In-situ testing and instrumentation of a test-embankment at Hoegaarden, Belgium

Construction et instrumentation d'un remblai d'essai à Hoegaarden, Belgique

J. Maertens & F. Theys – *Tuc Rail, Brussels, Belgium*
P. De Schrijver & A. Baertsoen – *Ministry of the Flemish Community, Geotechnics Division, Ghent, Belgium*

ABSTRACT : Between Brussels and Liège the HST railway will be constructed parallel to the motorway E40 at a distance of only 10-15 m. Where crossing the valleys of the Velp, Oorbeek and the Grote Gete, landfills of 8 to 10 m height have to be constructed on the existing motorway embankments and alluvial deposits of peat and clay. In order to predict the undrained stability and deformations of the future HST platform and of the existing motorway, the decision was taken to construct an experimental landfill at Hoegaarden in the valley of the Grote Gete. Before starting the landfill, the necessary instrumentation comprising a deep settlement gauge, profilometers, piezometers and inclinometers, was installed. The results of the measurements show that the settlements and porewaterpressures in the alluvial compressible layers are less than those predicted and that there were no problems concerning the undrained stability of the embankment, eventhough the landfill was contructed very fast.

RESUME : Entre Bruxelles et Liège la ligne TGV sera réalisée le long de l'autoroute E40 en site propre à 10-15 m de distance de la bande de sécurité de l'autoroute, en partie sur le talus du remblai existant. A l'endroit du franchissement des vallées de la Velpe, Oorbeek et de la Grande Gete, des remblais d'une hauteur de 8-10 m seront à réaliser sur le remblai existant et des terrains alluvionaires constitués de tourbe et d'argile. Afin d'analyser la stabilité à court terme et les déformations du futur remblai TGV et de l'autoroute adjacente, il a été décidé de réaliser un remblai d'essai à Hoegaarden, à l'aplomb de la vallée de la Grande Gete. Avant la réalisation de ce remblai d'essai, un dispositif d'instrumentation comprenant un extensomètre, des profilomètres de tassement, des jalons, des cellules de pression interstitielle et des inclinomètres, à été mis en place au sein du talus autoroutier. Les mesures montrent que les tassements et les surpressions interstitielles sont moins importantes que celles estimées et qu'il n'y a pas eu des problèmes de stabilité pendant la montée du remblai, pourtant mis en oeuvre très rapidement.

1 INTRODUCTION

Between Brussels and Liège the High Speed Railway (HST) will be constructed parallel to the existing motorway E40 at a distance of only 10 to 15 meters. As the area is very hilly this means that at the crossing of some valleys important landfills have to be installed partially on the existing embankments of the motorway. Some details are given in figure 1.

The embankments of the motorway E40 have been installed in the early seventies and consist of loam stabilised with quicklime. At the crossing of the alluvial valleys of the Velp, Oorbeek and Grote Gete, where up to 6 m thick alluvial clay and peat layers are encountered, embankments with a height of 8 to 12 meters have been installed. The gradient of the embankment slope is of 1:3 to 1:3,5. To accelerate the consolidation of the alluvial layers, sand piles with a diameter of 0.40 m were placed in a square grid of 3 m x 3 m.

For the construction of the high speed railway link an additional landfill of up to 10 m height has to be installed partially on the existing embankment slopes. As very little information was available on the behavior of embankments of loam, stabilized with quicklime, it was very difficult to predict the undrained stability and the deformations to be expected. So there was decided to install a test embankment on the existing motorway embankment.

2 GEOTECHNICAL INVESTIGATION

Cone penetration tests and borings were performed through and near the existing motorway embankment. Typical cone penetration tests and the results of a boring are given in

