GEOTECHNICAL AND STRUCTURAL MEASUREMENTS FOR A DEEP EXCAVATION NEAR AN EXISTING NAVIGABLE LOCK

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Abstract

This paper is concerned with the deep excavation of a building pit in close vicinity to the existing lock of Uelzen I. Geotechnical measurements are applied to ensure the safe operation of the existing lock and in order to monitor the building pit. The measurements and the factors that influence the measurement results are presented for the presently intermediate state of excavation of the building pit.

1 Introduction

The Elbe-Seiten Canal connects the Mittelland Canal with the river Elbe. It is 115 km long and is primarily situated in the Lüneburg Heath, North Germany. The height difference between the Mittelland Canal and the Elbe is 61 m thus necessitating a lock in Uelzen and a ship lift in Scharnebeck near Lüneburg. The Uelzen I lock overcomes a difference in height of 23 m.

The joint tapes of the lock are very sensitive and a big damage has already occured. Although the joints are being intensively monitored, the long term stability of the lock can thus not be guaranteed *(Eißfeldt, Siebenborn, 1998)*. Furthermore, a traffic prognosis for the next few years predicts an increase traffic for the Elbe-Seiten Canal.

This predicates the need for an increased lock capacity at Uelzen. A new lock system Uelzen II is being built next to the existing lock Uelzen I. The new construction is going to be operated alongside the existing lock and will provide for uninterrupted operation, should the unstable lock of Uelzen I be defective (Wachholz, 1997)

Boulder clay and a lower sand layer present the subsoil of the building site for Uelzen II The boulder clay is of semi-solid consistency. The lower sand layer consists of fine to semi grained sand. The strength and the density of the sand is remarkably high. The cone resistence is $q_c > 50$ kN/m². The ground water table lies at 45 mNN and it is perched on 30 - 32 mNN.

A 53 m wide, 265 m long and 18 m deep building pit is necessary for the construction of the new lock Uelzen II. The building pit is still under construction.The contractor E.D. Züblin designed the building pit as a watertight basin. The vertical sheeting is made of 1,2 m thick slurry walls, which are supported by two layers of braces. The horizontal bottom is constructed as a 1.5 m thick jet grouted slab. The jet grouted slab must be able to take a water pressure of 150 kN/m². Figure 1 shows the cross section with the existing lock Uelzen I and the building pit.

