RISK MANAGEMENT APPLIED TO TUNNELS

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GeoQ

All tunnel projects require some sort of solid foundation, but ground conditions bring some degree of uncertainty to every tunnel project. Dealing properly with uncertainty over ground conditions can make the difference between the commercial success and failure of a tunnel project. With margins in the construction industry at historic lows, and with costs of failing to accurately predict ground conditions becoming increasingly high, the importance of proper management of the variety of groundrelated risk is paramount. Risk management has demonstrated its value in many industries, but the full lessons of that experience has not yet fully reached all aspects of civil engineering. In particular, the importance of individuals and their own awareness of risks and how to manage them has often been overlooked. Martin van Staveren has written a new kind of book on ground risk management, the GeoQ concept. Based on many years of professional experience and proven risk management techniques.

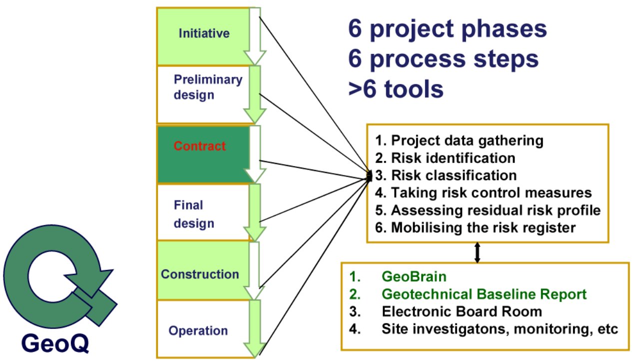

Figure 1
GeoQ

Tunnelling in the Netherlands

All the work that is done in the field of soil deformations due to shield tunnelling in the Netherlands can be put in a risk management perspective. In early nineties, the bandwidth for prediction and controlling tunnelling was far too large to start tunnelling in the sensitive ancient inner cities of the Netherlands.

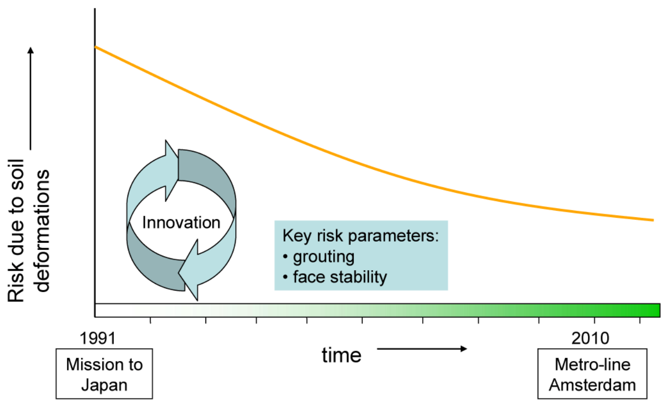

Figure 2
Reduction of risk due to soil deformations as a function of time

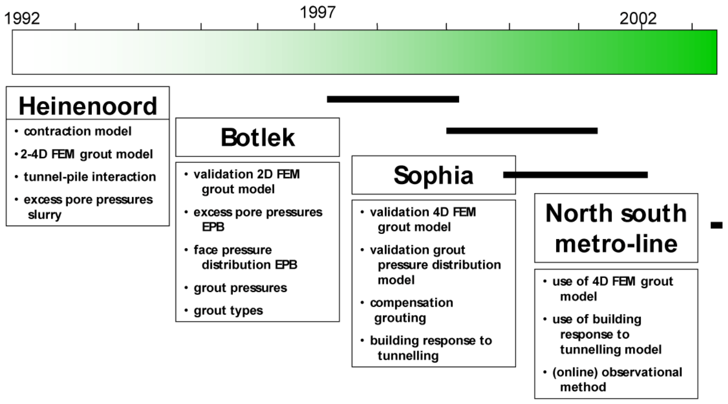

Figure3
Research on soil deformation in relation to Dutch shield tunnel project

One can say that to narrow this bandwidth a risk management process started by the visit of a Dutch delegation Japan in 1991. In 2002, the bandwidth was narrowed to such an extent that tunnelling the North-South Metro Line in the sensitive ancient city centre of Amsterdam is feasible. In this process, the "innovation circle tool" has been applied.

