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Comparative long term survey of geosynthetic cap lining systems

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ABSTRACT:The stability of geosynthetic lining systems used on landfill slopes is a difficult design problem. Indeed the multilayer structure of these confining barriers linked to often steep and very long slopes, makes the risk of tangential sliding very real. In the literature, there are reports of a certain number of large scale experiments, but usually for shorter slopes than the following (more than 50m) and much shorter observation times (2 years in this case). Neither have many case histories been subjected to such thorough monitoring. The essential result obtained is that large relative tangential displacements between the barrier's components are observed on fitting it, but that over the 2 years of observations which followed, the geosynthetic lining system followed the important deformation of the waste embankment without internal sliding. This article is completed by a second article in the same conference, dedicated to the fine measurement of properties of the interfaces between the various components of the geosynthetic lining system (Reyes-Ramirez et al.2002).

1 INTRODUCTION

Geosynthetic lining systems are increasingly used as confining barriers for landfill slopes, but some cases of instability have been observed (Brink et al.1999). A certain number of large scale experiments have been performed (Gourc et al.1997,Daniel et al.1998) and design methods suggested (Soyez et al.1990) as well as models such as the Finite Element Method (Feki 1996 , Villard et al.1997) .

However, the calibration of design methods using measurements from real sites has proved difficult, because on the one hand the measurements of tangential displacements of various geosynthetics and soil layers are difficult to make, as this article shows, and on the other hand, the experimental evaluation of interface friction relationships is also difficult, as shown in the companion paper at this conference (Reyes-Ramirez et al.2002).

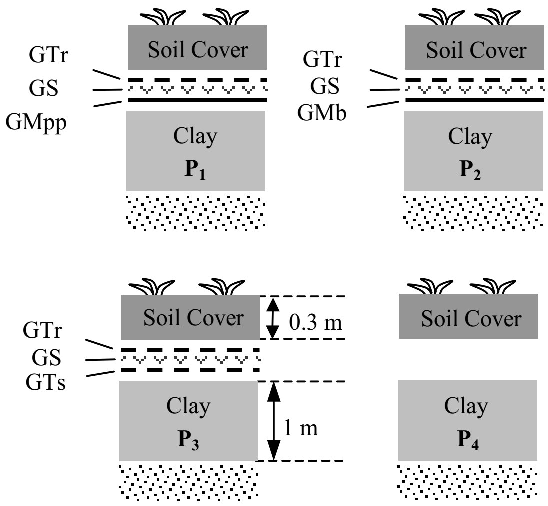

Figure 1. The 4 different geosynthetic lining systems on slope (Torcy landfill)

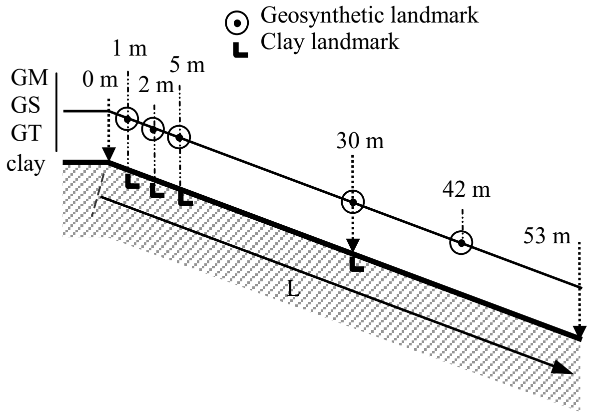

Figure 2. Position of the landmarks on the geosynthetics and clay layer for monitoring the tangential displacements

2 PRESENTATION OF THE EXPERIMENT AND SHORT TERM BEHAVIOUR (time t_c to t_c + 72h)

This experiment, as well as the short-term behaviour of the geosynthetic lining system, i.e. installation on a slope, have been presented in a previous article (Villard et al.2000). The test was performed at Torcy, a landfill belonging to the SITA Group. The main results are summarized here.