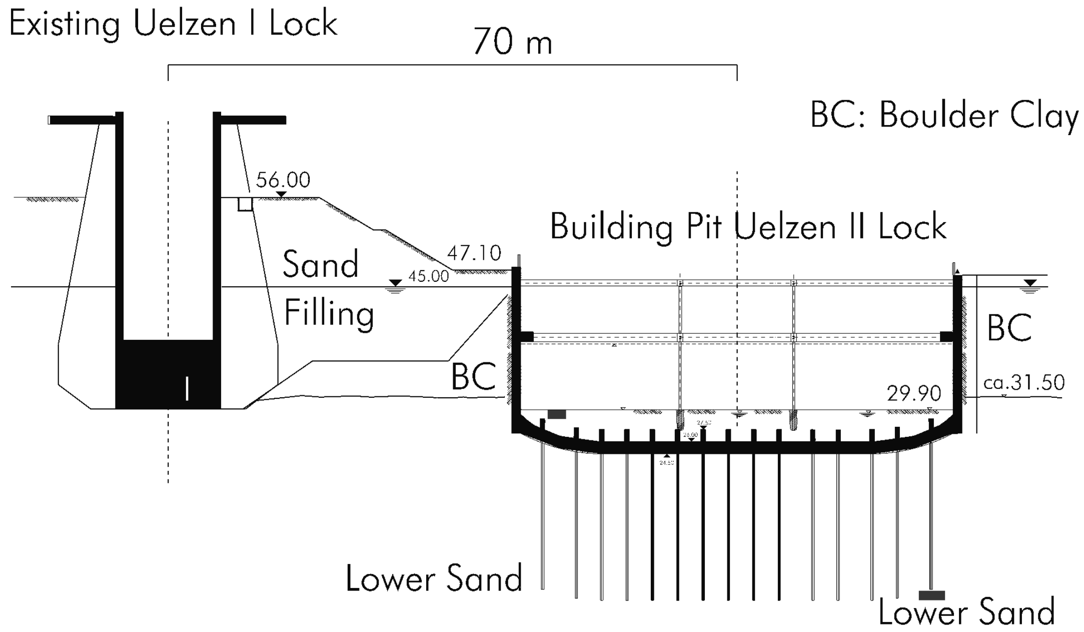

Figure 1: Cross Section existing Uelzen I Lock and Building Pit Uelzen II Lock

Figure 2 gives a panoramic view of the building site. The photo looks from South (upper water level) to North (lower water level). On the left hand side the exisiting lock is shown. The upper layer of the braces inbetween the slurry wall is already constructed and the excavation continues underneath the braces.

There is a distance of 70 m between the axis of the existing lock and the new lock. The clear distance between the locks will be 30 m. Due to the close vicinity of the locks the excavation of the building pit might have an influence on the existing lock. Additional displacements of the Uelzen I lock has to be minimized because of the sensitive joint sealings. These circumstances presented the major criterion for the design of the building pit.

To insure the safe operation of the existing lock geotechnical measurements are undertaken. Displacements, strains and forces are thus recorded.

Figure 2: Panoramic view of the biulding site

2 Conception of the measurements

The measurements have to point out the influence of the ecavation on the existing lock and to ensure a stable building pit. To achieve this aim

- the displacements in the subsoil of the surrounding of Uelzen I and
- load-deformation behaviour of the building pit

must be monitored.

Calculations with the Finite-Element-Method are executed to choose the relevant spots for the measurements and to predict the displacements. The prediction shows only a minor influence with only a few mm deformation of the existing lock, when the building pit will be fully excavated. *(Schwab, Kayser, 1999).*

The concept of the measurements includes 8 cross sections (MQ). In MQ 1 and MQ 2 the existing lock and the building pit are measured. The two MQ are situated closed to the first excavations. Thus the results of the measurements during the first excavation can be compared with the prediction in an early state of excavation and the prediction can be improved for the following states of excavation. The remaining MQ are only used to monitor the building pit. Figure 3 shows a location plan of the building site, the existing lock and the MQ.

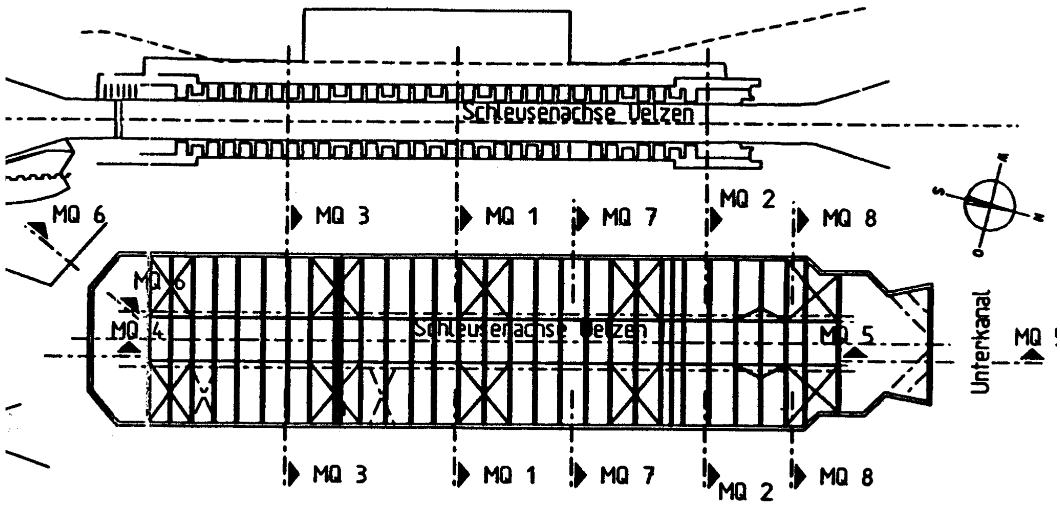

Figure 3: Location plan with instrumentated cross sections (MQ)

MQ 1 is the main cross section. It is situated in the middle of the building pit. Figure 4 shows the instrumentation of MQ 1. Hardly any deformation caused by the excavation is likely to occur 60 m under ground level, therefore this level is assumed as the fixed benchmark. The displacements in the surrounding subsoil of the existing lock are measured by rod-extensometers in vertical direction and by inclinometers in horizontal direction. The rod-extensometers are designed as 6-point-extensometers. One horizontal inclinometer is installed to measure the settlements of the ground surface inbetween the building pit and the existing lock. The top of every instrumentation and a choice of points on the ground surface are surveyed geodetically in horizontal and vertical direction. Additional survey points are situated on every chamber block.