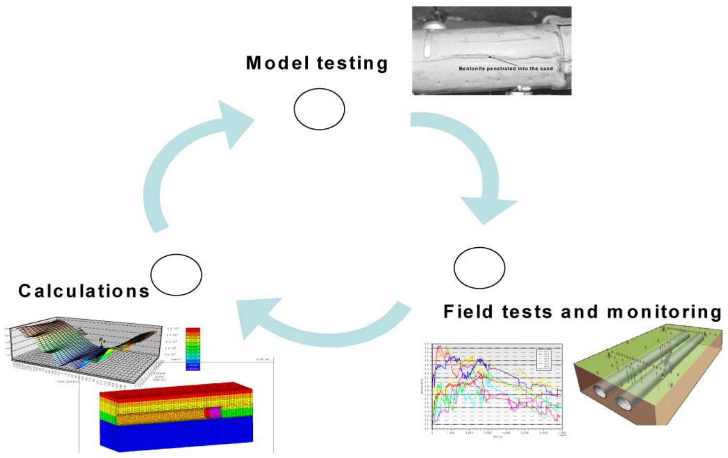

Figure 4
Innovation circle for grouting

Two examples of the innovation circle are presented in this presentation: for grouting and for face stability. Furthermore a brief overview on soil deformation research in the Netherlands in relation to the different tunnelling projects is given. Finally, a general overview is given for the present Dutch situation; this is an interpretation of design procedures of the different projects from a risk management point of view.

The groene hart tunnel case

The Groene Hart tunnel is a 7190 m long, 14.9 m diameter shield tunnel, part of the high-speed railway link between Amsterdam and Paris. The risk management in the initiative, the preliminary design, contract, final design and construction phase is presented. At the end of the initiative phase a (very expensive) bored tunnel was chosen under the Green Hart, this was a political decision no technician had foreseen. Starting the preliminary design the tunnel project was based on risk management control. Some of boom, structural integrity, integrity of the Green Hart and time. For all these items, special research was initiated to the first air shaft knowledge to be able to manage the risks to an acceptable level. To make use of the international knowledge and experience in the field of shield tunnelling a D&C contract was chosen. As planning was tight in advance of the contracting phase a symposium was held to inform the market about the tunnel project and all of the key risk items. Also during the contracting phase, the full risk dossier was shared. This resulted in a very competitive innovative winning design that was taking care of all key risk items. During the detailed design phase and the construction phase, the client and the contractor only discussed the key risk items in an open constructive way.

Figure 5
The lanching shaft of the Groene Hart tunnel with at the bottom side the first air shaft

Figure 6
The full scale tunnel lining test facility with 3 full rings

2 probabilistic analysis of the soil deformations. As a client should not interfere in the details how a contractor runs the TBM the Project organisation HSL-zuid has chosen not to demand an extensive monitoring program. To minimise the risk of delays due to large instabilities in loose sands layers and to ensure a well embedded lining it was chosen to restrict the surface settlements to 10-25 mm. The idea was that small settlements are only possible with good face stability and a good grouting. The result would be a limited chance on instabilities (calamities) and a good filled tail void.

The goal of project organisation HSL-zuid for this probabilistic analysis was to get an insight in the variations of the surface settlements to be expected during normal tunnelling operations and to detect critical sections. Based on the geology and depth of the tunnel the 7160 m length was divided into 15 sections. For each section series of FEM analyses where made. The stiffness and strength of individual soil layers and the pore water pressures and the unit weight of the soil were varied in the FEM computations. These variations where based on the 5% upper and lower limit results of the geo-statistical analysis of the extensive soil investigation. In the analysis the grout and slurry pressures where also varied. The basis of this analysis was the design of the contractor Bouygues-Koop with his proposed grout and slurry pressures. The results of these FEM analysis where combined to a mean, 5% upper and 5% lower bound prediction of the settlements.

Further, an analysis was made on the minimum and maximum face pressure based on analytical methods to detect critical sections. A long critical section was detected in a deep polder. The critical mechanism was the propagation of tunneling induced excess pore water pressures in the confined aquifer resulting in a loss of vertical stability of the overlaying aquitard in the polder consisting of very soft organic clay. For this a detailed analysis was made and during tunnelling the results of this analysis where verified by measurements. Then it was chosen to take extensive mitigation measures to ensure the vertical stability of the soft organic clay layer during tunneling.

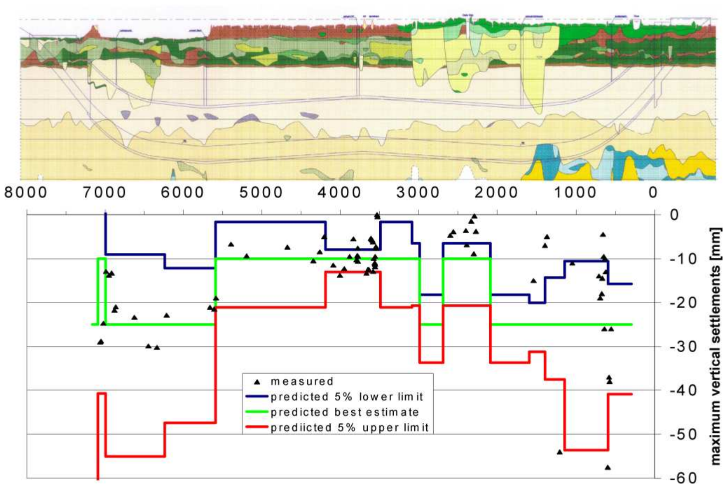

Figure 7
The geological profile of the Groene Hart tunnel and the settlement prediction band and measurements

