Geo Risk Scan – Getting grips on geotechnical risks

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ABSTRACT: Ground conditions appear a major source of cost overruns in infrastructure projects, which has been confirmed by recent Dutch research. As an answer to these cost and time overruns, ground related risk management has rapidly evolved in recent years. Deltares for instance developed the GeoQ-method. In the Netherlands, Rijkswaterstaat, the Centre for Public Works of the Dutch Ministry of Public Works and Water Management, is initiator and owner of all federal infrastructure projects. They asked Deltares to perform a Geo Risk Scan on five selected projects of the top 20 largest Dutch infrastructure projects. The Geo Risk Scan proved to be an effective tool for quickly providing information about the degree and the quality of ground related risk management in infrastructure projects. This paper describes the Geo Risk Scan, as well as its application within five projects. The evaluation of the five projects resulted in six main lessons which are further elaborated in 20 recommendations. These lessons may help project owners, engineers, and contractors to manage their construction projects.

1 INTRODUCTION

1.1 *Successful and unsuccessful projects*

What makes the difference between a successful and an unsuccessful construction project? A project that is completed well within budget, time, and its requirements, or not? It can not be its size and complexity, because there are successful and unsuccessful ones, amongst small and large, as well as simple and complex projects. It is also not its location, because every country seems to have its successful and problematic projects. It is even not because of ground conditions, as we all know examples of successful projects that have been completed in very difficult ground conditions. There must be another reason. Perhaps it is the way the management team of a project is able to manage the inherent presence of risk, during all phases of realizing the project.

1.2 *Risk Management as an answer to failure costs*

Several studies indicate that failure costs in the construction industry are typically 10 to 30 percent of the total construction costs (Avendano Castillo et al., 2008). This seems to be a worldwide phenomenon. There is also abundant evidence that unexpected and unfavourable ground conditions have a serious stake in these failure costs (Van Staveren, 2006). In the Netherlands, Rijkswaterstaat, the Centre for Public Works of the Dutch Ministry of Public Works and Water Management, is initiator and owner of all federal infrastructure projects. Therefore, Rijkswaterstaat decided to pay particular attention to the management of ground related risks within their projects.

1.3 *Ground related risk management*

The development and application of geotechnical risk management gets more attention in recent years. More and more, it is considered an effective and efficient way of work process for controlling all types of ground-related risk. For instance Deltares, formerly known as GeoDelft, developed the GeoQ-method (Van Staveren, 2006), that is already used in many construction projects with good results. The GeoQ approach is in fact an in-depth application of the RISMAN project risk management method. GeoQ focuses on controlling ground-related risks. The method is based on six generally accepted risk management steps:

1. Determination of project objectives and data collection;
2. Risk identification;
3. Risk classification and quantification;
4. Risk remediation;
5. Risk evaluation;
6. Transfer of risk information to the next project phase.

These risk management steps should be explicitly taken in all phases of a construction project. Ideally, the ground related risk management process starts in the feasibility phase and is continued during the (pre)design phase, the contracting phase, the construction phase and the operation and maintenance phase. Obviously for being effective and efficient, the ground related risk management should be aligned with more general project risk management approaches. Because of the similarity of risk management steps, this should be no problem.

The main differentiating feature of ground related risk management, when compared to generic project risk management, is its specific attention to geotechnical risk and its remediation. Therefore, ground related risk management uses conventional risk management approaches, such as qualitative risk assessments, as well as specific geotechnical approaches. The latter includes for example risk-driven site investigations and monitoring programmes.

2 SET UP OF A GEO RISK SCAN

2.1 *Introduction and objectives*

For gaining insight in the degree and quality of geotechnical risk management in projects, Rijkswaterstaat asked Deltares to perform a Geo Risk Scan on five selected projects out of the top 20 largest Dutch infrastructure projects. The main objectives were gaining insight in the type and characteristics of ground related risks, the possible consequences when these risks would occur, and the degree to which risk remediation measures were taken within the projects. Moreover, the results of the Geo Risk Scan would generate a quality judgement about the degree of geotechnical risk management.