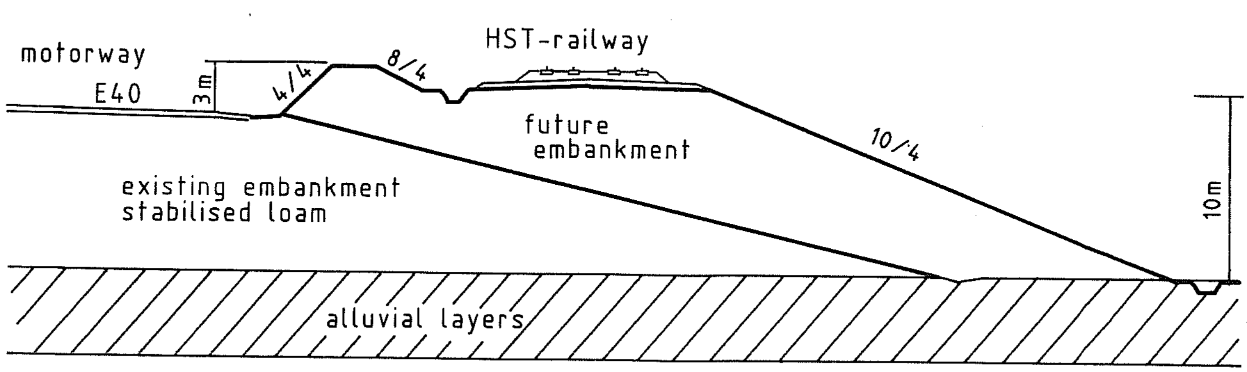

Fig. 1. Construction of HST-railway parallel to existing motorway.

Table 1. Geotechnical characteristics

	q_c MPa	ρ t/m^3	w %	w_L %	w_P %	I_p	m_v 1/MPa	C_c	C	c_v m^2/s	k m/s	c' kPa	φ' °	c_u kPa
Embankment Stabilised loam	> 10	1.9	18	35	21	14	< 0.2	< 0.1	> 100	$> 1.10^{-5}$	1.10^{-7}	30	33	90
Alluvial clay	0.3	1.5	68	80	34	46	1.0	0.4	12	3.10^{-8}	4.10^{-10}	20	25	35
Alluvial peat	0.4	1.1	450	--	--	--	2.0	2.3	5	1.10^{-7}	1.10^{-9}	5	20	70
Sand and gravel	> 10	2.0	--	--	--	--	< 0.2	< 0.1	> 100	$> 1.10^{-5}$	1.10^{-4}	0	35	--
Clayey sand	6	2.0	--	--	--	--	0.2	< 0.1	60	$> 1.10^{-5}$	1.10^{-7}	0	33	--

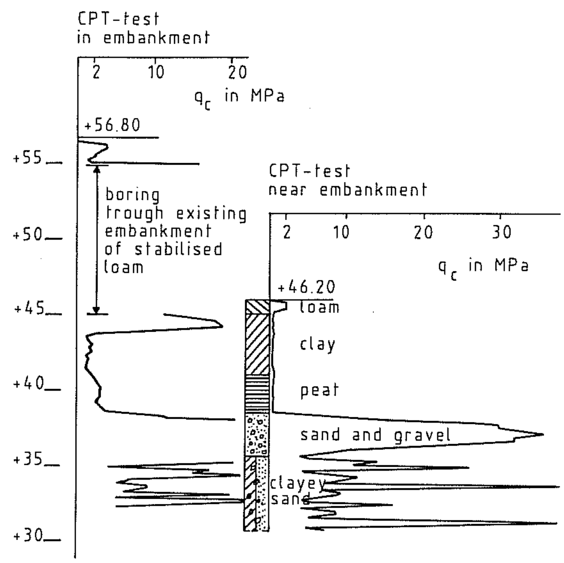

Fig. 2. CPT-results and boring

figure 2. The existing embankment of stabilised loam was very hard and preboring was necessary to penetrate for testing the underlaying alluvial layers. For the determination of the geotechnical characteristics of the fill and the alluvial layers, laboratory tests were executed on undisturbed samples. Geotechnical characteristics are given in tabel 1. The given characteristics for the alluvial clay and peat are those for borings near the existing embankment, at a distance where the alluvial layers are not influenced by the load of the existing embankment.

3 DESIGN OF THE RAILWAY EMBANKMENT

The easiest and cheapest solution consists of the installation of the railway embankment without special measures for the existing embankment and the underlaying alluvial layers. However, before deciding on applying this solution, the following conditions have to be fulfilled :

- the safety factor for the overal stability of the embankment has to be sufficient
- the residual settlements, expected after the installation of the railway tracks, have to be acceptable
- no unacceptable settlements of the motorway occur.

From a preliminary study there was found that :

- the overal stability problem can be solved when the railway embankment is installed very slowly, and provided no tension cracks occur in the existing motorway embankment
- the settlements which are expected after the installation of the railway tracks can be limited by putting a surcharge on the landfill over a sufficiently long period
- the prediction of the behavior of the existing embankment is very difficult because of the following reasons :
  . there is an uncertainty on the large scale stiffness of the embankment consisting of loam stabilised with quicklime
  . it is very difficult to get an idea of the permeability of the alluvial layers and of the draining efficiency of the sand piles, installed more than 25 years ago.

