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Educating Geotechnical Risk Management

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ABSTRACT: Education is of paramount importance. It allows the next generation of geotechnical professionals to answer the increasing demands of construction projects. These are caused by growing pressures on costs and time, and easily affect safety and quality. One of the answers to these challenges is the well-structured application of geotechnical risk management in all phases of construction projects.

For this reason, the Civil Engineering and Applied Earth Sciences Faculty of the Delft University of Technology, The Netherlands, decided to develop the MSc course Geo Risk Management. This course is part of the core curriculum and any student doing a MSc in Geotechnical Engineering has to take it. In total, the course contains 12 blocks of lectures, with each block including two hours.

Geo Risk Management aims to teach the student how to apply structured management of ground-related risk during the entire process of any construction project. The tried and tested GeoQ approach for ground-related risk management serves as a framework for the course. This paper's authors jointly developed the course, based on their extensive professional practices in The Netherlands and abroad. They lecture the course as well, for the first time in February and March of 2007.

The main objective of this paper is to inspire professionals in academia and the industry to develop and attend similar courses elsewhere. These may be undergraduate MSc courses, postgraduate courses or summer courses. The latter two types may become particularly useful to geotechnical practitioners.

The Geo Risk Management course is subdivided in two main parts. Part one concerns the theoretical part of geotechnical risk management. It explains the concepts of uncertainty, risk and risk management. Due attention is given to the often under-estimated human factor in geotechnical risk management. The key-roles of individual professionals and their teams, within the entire risk management process of construction projects, are highlighted. Six generic project phases and six generic risk management steps are presented. Also, an abundant number of existing tools that facilitate the risk management process are introduced.

Part two covers a number of specific topics, merely based on certain types of geotechnical constructions. Examples are underground constructions, such as tunnels, water retaining structures, and infrastructure such as roads and railroads. The focus of part two is on how to apply geotechnical risk management in our day-to-day practices. Cases demonstrate the pitfalls and the opportunities of ground-related risk management.

In summary, this paper presents the main structure and content of the new Geo Risk Management lectures of the Delft University of Technology. Also feedback of the students, as gained during running the course for the first time, will be shared with the readers. Such feedback may help us during the further development of geotechnical risk management in general and its education in particular. The paper ends with a number of conclusions about this rather yet unexplored adventure of teaching risk management, rather than the more conventional risk analysis, to MSc students in Geotechnical Engineering.

1 INTRODUCTION

Today's global construction industry is facing a serious rise in complexity. This situation is caused by an ever increasing demand on qualities, functions, safety, sustainability, as well as tight cost and planning control in all sorts of construction projects. Furthermore, changing interests and perceptions of the many stakeholders of construction projects do not only create even more complexity. These dynamics increase also the already abundantly available uncertainties in most construction projects, ranging from market and thus cost and profit fluctuations to rather unexplored subsoil conditions. Such uncertainties occur during the entire process of realisation of any construction project, from the earliest feasibility studies towards operation and maintenance of the realised project.

Ground conditions are widely acknowledged as one of the main uncertainties or risk factors in most construction projects. Actual ground conditions and consequential behavior are inherently difficult to predict, as these can and will only reveal during the construction and operation phases. However, in those stages, any remediation measures to cope with differing ground conditions are often expensive and time consuming, if possible at all. As for instance mentioned by Fookes et al (2000), numerous case histories over the last century show that failure to anticipate ground conditions is a main factor in construction problems.

Probably quite remarkable for engineers, causes of failure in many projects are not of technical origin. For instance, a recent study of Bea (2006) highlights the dominant role of the people factor in geotechnical engineering and construction failures. His findings are based on more than 600 well-documented cases of failing civil engineering projects during almost 20 years. In some 80 % of the cases failure has been caused by non-technical factors, such as human, organizational and knowledge uncertainties. These results align with similar findings by Sowers (1993). His study of more than 500 well documented foundation failures showed that 88 % of them were caused by human shortcomings. The remaining 12 % was caused by a lack of technology. It appears that effective construction project management is as least as important as effective construction technology. In other words, severe blending of technical and managerial subjects will be required for realizing successful projects that effectively deal with the presented challenges. We seem therefore desperately in need of a new engineering education approach, at least when it comes to geotechnical engineering and construction. This paper presents an example for such an new engineering education approach by describing both the theoretical and the practical part of the Geo Risk Management lectures.

