Large Retaining Structures Reinforced by Geosynthetics: French Case Histories

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Proceedings: Fourth International Conference on Case Histories in Geotechnical Engineering, St. Louis, Missouri, March 9–12, 1998.

LARGE RETAINING STRUCTURES REINFORCED BY GEOSYNTHETICS FRENCH CASE HISTORIES

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Paper No. 5.12

ABSTRACT

French experience in earth embankments reinforced by geosynthetics dates back more than 25 years. This technique was developed on the basis of reference structures fitted with instruments to monitor their behaviour. Three of the largest structures built have been chosen in this paper as they are typical of the different construction technologies used in France.

KEYWORDS

Retaining structure, reinforcement, geosynthetic, facing, internal behaviour, global behaviour

1 INTRODUCTION

France has lengthy experience of structures reinforced by geosynthetics. The structures are generally built for retention purposes. Since the first applications more then 25 years ago, the geotextiles used have obviously changed but, above all, construction technologies have changed even more, especially with respect to the facing. The facings were initially made of uncovered geotextile and it was difficult to protect them from UV solar radiation.

The modern structures presented here make use of very different technologies for the facing : vertical geotextile facing doubled by a prefabricated concrete wall (Foix, § 2), sloping facing with vegetation (Lourdes, § 3), segmental wall made of concrete units linked to the geotextiles (Brides les Bains, § 4).

Another specific feature of geotextile-reinforced structures is that they are subject to relatively high strains but, as will be shown later, this strain occurs mainly during the construction process. The current design of this type of structure is based on the ultimate limit state, or in other words, it does not allow strains to be determined with any accuracy.

In view of the considerable height of the structures presented, it seemed of some interest to monitor their behaviour during the construction period and for several years after. The main difficulty here lies in the special instrumentation to be developed for this purpose, given that the conventional equipment used in civil engineering is often unsuitable. This article presents a reliable set of instrumentation, proven on several geotextile-reinforced structures.

2 FOIX RETAINING STRUCTURE

2.1 Presentation of the structure

Table 1 and figure 1 summarise the main characteristics of the structure built in 1994. The facing, imitating natural rock, is separated from the reinforced embankment. A retractable form, positioned with respect to a fixed geometric reference, enables each elementary layer to be compacted. On completion of the embankment, the form supports are removed and the reinforced concrete screen is installed 80 cm in front of the embankment.

Tableau 1 : Foix main characteristics

	Block 1	Block 2	Block 3
Hauteur : H (m)	7	6.1	5.6
Inclination : β (°)	90	90	90
Soil* : ϕ' (°)	40	40	40
Soil* : c'	0	0	0
Geotextile** : T_f strength (kN/m)	400/300	200/150/100	75/50
Geotextile** : J stiffness (kN/m)	3300/2500	1700/1250/830	625/415
Length : L (m)	8.5	6.5	5/3.5
Spacing : ΔH (m)	0.30	0.40	0.40

