Geosynthetics: Applications, Design and Construction, De Groot, Den Hoedt & Termaat (eds)

 ISBN 90 5410 836 3

Lining system using polypropylene geomembrane in waste landfill

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ABSTRACT: A research and development programme has been carrried out to evaluate the performances, and to define the design and installation criteria of a polypropylene geomembrane used in lining systems of the active barrier in municipal waste landfills. The programme was supported by the installation of such a polypropylene geomembrane lining system for the expansion of the waste landfill located in St Fraimbault (France). The programme was focused on four items: (i) the geomembrane identification, (ii) the conditions of seaming and the acceptance criteria, (iii) the performances of a typical geomembrane lining system, and (iv) the long term behaviour of the geomembrane related to the immersion in leachate.

1 INTRODUCTION

The 1990's saw the first use of polypropylene geomembranes for canal linings, floating covers of reservoirs, and caps of waste landfills. Using the support of the expansion of the municipal waste landfill located in St Fraimbault (Mayenne, France), France Déchets, F.D. Conseil, France Erosion, GeoSyntec Consultants, Montell Polyefins and Siplast set up a research and development programme on the use of such polypropylene geomembranes for geomembrane lining systems to be installed in landfills.

2 RESEARCH AND DEVELOPMENT PROGRAMME

2.1 *The St Fraimbault expansion*

Three new cells were constructed in 1995 at the St Fraimbault landfill. The design of the owner included a leachate drainage system at the bottom of the cells, which consists of a granular material layered on a lining system, and a lining system on slopes. The leachate drainage system works as an active barrier on top of the passive barrier consisting of the clay in place on the site.

For economical, technical and regulatory reasons, the owner agreed to use a polypropylene (PP) geomembrane Hydronap. The lining system which was installed can be described (from top to bottom) as follows:

- a protective geotextile;
- a PP geomembrane (1 mm);
- a support geotextile.

Photograph 1 illustrates the installation of the lining system and the drainage layer in the cell n° 1.

2.2 *Objectives of the programme*

The programme was set up between different partners: the owner of the landfill, the producer of

Photograph 1. Construction of the cell n° 1 of the St Fraimbault landfill expansion.

the polymer, the manufacturer of the geomembrane, the installer of the lining system and consultants with abilities in landfill design and geosynthetics.

The objectives of the research and development programme were (i) to assess the performances of such polypropylene geomembranes used in lining systems for landfills, and (ii) to define the design and installation criteria for these geomembranes.

2.3 *Organization of the programme*

The organization of the programme was described by Matichard and al (1995). It was focused on four items:

[1] Identification of the geomembrane;
[2] Seaming conditions and acceptance criteria of seams;
[3] Performances of the geomembrane used in a typical lining system;
[4] Long term behaviour of the geomembrane related to its immersion in leachate.

2.4 *The actual progress*

Items [1] to [3] were performed in 1995 and early 1996. Regarding item [4], immersion in leachate of samples was performed at the end of 1995 and the first results after six months of immersion will be discussed during the oral presentation at Eurogeo 96. The paper presents the main results of item [1] to item [3].

3 GEOMEMBRANE IDENTIFICATION

The polymer used for the manufacture of the geomembrane is produced by Montell Polyefins and is identified as Astryn Flexible Polypropylene Alloy. The process consists to incorporate 65 % of ethylene-propylene rubber into the semi-crystalline polypropylene matrix directly in the reactor.

The quality control performed by the manufacturer gave the average values of the characteristics, presented in Table 1, of the geomembrane installed at the St Fraimbault site.

Table 1. Characteristics of the PP geomembrane installed at the St Fraimbault site (Quality Control).

Density	ASTM D 1505	0.905
Thickness	ASTM D 751	1.00 to 1.10 mm
Tensile Strength	ASTM D 638	21.7 to 24.9 MPa
Break Elongation	ASTM D 638	820 to 921 %
Tear Strength	ASTM D 1004	61.1 to 77.3 N
Puncture Strength	FTMS 101C	194 to 231 N

Table 2. Tensile characteristics of the PP geomembrane installed at St Fraimbault according to NF P 84 501.

	$\theta = 20°C$		$\theta = 50°C$	
	Roll	X-Roll	Roll	X-Roll
α_y (kN/m)	4.1	5.6	3.1	4.2
$\varepsilon(\alpha_y)$ (%)	54	44	32	40
α_f (kN/m)	10.1	10.9		
$\varepsilon(\alpha_f)$ (%)	628	564		

α_y tension at yield, $\varepsilon(\alpha_y)$ elongation at yield, α_f tension at failure,(α_f) elongation at failure.

