Geotextile Reinforced Embankment to Cross a Peat-Bog

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ABSTRACT: The East highway by-pass project of Troyes in France crosses a peat bog where the thickness of peat is approximately 2 to 3 m. The maximum design height of the embankment is approximately 7 m. The use of a geotextile reinforced embankment was selected among other techniques. Prior to the construction of the actual highway embankment, an experimental embankment was constructed and monitored. Measurements of foundation soil settlements, horizontal soil displacements at the bottom of the embankment and geotextile strains are discussed. The experimental embankment showed that the primary goal which was the removal of peat by punching was not reached while the global stability was improved. It appears that the rate of settlement versus time is rather uniform.

1 INTRODUCTION

The highway program of the Aube Department in France includes the construction in 1993-1994 of the East highway by-pass of the City of Troyes. The design project crosses a peat-bog at a place named Argentolle with an embankment of a height in the range of 5 to 7 m. The geotechnical study has shown that the embankment will rest on a 2.5 to 3 m thick peat layer overlying the chalk bedrock. Several techniques to cross this peat bog were analysed: removal of the peat, loading phases, drainage and reinforcement trench, and reinforced embankment. The "Direction Départementale de l'Equipement de l'Aube" finally decided to use a geotextile reinforced embankment in order to have a construction consistent with the site conditions, schedule, preservation of the bog and maintenance of the highway embankment.

As the selected construction technique is still considered innovative, an experimental embankment was constructed and monitored prior to the construction of the actual one.

2 SITE DESCRIPTION

The Argentolle site is located close to the City of Troyes in eastern France. The peat bog to be crossed has some areas of standing water. A geotechnical study was performed by the "Laboratoire des Ponts et Chaussées de Nancy" in order to assess the conditions to cross this bog. A temporary road access was constructed on the peat to allow field investigations; dynamic penetration tests and scissometer tests were performed. A typical cross section of the ground along the project axis is shown on Figure 1.

The foundation soil can be described from top to bottom as follows:

- 1.5 m to 3 m of peat,
- 1 m to 2 m of clay with trace vegetative matter,
- 1 m to 1.8 m of clayey gravel, and
- bedrock of soft chalk.

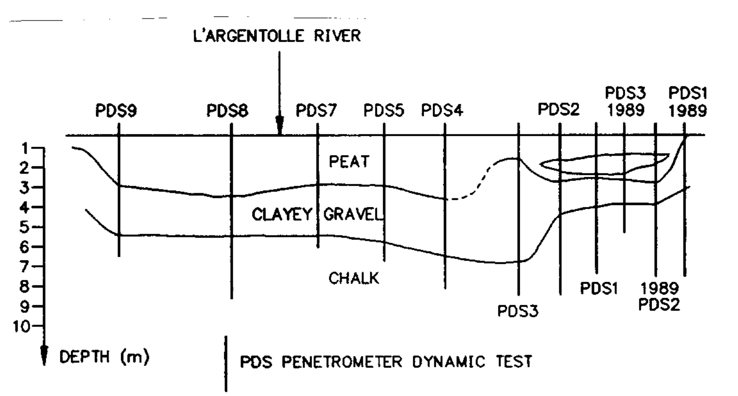

Figure 1. Cross section of the soil foundation along the project axis at the Argentolle site.

The main characteristics of these soils are summarized in Table 1 where w_n is the natural moisture content, c_u the undrained cohesion in place, R_d the dynamic penetration resistance, and C_c the compressibility coefficient.

Table 1. Geotechnical characteristics of foundation soil, at the Argentolle site.

Soil	w_n (%)	Organic Content (%)	c_u (kPa)	R_d (kPa)	C_c
Peat	150 to 319	20 to 50	5 to 30	<500	1.56-2.44
Clay	44.1 to 85.7		40 to 60	0.5 to $2\ 10^3$	0.49
Gravel			90 to 100	4 to $5\ 10^3$	

3 DESIGN OF THE REINFORCED EMBANKMENT

The purpose of the selected construction technique was to reinforce the base of the embankment with high tensile strength geotextiles in order to prevent a failure by the classical rotational mechanism and to ensure that the embankment would punch through the peat. It was assumed that a significant fraction of the peat located under the embankment would be displaced laterally during the construction of the embankment.