*sandy soil **woven + non woven polyester

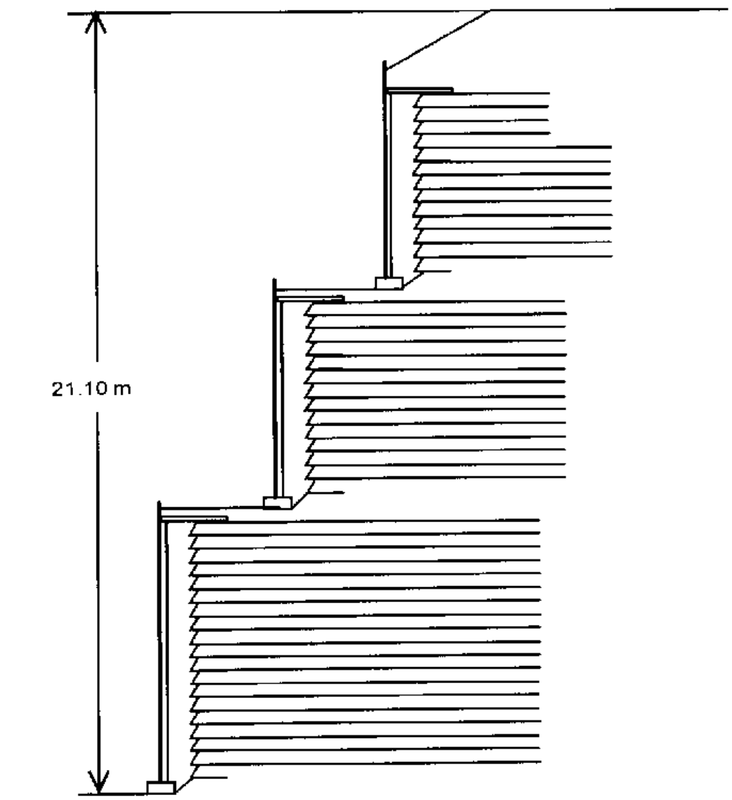


Fig.1 Cross section of Foix retaining structure

2.2 Instrumentation

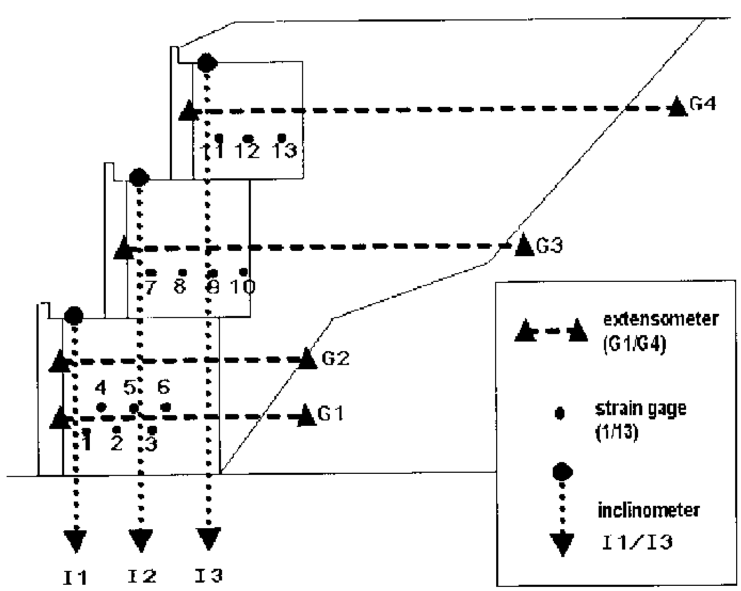


Fig.2 Foix instrumentation

Two measuring profiles were equipped with instruments (fig. 2). Each profile includes : 13 strain sensors fixed to the geotextile sheets, four rod-type horizontal extensometers linking the geotextile facing to a fixed point at the rear of the embankment ; three vertical inclinometers. Except for the inclinometers, all the measurements are continuously recorded.

2.3 Behaviour of the structure

The strains in the geotextiles (fig. 3) occur essentially during construction and would not appear to change much after completion (the observation period now exceeds three years). The strains recorded remain less than 2 %. At the end of construction, the maximum tensile stresses in the instrumented sheets are in the following range :

- * 40 kN/m for sheet with strain gage 2
- * 66 kN/m for sheet with strain gage 5
- * 19 kN/m for sheet with strain gage 8
- * 27 kN/m for sheet with strain gage 11

