Assessment of a PVC Geomembrane Used in a Landfill Cover System

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ABSTRACT: A polyvinyl chloride (PVC) geomembrane was used in combination with a geosynthetic clay liner (GCL) as a composite barrier in the cover system for the final closure of a paper mill sludge landfill. The landfill contained very compressible and low shear strength wastewater treatment sludge materials. During placement of a vegetative cover soil layer over an installed cover system panel, localized bearing capacity failure of the underlying sludge material occurred. As a result, the geosynthetics settled up to 2.4 m in a certain area. Geomembrane samples with and without seam were taken from the affected area for laboratory tests. The test results indicated that the mechanical properties of the geomembrane and seam exceeded the minimum requirements of the project specifications and were within the range of conformance test results. These results confirmed that PVC geomembranes are suitable for landfill cover system applications where settlement of the underlying waste may result in large stresses and strains in the geomembrane cover system.

1 INTRODUCTION

The purpose of this paper is to present the performance of a PVC geomembrane during construction of a final cover system for a highly compressible sludge landfill. The PVC geomembrane was selected on the basis of its mechanical properties, in particular its ability to tolerate large settlements. During construction of the final cover system, construction equipment caused large settlements of a portion of the installed cover system including the geomembrane. There was therefore concern over the integrity of the geomembrane. The results of the laboratory tests performed on the affected geomembrane and seam are presented and compared with the project specifications and results of conformance tests performed as part of construction quality assurance monitoring.

2 HISTORY OF THE LANDFILL

The landfill was constructed in 1974 for the disposal of wastewater treatment plant primary and secondary sludges, coal ash, and lime mud, which were waste byproducts of the pulp and paper manufacturing process. These waste byproducts, when combined, were typically fully saturated, with water contents in excess of 200 percent and shear strengths that ranged from 1 to 10 kPa. The sludges were very compressible and generated considerable leachate through consolidation under self-weight. Results of laboratory consolidation tests indicated that the modified compression index, $C_{C\epsilon}$, for the sludge was in excess of 0.30. The sludge had a very low bearing capacity because of its low shear strength. This had a direct impact on disposal operations and construction of the cover system for final closure of the facility.

The landfill covered approximately 10 hectares and had been developed by constructing a 15-m high embankment at the mouth of a small ravine to create the space for sludge disposal. The maximum depth of sludge in the landfill occurred at the lowest elevation of the ravine and was approximately 15 m; the average depth of sludge was about 9 m. In 1990, an innovative cover system that incorporated eight layers of geosynthetics was designed for final closure of the landfill facility. Construction of the final cover system began in June 1992 and was completed in January 1993 (Badu-Tweneboah et al., 1994).