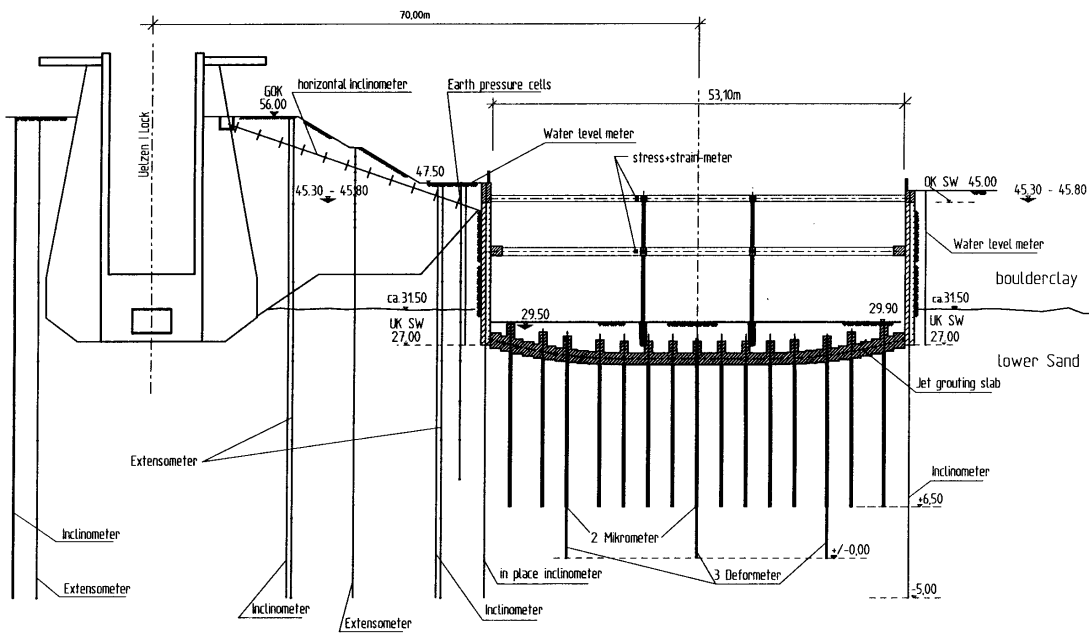

Figure 4: Cross section MQ 1

The displacements of the slurry walls are measured by inclinometers and the top of the wall is surveyed geodetically. The changing earth pressure caused by the excavation is measured with 12 earth pressure cells in horizontal and vertical direction. The latter are installed in one borehole. The braces inbetween the slurry wall are the most sensitive elements, due to their function as struts. This is why in 6 braces the forces are measured by concrete-pressure-cells and strain-gauges.

For the monitoring of the load-deformation-behaviour of the slab, 2 micrometers are fixed at the anchors and 3 deformeters are installed into the subsoil. The micrometers measure the forces and the load transference of the anchors. The deformeters measure the vertical displacements in the subsoil up to 24 m underneath the slab.

The principles of the MQ 2 are similar to MQ 1, but less instruments are installed and the maximum depth is 40 m under ground surface.

MQ 3 to 8 consist of micrometers and deformeters underneath the slab as well as inclinometers in the slurry wall. The sole aim of these MQs is to monitor the building pit.

In order for them to be measured continuously, every rod-extensometer and the inclinometer in the west-side slurry wall contain electronic gauges. The gauges work with vibrating wires. The other measurements are executed at weekly intervals by probes. All measurements are executed by the contractor. The data is stored on a server on the building site and can be loaded on local PCs by telephone.

