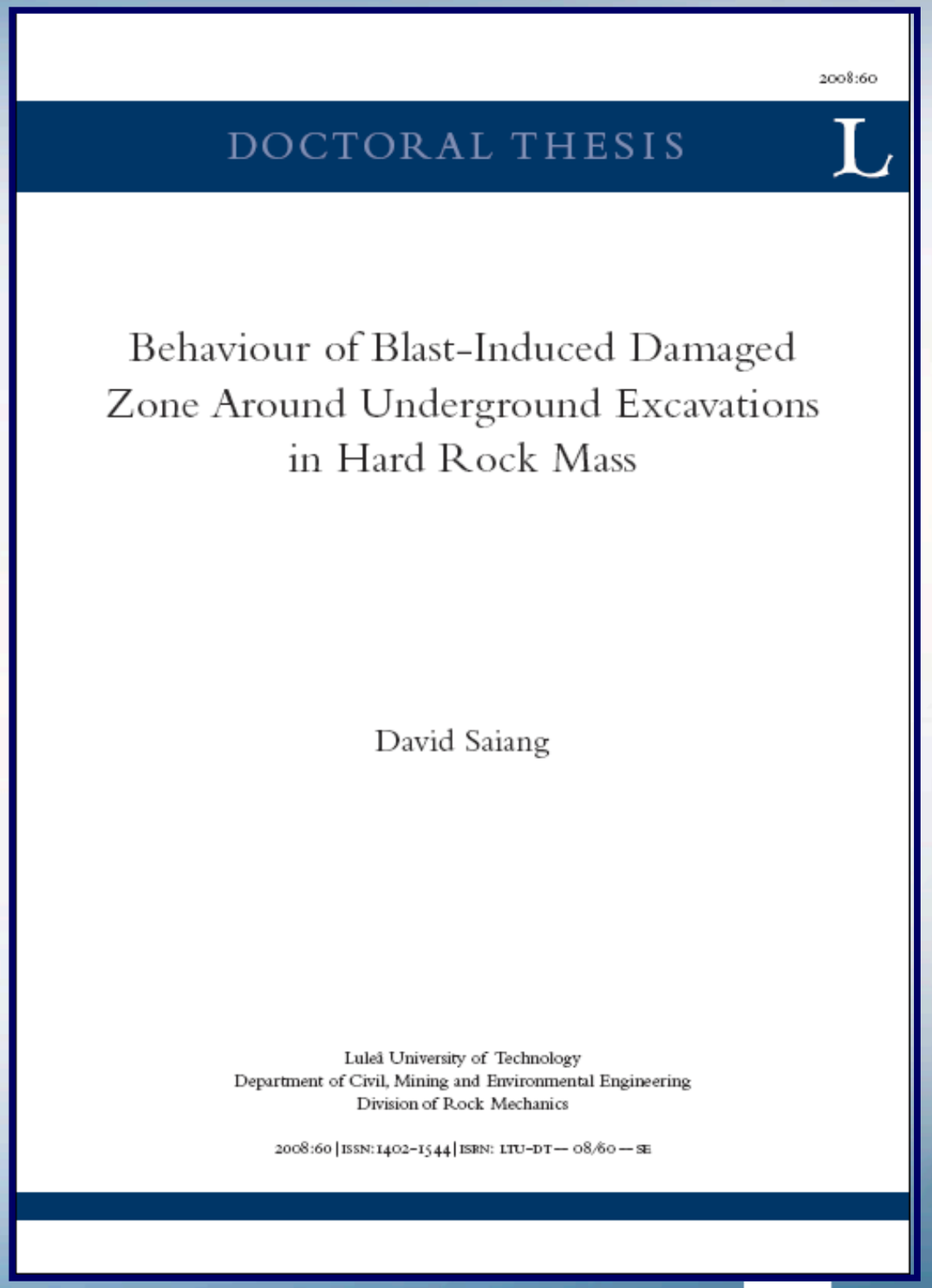
Behaviour of Blast-Induced Damaged Zone Around Underground Excavations in Hard Rock Mass

Problem statement

- Blast-induced damaged zone can affect the affect stability and performance of tunnel. But, we don't know how?
- Consideration of the blast-induced damaged zone has also been a source of additional cost.

Objectives

- Investigate the mechanical behaviour of blast-induced damaged rock.
- Identify important parameters that affect its behaviour
- Identify scenarios where the presence of the blast-induced rock can have significant impact on the construction and performance of a tunnel.