The geomembrane was also tested in laboratory according to the french standard NFP 84 501 to measure the tensile characteristics. Tests were performed at two temperatures: 20 and 50 °C.

A pseudo yield could be defined on the tensile force versus the elongation graph, and the results are presented in Table 2.

4 SEAMING CONDITIONS AND ACCEPTANCE CRITERIA OF SEAMS

4.1 *Seaming conditions*

Trial seams were performed by the installer on site with a hot air seaming machine Leister X84 using two speed (2 and 3 m/min), and five air temperature (350, 450, 500, 550 and 600 °C).

Shear and peel tests were achieved on the trial seams according to the standards NFP 84 501 and 84 502. The results are presented on Figure 1. Shear test results do not allow to define the best seaming parameters for the machine, while the peel test results seem to indicate a better behaviour of the seam achieved at a speed machine of 2 m/min and an air temperature between 500 and 600°C.

These results are only related to the geomembrane and the seaming machine which were used for this project.

4.2 *Acceptance criteria*

The PP geomembrane was installed and seamed in the cell n° 3 with parameters of the seaming machine close to the parameters discussed in section 4.1, which seem to produce the best seam for the geomembrane and the machine. Ten samples of seams were cutted from the seams on site. The conditions of seaming has been recorded by the installer for every seam, as part of his quality assurance, and the conditions for the sampled seams are presented in Table 3.

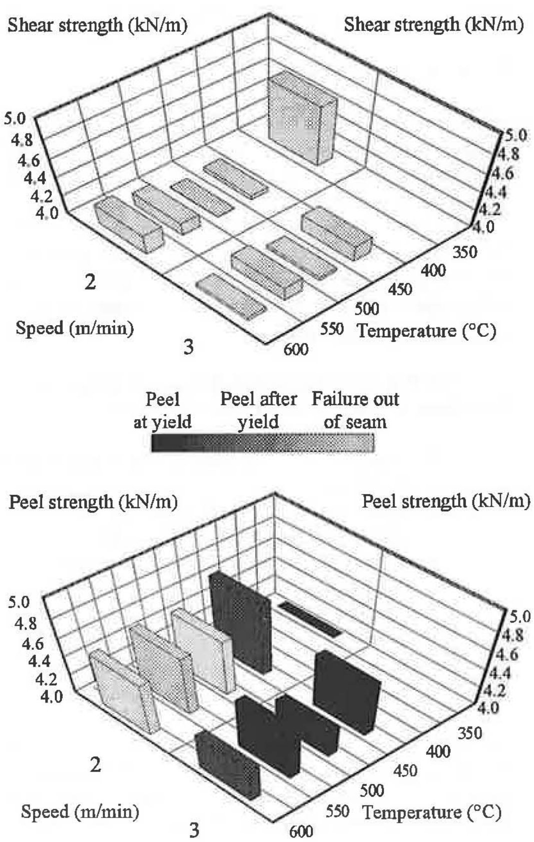


Figure 1. Shear and peel strengths of seams achieved with different temperature and speed of the machine. PP geomembrane St Fraimbault.

Table 3. Seaming conditions for the seams sampled in cell n° 3. PP geomembrane at the St Fraimbault site.

Seam	θ_a °C	θ_{gm} °C	θ °C	Speed m/min
2/3	14.5	20.0	600	2.2
5/6	15.0	20.0	600	2.2
8/9	9.5	12.5	600	1.8
12/13	8.0	11.5	600	2.0
22/23	13.5	20.0	600	2.3
24/25	21.0	25.0	650	2.3
28/30	25.0	32.0	600	2.3
33/34	24.0	30.0	600	2.3
39/40	27.0	36.0	600	2.2
42/43	23.0	26.0	600	2.2

θ_a ambiant air temperature, θ_{gm} geomembrane temperature, θ machine temperature

Shear and peel tests were performed on the samples of seams according to the french standards

