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Geotechnical risk management in the Netherlands

Management des risques géotechniques aux Pays-Bas

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ABSTRACT
During 2003 and 2004 GeoDelft has spent research effort on the development and implementation of GeoQ. GeoQ is a risk-based approach with the aim of guaranteeing the geotechnical quality of a project. Tools, both for process management of risks in projects as well as for the determination of geotechnical risks, have been applied in a number of projects. Results have been compared with those from a more classical approach, performing only geotechnical design calculations, often of a deterministic nature. This has shown evidence of two facts. Taking a risk management approach may impose a preliminary financial burden on the project. Identification and implementation of risk management alternatives could generate large savings to the project, outweighting by far the costs of the risk management approach. The paper will review the tools presently available and their use in a number of projects.

RÉSUMÉ
Pendant les années 2003 et 2004, GeoDelft a effectué de nombreuses recherches en vue de l'élaboration et de la mise en application de GeoQ. GeoQ est une approche basée sur une étude de risques, dont l'objectif est de garantir la qualité géotechnique d'un projet. Les outils disponibles, que ce soit pour la gestion de processus des risques inhérents à un projet ou pour la détermination des risques géotechniques, ont été utilisés dans plusieurs projets. Les résultats ont été comparés à ceux obtenus au moyen d'une approche plus classique, laquelle n'effectue que des calculs statiques géotechniques, souvent de nature déterministe. Cela a permis d'établir deux faits. Adopter une approche basée sur une gestion des risques pourrait, dès le départ, créer une pression financière sur le projet.
L'identification et la mise en application d'alternatives basée sur une gestion des risques pourraient générer des économies importantes au niveau du projet, dépassant de loin les coûts liés à une approche basée sur une gestion des risques. Cet article va passer en revue les outils disponibles à l'heure actuelle et leur utilisation dans un certain nombre de projets.

1 INTRODUCTION

Adequate attention for the subsoil is necessary for infrastructural projects. A key succes factor for effective risk management is the proper identification and handling of risks arising from differing subsoil conditions. GeoDelft has developed a general approach named GeoQ to deal with sub-surface risks and control total project costs. The GeoQ approach strives to bring transparency in many implicit risk-related decisions taken in a project. The approach can also consider uncertainties as possible chances for optimisation.

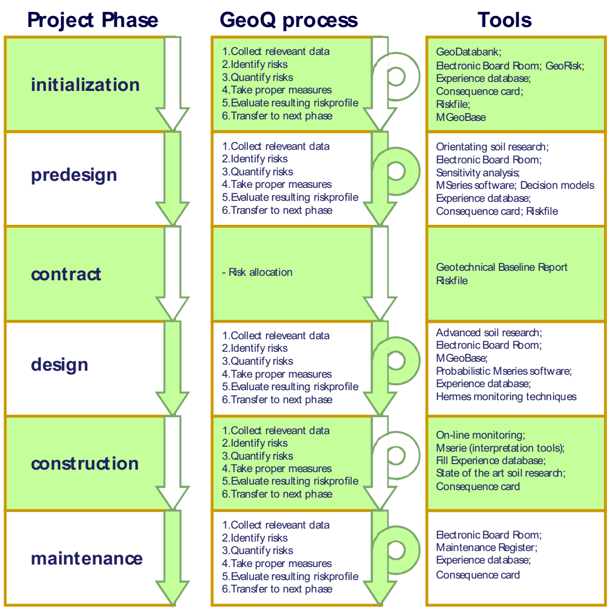

Figure 1. GeoQ approach as a cyclic, risk based approach of design, and construction in every phase of a project (Molendijk and Aantjes, 2003).

The first cornerstone of the GeoQ approach is a cyclic, risk based approach of design, and construction in every phase of a project (Fig.1). The second cornerstone is to mobilise all relevant information and knowledge to enable continuity of information between the various project phases. This will lead to an improvement of the total quality of the project and a related strong decrease of unexpected cost (Clayton, C.R.I., 2001; Molendijk and Aantjes, 2003; Staveren, M.Th. van, 2004).

