MECHANICAL PERFORMANCE OF HDPE GEOMEMBRANES SEAMS AFTER SUNLIGHT EXPOSURE

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ABSTRACT: Geosynthetic materials are increasingly used in solid waste landfills, but geosynthetic mechanical properties can change when exposed to sunlight. The experience with the evolution of mechanical performance due to UV radiation is not yet consolidated. Presently, at *Laboratório Nacional de Engenharia Civil* (LNEC) a research program concerning the evolution of the mechanical properties of HDPE geomembranes dual hot wedge seams exposed to sunlight during 12 years (expected service life of most Portuguese solid waste landfills) is under study. This paper presents the results of shear and peel tests in HDPE geomembranes dual hot wedge seams after 2, 3 and 5 years to sunlight exposure. The results are compared, on one hand, with those of the same specimens exposed to sunlight but covered by geotextile, and on the other hand, with those of the same specimens not exposed to sunlight. The change of tensile properties of covering geotextiles, after 3 years of sunlight exposure, is also presented. The analysis of the obtained results showed that the mechanical properties of the geomembrane seams were not affected significantly for the sunlight exposure until five years.

1 INTRODUCTION

Over the last years geomembranes have been included as a part of the barrier system in modern waste landfills, often permanently exposed without any external protection. Despite the many advantaged offered by geomembranes over traditional sealing materials, their properties can change with time, particularly when exposed to sunlight.

Several experimental studies provide information concerning the long term mechanical behaviour of geomembranes exposed to sunlight (Rowe & Sangam, 2002; Sangam & Rowe, 2002; Sangam et al., 2001; Cazzuffi et al., 1994, 1995; Hsuan et al., 1991), but most data are for geomembrane sheet and not for field seams, which can be more vulnerable, due to the mechanical and thermal solicitations during the seam process.

In order to study the evolution of mechanical properties of HDPE geomembranes dual hot wedge seams exposed to sunlight, during the expected service life of Portuguese solid waste landfills (12 years), a research program is in progress at the National Laboratory of Civil Engineering (LNEC).

The work is still in progress; the data presented in this paper refer to the first five years of sunlight exposure.

2 STUDY DESCRIPTION

The study was carried out on two phases. The first one consisted to the accomplishment of the natural aging of the geosynthetics to the sunlight exposure. With this purpose, during the construction of eight solid waste landfills (1998-1999), panels with the applied geosynthetics were built (see figure 1) and exposed to weathering. Figure 2 shows the distribution of these panels and waste landfills over the country. At the second phase, after 2, 3 and 5 years to sunlight exposure, samples (with a field seam at the middle) were cut from the exposed materials (on the eight panels) for testing the evolution of mechanical performance of geomembrane seams.

Figure 1 Example of a panel with a geomembrane sample exposed to weathering (waste landfill 3)

Figure 2 Distribution of waste landfills and panels over the country

2.1 *Tested materials*

Three different types of HDPE geomembranes, with 2 mm thickness, were used on the eight waste landfills.

During the construction of the different waste landfills, geomembrane samples (with a field dual-bonded lap seam in the middle) were collected and divided in three parts (see figure 3): part 1 was unexposed, part 2 was exposed to sunlight but covered with a geotextile and part 3 was exposed directly to sunlight. Three different types of geotextiles with photostabilizers were used.

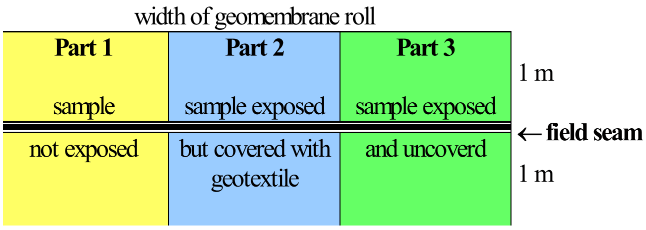


Figure 3 Different parts of the sample

The main physical characteristics and location of the geosynthetics used are summarized in table 1.

Table 1 Main physical characteristics and location

geosynthetic type	code	type	µ (g/m^2) EN 965	thickness (mm) EN 964-1	Location (landfill)
geomembrane	A	HDPE	1900	2	5, 7, 8
	B		1920	2	1, 3, 4, 6
	C		2000	2	2
geotextile	D	NW PE	300	3	3, 4, 6
	E	NW HDPE	300	2,5	1
	F	NW PP	250	2,4	2

2.2 *Test methods*

Seam strength was determined by testing, in shear and peel modes (see figure 4), the specimens cut from the field samples and from the samples not exposed to sunlight. Determination of seam strength in shear and peel modes was performed based on ASTM D4437 "Standard practice for determining the integrity of field seams used in joining flexible polymeric sheet geomembranes". A strip specimen with a 25,4 mm wide and 152,4 mm long was used. Initial grip separation was approximately 25,4 mm for peel mode and 101,2 mm for shear mode. Rate of grip separation was 51 mm/min. Due to the limitation of available material only three peel and three shear specimens were tested for each seam sample.