The reinforcement with geotextiles was designed according to a limit equilibrium method with the software CARTAGE developed by the "Laboratoire Central des Ponts et Chaussées". From past experience (Gourc, 1992) it is known that this design method is only representative to the situation at failure and not to the punching of the peat. It was assumed that tensions in geotextiles generated by the lateral displacement of the foundation soil would be lower than the ones at failure. Specifications for the reinforcement geotextiles are shown in Table 2 and a cross section can be seen on Figure 2. The cross section shows the structure which was specified to allow the construction of the reinforced embankment. In Table 2, T_f is the tension at failure, ϵ_f the strain at failure, F_T the tear resistance, ψ the permittivity, and O_{95} the opening size. The geotextile characteristics are to be measured according to the French standards.

Table 2. Specifications for the geotextiles used in the reinforced embankment at the Argentolle site.

	T_f (kN/m)	ϵ_f (%)	F_T (kN)	ψ (s^{-1})	O_{95} (μm)
Separation	≥ 25	≥ 30	≥ 1.2	≥ 0.1	<125
Reinforcement	≥ 120	≤ 20	≥ 1.7	≥ 0.1	

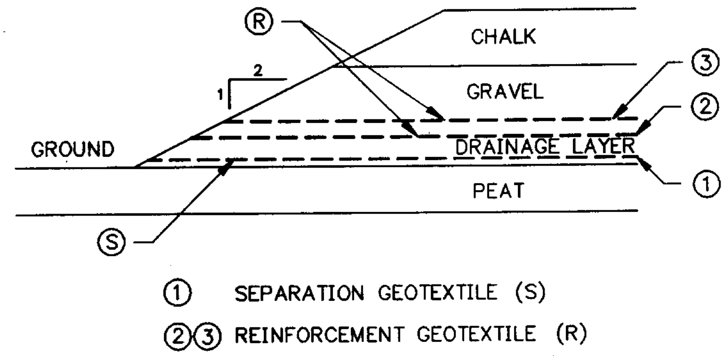

Figure 2. Cross section of the geotextile reinforced embankment at the Argentolle site.

The design included assumptions on the soil characteristics, the homogeneity of the site and the mechanism to occur. These assumptions needed to be checked. To that end, an experimental embankment was constructed and monitored to validate the possibility of removing the peat and the design.

4 EXPERIMENTATION

The experimental embankment was located on the most critical section of the project. Its design height was 7 m and the design size of the top platform was approximately 30 m x 30 m at the completion.

The parameters to be monitored and the corresponding measuring devices are described in Table 3. All the devices were connected to a "technical pit" located on the axis of the experimental embankment. The settlement of the technical pit was also monitored. Placement of the fill material (gravel and chalk) occurred during October and the beginning of November 1993 in two steps. It was organized to minimize construction time. The first step corresponds to the placement of 3.60 m of gravel (see cross section Figure 2), from bottom to top: drainage layer, first geotextile, 0.60 m of gravel, second geotextile, and 2.20 m of gravel. The second step is the placement of chalk on top of the gravel up to the final design height. When the work was stopped in November because of bad weather conditions, the height of the experimental embankment was 5.80 m on the axis.

During this placement, the width of the experimental embankment was reduced to 10 m on the cross section to try to provoke punching of the peat according to the monitoring results for the first step. This construction process was also planned for the first step but could not be implemented.

The completion of the embankment to its final geometry, which would have been the third step, was not performed in 1993.

Table 3. Instrumentation of the experimental embankment, Argentolle site.

Parameter to be monitored	Measuring Device	Accuracy	Location
Settlement	LPC Tassometers	0.01 m	3 cross sections of 5 points each
Horizontal displacement of the drainage layer	Metallic abutment plate	0.001 m	central cross section. Devices located at mid-height
Strain of geotextile (2)	cable transducer	0.1%	central cross section. Points spaced 4 m
Strain of geotextile (3)	cable transducer	0.1%	central cross section. Points spaced 4m
Pore pressure in drainage layer	pore pressure cell	0.1 kPa	6 points on central cross section

Note: Numbers in parentheses refer to circled numbers in Figure 2.

5 MONITORING AND RESULTS

5.1 Settlements

Settlements at the end of the first step (22 Oct. 93) are in the range of 0.14 m to 0.27 m (0.37 m on tassometer T3.5). With the second step they increased to values in the range of 0.25 m to 0.40 m (0.45 m on tassometer T3.5) at the end (04 Nov. 93). The completion of the experimental embankment was planned to begin on 9 February 1994. The measured settlements were in the range of 0.35 m to 0.60 m just before the beginning of work.

