HDPE geomembrane after 20 years of service

Testing reveals that most physical properties of 20-year-old pond liner pass today's requirements.

The following is a study of high-density polyethylene (HDPE) geomembrane lining material that was installed in Colorado, United States. Specifically, the geomembrane is a 100-mil (2.5-mm) HDPE smooth geomembrane. This geomembrane was produced using a non-continuous indexing roller manufacturing process. The continuous extrusion process widely available today was not in widespread use at the time the material was manufactured. The material was installed by SLT North America Inc., now GSE Lining Technology.

This material was used to line eight containment ponds at a steam electric generating station on the northeastern plains of Colorado, elevation 4,300 ft. (1,311 m). Currently plans are being developed to refurbish these ponds. Testing was performed to determine the effect of 20 years of service life. Remarkably, the testing showed that with very few exceptions such as Oxidative Induction Time (OIT) and some individual NCTL specimens, all other physical properties pass today's requirements.

Background

An HDPE geomembrane was chosen to line each of eight containment ponds at a 500 MW steam electric generating station. Two of these ponds contain high quality water for recycling back into the plant systems. They are 21 ft. (6.4 m) deep and relatively small (0.75 and 1.5 acres). Three of the ponds are intermediate quality (IQ) ponds that contain cooling tower blow-down water. One of these ponds is 21 ft. (6.4 m) deep with top dimensions of 430 x 380 ft. (131.1 x 115.8 m) with 3:1 side slopes. Water level in this pond varies from 5 to 18 ft. (1.5 to 5.5 m). The water has a pH of $8^{+/-}$. Total dissolved solids are about 25,000 mg/l and are comprised of sodium (5000 mg/l), chlorides (1,000 mg/l), calcium (700 mg/l) and sulfates (15,000 mg/l) among other elements. This is the pond that was sampled for the study. The other two ponds are used for bottom ash recovery. The first of these ponds is 1015 x 877 ft. (309.4 x 267.3 m) with a depth of 23 ft. (7 m). The second of these ponds is 410 x 100 ft. (125 x 30.5 m) with a depth of 12 ft. (3.6 m). Sample material was removed at the area of a weld in each of three different locations. By removing the

Table 1: Physical property comparison of current GRI-GM13 requirements vs. aged samples.

Property	Test Method	Units	GM 13	IQ Ponds		Evaporation Ponds	
				Exposed	Unexposed	Exposed	Unexposed
Density	ASTM D 1505	g/cc	0.940	0.947	0.947	0.947	0.945
Tensile Properties	ASTM D 638						
Yield Strength	Type IV	ppi	210	240	248	229	263
Break Strength	2 in./min	ppi	280	399	428	349	400
Yield Elongation		%	12	17	16	18	18
Break Elongation		%	700	962	1011	865	866
Tear	ASTM D 1004	lb_f	70	81	79	84	*
Puncture	ASTM D 4833	lb_f	180	196	216	207	*
Carbon Black	ASTM D 1603	%	2	2.3	2.3	2.2	2.1
OIT (low pressure)	ASTM D 3895	minutes	100	37	38	36	35
OIT (high pressure)	ASTM D 5885	minutes	400	242	289	263	249
SP NCTL	ASTM D 5397	hours	200	448	318	>469	*

Individuals for SP NCTL	Exposed (hours)	Unexposed (hours)
IQ 1W	352, 415	116, 172, 385, 406, 418
IQ 1E	405, 369, 421, 541, 515	142, 261, 243, 552, 487
IQ 2E	508, 508	*
EP C1	267, 451	*
EP C2	320, 249, >667, >667, >667	*

Individual Specimens for OIT (minutes)	Exposed		Unexposed	
	High Pressure	Low Pressure	High Pressure	Low Pressure
IQ 1W	313	27	283	27
IQ 1E	276	49	293	47
IQ 2E	137	36	151	39
EP C1	269	33	232	33
EP C2	257	38	265	37

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material at the site of a weld, one can test properties of both the exposed and the unexposed geomembrane, i.e., the material that comprises the overlap for the bottom of the weld has not been exposed to UV radiation. Material was sampled from the side slopes and labeled as follows:

- IQ-1E – East above water level
- IQ-2E – East intermittent water coverage
- IQ-1W – West above water level