Geo-engineering tools are available for the quantification of chances and consequences of unwanted events and for the design and engineering of countermeasures, reducing the possible risks to acceptable levels (Fig.2). Examples of these tools are

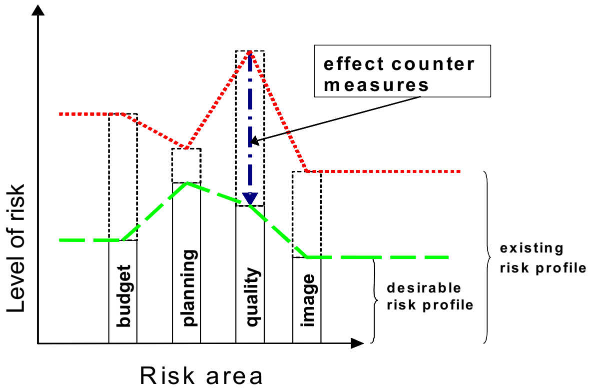

Figure 2. Effect of countermeasures, reducing risks to acceptable levels

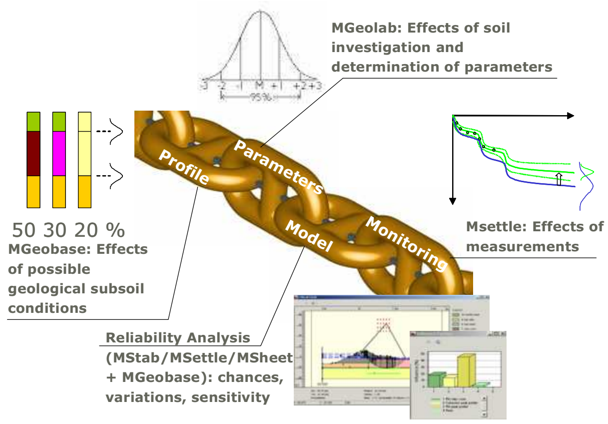

Figure 3. Example of a sequential application of geo-engineering tools

tools are probabilistic geotechnical software, field and/or laboratory investigation, involvement of specialists' expertise, monitoring techniques, etc. Figure 3 shows a sequential application of geo-engineering tools in the field of stability or settlement issues.

In this paper we will illustrate the application of GeoQ. Three examples are given, namely two case studies dealing with risk identification and management for unwanted events and one case study dealing with chances for optimisation, the latter one being illustrated with some data from other projects as well.

2 RISK IDENTIFICATION AND MANAGEMENT FOR UNWANTED EVENTS

2.1 *Case 1, Tweede Coentunnel/West-Randweg*

On behalf of the Ministry of Transport and Public Works, GeoDelft is currently involved as strategic partner in the contract preparation for the future West-Randweg / A5 and 2nd Coentunnel / A10 (Fig.4). These two motorway projects, situated at the western part of Amsterdam are intended to improve the traffic around Amsterdam in north- and southbound direction. In the course of 2005 both projects will be tendered as Design & Build-contracts.

Using the GeoQ approach GeoDelft performed a number of activities. Within several categories (Geotechnics, Geohydrology, Geo-ecology, Objects in Environment, Contractual Issues, and Quality of Data) in total 141 subsurface related risks were identified. For this purpose, experts from both the Ministry of Transport and Pubic Works and GeoDelft have met in the Electronic Board Room of GeoDelft. During the meeting the identi fied risks were also classified using the RISMAN-method,

Figure 4. Location future West-Randweg/A5 and 2nd Coentunnel/A10

resulting in a classified subsurface related risk-file. Using the risk-file, proper countermeasures were defined for the most important risks. The following specific measures are mentioned:

- Collection of historical data. As both projects were postponed earlier, a lot of geotechnical research was available, varying from data back in the 1960's to more recent data (1980). Archives from GeoDelft were used for this purpose.
- Definition of additional soil investigation. Based on the quality of the collected data an additional soil investigation programme was defined. New soil investigation techniques were used, such as defining compression moduli using K_0-CRS laboratory testing, creating a continuous subsoil profile using Consolitest, and in-situ determination of soil-elasticity by conepressiometer testing.
- Electronic database of soil investigation. All the historical and new subsoil data hase been collected within an electronical database. For this purpose a viewer is developed using MGeoBase (Fig.5).
- Geotechnical Baseline Report (GBR). Based on the evaluation of historical and new data and the risk-file a parameter set with key risk drivers is defined to create transparency within the risk-distribution between contractor and principal.

During the several steps within the GeoQ-approach the following matters were made explicit:

- Regarding the history of both projects it is not unlikely that for quite a number of risks identified at this moment, a number of possible measures has already been described and taken within several earlier studies and reports. Using GeoQ showed evidence that more effect will be generated from opening up relevant engineering practices from these earlier reports, instead of 're-engineering' certain risks.
- Beside the development of (visual) tools such as the MGeoBase-viewer, tools such as consequence charts and the Geotechnical Baseline Report will be very valuable in controlling risks in the coming project phase (i.e. contracting and auditing of (final) engineering by Ministery of Transport and Public Works).

