Performance of nonwoven geotextiles as protective layers for HDPE and PVC geomembranes

Geroto, R. E.
Escola de Engenharia de São Carlos, USP, São Carlos, Brasil
Vilar, O. M.
Escola de Engenharia de São Carlos, USP, São Carlos, Brasil

Keywords: protective layers, geomembrane, geotextile, lining systems, puncture tests.

ABSTRACT: The efficiency of geomembranes as lining systems is directly related to its integrity. In bottom liner systems, such as those used in landfills, geomembranes can get into contact with sharp materials, such as gravel of the drainage system. As a result, excessive deformation and holes can arise. To prevent geomembrane damage, nonwoven geotextiles are usually applied as protective layers. This paper deals with the performance of Polyester (PET) and Polypropylene (PP) nonwoven geotextiles as protective layers for Polyvinyl Chloride (PVC) and High Density Polyethylene (HDPE) geomembranes. This experimental program used 1.0 and 2.0 mm thick PVC and 1.5 and 2.0 mm thick HDPE geomembranes, PET and PP needlepunched nonwoven geotextiles with varying masses per unit area. The tests were conducted using hydrostatic puncture testing apparatus with truncated cones of 25 and 38 mm critical height (Hc) and subangular stones of 37 mm height as subgrade. The geosynthetics puncture resistance over test bases was measured and geomembrane failure mechanisms have been analyzed to understand the influence of geotextiles properties in the increasing of geomembrane/protective layer performance against puncture. The results showed that nonwoven geotextiles with the same unit weight, but manufactured with different types of polymers and needle densities, can exhibit different performances. The hydrostatic puncture tests on HDPE and PVC geomembranes were compared and indicate that these materials have different failure mechanism.

1 INTRODUCTION

The use of geomembranes as low permeability barriers systems in environmental applications has been continuously increasing due to their characteristics such as low permeability, installation easiness, besides their good chemical, biological and mechanical resistance.

According to Reddy & Butul (1999), geomembranes during their useful life are subjected to short term punching efforts caused by the fall of objects, machinery traffic and contact with grained materials, and long term damages that occur during the phase of landfill operation with overlying loads of deposited residues.

In order to minimize or restrict geomembrane stress which may compromise their integrity as a barrier, protective layers such as needlepunched nonwoven geotextiles must be employed.

The measurement of the performance of protective layers for High Density Polyethylene (HDPE) geomembranes, has been based on the methodologies proposed by Narejo, Koerner & Wilson Fahmy (1996) and guidelines developed by Federal Institute for Materials Research and Testing (BAM), presented by Seeger & Muller (1996), while the research presented by Stark, Boerman & Connor (2008) evaluated the performance of protective layers for Polyvinyl Chloride (PVC) geomembranes.

However, the measurement and definition of an acceptable limit state in relation to the effectiveness of the protective layers is a topic of concern among specialists.

This study is based on hydrostatic puncture tests and is intended to evaluate the performance of Polyester (PET) and Polypropylene (PP) needlepunched nonwoven geotextiles and the factors inherent to the selection of these materials when used as protective layers for the HDPE and PVC geomembranes.

2 MATERIALS AND METHODS

2.1 *Geosynthetics*

In this study, 1.5 and 2.0 mm thick HDPE geomembranes and 1.0 and 2.0 mm thick PVC geomembranes were used. The protective systems have been conceived as PET and PP short fiber needlepunched nonwoven geotextiles. The masses per unit area of PET geotextiles were 150, 300, 400 and 600 g/m², while for the PP it was 600 g/m² besides a configuration with a double layer of PP with mass per unit area of 600 g/m² each.

The results of needlepunched nonwoven geotextiles index tests are presented in Table 1.

Table 1. Nonwoven geotextiles properties.

