# Evaluation of a Leachate Collection System Buried under Class III Waste for over 25 Years

Kadambala, Ravi[1]; Ramana Kari[2]; Hernandez, Manuel[3]; Chris Gabel[4]
*SCS Engineers[1], rkadambala@scsengineers.com, 954-571-9200; Solid Waste Authority[2], rkari@swa.org, 561-640-4000; SCS Engineers[3], mjhernandez@scsengineers.com, 954-571-9200; CDM Smith[4], GabelCJ@cdmsmith.com, 703-691-6430*

**Introduction:** The Solid Waste Authority of Palm Beach County, FL (SWA) owns and operates the Palm Beach Renewable Energy Park (PBREP), which includes a permitted landfill with a 320-acre footprint; of which 250 acres is Class I waste disposal area and the remaining 70 acres is for Class III waste disposal. The PBREP site also contains a refuse derived fuel (RDF) waste-to-energy (WTE) facility and a new mass burn WTE facility that commenced commercial operations in mid-2015. The combination of these WTE facilities drastically reduced the quantity of municipal solid waste (MSW) and Class III waste disposal while significantly increasing the quantity of ash disposal. The increased need for ash disposal in the near future, coupled with the low incoming tonnages of Class III waste prompted SWA to close the Class III landfill in the near future. In 25 years, only a limited amount of waste was added in Cell 8, and the depth of waste varied approximately from 25 to 35 ft. within the Cell. An access road was built within the footprint of Cell 8 and was used for more than 20 years as the main haul road to the active cells of the Class III Landfill. The presence of approximately 50,000 tons of asbestos-contaminated waste and limited waste in Cell 8 prompted relocation of all waste and demolition of the Cell. The relocation of the waste provided a rare research opportunity to study the effects of waste on the leachate collection system (LCS) after 25 years and assess the performance of the system. Most of the research till date on the performance of the LCS components over time has either been of laboratory work making use of accelerated aging tests or modelling techniques (Koerner, et al. 1990; Koerner, et al. 2005; Rowe 2005; and Rowe 2009), however the validity of the results are often challenged. Seldom are we presented with the opportunity to access actual components of LCS that have undergone field exposed conditions. This paper provides a case study for evaluating the performance of the various components of a 25-year old LCS buried under Class III waste.

The Class III waste include yard trash, construction and demolition (C&D) debris, processed tires, asbestos, carpet, cardboard, paper, glass, plastic, furniture other than appliances, or other materials approved by the Florida Department of Environmental Protection (FDEP). The LCS of Class III Landfill Cell 8 was a herringbone design, and consisted of a two (2) feet granular drainage layer, leachate collection pipes surrounded by a gravel pack, a 200 mil geocomposite drainage blanket, a 60 mil high density polyethylene (HDPE) geomembrane and six (6) inches of a compacted clay layer.

**Field Work:** The construction of Class III Cell 8 was completed in 1989 and was operational in 1990. The relocation of Class III waste from Cell 8 was completed during the summer of 2014. The granular drainage layer, gravel and HDPE pipes were sampled and analyzed in fall 2014. The HDPE pipes were also surveyed. Six (6) samples of the gravel and eleven (11) samples of the granular drainage layer were collected from various locations. The samples were collected in standard sand bags as shown in Figure 1 below.

Cell 8 had nine (9) lateral six-inch (6”) diameter perforated leachate collection HDPE pipes which were connected to a six-inch (6”) diameter main header pipe. The leachate from the header pipe drained to a dedicated manhole outside the Cell. The Cell also had six-inch (6”) diameter non-perforated leachate clean-out HDPE pipes. The lateral pipes were surveyed every 100 ft. on top of the pipe using a Real Time Kinematic (RTK) Global Positioning System (GPS).

