Full Scale Loading Tests on a RATP Retaining Wall: Results and Discussion

M. Khay
Centre d'Experimentation Routiere CER, Grand Quevilly, France

J. Kada
Regie Autonome des transports Parisiens, France

C. Plumelle
Centre Experimental de Recherches et d'Etudes du Batiments et des Travaux Publics, France)

Abstract

The article presents the results of a rupture load test on a retaining wall made of soil-thread material Texsol. The support structure is a retaining wall 5 metres high built to widen a platform for a temporary deviation on the A line of the Paris regional express railroad network. The tests show a tilt type rupture of the structure at its base, together with horizontal displacement of the overall structure. Analysis of the results by rupture calculation enables validation of the design method recommended in the 1990 Lcpc-Sétra technical guide.

1 Introduction

In order to enable repair work on the railroad bridge of the A line of the regional express railroad network linking Paris to Saint Germain en Laye (France) and maintain traffic during the works, a temporary bridge was built to enable the deviation of traffic.

The deviation meant the platform of the existing track had to be widened on either side of the temporary bridge by means of embankments and the construction of 3 retaining walls made of Texsol soil-thread material. The structure enabled the track platform to be widened with an effective width of 4.5 metres. The provisional track was thereafter used for railroad traffic over a period of 17 months. Measurements made for follow-up over time of settlement and displacement during the period in question indicated satisfactory embankment behaviour.

At the conclusion of the provisional operating phase, one of the retaining structures was maintained in order to perform a rupture load test. Experiments on a full-scale structure of this kind continue on from testing previously carried out on experimental structures. Their purpose is to fine-tune under worksite conditions the design method as recommended in the 1990 Lcpc-Sétra Technical Guide.

2 Presentation

2.1 Material

The soil-thread Texsol is now well-known and commonly used in civil engineering. Its main technical characteristics have been published in various documents. Its main scope of application is the construction of retaining walls with overburden or backfill.

A technical guide for its use has been developed providing recommendations and necessary for the manufacture and implementation of the material, as well as for the construction of retaining structures and the design method (Khay and Gigan, 1990).

2.2 Description of test structure

The structure, located on the left bank of the river Seine, is 60 metres long. Figures 1 and 2 indicate the location of the test structure and its main geometric characteristics. It is a retaining wall made with backfill, 5 metres high, 1.5 metres at its base and 0.5 metres at its top, inclined at an angle of 65 degrees in relation to the horizontal. It was built using a special Texsoleuse machine.

2.3 Geotechnical characteristics of backfill and test wall

The geotechnical characteristics retained for the design calculation of the structure were obtained using SPT and pressuremeter reconnaissance tests. The characteristics are given in figure 3. Before the load tests were performed, a reconnaissance survey was carried out by core boring to a depth of 10 metres, which continued with destructive boring to a depth of 20 metres into the backfill behind the test wall.

3 Load tests

The test wall was 10 metres long. It was isolated from the rest of the structure by vertical trenches cut into the test wall and the backfill.

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Preliminary parametric calculations were made in order to determine the overload capacity and its position in relation to the wall. A support embankment was built in order to limit the overload capacity to be applied and obtain a rupture in the test wall.

3.1 Load system

The overload was applied by means of an overload bar 1 metre wide and 10 metres long, placed 1 metre from the top of the wall. The assembly comprised a steel beam driven by four hydraulic jacks resting on four vertical tie rods anchored into the deep layers of the ground. The device was calculated in order to develop an overload of 800 kN/m^2 (figure 4). The estimated rupture load is of the order of 280 kN/m^2.

3.2 Instrumentation

The instrumentation was defined to enable control of application of the overload, follow-up of the displacement of the embankment and of the wall face, and measurement of the stresses developed at the base of the wall: load cell for applied load force, settlement-inclinometer for embankment displacements, displacement transducers for the wall face displacements and earth pressure cells for stress involved in the wall.

The instrumentation was set up one week before the experiment was carried out. Figure 5 shows the instrumentation layout.