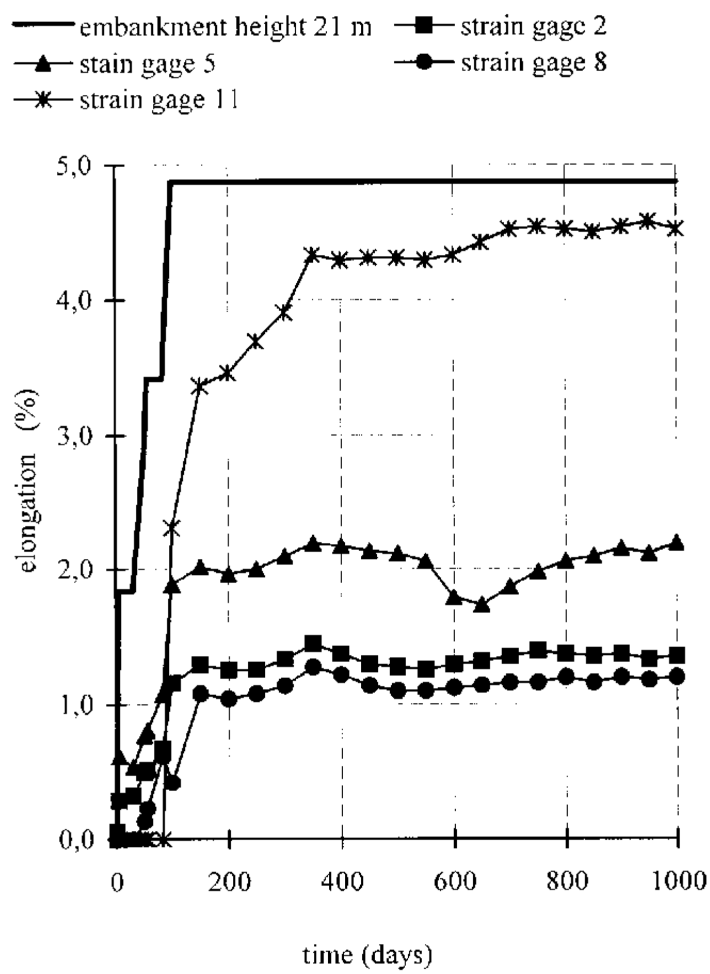


Fig.3 Strains in geotextile sheets (Foix)

Horizontal displacements (fig. 4) measured by the inclinometers and by the extensometers are in agreement. The kinematics of the structure corresponds to a rotation around the base in the downstream direction, associated with a slight lateral movement of the base.

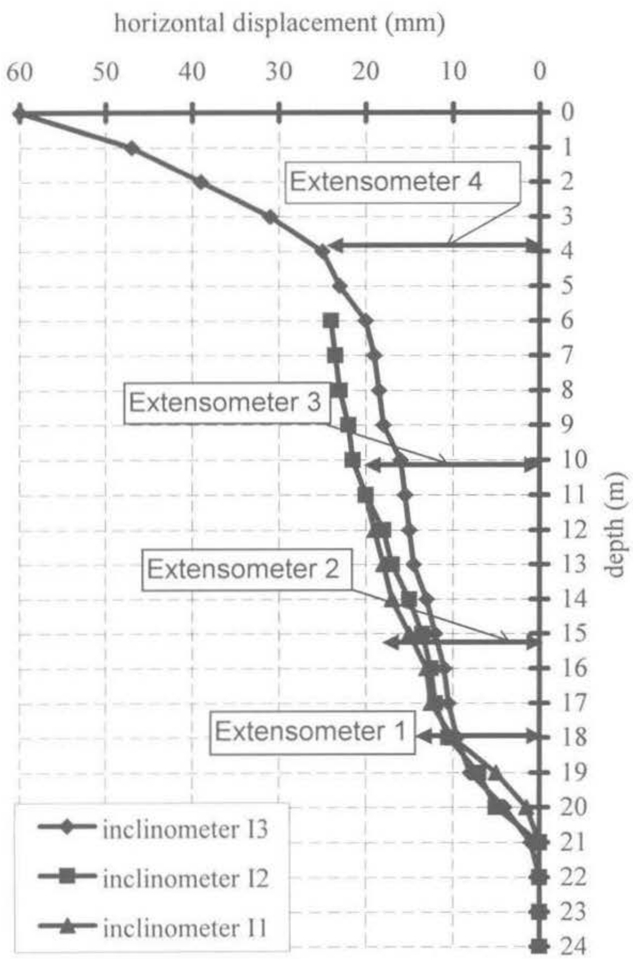


Fig.4 Horizontal displacements from inclinometers and from extensometers (Foix).