2 EDUCATION AND GEO RISK MANAGEMENT

2.1 The need for risk management education

In many parts of the world there are already promising responses to today's demanding construction industries. In Europe, national changes initiatives have been initiated to strengthen the construction industry over the last years in countries such as the UK, Denmark, Finland, Norway and The Netherlands. Outside Europe similar initiatives are running in for instance Australia, Hong Kong, and Singapore.

One of the answers to today's and tomorrows challenges is the well-structured application of risk management in general and geotechnical risk management in particular. For becoming really effective, risk management should be embedded and consistently applied in all phases of a construction project. Within the construction industry, and its education as well, attention to continuous risk management, rather than a few moments of risk analysis still rather new. Starting this education is of paramount importance. Practising professionals, but in particular students, should become educated in trained in the basic risk management principles and practices. Only then the next generation of engineering and construction professionals will be able to properly answer the ever increasing demands of construction.

2.2 A New MSc course – Geo Risk Management

In September 2006, the faculty of Civil Engineering and Applied Earth Sciences of the Delft University of Technology started their brand new MSc in GeoEngineering. It covers the main aspects of geotechnical engineering, as taught at many technical universities. At present, the GeoEngineering section includes five chairs: Soil Mechanics, Groundwater Mechanics, Foundation Engineering, Underground Space Technology, and Engineering Geology. The Geo Risk Management course is part of the core curriculum of the MSc in GeoEngineering, which means that any student aiming to complete a MSc in Geo Engineering has to follow it.

The authors of this paper developed and lecture the Geo Risk Management course. The first author took the first rather theoretical part and his co-creator was responsible for the second and more practical part of the lectures. Additionally, prof. Johan Bosch of the Delft University of Technology and dr. Gerard van Meurs of GeoDelft, provided a guest lecture each. The Geo Risk Management lectures were for the first time provided in February and March of 2007.

2.3 Aim of the Geo Risk Management course

Geo Risk Management aims to teach the student in particular why and how to apply structured management of ground-related risk during the entire process of any construction project. After following the course, any student should be aware of the inherent risk of ground within civil engineering and construction, including the impact and difficulties of the people factor. Furthermore, the student should be able to apply principles of ground-related risk management during the entire project management process for a variety of civil engineering constructions.

Such course objectives align and support the recommendations for developing the academic education for the construction industry towards more generic expertise. For instance, the Dutch construction industry steering committee, the Regieraad Bouw, advocates to educate all-round civil engineers, who should gain also knowledge of less in-depth but critical subjects like project management (Regieraad Bouw en PSIBouw, 2006). Without doubt, risk management competencies, including awareness of the inherent complexity of the people factors, fits well within these recommendations.

2.4 Two parts – theory serves practice

The Geo Risk Management course is subdivided in two main parts. Part one concerns the theoretical part of geotechnical risk management. It explains the concepts of uncertainty, risk and risk management. The tried and tested GeoQ approach for ground-related risk management in construction projects serves as framework (van Staveren 2006). The GeoQ risk management framework involves six generic project phases and six generic risk management steps. Abundant tools for facilitating the risk management processes are ready available. Due attention is given to the often under-estimated people factor in geotechnical risk management. The key-roles of individual professionals and their teams in all project phases are highlighted.

Part two covers a number of specific topics, merely based on certain types of geotechnical constructions. Examples are underground constructions, such as tunnels, water retaining structures, and infrastructure such as roads and railroads. The focus of part two is on how to apply geotechnical risk management in our day-to-day practices. A lot of examples and cases demonstrate the pitfalls and the opportunities of ground-related risk management. In total, the course contains 12 blocks of lectures, with each block including two hours.

2.5 The remaining part of this paper

The content of the Geo Risk Management course seems worldwide quite new. Real equivalents have not yet been identified by its developers. Therefore, the lectures of part one and part two will be introduced in the remaining part of this paper. There is a focus on part one, the more theoretical part, because it proved to be the most deviating from the other courses of the MSc GeoEngineering at the Delft University of Technology. Van Staveren (2006) gives more detailed information about many of the aspects covered by the lectures and served as the lecture's reference book.

Feedback of the students, as gained during the course, is also shared with the readers. Such feedback may help us with (further) developing geotechnical risk management in general and its education and training in particular. The paper ends with a few conclusions.

3 GEO RISK MANAGEMENT-THEORY

3.1 Lecture 1 – Introduction

This first lecture aims to provide an overview of the new course on geotechnical risk management. After presenting the lecturers and the structure of the course, the first hour gives an introduction to the challenges and opportunities in the global construction industry. Major challenges presented are increasing complexity, the often still underdeveloped integrity and high failure costs, in which unexpected ground conditions have a serious stake. The many ongoing change initiatives world-wide provide interesting opportunities for the global construction industry, together with the adoption of rather new concepts, such as systems thinking and risk management.