In order to achieve these objectives the Geo Risk Scan aims to quickly scan both process and content of the ground related risk management within a project. The execution of a well-structured risk management process, by taking the presented six risk management steps, is considered as the main boundary condition for generating effective and efficient geotechnical risk management.

If necessary, recommendations to the project organisations are provided in order to improve the project performance and reducing the probability of ground related failure costs.

2.2 *Structure of a Geo Risk Scan*

The basis of the Geo Risk Scan is the GeoQ approach mentioned above. Using this approach the Geo Risk Scan was executed focussing furthermore on aspects such as:

- Deviation between process and content
- Within the context of a project, the scan is executed from a more generic analysis to more detailed analyses on specific points of interest for the projects scanned
- Any scan starts with a qualitative analysis; quantitative analyses are only performed when considered necessary, based on the qualitative analysis

The following four stages are identified regarding these basic assumptions. The first two stages in fact form the Geo Risk Scan; the latter two stages can be completed within a project, depending on the results of the first two stages.

1. Geo Quick Scan - qualitative process test;
2. Geo Check - qualitative content and product test;
3. Geo Risk Analysis - quantitative content analysis;
4. Implementation - Geo Risk Management as a routine work process

3 EXECUTION OF A GEO RISK SCAN

3.1 *Stage 1: Geo Quick Scan*

3.1.1 *Execution of a Geo Quick Scan*

In order to be able to perform this stage, first one has to gain insight in the project objectives and context. Therefore, an interview is planned with the project management team. It is important to have at least an interview with the technical project manager, who is normally responsible for the technical part of a project. For larger projects, it can be of good help to interview the risk manager (when present within the project), project leaders of specific elements of the project and the contract manager.

The interview is based on a standardized questionnaire and deals mainly with the GeoQ approach. Examples of questions are:

- Is the GeoQ approach recognizable in the scanned project?
- Have all six steps been *fully* elaborated in each project phase? Is everything done in order to get good results from the risk management steps?
- Have all six steps been *explicitly* elaborated in each project phase?

It is important to know whether a step is performed explicitly, following a plan or just as some sort of unaware coincidence. In general, when a step is only performed implicitly, it is not guaranteed that in next project phases or in other projects the same risk driven project management is applied. This could cause negative consequences. Further insight is gained by asking for the products available from these steps and the knowledge and tools that have been used in the project to assist in the elaboration of the steps.

3.1.2 *Results of Geo Quick Scan*

Elaboration of the interview and studying of the gathered information make it possible to evaluate the Geo Quick Scan. Scores are based on table 1 (made for each project phase) and the accompanying legend. Moreover, the application of the six main lessons learned (next chapter in this paper) is checked. Besides this score, recommendations are provided for improvement of the ground related risk management process.

Table 1: Scoring the Geo Quick Scan

Step in GeoQ-approach	**Degree of explicit execution**	**Degree of complete execution**
1. Setting objectives and data collection		
2. Risk identification		
3. Risk classification and quantification		
4. Risk remediation		
5. Risk evaluation		
6. Transfer of risk information		

1 point: step isn't executed
2 points: implicitly, but not fully elaborated
3 points: explicitly, but not fully elaborated
4 points: implicitly, and fully elaborated
5 points: explicitly, and fully elaborated

The total amount of points from table 1 gives the judgement and a 'report mark':

– < 20 very insufficient 4
– 20 – 22 insufficient 5
– 22 – 24 moderate 6
– 24 – 26 sufficient 7
– 26 – 28 good 8
– > 28 excellent 9

3.2 *Stage 2: Geo Check*

3.2.1 *Execution of a Geo Check*

The work in the Geo Check phase is focussing on the points of attention resulting from the Geo Quick Scan. The Geo Check deals particularly with the content or quality of the projects ground related risk management. Analyses and calculations from the project are checked qualitatively by making use of experienced geotechnical engineers. New calculations are not performed in this stage. The primary focus is checking the work already performed by the project organisation. For example, the following questions should be answered during the Geo Check:

– Are correct starting points chosen in relation with boundary conditions of the project?
– Are all relevant ground related risks identified?
– Are calculations been performed for the relevant identified risks?
– Are appropriate models and techniques applied?
– Are results of the performed analyses according to expectations?

