High Normal Stress Compression of Geosynthetic Lining System

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ABSTRACT: Currently the primary method of final disposal for most waste is in a landfill. Landfills are being designed to have larger capacities, which results in large vertical stresses that can effect the bottom liner system. The scope of this paper is to take a preliminary look at the effect of high vertical stresses on geosynthetic liner systems.

The primary goal of this investigation was to determine the reduction in transmissivity of the leachate collection system and the effect of high normal stresses on the strength of the geosynthetics.

A compression loading frame capable of maintaining a constant high normal stress was developed for the long-term tests. The samples were tested for 1000 hours, removed, visually inspected, and tensile tested to determine the strength of the materials. Results showed little effect on the strength of the geosynthetics, but a significant reduction in the drainage systems transmissivity.

1 INTRODUCTION

This paper is based on research that was conducted for the Pennsylvania Power & Light Company. The research project was undertaken to evaluate a proposed liner system for a fly ash disposal area, which was expected to experience excessively large vertical stresses. The proposed liner system was developed by PP&L, utilizing EPA guidelines (EPA 1988). In order to evaluate the liner system performance under high normal stresses, two different testing procedures were performed.

The vertical stress was calculated to be 768 kPa (16,000 psf), based on the height and the density of the fly ash. This value does not represent the addition of a factor of safety.

The liner system that was being considered for this facility was a geosynthetic clay liner, a 1.2 mm PVC geomembrane, and a double geonet drainage system with the option for a geotextile between the geonet and the geomembrane. Figure 1 shows the cross-section of the two liner configurations that were being considered.

2 EXPERIMENTAL DESIGN

Two different geomembranes and two different geotextile configurations were being considered for use in the liner system for this facility. Therefore, four different liner systems, shown in Figure 1, were being evaluated to determine the effects of the high normal stress on the performance of the systems.