Properties		Units	Geotextile				
			PET150	**PET300**	**PET400**	**PET600**	**PP600**
Mass per unit area		g/m²	168.3	293.2	353.2	576.4	593.2
Thickness		mm	1.58	2.50	2.19	3.36	4.62
CBR Puncture		kN	0.98	1.82	2.67	3.79	5.06
		mm	51.37	58.85	50.67	58.05	56.45
Tensile Strength	MD	kN/m	7.05	9.94	10.92	21.96	21.87
		%	68.95	93.49	73.64	77.68	82.18
	XMD	kN/m	6.79	13.24	21.60	26.70	37.20
		%	98.53	92.56	55.40	75.64	62.33

Table 2 shows the results of index tests performed with HDPE and PVC geomembranes.

Table 2. Geomembranes properties.

Properties		Units	Geomembrane			
			HDPE 1.5	**HDPE 2.0**	**PVC 1.0**	**PVC 2.0**
Thickness		mm	1.517	1.948	1.009	1.918
Density		g/m³	0.949	0.947	1.320	1.295
Puncture Resistance		N	709.80	744.00	314.80	559.60
		mm	19.20	12.49	23.02	22.48
Yield Tensile Strength	MD	kN/m	32.47	36.26	-	-
		%	15.52	16.41	-	-
	XMD	kN/m	34.76	38.56	-	-
		%	14.25	15.55	-	-
Break Tensile Strength	MD	kN/m	48.72	60.30	16.89	29.95
		%	790.70	766.90	394.20	474.50
	XMD	kN/m	47.29	57.19	13.83	27.07
		%	784.90	784.80	364.60	482.20

2.2 *Apparatus*

In order to evaluate the development of needlepunched nonwoven geotextiles as protective layers and the geomembrane behavior in face of the punching stresses, a set of hydrostatic puncture tests have been carried out, according to the standard test method, ASTM D 5514.

This test is carried out in a 500 mm diameter circular pressure vessel with truncated cones or natural materials (subangular stones) placed on the base of the chamber and the geomembrane is positioned over these elements. In this study tests have been carried out with truncated cones with an exposed height (Hc) of 25 mm and 37 mm and a variation with the employment of natural materials composed of sharp pointed and lamellar stones with 37 mm height.

The hydrostatic puncture tests is performed by applying a hydrostatic pressure on the geomembrane surface at a rate of 15 kPa per minute, until the rupture of the element or until reaching a 1800 kPa limit pressure. Figure 1 shows the truncated cones in circular pressure vessel.

Figure 1. Truncated cones in pressure vessel.

The arrangement with subangular stones used as alternative test, in circular pressure vessel, is presented in Figure 2.

Figure 2. Subangular stones in pressure vessel.

3 RESULTS

The results of hydrostatic puncture tests (failure pressures) for a 1.0mm thick PVC geomembranes are presented in Figure 3.

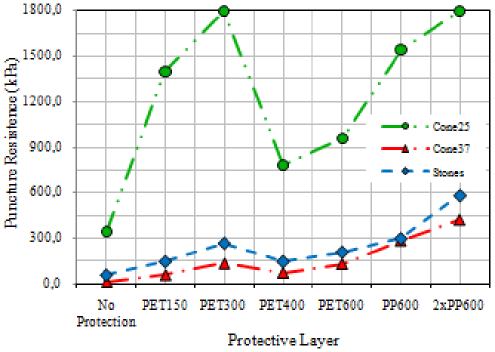

Figure 3. Performance testing for 1.0mm thick PVC GM.

The results of hydrostatic puncture tests (failure pressures) for a 2.0mm thick PVC geomembranes are presented in Figure 4.

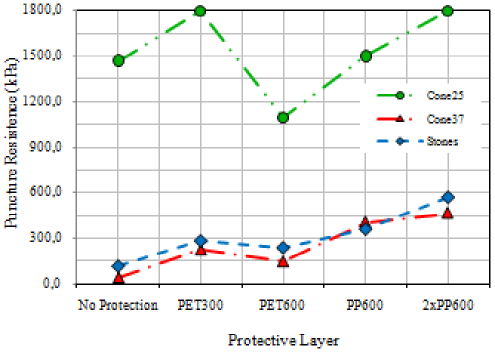

Figure 4. Performance testing for 2.0mm thick PVC GM.