3.2.2 *Checklists*

Despite the experience of geotechnical experts, it is of major importance to assure all foreseeable risks are indeed identified. Therefore, using standardized checklists is very useful. These checklist have been developed for building pits, roads and dikes for quickly gaining insight in the completeness of the identified ground related risks. These checklists proved to be of good assistance in all performed Geo Risk Scans.

All risks in the checklists are classified as geotechnical risks, geohydrological risks, geo-ecological risks, risks related to objects or obstacles in the ground, risks related to contract requirements or construction risks. All risks are described in terms of causes and consequences. The consequences are by definition unwanted events.

By using this structure of the checklists, it is possible to use them on different scales. If the project is still in the feasibility phase, risk identification can be done only on the scale of unwanted events. When more detail is required, one can work from causes to sub causes and estimate the risks accordingly.

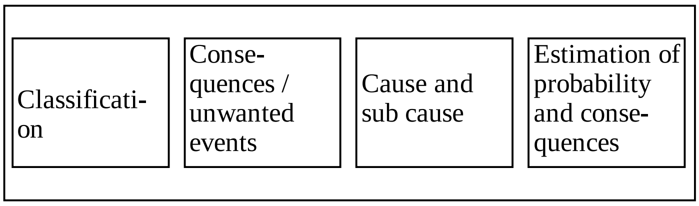

Figure 1: Structure of checklists

3.2.3 *Results of Geo Check*

When a Geo Check is performed, the project organisation gaines insight in the following questions:

– Are unacceptable ground related risks present in the project?
– Have already risk remediation measures been identified for these risks? (based on expert judgement during the Geo Check)
– Which unacceptable risks are still present?

Answers on these questions are described as recommendations for improving the in-depth quality of ground related risk management. Besides these recommendations a risk table (table 1) is presented. Such risk tables proved to be a more practical way of displaying the project risks than conventional risk graphs (figure 2), without loosing insight. Finally, the Geo Check is evaluated by giving a 'report mark' on a scale of 1 to 10, based on expert judgement.

Table 1: Risk table

Unwanted event	Probability	Consequence	Risk	Risk after implementation of measures recommended in scan

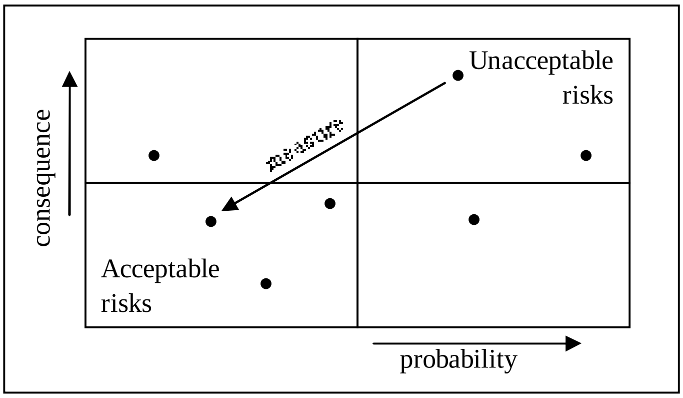

Figure 2: Risk graph

3.3 *Results of Geo Risk Scan*

After execution of the Geo Quick Scan (process) and the Geo Check (content) a total overview of the degree of a projects ground related risk management is available. Rijkswaterstaat asked for a project portfolio of all scanned projects in order to be able to compare the results of the different project scans. Figure 3 shows the matrix which made this possible. Each scanned project can be placed in the matrix.

Content is evaluated as of more importance than process. After all, when the results of a project are good, the project objectives will not be affected. Therefore, projects with bad scores for the Geo Quick Scan still can get a good or moderate overall score. Nevertheless, these projects should keep focus on improving the process of ground related risk management. Maybe, it was only a coincidence that the content part of ground related risk management of the project had good results!