The second hour serves as some kind of appetizer for the lectures to follow. It presents a variety of problems in a variety of projects world-wide, with one common element: the unexpected behavior of ground. There is one main message: ground is a (very) complicated foundation and construction material. Its inherent uncertainties and associated risks will never become completely eliminated. Therefore, we have to deal with these ground risks, which serves as the rationale and motivation for the remaining lectures.

3.2 Lecture 2 – From uncertainty via risk to geo risk management

Lecture 2 starts with presenting and discussing a number of relevant concepts: uncertainty, risk, risk management, ground, and finally ground risk management. For instance, as set out by Blockley and Godfrey (2000), we should acknowledge three types of ground uncertainty: randomness, fuzziness and incompleteness. These terms are explained and related to the ground sampling and ground engineering practices. With regard to risk, three main different types of risk are introduced and explained. Having the ability to distinguish between these risk sets of pure and speculative risk, foreseen and unforeseen risk, and information and interpretation risk, will help any ground-related engineer a great deal with effectively managing these risks during the entire construction process. Figure 1 present the relationship between the presented types of uncertainties and speculative and pure risks.

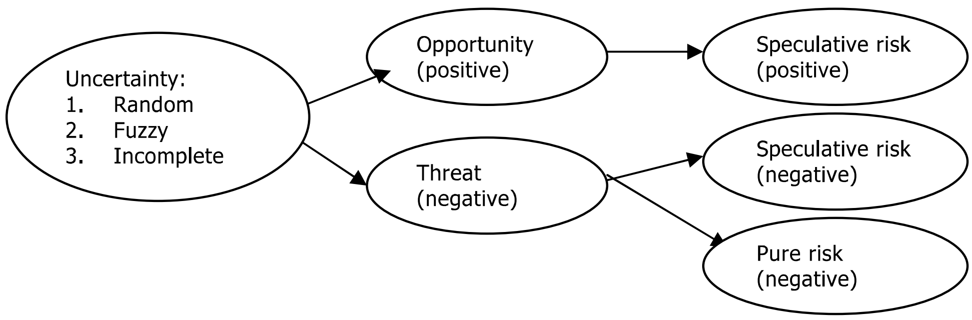

Fig.1 A simple relationship between uncertainty, pure risk, and speculative risk (Van Staveren, 2006).

Regarding to risk management, two of the main schools of risk management are explained: the scientific school and the heuristic or rule of thumb school of risk management. The latter has a more qualitative approach than the first one. Heuristic or rule of thumb risk management involves acknowledgement of experiences, engineering judgement and a certain degree of subjectivity. The size of this paper does not allow to further explain and discuss such terminology. For instance, Van Staveren (2006) gives more detailed information.

Within the lecture, ground conditions are considered as including not only ground itself, but also ground water, any type of possible pollution, and man-made structures. Examples of the latter type are old foundation piles or buried pipelines. Combining these concepts brings us to four main types of ground-related risk: geotechnical risks, geohydrological risks, geo-environmental risks and man-made obstruction risks. Consequently, ground risk management or geo risk management is defined as the overall application of policies, processes and practices dealing with ground-related risk. By the end of the first hour, the students should be able to define their own ground-related risks by clearly mentioning and distinguishing between the risk event, the risk cause, the probability of risk occurrence (quantitatively or qualitatively), and the expected risk effect.

The second lecture hour presents the so-called GeoQ concept. With the Q of quality, GeoQ is a risk-driven approach to manage ground conditions and behaviour in a structured way for successfully completing any civil engineering project, during all project phases and for all stakeholders involved. GeoQ presents a flexible framework with six generic project phases and six generic risk management steps. Each of these steps should be taken in every distinct project phase. This GeoQ approach has been initiated by the Dutch National Institute for Geo-Engineering GeoDelft in 2000. It has been further developed in practice since, with many different parties, by its application in a number of phases of a variety of civil engineering projects. GeoQ matches easily with existing risk management approaches, such as MARIUN in the UK and RISMAN in The Netherlands. Finally, this lecture positions ground risk management in the landscape with ground engineering, natural hazard management, project management, quality management, and knowledge management.

3.3 Lecture 3 – The human factor in ground risk management

Giving detailed attention to the human factor in lectures on geotechnical risk management at a civil engineering department seems a rather innovative approach. The need for it has already become clear by the research of Bea (2006) and Sowers (1993), as mentioned earlier in this paper. For those readers not yet convinced, there is a citation of Brandl (2004):

"There are no insurmountable weak soils or rock, there are only weak engineers".