2.2 *Case 2, Alblasserwaard*

In the Netherlands, in the very dry summer of 2003 two secondary dikes broke and thousands of cubic meters of waters flooded into living area's creating a lot of damage. Immediately after this event, public questions were asked about the safety of the thousands of secondary dikes. Since it is almost impossible to investigate all these small green dikes, a new method of approach was developed to look at the stability of a dike. This method is called Rational Risk approach for Dikes (RRD) and includes a more geological view of the surrounding area of the dike.

The principle of the RRD-method is that uncertainties in dike material and subsoil are approached starting from their possibility of appearance. From a geological point of view, an area can be divided in different geological zones. Every cross section over a dike in a zone will be combined with possible geological subsoil conditions and calculations of slope stability will be made for each of the possible appearances. The safety factor of the several calculations is being translated in a chance of failure. This process requires an automated approach of transforming information about geometry, soil conditions to an input file for stability calculations and transforming the results of the calculations into maps. Up to 3000 stability calculations can be made per day. The RRD-method has been applied for about 80 kilometers of secondary dikes in the Province Zuid-Holland.

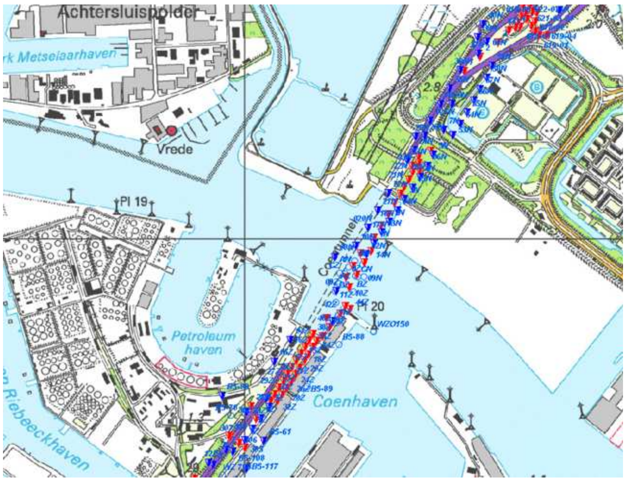

Figure 5. View of part of the location with geotechnical data points

Main goal is to obtain global information about the structure of the dike and the subsoil in its surrouding area, and to calculate the slope stability of the dike under wet conditions. For every 100 m of dike slope stability has to be assessed. To reach this goal the following approach is taken:

- Establishing a geological subsoil model, including estimation of soil properties and groundwater tables, and the linking of this data with the information of the cross sections in a dataset.
- In the areas with a lot of diversity or uncertainty in the subsoil model a small field investigation is performed (25 CPTs) to obtain a sharper transition of a geological zone.
- The automatic calculation of the safety factor of 800 cross sections, analyses of the results and giving recommendations.

The results of the calculations are shown in figure 6. In the figure the calculated chances of failure are given as a coloured dot. A green dot means that chance of failure is better than the required minimum, whereas a red dot means that the chance of failure is lower the required minimum. The orange dots are uncertain. This can mean that more detailed information is needed.

With the results of the RRD method the client is able to make the proper decisions. The advantages are:

- In a short period of time there is information available about the possibility of weak spots in the dikes. With a traditional approach, detailed field and laboratory investigation, this would have taken years.
- Identifying and improving the sections with the highest risk will result in the most effective method of increasing the safety of the dike.
- Field and laboratory investigation can be directed to the most vulnerable sections of the dikes. The results of this specific soil investigation will give a quick answer if there is a real risk or if there was a shortage of information.
- The automatic work process results in the same amount of time in more detailed information than with a traditional approach.