Other solutions have also been studied, such as :

- the installation of new vertical drains through the existing embankment
- the installation of stone columns in the alluvial layers underneath the existing embankment
- the installation of a cut- off screen along the motorway through the existing embankment in order to limit the possible settlement of the motorway
- the construction of a flyover founded on piles.

4 TEST EMBANKMENT

As all these solutions seemed rather expensive it was decided to install a test embankment. This would prove wether the landfill could be build without special measures.

Due to the fact that the area outside the existing embankment was not yet expropriated, the test embankment was constructed on the embankment slope of the motorway. The test embankment had to be realized with a slope of 1 : 1.25. The surface at level + 59.52 is of 15 m x 30 m. Details of the test embankment are given in figure 3.

Before the start of the installation of the test embankment four additional CPT tests were performed through the existing embankment. The results of these CPT tests are given in figure 3. The results show that the cone resistance in the alluvial layers has increased due to the earlier installation of the motorway embankment. For the alluvial layers under the existing embankment, better geotechnical characteristics than those in table 1, can be adopted.

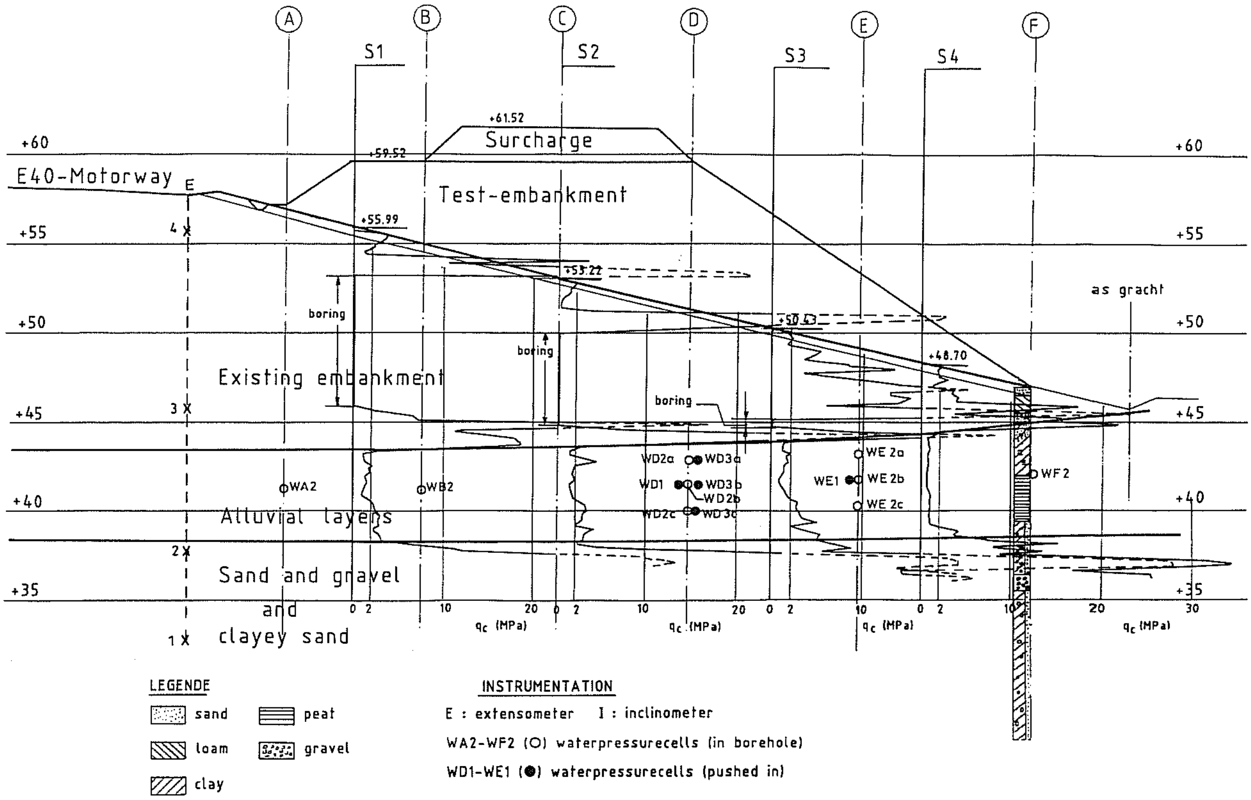

Fig. 3. Test-embankment and instrumentation

After the installation of the necessary instrumentation, the test embankment was realized in august 1995 over a period of two weeks, up to the level of + 59.52. After two months an additional 2 meters were added. This surcharge was removed after about 10 months. The fill of the test embankment consists of compacted clean sand.