Table 1. Mechanical characteristics of geosynthetics

	Name	Thickness (mm)	T_f (kN/m)	ε_f (%)	J (kN/m)
GTr	Rock Pec 75	2.5	95	12	580
GTs	S41	1.6	12	80	27 (ε=10)
GMb	Terranap431	4	25	60	80 (ε=15)
GMpp	Hydronap	1	13.9 6.5*	616 29*	51(ε=7.5)
GS	5902	4.4	7.5	30	25

* yield value

Table 2. Friction angles ϕ_g at the interfaces (shear box)

	ϕ_g (°)	ϕ_g (°)	ϕ_g (°)
P_1	Clay/GMpp : 13.8	GMpp/GS : 7	GS/GTr: 18
P_2	Clay/GMb : 18	GMb/GS : 31	GS/GTr: 18
P_3	Clay/GTs : 33	GTs/GS : 15.5	GS/GTr: 18

Four trials were considered, corresponding to the lining systems in Figure 1, covering a waste embankment 15 metres high, installed on a slope at 3/1 with the horizontal. We are concerned here with trials P1 and P2, in the knowledge that P4 is the reference, with no geosynthetic. The tensile properties of the geosynthetics are noted in Table 1 and the friction properties in Table 2. It was noted that polypropylene, GMpp, and bituminous,GMb geomembranes differ considerably in their tensile behaviour as well as their friction properties, bituminous geomembrane being much rougher.

Note that for the authors of the article, optimizing the design of a geosynthetic lining system consists of giving each layer of geosynthetic a well-identified function: watertighness function for the geomembrane GM without any tensile mobilization, stabilization of the soil cover by tensile mobilization of the geotextile GTr..

The monitoring principle consists of measuring tangential displacement using cables attached to different points of the barrier's components (Fig.2 and Villard et al.2000) and connected to a monitoring table fixed on top of the embankment (Fig.5). Figures 11 and 12 show photos of the experimental site.

Figures 3 and 4 show the distribution of the tangential displacement of the different components of P1 and P2 along the slope (distance L from the top), between the time construction is ended (tc) and time (tc + 72 hours): in both cases, a "critical interface" was noted depending on which the sliding (difference in displacement between the two geosynthetics in contact) was strongest: for P1, between the geomembrane GMpp and geospacer GS (ϕg = 7°, interface with the least friction) and for P2 between the geospacer GS and the geotextile for reinforcement GTr (ϕg= 18°, same condition).

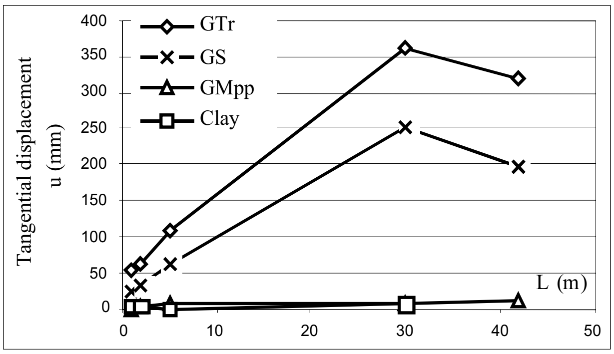

Figure 3. Trial P_1 - tangential displacements in the different components at tc

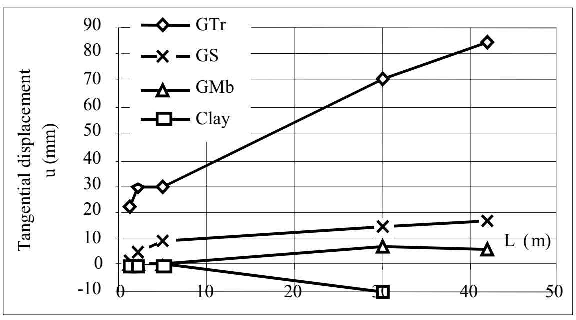

Figure 4. Trial P_2 - tangential displacements in the different components at tc

3. COMPARATIVE LONG-TERM SURVEY OF THE GEOSYNTHETIC LINING SYSTEM (time $t > t_o = t_c + 72$ h)

The long-term monitoring of the 4 trials is based on the same principle as for the short term, with measurement of tangential displacement using inextensible cables attached at different points on the slope (Fig.2). On the other hand, in long-term monitoring,additional measures to this type of devices should be needed because the waste embankment, consisting of domestic and non hazardous waste, is compressible: the profile of the slope is deformed, and more seriously, the monitoring table at the top of the slope settles, following the waste body deformation. The principle of the support of the cables by the monitoring table is shown in Figure 5: a counterweight and a pulley keep the cable under tension and the displacement of the cursor evaluates the distance (D) in time (t) between the landmark and the pulley (Fig.6a). Let (Do) be the reference value at the start time (to), which here will be time (tc + 72h) of chapter 2.