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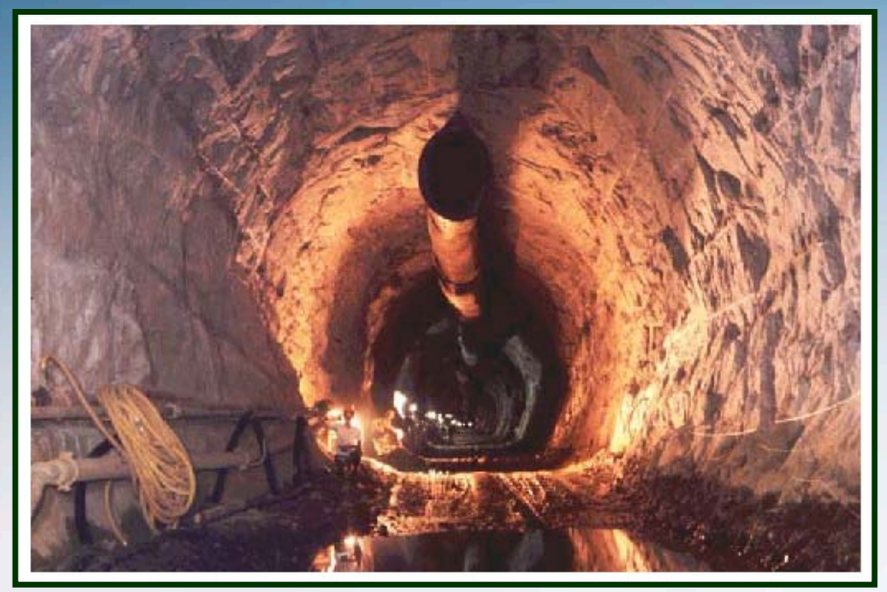
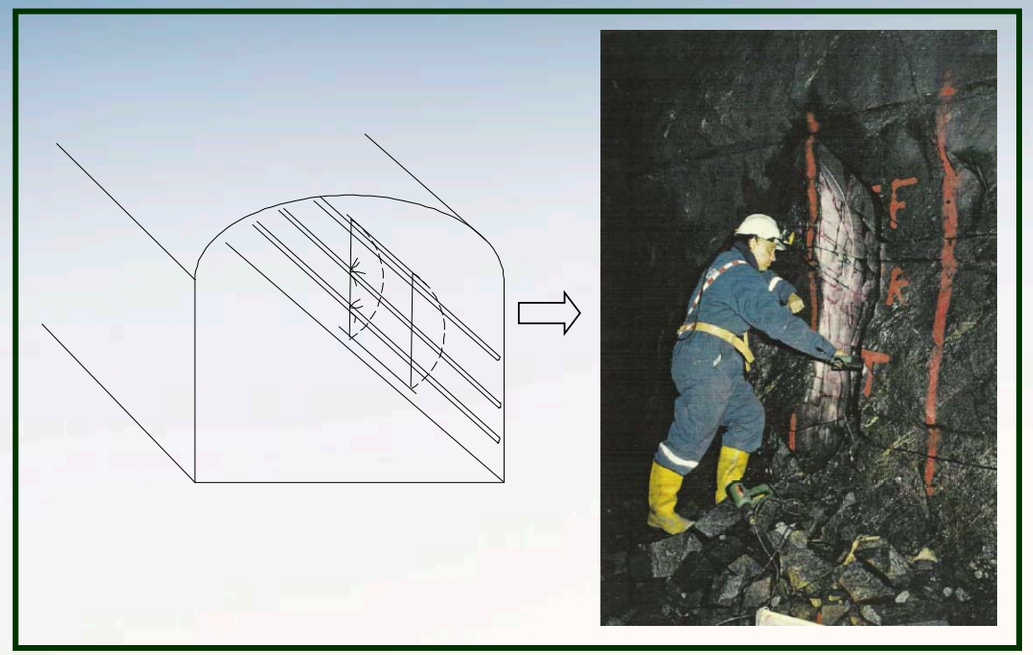