3.3 Load diagram

Loading, which took place over two days, was carried out in successive incremental steps of approximately one hour. A creep phase of approximately 12 hours also took place at the end of the first day of testing. The loading diagram is given in figure 6. The photographs in figures 7 and 8 show the test embankment and the loading system.

4. Measurement results

Loading test took place up to 350 kN/m2 with horizontal displacements measured of the order of several centimètres.

4.1 Embankment settlement and displacement

No significant settlement was observed between 0.3 and 5.8 metres, as well as between 6.9 and 18.9 metres in depth. The curves show that settlement only concerned the ground layer situated at a depth of between 5.8 and 6.9 metres. At the end of the tests, settlement at the top reached 27 mm, accompanied by a heave of the upper metre of the embankment between the overload and the wall. Settlement-inclinometer measurements show that the deformation concerns the embankment up to a depth of some 5 metres. Maximum horizontal displacement was observed at a depth of the order of 1.5 metres, which reached 68 mm at the end of testing(figure 9).

4.2 Wall displacement

Measurement of the horizontal displacement of the wall face shows a profile similar to that observed in the embankment. The maximum wall face displacement is located some 1.5 metres away from the head of the wall (figure 10). The profiles clearly reveal rotational movement at the base of the wall. The maximum displacement attained at the end of testing is 62 mm.

4.3 Vertical stress within the wall

The vertical stress developed at the base of the wall during loading remains relatively low and shows weak load transfer during wall rotation (figure 11).

4.4 Analysis of wall behaviour

Analysis of displacement measurements indicates that the wall is subject to a moment of tilt at its base, together with horizontal displacement of the overall structure. The movement is confirmed by the vertical pressure measurements recorded at wall base sensors PV3 and PV4. Large displacement occurred at overloads greater than 250 kN/m^2.

5 Design method

The calculation method used to analyse the results is different from that used in designing the structure. The improved method recommended in the Lcpc-Sétra technical guide takes into account the height of the wall and the slope of its front face (Khay, Gigan and Ledelliou, 1990). Analysis by rupture calculation concerns the overall stability as well as the internal stability of the structure with regard to both circular and non-circular failure. Depending on the geometric characteristics of the structure, a stability study of gravity wall type in relation to tilt, base slippage and internal and external punching has to be performed. The method takes into account the anisotropic cohesion of the material characterized by the angle of slope of the layers implemented in the construction of the wall.

The calculations carried out after load testing in compliance with the above recommendation show that, based on a hypothesis of zero cohesi of the embankment soil, the different factors of safety were inadequate and that the design would have resulted in a wall with a much greater depth of spit or base of the wall (figure 12). Preliminary calculations carried out to design the rupture overload also confirm the validity of the method proposed. Finally, it should be pointed out that the results of these tests were used for finite element modeling (Kada, 1993).

6 Conclusions

The load tests carried out in the case of real site conditions and construction enabled confirmation of the large-scale deformation behaviour of retaining structures made of soil-thread material observed in previous experimental structures. The calculations carried out based on the results of these tests support the validity of the design method recommended in the 1990 Lcpc-Sétra Technical Guide, which emphasizes safety.

Acknowledgements

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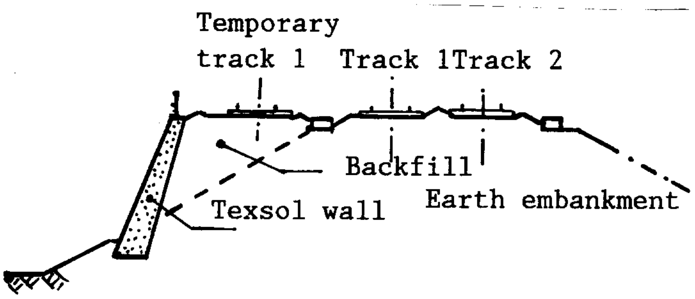