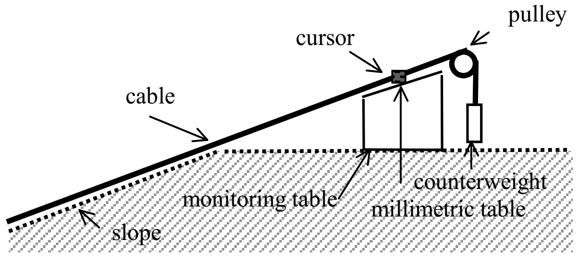

Figure 5. Monitoring of the tangential displacements

The cursor displacement measured on the monitoring table is $\Delta D = (Do - D)$, but because of the significant displacement of the landmark on the one hand and the pulley on the other, the value of this displacement is quite different from that of the displacement tangential to the slope, which is required (Fig.6a).

To obtain the real value of tangential displacement, we therefore completed the observation with topographical monitoring of the slope profile: the 12 landmarks are 5 m apart along the slope and placed on top of the cover soil. The interpretation is based on the hypothesis that vertical settlement (s) of a point M' on the geosynthetic or the clay is equal to the displacement of point M on the surface (obtained by topographical measurement) of the same co-ordinate (y). (Fig.6b).

For measured surface displacement (dy , dH), settling

$s = dH - dy . \tan \beta$

with β the angle of the deformed slope.

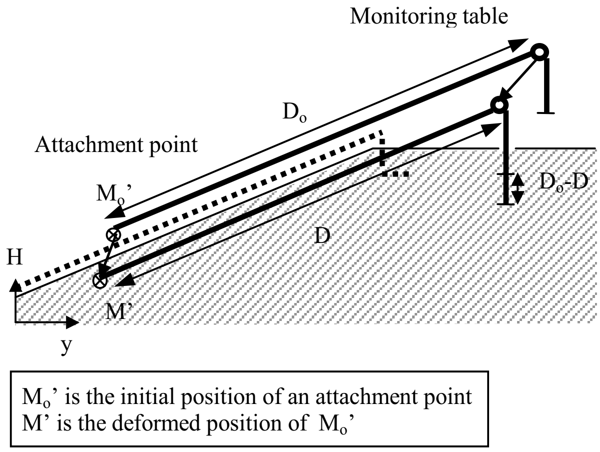

Figure 6a: Scheme of the actual displacements of an attachment point(landmark) and the induced cursor displacement on the monitoring table.

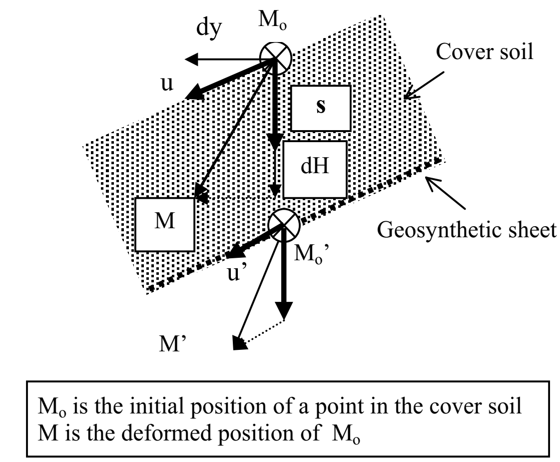

Figure 6b. Comparison between the displacement of a point in the cover soil and an attachment point

Let (y_T , H_T) be the co-ordinates of the monitoring table pulley at time (t – to) after construction , (y' ,H ') those of point M' at the same time and (y'o , H'o) those of point M'o corresponding to the end of construction + 72 hours (t = to).

Giving the expression:

$$(Do - \Delta D)^2 = (y_T - y'o + dy')^2 + (H_T - H'o + s + dy'.\tan\beta)^2$$

ΔD being given by the displacement of the cursor on the monitoring table and the other parameters in the formula from topographical measurement, solving the equation gives (dy').

Finally, the tangential displacement (u') is obtained by the formula u' = dy'/cosβ.

