On the need for a risk-based framework in Eurocode 7 to facilitate design of underground openings in rock

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Overview

- Short introduction to risk and uncertainty in rock engineering.
- What is the overall purpose of a ”design”?
- The role of observational approaches in underground excavation.
- How does the revised EC7 consider risk and uncertainty?
  - Example: Geotechnical Complexity Class and the observational method
- Concluding remarks

Ref: Aven (2011, Reliab Eng Sys Safe, 99: 33–44)

What is risk? – a difficult key concept

- The word is believed to originate from
  - *risicum* (Latin) – ’danger, hazard’, derived from *resecare,* ’that which cuts’, referring to sharp reefs or cliffs at sea.
  - *rizq* (Arabic رزق) – ‘fortune, luck, destiny, chance of profit’.

Risky cliffs at sea: RMS Mulheim off Lands End

Ref: Aven (2011, Reliab Eng Sys Safe, 99: 33–44)

Today’s non-technical use of ’risk’ is unclear

Aven (2011) finds 3 possible non-technical uses of the word ”risk”:

1. ”Exposure to the possibility of loss, damage, injury, or other unwelcome circumstance; […]
2. A hazardous journey, or course of action; […].
3. A person or thing regarded as likely to produce a good or bad outcome in a particular respect; […].”

Ref: Aven (2011, Reliab Eng Sys Safe, 99: 33–44)

The technical use of ’risk’ also varies

Aven (2011) identifies, among others (!), the following uses of ’risk’:

- ’Expected loss’ (negative outcome)
- ’Probabililty of an undesired event
- ’Uncertainty (about a cost or loss)’
- ’Combination of probablility and severity of consequences’
- **’Effect of uncertainty on objectives’** (ISO 31000)

’Risk’ as defined by ISO 31000:

’Effect of uncertainty on objectives’

Not fully known geological conditions

To build a structure that satisfies the owner’s requirements and the society’s safety requirements, with minimized environmental impact.

’Risk’ as defined by ISO 31000:

’Effect of uncertainty on objectives’

⬆

‘How not fully knowing the geological conditions affects our objective to build a structure with sufficient quality’

Design? – an engineer’s decision under uncertainty

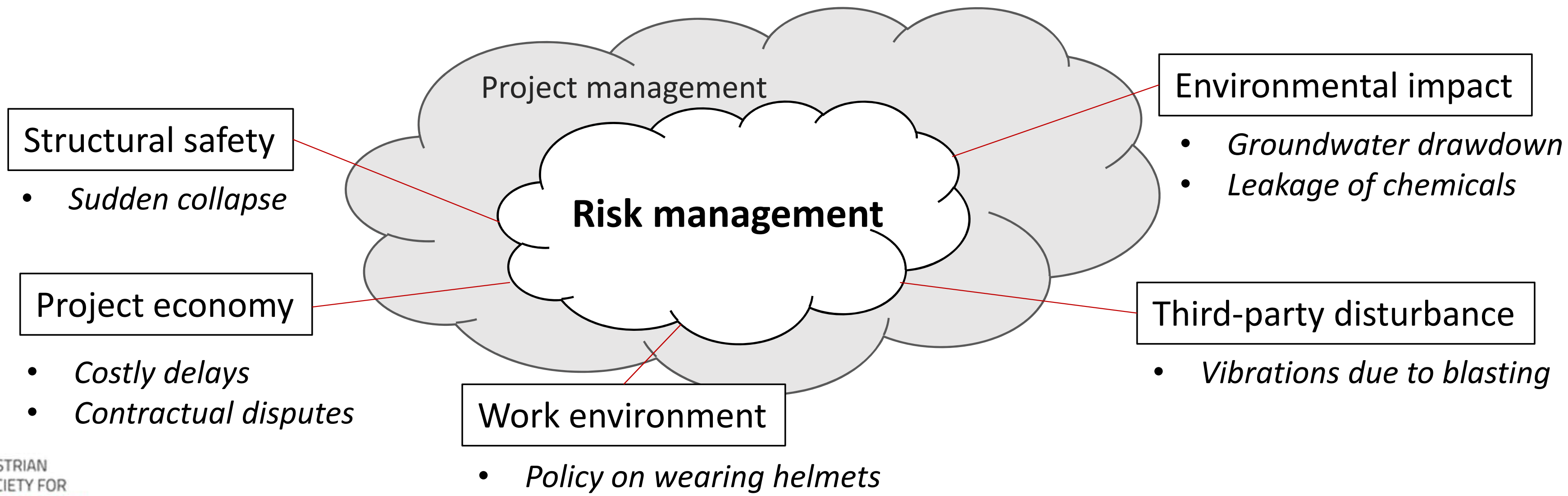
The fundamentals of making a structural design include:

- Collecting information about the construction material (investigations)
- Interpreting investigations and the involved **uncertainties**.
- Deciding on a structural design that is believed to satisfy all technical requirements **with sufficient safety margin with respect to the uncertainties**.

