Case history of a 20-year old exposed HDPE surface impoundment liner

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Keywords: geomembrane, high density polyethylene (HDPE), exposed durability, case history

ABSTRACT: This paper presents a case history of an exposed 20-year old HDPE geomembrane surface impoundment liner located in Somerset, Massachusetts, USA. Three liner samples were taken on the southerly facing side slope of the facility; horizontal runout, exposed side slope, and covered side slope. The aged material properties were evaluated and compared to the original as-manufactured properties. The properties are also compared to the currently used GRI-GM13 Specification. Test results indicate that the side sloped portion of the liner has decreased in its stress crack resistance (SCR) and its oxidative induction time (OIT) the most, the horizontal runout intermediate, and the covered portion the least. Slight increases in density might be the cause of decreased SCR, but clearly antioxidants are being depleted in accordance to the exposed conditions as anticipated. All other physical and mechanical properties remain essentially unchanged. The facility continues to be in service and is functioning well.

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), Hsuan, et al. (1998), and (Koerner, et al. 2005a). However, there are many applications where geomembranes are exposed to the atmosphere and, depending upon site-specific conditions, lifetimes promise to be considerably shorter than when buried. As opposed to covered or buried geomembranes, exposed conditions have three adversely affecting conditions imposed upon them. They are as follows;

- 21% oxygen (versus low oxygen levels or no oxygen at all),
- elevated temperatures (greatly depending upon the site), and
- ultraviolet light (also depending on the site).

Some applications where geomembranes are exposed are as follows (Koerner, et al. 2008);

- waterproofing of the facings of all types of dams,
- reservoir linings above the liquid level,
- canal linings above the liquid level,
- covers for reservoirs and surface impoundments,
- tunnel linings (although without ultraviolet light), and
- the upper surface of various geomembrane containers, bins, and boxes.

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 exposed conditions and are routinely used by many plastics industries, the automobile paint industry, many coatings applications, and others. Koerner, et al. (2005b, c and 2008) presents such data on a number of commercially available geomembranes where lifetimes of 30 to 40 years in a hot climate are predicted for properly formulated polymers. While such laboratory studies are important, the actual site-specific behavior for conformation as to validity of simulated laboratory exposure studies is critical. This paper presents such a case history on an exposed 20-year old high density polyethylene (HDPE) geomembrane liner of a surface impoundment containing power plant ash in Somerset, Massachusetts, USA.

2 BACKGROUND AND SITE CONDITIONS

This paper presents the 20-year performance of an HDPE exposed liner installed at the Brayton Point Power Station, Setting Basin No. 1, Somerset, Massachusetts, USA installed in 1989. The basin is 104 m long, 38 m wide, and 4.3 m in depth. The side slopes are two horizontal-to-one vertical, i.e., 26.6 degrees with the horizontal. The facility had been previously lined with a chlorinated polyethylene (CPE) geomembrane which was in "very poor condition" prior to the installation of this replacement liner in 1989.

The replacement system was designed by GEI Consultants, Inc., manufactured and installed by Gundle Lining Systems, Inc. (now GSE Lining Technology, Inc.), and the construction quality assurance was monitored by GeoServices Inc. (now Geosyntec Consultants, Inc.). The site is shown in Figure 1 immediately after geomembrane installation and before the ash material was placed in it.

Figure 1. Surface impoundment liner as installed and before ash placement

Upon removal of the CPE geomembrane, the soil subgrade was regarded and compacted. A 270 g/m^2 needle punched nonwoven geotextile was placed on the soil and then a 2.0 mm thick smooth HDPE geomembrane was installed. Seam welding was done by the flat extrusion method (a method that is now depreciated, see U.S. EPA, 1991). The flat base of the impoundment was filled with ash leaving the horizontal runout and upper surface of the slope exposed. Figure 2 shows the situation where locations "1" and "2" have been exposed to the atmosphere continuously. Location "3" was covered with ash and the white residue clearly outlines the upper limit of ash placement. There was no visual degradation of the geomembrane at any location even beneath the white residue shown in the photograph.

