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Deformation capacity of slurry walls and their water retaining capacity – a project description

Capacité de déformation des murs de boue et leur capacité de rétention d'eau – une description de projet

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ABSTRACT: Subsurface construction in the Netherlands is dominated by the presence of a high ground water table. One of the key engineering aspects is creating dry working conditions during the execution of the work and creating a structure with acceptable water leakage during the life span of the structure. In this paper the construction of a tunnel is described. To create a water sealing barrier around the project perimeter a slurry wall was installed. The water table was lowered within the project perimeter and an excavation with natural slopes at 5,0 m distance from the slurry wall until ca. 12,0 m below surface level was performed to create the tunnel ramps and a building site where the tunnel segment was constructed. During the lowering of the water table and the excavation the slurry wall will deform as friction needs to be mobilized to maintain slope stability. In the design phase numerical analyses of the slurry wall have been performed to determine these deformations and validate the water retaining property. The results of the numerical analyses were validated by incline measurements of the slurry wall. This paper presents the results of these analyses and the results of the inclinometer measurements.

1 INTRODUCTION

For the construction of a new highway by-pass near the city Leeuwarden in the Netherlands the crossing of a waterway was needed. An immersed tunnel was selected as optimal crossing and construction method. The project location was characterized by the presence of a ground water table approximately 1 m below surface level and the presence of soft Holocene clay deposits. To minimize undesirable influence to the surroundings caused by the construction of the tunnel and during the life-span of the tunnel, measures to prevent water flow needed to be taken. The lowering of the water table in the surrounding of the project area due to water flow could potentially lead to 1) surface settlement, 2) de-hydration of agricultural area's 3) Increase of salinity of surface water, due to high saline ground water at depth 4) high maintenance costs to process the water volume. To prevent water flow a horizontal water barrier consisting of a non-structural slurry wall was used, for the vertical barrier the natural presence of a clay layer at ca. 30 m depth was used. To reduce the cost of the slurry wall the need for a HDPE screen in the slurry wall to assure the water retaining property of the wall was evaluated. The construction method involved the following stages; 1) Installation of a slurry wall around the project perimeter, 2) excavation of the tunnel construction site for the immersed tunnel, 3) construction of tunnel segment and preparation of the final tunnel location 4) immersing the tunnel segment and construction of the tunnel ramps. Figure 1 shows a schematic plan view of the project location.

2 SITE INVESTIGATION AND SITE CONDITION

An extensive site investigation program was performed consisting of CPT's, boreholes and a laboratory testing program. CPT's were performed to determine the stratigraphy at the project location and to assure the presence of the clay layer at depth over the project area. Based on an interpretation of the CPT data and the available boreholes the general site conditions can be described as follows; a soft silty Holocene clay layer until a depth of ca. 10 m; a sandy clay layer until a depth of 14 m; a loam layer until a depth of 17 m; an over-consolidated Pleistocene sand layer until a depth of 30 m; an over-consolidated stiff clay layer until the maximum exploration depth (41 m). A typical CPT profile is shown in figure 2. To determine strength and stiffness

parameters laboratory testing was performed on soil samples taken by an Ackermann sampling device. The soft clay layer until a depth of 10 m is dominating the behavior of the slurry wall. The description of the lab testing program in this article will be limited to this layer. The lab testing program for this layer consisted out of 9 triaxial (CU) tests and 8 Oedometer tests with unloading steps.

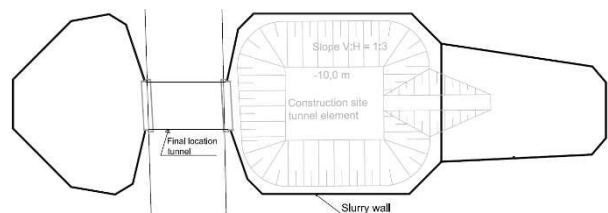


Figure 1. schematic plan view of the project location

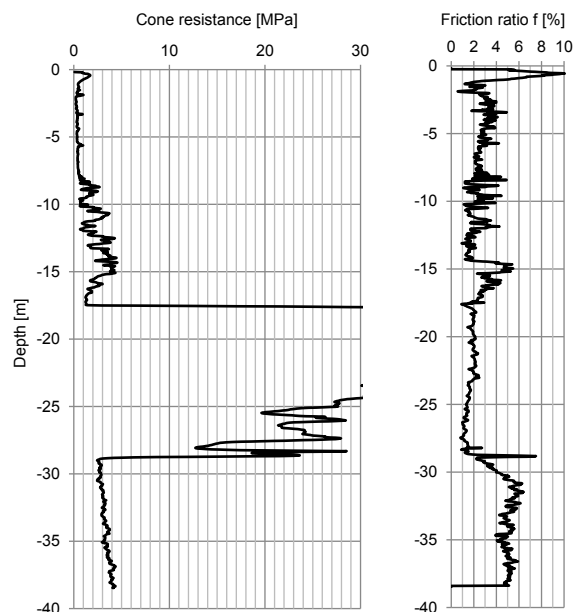


Figure 2. typical CPT profile of the project location

3 NUMERICAL ANALYSIS

To determine the expected rotation of the slurry wall numerical analyses were performed and compared to the rotation capacity of the slurry wall. The numerical analyses were performed with the finite element software PLAXIS. The Hardening Soil model (Schanz et al. 1999) was used to model the soil layers of interest. To determine the rotation capacity of the slurry wall lab testing was performed on samples of the cement-bentonite mixture (lab and in-situ samples).