Souterrain case

The Souterrain in The Hague, also known as the “Tramtunnel” combines a Light Rail Line underneath the busiest pedestrian shopping area in the centre of the city with a large number of parking facilities. At its deepest point the Souterrain has three different levels: 2 floors with parking facilities and below those the double Light Rail Line at the 3rd level. The Souterrain contains two Rail Stations, one at “Grote Markt” and one at “Spui”. The length of the tunnel is 1250 m and its maximum depth is 13m. During the construction cost nearly tripled here the main lesson learned are discussed February 1998 a leak developed in the jetgrout arch in part 16 of the “Kalvermarkt”section of the Souterrain. Sand erosion from outside the tunnel lead to sinkholes at ground surface. To stop flow of water and sand towards the tunnel and to prevent damage

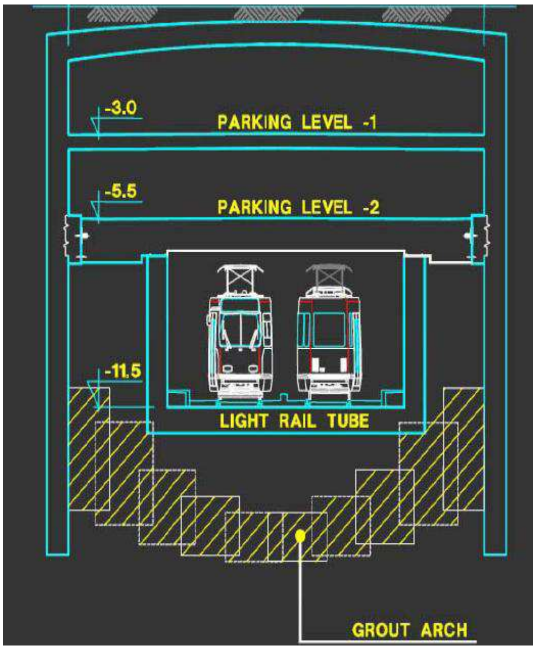

Figure 8
Section of the Souterrain with a Jetgrout arch

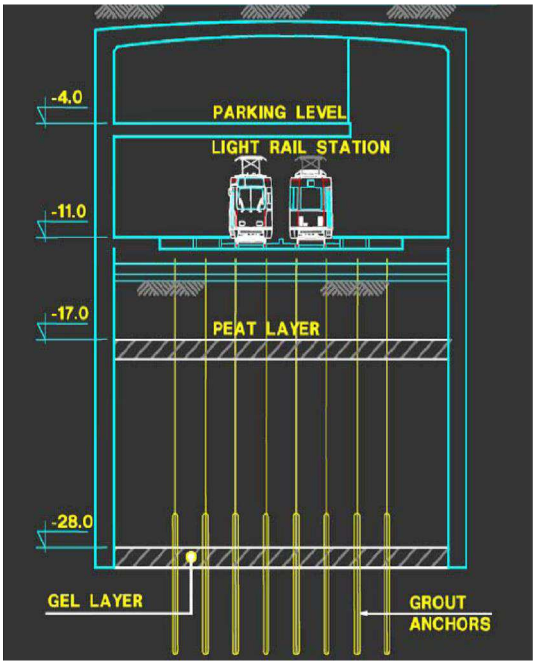

Figure 9
Section of the Souterrain with a Soft-gel injection layer

Construction stopped for approximately two years. When, after a two year standstill, construction started again in July 2000 it had become apparent that the deep wells in station Spui had lost much of their capacity to de-water the soil contained between the diaphragm walls and the deep gel layer. Circumstances called for interaction between measurements and construction phasing. The original design approach aimed to minimise construction costs by taking into account the variable width and depth of the tunnel over its length. By using different construction techniques depending on local depth and width of the tunnel, an optimized construction scheme was defined.

The lessons learned where:

1. minimize the amount construction types as transitions always significantly increase the risk profile

2. make an in-depth what-if scenario analysis, especially if a system is optimized to its extreme.

In the end, the use of the Observational Method (OM) led to the successful completion of Station Spui. The combination of the new monitoring with existing measurements led to changes in the construction sequence, reducing settlements below adjacent buildings. This was helped by a changed, more flexible and adaptive organisation of the project. The late implementation of OM was hindered by the original "optimised", but relatively inflexible, design.

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