High Speed Railway Link South: on the horizontal move

Horizontal displacements of a concrete U-shaped cutting near Rotterdam

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Summary

Due to the deformations of the subsoil caused by an embankment, a concrete U-shaped cutting for the high speed railway link, which is founded on piles, will displace horizontally. To ensure that the structure will remain within the tight deformation requirements defined by the HSL organisation, a calculation procedure was developed using 2D and 3D F.E.M. calculations.

Keywords: settlement, F.E.M. method, horizontal displacements, bending moments, soft soil, cutting

1. Introduction

In the area north of Rotterdam over a distance of 3 km, the High Speed Railway Link (HSL) Amsterdam – Antwerp is built in a reinforced concrete U-shaped cutting or channel structure at 3 m below groundlevel (figure 1). Horizontal movements of the structure, due to vertical and horizontal deformations of the subsoil below an embankment near the structure might be in conflict with the tight deformation restrictions for the HSL.

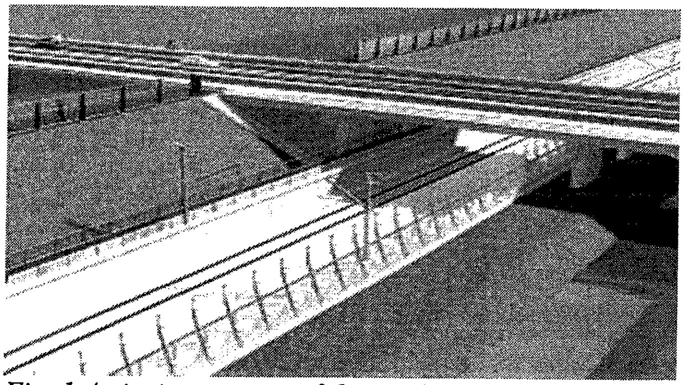

Fig. 1 Artist impression of the U-shaped cutting

2. Situation

The cutting, with a total length of 3 km and an internal width of 11.7 m, consists of two parts. The main part of the cutting is built at 3 m below groundlevel; the rest of it is built at 6 m below groundlevel. The structure will be founded on prefab concrete piles ø450 mm piles with pile tip elevations at 20 to 25 m below groundlevel. The total structure is divided into coupled sections of 35 m between the expansion joints.

At a distance of 3 m from the structure, an embankment is constructed as a noise barrier and as a landmark (figure 2). The embankment will be built up in four phases to a height of 7 m. After consolidation, the front slope of the embankment is designed 1:2. The back slope of the embankment will be placed after finishing the concrete structure of the cutting.

The subsoil varies along the structure and generally consists of 9 m soft clays and peat overlying Pleistocene sands.

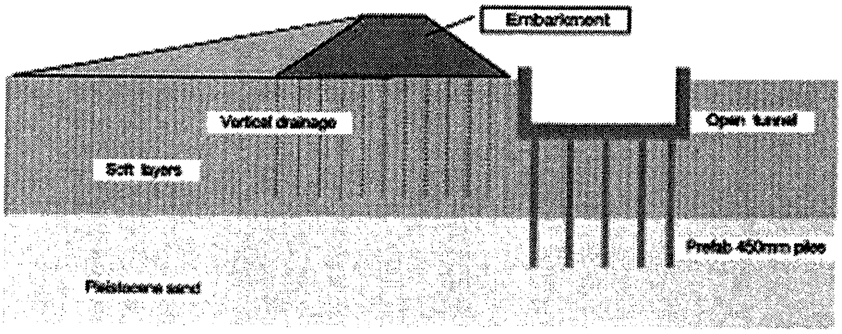

Fig. 2 Cross section of the cutting and embankment

3. Horizontal deformation criteria

The HSL organisation [the client] has defined very strict requirements for the horizontal movements of the structure and the track, which are fixed to the cutting floor because of the comfort of the passengers and to limit the maintenance of the track. The requirements are as follows:

- a maximum deformation of 10 mm over 100 years or
- a very small rotation of less than 1 in 2000, which allows 17,5 mm displacement over a 35 m section.

4. Problem definition

The construction sequence and the stratigrafy of the subsoil will have consequences for the cutting. Horizontal deformations due to primary and secondary settlements below the embankment will occur, causing:

- horizontal deformations of the structure and the track
- high horizontal groundpressures on the wall near the embankment (not included in this article)
- bending moments in the piles
- forces in the coupling elements between the sections

Because of the complex situation (an embankment next to the concrete structure, the construction sequence and the strict requirements), a correct understanding of the above phenomena is very important.

5. Finite element analysis

The contractor has to demonstrate that the structure will remain within the requirements defined by the HSL organisation. Therefore, an analysis procedure was set up to calculate horizontal deformations over a period of 100 years.

To be able to determine the displacements of the soil and the structure and to take into account the interaction between the soil and the structure, the F.E.M. computer programme PLAXIS was used. Hence, it was possible to determine the time-dependent behaviour of the soil in terms of primary and secondary settlements by using the Soft Soil Creep model. Firstly, an analytical model with the well-known consolidation theory of Koppejan was used to determine vertical primary and secondary displacements caused by the embankment. This "Koppejan" settlement analysis was executed because of the large experience with the model and its parameters. Secondly, the results of this exercise were translated to parameters for the Soft Soil Creep model.

Within the 2D PLAXIS model, piles are simulated as walls of infinitive length. Therefore, to determine the deformation of the piles and the movement of soil between the piles, the PLAXIS 3D programme was used. Unfortunately, the 3D version cannot take into account the consolidation process, thus being restricted to drained analysis only.

The following steps have been performed to determine the horizontal deformation for each selected cross-section:

Step 1: Analysis of vertical primary and secondary settlements using conventional settlement analyses (no structure included). The soft soil creep parameters λ^*, κ^* en μ^* for the PLAXIS 2D and 3D model were derived by matching the PLAXIS 2D results with the "Koppejan" settlement analysis on the primary and secondary settlements.

Step 2: Drained analysis of the structure in the PLAXIS 3D model (figure 3). The 3D model was used to determine the horizontal movements of the cutting and the behaviour of soil around the piles, based on the calibrated parameters. The bending moments in the piles are also determined with the 3D model.

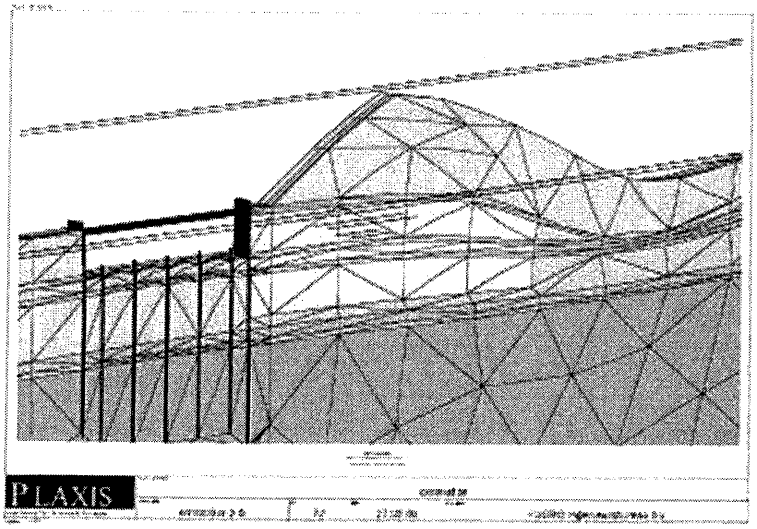

Fig. 3 PLAXIS 3D mesh