The soil model of the dominating layer was calibrated to the available laboratory test results (triaxial tests and Oedometer tests) by simulating the test conditions and comparing them to the measurements of the laboratory tests. An example of a comparison is shown in figure 3. Parameters were chosen carefully taking soil variability into account.

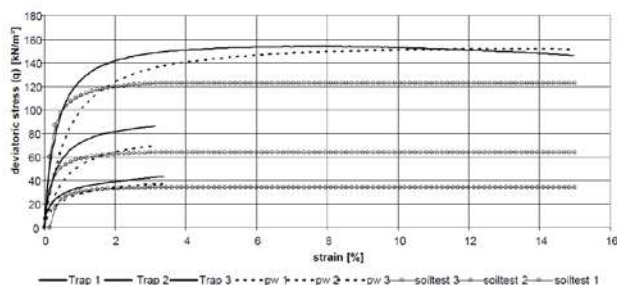


Figure 3. comparison of a numerical simulation and measurements of a triaxial test

The slurry wall has time dependent properties as the mixture is still curing during the construction phase. In figure 4 the test results of the compressive strength are shown. The solid line shows the result of lab-samples the circles the samples taken in the field. The sole function of the slurry wall is to act as a water barrier. To validate the ability of the wally to fulfill this function a check was performed whether cracking that could compromise the water retaining property.

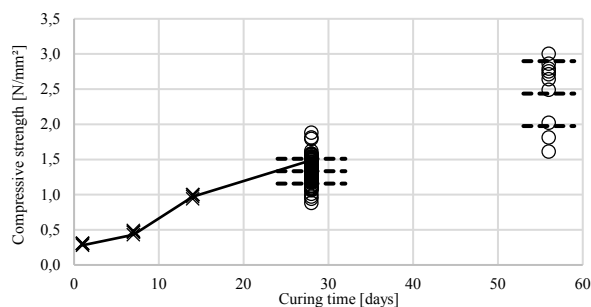


Figure 4. compressive strength development in time

Figure 5 shows the geometry of the numerical model used in the analyses. Variation calculation were performed to investigate the influence of parameter variation and model assumptions to the calculation result (e.g. geometry, drainage conditions, model parameters). The structure was considered to be a CC3 structure according to NEN-EN 9997. The model parameters and top loads have been applied accordingly. The calculated deformation of the slurry wall is shown in figure 6. A check of the stresses in the slurry wall with the calculated rotation showed that the capacity of the wall was not exceeded. The results of the evaluations facilitated the omission of the HDPE screen in the slurry wall in terms of rotation and reduced the costs of the slurry wall. As the HDPE screen acted as a backup system to assure the water retaining property of the wall, mechanisms that could compromise the water retaining property of the wall were carefully evaluated.

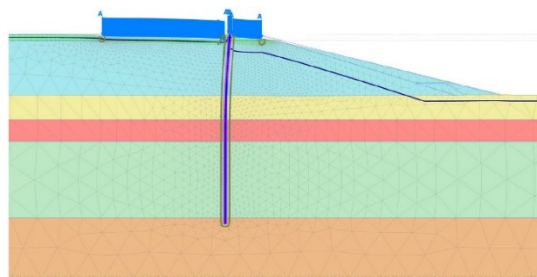


Figure 5. geometry of the numerical model used in the analyses

4 FIELD MEASUREMENTS

To validate the numerical analyses and to verify the water retaining properties of the slurry wall the deformation of the wall were measured and the measurements were compared to the results of the numerical analyses. The deformation of the slurry wall was measured by installing a square hollow section in the wall that facilitated rotation measurement of the slurry wall with an inclinometer.

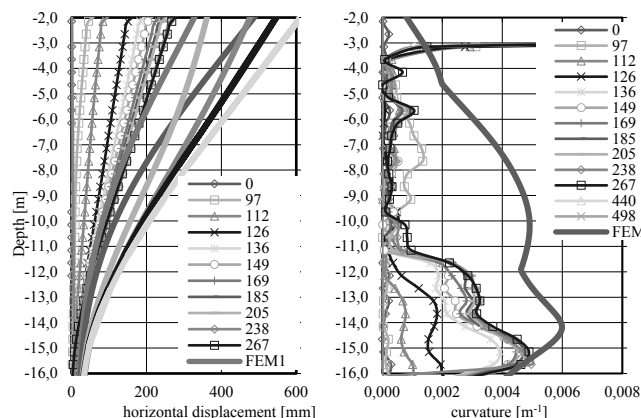


Figure 6. comparison of measured and calculated horizontal displacement (left) and absolute curvature (right)

Figure 6 shows the measurement and calculated horizontal displacement and curvature of the slurry wall. The measured values are indicated with marking and the number of days after the first measurement is shown in the legend. In the curvature graph the envelope of the FEM analyses is shown. Due to uncertainty in the calculation assumption a large number of variation calculations were performed. Depending on the considered analysis the FEM analysis show reasonable agreement with the measurements.

5 CONCLUSION

The design process of a slurry wall for a tunnelling project has been described. The deformation of the wall was calculated by FEM-analyses and the results were compared to the in-situ measurements of the horizontal displacement of the wall. The FEM-analyses show reasonable agreement with the measurements. The FEM-analysis facilitated the omission of a HDPE-screen in the slurry wall due to a higher rotation capacity then the demand and the in-situ measurement verified this. Other mechanisms that potentially can compromise the water retaining property of the wall should carefully be evaluated.

6 REFERENCES

Schanz, T., Vermeer, P.A., Bonnier, P.G., 1999. The hardening soil model: formulation and verification, Beyond 2000 in Computational Geotechnics. Balkema, Rotterdam.