5 MONITORING INSTRUMENTATION

Before bringing up the test embankment, the necessary instrumentation was installed :

- waterpressurecells of which 9 were installed in boreholes and 5 were pushed into the soil
- 2 inclinometers upto 20 m of depth at the toe of the existing embankment
- 10 settlement plates and 2 profilometers installed on the existing embankment
- 1 extensometer next the motorway with measuring points at 2 m, 12 m, 20 m and 25 m depth.

Details of the installed instrumentation are given on fig. 3.

6 RESULTS OF MEASUREMENTS

The results of the measurements are outlined in the figures 4 to 7.

Some typical results of the waterpressure measurements are given in figure 4, together with the settlements measured by mean of the settlement plates. The porewater overpressure under the top of the test embankment was about 3 m in the alluvial clay and about 1.5 m in the underlaying alluvial peat. Close to the toe of the fill, the porewater overpressure was about 2 m. The reduction of the overpressure was faster in the waterpressurecells near to the toe of the embankment.

Bringing up the surcharge of 2 m, led to a general increase of waterpressure of about 0.5 m.

Notice that concerning the measurements of the waterpressurecells, only the results of the cells installed in boreholes (type Glötzl) are given. The other cells gave an overpressure of several meters, right after pushing them into the alluvial soil. These overpressures took off too slowly in time. So the results of these cells were found to be unreliable.