Fig.1 Section view of structure

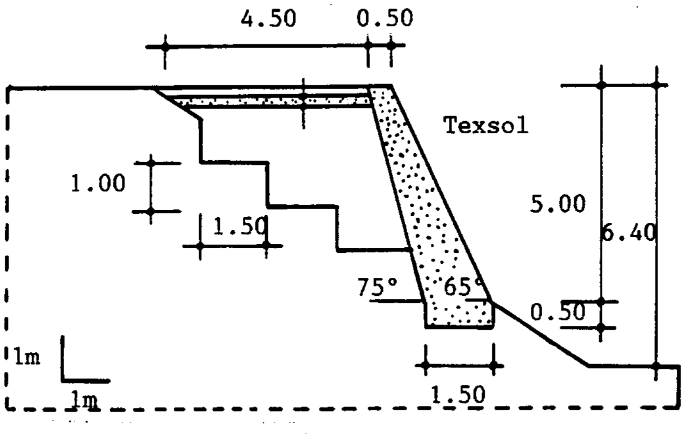

Fig.2 Geometric characteristics of structure

	Unit weight (kN/m3)	Friction angle (degree)	Cohesion (kPa)
At construction			
Backfill	18	30	0
Embankment	19	30	10
Texsol	17	38	100
Before tests			
Backfill	21	36*	30*
Embankment	20	28.5*	53*
Texsol	17	38	C