The other three ponds are evaporation ponds. These ponds take all waste from the plant, mostly brine waste from the brine concentrators. As expected, dissolved solids are very high in these ponds. Two of these are 14-acre (5.67-ha) ponds and the other is 10 acres (4 ha) (the one that was sampled). The 10-acre (4-ha) pond and one of the 14-acre (5.67-ha) ponds are 10 ft. (3 m) deep from the bottom of the liner to the top of the dike. They have 1 ft. (0.3 m) of sand on the bottom that was placed when the liner was installed. Both now have 4 ft. (1.2 m) of salt sludge in them. Raising the sides of the pond recently expanded the third pond by 6 ft. (1.8 m). Samples were taken as from the 10-acre (4-ha) evaporation pond 'C' and labeled as follows:

- EP-C1 – South side above water level
- EP-C2 – West side above water level

Performance

The geomembrane was manufactured in 1980. At that time, the following tests were performed:

- Density — ASTM D 792
- Tensile strength — ASTM D 638, Type IV, 2 ipm (51 mm/min.)
- Tensile elongation — ASTM D 638, Type IV
- Carbon black content — ASTM D 1603

In June 2000, samples of this material were removed and the testing above was performed. The specimens from the three intermediate quality ponds have been averaged together, as have the two specimens from the evaporation ponds for simplification of reporting. For the more critical durability tests such as OIT and NCTL, the individual data are also presented. Unfortunately, the QA/QC certs for this material have been lost throughout the years so the original 1980 test data are not included in the tables. Additional testing, not yet part of routine QA/QC testing some 20 years ago was also performed on this geomembrane. This testing includes:

- Oxidative induction time — ASTM D 3895 (low pressure)
- Oxidative induction time — ASTM D 5885 (high pressure)
- NCTL – ASTM D 5397
- Puncture resistance — ASTM D 4833
- Tear resistance — ASTM D 1004

Table 1 contains the actual test values for exposed material, unexposed material and the current GRI-GM 13 requirements for the above tests. For each of the specimens mentioned previously, samples were tested from two areas for each of the 5 specimens. These samples were taken at the site of a fusion weld, including about 1 ft. of exposed material and at least 6 in. of unexposed material. As part of routine fusion welding for this project, the geomembrane was overlapped at least 6 in. The flap that is on bottom as the two pieces are overlain and welded is not exposed to either the solution in the pond or to UV radiation from the sun. The flap that is on top as the pieces are welded is exposed to both the pond solution and UV radiation (when the water level is down). These samples are labeled in the table as simply exposed and unexposed. The testing for the exposed portion was tested using five replicates for machine and cross direction (where applicable). For the unexposed portion, two specimens were tested. The reason for the variability is that the unexposed flap was narrower in many instances and thus there was less material to test. In order to test as many aspects as possible, the number of specimens per test was reduced.

Photo 1: Three of the eight lined containment ponds: An evaporation pond is pictured on the left side of the photo, while two intermediate quality ponds are visible on the right.

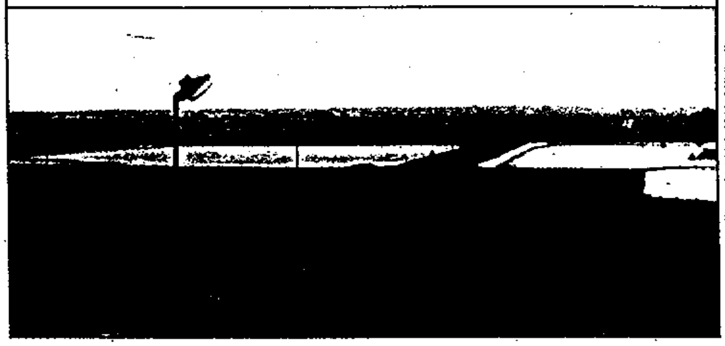


Photo 2: Desiccated soil can be seen beneath a liner sample taken above the water line (an exposed sample).

