Stability of different inclined cap liner systems - Landfill field trials

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ABSTRACT: The stability of geosynthetic lining systems on landfill slopes is a big concern. In the framework of a scientific experimental programme focused on the global geomechanical behaviour of a waste disposal, monitoring of the waste body and of the cap cover was carried out, starting at the beginning of the waste dumping, and following during the construction until the covering by a cap liner. This paper is specifically dedicated to stability trials of different cap barriers systems along a slope, inclined to 17° with horizontal and 50 m long. One of the important results is the high sensitivity of the relative displacements of the different components of the cap liner to the interface friction relationship, and to the mode of construction. In the present time, the registration of field measures is going on and updated results will be produced for the conference.

1 THE LANDFILL OF TORCY AND THE CAP SLOPE LINING SYSTEMS

In the framework of a large research programme, sponsored by the French Environmental Public Agency ADEME, a cell of the landfill of Torcy was selected for a geotechnical survey of the waste mass settlements and for a specific study of the comparative stability of different cap lining systems on slope.

Non hazardous industrial waste is dumped until a height of 14 m. The final shape of the landfill is similar to a tumulus with slopes 3/1with the horizontal. The corresponding slope length is 50 m. In these conditions, significative displacements of the different components of the liner were reported in the literature (Brink et al, 1999; Daniel et al, 1988).

For the Torcy site, 4 different lining systems were implemented on the same slope area (Figure 1). Their length is approximatively 50 m and the width of every trial, 5.3 m corresponding to the width of the most narrow geosynthetic layer. The four systems are in agreement with the French official guidelines for cap liners of landfills of class II.

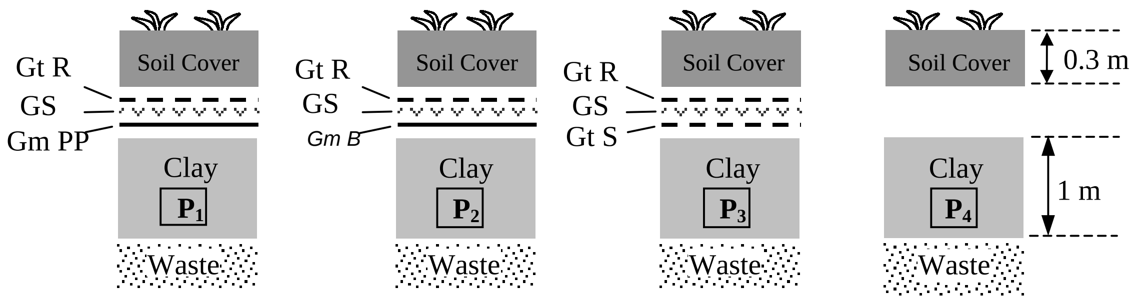

Figure 1. The 4 different lining systems on slope.

- The “active barrier” is a sloping layer of fine soil (generally speaking called “clay”), 1m thick, implemented progressively with the lift of waste (“Christmas tree” shape). Important differences in the water content were measured (w=13 % at the top and bottom and 23 % in the medium area), which could influence the interface friction properties.
- 4 different trials P_1, P_2, P_3 and P_4 were monitored. For all the cases, a soil cover 0.3 m thick was implemented as a protection of the liner system. It’s worth noting that the soil layer was spread, starting from the toe of the slope : the mechanical showel was climbing laterally to the experimental trials, since every experimental liner is spaced out 5 m apart, and a slight compaction is carried out by the showel.
- The geomembrane (Gm) placed on the “clay” layer has for main function, according to the french regulation to stop the rainfall water collected by the geospacer (GS) of trials P_1, P_2, P_3. In case P_3, the geomembrane is replaced by a non-woven geotextile as separator (Gt S).
- Just below the cover soil layer, a high tensile strength geotextile (called geotextile of reinforcement, Gt R) has for main roles bothly to sustain the top cover soil and to avoid the clogging of the geospacer.