This possible weakness of these engineers starts if there is no awareness of the role of the people factor in engineering in general and ground risk management in particular. Therefore, the concept of the individual professional, his or her inherent differences in risk perceptions, and how these may contribute to geotechnical risk management are explained during the first lecture hour. Some exercises with the students demonstrate how sound facts easily result into totally different interpretations. Table 1 is retrieved from Van Staveren (2006) and based on work performed by Clayton (2001), Kort (2002), and Koelewijn (2002). This table illustrates the effects of these differing engineering opinions in geotechnical analyses, which results in wide margins of calculated results.

Table 1. Margins within geotechnical engineering (Van Staveren, 2006).

Geotechnical analysis	Calculated		Measured
	Minimum	Maximum	
Pile bearing capacity (Clayton, 2001)	1000 kN	5400 kN	2850 kN
Horizontal sheet pile deformation (Kort, 2002)	50 mm	500 mm	100 mm
Slope stability safety factor (Koelewijn, 2002)	0.36	1.65	-

As we are not able anymore to work on our own in today's demanding engineering and construction practices, the second lecture hour focuses on teams. The concept of the team is introduced, with special attention to a variety of aspects. Examples are the differences between groups and teams, the hurdles to overcome before real team performance, the role of culture and risk communication in teams, the danger of groupthink, and so on. Within the construction management process three types of team are in particular important: expert teams, multi-disciplinary teams and teams as change agents. The latter are for instance required for implementing risk management practices in project organizations. At the end of this lecture some words are dedicated to those parties we are performing for: public and private clients, as well as our societies.

3.4 Lecture 4 – The GeoQ ground risk management process

This lecture connects thinking about the GeoQ concept of the lectures before with actual doing by applying the GeoQ process in the remaining lectures. The six generic GeoQ steps of gathering project information, identifying risks, classifying risks, remediating risks, evaluating risks and finally mobilizing all relevant risk information to the next project phase are introduced and discussed. These steps are presented in Figure 2.

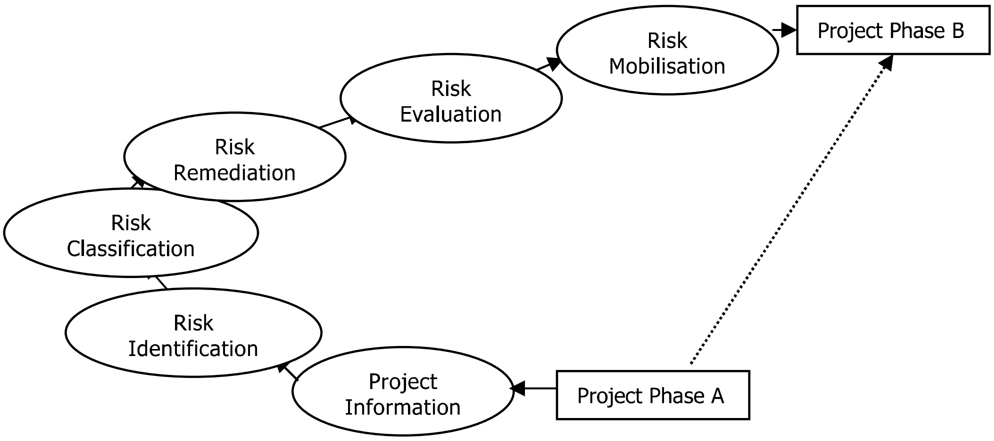

Fig.2 Six cyclic GeoQ steps from project phase A to project phase B (Van Staveren 2006).

For each step a lot of tools are available and many of them are briefly introduced in this lecture. Here the students recognize some risk analysis tools from other MSc lectures as well, such as Fault Tree Analysis (FTA) and Failure Mode Effect and Criticality Analysis (FMECA). Now they become also aware of the very fundamental difference between risk analysis and risk management. The first is basically just a tool, however a very important one, in the entire risk management process that ideally continues from the early beginning to the end of the project's lifetime.

While the six GeoQ risk management steps are fixed, they should be applied one by one in a structured way, the six GeQ risk management phases are much more flexible. These phases are topic of the second lecture hour and they include the feasibility phase, the pre-design phase, the design phase, the contracting phase, the construction phase and the operation and maintenance phase. The position of the contracting phase depends on the type of construction contract. Contracting will occur just before construction in case of conventional contracts. For design and construct type of contracts, the contracting phase is before the design phase or even before the pre-design phase. For very large or rather small projects the number of project phases can be extended or combined. This does not effect the GeoQ process, as long as the six steps are strictly performed in each project phase.