*A part of the research was done when the authors Ravi Kadambala and Manuel Hernandez were employed with CDM Smith prior to joining SCS Engineers.*

Figure 1 (a). Granular Drainage Layer Samples

Figure 1 (b). Gravel Samples

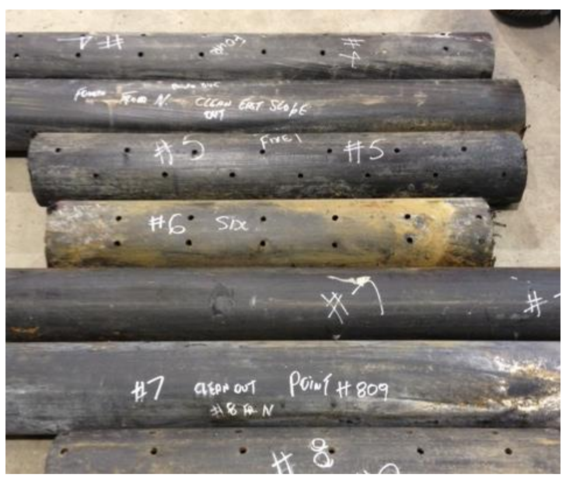


Figure 2. HDPE perforated pipe Samples

The geocomposite and HDPE geomembrane were sampled in Fall 2014 (see Figures 3 and 4), and analyzed in Spring 2015. Six (6) three (3) foot by three (3) foot samples both the geocomposite and HDPE geomembrane were cut using an X-Acto knife as shown below. Two (2) additional HDPE geomembrane samples with extrusion and fusion welding were also collected. Two (2) three (3) foot by three (3) foot samples of the fabric filter used to wrap the gravel around the perforated leachate collection pipe were also collected.

Figure 3(a). HDPE geomembrane Sampling

Figure 3(b). HDPE geomembrane Sampling

Figure 4(a). Geonet Sampling

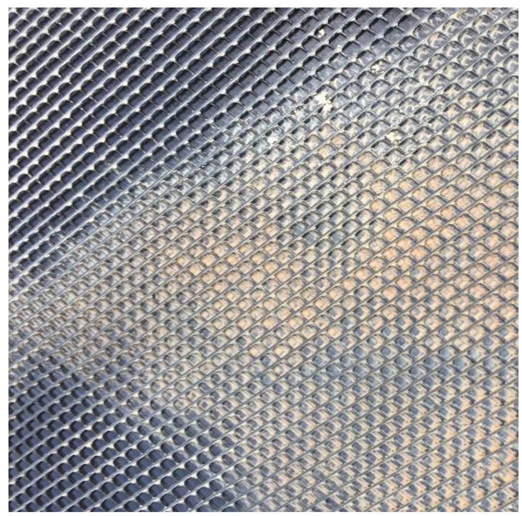

Figure 4(b). Geonet Sampling

**Evaluation Criteria:** The performance of the various components of the Cell 8 LCS system were compared to the design standards of the Florida Administrative Code (FAC) applicable in the year 1989 (Chapter 17-701) as well as the current FAC Rules (Chapter 62-701). Class III landfills in 1989 were exempt from the liner, leachate and gas controls required in FAC Rule 17.701.050(4). SWA was proactive and designed the Class III Cell 8 with a liner system.

Excerpts of the FAC Rule 17.701.050(4) for LCS with liner systems are as follows. The synthetic liner shall consist of at least a reinforced 30 mil membrane or a 60 mil unreinforced membrane that meets minimum requirements of the national Sanitation Foundation standard number 54. The liner shall be protected from physical damage from above and below the membrane, by bedding soil material underlying the liner and a minimum 24 inch thick protective soil layer on top of the membrane; both the bedding and protective layer shall be free of rocks, roots, debris, sharps or particles larger than 1/4 inch. At least a 12 inch drainage layer above the liner shall have a permeability greater than $1x10^{-3}$ cm/sec at a slope to promote drainage. A drainage tile or pipe collection system shall be designed to efficiently remove leachate. Granular material or synthetic fabric filter overlying or surrounding the leachate collection and removal system shall be designed to prevent clogging of the collection system by infiltration of fines from the waste or drainage layer.