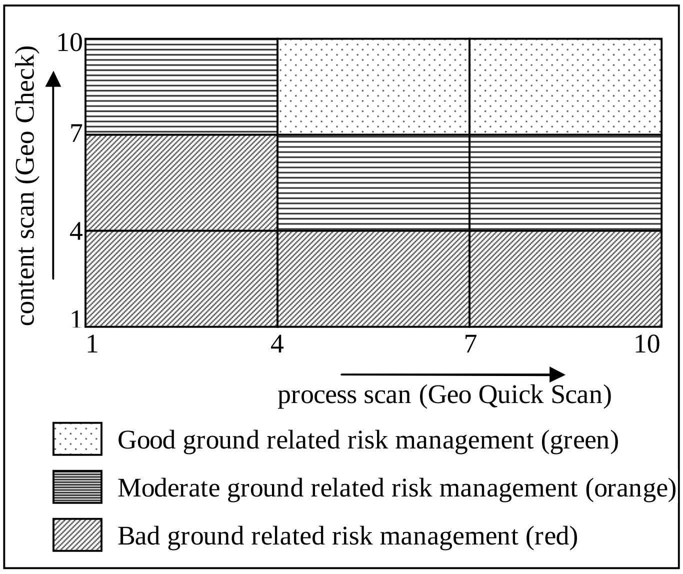

Figure 3: Quality matrix and project portfolio

3.4 *Stage 3: Geo Risk Analysis*

The aim of the Geo Risk Analysis stage is to improve projects ground related risk management, either with focus on process, or with focus on content by performing extensive and if necessary quantitative analyses. Executing the Geo Risk stage, a project in the bottom left corner of the quality matrix in figure 3 should move to the upper right corner of the matrix by executing the Geo Risk stage.

Analyses are executed on unacceptable risks as identified in the Geo Check and recommendations of both Geo Quick Scan and Geo Check are elaborated. If necessary, advanced risk management tools can be used, as well as geotechnical calculations. Examples are the use of an Electronic Board Room for brainstorm/expert sessions, contractual risk allocation by the Geotechnical Baseline Report, model experiments, field monitoring, and so on. This makes it possible to analyse and quantify any remaining unacceptable risks in order to select and execute proper measures. The project team itself can execute work during the Geo Risk Analysis stage.

At the end of the Geo Risk Analysis stage, the optimal risk assessment strategy can be chosen. Possibilities are avoiding the risk, reducing risk probability and or consequence, and risk transfer to a third party.

3.5 *Stage 4: Implementation*

All information gathered and recommendations from the previous stages will not improve the projects work, unless it is implemented in the projects work. Therefore, the implementation can be seen as the most important stage! Implementation has to be done by the project team itself. This stage is beyond the scope of this paper and for instance elaborated in Van Staveren (2009).

4 LESSONS LEARNED

The evaluation of the five scanned projects resulted in six main lessons which are further elaborated in 20 recommendations. All lessons are described in this chapter of the paper. The lessons are subdivided in two main types.

The first set of lessons may help to improve the application of well-structured ground related risk management during projects. These lessons are interesting for owners who are responsible for the geotechnical conditions in their projects, as well as for contractors or engineers who have to manage ground conditions towards successful project results. These lessons are referred to as lessons dealing with content (C).

The second set of lessons teaches how the coordination and delegation of managing geotechnical risk by owners can be improved. These lessons seem particularly relevant for owners who use innovative design and build type of contracts and are referred to as lessons dealing with process (P).

4.1 *Lesson 1 - clear risk management positioning*

Lesson 1 concerns the positioning of ground related risk management within the project.

4.1.1 *Ground related risk management should be an integral part of project risk management, but with explicit status (P)*

In all of the five scanned projects, ground related risks were an integral part of the total risk management. From a project management point of view, this seems a good strategy, because more aspects than only ground related risks are of importance for a project. From a geotechnical specialist point of view, this gives the opportunity to give ground related risks the proper attention.