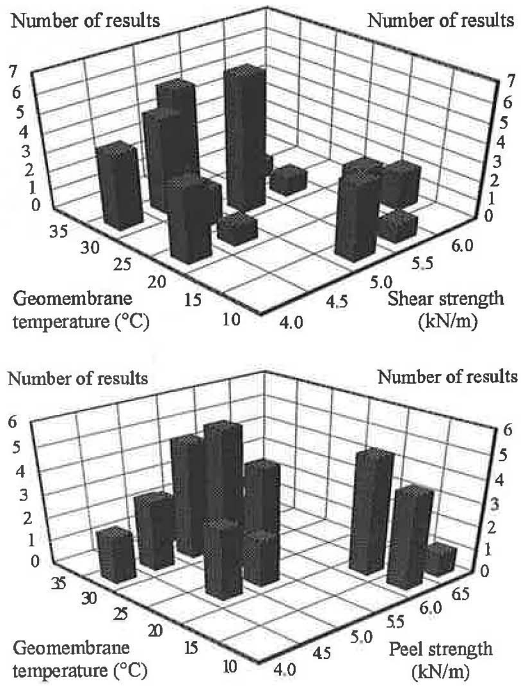


Figure 2. Shear and peel strengths of seams sampled during the construction of the cell n° 3 at the St Fraimbault site. PP geomembrane.

NF P 84 501 and NF P 84 502. The test results, which are presented on Figure 2, show that two different populations of results can be statistically identified:

(1) Seams 2/3, 24/25, 28/30, 33/34, 39/40,42/43
(2) Seams 8/9, 12/13

Note: two sampled seams were eliminated for this study as only partial results (shear strength or peel strength) were available.

The population (2) is related to the seams made with the lowest geomembrane temperature (see Table 3).

A statistical analysis has been performed on population (1). For this analysis the distributions of the shear strength and the peel strength of the seams are presented on Figure 3.

Lower and upper limits were calculated for a 95 % confidence interval for shear and peel strengths:

Shear:	3.80 kN/m <	< 5.46 kN/m
Peel:	4.23 kN/m <	< 5.59 kN/m

These criteria do not allow, for the tested samples of seams, to eliminate some samples for which a partial peeling (at the yield or beyond the yield point) was observed during the peel tests (see Figure 4).

The conclusion of this study must not be extrapolated to other projects without answering to a better understanding of the PP geomembrane seam behaviour (partial peeling occuring during some peel tests at the pseudo yield or beyond).

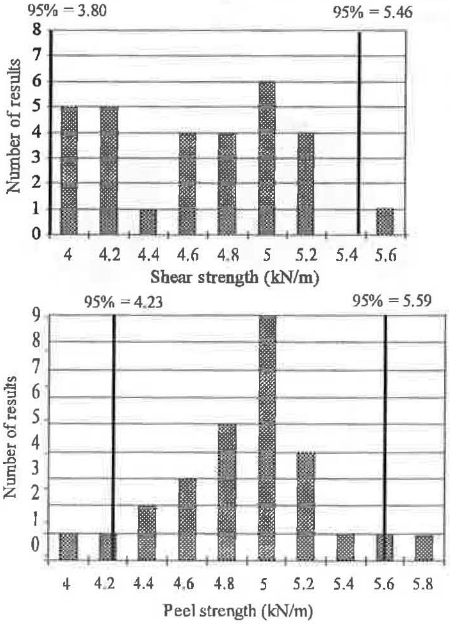


Figure 3. Distributions of shear strength and peel strength of the seams sampled during the construction of the cell n° 3 at the St Faimbault site.

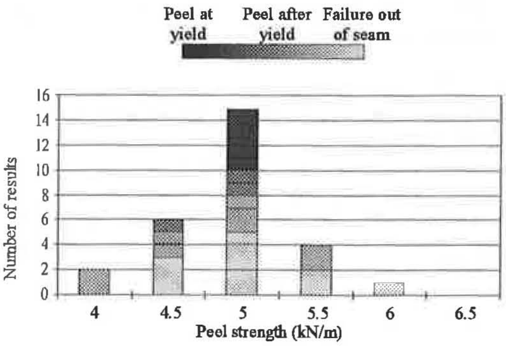


Figure 4. Failure mode of the seams, sampled during the construction of the cell n° 3 at the St Fraimbault site, in a peel test related to the peel strength.