3 FINAL COVER SYSTEM COMPONENTS

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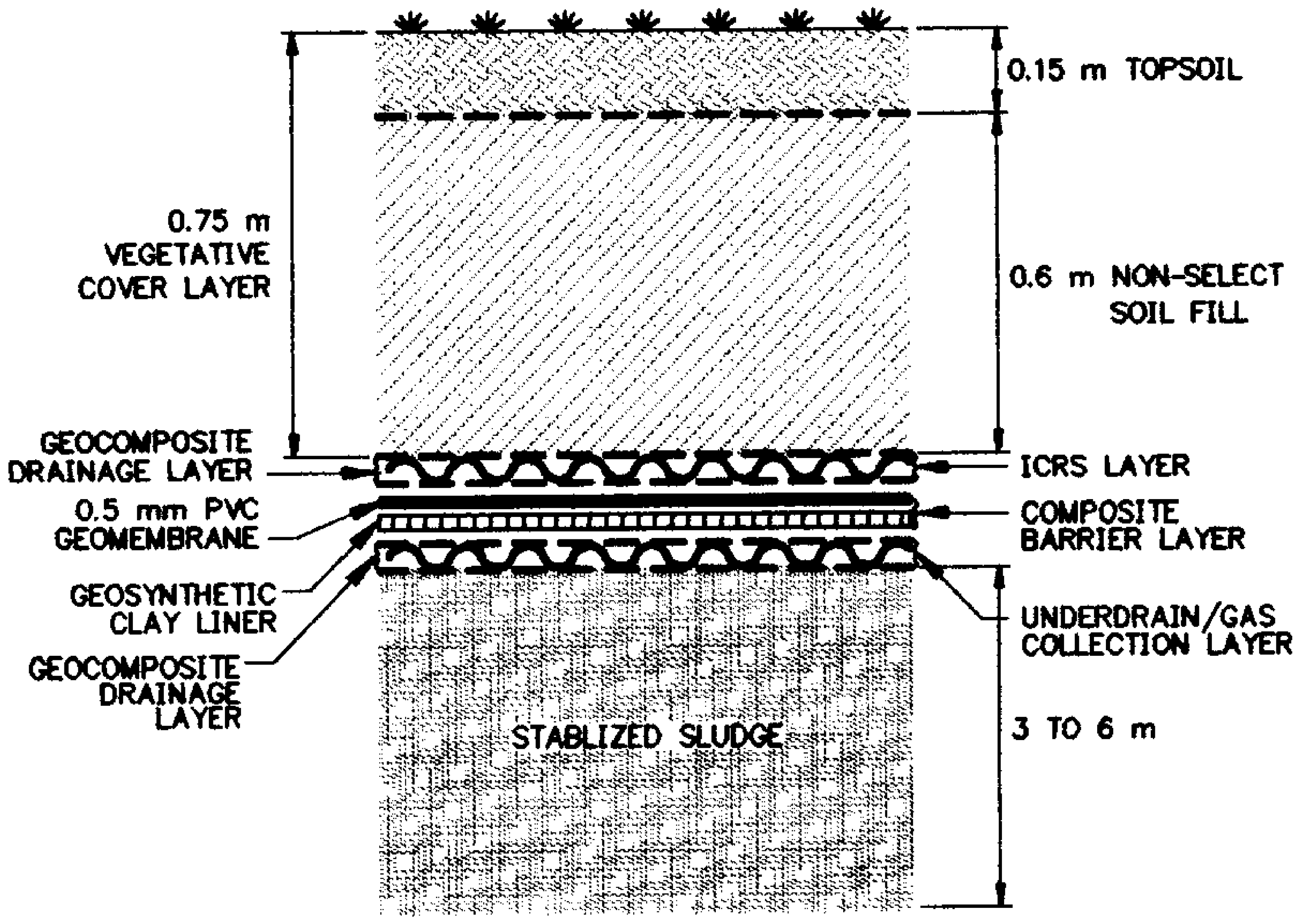

Fig. 1 Final cover system profile.

cover was to support vegetation as well as protect the underlying layers from root penetration and frost damage. The geocomposite drainage layer immediately below the vegetative cover layer served as an infiltration collection and removal system (ICRS) for the control of precipitation that infiltrated through the vegetative cover layer. The composite barrier consisted of a 0.5-mm thick PVC geomembrane placed on top of a GCL. The purpose of the composite barrier was to: (i) minimize leakage of precipitation into the landfill, thereby minimizing the rate and quantity of leachate generation; (ii) minimize upward migration of leachate out of the landfill; and (iii) reduce the volume and rate of gas discharged to the atmosphere through the final cover system. Below the composite barrier was a geocomposite layer that served as an underdrain layer for the collection and removal of leachate expelled from the sludge due to consolidation caused by placement of the final cover system and by self-weight. This underdrain layer also served as a gas collection layer for the control of gas migration from the landfill.

Each of the two geocomposite drainage layers consisted of a layer of geonet placed between two needlepunched nonwoven geotextile layers. The geotextiles functioned as filters and/or separators.

The geosynthetics were used as the major components of the cover system in lieu of conventional earthen construction materials in order to reduce the vertical stress applied to the sludge, thereby decreasing the total settlement and the volume of leachate generated due to consolidation of the waste.