3.5 Lecture 5 – Six projects phases and some ground risk management tools

Lecture 5 is the last rather theoretical lecture on ground-related risk management. This lecture explores a number of tools in more detail for five of the six distinguished project phases. Examples are site classification and scenario analysis in the feasibility phase, team-based risk identification and classification in the pre-design phase, and risk-driven site investigations in the design phase.

Many tools have their proven benefits well beyond ground-related risk management. An example is team-based risk identification and classification, by support of information and communication technology. Figure 3 shows a typical setting, in which a team of professionals, either mono-disciplinary or multi-disciplinary, participate a risk management session in a so-called electronic board room (EBR). The laptop computers and easy to use risk management software allows them to brainstorm anonymously on risk identification and classification. These individual professionals can build forward on the results of their team members, while unfavorable team effects are limited because their any input remains unidentified by team members.

Fig.3 A typical setting of an EBR-facilitated and team-based risk session. (© with permission of GeoDelft)

In the GeoQ phases of contracting and construction risk management, risk management tools such as contractual allocation of the risk of differing ground conditions by the Geotechnical Baseline Report (GBR), as well as the observational method, supported by online monitoring, are presented and discussed. Also for the operation and maintenance phase appropriate tools for ground-related risk management are ready available. Again, reference is made to Van Staveren (2006), because the two lecture hours of block 5 proved to be too short to discuss these tools as well.

4 GEO RISK MANAGEMENT-PRACTICE

4.1. Lecture 6 – Ground risk management and ground properties

This lecture gives some insight of primary and secondary ground related uncertainties. The first type has to do with the ground layers, classification and significant surprises. The second type of uncertainty has to do with uncertainties in ground parameters (thickness of layers, strength, etcetera). As pointed out, the primary risk is making a false schematization. The geotechnical codes do not specify how to deal with these kind of risks and present a 'misleading accuracy'. The following 'basic' solutions are given: a) combining all available data, information and (local) knowledge, and b) using in situ testing and/or the observational method. The students are given some examples of 'strange/unexpected' soil behaviour. The concept of 'exploding assumptions' is introduced. Figure 4 shows how the different uncertainties of ground etcetera can lead to very different results of for instance a slope stability problem. For a representative case, given a certain amount of data, the stability factor SF can vary between 2.20 (certainly stable) to 0.80 (probably not stable). Other topics are the step by step approach in soil investigation and design process, the importance of good data management, and communication risks and choices in terms of end-user values. The students must understand that in geotechnics, just following the codes is not good enough to ensure a good project (for the project-team, the client and the end-users).

4.2. Lecture 7 – Ground risk management and levees

A historical overview of the Dutch levee safety approach is given. The old and modern ways of dealing with uncertainties, building with nature, life cycle concepts and organization and communication are compared. Some interesting perspectives were already mentioned in a very old Dutch guideline on Levee Engineering (Vierlingh, 1579).

The multi-step approach on levee investigation and safety assessment is elaborated. Also the good practice of combining a) a sound analysis of data and failure mechanisms with b) inspection results and levee behaviour in various circumstances is pointed out. The importance of switching from ‘precise safety assessment’ to ‘robust levee reconstruction’ is showed, and the pro’s and contra’s of levee reconstruction concepts in terms of costs, planning and risks are discussed.