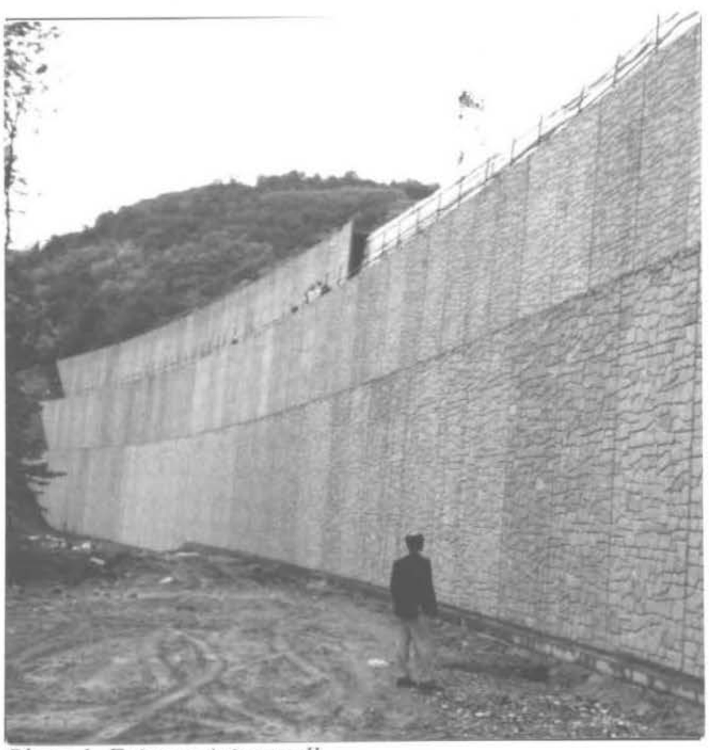


Photo 1 Foix retaining wall.

Over the 3-year observation period, displacements of the embankment (fig. 5) occurred during the construction period and continued for several months after completion. For the last two years, horizontal displacement of the top level has been of the order of 1.5 mm/year. Compared to the strains on the geotextile sheets, these displacements prove that the reinforced embankment moves in a single block (monolithic).

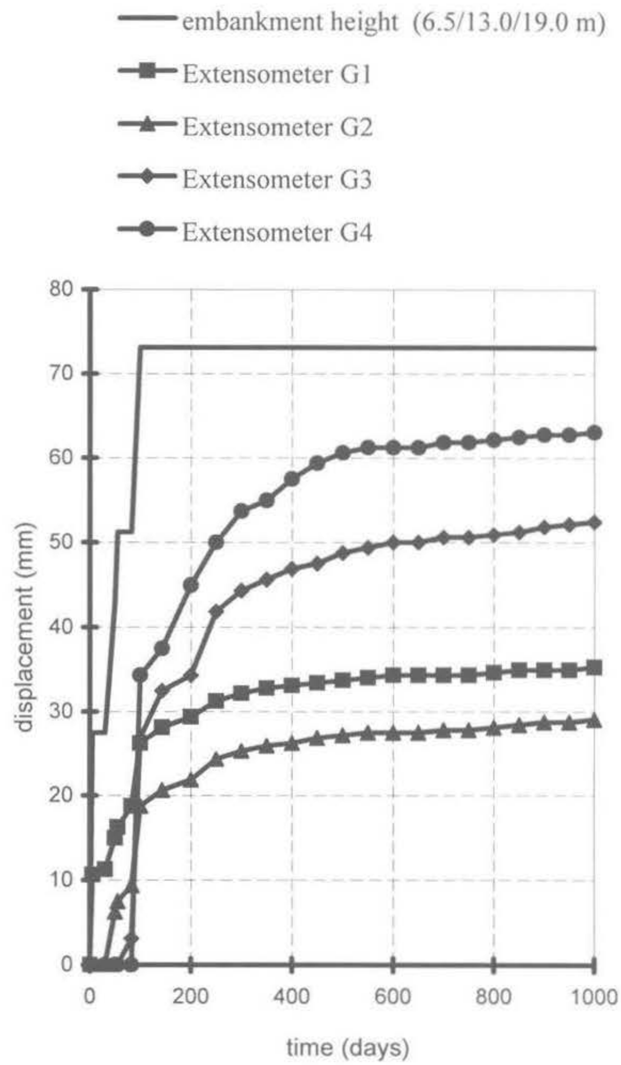


Fig.5 Horizontal displacements (Foix)

3 LOURDES RETAINING STRUCTURE

3.1 Presentation of the structure

The reinforced embankment (fig. 6 and table 2) has a flexible facing with natural vegetation growing in it, made up of a geogrid which retains the top soil. A measurement profile was equipped with 12 strain sensors fitted to the geotextile sheets, three horizontal extensometers and one vertical inclinometer.

