Kungl Tekniska Högskolan

ENGINEERING GEOLOGICAL INFORMATION

- ITS VALUE AND IMPACT ON TUNNELLING

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Stockholm 1998

Doctoral Thesis 1027
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Summary

In this thesis the use of engineering geological information, with emphasis on geological hazards, within underground projects is reviewed and discussed. Based on a decision and risk analysis approach, requirements on engineering geological information and a concept of making statistically based engineering geological prognoses is proposed.

Decision and risk analysis provide a framework and wide variety of tools for approaching a problem in a logic and stringent way. In the case of underground construction, the technique has a potential of improving the decision process and the handling of engineering geological information. The nature of the decision, being the main issue throughout the complete thesis, may in short be summarized as:

- a definition of possible alternatives,
- a definition of a decision criterion,
- an analysis of possible outcomes and
- an estimation of the probability of possible outcomes.

One important part of decision and risk analysis is to understand and describe the process of events, following a realization of a hazard and ending with some sort of damage. Furthermore to understand and describe events that may initiate the realization of a geological hazard. The following definition is introduced: *A geological hazard (e.g. flowing ground), is a threat of a potential damage (tunnel failure) and is a built-in property of a risk object (the rock mass). The damage event causes damage, i.e. in a wide sense loss of resources. The initiating event (e.g. unsuitable or incautious excavation) triggers a damage event. Warning bells (in this case e.g. increased deformations or muddy water flow from probe holes) indicate that a hazards is about to be realized.* It is concluded that geological hazards play an important role within underground construction and envisaged that a better understanding of the hazards themselves and the process from an initiating event to the actual damage will lead to a more cost effective execution of underground projects. A description and analysis of common damage events, warning bells and initiating events show that in order to avoid damage it is within the risk analysis work important to focus not only on technical/geological problems but also on management of the project organisation. Good communication and transferring of correct information are found to be key factors to carry out successful projects. In this respect it is also concluded that risk analysis and quality assurance are closely related.

Engineering geological information and prognoses play an important role in decision-making throughout an underground project. However, the complex nature of geological hazards necessitates a stringent handling of engineering geological information and a comprehensive quality assurance which reach beyond the scope of traditional systems. As a consequence of this the concept of EGIR (Engineering Geological Information Requirements), including a top-down philosophy when approaching geological problems, is introduced. The four corner-stones within EGIR are; the decision, the quantification of uncertainty, the language and the quality assurance.

The first requirement implies that all engineering geological information must be adapted to and relevant for the current decisions and the current project stage. The decision is the main issue and should be put in focus. Decision and risk analysis provide a general framework and specific tools for fulfilling this requirement.

Secondly, uncertainty related to the information should be quantified, primarily by using statistical modelling. It is shown that it is possible to create stochastic geo-models based on traditional statistical modelling principles for example in order to model spatial variability in rock. Furthermore, that a bayesian approach provides a possibility for combining subjective judgement with observational data and update prior knowledge as additional observations are made available. This implies an excellent tool of achieving better handling of uncertainty. Thereby, the making of reliable engineering geological prognoses as a basis for decisions is facilitated.

The third requirement says that explicit information must be comprehensive enough to flow properly through the project organisation and yet be understandable. It must be unambiguous and adapted to the receiver. It is for example argued that traditional rock classification systems, where a lot of information is truncated and translated into one single value, sometimes but far from always fulfil this requirement. Especially engineering geological information used during the construction stage must be more comprehensive and more focused upon geological hazards.

Finally, the information should be quality assured. As the engineering geological information is related to very complicated processes, a dual quality system is proposed. This systems aims at doing the things right, as emphasized in traditional quality systems, and doing the right things.

By step-by-step fulfilling EGIR and applying a top-down working procedure (decision-model-data) one will automatically get a system or a working procedure for forming, carrying and transferring engineering geological information and establishing engineering geological prognoses that has the potential of improving the overall execution of underground projects. The proposed methodology has been applied to three Swedish case studies each representing a typical problem often encountered in underground projects. For each case, the concept of EGIR and a project specific, specially developed stochastic geo-model have been tested. The first case, from the Stockholm Ring Road Project, is an example of modelling a geologic boundary (depth to rock surface) with kriging. Secondly, a layered stochastic geo-model has been employed to calculate expected time and amount of construction material for a TBM-tunnel at the Äspö Hard Rock Laboratory. The last case, from the Hallandsås Railway Tunnel Project, illustrates the use of a bayesian stochastic geo-model for predicting excavation conditions, ahead of the tunnel face, for the coming rounds. The results from the case studies indicate that it is possible:

- To focus upon the important decision and gather relevant engineering geological information for making a prognosis as basis for this decision, by employing a top-down approach.
- To handle and quantify uncertainty, as long as some main demands on the statistical modelling are fulfilled. Stochastic geo-models should consequently; reflect the nature properly (be geologically logical), include routines for updating, include routines for expressing the reliability of investigation methods and programmes, and make subjective assessments possible.
- To use a language related to engineering geological information that is understood, possible to communicate, unambiguous and adapted to the receiver. This requirement is easier fulfilled by evaluating the sender-receiver situation, evaluating the depth of messages (information-exformation) and define classes or states relevant for the current decisions and problems.

The last requirement according to EGIR is to gain a satisfactory quality assurance of the engineering geological information. This issue is really outside the scope of this thesis but literature studies carried out and the author's experience indicate the need for a quality system based on a broad definition of quality.

Altogether it might be concluded that the implementation of decision and risk analysis, EGIR and the top-down philosophy (for approaching engineering geological problems), outlined in this thesis, has a potential of making the execution of underground projects more successful and cost effective. However, it is also important to remember that if an unsuitable model and/or wrong engineering geological information are used, the basis for decisions may be insufficient or wrong. Examples are given in the thesis.

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