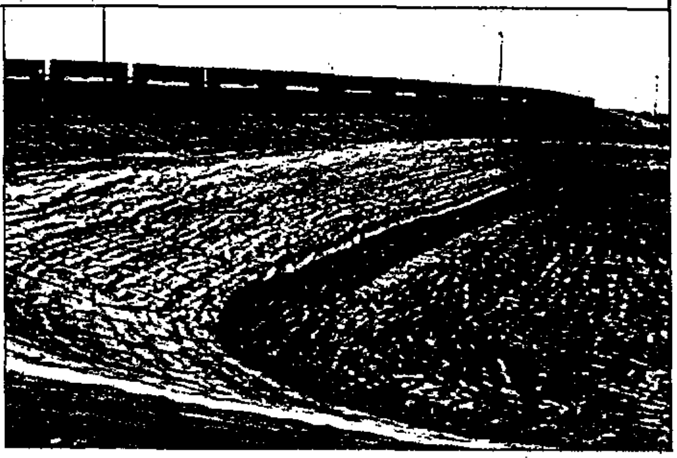
Analysis

Density

There is no apparent change in density. The colored density of 0.945–0.947 g/cc is

Photo 3: A sample taken from an area with intermediate water coverage. The soil is more supple (not desiccated) as can be seen by the footprints.

Photo 4: One of the intermediate quality ponds, drained in preparation for cleaning and sampling.



what would be expected for HDPE geomembranes in production at the time this material was produced and installed.

Tensile values

The specimens that were received for testing contained surface scratches. These abrasions likely reduced the tensile properties somewhat. Even with this being considered, all tensile properties are above what is commonly specified for this industry today. This is to be expected because the geomembrane was not subjected to any chemicals that could be absorbed, affecting tensile properties. Likewise, the individual ponds had similar tensile properties within pond type—no one pond performed especially well or especially poorly.

Carbon black content

Again, these values are likely the same as when the material was first produced. Carbon black cannot leach out of polyethylene over time.

Carbon black dispersion

All specimens had very good (A1 classification) dispersion.

Oxidative induction time

Both high- and low-pressure oxidative induction tests were performed on the exposed and the unexposed material. The average OIT values are contained in Table 1. The OIT values seem to be independent of the type of pond or whether the material was exposed or not. The one exception to this, as can be seen from the individual data below, is IQ 2E. The only apparent difference between IQ 2E and the other ponds is intermittent water coverage.

The current requirement for OIT is 100 and 400 minutes for low-pressure and high-pressure OIT, respectively. However, these numbers are the result of 20 years of improvements in antioxidants and resins. At the time of the manufacture of this material, the typical low-pressure OIT values that could be expected were 50 minutes. Taking this into consideration, it is obvious that the stabilizers are still present and are still doing their job.

SP NCTL

This test was not even conceived when this material was produced. This is currently thought to be one of the best indicators of long-term performance. The average values achieved by this 20-year-old material are still above the common industry requirement of 200 hours. Of the 26 specimens that were tested, only three failed (11.5%) the current industry specification of 200 hours. While some individual specimens broke before 200 hours, others were removed at 667 hours without failure. The variability is wider than would be expected in current-day production. However, surface effects such as oxidation and scratches likely contributed to the variability of the failure times. The average of the five specimens includes the time at which the specimens were removed.

One interesting thing to note about NCTL performance is that both the average and individual readings indicate better NCTL performance for the exposed specimens than for the unexposed specimens. While many of the unexposed specimens were too small to perform SP NCTL, the two specimens for which a comparison is available, IQ 1W and IQ 1E, indicate this. Furthermore, of the exposed specimens, the material in the evaporation ponds demonstrated superior NCTL performance to the material in the intermediate quality ponds. Three of the five evaporation pond specimens did not fail after 667 hours.

Summary

Rigorous modern day testing was performed on 100-mil HDPE exposed for 20 years to wastewater from a steam electric generating station in Colorado. No significant reduction in the primary physical properties was observed (tensile, tear, puncture, carbon black or density). The only testing that indicates some reduction in original properties is OIT testing. Considering how much lower these values were at the time of manufacture as compared to modern day geomembranes, it is obvious that low amounts of antioxidant are still present in this geomembrane. While not at the levels required by current-day standards to ensure protection, they are still at more than half the likely level at the time of manufacture.

This study demonstrates that after 20 years, a geomembrane, depending on the conditions to which it is exposed, can still perform its desired function. Because today's resins, resin stabilizers and manufacturing techniques have improved significantly over the last 20 years, logic would dictate that today's geomembranes will last even longer. GFR

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