Tableau 2 : Lourdes main characteristics

	Block 1	Block 2	Block 3
Hauteur : H (m)	7.3	8	12
Inclination : β (°)	75	50	50
Soil* : ϕ' (°)	35	35	35
Soil* : c'	0	0	0
Geotextile** : T_f strength (kN/m)	300 (n=11)	200 (n=14)	200 (n=13)
Geotextile** : J stiffness (kN/m)	2600	1220	1220
Length : L (m)	10.2	14.3	13.2
Spacing : ΔH (m)	0.60	0.60	0.60

*well graded sandy gravel **woven polyester

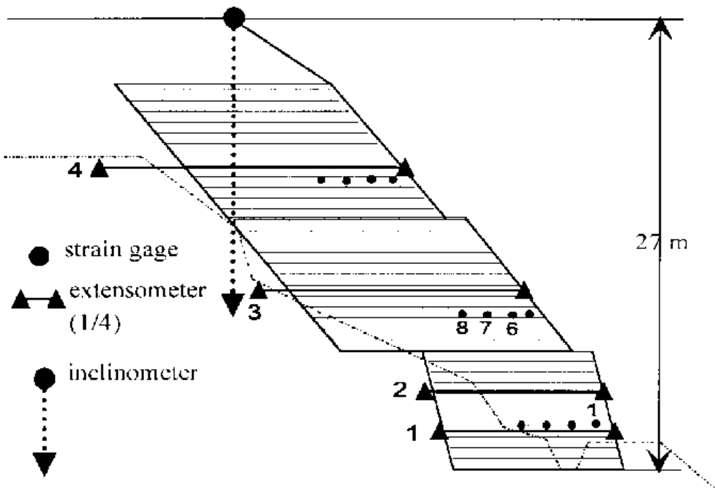


Fig.6 Lourdes instrumentation

3.2 Behaviour of the structure

Most of the strain in the geotextile sheets occurred during the construction period (fig. 7). These strains, observed on a sheet of the middle block, never exceeded 2% and were the highest values recorded in this structure ; the corresponding tensile stresses in the geotextile sheet were 20 kN/m. A few months after completion of works, these strains would appear to have stabilised.

A relatively large part of the overall displacement of the structure (fig. 8) occurred after completion of the works. During the period when the strains in the reinforcing geotextile sheets would appear to have stabilised, the overall displacement continued at a rate of about 4 mm/year.