* CU tests

Fig.3 Geotechnical characteristics of soils

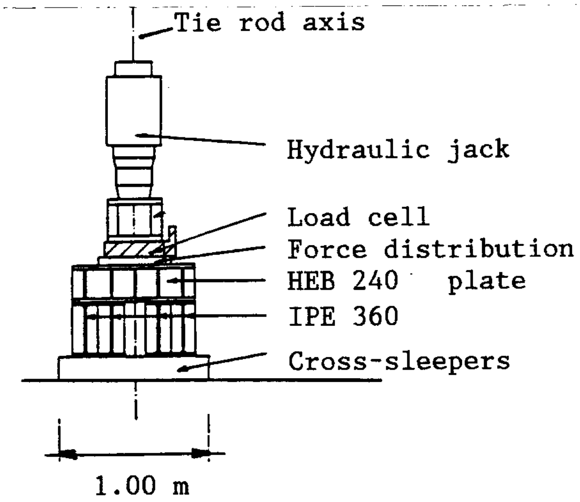

Fig.4 Application of overload

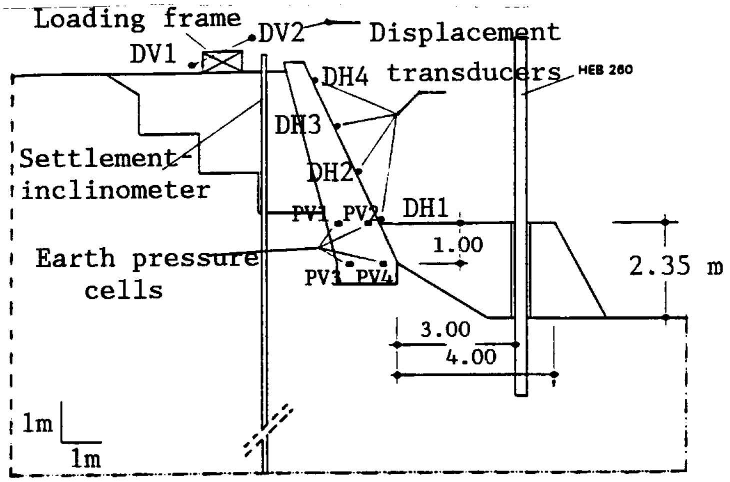

Fig.5 Wall instrumentation: cross-section

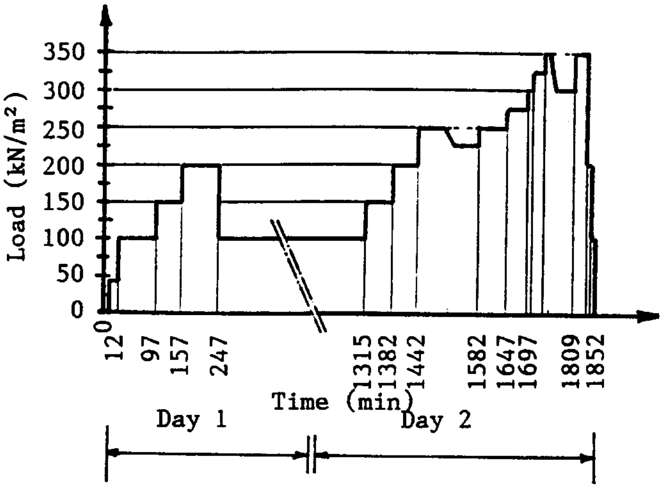

Fig. 6 Loading diagram

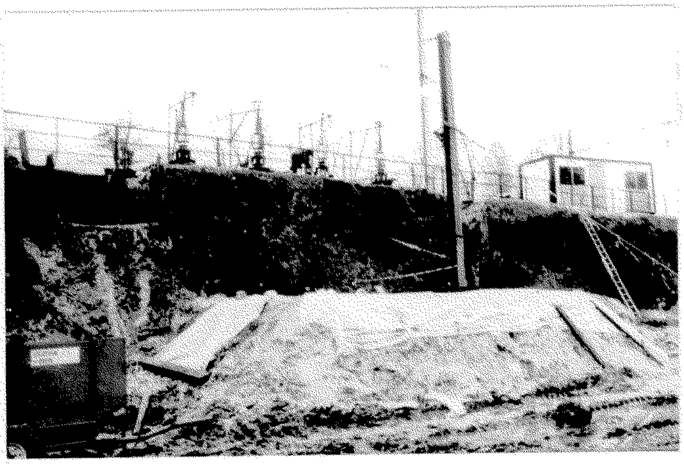

Fig. 7 View of test embankement

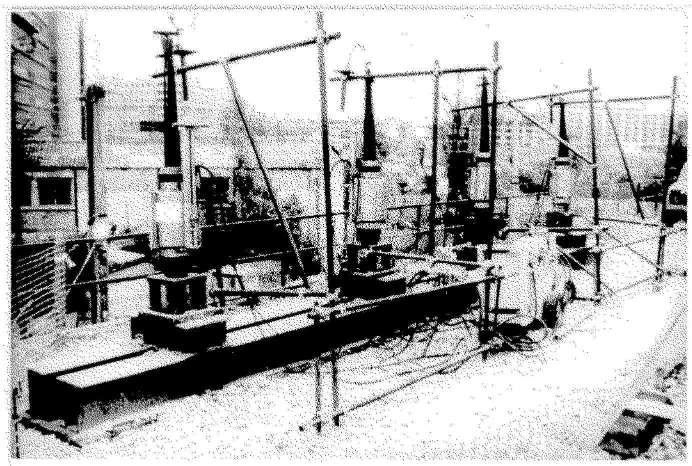

Fig. 8 View of loading system

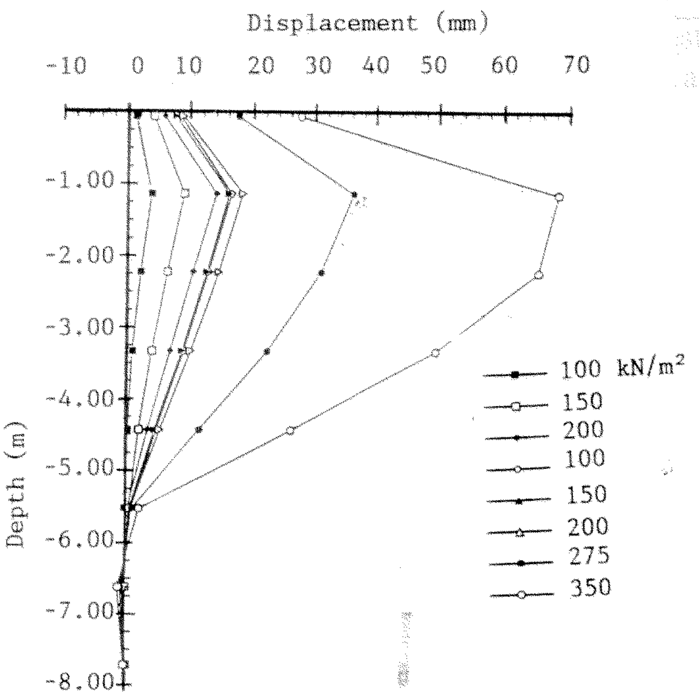

Fig. 9 Horizontal displacement of the inclinometer perpendicular to the wall

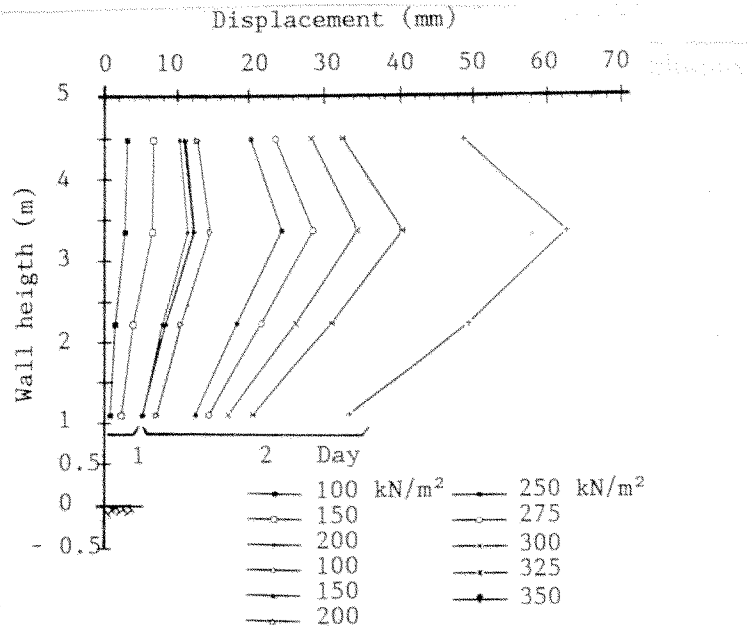

Fig.10 Horizontal displacement of the wall face in relation to load

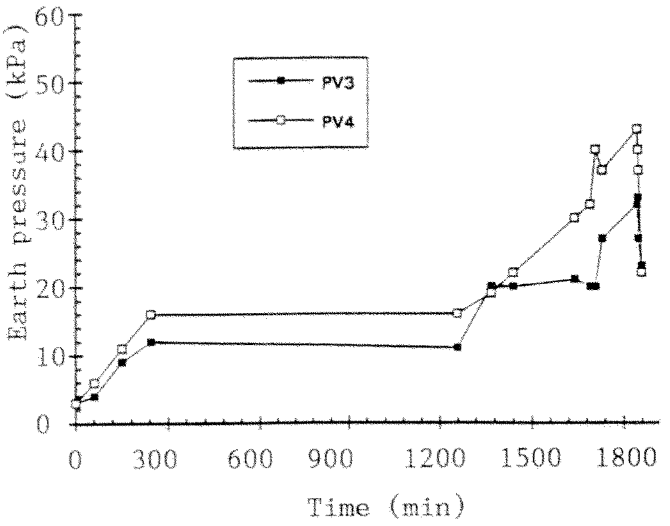

Fig.11 Variation in stress at wall base in relation to overload

Stability analysis
At construction

	Soil Characteristics			Factors of safety
	Unit weight (kN/m3)	Friction angle (degree)	Cohesion (kPa)	
Backfill	18	30	0	FS = 1.82
Embankment	19	30	10	
Texsol	17	38	100	
Surcharge		30 kN/m²		

Lcpc-Sétra specifications

Backfill	18	30	0	FS = 0.76
Embankment	19	30	10	(1.3 required)
Texsol	17	38	C anisotropic	Overturning
Surcharge	30 kN/m²			F=1.18 (1.5 required)

Backfill	18	30	10	FS = 1.22
Embankment	19	30	10	(1.3 required)
Texsol	17	38	C anisotropic	Overturning
Surcharge	30 kN/m²			F=47 (1.5 required)

Fig.12 Results of stability analysis as a function of embankment soil characteristics