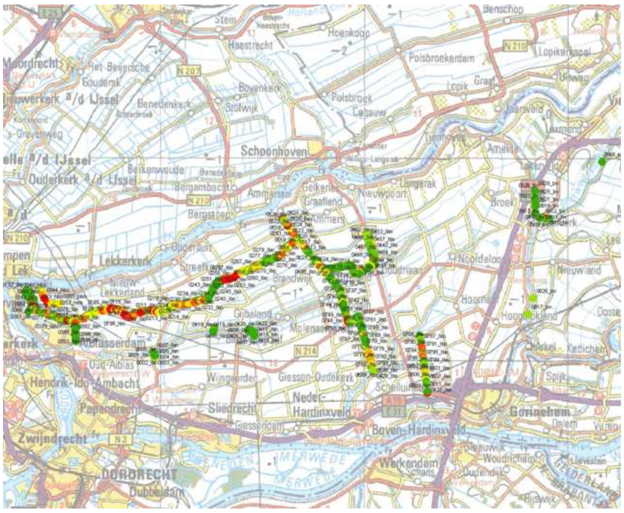

Figure 6. Safety factor of 800 cross sections

3 CHANCES FOR OPTIMISATION

3.1 *Case 3, Technopolis*

The Municipality of Delft plans an industrial estate located south of the campus of the Delft University of Technology and west of the main motorway A13 connecting The Hague and Rotterdam (Fig.7). For this 'Technopolis' area a study was performed indicating the best way of preparing the site for building activities. In the lower parts of the Netherlands with a high groundwater table, such as here, preparation usually consists of replenishing the site with a sand layers of a certain thickness (e.g. 2 or 3 m). When settlements caused by the consolidation of the underlaying soft soils such as clay and peat have reduced significantly, construction of infrastructure and facililites may start. In the end, an unsaturated sand layer of e.g. 1 to 1.5 m above the groundwatertable is available for underground burial of cables, pipes, etc., as well as for limited excavation of building sites to allow for the construction of shallow parts of the foundations.

Based on available and newly required geotechnical information the sensitivity of the site for settlements could be assessed. A combination of geological and geotechnical data with settlement data allowed for a distinction in areas, requiring for site preparation relatively moderate measures or relatively more complex and expensive measures. Time required for consolidation and site preparation and the costs of the total operation are important aspects in the assessment of the overall feasability of the project. Costs of different methods of road preparation, available time frame, and requirements set for the development of the industrial estate may be used in the consideration of how to develop various parts and within these, different lots.

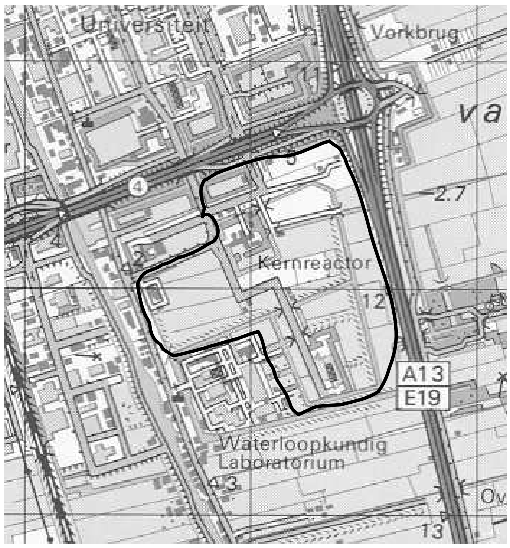

Figure 7. Sitemap 'Technopolis'

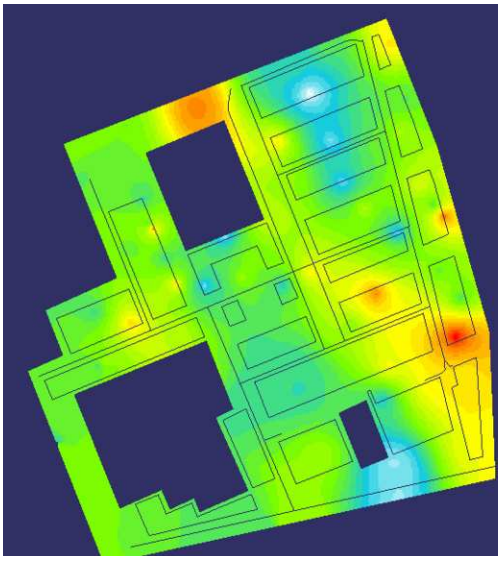

Figure 8. Final settlements calculated with MGeobase/Msettle

From geo-engineering perspective, important questions are how to calculate the range in possible outcomes of:

- remaining settlements from the moment construction of infrastructure and facilities has started
- quantities of sand required for different methods of site preparation.