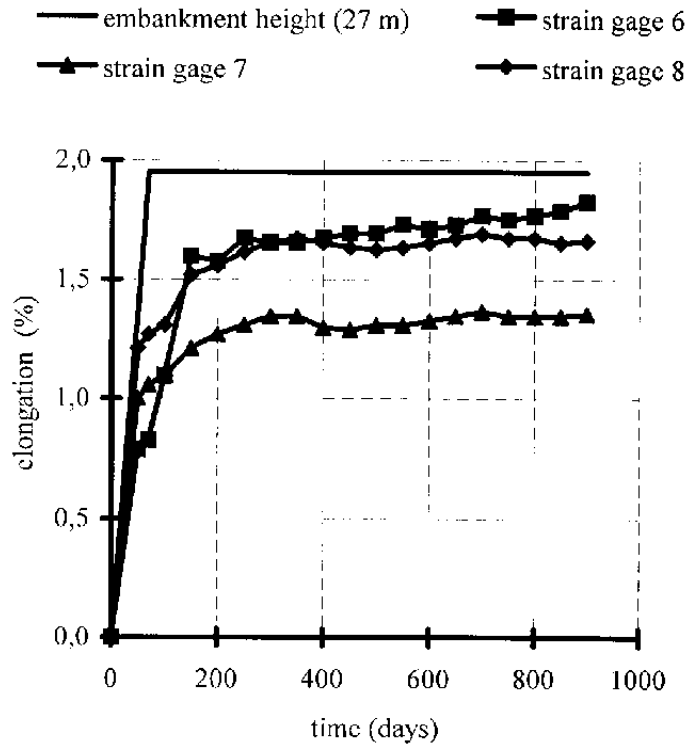


Fig.7 *Strains in geotextile sheets (Lourdes)*

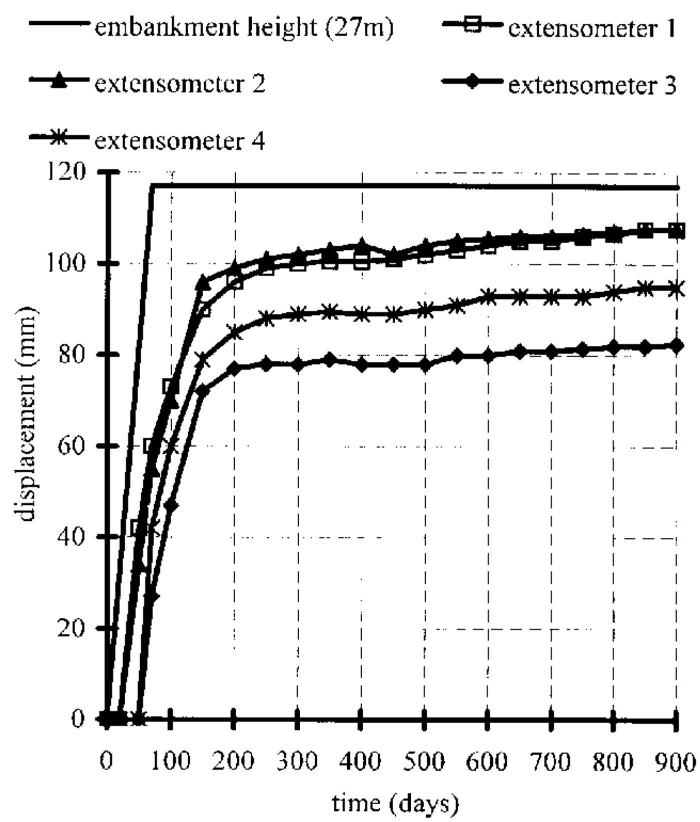


Fig.8 Overall displacements of Lourdes structure

4 BRIDES LES BAINS RETAINING STRUCTURE

4.1 Presentation of the structure

As part of the works to improve access to the sites of the 16th Winter Olympic Games in Albertville, the construction of a bypass around the town of Brides les Bains required a road section along a mountain side. In order to cross over the numerous thalwegs encountered, a technique of nailing in cuts and geotextile-reinforced soil in fills was used. Completed in 1991, the structure is characterised by its segmental wall. The concrete units clamp the geotextile sheets between two layers of sand, thereby avoiding any direct contact of the sheet with the concrete which could otherwise lead to hydrolysis of the woven polyester. The instrumented profile was located at the point of maximum height of the structure (fig. 9) where the road crosses one of the thalwegs (photo 2). The main geometrical and geotechnical characteristics of this profile are indicated in table 3.