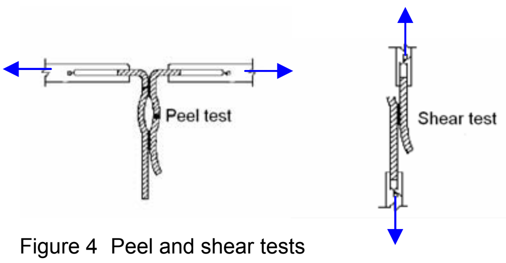


Figure 4 Peel and shear tests

2.2.1 *Shear test*

Shear strength and shear strain (at yield) were recorded.

The minimum acceptable value for shear strength according to US EPA (1993) was 30kN/m for the type and thickness of used geomembranes. It was adopted the minimum acceptable value for strain at yield, proposed by Haxo (1990), e.g. 10% for strain at yield.

2.2.2 *Peel test*

Peel strength and the location and nature of the rupture (see figure 5) were recorded. The minimum acceptable value for peel strength according to the NSF International Standard 54 was 23 kN/m for the type and thickness of used geomembranes.

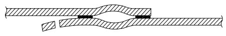
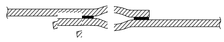
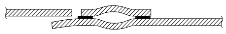
Types of rupture	Rupture code	Rupture description
	AD	Adhesion failure
	RPT	Rupture in sheeting. Rupture can be in either top or bottom sheet
	SE1	Rupture at outer edge of seam. Rupture can be in either top or bottom sheet
	SE2	Rupture at inner edge of seam through both sheets
	AD-RPT	Rupture in first seam after some adhesion failure. Rupture can be in either top or bottom sheet

Figure 5 Location and nature of the rupture for dual-bonded lap seam, according NSF 54 (1993)

2.2.3 *Tensile tests*

For covering geotextiles, the evolution in tensile strength and strain after sunlight exposure were also studied. Determination of peak tensile strength and strain at peak was performed in accordance with EN ISO 10319 "Geotextiles and geotextile-related products: wide-width tensile test".

3 TEST RESULTS

The results of the present study were analysed to evaluate the following aspects related with geomembrane seams:

- influence of covering geotextiles
- influence of sunlight exposure

For covering geotextiles, the evolution in tensile strength and strain after 3 years of sunlight exposure is also presented.

3.1.1 *influence of covering geotextiles*

To study the influence of covering geotextiles regarding the mechanical behaviour of exposed geomembrane seams to sunlight, the results of peel and shear tests of geomembranes exposed to sunlight covered or not with geotextiles were compared.

3.1.1.1 shear tests results

The mean values of shear strength evolution for covered and uncovered geomembrane seams, exposed to sunlight during 2, 3 and 5 years, are presented in figure 6.

From figure 6 we can observe that the maximum variation of the shear strength among covered and uncovered geomembranes seams was 1,3 kN/m (landfill 8).

Notice that all the measured values are higher than 30kN/m.

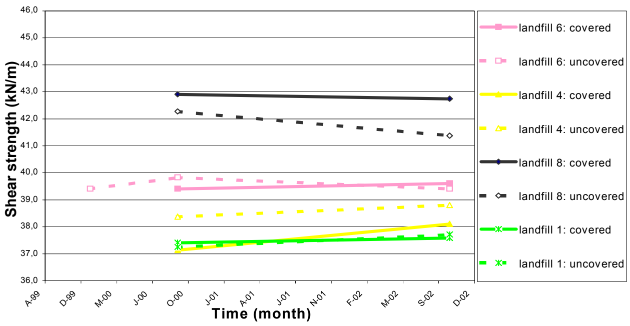


Figure 6 Evolution of shear strength for covered and uncovered geomembranes

The mean values of shear strain evolution for covered and uncovered geomembrane seams, exposed to sunlight during 2, 3 and 5 years, are presented in figure 7.