However, ground related risks need special attention, having specialists dealing with them and executing specific remediation measures. Most remarkable is that ground related risks have mainly consequences during the construction and maintenance of the project. Consequently, these risks are often not given the attention they need, or thought about as solvable, during the design phase. In each specific project it is recommended that in early stages geotechnical experts determine whether or not this may result in unacceptable risks later on in the project.

Therefore, ground related risks need an explicit status in the total risk management. In two of the five scanned projects this approach was used with good results.

4.1.2 *All specific ground related risks should be part of a project's risk register (P&C)*

All ground-related risks should not only have an explicit status, they should also be part of the project risk register. Often, only imprecise ground-related risks are part of the project risk register. For example, phrases like "soil investigation is insufficient for making a good design". Such fuzzy descriptions make explicit risk management difficult and probably even impossible. It is unclear which measures have to be taken and what the anticipated effects are.
Therefore, it is recommended that the ground-related risk register is part of the overall project risk register.

4.2 *Lesson 2 - clear risk management responsibility*

Lesson 2 highlights the importance that any identified ground related risk needs one or more owners. Otherwise the risk will not get the required attention for adequate remediation.

4.2.1 *Appoint a coordinator who is responsible for ground related risk management (P)*

Scanning the five projects showed the importance of somebody in the project acting as a coordinator of all ground related issues. The quality of the project largely improved by such a coordinator. It is not necessary that this person also is responsible for the ground related risks themselves. The technical manager of a big infrastructural project is usually too busy to give ground related risks the proper attention. The mentioned coordinator should assist the technical manager.

4.2.2 *All ground related risk should be allocated contractually to one or more of the parties within a project (P)*

Because of the inherent ground related uncertainty it is very important to contractually arrange the responsibilities for unwanted events caused by differing soil conditions. At least, it is important to think about the consequences, when ignoring risks caused by the uncertainty accompanying the soil.

One could simply divide all risks to one or the other party, but often partial risk allocation is preferred. For instance the principles and practices of the geotechnical baseline report (GBR) are recommended (Essex, 2007). The main principle is to allocate any risk to the party involved that is best able to manage the risk. Sometimes sharing a risk is preferred, as both parties are (un)able the manage the risk by their own.

4.2.3 *Ground related risks, completely allocated to the contractor, needs still evaluation by the client (C)*

In integrated contracts, many risks are transferred from the client to the contractor. However, the client still bears consequences when the risks occur. This is especially the case for immaterial consequences, like loss of reputation, safety or political risks. The project management team can use monitoring and other quality checks in order to keep control over these risks. These checks should not only be process checks, but should also include in depth analyses of content.

4.3 *Lesson 3 - clear risk communication*

Lesson 3 stresses the importance of transparent risk communication between all parties involved in the project, as early in the project as feasible.

4.3.1 *Link explicitly the functional and technical level of project organisation to each other (C&P)*

All five scanned projects used integrated contracts, where the contractor also had to do the design or even finance and maintenance. This implies that the project organisation has to pay much attention to the functional description of project specifications. By this way, all identified risks need to be transformed to the contractor.

During scanning of the five projects two handicaps were shown:

– (Geo)Technical experts have difficulties in translating their recommendations to this functional level.
– On the other hand, project managers have difficulties in translating the technical requirements of the experts to functional requirements.

Only one of the five projects excelled in this link between project management and ground related technical experts. This precious link was formed by one person who could 'speak both languages'. This is recommended for every project.

4.3.2 *The risk file of a client should be known by the contractor and vice versa (P)*

Every project organisation of the five scanned projects had a dilemma about sharing their risk file with the contractor. Many different concepts of sharing this information (or not) were encountered.

One might think it is desirable to show the contractor all identified (ground-related) risks and vice versa. By doing so, project organisations however feel like attracting responsibility to themselves, because the information given to the contractor can contain misconceptions. Though, this last option is not esteemed to be correct. Risks are only transferred as points of attentions and can not be wrong. Another rationale is that with innovative design and build type of contracts, one might be pushing the contractor in some direction, when exchanging risk information. After all, the intention of an integrated project is to use the knowledge and experience of the contractor for the design and the client should not give implicit directions to a design.