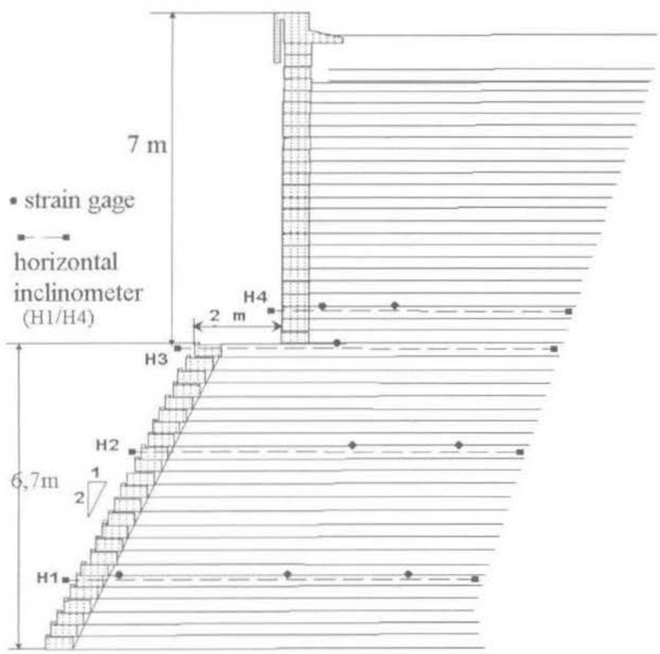


Fig.9 Brides les bains cross section

Tableau 3 : Brides les bains main characteristics

	Block 1	Block 2
Hauteur : H (m)	6.7	7
Inclination : β (°)	63.5	90
Soil* : ϕ' (°)	35	35
Soil* : c'	0	0
Geotextile** : T_f strength (kN/m)	150	150
Geotextile** : J stiffness (kN/m)	1300	1300
Length : L (m)	9.00	6.00/8.00
Spacing : ΔH (m)	0.30/0.60	0.60

*silty gravel **woven polyester

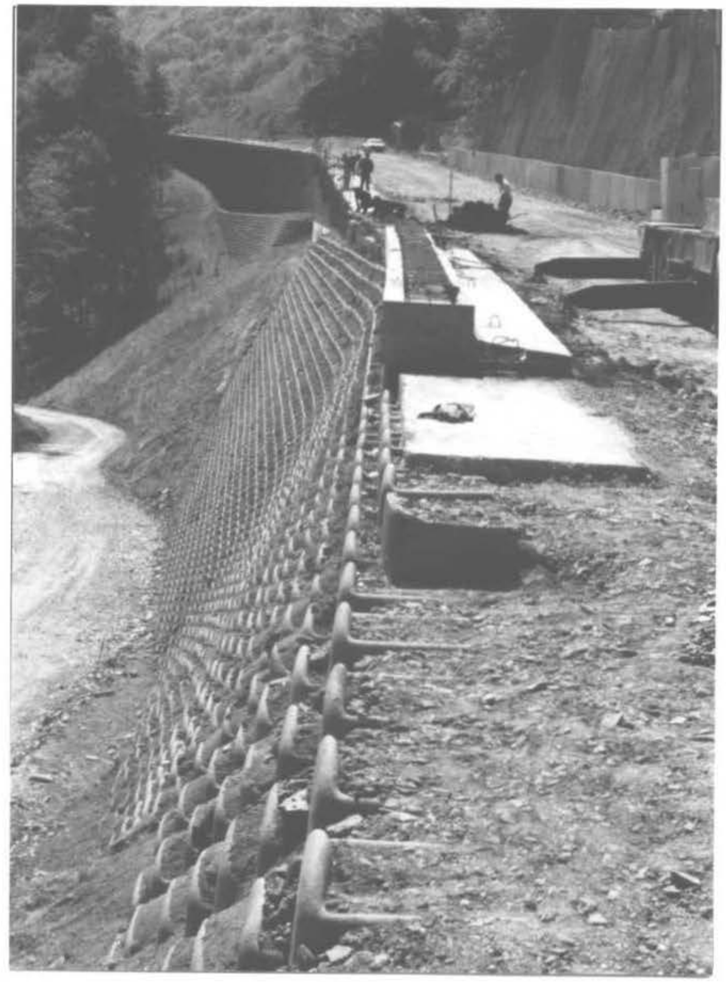


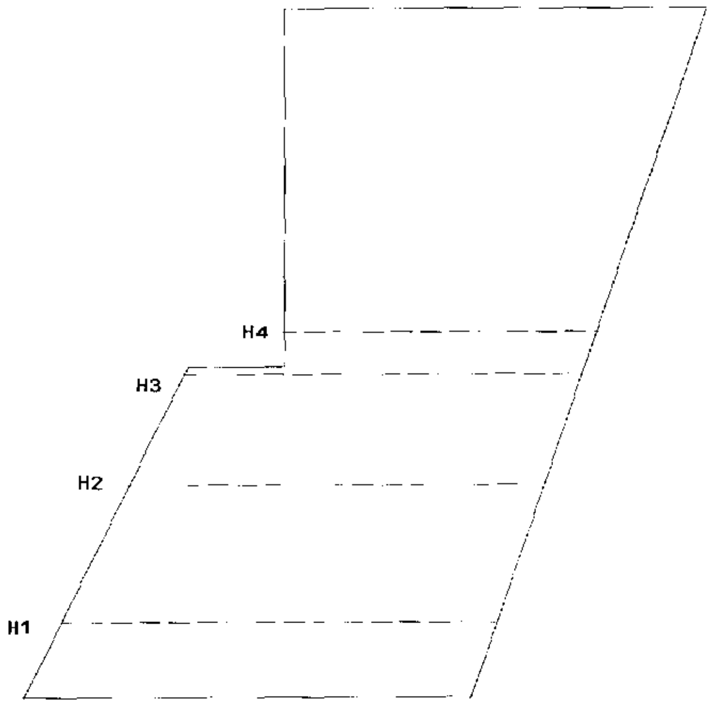
Photo 2 General view of Brides les bains retaining structure during construction