3 Influences on the measurements

3.1 Introduction

The existing lock is exposed to seasonal differences of temperature and to cyclic loads caused by locking. These two factors have nothing to do with the excavation, but they nevertheless both influence the measurement results. Therefore this influence has to be determined prior to excavating in order to eliminate it from measurement results.

3.2 Temperature

The temperature of the air and of the water changes according to the season. The inner chamber walls are exposed to a difference in temperature of about 60 °K. The temperature in the subsoil is relatively constant (about 10°C), so the temperature of the outer surface of the chamber wall is constant as well. Thus the difference in temperature between the inner and the outer surface changes with the seasons. This leads to an expansion of the wall in summer and to a contraction in winter. The displacemants are shown in principle in figure 5.

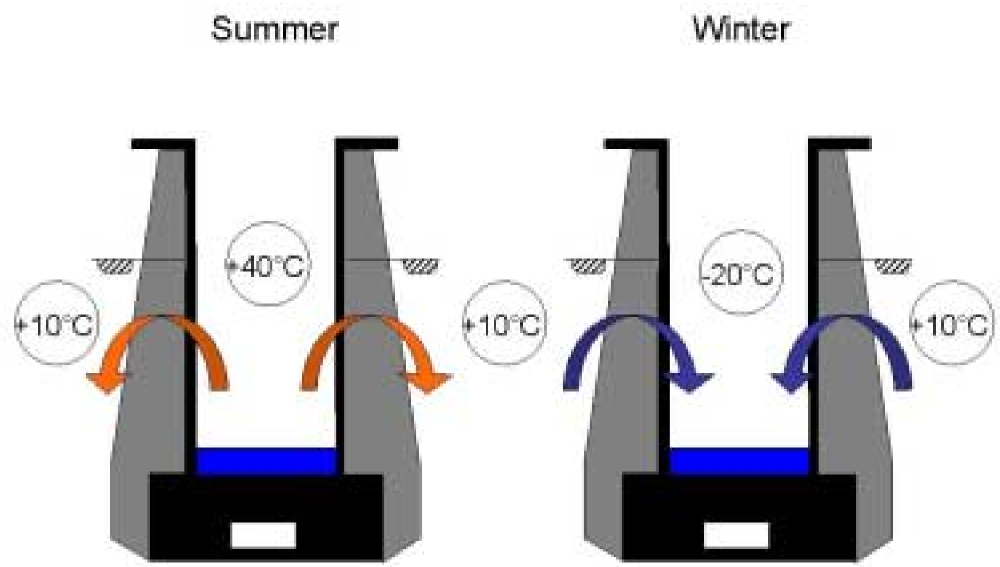

Figure 5: Displacements by Temperature

3.3 Operation of the lock

When a ship is locked from the lower water level at 42 mNN to the upper water level at 65 mNN a water pressure of 230 kN/m² is loaded onto the chamber wall. This leads to an outward deformation of the top of the chamber wall by 25 mm.

The deformation of the lock leads to displacements of the subsoil. These deformations are shown in figure 6. The displacements on the ground surface amount to 10 mm in horizontal direction. Due to transverse strain the ground surface is lifted up to an amount of 1 mm.