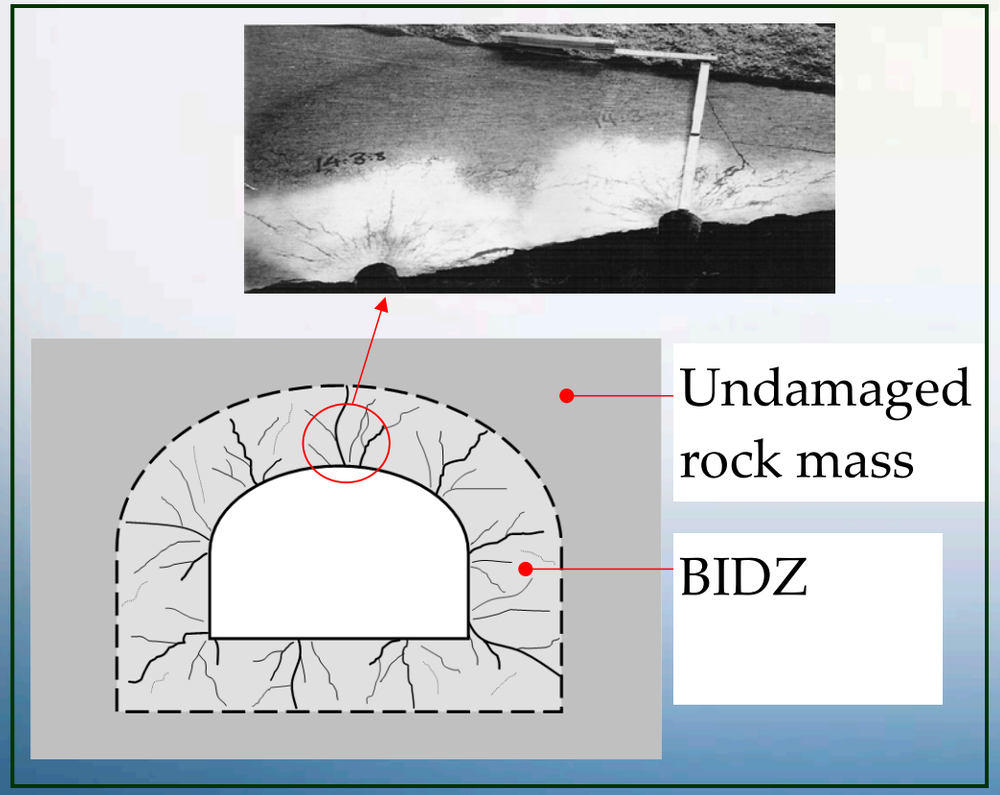
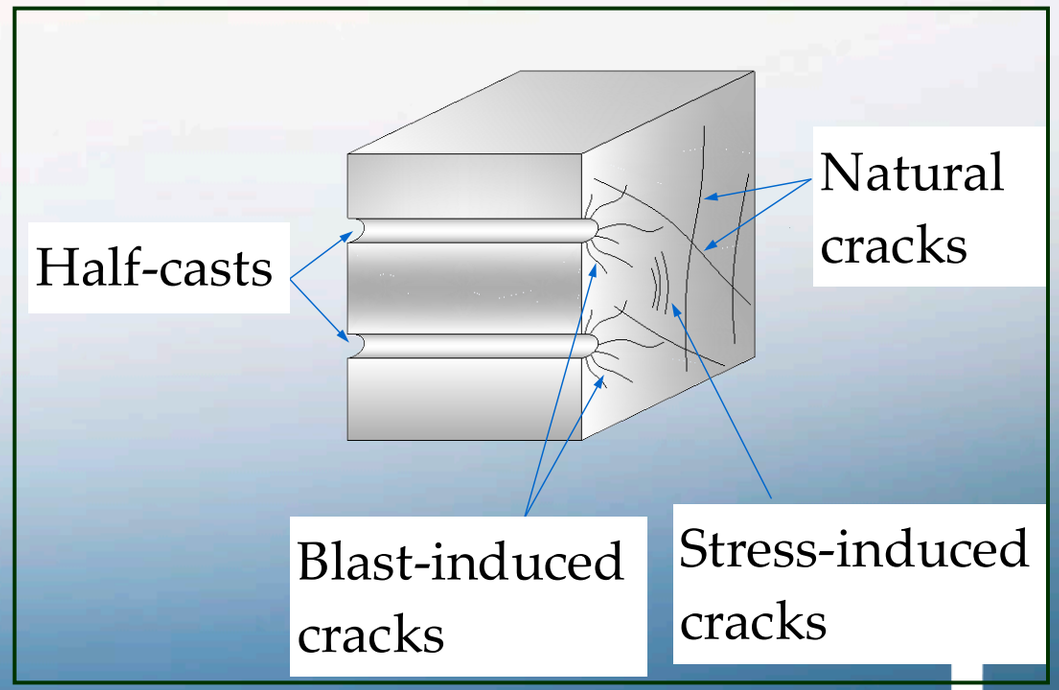
The Blast-Induced Damaged Zone (BIDZ)