Excerpts of the FAC Rule 62.701(400) current for Class III landfills are as follows. A Class III landfill shall be constructed with a bottom liner consisting of a single 60-mil minimum average thickness HDPE geomembrane. The primary leachate collection and removal system shall have a granular drainage layer above the top geomembrane liner, at least 12 inches thick, with a permeability of not less than $1 \times 10^{-3}$ cm/sec, overlain with an additional 12 inches of protective material. The minimum slopes for the collection pipes of the leachate collection system, i.e., lateral and header pipes, shall be 0.3 % after predicted settlement and demonstrate positive drainage.

**Results and Discussion:** The granular drainage layer samples were analyzed by performing sieve analysis (ASTM D422) and a permeability test (ASTM D2434). The permeability test was determined at 95 percent of the maximum dry density per ASTM D1557. Table 1 summarizes the sieve analysis and permeability test results for the granular drainage layer samples.

Table 1. Sieve analysis and permeability test results for granular drainage layer

| Sieve No. | Sample #1 (% passing) | Sample #2 (% passing) | Sample #3 (% passing) | Sample #4 (% passing) | Sample #5 (% passing) | Sample #6 (% passing) | Sample #7 (% passing) | Sample #8 (% passing) | Sample #9 (% passing) | Sample #10 (% passing) | Sample #11 (% passing) | Average of all Samples (% passing) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1-inch | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 3/4-inch | 100 | 99 | 100 | 100 | 100 | 98.9 | 98.1 | 100 | 99 | 100 | 99.l | 98.1-100 |
| 3/8-inch | 99.1 | 96.8 | 97.1 | 98.7 | 99 | 97.2 | 96.9 | 99.2 | 98.1 | 98.9 | 98.4 | 96.9-99.1 |
| #4 | 97.7 | 94.7 | 94.7 | 96.8 | 97.5 | 95.6 | 96.2 | 98.l | 96.4 | 98.l | 97 | 94.7-98.1 |
| #8 | 96.5 | 93.2 | 92.4 | 94.3 | 96.1 | 94.9 | 95.6 | 96.9 | 95.3 | 97.l | 96.2 | 92.4-97.1 |
| #10 | 95.8 | 92.6 | 91.8 | 93.5 | 95.4 | 93.5 | 94.9 | 95 | 94.6 | 96.9 | 95.3 | 91.8-96.9 |
| #16 | 94 | 90.9 | 89.8 | 91 | 94.9 | 93.1 | 93.9 | 92.7 | 93.7 | 96.4 | 94 | 89.8-96.4 |
| #20 | 91.3 | 89.7 | 88.4 | 89.l | 92.3 | 91.3 | 91.5 | 88.8 | 92.5 | 94.7 | 91.6 | 99.4-94.7 |
| #30 | 86.2 | 87 | 85.9 | 84.8 | 87.9 | 82.9 | 82.2 | 86.3 | 88.2 | 90.9 | 84.1 | 82.2-90.9 |
| #40 | 76.l | 77.9 | 79.1 | 73.6 | 73.3 | 72.2 | 65.7 | 76.2 | 72.6 | 79.2 | 71.9 | 65.7-79.2 |
| #50 | 46.2 | 48.5 | 59 | 49.6 | 52.8 | 52.4 | 47.5 | 49.6 | 42.4 | 55.5 | 45.4 | 42.4-55.5 |
| #80 | 25.1 | 20.7 | 30.3 | 22.9 | 21.3 | 27.1 | 17.1 | 30.4 | 13.9 | 25.1 | 12.8 | 13.9-30.4 |
| #100 | 18.3 | 11.9 | 18.3 | 10.7 | 13.6 | 16.6 | 6.8 | 27.2 | 7.1 | 18.8 | 8.3 | 6.8-27.2 |
| #200 | 9 | 9.8 | 9.7 | 9.6 | 7.2 | 15.9 | 6 | 27 | 7.1 | 12 | 5.1 | 5.1-12.0 |
| Hydraulic Conductivity (cm/sec) | $5.05 \times 10^{-3}$ | $5.02 \times 10^{-3}$ | $5.17 \times 10^{-3}$ | $4.71 \times 10^{-3}$ | $4.59 \times 10^{-3}$ | $5.09 \times 10^{-3}$ | $4.98 \times 10^{-3}$ | $5.40 \times 10^{-3}$ | $4.91 \times 10^{-3}$ | $4.54 \times 10^{-3}$ | $4.71 \times 10^{-3}$ | $4.92 \times 10^{-3}$ |