4.2 Instrumentation

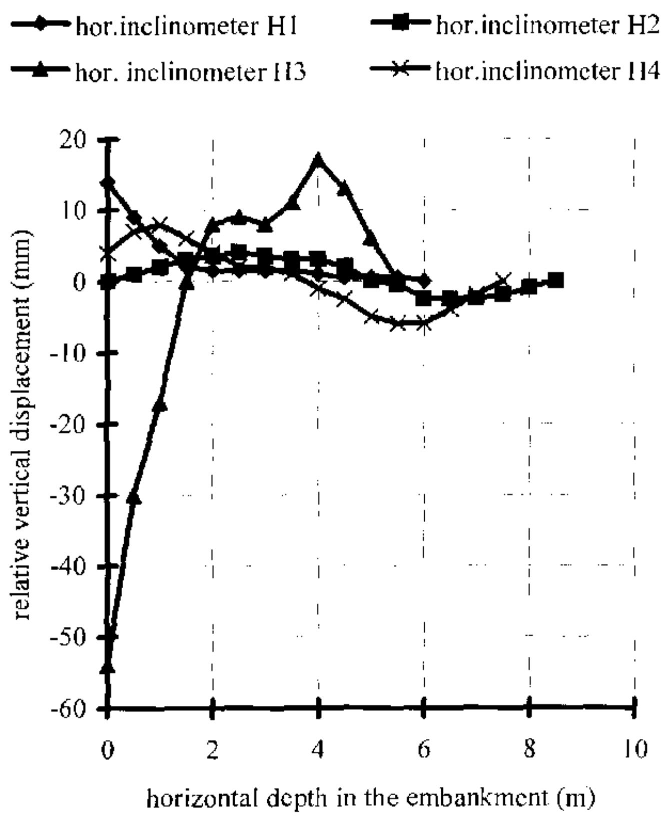
The instrumentation includes sensors for measuring the elongation of four geotextile sheets at four different levels, and four horizontal inclinometer tubes placed in the vicinity of these sheets.

4.3 Behaviour of the structure

The maximum strain measured in the geotextile sheets on completion of construction was 1.3 %, which is well below the failure strain value of about 12 %. Virtually no additional strain has been observed since then. This stabilisation has been confirmed by the inclinometer measurements, although a certain differential movement of the segmental walls and the reinforced soil embankment may be observed (fig. 10). This figure presents the relative movements after construction.



(a)



(b)

Fig.10 Vertical movements observed after construction, from horizontal inclinometers. (a) *: location of the inclinometers ;* (b) *: relative movements*

5 CONCLUSIONS

The behavioural analysis of the structures described in this article, coupled with the experience acquired over the past 25 years, show that geosynthetic reinforcement is an important technique. The main conclusions to be drawn are as follows :

- various construction processes have given proof of their efficiency, especially with regard to the problem of the facing, with three possible solutions : prefabricated concrete outer wall, sloping facing with vegetation, segmental wall with units linked to the geotextile,
- most of the strain induced in these structures, reputed to be "flexible" and "deformable", occurs during the construction period,
- the stress levels in the reinforcing sheets remain low with time, generally less than 20% of the tensile strength,
- however, for major structures, regular monitoring of the behaviour is recommended ; this could be achieved by using specific instrumentation and the same overall strain values must be obtained using two different methods (redundant monitoring system).

ACKNOWLEDGEMENTS

The authors wish to thank Cl. Mieussens, J. Marchal and J.P. Rajot from LPC network who performed the field experimentations.

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