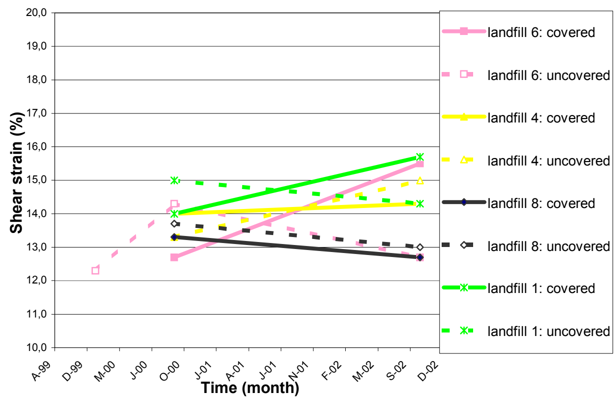


Figure 7 Evolution of shear strain for covered and uncovered geomembranes

From figure 7 we can observe that the maximum variation of the shear strain among covered and uncovered geomembranes seams was 2,8 % (landfill 6).

Notice that all specimens had shear strain values higher than 10%.

3.1.1.2 peel tests results

The mean values of peel strength evolution for covered and uncovered geomembrane seams, exposed to sunlight during 2, 3 and 5 years, are presented in figure 8.

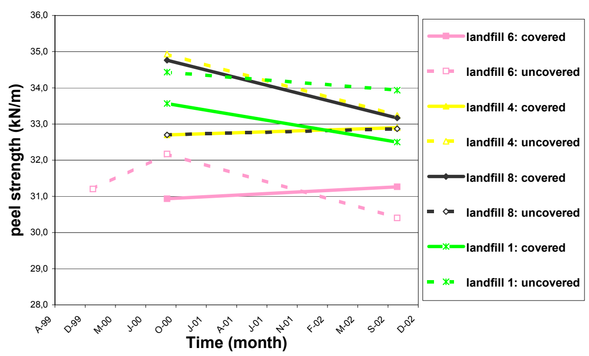


Figure 8 Evolution of peel strength for covered and uncovered geomembranes

From figure 8 we can observe that the maximum variation of the peel strength among covered and uncovered geomembranes seams was 2,1 kN/m (landfill 4).

Notice that all the measured values are higher than 23 kN/m.

No specimens had rupture type AD-RPT or AD.

3.1.2 *influence of sunlight exposure*

To study the influence of sunlight exposure regarding the mechanical behaviour of geomembrane seams, the results of peel and shear tests of geomembranes exposed and unexposed were compared.

3.1.2.1 shear tests results

The mean values of shear strength evolution for exposed and unexposed geomembrane seams to sunlight during 2, 3 and 5 years, are presented in figure 9.

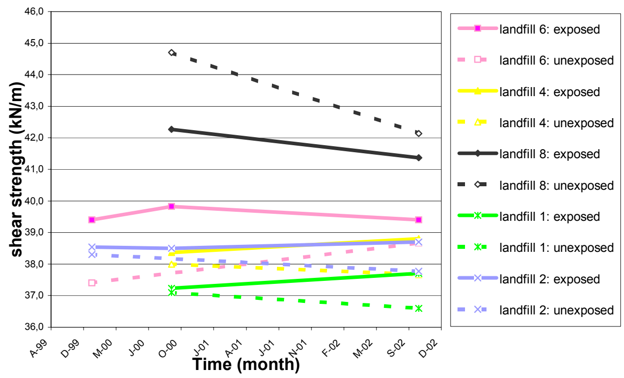


Figure 9 Evolution of shear strength for exposed and not exposed geomembranes

From figure 9 we can observe that the maximum variation of the shear strength among exposed and unexposed geomembranes seams was 2,4 kN/m (landfill 8).

After five years of sunlight exposure, the maximum variation of the shear strength was 0,9 kN/m (landfill 8).

Notice that all the measured values are higher than 30kN/m.

Unfortunately, we cannot compare shear strain evolution for exposed and unexposed geomembrane seams due to the lost of shear strain values for unexposed geomembrane seams sample collected in September 2000.

3.1.2.2 peel tests results

The mean values of seam strength evolution for exposed and unexposed geomembrane seams to sunlight during 2, 3 and 5 years, are presented in figure 10.