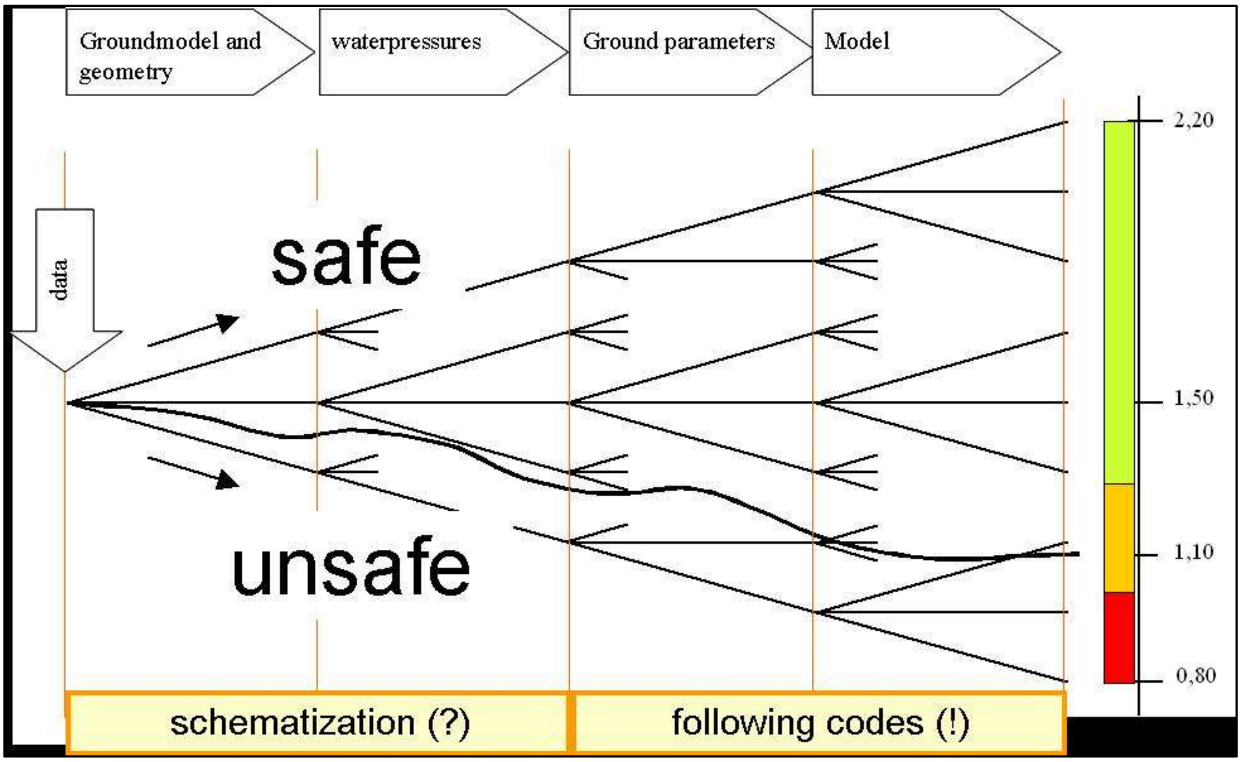

Fig.4 Exploding assumptions (van der Meer and Calle, 2007)

Uncertainties in predicting levee failure are demonstrated in a full scale test at a river dike near Bergambacht, The Netherlands (Lindenberg et al, 2001). In this test, the uplift failure mechanism was successfully provoked. Students are made aware that real tests are a great way to test our (lack of) knowledge, and that predicting the moment and way of failure is not (yet) possible without deformation data. Furthermore, developments like climate change forces us to improve our knowledge of the actual strength of our levees by using modern data acquisition and processing techniques, and we must present this information in terms of risks, in a way the end-users (public, calamity-teams etc.) can understand.

4.3. Lecture 8 – Ground risk management and underground construction

The two guest-lecture hours of block 8 are fully dedicated to one of the largest and probably most complicated underground projects under construction in The Netherlands to date: the North-South metro line in the historic Dutch capital of Amsterdam. After an introduction of this nearly 2000 million euro project, the lecture presents geotechnical risk management aspects of the bored tunnel, the cut and cover construction of the very deep and narrow stations, and the passage below the historical and sensitive building of the Amsterdam central train station.

4.4. Lecture 9 – Ground risk management and building projects

The realization of building projects in urban areas are categorized as complex. First of all, working in city centres means coping with existing structures in use, and therefore dealing with many people with often different interests (stakeholders, inhabitants, politicians), but also most likely in a complex subsoil situation (ground, groundwater, pollution, man-made obstructions such as old piles, cables). And finally, most projects will require a building pit, with its specific problems.

This lecture focuses on the ‘building pit problem’, representing a common but difficult type of geotechnical engineering project. A systematic break-down of the problem is made (fault tree), and the key risks and choices in each project stage are pointed out. The interaction during execution with all kinds of activities and the effect on piles, constructions, etcetera, are shown. Some examples of execution bloopers are presented. The do's and don'ts of monitoring, action and communication plans are discussed.