Figure 3 illustrates the settlements versus time. It can be seen that the mechanism is more a consolidation one than a punching one. The settlement curve obtained with tassometer T3.5 is different from the curves at other locations of measurement, perhaps because some waiting fill material was piled at the location of this tassometer prior to the construction of the experimental embankment.

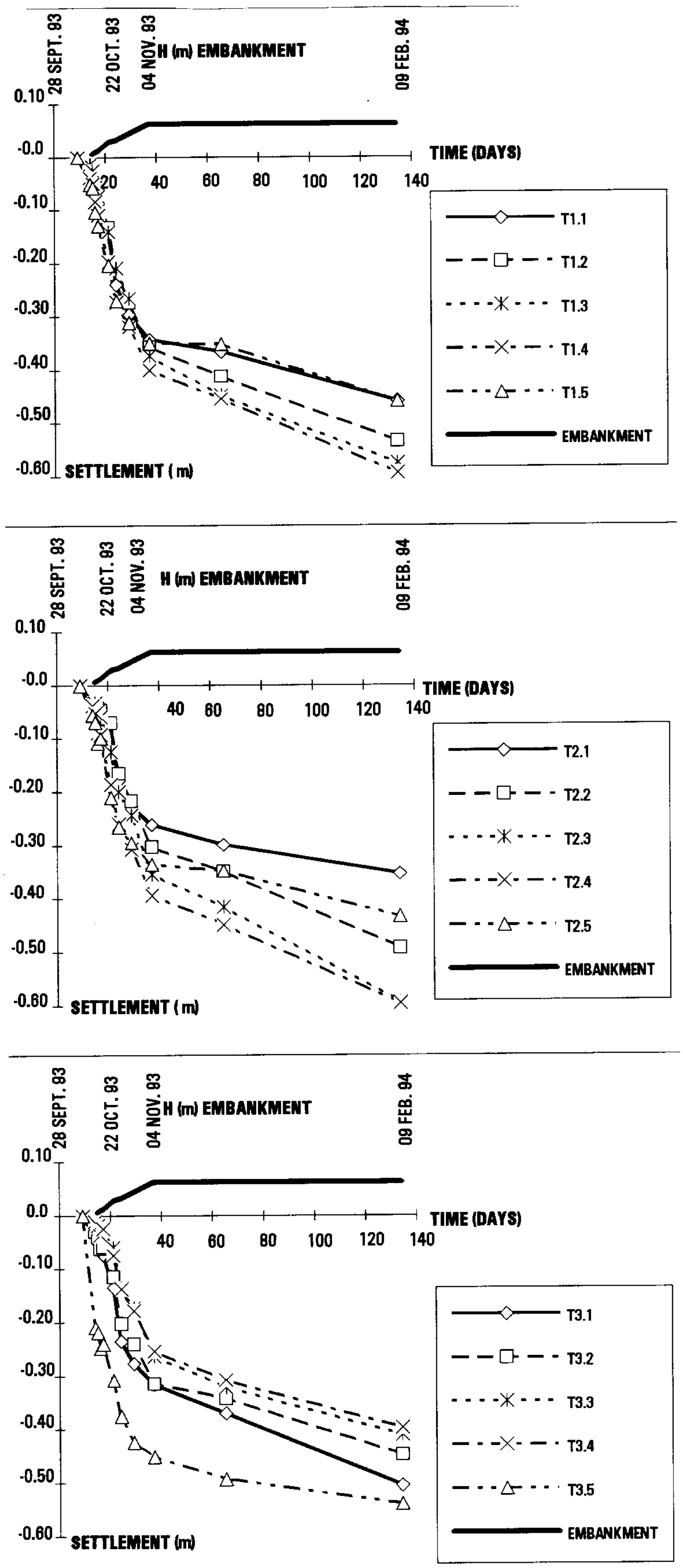

Figure 3. Settlements measured on the experimental embankment.