The permeability of the granular drainage layer for all samples were above $1 \times 10^{-3}$ cm/sec, indicating that the sand still meets the requirements of the 1989 and current FAC rules. The granular drainage layer placed directly above the landfill bottom lining system geosynthetics are generally classified as SW or SP in accordance with the Unified Soil Classification System (USCS). The sieve analysis of the granular drainage layer samples can be classified as SM or SC, indicating the expected increase in fines over time.

The gravel samples were analyzed by performing sieve analysis (ASTM D422). Table 2 summarizes the sieve analysis for gravel samples. The results indicate that the gradations of the gravel samples seem to be similar to what was installed. The content of fines in the gravel samples have not increased significantly over time, indicating that the geotextile filter used to wrap the gravel around the pipe performed well, thereby preventing fines from intruding into the gravel layer.

Table 2. Sieve analysis for gravel samples

| Sieve No. | Sample #1 (% passing) | Sample #2 (% passing) | Sample #3 (% passing) | Sample #4 (% passing) | Sample #5 (% passing) | Sample #6 (% passing) | Sample #7 (% passing) | Average of all Samples (% passing) |
|---|---|---|---|---|---|---|---|---|
| **3-inches** | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| **2 1/2-inches** | 90 | 99 | 97 | 90 | 97 | 92 | 93 | 90-99 |
| **2-inches** | 81 | 99 | 96 | 79 | 94 | 84 | 84 | 79-94 |
| **1 1/2 -inches** | 52 | 89 | 74 | 47 | 71 | 64 | 44 | 47-89 |
| **1-inch** | 15 | 52 | 33 | 15 | 25 | 26 | 14 | 15-52 |
| **3/4-inch** | 6 | 25 | 18 | 6 | 6 | 15 | 7 | 6-25 |
| **1/2-inch** | 4 | 12 | 10 | 4 | 4 | 11 | 5 | 4-12 |
| **3/8-inch** | 3 | 9 | 5 | 2 | 1 | 9 | 4 | 1-9 |
| **#16** | 1 | 5 | 1 | 0 | 0 | 5 | 3 | 0-5 |

The HDPE pipe samples were examined visually for print lines, permeation and pitting in the weld bead. The wall thickness of the pipe varied from 0.292-0.641 inches. There were no visible print lines, and no signs of permeation on cut ends before weld on the pipes as shown in Figures 5. The bead on the pipe had good consistency in size with no signs of pitting in the weld bead as also shown in Figures 5.

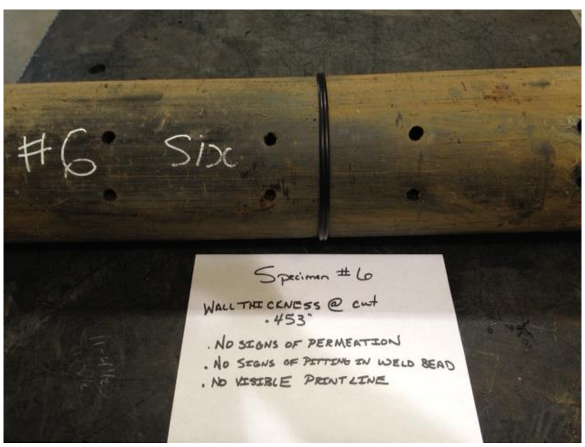


Figure 5(a). Perforated HDPE Pipe


Figure 5(b). Non-perforated HDPE Pipe

The HDPE pipes were generally clean with minimal scaling on the pipe. The perforations looked clean and were not clogged with solid precipitates. SWA routinely water jet cleans the LCS pipes using 4,000 psi pressure. In general, Class III landfills do not generate leachate that can cause biological clogging, and chemical and/or biogeochemical precipitation. A bend-back test was performed on these pipe samples to test for ductility of the pipe. The bend back test performed on the specimen successfully passed as ductile as shown in Figure 6.