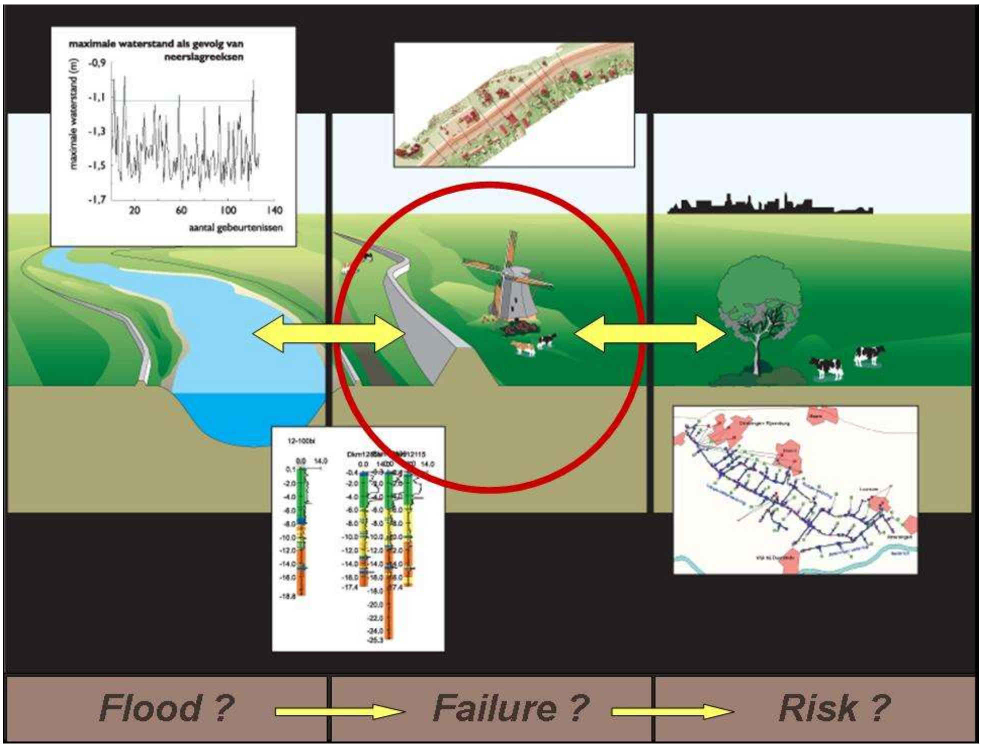

Fig.5 Risk based safety assessment of river dikes

Finally a simple case is presented, showing that even in simple projects many things will go wrong if risks are not managed properly. A systematic risk identification and classification is given, as presented in Figure 6. The students learn that entering the execution stage, the role of the geo risk manager changes dramatically. There are new, more and often very different actors. There are more initiatives and less time to think and to act. The public and media attention is increased. As an important geo risk factor, building activities can change the soil and groundwater properties, and that during execution new (reassuring or alarming) information can come up. Some examples of the 'domino effect' are given: minor events leading to large consequences.

4.5. Lecture 10 - Ground risk management and infrastructure projects

Line infrastructure projects on soft soils in densely populated countries, such as the Netherlands, are difficult to realize: there is no time (the traffic must go on) en we want no settlements (no humps and bumps, and no traffic jams because of maintenance). The importance of having a complete picture of all potential risks at the start of such a complex project is pointed out. The use of different materials and concepts, and the risks they might introduce, is discussed. Different elevation concepts and their risk profiles are presented. Finally, a complex road widening project is worked out. In this case, a number of new road embankment concepts and their impact on costs, planning and risks are demonstrated. This project dealt with these risks by combining engineering capabilities of the principal, the contractor and the consulting geo-engineer.

4.6. Lecture 11 – Geoenvironmental ground risk management

The topic of the two hours of guest lecture 11 is fate and migration of contaminants in the ground. After presenting a few famous cases of soil pollution and their remediating measures in The Netherlands, some basic phenomena of ground and ground water in relation to characteristics of pollution are presented. This information serves as basis for three methodologies to manage geoenvironmental ground risk: the source-path-receptor concept, the isolate–control–monitor approach, and the flexible emission control concept.

