ONLINE MONITORING FOR THE CONSTRUCTION OF EMBANKMENTS FOR BETUWEROUTE

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ABSTRACT

The Betuweroute is a double track freight railway line under construction connecting the world port of Rotterdam to the European hinterland. The western part of this 160 kilometres of new railway line runs through densely populated, the typically Dutch polder areas. The soil conditions in this area are very poor. Due to political debates, resulting in serious delays, short construction times were required. A traditional embankment of sand fill was preferred, however at the start of the project it was uncertain whether stability and settlement requirements could be met. Further the new embankment had to be constructed parallel to an existing railway line and the important A15/E31 motorway.
To deal with these risks an extensive online monitoring program was developed to enable the practical use of the observational method. The online monitoring approach, as an integral part of the risk management system, enabled a significant reduction of total project costs. Monitoring data, which partially has been collected fully automated, was stored in a central database. Software tools were developed to present the monitoring data in a ready to interpret format. To serve the many parties involved in the project the database could be assessed from virtually everywhere using internet technology.

KEYWORDS

MONITORING / INTERNET / RISK MANAGEMENT / OBSERVATIONAL METHOD / VALUE ENGINEERING / SOFT SOIL

1. INTRODUCTION

The Betuweroute is a double-track freight railway and the first railway in the Netherlands that is designed exclusively for freight transport. The 160 km kilometres of freight track will ensure that cargo arriving at the port of Rotterdam is transported quickly and safely to the European hinterland.
The Sliedrecht-Gorinchem section of the Betuweroute is the most difficult part of the new railway track. It runs parallel to sensitive existing infrastructure, available construction time is short and critical for the total project and last but not least, local soil conditions are very poor. Situated in the western part of the Netherlands, a typically Dutch polder landscape and its delicate hydrological systems had to be crossed.
The overall high risk profile of the Sliedrecht-Gorinchem section of Betuweroute, especially regarding several geotechnical issues, formed the starting point for the formation of “Waardse Alliantie”, an alliance between ProRail Project organisation Betuweroute (client) and HBSC (a combination of four Dutch and Belgium contractors: Heijmans, Boskalis, Structon and CFE). Together they took on the challenge to re-design and build this Betuweroute section within a tight time schedule and within a fixed budget. Both parties agreed to share cost of identified risks including unexpected soil conditions and damage to existing infrastructure. On the other

hand, the alliance was challenged to optimise the available design as cost reductions would also be shared among the parties involved. Originally, ten years of maintenance was included in the contract to guarantee a qualitatively sufficient design.
Value engineering and a close co-operation of all parties involved formed the basis for the current success of “Waardse Alliance”. The alliance started in October 1999 and is still on schedule to complete the project in November 2003. Many optimisations have been implemented successfully. A reduction of 5 to 10 % of total project cost (10 to 20 million Euro) is expected. A large part of the realised cost reductions, have had their origin in sound risk management regarding the geotechnical aspects of the project. On-line monitoring was one of the main pillar supporting the performance of geotechnical risk management on-site.

2. OBSERVATIONAL METHOD

In an early stage of project it became clear that sound geotechnical risk management and the implementation of the observational method formed the key to a success for the alliance. As the contractual time schedule was very tight, the principles of the observational method had to be implemented in an innovative manner to be successful. Monitoring is the data acquisition side of the observational method, however data without interpretation and action taken on the basis of this information is still useless.
Unfortunately, in many projects monitoring is carried out only because it is mentioned in the contractual documents, resulting in lockers full of unused data. In such projects monitoring is a waste of money. Aware of these negative experiences from other project, GeoDelft argued for a rigid embedding of monitoring in the formal decision structure of the alliance. Monitoring is a powerful tool to get grip on the true behaviour of soil. Through a coupling with risk management, understanding of the importance of acting on monitoring data is guaranteed at all management levels. Support of the project management is required to secure the necessary attention of acting on monitoring data throughout the whole duration of the project.
Embedding of monitoring in risk management challenge the geotechnical engineers to optimise the required monitoring.

2.1. Monitoring programme

Starting point for the design of a monitoring programme is the risk analysis. Starting from a recognised risk, indicators have to be defined that reflect the performance of the ongoing construction. For every indicator, a prediction of the expected (best-guess) behaviour shall be available. Next the threshold for unwanted behaviour has to be determined and the action that has to be taken in case of reaching a threshold are be defined.
Monitoring of soil behaviour is often a good indicator to establish whether design assumptions correlate with the true behaviour on site. The advantage of these type of measurements is the often early warning for unwanted behaviour, allowing remedial actions to be taken before unacceptable damage occurs. However, monitoring of soil behaviour has its practical limitations regarding accuracy and reliability. In case of an endangered object, monitoring of soil behaviour preferably should be combined with monitoring the deformation of the object itself. In many cases the deformation of an object itself shall be less that the driving soil deformations. There might be also risks for which monitoring of soil behaviour is inappropriate, in such cases measurement might be done on the object itself.