Figure 6. Bend back test on perforated HDPE Pipe

A hydrostatic pressure test was performed on non-perforated HDPE pipe samples to test for maximum operating pressures of the pipe using ASTM F2164 as shown in Figure 7. The hydrostatic pressure test of the pipes indicated that it held close to 4 times its working pressure of 80 psi before it failed.


Figure 7. Hydro test on non-perforated HDPE Pipe

Table 3 summarizes the post-settlement slopes of the lateral LCS pipes. The average post-settlement slopes of the pipes were observed to be 0.45%. This exceeds the current FAC requirement of 0.3 % minimum slopes for the LCS pipes after predicted settlement, and it demonstrates positive drainage.

Table 3. Post-settlement slope of the lateral LCS pipes

| | LCS Pipe 1 | LCS Pipe 2 | LCS Pipe 3 | LCS Pipe 4 | LCS Pipe 5 | LCS Pipe 6 | LCS Pipe 7 | LCS Pipe 8 | LCS Pipe 9 | Average |
|---|---|---|---|---|---|---|---|---|---|---|
| **Post-Settlement Slope (%)** | 0.47% | 0.47% | 0.49% | 0.40% | 0.44% | 0.48% | 0.45% | 0.52% | 0.37% | 0.45% |

Figure 8 provides a graphical representation of post-settlement slope of one of the lateral LCS pipes in Cell 8.

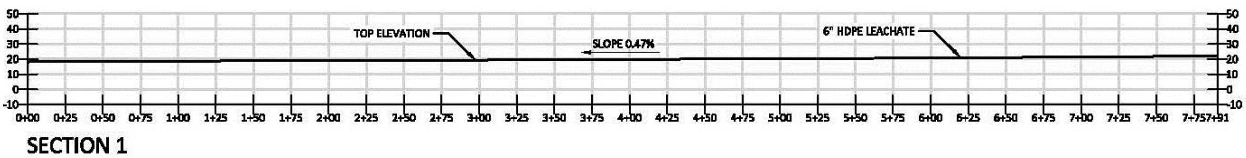


Figure 8. Post-settlement slope of a lateral LCS pipe

The geomembrane samples were tested for thickness (ASTM D5994), density (ASTM D1505), tensile properties (ASTM D6693 Type IV), tear resistance (ASTM D1004), and puncture resistance (ASTM D4833). The results were compared to current 60-mil HDPE geomembrane geosynthetic institute GRI Test method GM-13. Table 4 summarizes the average results of the properties tested. Results indicate that the geomembrane samples exceed all the current 60-mil HDPE geomembrane standards.

Table 4. Properties of the geomembrane samples

| | **Thickness** | | **Strength @ Yield** | | **Strength @ Break** | | **Elongation @ Yield** | |
|---|---|---|---|---|---|---|---|---|
| | Avg. | Min. | MD | TD | MD | TD | MD | TD |
| | (mils) | (mils) | (ppi) | (ppi) | (ppi) | (ppi) | (%) | (%) |
| Sample Properties | 61.84 | 58.9 | 178.8 | 182 | 233.7 | 243.7 | 15.81 | 15.75 |
| GRI GM-13 | Nom. | -10% | 126 | | 228 | | 12 | |
| | **Elongation @ Break** | | **Tear Resistance** | | **Puncture Resistance** | | **Density** | |
| | MD | TD | MD | TD | (lbs) | | (g/cc) | |
| | (%) | (%) | (lbs) | (lbs) | | | | |
| Sample Properties | 661.2 | 701.9 | 55.5 | 55.1 | 150.8 | | 0.9476 | |
| GRI GM-13 | 700 | | 42 | | 108 | | 0.94 | |

The seam properties of the geomembrane samples were tested for shear strength (ASTM D6392) and peel adhesion (ASTM D6392) for both extrusion and fusion welds. The results were compared to current 60-mil HDPE geomembrane geosynthetic institute GRI Test method GM-19. Table 5 summarizes the average results of the properties tested. Results indicate that the geomembrane samples meet and exceed all the current 60-mil HDPE geomembrane standards.

