIT) values.

The density increase accompanying the material as it ages into equilibrium over time brings about an expected increase in crystallinity. In turn, higher crystallinity results in lower SCR, in this case a decrease of 35%. That said, with a 209 hour original value the resin would not meet the current specification value. This particular resin is no longer being used in the HDPE geomembrane market. The OIT decrease of 28% is well understood and expected (Hsuan & Koerner 1998). Until the antioxidants are depleted, no changes are anticipated in the mechanical test properties of tensile, tear or puncture values.

As shown in Figure 2, hot wedge seam samples were taken and tested according to present standards, i.e., ASTM D6392, and compared to one another. The results are also compared to the current specification values in GRI-GM19. Table 2 presents these results.

Table 2. Test results of HDPE field seams per ASTM D6392

Property	GM19 Values	Extrusion	Fusion
Shear strength (kN/m)	44	50	49
Shear elongation (%)	50	>50	>50
Locus of break(1)	FTB	SE1	SE1
Peel strength (kN/m)	33	39	40
Peel separation (%)	25 (max.)	0	0
Locus of break(1)	FTB	SE1	SE1

Note: (1) There are various locus-of-break codes in ASTM D6392. All attempt to discriminate between failure within the seam area and in the adjacent sheets, the latter being required. Such adjacent sheet failure is known as a film tear bond (FTB).

Regarding both the fillet extrusion and dual track hot wedge fusion seams, both shear and peel strengths are similar in their original and aged conditions and both pass the current specification. Also, seam elongation

and type of break are acceptable. All seams that we saw were in excellent shape after twenty-two (22) years of service.

4 SUMMARY AND CONCLUSION

The geomembrane looks to be in very good shape after twenty-two (22) years of service as a liner to a MSW landfill. In this regard, most of the anticipated lifetimes of geosynthetics (and geomembranes in particular) are such that lifetimes of the associated "system" can be obtained. For example, most transportation systems require 75-100 years lifetime and properly formulated materials can meet this need.

The opportunity presented itself to sample a 22-year old HDPE geomembrane liner. Sheet material, as well as seams, were taken and tested so as to compare to the original (as-manufactured) material. The aged values were also compared to current specifications; GRI-GM13 for the sheet and GRI-GM19 for the seams and looked great. Furthermore, both the original and aged values exceed the specification values.

In conclusion, this particular geomembrane is serving its function as intended.

REFERENCES

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ASTM D6392, Standard specification for "Determining the integrity of nonreinforced geomembrane seams produced by thermo-fusion methods".

GRI-GM13 Standard specification for "Test methods, test properties, and testing frequency for high density polyethylene smooth and textured geomembranes".

GRI-GM19 Standard specification for "Seam strength and related properties of thermally bonded polyolefin geomembranes".

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