5.2 Horizontal soil displacements

Horizontal soil displacements measured at mid-height of the drainage layer are in the range of 6 mm to 34 mm at the end of the first step (22 Oct. 93), 6 mm to 49 mm at the end of the second step (04 Nov. 93) and 9 mm to 82 mm before the third step (09 Feb. 94) as on Figure 4. The drainage layer is in extension on the side (T1-2-3) and in compression on the side (T4-5-6), where settlements seem to be the greater.

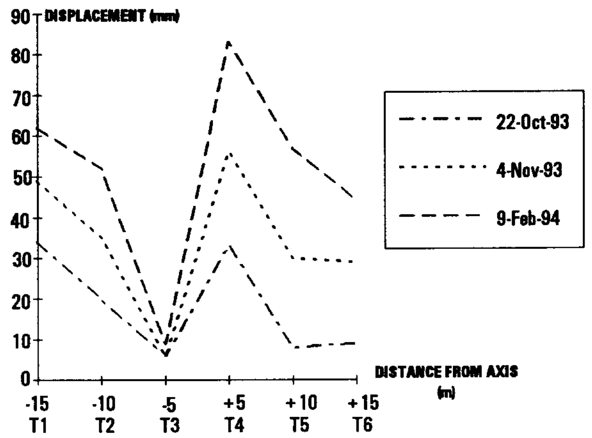

Figure 4. Horizontal displacements of the drainage layer soil during construction of the experimental embankment.

5.3 Reinforcement geotextile strains

The average strain was calculated at regularly spaced locations (cable devices C1 to C22) on reinforcement geotextiles from the measured differential displacement of two points spaced 0.50 m. The greater values are listed in Table 4.

Table 4. Greater strain calculated on reinforcement geotextiles.

Greater strain (%)	22Oct.93	04Nov.93	09Feb.94
Upper geotextile*	0.4	0.7	0.8
Lower geotextile	0.8	1.3	1.7

* The upper geotextile was observed in "compression" except at some locations for which values are indicated in the table.

Distribution on the instrumented cross section of the average calculated strain can be seen on Figure 5. During the construction of the experimental embankment, a significant increase of strain is not observed except on the location device 7 (+2.5 m from the axis) in the central zone. The greater value at the beginning of the third step (09 Feb. 94) is calculated on location device 7. The lower geotextile is mainly mobilised in the axis zone with an average strain about 2%. The upper geotextile does not seem really mobilised. The displacement measured in the drainage layer at location 4 (+5.0 m from the axis) gives a calculated average strain in agreement with the one measured on the lower geotextile at location 7.

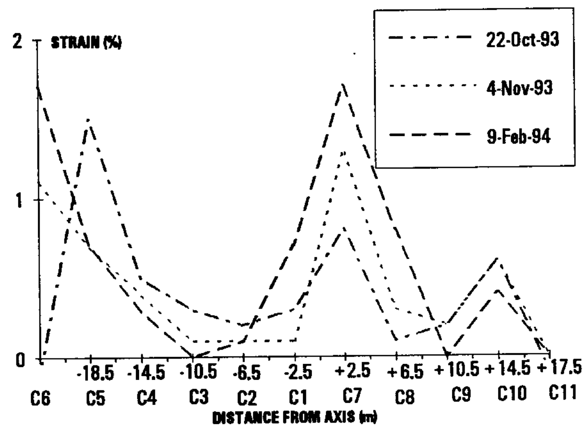

Figure 5. Calculated strain of the lower reinforcement geotextile during the construction of the experimental embankment.

6 CONCLUSION

Only partial conclusions can be made because the original plan for the experimental embankment was disturbed by the weather conditions. The construction was slower than planned and the work is not completed.

The primary goal of removing the peat by punching was not reached. The mechanism which occurred was mainly a consolidation one.

On the other hand the use of geotextile reinforcements has allowed construction of the embankment to the final design height without any failure which would not be the case with a classical construction according to the stability analysis performed as part of the geotechnical study. The settlement-time behaviour is relatively well uniform.

The maximum tensile force calculated from the average strain is about 20 kN/m on the lower geotextile which appears to be three times less than the design value. The final strain with the completion of the experimental embankment has still to be calculated to back analyse the design.

REFERENCES

Gourc, J.P., "The Geosynthetics in the Embankment Structures", Earth Reinforcement Practice, Ochiai, H., Hayashi, S., and Otani, J., Eds., Proceedings of Kyushu 92, Fukuoka-Kyushu, Japan, Nov 1992, Vol. 2, pp. 771-798.