5 LINING SYSTEM PERFORMANCES

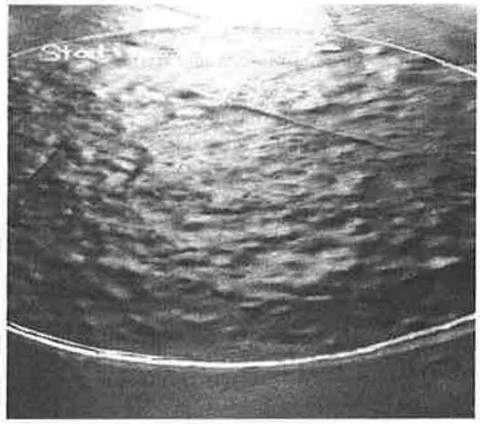
5.1 *Puncture resistance*

A large static column test (SCT) was performed on a typical drainage system for a municipal landfill according to the french regulations. As described in section 2.1, a typical drainage system consists of a granular material layered on a lining system. The SCT was performed to characterize the performance of a PP geomembrane, included in the lining system, to be punctured or not by the granular material when filling the cell with waste.

The drainage system which was so tested can be described as follows (from top to bottom):

- drainage layer consisting of a rolled gravel 10-25 mm;
- a protective geotextile (the one used at St Fraimbault and described in Table 4);
- a PP geomembrane (the one used at St Fraimbault);
- a compacted clay subgrade.

A static load of 100 kPa, corresponding to the heigth of waste at the St Fraimbault site, was applied during 24 hours on the system. The sample area was about 1 m^2. The geomembrane was then carefully removed, observed and tested in a three dimensional tension test (GRI/GM4 method). No damage was observed after the removal of the gravel, excepted some rounded depressions caused by overlying stones. Photograh 2 presents the sample of geomembrane after the 24 h loading.



Photograph 2. Static Column Test on a typical drainage system including a lining system with a PP geomembrane. Top surface of the exposed geomembrane.

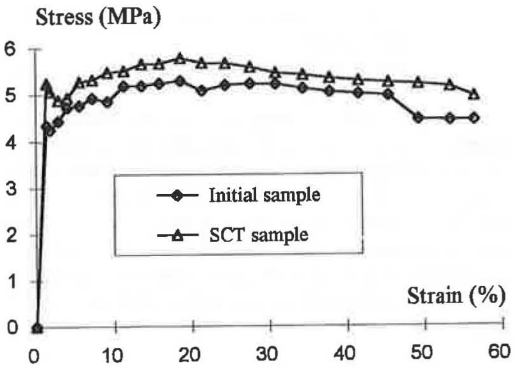


Figure 5. Results of three dimensional tension tests (GRI-GM4) on PP geomembrane sampled from a roll in comparison with the sample tested in the SCT.

Figure 5 presents the tension behaviour observed during the three dimensional tension test on the removed geomembrane in comparison with the tension behaviour of a sample of geomembrane from a roll. No difference can be observed in the failure mode. Stress and strain at failure are similar between the two samples of geomembrane (SCT sample and roll sample).

5.2 *Interface behaviour*

In order to evaluate the behaviour of typical soil-geomembrane or geosynthetic-geomembrane interfaces, friction tests were performed by the Soil Geosynthetic Interaction Laboratory of GeoSyntec according to the ASTM D 5321 standard on the following interfaces:

- (1) Geomembrane-Geotextile
- (2) Geomembrane-Geonet
- (3) Geomembrane-Compacted clay

The test conditions are summarized in Table 4 and the test results in Table 5, as the friction angle φ_g and the adhesion C_g

Table 4. Friction test conditions on the PP geomembrane interfaces. St Fraimbault.

	Geomembrane -Geotextile	Geomembrane-Geonet	Geomembrane-clay
σ_n (kPa)	20.7, 96.5 and 248.0		
Shear rate	5 mm /min	5 mm / min	1 mm / min
Interface	Non woven needlepunched (one face heat-treated,upside) Roll direction. Wet interface.	Geonet 5mm thick. Roll direction. Wet interface.	Initial clay conditions: $\gamma = 0.95\ \gamma_{OPN}$ $W = W_{OPN} + 2$

