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Geotechnical Risks in a Deep Building Bit in The Hague's Old City Centre – Project Veenkade Case Study of the Restoration of an Old Canal and a New Underground Parking Garage

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Abstract. In The Hague, a 2 storey parking garage was built beneath a reinstated canal at the Veenkade with 160 parking places. The canal and the parking garage were installed at minimum 3 - 6 m distance from old houses with a shallow foundation by means of a 10 m deep building pit. A risk analysis was undertaken and major risks were identified, resulting in mitigating measures, e.g. compensation grouting in combination with very accurate monitoring. The structure was completed in 2014.

Keywords. Geotechnical Risks, 10 m deep building pit, compensation grouting, waterbalance measuring system, Geo-communication, Geo-Impuls

1. Introduction

In The Hague, in the 1920's the ancient canal at the Veenkade was converted into a culvert in order to provide space for the increasing traffic.
In 2010, the Municipality planned to reinstate the canal with a 100x18 m, two-storey Fully Automatic Parking Garage (VAB) with 160 parking places underneath. Around the canal construction site, most buildings are 19th century houses on a shallow foundation at 0.8 to 3 m below ground level.

The canal will be re-installed at a minimum distance of 3 – 6 m from the houses by means of a 10 m deep building pit.

The concrete structure of the canal and the parking garage were completed in 2014 (see figure 1). Presently the fully automatic parking facilities are being installed.

The project was adopted in the Geo-Impuls-Geocommunication program, where communication of geotechnical risks between geotechnical designers, local inhabitants, Municipality and media was instituted.

Figure 1. Artist impression of the new Canal

2. Design of the structure

The quay walls of the new 18 m wide canal consist of sheet piles, which are installed from ground level (NAP + 1 m) down to NAP – 13.5 m (figure 2 refers). A 1.2 m thick underwater concrete floor is constructed with the top at NAP

– 8.35 m, overlain by a reinforced concrete slab of 0.45 m thickness. An intermediate floor is constructed at NAP – 5.4 m, whereas the cover of the parking garage and the bottom of the canal is formed by a concrete slab at NAP – 2.5 m.

A concrete wall is fitted against the sheet piles and along the canal furnished with masonry. In order to prevent uplift, 15 m long GEWI-piles are installed below the floor down to NAP – 25 m in a 2.0·2.1 m grid.

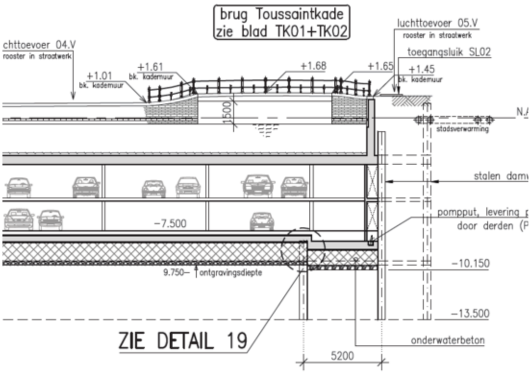

Figure 2. Cross-section of the new Canal and the Parking Garage

The construction sequence was as follows:

- Installation of sheet piles
- Demolition of the old culvert
- Installation of the GEWI-piles
- "Wet" excavation of the building pit up to NAP – 10 m and applying struts during excavation at 1 (locally 2) levels.
- Installation of underwater concrete
- Pumping out of water and installation of concrete walls and floors inside the building pit.
- Remove temporary struts and re-instate the canal.

3. Boundary conditions

The soils consist of sands with a local peat layer at 2 to 3 m depth and some thin stiff clay layers. Locally the sand is very dense (cone resistance over 20 MPa). The groundwater table is at NAP – 0.4 m (1.5 m below ground level).

The buildings next to the building pit are mainly from the 19th century. These buildings are founded on shallow footings.

All buildings were inspected beforehand and any visual damage was reported. Furthermore settlements and rotations/distortions of the buildings were determined. The results were compared with risk-criteria according to Burland et al. (1977) and Boscarding and Cording (1989), which are summarized in Table 1.