The present design of the lining systems is based on the separation of functions (one geosynthetic for one function): the geotextile of reinforcement has in charge the stabilization of the cover soil, limiting the function of the geospacer to transmissivity and the function of the geomembrane to watertighness without tensile elongation. The actual behaviour could be different if the interface properties are not under control (see below).

The present paper focus on P_1 and P_2 trials which can be distinguished by the geomembrane type. For P_1 it is a polypropylene geomembrane (Gm PP) and for P_2, it is a bitiminuous one (Gm B). The differences in the mechanical characteristics are significant, related to the tensile stiffness (tensile modulus J), the tensile strength (T_f for a strain ε_f) (Table 1) and the friction properties (Table 2).

Table 1. Characteristics of geosynthetics used

	Name	t (mm)	T_f	ε_f(kN/m)	J (kN/m)
Gt R	Rock Pec 75	2.5	95	12	580
Gt S	S41	1.6	12	80	27 (ε=10%)
Gm B	Terranap 431	4	25	60	80 (ε=15%)
Gm PP	Hydronap	1	13.9	616	51 (ε=7.5%)
			6.5 *	29*	
GS	5902	4.4	7.5	30	25

*Values obtained at peak.

Table 2. Friction angle ϕ_g at the interface (shear box)

	ϕ_g (°)	ϕ_g (°)	ϕ_g (°)
P_1	Clay/Gm PP : 13.8	Gm PP/GS : 7	GS/Gt R : 15
P_2	Clay/Gm B : 18	Gm B/GS : 31	GS/Gt R : 15
P_3	Clay/Gt S : 33	Gt S/GS : 15.5	GS/Gt R : 15

To attach the geosyntyhetics at the top of the slope, a large trench of anchorage (1 m deep and 1 m wide) was used to bury the geosynthetics in such a way that no important sliding of geosynthetics could be observed at the top edge. The pull-out strength of the anchorage trench has be estimated higher than the tensile strength of the strongest geosynthetic on slope (Feki, 1996).

2 MONITORING OF THE LINING SYSTEMS

The different trials are instrumented with a monitoring system previously used by the authors (Gourc et al;, 1997) to efficiently register the displacements along the slope :

Thin metallic cables, sleeved in PVC tubes to insure a free displacement, are attached on every geosynthetic layer at a distance 1, 2, 5, 30 and 42 m from the top of the slope (Figure 2 and Figure 3). Every cable is linked for reference to a monitoring panel (one for every trial) founded at the top of the slope (Figure 4) Displacements are measured by means of cursors sliding on a millimeter table. In addition a cable is fixed in the anchorage trench.

To register the possible displacements of the clay layer, metallic corner elements are buried in the soil and attached to cables, following the same process.

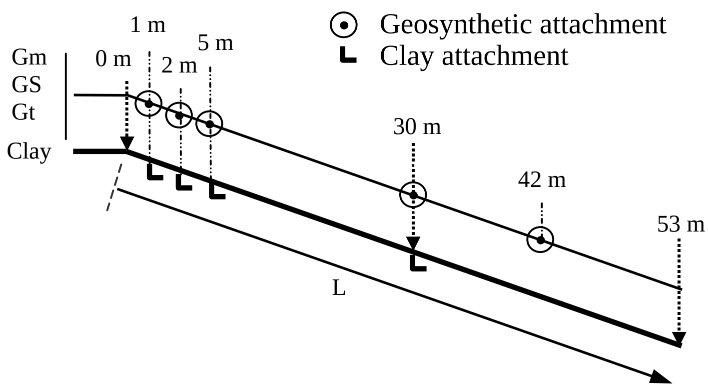

Figure2. Position of the attachments to the geosynthetics and clay layer for monitoring of the differential displacements along the slope.