The calculated tangential displacement (u') at L= 5 m (Trial P1) and L = 30 m (Trial P2) from the top of the slope are displayed on the Figures 7 and 8 , for a period of 18 months since the end of construction, as well as the displacement (u) of the surface

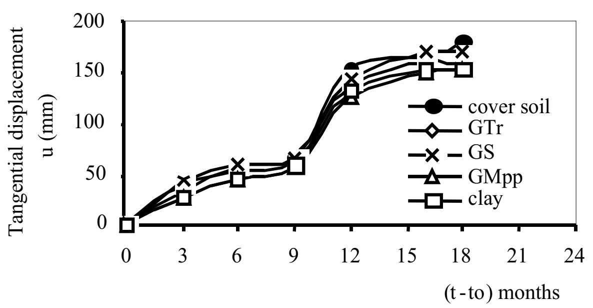

Figure 7: Trial P1 - Tangential displacements of the different components of the lining system

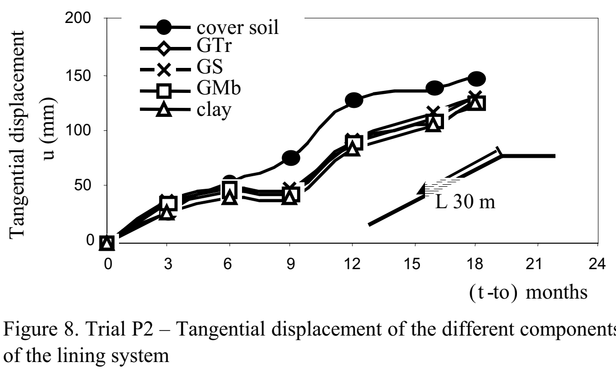

Figure 8. Trial P2 – Tangential displacement of the different components of the lining system

The results given in figures 7 and 8 can be considered to be original and very interesting:

- It may be noted that displacement tangential to the slope observed over almost two years was considerable, about 150 mm .
- This displacement is almost identical for all the barrier's components, which demonstrates that there is no sliding between the different layers of the geosynthetic lining system , unlike the first post-construction phase (Fig.3 et 4). This is therefore a global displacement of the barrier, which simply follows the deformation of the subjacent waste embankment. No creep strain is observed in the geosynthetics.
- The displacement values (u') calculated can be assumed to be reliable because, in spite of the fact that they were obtained indirectly from a combination of topographical measurements on the one hand, and tangential displacement measurements on the other, they are always comparable to values of (u), tangential displacement of the surface of the cover soil obtained only from topographical measurements.

4.LONG TERM DEFORMATION OF THE LANDFILL SLOPE:

This experiment, performed over two years, allowed us to observe the deformation of a waste embankment due to creep behaviour. Figure 9 shows the "displacement" vectors obtained from surface topographical measurements (vectors on a specific scale). Figure 10 shows that the deformations for the 4 profiles P1, P2 ,P3, P4 are very close, giving evidence of good homogeneity in the behaviour of the waste fill.

Figure 13, which plots the vertical settlement (s) versus elapsed time confirms the similarity of behaviour for all 4 profiles over time.

Analysis of these slope deformations at this landfill confirms that the slopes do not remain flat over time. In the present case, a simple convexity ("doming" of the slope) is observed, but it is quite common to observe a double convexity with a point of inflexion.

This leads to a new area of research, involving the study of not only the stability of the capping with respect to sliding, but also of bending strength of the confining barrier subjected to differential settlement. It is predictable that a geosynthetic barrier, in this case, will show much better behaviour than a clay barrier, because of its greater ability to withstand bending-shearing stresses.

5 CONCLUSION

The sliding stability of geosynthetic lining systems on landfill slopes constitutes a difficult problem. Careful monitoring of 4 experimental sections took place over 2 years. This monitoring showed that the construction phase is a critical phase, conditioned by the method of implementation. During the two years, no creep deformation of the geosynthetic was observed, the major deformations observed being due to creep deformation of the waste fill. The geosynthetic lining system was shown to be flexible enough to follow the movements of the waste embankment without damage.