Table 1. Risk categories

Risk Category	Risk Category Burland Boscarding	Building condition	Measured relative rotation
Category 3	4-5	Poor to very poor	> 1:300
Category 2	2-3	Fair to poor	1:300 to 1: 600
Category 1	0-1	Good to fair	< 1:600

All 19th century buildings were characterized in the most critical Risk Category 3.

Therefore, the Building Authorities limited the maximum rotation of the buildings during the works to a very strict requirement of 1:1200.

4. Geotechnical Risk Analysis

An extensive risk analysis was executed.

All risks with their consequences were evaluated in a fault tree. Part of a fault tree is shown in Figure 3.

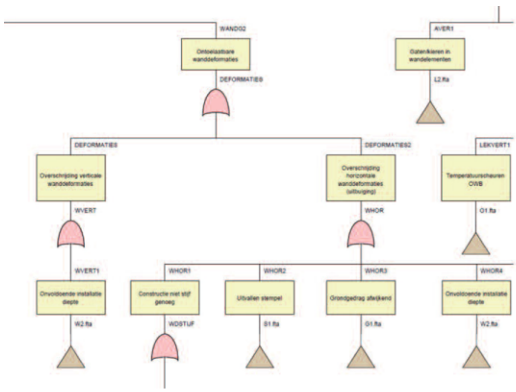

Figure 3. Fault tree

The chances of risk occurrence were evaluated in a 1 to 5 scale, where the effects of the risks were estimated in a scale 1 to 10. The risks are defined as chances of occurrence times the effect, as is illustrated in figure 4. In figure 4 the risks are classified, where red and green colors indicate high and low risks respectively. Yellow and orange zones show intermediate risks.

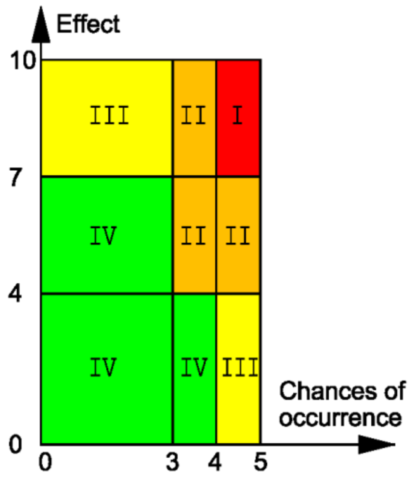

Figure 4. Classification of Risks

The classification of the various zones is given in Table 2.

Table 2. Risk classification

Risk Class	Remedial measures
I	Risk unacceptable - Change of design
II	Preventive measures
III	Measures based on monitoring
IV	Low risk: no specific measures

From the analyses, five major risks were determined:

1. Sheet piles cannot be installed to the required depth;
2. GEWI-piles do not have the required tension capacity;
3. Rotation of the surrounding buildings exceeds 1:1200;
4. Leakage of the building pit;
5. Stop of the building process due to vibrations, deformations of houses or public opinion.

5. Remedial Measures

5.1. General

First of all, the building pit was divided into two compartments (see figure 5). This was part of a strategy to allow traffic to use the new bridge over the canal in an earlier stage. The first compartment to be constructed, however, was surrounded by relatively new buildings on piled foundations, which were less sensitive to possible soil deformations. By measuring the soil deformations by means of inclinometers, an excellent insight in the deformations at the more critical second compartment was obtained.

Figure 5. Excavation in 2 compartments

This is why the second compartment was built with the two struts, as specified in the contract.

5.2. Risk – Sheet piles Cannot Be Installed to Required Depth

Due to the sensitive houses around the building pit, driving or vibratory installation of sheet piles AZ 40-700N to NAP – 13.5 m was not possible. Therefore the sheet piles of the building pit were installed by pressing in combination with fluidising (ABI Hydro Press system of Van 't Hek). Even at only 3 m distance from the buildings, installation of the sheet piles was possible by this method. Before execution in the project, an installation test was undertaken.