		probability			effect			prob	eff	risk
		knowl	period	way	time	costs	qual			
1	SITE/PROJECT RISKS									
1.1	no parking cellar	1,0	0,5	0,9	1,5	1,5	1,5	2,4	4,5	6,9
1.2	soil pollution (chicken slaughtery)	1,5	1,0	1,0	1,5	1,0	1,0	3,5	3,5	7,0
1.3	objects at risk (church e.g.)	0,5	1,2	1,2	1,0	1,0	0,5	2,9	2,5	5,4
1.4	wooden foundations	1,5	0,5	1,0	1,0	1,5	0,5	3,0	3,0	6,0
1.5	etc							0,0	0,0	0,0
2	PERMIT RISKS									
2.1	no building permit	0,9	0,5	1,0	1,5	0,8	0,8	2,4	3,1	5,5
2.2	delay because of procedure	1,3	0,9	0,9	1,7	1,2	0,5	3,1	3,4	6,5
2.3	architecture	0,6	0,5	1,0	1,5	0,5	0,5	2,1	2,5	4,6
2.4	groundwater	0,8	0,5	1,0	1,5	0,5	0,5	2,3	2,5	4,8
2.5	etc							0,0	0,0	0,0
3	EXECUTION RISKS									
3.1	groundwater control fails	0,5	1,0	1,0	0,5	0,5	0,5	2,5	1,5	4,0
3.2	instability building pit	0,5	1,0	1,5	1,0	1,0	0,5	3,0	2,5	5,5
3.3	deformations / damage objects	0,5	1,0	1,0	1,0	1,0	0,5	2,5	2,5	5,0
3.4	noise / vibrations	1,0	0,5	0,5	1,0	1,0	0,5	2,0	2,5	4,5
3.5	surprises archeological etc	0,5	0,5	1,5	1,5	1,0	0,5	2,5	3,0	5,5
3.6	etc							0,0	0,0	0,0

Fig.6 Example of a Risk Table, feasibility phase (score: from 0,5 - relatively positive - to 1,5 - relatively negative)

4.7. Lecture 12 - Ground risk management summary

The very last two lecture hours are used for presenting a summary of the preceding lectures, discussing and answering questions of the students, and by providing some guidance on the written and case-based exam.

5 STUDENT FEEDBACK

Finally, some elements of the student feedback during the lectures will be shared, as gained during the Geo Risk Management lectures. During the first lectures, some of the MSc students showed difficulty with acknowledging the inherently different risk perceptions between people, even between rational human beings as engineering students. The unavoidable consequences of these inherent differences in risk perception, such as just following the geotechnical engineering and construction guidelines being not sufficient for a risk managed design and construction process, did shake their engineering world view to some extent. Such examples conflict with their (educated) view of engineering as a basically rational and objective way of doing. These responses correspond with common practice, as for instance explained by Van Staveren and Chapman (2007).

It was therefore very rewarding to notice a change in student awareness and attitude during the progress of the lectures. They showed not only to acknowledge the fact of differences in the client's, (geotechnical) engineer's and contractor's risk perceptions. They also demonstrated to consider it in their remarks and questions during the lectures.

Apart from their interest in risk perceptions, the students showed also interest and involvement in the contractual consequences of dealing with (different) ground conditions, from a risk management perspective. Furthermore practical tools like a six-step model to arrive at a risk driven site investigation and the cases with their practical problems and solutions raised their particular attention. The students suggested to even further integrate the GeoQ theories within the practical cases, which aligns with the lecturer's ambition for the next Geo Risk Management course.

6 CONCLUSIONS

In view of the ongoing increase in complexity of today's construction projects, with often a dominant role of the (differing) ground conditions, the Delft University of Technology started with an entire new MSc course: Geo Risk Management. Combining risk management aspects, which includes elements like the people factor, with conventional geotechnical engineering and engineering geology proved to be quite new for the students. While the students demonstrated a rise in awareness about the people factor during the lectures, most of the case-based exam results demonstrate still a rather conventional engineering approach. Most of the students still tend to focus on the best solution, from a technical point of view, while underestimating the more social aspects, like reaching agreement with the merely non-technical stakeholders of construction projects and effectively anticipating on contractual aspects. It seems thus quite difficult for technically oriented students to embed a true risk and opportunity driven approach within the ruling design and construction approaches. Perhaps, there should be some more attention to dealing with uncertainties and risk, earlier in the curriculum, to develop an explicit risk and opportunity driven mindset as soon as possible in their studies. Another possibility is further integrating risk management aspects within the typical design and construction courses of the students.

Anyhow, after evaluating the lectures and the exam results, the aim of the Geo Risk Management course appears to be reached. Student became aware about why and how to apply structured management of ground-related risk during the entire process of any construction project. They are also (more) aware of the inherent risk of ground within civil engineering and construction, including the impact and difficulties of the people factor. Most of the students demonstrated being able to apply at least some of the principles of ground-related risk management in the examined case study.

Finally, and probably most important, the rather innovative combination of geotechnical risk management, the people factor, a lot of geotechnical risk analysis tools and many cases from practice, all blended in one new course, has been enthusiastically attended by the MSc students. They showed a serious motivation to apply it in their near future professional practice. This future will teach us how our construction industries, and thus our societies, will benefit from integrated geotechnical risk management education.

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