For every indicator, a suitable instrument and required frequency of data of acquisition and processing has to be established. This should of course be done in relation to the underlying risk. The following questions should now be answered:

- Are the consequences of exceeding a threshold calculable and acceptable?
- Are the consequences the same along the whole section or is differentiation in amount of monitoring possible?
- Are actions that have to be taken in case of exceeding a threshold clear?
- Is enough time available between the collection of raw data and the moment of taking these remedial actions on the basis of interpreted data?
- Are the cost of monitoring still in balance with the accompanying risk?

The answers to all of these questions shall be positive. If positive, an effective monitoring programme will come into being as only relevant data will be collected in an optimum amount. If not, monitoring is probably not the appropriate control for the underlying risk and an alternative has to be found.

2.2. Embedding in organisation

To control risks, gathering field measurements only is not sufficient. Raw monitoring data usually consists of measured elevations, frequencies or volt. These data has to be processed to enable interpretation. On a 22 kilometre section as described in this paper data handling is a very important item. Therefore the monitoring programme should be lean (except for reasons of redundancy of sensitive or important instruments of course).

In most occasions, people acquiring the data are not the people who interpret the data. Furthermore, people who interpret the data do not necessary have the authority to interference in the ongoing construction. To really control risks using the observational method, sound embedding in the organisation is a must. From workman to manager, every one has to be aware of the importance of monitoring.

2.3 Internet access

To be able to effectively handle the enormous amount of data gathered at the Sliedrecht-Gorinchem section of Betuweroute, extensive automation was implemented. For example stability control of the hydraulically placed sand fill asked for reading of instruments twice a day at some difficult to reach locations in the polder area. Interpretation of these data should be done within one or two days to allow for flexibility in the sand fill process. For this reason installed piezometers were coupled to a data loggers which acquired a reading twice a day. These loggers had its own power supply through a solar panel and were read out daily by to a central computer through a GSM modem. Thus collected data was automatically processed and stored in a the central database. The database could be assessed using visualisation software, through an internet connection (figure 1). The geotechnical design and evaluation software could also communicate with the central database which enabled fast interpretation of monitoring data. The use of an internet connection enabled simultaneous interpretation at various locations which made on-site consultation of the back-office available. The use of a central database ensured uniformity of data and availability of data 24 hours / 7 days a week.

Besides these advantages, all data can be handed over to the future track owner easily, enabling the use of construction data for prediction of maintenance. The Sliedrecht-Gorinchem section of Betuweroute was the first project in the Netherlands using such an advanced monitoring system. Nowadays, many projects make use of the positive experiences gained.