Typical features of the sheet pile installation:

- A fluidising tube is welded at the outside of the sheet pile (side of the excavation) down to 50 mm above the sheet pile tip.

- Fluidising is executed under high pressure with low water flow (max 25 l/min).
- No water must be observed at ground level.

The installation of the sheet piles was very successful. Only very locally, in non-critical zones, the sheet piles did not reach the required installation depth. Here, jet grouting beneath the sheetpiles was applied to provide sufficient fixity at the tip.

5.3. Risk – Insufficient Tensile Capacity GEWI-piles

For the tension piles below the underwater concrete floor, GEWI-piles were proposed with tendon diameter of 63.5 mm, extending to an elevation of NAP – 25 m. The outer diameter of the piles was 205 mm, the length of the grouted body was 14 m.

The GEWI-piles were constructed by drilling of a double casing and subsequent retrieval of the casing under continuous grouting pressure.

In order to minimize the risk of unsufficient bearing capacity, three anchor piles were tested up to failure at a separate location next to the building pit. The bearing capacity of the test anchor piles was sufficient. For the tests an α_t-pile factor of 0.012 resulted, which was in excess of the α_t-values of 0.011 used in the design.

In total 485 GEWI-piles were installed from a level of NAP – 2 m. After excavation to NAP – 13.5 m, only 5 piles were damaged. These could be repaired.

5.4. Risk – Settlement of the Surrounding Buildings

The requirement of a maximum allowable rotation of the buildings due to the construction of 1:1200 was very strict. This requirement lead to extensive FEM-analyses, which was focused on the deformations of the shallow foundations of the 19th Century buildings. The bottom of the foundations was at 0.8 m to 3.0 m below ground level. During construction the deformations were monitored extensively.

The results of the analyses showed that the deformations of the foundations of most buildings could remain within the 1:1200 limits. The analyses lead to the application of 2 struts at NAP + 0.5 m and NAP – 1.75 m. The latter struts were prestressed.

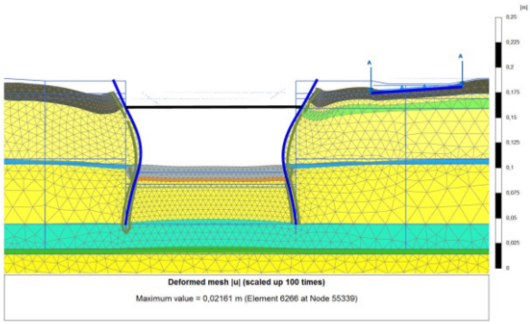

Figure 6. Example PLAXIS model

At one location (elevator shaft at the Veenkade) the 1:1200 requirement was not met. Here the distance between the building pit and the footings was only 3 m. At this location compensation grouting was applied.

So-called "tubes a manchettes" (TAM's) are installed below the footings (Figure 7). A TAM consists of a steel pipe with openings every 0.5 m, which are sealed by a valve. Through the valves, cement-grout can be injected under pressure, causing the grout to penetrate into the soil below the foundations. Consequently the foundations can be lifted over 1 - 5 mm. The grouts hardens and the upward deformations are permanent.

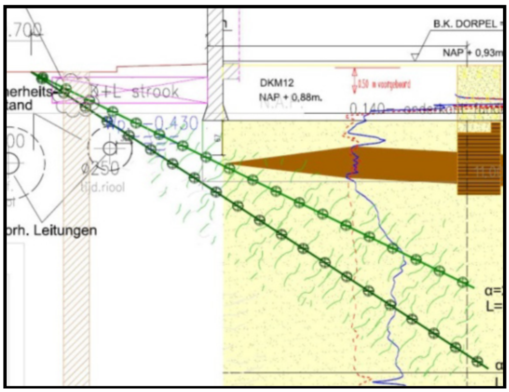

Figure 7. Compensation grouting

An extensive monitoring program was set up to verify the deformations and take actions, before the displacements reached the signaling value or the intervention value (stop of the construction activities).