Figure 2. Photograph of side slope of site before geomembrane sampling

Figure 3 shows that a continuous geomembrane sample was cut from the horizontal runout (up to the point where it enters into the anchor trench), along the exposed side slope and then into the covered portion at the toe of the slope. Here some ash was hand excavated so as to have sampled material that was never exposed. Location 3 extends below the white residue portion of the liner. These three sample locations are marked, "1", "2" and "3", respectively. The sample, in a continuous section, was approximately 6.5 m long and 2.2 m wide and was shipped to GSI's laboratory for testing and analysis. The sampled location in the field was then repaired using a recently manufactured cap-strip of similar material and then seamed using an extrusion fillet of the same material. The repair was properly evaluated using the vacuum box method, U. S. EPA, 1991.

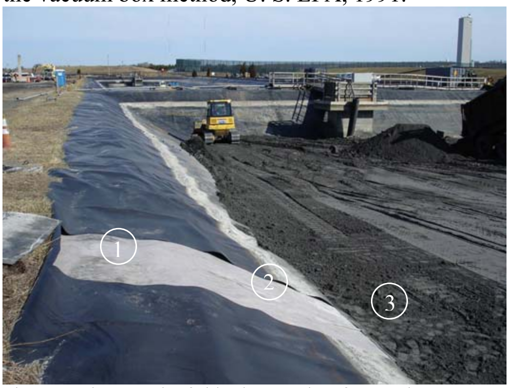

Figure 3. Photograph of side slope at site after continuous sample was taken and shipped to laboratory for testing

3 TEST RESULTS AND COMPARISONS

The focus of this case history is to quantify by means of physical, mechanical and endurance testing if the geomembrane was degrading, if so to what degree, and furthermore to evaluate any differences between the three indicated locations. All testing was performed according to current ASTM Standards and results compared to the currently used GRI-GM13 Specification. Unfortunately, there is no archived material from the original installation available, however, several of the manufacturers certification values and the CQA test values are available and will be used where possible. Table 1 presents the test property results stemming from this testing program.

Table 1. Test results for 2.0 mm smooth HDPE geomembrane at Somerset, Massachusetts

Property	ASTM Method	Unit	Original Values	Aged Values 1	Aged Values 2	Aged Values 3	GM 13
Thickness, (min. ave.)	D5199	mm	2.05	2.00	2.06	2.00	2.00
• lowest individual of 10 values		mm	1.98	1.96	1.91	1.93	1.83
Density (min.)	D1505/ D792	g/cc	.947	.949	.947	.950	.940
Tensile Properties[(1)] (min. ave.)	Type IV						
• yield stress	D6392	kN/m	36.4	36.9	37.3	35.0	29.4
• break stress	D6392	kN/m	59.5	46.7	47.3	50.4	53.2
• yield elongation	D6392	%	18	15	16	17	12
• break elongation	D6392	%	826	643	712	692	700
Tear Resistance (min. ave.)	D1004	N	314	298	303	316	249
Puncture Resistance (min. ave.)	D4833	N	n/a	805	819	810	641
Stress Crack Resistance[(2)]	D5397 (App.)	hr.	n/a	267	179	327	300
Carbon Black Content (range)	D1603	%	2.41	2.6	2.5	2.6	2.0-3.0
Carbon Black Dispersion	D5596	Cat.[(3)]	1	1	1	1	1 or 2
Oxidative Induction Time (OIT)	D3895	n/a	n/a	63	35	80	100

(1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction
Yield elongation is calculated using a gage length of 33 mm
Break elongation is calculated using a gage length of 50 mm.
(2) The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.
(3) Carbon black dispersion for 10 different views: all 10 in Categories 1 or 2
n/a The puncture test probe was FTM 101C and the stress crack resistance procedure was ASTM 1683, both of which have changed significantly since 1989 and thus comparisons are not possible. Also, OIT tests were not performed.