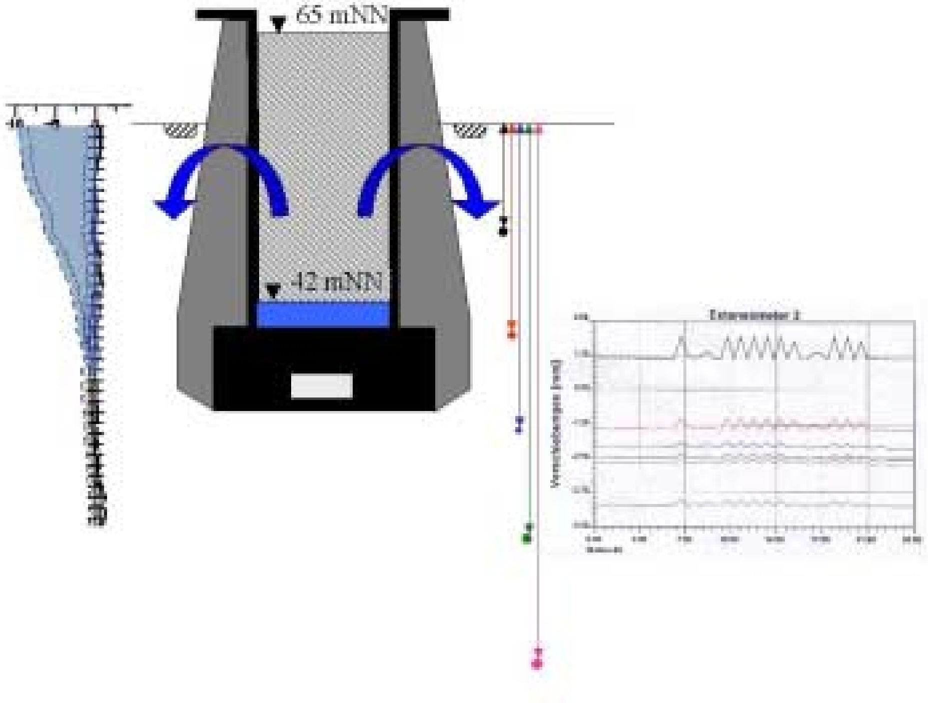

Figure 6.Displacements due to Operating

4 Results of Measurements

4.1 Building Pit

The present state of excavation is on 38 mNN, which is equivalent to an excavation depth of about 7 m. The final depth of 30 m NN has not yet been reached. Figure 7 shows the measurement results for the main points of the building pit. The maximum force in the braces is 700 kN, the statics allows ca. 2400 kN.

Measurement results are predominantly lower than predicted by the FE-calculation. Only the vertical displacement of the slab is in the same order of magnitude as calculated.

4.2 Existing Lock

The most interesting results for the existing lock are the vertical displacements. Figure 8 shows the settlement of the surface of the previous 18 month, measured by a rod-extenometer closed to the existing lock. Additionally the general temperature in 2000 on the building site is shown.

The plot shows a continuing settlement in slight oscillation. The settlement cannot result from the excavation, which started in September 2000. The subsoil consists of sand, which was built into the open building pit of Uelzen I lock. The measured settlement is related to the operation of the lock. Due to the locking, the subsoil is exposed to cyclic loads, which leads to a compaction of the sand. The compaction causes settlement of the ground surface of 11 mm/a. This is obviously a longterm process, because the lock has been in operation for nearly 25 years.