To facilitate placement of the vegetative cover soil and to support the weight of construction equipment, a 3-m to 6-m thick layer of stabilized sludge was placed above the in-place sludge. The stabilized sludge consisted of sludge mixed with bark and fly ash to provide a minimum undrained shear strength of 24 kPa (Badu-Tweneboah et al., 1994). Construction specifications required the use of low ground pressure dozers with a maximum ground pressure of 34 kPa for placement of the 0.75 m vegetative cover soil layer.

4 PVC GEOMEMBRANE INSTALLATION

The PVC geomembrane rolls were factory-fabricated into 40 panels with a width of 21 m. The total area of the PVC geomembrane installed over the landfill was measured to be 102,680 m^2. A total of 14 samples were retrieved from the 40 fabricated panels for laboratory conformance testing. The results of the conformance tests were compared with the project specifications to ensure conformance with the material property requirements.

Adjacent PVC geomembrane panels were bonded in the field using a solvent-adhesive welding technique. The completed PVC geomembrane seams were visually examined for workmanship and continuity. Nondestructive and destructive tests were performed to evaluate the integrity of the field seams. The air lance testing method was used to nondestructively test the field seams in order to evaluate their continuity. Laboratory destructive testing was performed to evaluate the strength of the field seams. Testing was performed to determine the bonded seam strength and peel adhesion using the test methods provided in ASTM test standards (ASTM, 1991). The overlying layers were immediately installed after acceptable results had been obtained for the field seams.

5 PLACEMENT OF COVER SOIL

Low ground pressure dozers were used to place the 0.75-m thick layer of vegetative cover soil over installed panels. The cover soil materials were hauled from the landfill perimeter and spread over the installed geosynthetics using the low ground pressure dozers. It was necessary to use closed portions of the landfill as haul roads to facilitate placement of cover soil in other areas. As a result, closed portions were subjected to repeated loading from the combined weight of construction equipment and cover soil materials which subsequently led to pumping of the subgrade. Pumping of the very low shear strength, fully saturated sludge into the stabilized sludge layer progressively reduced the shear strength of the stabilized sludge layer. This led to the development of localized bulges, and at times placement of excessive thickness of soil (Badu-Tweneboah et al., 1994). Placement of excessive thickness of soil caused immediate settlement, which was difficult to observe because the depressed (i.e., settled) area was filled immediately with soil as the dozer trafficked the area with cover soil.

As a result of placement of excessive thickness of soil, localized bearing capacity failure of the underlying subgrade material occurred in a 60-m long by 18-m wide area of an installed panel; this area is hereafter referred to as the affected area (Fig. 2).

Fig. 2 A view of the localized bearing capacity failure caused by placement of excessive thickness of soil.

6 FAILURE INVESTIGATIONS AND CORRECTIVE ACTIONS

Test holes were excavated to determine the thickness of cover soil placed over the geosynthetics in the affected area. Fig. 3 shows a profile of the thickness of cover soil and settlement of the geosynthetics.