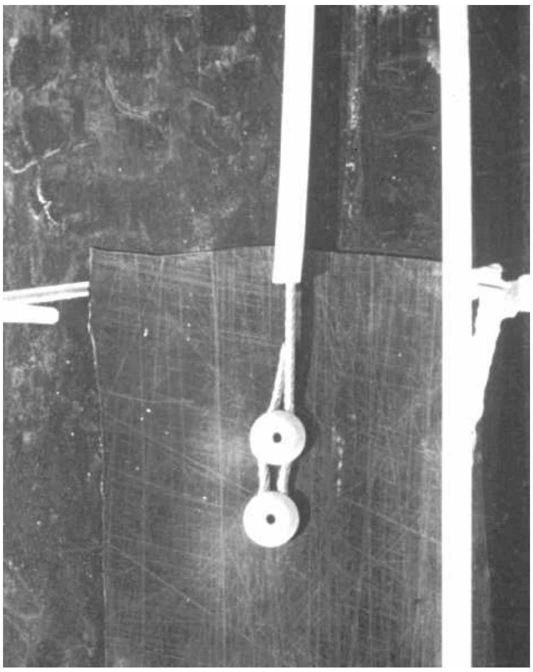

Figure 3. Attachment of a cable to the geomembrane sheet, for measure of the displacements.

3 EVALUATION OF THE FRICTION PROPERTIES AT THE INTERFACE

It was demonstrated elsewhere (Soyez et al, 1990) by the authors that a pertinent design of lining systems on slopes requires a realistic evaluation of the friction properties at the different interfaces geosynthetic-geosynthetic or geosynthetic-soil.

Special devices are available at the Lirigm of the Grenoble University for friction tests. All the interfaces were tested, using two different standard facilities (Lalarakotoson et al, 1999).

The first apparatus is a direct shear device, with a square box (0.3 m x 0.3 m). The selected vertical normal stress values are 75 kPa, 50 kPa and 25 kPa. This kind of apparatus is mainly used for interfaces subjected to normal stresses higher than 50 kPa, due to the design of the direct shear box (Standard CEN – 12957-1). The actual normal stress in the field is σ=5 kPa, corresponding to the 0.3 m thick cover soil.

The second apparatus is a inclined plane (Figure 5) with a tilting base (0.8 m x 1 m), mainly dedicated to friction tests under low normal stresses (standard CEN – 12957-2).

The Table 2 summarizes the friction angles obtained for the different interfaces, using the direct shear test.

It's worth noting the important gap between friction properties of the geospacer (GS : geonet) in interface with the two different geomembranes, polypropylene (Gm PP of the trial P_1) and bituminous (Gm B of the trial P_2).

The corresponding diagrams for direct shear tests are displayed on the Figure 6. Unavoidable consequences on the global behaviour on the trials P_1 and P_2 could be expected, induced by the friction difference.

Generally speaking, the limit friction angle values, obtained from the inclined plane (under lower normal stress) are higher than the ones obtained from the direct shear box. On Figure 7, the diagrams corresponding to the geospacer (GS) in interface with the geomembrane (Gm PP) or with the geotextile of reinforcement (Gt R) are presented, for a normal stress (σ = 5.5 kPa). β is the increasing slope angle and U is the corresponding displacement tangential to the inclined plane.

