Engineering Projects, Failures
And Profilagons

John A Hudson
How do we think about ‘Special Conditions’ – i.e. conditions outside the range of ‘normal’ conditions

For a variety of variables, e.g. rock fracturing, rock strength, rock stress, temperature, etc., we have:

‘Normal’ conditions

Special conditions
Some of the special condition features for rock engineering projects and potential engineering failures are:

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So how can we think about these conditions in preparation for modelling and design?
Such conditions can also be presented in a circular diagram of this form.
We have already looked at one of these:

High rock stress and spalling
Mixed soil-rock, and sampling problems

High temperatures

Low temperatures

Adverse chemical conditions

Excavation adjacent to existing structures

Complex geology

Fracturing - high density and/or large fractures

High water pressure and flow

High/low rock stress, spalling

Standard underground rock engineering

Unlined hydroelectric water tunnel may need internal steel lining

Karst, weak layers, squeezing

Problematic environmental circumstances

Well developed rock spalling in the form of slabbing in a footwall drive at 2600 m depth, East Rand Proprietary Mines Ltd, Central Witwatersrand goldfield, from Ortlepp, 1997
Examples of stress-induced spalling

- Mixed soil-rock, and sampling problems
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Another special condition is high water pressure and flow.
Complex geology

e.g. anisotropic rock conditions which we have studied

Failure induced by the pervasive ductile fabric

Angle $\beta$ between the applied stress and the normal to the pervasive ductile fabric

Rock strength

$0$, $30$, $60$, $90$
Excavation adjacent to existing structures

One of the biggest headaches and a very delicate part of the whole construction arose from the decision to put a station right opposite Big Ben.

Not only did this require a huge excavation to accommodate seven storeys below ground, but the building was also required to support seven storeys above, to provide much needed office space for Members of Parliament.
Let us now consider a more awkward ‘special condition’:

**Sustainable development**

“Is the exploitation of underground space compatible with the concept of sustainable development?”

Bruntland 1987 definition: “Development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs”
Factors that have to be taken into account include function, project lifespan, future technological developments and disorder created.

The ‘special condition’ question is “Given an existing underground system (whether a virgin space or an already developed space), is it acceptable to locate a new facility in the system — within the context of sustainable development?”

Existing system

Proposed new project
Unusual rock engineering project objective…

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An artistic underground project is the proposed Chillida sculptural space, or negative sculpture, which will be inside Mount Tindaya on the island of Fuerteventura, Canary Islands.

In 1966, the sculptor Eduardo Chillida explained his objective as, “To create a space inside a mountain that would offer men and women of all races and colours a great sculpture dedicated to tolerance...”
Unusual objective: please build me a spherical underground cavern with a diameter of 1000 m.
Stress concentration is independent of excavation size.

So, in an unfractured rock mass, the cavern could be any size?

100 m, 1000 m?

\[
\sigma_\theta = \frac{1}{2} \sigma_v \left[ (1 + k) \left( 1 + \frac{a^2}{r^2} \right) + (1 - k) \left( 1 + 3 \frac{a^2}{r^2} \right) \cos 2\theta \right]
\]
Let us consider now the special conditions profiles of some example tunnelling and rock engineering projects
Designing a simple tunnel near the cliff face

- Mixed soil-rock, and sampling problems
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Excavation adjacent to existing structures

Unusual project objective

Complex geology

Standard underground rock engineering

Problematic environmental circumstances

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High rock stress, spalling

Mixed soil-rock, and sampling problems

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High rock stress, spalling
The Jinping II hydropower project site in China

Rock spalling

2500 m overburden + faults in Triassic limestones
JinPing II water transfer tunnel

- Mixed soil-rock, and sampling problems
- High temperatures
- Low temperatures
- Adverse chemical conditions
- Excavation adjacent to existing structures
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Radioactive waste disposal
Designing a repository for high-level radioactive waste

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Designing a rock slope adjacent to a highway in hard rock

- Mixed soil-rock, and sampling problems
- High temperatures
- Low temperatures
- Adverse chemical conditions
- Excavation adjacent to existing structures
- Unusual project objective
- Complex geology
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Profilagons

- Standard underground rock engineering
- Simple tunnel near cliff edge
- Rock slope near highway
- Standard underground rock engineering
- Standard underground rock engineering
- Deep water transfer tunnel
- Radioactive waste disposal
But can these project special conditions profiles be accommodated in the site investigation and hence also in the numerical design methods?
This leads to Technical Auditing—which we will discuss in the next lecture.

'Soft' Audit

Obtains the basic information for establishing the essence of the problem

Ability to present what is being done

'Hard Audit'

Obtains the detailed information on all the procedures being used

Ability to state the details of what is being done

Audit Evaluation

Establishes whether the modelling is adequate to meet the objectives

Ability to state whether the modelling is adequate for the purpose
Finally don’t forget that there are problems of scale and time…

from Yow and Hunt, IJRMMS, 2002
End of Lecture 9