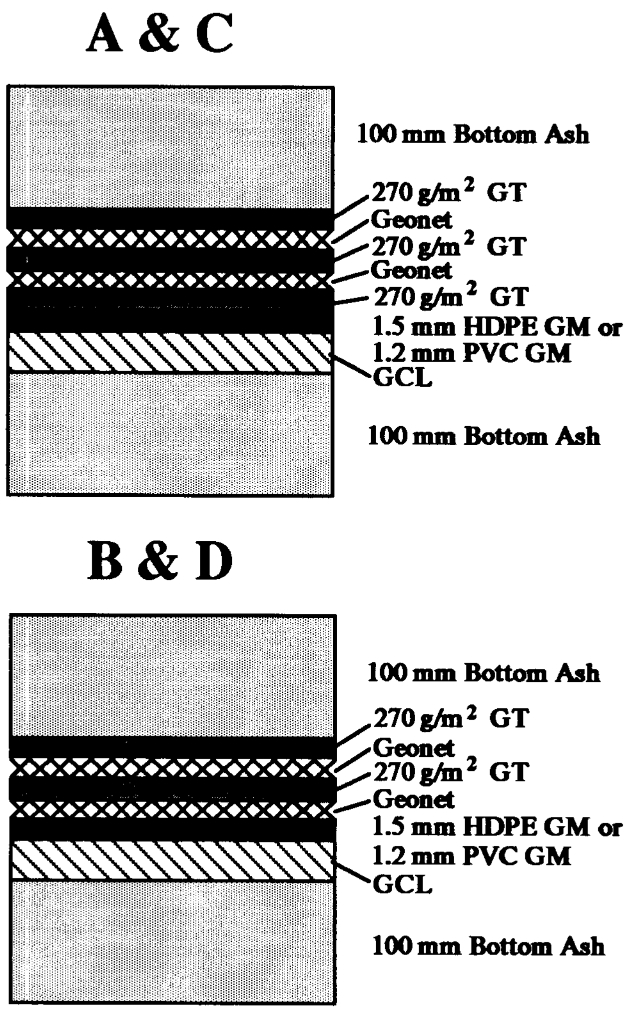

Figure 1 - Liner System Cross-Sections

The evaluation of these liner systems was performed using two different testing methods. The first method was transmissivity (ASTM, 1987). The transmissivity testing was conducted to determine the effect of the high normal stress on the ability of the geonet to transmit fluid. In order to simulate the effect of the geosynthetic clay liner under the geomembrane, a neoprene foam was used. This foam acted as a deformable subbase, much like a hydrated GCL, which allowed for the geomembrane to deform into the geonet. Four hydraulic gradients and three normal stresses were used on 200 mm by 200 mm specimens. Figure 2 shows the cross-section of the transmissivity testing.

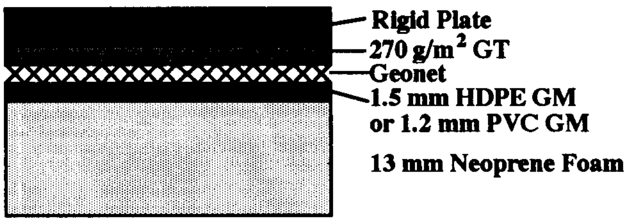

Figure 2 - Typical Transmissivity Cross-Section

The second method of evaluation was compression testing. In order to determine the long term effect of the high normal stress on the liner system, a testing apparatus was developed specifically for this testing. The equipment was designed to impart a constant normal stress on the liner system cross-section. The normal stress was held constant, at 768 kPa, on each of the four different cross-sections for 1000 hours. The compression samples were 300 mm by 300 mm and the four different landfill liner cross-sections were simulated. The four (4) cross-sections were constructed as shown in Figure 1. Each of the liner systems was then disassembled, visually inspected, and the geomembranes were wide width tensile tested to determine strength loss (ASTM, 1988).

The following considerations were taken to evaluate the liner system:

Geomembranes
- 1.5 mm HDPE
- 1.2 mm PVC

Geotextile between the geonet and geomembrane
- none
- 270 g/m² PET

Evaluation tests
- Transmissivity
- Compression

3 HDPE GEOMEMBRANE TESTS

The testing of the HDPE geomembrane in conjunction with the geonet was first done to determine the effect of the intrusion of the geomembrane into the geonet or compression of the geonet. The testing was conducted up to the required normal stress of 768 kPa, and Figure 3 shows graphically the reduction in transmissivity of this system under increasing normal stress. This general trend was also seen in research that was presented in Designing with Geosynthetics. (Koerner, 1994)

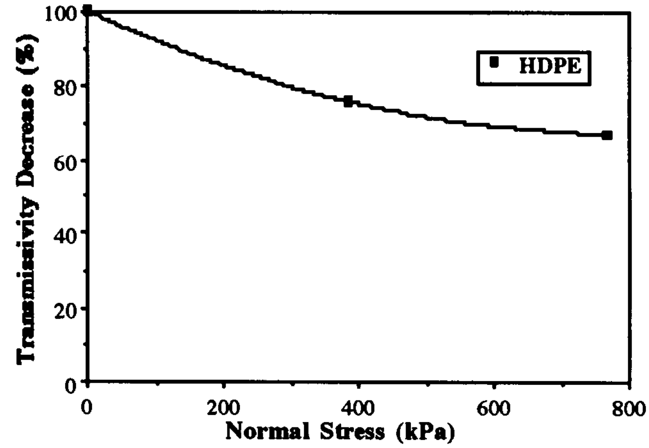

Figure 3 - Decrease in Transmissivity vs. Normal Stress - HDPE Geomembrane

It can be seen from the graph that the transmissivity is decreasing under increasing normal stress. The graph does not show if the HDPE has intruded into the net, or if the net had been compressed. Upon removing the components from the transmissivity device, it could be seen that the HDPE did not significantly intrude into the geonet. No markings or indentations from the geonet could be seen on the HDPE.

The second set of tests were the compression tests, which were tested for 1000 hours.