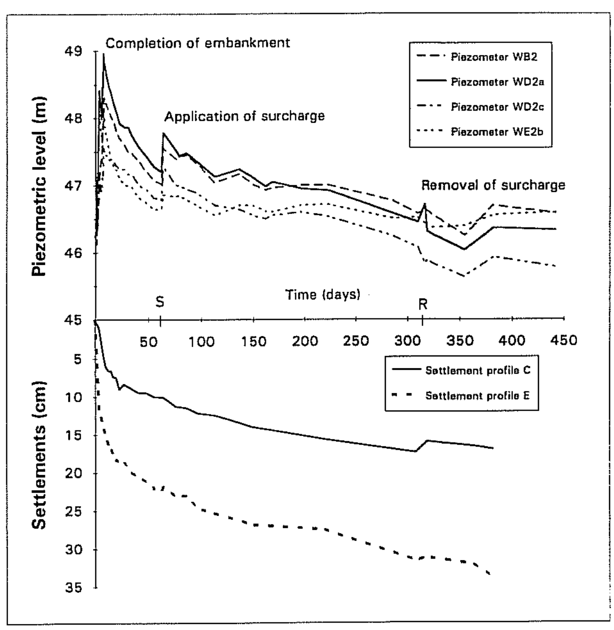

Fig. 4. Results waterpressurecells and settlement plates

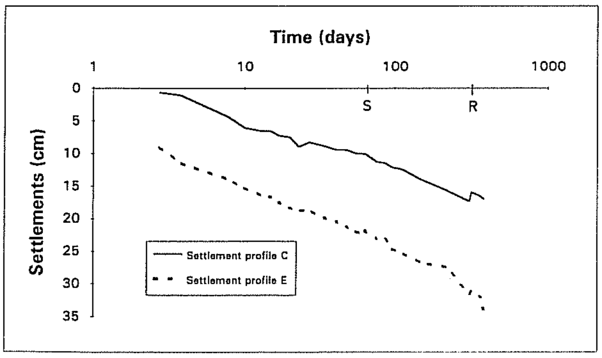

Fig. 5. Results settlement plates

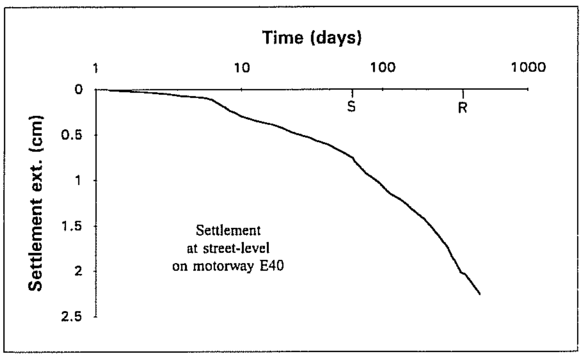

Fig. 6. Results extensometer

On figure 5, the settlements at the profiles C en E are given as a function of the log of time. From this figure it can be seen that the surcharge of 2 m had only an influence on the settlements at profile C and not on the settlements at profile E. The maximum settlement after 400 days is about 0.35 m.

The settlements at the motorway, measured with the extensometer, are given in figure 6. After 400 days, a settlement of about 0.02 m was measured. The settlement is for about 80 % due to compression of the alluvial clay and peat and for about 20 % due to compression of the motorway-embankment. Bringing up the surcharge of 2 m had a percible influence on the settlement.

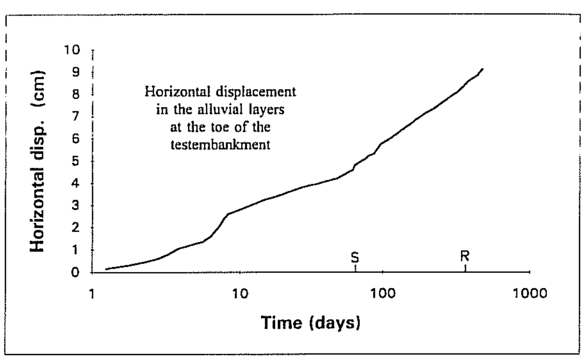

Fig. 7. Results inclinometer

The maximum horizontal displacements at the toe of the embankment are given in figure 7. Those displacements were measured with an inclinometer. The displacements reach their maximum in the upper 8 m alluvial layers. Horizontal displacements in the deeper layers are negligible. The maximum horizontal displacement in the alluvial layers after 400 days is about 0.10 m.

Settlements and horizontal displacements do not increase lineairly with the log of time. They rather increase lineairly with time. The alluvial layers do not behave as Terzaghi's law prescribes.

7 CALCULATIONS

With a Finit Element Method program a simulation of the construction of the test embankment was performed with the soil conditions as described in table 2. Figure 8 shows the deformed mesh. Under the maximum height of the test

	ρ t/m³	n %	c' kPa	φ' °	K MPa	G MPa
New embankment	1.8	--	5	35	10	4
Embankment Stabilized loam	1.8	--	20	33	40	16
Alluvial clay	1.6	55	10	30	2	0.8
Alluvial peat	1.3	75	5	25	1	0.4
Sand and Gravel	2.0	40	0	35	30	12

Table 2. Geotechnical characteristics for FEM-calculation

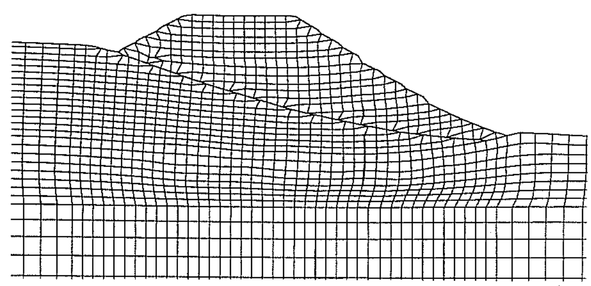

Fig. 8. FEM-calculation

embankment the FEM-program predicted a vertical deformation of about 0.45 m at the surface of the existing embankment. At the toe a horizontal deformation of about 0.15 m in the alluvial layers was calculated. The measured settlements (about 0.35 m) and the measured horizontal displacement (about 0.10 m) are less than the calculated deformations. The FEM-program gave a safe approximation of the deformations which can be expected.

8 CONCLUSION

The test embankment at Hoegaarden, with continuous field-measurements during and after the construction, gave the necessary information about the behaviour of the existing motorway embankment and the underlaying alluvial layers.

There were no problems concerning the undrained stability of the embankment eventhough the test embankment was constructed very fast. The measurements confirmed the expected deformation fenomena. Measured settlements, wateroverpressure and horizontal deformations were lower than those calculated with the FEM-model.

The truly scaled test project was the best instrument to obtain reliable information about the deformations and the stability of the future HST-embankment.