The results of hydrostatic puncture tests (failure pressures) for a 1.5mm thick HDPE geomembranes are presented in Figure 5.

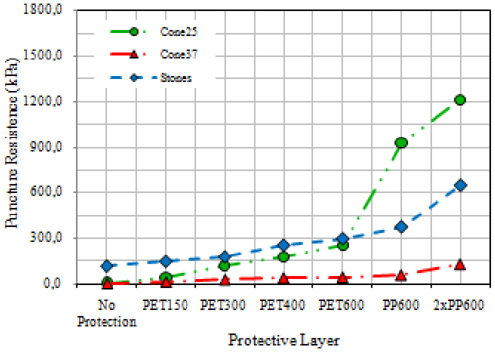

Figure 5. Performance testing for 1.5mm thick HDPE GM.

The results of hydrostatic puncture tests (failure pressures) for a 2.0mm thick HDPE geomembranes are presented in Figure 6.

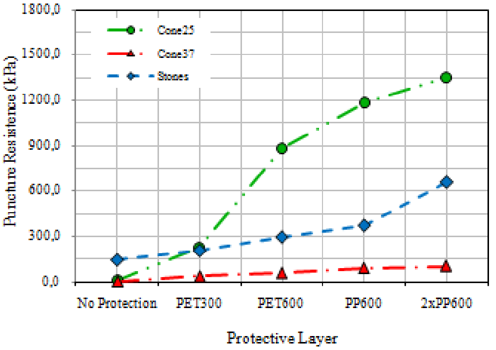

Figure 6. Performance testing for 2.0mm thick HDPE GM.

4 COMMENTS

Based on the results of the hydrostatic puncture tests it was verified that the use of needlepunched nonwoven geotextiles as protective layers provided a resistance increment to the PVC and HDPE geomembranes. Results also have showed that the more flexible PVC geomembranes performed better when compared to HDPE geomembranes in face of puncture stresses.

In the truncated cones tests, it was possible to observe that the PVC geomembranes, when subjected to gradual hydrostatic loading, has deformed coating the cone region and providing a better distribution of the tensions acting on their surface. In the case of HDPE geomembranes, it was verified that they slightly deformed during the loading stage. Thus a large concentration of tension has arisen on the contact point of the geomembrane surface with cone tip and the failure of the element was observed at relative low pressures.

It was also verified that PVC geomembrane fails only after the rupture of the protective layer, and, consequently, with the direct contact of the geomembrane with the cone. As far as the HDPE geomembrane is concerned, it was verified that rupture occurred regardless of the rupture of the protective layer. Those features suggest, a better performance of the more flexible geotextiles to protect the PVC geomembranes, while for the HDPE geomembranes, a better performance was verified for the geotextiles with larger mechanical resistance.

The mass per unit area parameter did not show a significant influence on the resistance increments obtained. This feature is more evident in the cone configuration with an exposed height of 25mm (see results for PP and PET 600g/m²).

Figures 7 and 8 show the different patterns of geomembrane rupture for PVC and HDPE, respectively.

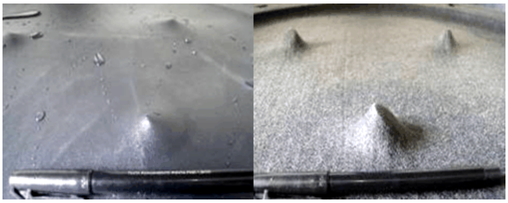

Figure 7. Rupture of PVC after protective layer failure.