Balancing between these both ways, from point of view of a professional client, it is recommended to always exchange risk information between parties; at least after the tender phase.

4.3.3 *Tests should be applied on feasibility of requirements with a geotechnical scope (C)*

Requirements with a direct relation to (geo) technical aspects can be stricter than the maximum accuracy of predictions in the design and construction phase. For example, settlement requirements for roads are often more stringent than can possible be designed and constructed within reason using 'state-of-the-art' techniques and models. Negative consequences are over dimensioning or relatively big efforts for maintenance. It is therefore recommended to verify the feasibility of those types of requirements.

4.4 *Lesson 4 - a ground related risk register*

Lesson 4 underlines the importance of a correct, complete and up-to-date ground related risk register and gives recommendations for realization.

4.4.1 *Description of a risk needs to satisfy basic demands (C&P)*

This is a general recommendation that is applicable on all types of risks; also ground related risks. It is important to describe a risk in the risk file with at least the following aspects:

– Cause (in words) of the risk
– Consequence (in words) of the risk
– Determination of probability of the risk
– Determination of amount of consequences of the risk (failure costs, quality loss, delays, loss of image & public confidence, etc.)
– Possible remediation measures
– Owner of the risk
– Responsibility for the risk

4.4.2 *All GeoQ steps should be explicitly executed step by step during each project phase (P)*

Following the six risk management steps will lead to good risk control of a project and hence a correct and complete risks register. This is generally accepted. Therefore, a crucial aspect in all Geo Risk Scans was the examination of the way these steps were followed in the scanned projects. However, looking back at project activities it always seemed possible to divide them to the six risk management steps. One needs to keep in mind that real risk management is only possible when these steps are taken with an explicit plan.

Risk management steps are performed with a cyclic approach. Consequently the steps are not always performed in succeeding order. For example gathering of extra information (executing extra soil investigation) is part of step 1, but can be done as a measure identified in step 4. Therefore, when risk management steps are not performed in succeeding order, there needs to be an induced explanation by the risk management process itself (see previous example).

4.4.3 *A ground related risk session should be organized in early project phases (P)*

In early stages of a project little investments are made and steering possibilities are still high. This underlines the importance of risk sessions in the early project phases. However, technical risk sessions are often ignored during the first project stages because project management conceives technical risks as solvable in later project stages. As a consequence of this assumption optimal technical solutions might be overlooked in the early stage of the project. This will require much more effort in later project stages. Therefore also technical risk sessions should be planned in the early stages.

One of the scanned projects proved this to be true. From an early risk session one major construction risk was identified. Extra soil investigation was executed and the risk got special attention during the tender phase in which the contractor had to make a plan to show how this specific risk was managed.

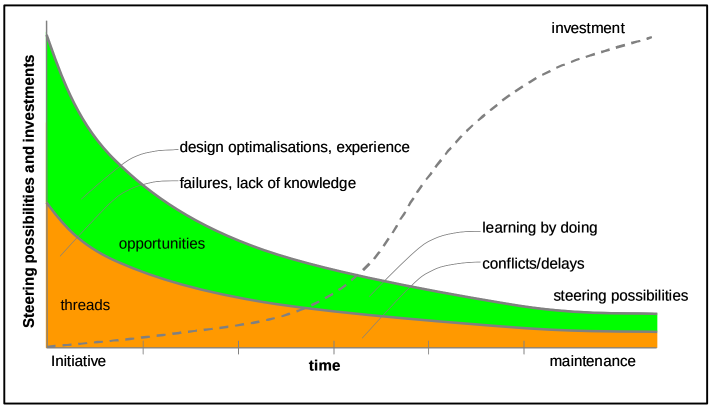

Figure 4: Need of early risk sessions

4.4.4 *Communication should be explicitly risk based between project and third parties (P)*

A project organisation can call in the help of third parties (e.g. for soil investigation, monitoring, technical advice, etc.). Third parties are often called in to manage (implicitly or explicitly) identified risks. It is important to communicate these risks as an instruction. This ensures that the right analyses are executed by third parties.