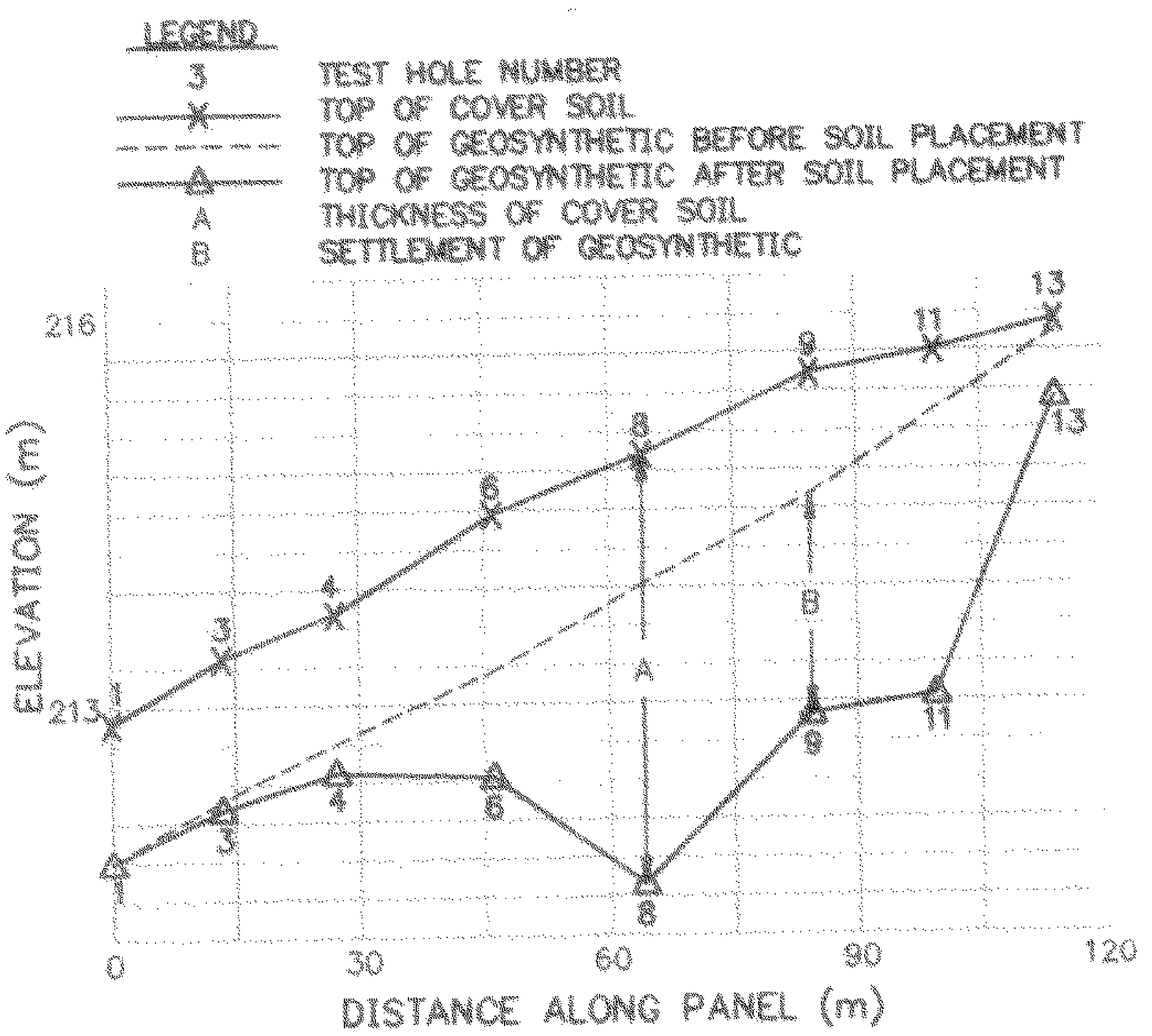

Fig. 3 Profile showing thickness of cover soil and settlement of geosynthetics in the affected area.

The figure shows that up to 3.7 m of soil was placed in one area. The 3.7 m of cover soil corresponded to an applied stress of about 70 kPa, which greatly exceeded the design strength of the stabilized sludge subgrade. The settlement of the geosynthetics in the affected area was determined to range from 0.10 to 2.4 m.

A backhoe and hand shovels were used to remove the cover soil in the affected area to allow the underlying geosynthetics to be examined for damage or seam separation (Fig. 4).

Fig. 4 Removal of cover soil for inspection of geosynthetics for damage or seam separation.

It was observed that the cohesive nature of the cover soils caused them to stick to the top geotextile component of the ICRS geocomposite drainage layer. These geosynthetic layers were therefore damaged during the cover soil removal process. The geomembrane showed signs of tension in the form of lateral wrinkling but had no tears, scratches, or separated seams, except for few locations which were torn by the backhoe. However, the underlying geosynthetics, particularly, the GCL were observed to have had seam separation.

The affected area was subsequently repaired by: (i) removing all cover soil and geosynthetics; (ii) restabilizing the sludge with bark and regrading the surface; and (iii) reinstalling the cover system using new geosynthetic materials. Placement of the cover soil over this area was performed using low ground pressure dozers much smaller than those used in the initial stages of construction. Additional grade control measures were instituted to ensure that not more than the required 0.75 m of cover soil was placed over the installed geosynthetics.