Conclusion: Risk is a necessary concept to account for in design!

Design as a part of the risk management work

- Structural design is just one aspect, out of many, in the project's risk management work.
- All of them carry uncertainties that may affect the objective!



Reducing risks

To reduce a risk, target either

- the probability of occurrence, or
- the consequence.

We can reduce our view of the probability of occurrence by reducing the present uncertainties.

Epistemic and aleatory uncertainties

There are two types of uncertainty that must be separated:

- Epistemic uncertainty
  - Caused by lack of knowledge
- Aleatory uncertainty
  - Caused by randomness

Aleatory uncertainty is like throwing dice: No matter the number of throws, we cannot predict the next result.
The uncertainty regarding the future strength of a concrete beam that has not been cast yet is aleatory.

Epistemic uncertainty is like a deck of cards: Shuffled, we don't know the order, but once flipped, the uncertainty is gone.
Most geological uncertainties are epistemic.

Methods to manage the geological risk

- Geological uncertainties can be reduced through
  - Investigations in early project phases
  - Monitoring and observations during construction

← Expensive and difficult for underground openings (cfr. excavation in soil)

- Consequences are trickier to reduce:
  - Move sensitive objects from influence area (?)
  - Evacuation alarms in case of danger

Conclusion: reducing uncertainties during construction is the most cost-efficient way for underground projects.

Observational method – uncertainty reduction during construction

Photo: www.peck.geoengineer.org, with permission

Prof Ralph Peck

- Prepare a preliminary design:
  - Define in advance alarm limits toward unacceptable behaviour.
  - Plan in advance how to find out whether the behaviour is acceptable or not.
  - Plan what you will do, if the behaviour is found to be unacceptable.
  - Unacceptable behaviour may not occur too often, because contingency actions are usually expensive.

- Observe the behaviour during construction and put contingency actions into operation if they are needed.

Changes the design during construction to adjust to the actual conditions, thereby reduces the epistemic uncertainty.

Conclusion: we find the observational method fundamental to rock engineering design, as it efficiently targets the epistemic uncertainty.

Comparison of the risk-based view with the EC7 draft
(April 2017)

Does the draft acknowledge and support cost-efficient methods to reduce risk in the design of underground openings?

The Geotechnical Complexity Class
– defines required effort in ground investigation

A **ground model** is a description of ground information for engineering design purposes.

Requirements in the April 2017 draft of EC7:

- A ground model shall be developed for all geotechnical designs.
- The ground model shall include a statement about the **complexity** of the geotechnical design.
- Geotechnical structures shall be classified according to the complexity of the design situation in one of three Geotechnical Complexity Classes.

GCC proposal in EC7 draft

Table 4-1 Preliminary selection of Geotechnical Complexity Class

Class	Com-plexity	General characteristics
GCC1	Low	Uniform ground conditions and standard construction technique.
GCC2	Medium	Variable ground conditions and standard construction technique, and moderate thickness of made ground.
GCC3	High	Difficult soils, sliding ground, complex ground-structure-interaction, etc…

From the April 2017 draft of EC7 (slightly simplified)

GCC and required ground investigation effort is linked

Consequence class	Geotechnical complexity class		
	Low	Medium	High
High (CC3)	GIL2		GIL3
Medium (CC2)		GIL2	
Low (CC1)	GIL1		GIL2

- The minimum ground investigation level (GIL) shall be chosen depending on the CC and the GCC.
  - GIL1: desk study and site investigation
  - GIL2: new investigations that identifies the location of critical formations + GIL1
  - GIL3: evaluation of variability of parameters for all critical formations with high quality sampling and testing + GIL2.

Does the draft conform to the risk-based view?

Implications of ground investigation requirements

- Ground complexity is related to geotechnical uncertainty, but constitutes only one aspect of it.
  - ➢ We believe that the ”lack of knowledge” should be the determining factor.

- The code meddles in the engineer’s risk management work.
  - ➢ When uncertainties are reduced (before or during construction) is an **economic** decision for the engineer, which the code should not regulate.

NOT a safety-related decision!

Does the draft conform to risk-based design?

Implications of ground investigation requirements

- The selection of GCC is superior to the selection of design verification method in the 2017 draft.
  - With a risk-based view on design, it must be the other way around:
    1. Select verification method (calculation, prescriptive measure, observational method)
    2. Prescribe amount of uncertainty-reduction, **conditionally** on verification method.
  - Otherwise, the advantage of the observational method is lost, as the required amount of investigations is the same, regardless of monitoring effort during construction.

Possible future cost increase in underground projects?

Concluding remarks

We believe that:

- a risk-based view on design is fundamental in a geotechnical design code to ensure an efficient use of resources while providing sufficient safety.

- the current draft needs revision, in particular with respect to the GCC and its link to ground investigations and design verification methods.

  - Otherwise, we fear that the observational method will not be economically feasible in any situation at all.

Thank you for your attention!

Discussion is most welcome