Comments on the comparisons of test values follow:

- The original and aged thickness values are in agreement with one another. Furthermore, they are all in excess of the current specification's lowest individual values.
- The original and aged density values are in close agreement and all are well above the current specification value.
- The original and aged values of yield stress and yield elongation are in agreement and also pass current specification values. However, this is not the case for the break stress and break elongation wherein both have decreased over time. Both are also slightly less than current specification values. That said, all samples had many surface scratches of depths ranging from nominal to about 0.30 mm at the largest. It is felt that these scratches lowered break values but did not affect yield values.
- The aged tear resistance values are approximately equal to the original and are well above current specification values.
- The aged puncture resistance is constant over the three locations and is well above current specification values. Unfortunately the test probe has changed from a narrow hemispherical point geometry to a flat tip of different sizes and a comparison with original values cannot be made.
- The stress crack resistance (SCR) is interesting in that the exposed slope locations have shorter times than the covered location. Also, both exposed locations are less than the current specification value. There is no comparison to the original values since this test method has changed completely over time.
- The original and aged carbon black content is essentially unchanged and also meets current specification values.
- The original and aged carbon black distribution is unchanged and also meets current specification values.
- The oxidation induction time (OIT) values are interesting in that the exposed slope is less than the exposed flat runout, and both are less than the covered bottom sample. (This is identical in behavior to the SCR behavior). All values are less than the current specification values.

SUMMARY AND CONCLUSIONS

Most studies on degradation and lifetime prediction of geomembranes (and for that matter all geosynthetics) have focused on covered or buried in-situ conditions. In this regard, the anticipated lifetimes of geomembranes are such that lifetimes of the associated "system" can be assured. For example, geotechnical systems typically require 75-100 years lifetime and properly formulated materials can meet this need. Hydraulic structures (dams, canals, reservoirs and tunnels) require somewhat longer lifetimes, perhaps 200 years, and buried lifetimes can fulfill this need as well. Environmental applications such as landfill liners and covers require the longest lifetimes and even here current resins and proper formulations appear to be able to satisfy the need of hundreds of years.

Exposed, the geomembranes certainly have shorter lifetimes but an estimate of "how long" is just in its initial stage of investigation. The imposition of full oxygen, high ambient temperature, and ultraviolet light all combine to shorten lifetimes of an equivalent material to a considerable extent. In exposed conditions, the site-specific location, orientation, atmospheric conditions, etc., are all extremely important.

The options for degradation and lifetime predictions are simulated laboratory incubations (using either the fluorescent ultraviolet tube device or xenon arc device weatherometers) or field retrieval of aged materials. This paper is of the latter approach.

In this regard, the opportunity presented itself to sample a 20-year old smooth HDPE liner which was exposed on the upper horizontal runout and on the southerly exposed side slope. Also sampled was the material beneath the ash fill at the base of the facility.

A number of physical, mechanical and endurance tests were performed on the three field retrieval samples and the results were compared to the geomembrane's original values and to the currently used GRI-GM13 Specification. It was found that thickness, density, tear resistance, puncture resistance, carbon black content, and carbon black distribution are statistically close to one another and to the original values. They are also equal, or in excess, to the current specification.

Regarding tensile properties, the values at yield (stress and elongation) were comparable to one another, equal to their original values, and generally meet the current specification. The tensile values at break (stress and elongation) were equal to one another, but lower than the original, and slightly lower than the current specification. The decrease in behavior at break was attributed to numerous top surface scratches which were generated during the 20-year service life. The lower surface had a geotextile beneath the geomembrane and was not affected in this regard.

Regarding stress crack resistance (SCR), the test in use in 1989 was ASTM D1609, the so-called "bent strip test". For this particular geomembrane its certified value was over 1000 hours, but the test was subsequently superseded by ASTM D5397, the "notched constant tensile load" test. The latter was performed and it was found that values are 179, 267 and 327 hours for the exposed slope, exposed horizontal, and buried samples, i.e., Locations "2", "1", and "3", respectively. This is expected in that the slope SCR is lower than the flat surface SCR and both exposed samples are lower then when covered. Also noted is that both exposed samples are presently lower than the current specification. The original material was not available for evaluation according to the current test method.

Regarding the oxidative induction (OIT) test results, they follow the SCR behavior exactly. The values of OIT are 35, 63 and 80 minutes for the exposed slope, exposed flat surface, and buried sample, i.e., Locations "2", "1", and "3", respectively. The effect of sunlight impinging on the slope has depleted the antioxidant the most, followed by the flat surface and the least being the covered sample. That said, all three current OIT values are lower than the current specification. Unfortunately, the original material was not available for its OIT value.

In conclusion, this 20-year old geomembrane continues to serve its intended function and the decreases in SCR and OIT properties are anticipated and within expected values. Hopefully, the sampling and testing can be repeated in another 20-years in the future.

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