ACKNOWLEDGEMENTS

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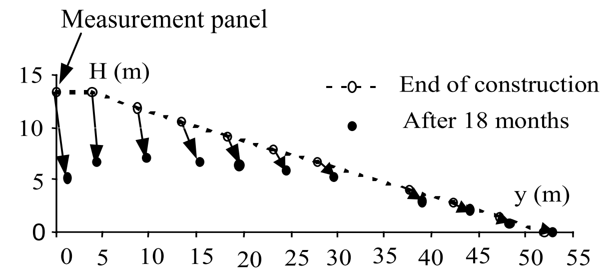

Figure 9. The deformed profile of trial P1 after 18 months from the end of construction (displacement scale: 10mm for actual displacement 500mm)

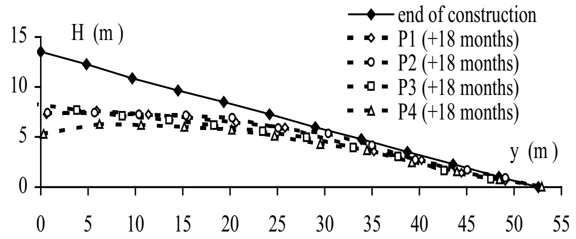

Figure 10. Comparison of the deformed profiles of the four trials after 18 months from the end of construction

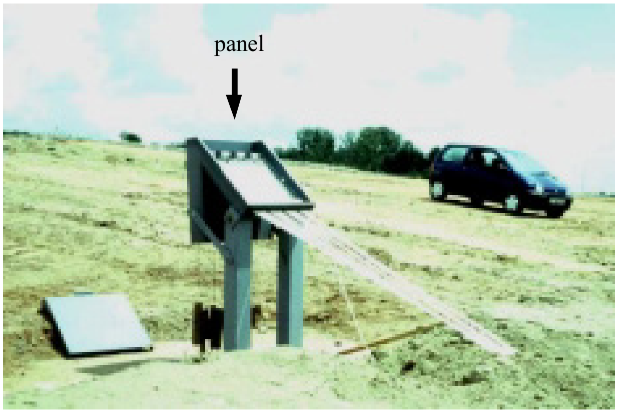

Figure 11. Top of the slope , monitoring table and cables for tangential displacement measurement.

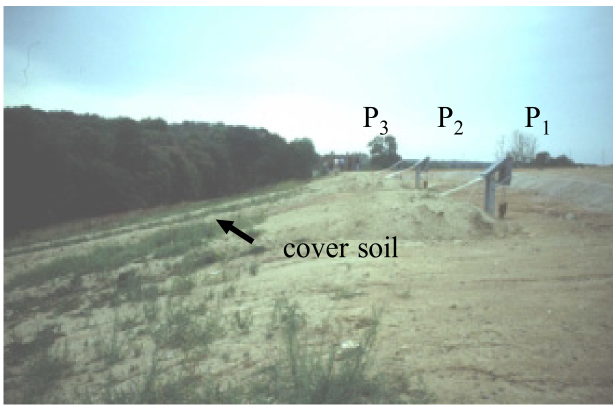

Figure 12. Overview of the experimental site from the top of the landfill

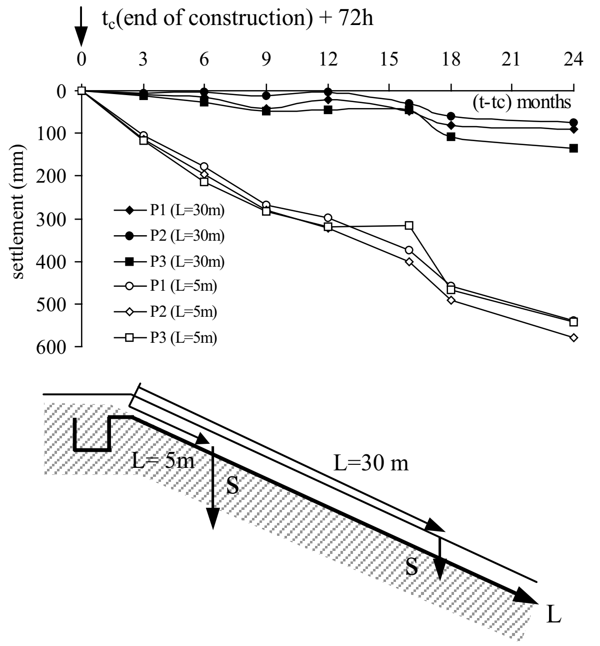

Figure 13. The deformed profile of trial P1 after 18 months from the end of construction

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