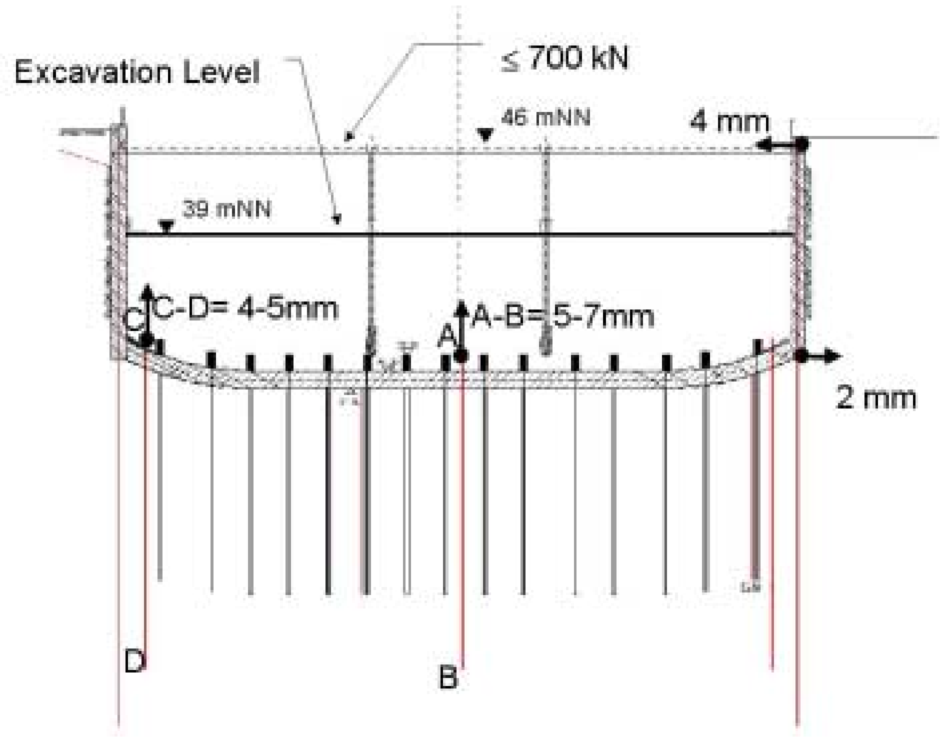

Figure 7: Deformations of the Building Pit, Intermediate Excavation Level 39 mNN

The settlement oscilliates in the way shown in figure 8 over the period of 20 month. The oscilliation is related to the temperature. As a result of increasing temperature the velocity of settlement decreases. Using a 28-d-average for the temperature, the influence of seasonally oscillating temperatures amounts to 2,5 mm/12,5 K or 0,2 mm/K. The horizontal displacments resulting from changes of temperature are in the order of magnitude of 5 – 8 mm at the ground surface closed to the lock.

Deformations relating to the excavation of the building pit did not occur. In January 2001 a ground water lowering of 70 – 90 cm under the existing lock was executed.Thus vertical stress in the subsoil increased because of decreasing hydrostatic uplift. This leads to settlement of 0,75 mm at the ground surface as one can see in figure 8. Besides soil deformation, the change of vertical load during the operation leads to changes in the groundwater level of up to 40 cm.

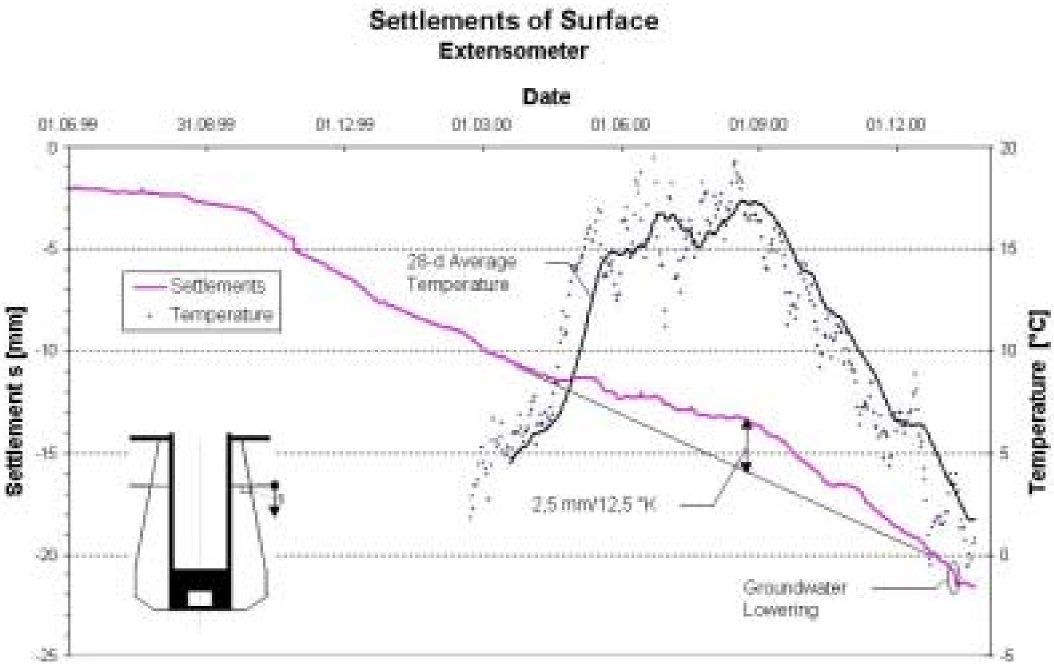

Figure 8: Settlements of Surface alongside Uelzen I Lock

5 Conclusion

The present measurement results show that there is no influence of the excavation on the existing lock. The cyclic load resulting from locking leads to a compaction of the sand alongside the lock. The seasonal temperature leads to vertical displacemants on the ground surface of 0,2 mm/K next to the lock. The influence of temperature and locking is thus much bigger than that of the excavation.

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