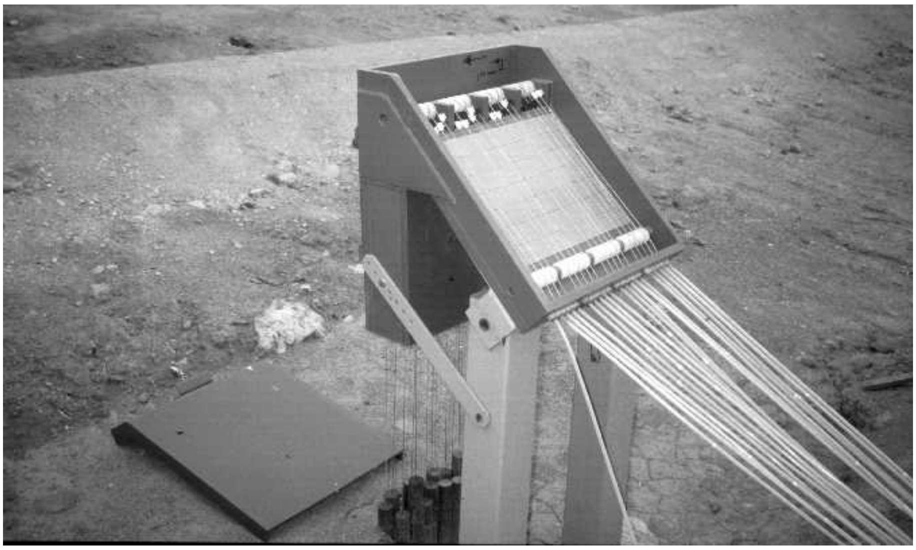

Figure 4. Monitoring panel at the top of the experimental slopes for measurement of the cable displacements.

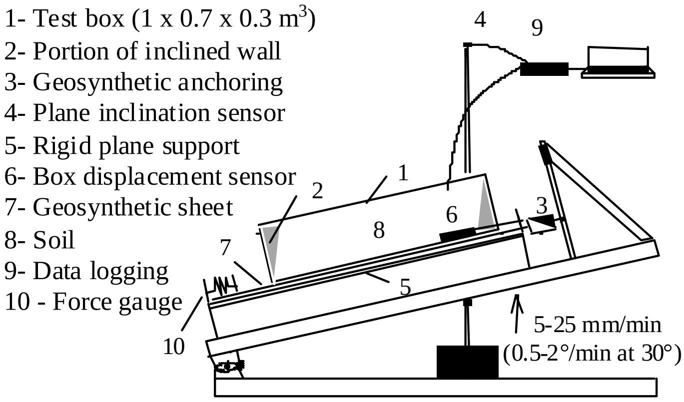

Figure 5. Tilting test – (inclined plane)

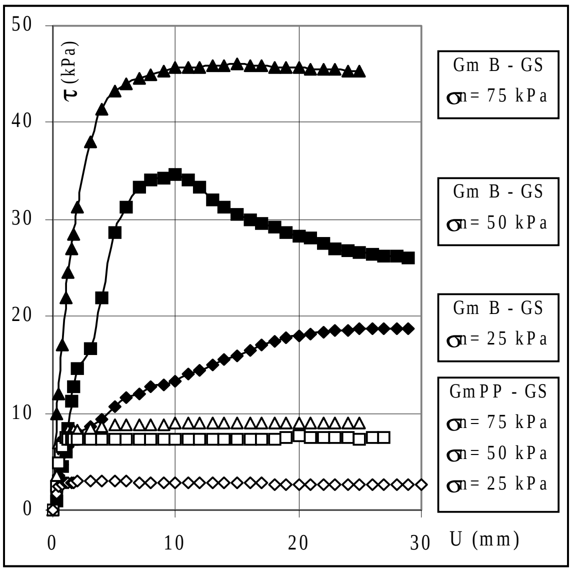

Figure 6. Friction behaviour for the two different geomembranes in interface with the geospacer (Shear Box)

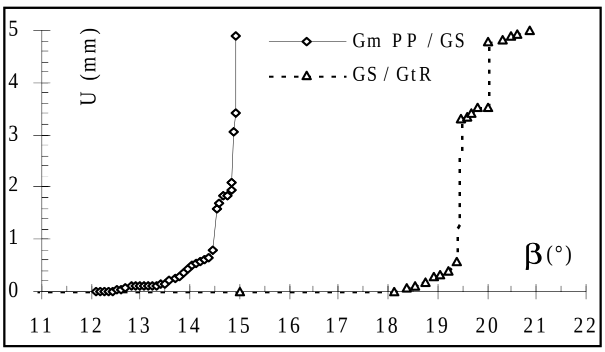

Figure 7. Friction behaviour for two different interfaces geospacer/geomembrane PP or geotextile of reinforcement Gt R (Inclined Plane).