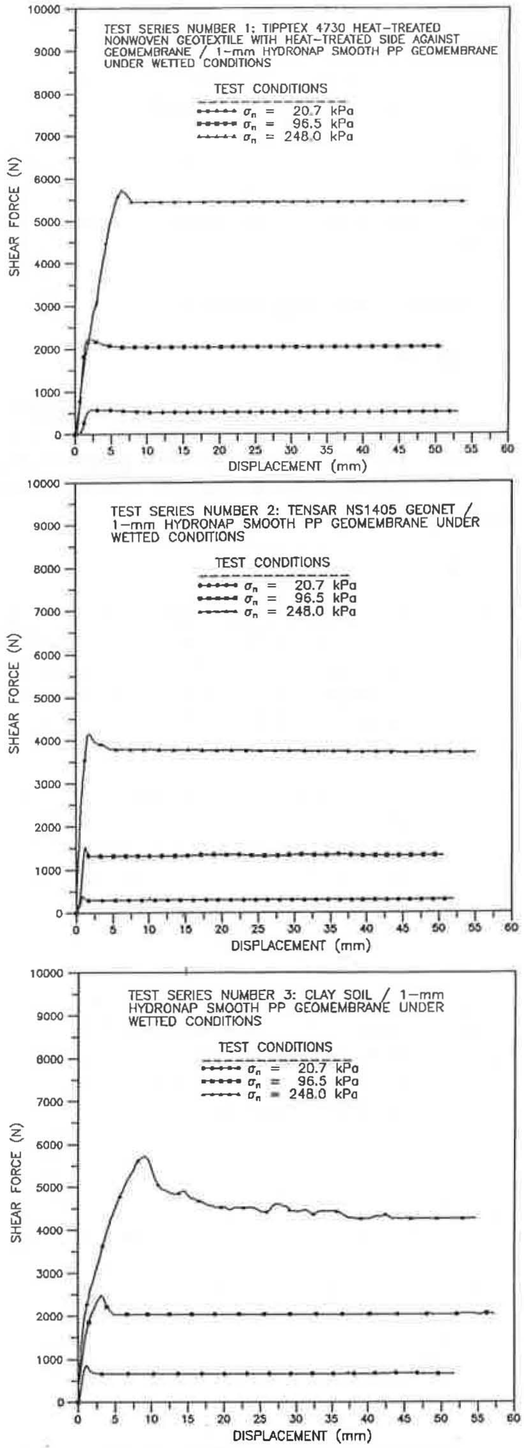


Figure 6. Interface behaviour (ASTM D 5321): (1) geomembrane-geotextile, (2) geomembrane-geonet, (3) geomembrane-compacted clay.

Table 5. Friction test results on the PP geomembrane interfaces. St Fraimbault.

	Interface 1		Interface 2		Interface 3	
	Peak	Residual	Peak	Residual	Peak	Residual
φ_g (°)	14	13	10	9	13	10
C_g (kPa)	1	0	0	0	4.6	4.3

The behaviour of the tested interfaces is illustrated on Figure 6.

6 LONG TERM BEHAVIOUR

6.1 *Objective*

The objective of the research and development programme related to the long term behaviour was to assess the durability of the PP geomembrane related to its immersion in leachate of a municipal waste landfill.

6.2 *Bibliography*

Information is available in bibliography (Shah et al, 1993; Palo, 1994). EPA 9090 test was performed on the PP geomembrane. Samples were immersed during four months in the leachate of the Delaware (USA) landfill at 23 and 50°C. Results reported by Palo (1994) can be summarized as follows:

- no change in tensile strength at yield and at failure;
- no change in tear strength;
- loss of 25 / 30 % of the hydrostatic pressure strength;
- loss of 20 / 25 % of puncture strength at yield, and no change at failure.

Palo (1994) reported other tests with organic solutions. After 54 days of immersion at 23°C a loss of about 15 % of the tensile strength at yield was observed for some organic solutions, as polyefins could be damaged by non polar organic solvents.

6.3 *Immersion on site*

According to the procedure set up with the research and development programme, and in order to assess the performance with time of the PP geomembrane, samples were immersed in the leachate collection system of the three cells constructed for the St Fraimbault expansion. Samples are immersed in the flow of leachate.

Three types of samples were installed in the leachate collection system:

- samples removed from a roll;
- sample removed from a second static column test;
- samples of seam.

Samples will be removed from the leachate six months, one year and two years after the immersion, which corresponds to the closure of these cells. Density, thickness and tensile characteristics of the samples, removed from the leachate, will be tested and compared with the same characteristics measured on a sample of geomembrane which was stored in a dark room on site at the same time of the immersion.

7 CONCLUSION

The research and development programme related to the use of polypropylene geomembrane in lining systems for landfills described in this paper has provided and will provided designers, installers, and landfill managers a technical database to judge the performances of such geomembranes. The programme is still running and will end in about one year.

ACKNOWLEGMENT. The authors thanks the installer France Erosion for his contribution to the research and development programme during the construction of the St Fraimbault landfill expansion.

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