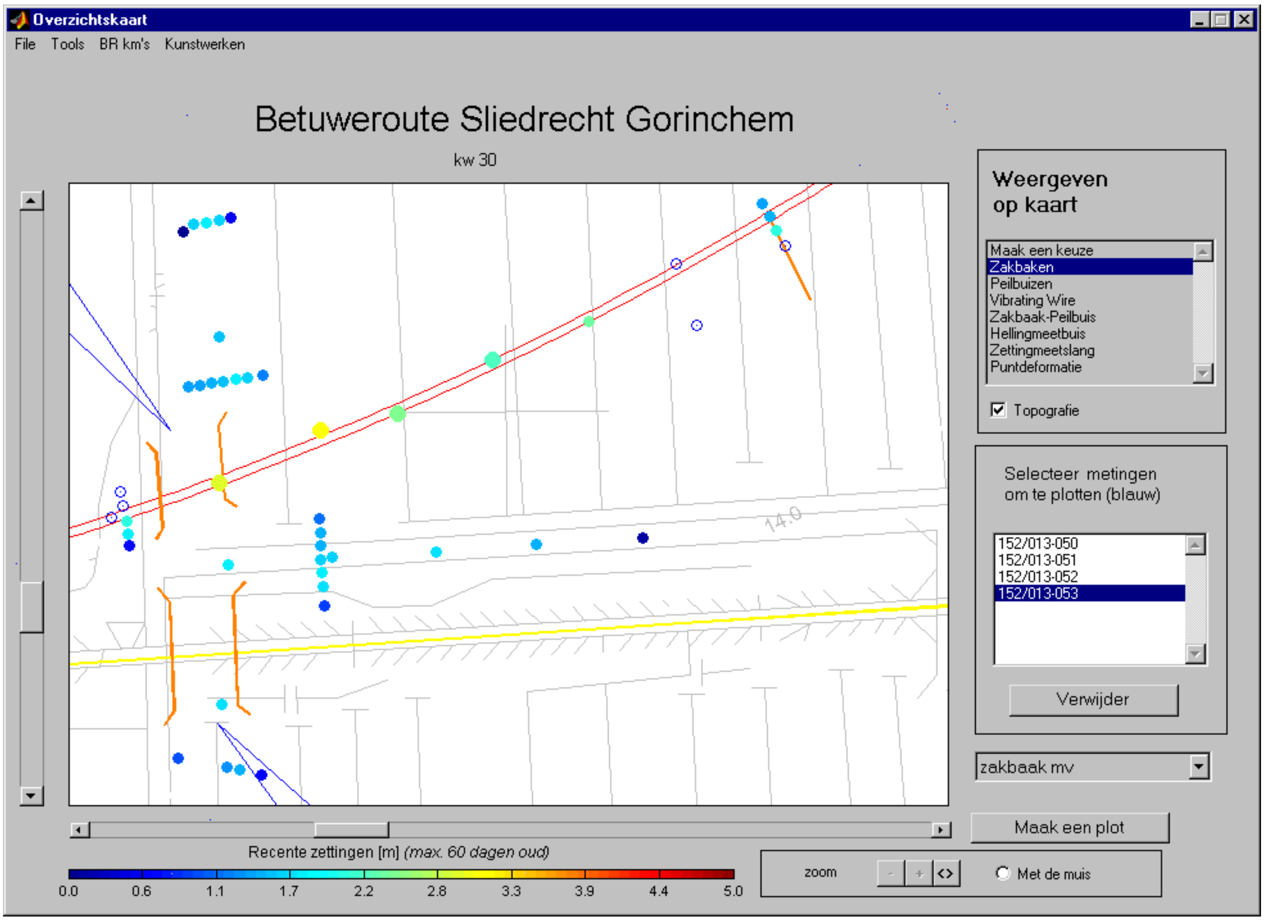

Figure 1 – Visualisation of locations and last measurements of settlement beacons

3. CONSTRUCTION PARALLEL TO THE EXISTING A15/E31 MOTORWAY

Approximately 9 out of the 22 kilometres embankment section of the Sliedrecht-Gorinchem contract, Betuweroute runs parallel with the existing A15/E31 motorway. The A-15/E-31 motorway is one of the main east-west road connections cross cutting the Netherlands. Parts of the motorway of today are more than 100 years old. As in earlier times construction data was not archived, little is known about the construction of the foundation of the existing embankment. From other projects and reconstruction works along the A15/E31 it was known that the condition of the foundation is very variable but in many location extremely vulnerable. Locally, the road might be founded on wicker and floats more or less on top of the very soft peaty soils. At other locations the embankment consists of more than 12 m very loose sand.

3.1 Risk analysis

The original idea to prevent damage to the existing road involved installing of a sheet pile wall between A15/E31 and the new embankment for Betuweroute. It was thought that such a separating wall could prevent damage to the motorway. However, a specific risk analysis for the parallel sections pointed out that due to compaction, installing a sheet pile wall in the embankment of the motorway would almost certain create a lot of damage and hindrance for traffic itself. Balancing all the risks it was decided to abandon the idea of a sheet pile wall and start an extensive monitoring programme instead.

Figure 2 - A-15/E-31 motorway and Betuweroute under construction

One important conclusion of the risk analysis regarded the reaction time available between occurrence of settlement and damage to the asphalt. The occurrence of settlement is a very slow process and gradually changes stress levels in the embankment of the motorway. The direct damage from settlement is predictable and surface maintenance on the motorway can be scheduled. A very fast and therefore much more severe damage mechanism is internal collapse of sand body because of the extreme loose compactness. Such as collapse is initiated by changes in stress level and acting direction of the stresses. In theory settlement can initiate such a collapse and might undermine the motorway for a long period without being noticed. In case of a collapse cracks and differential settlement up to 0.1 m will form in the pavement resulting in a dangerous situation for the traffic within some hours. The length of such a section might by 50 to 100 m or even more, but its exact location is not known in advance.

Traditional geotechnical monitoring is no option to control such a risk as it would always take to much time to acquire, process and interpret data. Furthermore a decision to close of one or more lanes of such an important motorway can not be taken without a visual check on what is going on. It was decide that only a daily visual inspection of the road would enable an early detection of pavement damage. Settlement beacons could be used verify the design assumptions on settlement only, although in some occasions open spaces underneath the pavement might be detected before any damage is visible.

3.2 Cost reduction

The risk analysis had made clear that the traditional approach using a sheet pile wall in between the motorway and Betuweroute would lead to high additional cost (approximately 4 million Euro) and would cause unacceptable hindrance for the traffic over a period of several months because of the expected damage during installation of the sheet piles. Careful construction and an intensive visual inspection was likely to be much cheaper as damage was expected only over limited areas. Furthermore, the daily inspections increased safety for the traffic anyway as damage was always noticed in an early stage.

Construction of these sensitive sections is now completed for almost one year and some damage has occurred in very limited sections only. The hindrance for traffic caused by these damages was negligible. The total costs that have been spend on repairing the pavement of the motorway was far less than would have been the case using a sheet pile wall. The cost of the extensive additional monitoring was only 10% of the cost of the sheet pile wall.

The transparent risk analysis strongly helped to obtain permission of the Dutch road authorities to use the approach described above

CONCLUSIONS

Using the observational method to compensate for uncertainties in geotechnical design and construction is undisputed worthwhile. Preferably it should be embedded in the project risk management system.

Value engineering through an optimisation of the traditional design was enabled through the modern implementation of the observational method.

On this project millions of Euro were saved because the management believed in the observational approach. The additional cost for monitoring and supervision was less than 10% of the saved cost.

The contractual form of an alliance has stimulated innovation in this project. The modern implementation of the observational method as developed in this project now is recognised as state of the art in the Netherlands.