4 OBSERVED BEHAVIOUR OF THE DIFFRENT LINING SYSTEMS

The evolution of the displacements of the different components of the lining systems P_1 and P_2 is presented on the diagrammes below.

L is the distance measured along the slope from the top edge (Figure 2). As the soil cover is spread from the toe, L_t corresponds to the maximum height of the soil cover, measured as L from the top edge : L_t=0 is obtained for a total covering of the sloping liner system (end of construction). The time corresponding to the end of construction is t_0.

On the Figures 8 and 9, we display the variation of the displacements of respectively the geotextile of reinforcement (Gt R) and the geospacer (GS) of the trial (P_1) during the implementation of the soil cover.

Firstly the very low displacement at the top edge of the slope for the two geosynthetics confirms the possibility to consider the anchorage as a fix point.

The variation of displacements along the slope, at a fixed time, is strongly dependent of the mode of soil covering. Starting from the toe, geosynthetics are stretched as early as soil cover is spread (L_t=40.7 m).

However when displacement decreases with increasing L, this phenomenon is theoretically related to a shortening of the geosynthetic. This is observed in the lower part of the two geosynthetics when the soil is covering a significative part of the liner system.

In a previous field experience (Gourc et al, 1997), a similar observation was assumed to be correlated to folds in the geosynthetics sheets and to the lower cover soil acting as a passive thrust mass. So the geotextile Gt R and the geospacer GS would be subjected to tensile force in the upper part and compression force in the lower one.

More, the displacements are not stabilized at the end of the covering process, since significative displacements are observed between (t_0) and (t_0+72h).

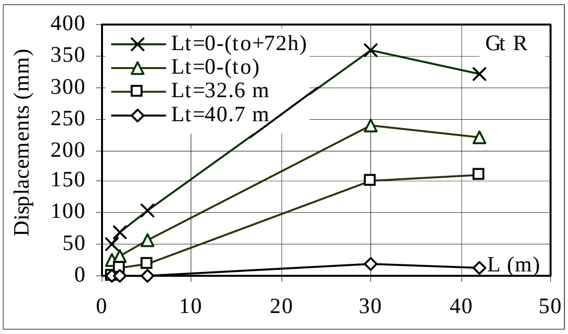

Figure 8. Trial P_1 – variation of the displacements at the geosynthetic of reinforcement attachments during the soil covering process.

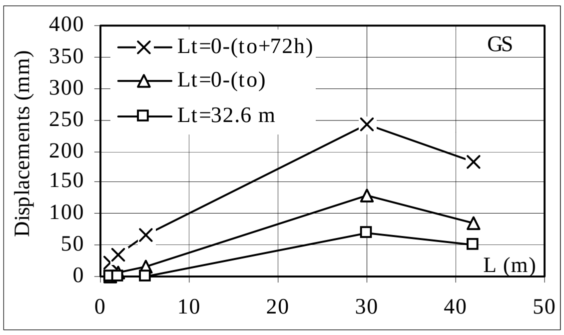

Figure 9. Trial P_1 – variation of the displacements at the geospacer attachments during the soil covering process.

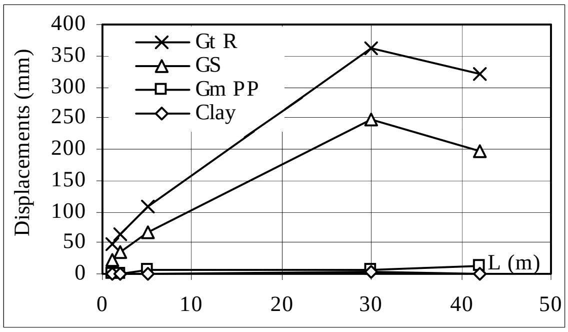

Figure 10. Trial P_1 – displacements in the different geosynthetics at (t_0+72h).