The testing equipment was set-up to constantly read the applied stress to the system. The load was constantly adjusted, through a hydraulic regulator, to maintain the required stress, which was necessary due to stress relaxation of the liner system.

After 1000 hours, the tested liner systems were disassembled and visually inspected. The description of the visual inspections are listed below.

• Cross-section A - HDPE Geomembrane with Geotextile

The top geotextile was not damaged by the course aggregate in the bottom ash. The geotextile was intruded into the top geonet.

The top geonet had experienced roll-over of the ribs, which would have decreased the thickness of the net and it's ability to transmit fluid.

The middle geotextile was "quilted", and had intruded into both the top and bottom geonets.

The bottom geonet had experienced roll-over of the ribs, which would have decreased the thickness of the net and it's ability to transmit fluid.

The bottom geotextile had intruded into the bottom geonet.

The HDPE geomembrane had been very slightly imprinted by the geonet, with the geotextile acting as a protective layer.

The GCL was very stiff after 1000 hours. The GCL was cut for observation purposes, and it was seen that the bentonite had hydrated slightly and consolidated into a perfectly even cross-section. The moisture content of the bottom ash at the beginning of the test was 9.1%, and at the end of the test it was 8.3%. Suggesting that the GCL had absorbed enough water to obtain an equilibrium at that stress level. The GCL also had indentations on the bottom from the larger particles in the bottom ash.

• Cross-section B - HDPE Geomembrane without Geotextile

Same as A, except as follows:

The HDPE geomembrane had slightly intruded into the geonet, more than the geotextile protected system listed in cross-section A. It did not appear that the HDPE had intruded into the bottom geonet.

After the 1000 hour test was completed, the geomembrane samples were removed and then wide width tested for tensile strength. The samples were cut to the required 200 mm by 200 mm specimen size. In addition wide width tensile tests were also performed on undisturbed specimens. This was done to obtain control values to compare the wide width tensile results of the long-term compression geomembranes. These results are shown in Table 1.

Table 1 - Wide Width Tension Testing Results
HDPE Geomembrane values @ Yield

	Strength (MPa)	Strain (%)
HDPE Control	**17**	**23**
HDPE w/GT	**19**	**15**
HDPE w/o GT	**18**	**35**

No trends can be drawn from these results since the data is so sparse. More testing is required to determine the effect of the high normal stress on the liner system.

4 PVC GEOMEMBRANE TESTS

The testing of the PVC geomembrane in conjunction with the geonet was done to determine the effect of the intrusion of the PVC geomembrane into the geonet. The testing was conducted up to the required normal stress of 768 kPa, and Figure 4 shows graphically the reduction in transmissivity of this system under increasing normal stress.

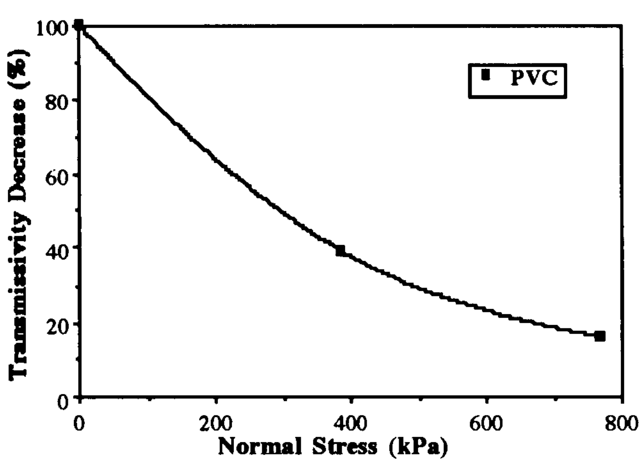

Figure 4 - Decrease in Transmissivity vs. Normal Stress - PVC Geomembrane

It can be seen from the graph that the transmissivity is decreasing under increasing normal stress. Upon removing the components from the transmissivity device, it could be seen that the PVC had severely intruded into the geonet. The PVC had been drastically scarred by the geonet.

The second set of tests were the compression tests, which were tested for 1000 hours.