The other way around it is also important for the project management to ask the third parties to report identified risks to them. This ensures a more completed risk file of the project and no important information gets lost.

4.4.5 *Explicit guarantee on completeness and correctness of ground related risks and analyses is necessary (P)*

Experts are of major importance in soil related risk management. Caused by the uncertainty of geotechnique, almost always different interpretations of the same risk can be expected. Guarantee on completeness and correctness of ground related risks therefore is important. One can think of big risk sessions with many experts, colleague checks, second opinions and use of checklists in order to guarantee this.

4.4.6 *Checklists are recommended as a check on the completeness of risk files (C)*

Accompanying the previous point checklists have proven to be of good help in order to check the completeness of risk files. In paragraph 2.4.2 is shown how a good checklist can be implemented and used.

4.5 *Lesson 5 - risk driven site investigations*

4.5.1 *Site investigation should be explicitly risk based (C)*

From a good (ground related) implemented risk management process, in situ ground investigation and supporting laboratory research can be identified as a good measure. After all, Performing in situ soil and lab research will gain insight in specific risks.

The risk management that let to the performing of the in situ soil and lab investigation should be extended in the plan for the investigation itself. Six basic steps can be used (Staveren, 2006) in order to be sure that the correct information is gathered. In short:

1. Determine ground related constructions;
2. Determine main mechanisms that affect the fit-for-purpose;
3. Determine the risks if the identified mechanisms act adversely;
4. Determine the design techniques for the identified measurements;
5. Determine the most critical ground parameters;
6. Determine the in situ soil and lab investigation considering the ground parameters and the geological heterogeneity.

4.5.2 *In situ soil and lab research should be flexible executed (C)*

By using a flexible approach of site investigation it is possible to adjust to the obtained results during execution. On the one hand more detailed research can be executed if more heterogeneity is encountered as expected. On the other hand the research can be done more broad if there is no reason for more detail.

4.5.3 *Quality control of site investigations is necessary (C)*

Lab and in situ soil research are used in calculations in order to make analyses. It is therefore of great importance that the parameters derived from lab and in situ soil research are reliable. There can also be contractual consequences when soil investigation results were send to the contractor but are proven to be wrong.

Question marks were stated in three out of the five scanned projects regarding the quality of the in situ soil and lab research. Especially with specialized experiments one should critically apply quality control. A geotechnical specialist should be able to perform these checks.

4.6 *Lesson 6 - risk driven field monitoring*

4.6.1 *Monitoring should be used as a tool for guarantee of quality and control of risks (C)*

Field monitoring is an excellent tool for controlling ground-related risks during the construction and operation phases of projects. Obviously, these programmes need to be defined according to the risk profile of the project. With integrated contracts, often monitoring is coordinated by the contractor. However, the client should always check the results of the applied monitoring for the key-risks of the project. Monitoring should not only be checked according to the process, but regular in-depth analyses of content should also be applied.

4.6.2 *Ground related risks should have an explicit place in a monitoring plan (C)*

Monitoring can be broader than only measuring for controlling ground related risks. However, ground related risks should have an explicit place in a monitoring plan in order to make sure the measurements make sense for the ground related risks to be monitored.

5 CONCLUSIONS

Unexpected ground conditions appear a major source of cost and time overruns in infrastructure projects, which is confirmed by recent Dutch research. The presented Geo Risk Scan proved to be an effective tool for quickly providing information about the degree and the quality of ground-related risk management in infrastructure projects. Six main lessons and supporting recommendations are derived from using the Geo Risk Scan in five major Dutch projects. The main lessons are:

1. Clear risk management positioning
2. Clear risk management responsibility
3. Clear risk communication
4. A ground related risk register
5. Risk driven site investigations
6. Risk driven field monitoring

These lessons seem to be generically applicable in construction projects. Ongoing application of these lessons in Dutch projects proves this conclusion.

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