7 INTEGRITY OF PVC GEOMEMBRANE

In the area where localized bearing capacity failure occurred, a sample from the PVC geomembrane parent material and a sample from the adjacent field seam were taken for laboratory conformance testing to evaluate the integrity of the geomembrane material and field seam. Testing was performed in accordance with ASTM test standards (ASTM, 1991). The results of the laboratory testing are summarized in Tables 1 and 2.

Table 1 Summary of PVC geomembrane property values.

PROPERTY	UNITS	PS[a]	CTR[b] MIN.	CTR[b] MAX.	FSTR[c]
Thickness (ASTM D 1593)	mm	> 0.48	0.49	0.73	0.50
Specific Gravity (ASTM D 792)	-	> 1.20	1.29	1.30	1.30
Tensile strength (ASTM D 882)	kN/m	> 8 (RD[d]) > 8 (XD[e])	8.6 8.2	14.2 (RD) 13.5 (XD)	9.5 (RD) 9.6 (XD)
Strain at break (ASTM D 882)	%	> 300 (RD) > 300 (XD)	362 362	490 (RD) 527 (XD)	414 (RD) 490 (XD)
Modulus of Elasticity at 100% Strain (ASTM D 882)	kPa	> 6900 (RD) > 6900 (XD)	8,810 8,810	11,010 (RD) 10,180 (XD)	10,445 (RD) 9,240 (XD)
Tear Resistance (ASTM D 1004)	N	> 27 (RD) > 27 (XD)	35.6 35.6	58.3 (RD) 55.2 (XD)	38.7 (RD) 40.9 (XD)

[a] PS = project specifications.
[b] CTR = conformance test results.
[c] FSTR = field sample test results.
[d] RD = roll direction.
[e] XD = cross roll direction.

Table 2 Summary of PVC geomembrane field seam property values.

PROPERTY	UNITS	PS[a]	FSTR[b]
Bonded Seam Strength (ASTM D 3083)	kN/m	> 6.4	8.2
Peel Adhesion (ASTM D 413)	kN/m	> 1.75 or FTB[c]	2.56

[a] PS = project specifications.
[b] FSTR = field sample test results.
[c] FTB = film tearing bond.

Table 1 presents a summary of the results of tests on the physical and mechanical properties of the PVC geomembrane field sample compared with the project specifications and conformance test results. These results indicate that the mechanical properties of the PVC geomembrane which was subjected to the loading from the 3.7 m of cover soil still exceeded the minimum requirements of the specifications and were within the range of conformance test results obtained from the geomembrane panels. Even though visual observations indicated signs of tension in the geomembrane, its mechanical properties were still within the range of conformance test results.

Table 2 presents a similar comparison of the PVC geomembrane field seam sample with the project specifications. Again, the mechanical property values of the field seam sample exceeded the specifications.

Based upon the results of the laboratory testing and comparison with the specifications, it was concluded that the integrity of the PVC geomembrane had not been affected by the stresses imposed by the loading from the 3.7 m of cover soil. These results confirmed that PVC geomembranes are suitable for landfill cover system applications where settlement of the underlying waste may result in large stresses and strains in the geomembrane cover system.

8 CONCLUSIONS AND RECOMMENDATIONS

The performance of a PVC geomembrane subjected to excess loading during construction of a final cover system over a very compressible, low shear strength waste material has been presented in this paper. Results of laboratory tests and comparison with the specifications and conformance test results showed that the PVC geomembrane and field seam were not impacted enough by the large stresses and strains imposed by the excess loading caused during construction to affect the integrity of the geomembrane. Therefore, PVC geomembranes are acceptable for construction over very compressible, low shear strength waste materials. To facilitate construction, however, stabilization of the upper few meters of the waste material may be required. Also, proper placement of cover soil may be necessary in order to minimize the development of bulges and localized bearing capacity failure. This can be accomplished by using lightweight equipment.

REFERENCES

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