The Figure 10 presents the displacements in the different components of the lining system for (t_0+72h). Clearly no displacement is recorded in the geomembrane and the clay support : the critical interface where the extreme differential sliding displacements are concentrated is the interface geomembrane (Gm PP) / geospacer (GS) exhibiting a very low friction angle (ϕ_g=7° - Table 2).

For the same conditions, the Figure 11 presents the results obtained for the trial (P_2). The result is dramatically different : the critical interface where the extreme differential sliding displacements are concentrated is the interface geospacer (GS) / Geotextile (Gt R) (ϕ_g =15° - Table 2) corresponding to the smoothest surface. In addition, it has to be noticed the mitigation of the displacements, comparing with the trial P_1, thanks to the high roughness of the geomembrane (Gm B) comparing with the (Gm PP). However, in the case of the geomembrane Gm B P_2 liner, there is no longer separation of the functions as recommended in chapter 2.

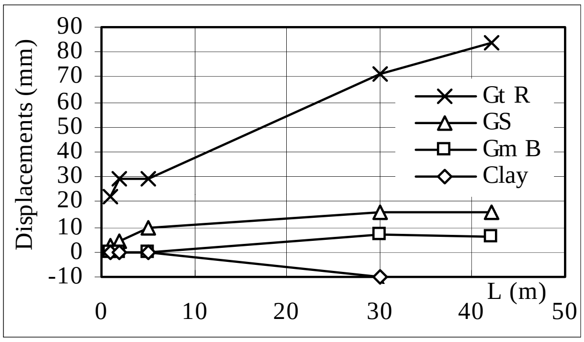

Figure 11. Trial P_2 – displacements in the different geosynthetics at (t_0+72h).

5 CONCLUSION

The comparative behaviour of the two trials P_1 and P_2 clearly illustrates how it's possible to modify the whole deformation of a lining system, only changing the friction properties of one interface (here Geomembrane / Geospacer).

Correlatively, the design of a composite liner required an accurate evaluation of the mechanical properties, friction relationship as demonstrated here, but also stiffness and creeps.

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REFERENCES

Brink D., Day P.W., Du Preez L. 1999. Failure and remediation of Bubul drive landfill, Kwazulu-Natal, South Africa, Sardinia 99, pp. 555-562.

Daniel D.E., Koerner R.M., Bonaparte R., Landreth R.E., Carson D.A., Scranton H.B. 1998. Slope stability of geosynthetic clay liner test plots. Journal of geotechnical and environmental engineering, Vol. 124, N° 7, pp. 628-637.

Feki N. 1996. Modèles physique et numérique de la stabilité des couvertures géosynthétiques sur pente : application aux centres de stockage de déchets, thèse de l'Université de Grenoble, 156 p.

Gourc J.P., Berroir G., Stock R., Begassat P. 1997. Assessment of lining systems behaviour on slopes, Sardinia 97, Vol. III, pp. 495-506.

Lalarakotoson S., Villard P., Gourc J.P. 1999. Shear Strength Characterization of Geosynthetic Interfaces on Inclined Planes. Geotechnical Testing Journal, GTJODJ, Vol. 22, N° 4, December 1999, pp. 284-291.

Soyez B., Delmas Ph., Herr Ch., Berche J.C. 1990. Computer evaluation of the stability of composite liners, Geotextiles and Geomembranes and related products, Balkema, Rotterdam, pp. 517-522.

Villard P., Gourc J.P., Feki N. 1997. Anchorage strength and slope stability of a landfill liner. Geosynthetics'97 Conference Proceeding, Vol. 1, Long Beach, California, USA, March 1997, pp. 453-466.