The testing equipment was set-up to constantly read the applied stress to the system. The load was constantly adjusted, through a hydraulic regulator, to maintain the required stress, which was necessary due to stress relaxation of the liner system.

After 1000 hours, the tested liner systems were disassembled and visually inspected. The description of the visual inspections are listed below.

• Cross-section C - PVC Geomembrane with Geotextile

The top geotextile was not damaged by the course aggregate in the bottom ash. The geotextile was intruded into the top geonet.

The top geonet had experienced roll-over of the ribs, which would have decreased the thickness of the net and it's ability to transmit fluid.

The middle geotextile was "quilted", and had intruded into both the top and bottom geonets.

The bottom geonet had experienced roll-over of the ribs, which would have decreased the thickness of the net and it's ability to transmit fluid.

The bottom geotextile had intruded into the bottom geonet.

The PVC geomembrane had been impregnated by the geonet, with the geotextile acting as a protective layer. The PVC was impregnated, through the geotextile, only by the ribs in contact with the geomembrane. The PVC was also embedded into the underlying GCL, which essentially made the two products into a single material. The PVC was difficult to peel away from the GCL, but upon separating the two products, it was observed that the underside of the PVC was also imprinted by the woven geotextile that makes up the top layer of the GCL.

The GCL was again very stiff, and had been intruded into by the PVC and geonet. The GCL was cut for observation purposes, and it was seen that the bentonite had hydrated slightly and consolidated into a perfectly even cross-section. The moisture content of the bottom ash at the beginning of the test was 9.1%, and at the end of the test it was 8.3%. Suggesting that the GCL had absorbed enough water to obtain an equilibrium at that stress level. The GCL also had indentations on the bottom from the larger particles in the bottom ash.

• Cross-section D - PVC Geomembrane without Geotextile

Same as C, except as follows:

The PVC geomembrane had been severely impregnated by the geonet, by both ribs of the geonet, more than the geotextile protected system listed in cross-section 3. The PVC was embedded into the underlying GCL, which essentially made the two products into a single material. The PVC was difficult to peel away from the GCL, but upon separating the two products, it was observed that the underside of the PVC was also imprinted by the woven geotextile that makes up the top of the GCL.

After the 1000 hour test was completed, the geomembrane samples were removed and then wide width tested to determine the tensile strength of the PVC. The samples were cut to the required 200 mm by 200 mm specimen size. In addition, wide width tensile tests were also performed on undisturbed specimens. This was done to obtain control values to compare the wide width tensile results of the long-term compression geomembranes. These results are shown in Table 2.

Table 2 - Wide Width Tension Testing Results
PVC Geomembrane values @ Break

	Strength (MPa)	Strain (%)
PVC Control	**15**	**430**
PVC w/GT	**15**	**360**
PVC w/o GT	**15**	**350**

No trends can be drawn from these results since the data is so sparse. More testing is required to determine the effect of the high normal stress on the liner system.

5 - CONCLUSIONS AND RECOMMENDATIONS

It is recommended that further testing be performed to gather more information about the behavior of geosynthetic liner systems under high normal stresses.

Based on the results from the testing program described, several conclusions and recommendations are drawn:

1. The transmissivity under the high normal stress showed significant reduction in all four liner systems tested. Nevertheless, they all retained flow capability. Further study of the effect of the long term compressive loading is recommended.

2. Based on the visual evaluation of the long-term test samples, the HDPE geomembrane, both with and without geotextile protection, received little impregnation from the geonet under the high normal stresses. The PVC geomembrane received significant impregnation, especially the sample without the geotextile protection.

3. Based on the final wide width tensile test results, all of the geosynthetic materials showed no strength reduction after 1000 hours of high normal stress compression. However, the PVC geomembrane, in both cases, showed a 20% reduction in terms of the failure strain, as compared to the control specimens. It is recommended to extend the time of compression loading up to 10,000 hours in order to better quantify the effect of the liner system under high normal stress.

REFERENCES

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