Table 5. Seam properties of the geomembrane samples.

| | | Peel Peel Strength (ppi) | Shear Shear Strength (ppi) |
|---|---|---|---|
| **Sample 1** | **Fusion** | 96.2 | 154.8 |
| **GRI GM-19 (std.)** | **Fusion** | 91 | 120 |
| **Sample 2** | **Extrusion** | 111 | 171 |
| **GRI GM-19 (std.)** | **Extrusion** | 78 | 120 |

The geonet and geotextile were also sampled and are currently being tested in the laboratory. These properties will be reviewed and discussed as a part of a follow-up paper.

**Conclusion:** The resulting test data of the various Class III Cell 8 LCS components tested suggest that the LCS still meet the requirements of the FAC in 1989 as well as current regulations. The results are based on the fact that in 25 years, only a limited amount of waste was added in Cell 8, and the depth of waste varied from approximately 25 to 35 ft. within the Cell. Also, SWA is proactive and performs routine maintenance of their LCS system.

**Acknowledgement:** The authors of this paper would like to acknowledge the contributions of Nathan Mayer, SWA; Dr. Timothy Townsend, University of Florida; and Dr. Daniel Meeroff, Florida Atlantic University. The authors would also like to thank CDM Smith, ISCO pipes and GSE world for their support with testing the samples.

**References:**

- ASTM D422, Standard test method for “Standard Test Method for Particle-Size Analysis of Soils”.
- ASTM D2434, Standard test method for “Standard Test Method for Permeability of Granular Soils”.
- ASTM D5994, Standard test method for “Standard Test Method for Measuring Core Thickness of Textured Geomembranes”.
- ASTM D1505, Standard test method for “Standard Test Method for Density of Plastics by the Density-Gradient Technique”.
- ASTM D6693 Type IV, Standard test method for “Standard Test Method for Determining Tensile Properties of Non-reinforced Polyethylene and Non-reinforced Flexible Polypropylene Geomembranes”.
- ASTM D1004, Standard test method for “Standard Test Method for Tear Resistance (Graves Tear) of Plastic Film and Sheeting”.
- ASTM F2164, “Standard Practice for Field Leak Testing of Polyethylene (PE) and Crosslinked Polyethylene (PEX) Pressure Piping Systems Using Hydrostatic Pressure”.
- ASTM D6392, Standard test method for “Standard test method for “Standard Test Method for Determining the Integrity of Non-reinforced Geomembrane Seams Produced Using Thermo-Fusion Methods”.
- Florida Administrative Chapter Code 62.701 Solid Waste Management Facilities (2015)

- Florida Administrative Chapter Code 17.701 Solid Waste Management Facilities (1989)
- GRI-GM13 Standard specification for "Test methods, test properties, and testing frequency for high density polyethylene smooth and textured geomembranes".
- Koerner, R. M., Halse, Y. G. & Lord, A. E. Jr. 1990. "Long-term durability and aging of geomembranes," Proceedings Waste Containment Systems, R. Bonaparte Editor, Geotechnical Special Publication No. 26, ASCE, pp. 106-134.
- Koerner, R. M., Hsuan, Y. G. & Koerner, G. R. 2005. "Geomembrane lifetime prediction: unexposed and exposed conditions," GRI White Paper No. 6, Geosynthetic Institute, 19 pgs.
- Koerner, R. M., Hsuan, Y. G. & Koerner, G. R. 2005. "Lifetime prediction of exposed geomembranes used in new dam and dam rehabilitation," Proceedings 2nd UK-IGS Symposium, N. Dixon et al. Editors (CD).