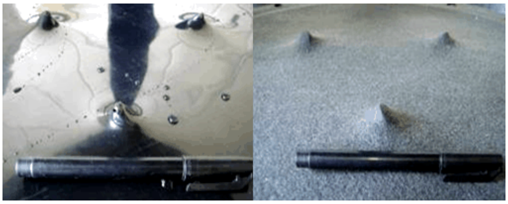

Figure 8. Rupture of HDPE before protective layer failure.

In the tests with subangular stones, HDPE geomembranes were more likely to fail contact with sharp pointed stones, that is, the rupture of the element occurred by puncture. On the other hand, PVC geomembranes showed the tendency to fail in the contact with lamellar stones, that is, the rupture of the material occurred by tearing. These facts can be verified in Figure 9, for PVC geomembranes, and in Figure 10, for HDPE geomembranes.

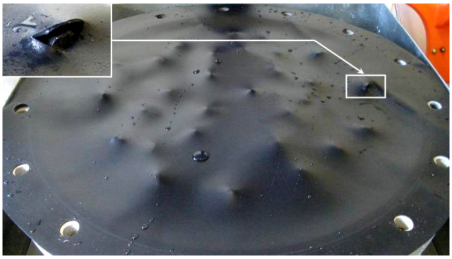

Figure 9. Tear rupture in PVC geomembrane.

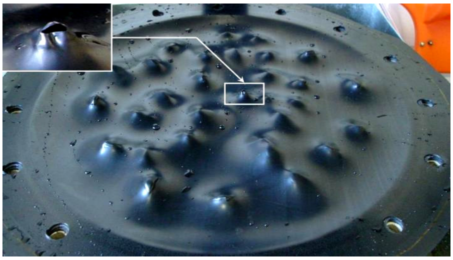

Figure 10. Puncture rupture in HDPE geomembrane.

In subangular stones performance testing, the PVC geomembrane was more effectively protected by the more flexible geotextiles, while in case of HDPE geomembrane the better performance was associated to the more resistant geotextile.

5 CONCLUSIONS

In this study the behavior of the PVC and HDPE geomembranes was evaluated under hydrostatic puncture tests, isolated and with protective layers composed of needlepunched nonwoven geotextiles

PVC geomembrane has shown better performance in hydrostatic puncture tests when compared to HDPE geomembranes. This behavior was associated to the fact that the more flexible PVC geomembrane allows a better distribution of stress in the contact surface, while the HDPE relatively more rigid geomembrane generates stress concentration at the contact point with the cone tip or the stone.

The HDPE geomembrane better performed with the protection of needlepunched nonwoven geotextiles that showed greater mechanical resistance, regardless of the mass per unit area of the elements. The PVC geomembranes puncture resistance performance was improved by the use of more flexible (less needlepunched) geotextiles, since coats the perforating element during the loading phase thus preventing the direct contact with the geomembrane.

Considering the aforementioned topics, it is suggested that the selection of protective layers must be addressed considering the distinct behavior under puncture, for HDPE and PVC geomembranes.

REFERENCES

ASTM D 5514 (2006). Standard Test Method for Large Scale Hydrostatic Puncture Testing of Geosynthetics". Philadelphia.

Narejo, D.; Koerner, R. M.; Wilson-Fahmy, R. F. (1996). Puncture Protection of Geomembranes. Part 2: Experimental. *Geosynthetics International*, Vol. 3, nº 5, pp. 629-653.

Reddy, D.V.; Butul, B. (1999). A comprehensive literature review of liner failures and longevity. *Center for Marine Structures and Geotechnique*, Florida Atlantic University, 146 p.

Seeger, S.; Müller, W. (1996). Requirements and Testing of Protective Layer Systems for Geomembranes. *Geotextiles and Geomembranes*, nº 14, pp. 365-376.

Stark, T. D.; Boerman, T. R.; Connor, C. J. (2008). Puncture Resistance of PVC Geomembranes Using the Truncated Cone Test. *Geosynthetics International.* Vol. 15, nº 6, pp. 480-486