The monitoring consisted of:

- Robotic total stations, automatically measuring x-, y- and z- deformations with 62 monitoring points, which were installed already 1 year before the start of the works.
- Inclinometer casings were placed along the sheet piles and 1 m in front of the buildings. Thus, horizontal deformations were registered, indicating also possible vertical deformations below the foundations.
- Waterbalance system, a highly accurate (+/- 0.5 mm) measurement of vertical deformations was installed with 21 measurement points inside buildings. This system was used to accurately measure the settlements and the heave due to the compensation grouting.

All deformations remained within the deformation limits of 1:1200.

Compensation grouting was used twice: at first initially after installation of the TAM's, secondly before the "wet" excavation of the building pit and subsequent pumping of the building pit.

5.5. Risk – Leakage of the Building Pit

A minimum groundwater level of NAP – 0.6 m must be maintained outside the building pit. Locally the groundwater table was lowered below this limit during a short period for excavations for cables and pipelines.
However, during pumping of the building pit, the groundwater in the surrounding area was not lowered.

The risk of leakage was reduced by thorough underwater inspections before pumping and welding of the slots of the sheet piles inside the building pit.

Furthermore many piezometers were installed, which continuously monitored the groundwater table.

5.6. Risk - Interruption of the Building Process due to Vibrations, Deformations of Houses or Public Opinion

The building process was not interrupted. This was due to the following precautions and measures:

- Due to compensation grouting and continuous monitoring of deformations, the displacements remained below acceptable levels.
- Larger vibrations were not allowed. In case vibrations could not be avoided the process was controlled using vibration monitoring.
- Open and transparent communication from the City of The Hague and from the contractor BAM Civiel anticipated on major complaints. Requests and complaints from the neighbourhood were addressed immediately.

6. Communication

The project Veenkade was included in the Geo-Impuls program, Geo-communication. The following actions were taken to optimize communication about the project:

- Personal contacts with the neighbourhood
- Up to date information of the project, using Twitter, website, digital newsletters and posters at the site location.
- The building site was made attractive to visitors: coloured information was attached to the fence, a visitors view point was installed, which gave a fantastic panorama over the site.
- Site visits were arranged on a weekly basis.
- Milestones in the building process were communicated with neighbours.
- Clear communication about risks, monitoring and remedial measures.

7. Conclusions

In The Hague a two-storey underground Fully Automatic Parking Garage (VAB, parking installation by Palis – Germany) was built beneath a reinstated canal at the Veenkade. A 10 m deep building pit was excavated at 3 – 6 m distance from sensitive 19th century buildings.

Large risks were at stake: small deformations would already cause a large damage to these sensitive structures. Much effort was put into the assessment of the risks before execution. Tests were performed to determine that the sheet piles could be installed without vibrations. The tensile capacity of the GEWI-piles was determined on site by means of investigation tests. Also settlements of the most sensitive foundations could be reduced by means of compensation grouting.

Furthermore, high tech real time monitoring of deformations helped to control the construction process.

Open communication (where previous experiences from the Geo-Impuls program were very useful) has assisted in reducing the nuisance for the neighbours.

The assessment of the risks in an early stage, the subsequent risk control and the good cooperation between City of The Hague, consultants, contractor and neighbours have resulted in a very successful project!

References

Baars, M. van (2013). Diepe Bouwput langs historische panden in centrum Den Haag – Deel 1, *Geotechniek Special*, pp 36 – 41, December 2013.

Haas, K. de, Baars, M. van, Marks, C. and Nieuwenhuizen, M. (2011). Duivels dilemma of ontwikkelingsvraagstuk – team Geo-Impuls helpt bij communicatie over geotechnische risico's, *Geotechniek,* pp 32-34, December 2011.

Spendel, C.J., Waals, E. van der, Marks, C. and Seters, A.J. van, (2015). Herstel historische gracht, aanleg van twee bruggen en een ondergrondse volautomatische autoberging in het centrum Den Haag – Deel II – de uitvoering, *Geotechniek*, pp 8-15, January 2015