Another issue is how to make use of measured settlements in terms of fine-tuning the predictions and/or adapting the site preparation schedule once site preparation has started. The overall sensitivity for settlements at 'Technopolis' was calculated by modelling a surcharge at every location of 2 m sandfill. The final settlements calculated with MGeobase/Msettle have been contoured (Fig.8). Shadings from light blue to dark red indicate increasing sensitivity. To compare four different methods of road preparation, remaining settlements after a certain point in time are calculated. If the remaining settlements are less than the required 0.1 m, areas are coloured white (Fig.9). For each of the methods, the settlements at the indicated point in time are compared with final settlements originating from a reference calculation. The remaining settlements are established by subtracting these final settlements from the calculated settlements for each method of road preparation. For site preparation, remaining settlements are allowed to be 0.4 m. More important for the preparation of sites it is to ensure enough stability for the access of building machinery on the site. A thickness of 0.7 m of sand is required to ensure this stability.

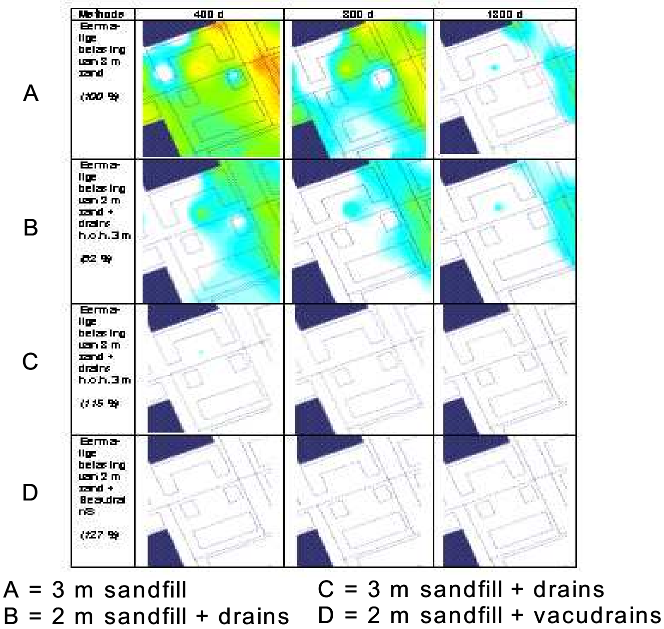

Figure 9. Comparison of four different methods of road preparation

Conclusions could be drawn with respect to the most proper planning in space and time of infrastructure and development of lots. Finally, road preparation with the use of drains in combination with 2 to 3 m of sand fill (depending on the required settlement) is considered to be the most viable option.

3.2 *'Technopolis' and data from other projects*

Cost savings can be realized by analyzing the site for locations that are most sensitive for settlement. These locations are to be incorporated carefully in the allocation of functions in the urban planning exercise. In the Municipality of Almere, this resulted in an alternative planning, saving an estimated 64 million Euro in the coming 50 years maintenance period of roads and sewerage systems.

Unfortunately, such a reshuffling was not possible at the 'Technopolis' area, so site and road preparation will take place at very peaty locations as well. Nevertheless, the difference with the original plans is that the area will not be sandfilled completely in one integral manner. Since most of the individual lots of the estate will be in use by buildings with a deep pile foundation, it is considered more important that building machinery can have 'stable' access to the lot than that the remaining settlements fulfill a certain requirement.

4 CONCLUSIONS

The three cases demonstrate that adequate risk management according to the GeoQ approach makes it possible to "tame" the dark and unknown subsoil.

The main benefit of the GeoQ approach is to create transparancy in subsoil risks to all parties involved. This allows for effective risk reduction or risk sharing between parties. Also opportunities for engineering optimisation ('value engineering') arise almost automatically, when the type and character of risks become clear via the GeoQ approach.

Allocation of risks and benefit sharing between parties involved may be a cost reducing following step (Staveren, M.Th. van, and Knoeff, J.G. (2003)). This proces will be highly supported by more availability and use of probabilistic approaches in geo-engineering, to allow for a proper quantification of risks and opportunities. Development and application of adequate software tools for this type of GeoQ risk management is a challenge for all of us acting in the global geotechnical community. This challenge will keep us busy in the next decennia.

REFERENCES

Clayton, C.R.I. (ed) (2001) Managing geotechnical risk: Improving productivity in UK building and consrruction. The Institute of Civil Engineers, London, 80 p.

Molendijk, W.O. and Aantjes, A.T. 2003. Risk management of earthworks using GeoQ Online. *Proceedings of Piarc congress*, Durban SA.

Staveren, M.Th. van, and Knoeff, J.G. (2003) The Geotechnical Baseline Report as Risk Allocation Tool, Proceedings of EurEngeo2004, Liège, Belgium

Staveren, M.th. van (2004) The subsoil – crisis or risk management? 2nd International Conference on Site Investigation, Porto, Portugal.