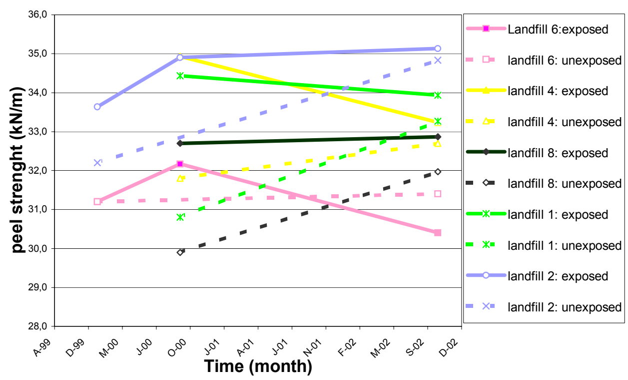


Figure 10 Evolution of peel strength for exposed and unexposed geomembranes

From figure 10 we can observe that the maximum variation of the peel strength among exposed and unexposed geomembranes seams was 3,1 kN/m (landfill 4).

Notice that all the measured values are higher than 23 kN/m.

After 5 years of sunlight exposure, the maximum variation of the peel strength was 1,8 kN/m (landfill 6).

No specimens had rupture type AD-RPT or AD.

3.1.3 *Tensile properties evolution of geotextiles*

Until now, we had only studied the evolution in tensile strength and strain after 3 years of sunlight exposure, for covering geotextile D.

The mean values of peak tensile strength and strain at peak for geotextile D are presented in table 2.

Table 2 Tensile properties evolution of covering geotextile D

	landfill	**samples**		**tensile strength*** (kN/m)	**strain at peak*** (%)
		placement date	**collected date**		
Geotextile D	4	Jan 99	Jan 99	16,79	155,62
			Sept 00	22,23	99,33
			Oct 02	18,60	96,69
	6	Nov 98	Nov 98	14,83	156,26
			Sept 00	-	-
			Oct 02	10,51	62,49

* According EN ISO 10319, in machine direction

From table 2 we can observe that the maximum variation of the peak tensile strength and strain among exposed and unexposed geotextiles samples was 5,4kN/m and 6,29% respectively (landfill 4).

4 CONCLUSION

In this paper were presented the results of shear and peel tests in HDPE geomembranes dual hot wedge seams after 2, 3 and 5 years to sunlight exposure

In general we may conclude, from shear and peel results, that the five years of exposure had not significant affected the seam strength and strain of geomembranes tested. These results might be considered consistent with the results presented by Hsuan (1991). Notice that all the measured values are much higher than the minimums acceptable values.

5 REFERENCES

ASTM D 4437 – Standard practice for determining the integrity of field seams used in joining flexible polymeric sheet geomembranes

Cazzuffi, D., Fede, L., Montanelli, F. E Rimoldi, P, 1994: Outdoor and UV-B Laboratory Weathering Resistance of Geosynthetics, Proceedings of Fifth International Conference on Geotextiles, Geomembranes and Related Products, Singapura, pp.1195-1198

Cazzuffi, D., Fede, L., Villa, C., Montanelli, F. E Rimoldi, P, 1995: The assessment of effects of natural and lab weathering exposure of geosynthetics, Proceedings of Fourth Landfill Symposium, Sardinia, pp.387-396

EN ISO 10319 - Geotextiles and geotextile-related products: wide-width tensile test

Haxo, H. E., Jr Kamp, C. L., 1990: Destructive Testing of Geomembranes Seams: Shear and Peel Testing of Seam Strength, in Geotextile and Geomembranes, nº9, pp.369-404

Hsuan, Y.G., Lord Jr., A. E., Koerner, R. M., 1991: Effects of Outdoor Exposure on a High Density Polyethylene Geomembrane", Proceedings of Geosynthetics'91 Conference, 1991, Atlanta, USA, pp.287-302

National Sanitation Foundation, 1993: Standard 54 for Flexible Membrane Liners. Revised in November

Rowe, R. K., Sangam H. P., 2002: Durability of HDPE Geomembranes, in Geotextile and Geomembranes, nº 20, Outubro, pp.77-95

Sangam, H, P., Rowe, R. K., 2002: Permeation of organic pollutants through a 14 year old fiel-exhumed HDPE geomembrane, Proceedings of 7th International Conference on Geosynthetics, Nice, France, pp.531-534

Sangam, H. P., Rowe, R. K., Mlynarek, J., Sarazim, P., 2001: Natural Weathering of a 14 Year Pre-Aged Geomembrane, Proceedings of Geosynthetics Conference, Portland, Oregon, USA, pp.149-162

US EPA, 1988: Lining of Waste Containment and other Impoundment Facilities, Proceedings of 2nd ed., U.S. Environmental Protection Agency, EPA/600/2-88/052, Cincinnati, OH 45268

US EPA, 1993: Quality Assurance and Quality Control for Waste Containment Facilities, EPA/600/R-93/182

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