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Investigations

- Field Investigation – Kiirunavaara Underground Mine (1 paper)
  - Extent of the damaged zone
  - Modulus of the damaged zone

- Numerical Study – Continuum and Coupled Continuum-Discontinuum techniques (5 papers)
  - Parameter study
  - Behaviour of damaged zone at shallow and deep excavations
  - Failure mechanisms within the damaged zone
  - A method estimating for the strength parameters of the damaged zone

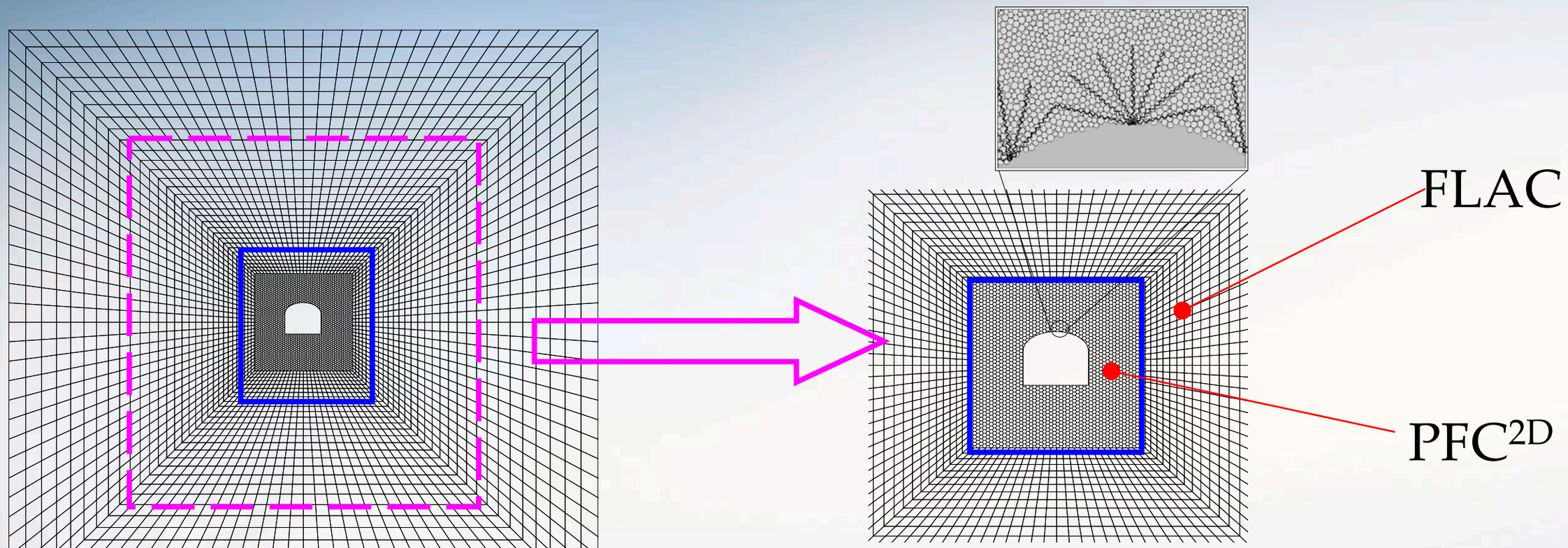
Key Results

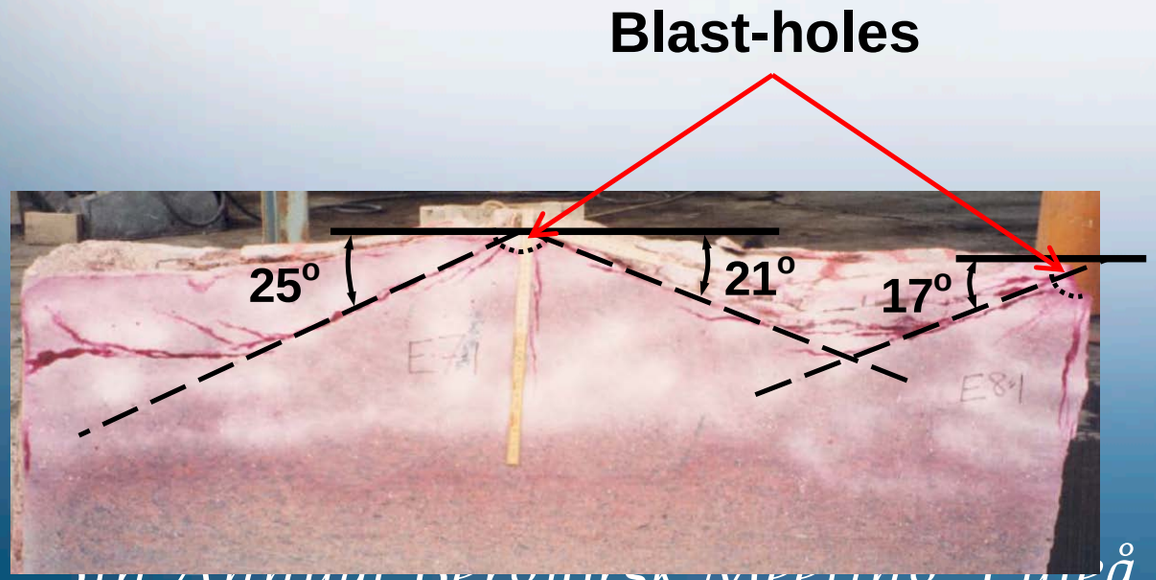
- BIDZ Investigation at Kiirunavaara mine
  - BIDZ extended 0.5 to 1.0 m
  - Modulus reduced by 10 to 30%

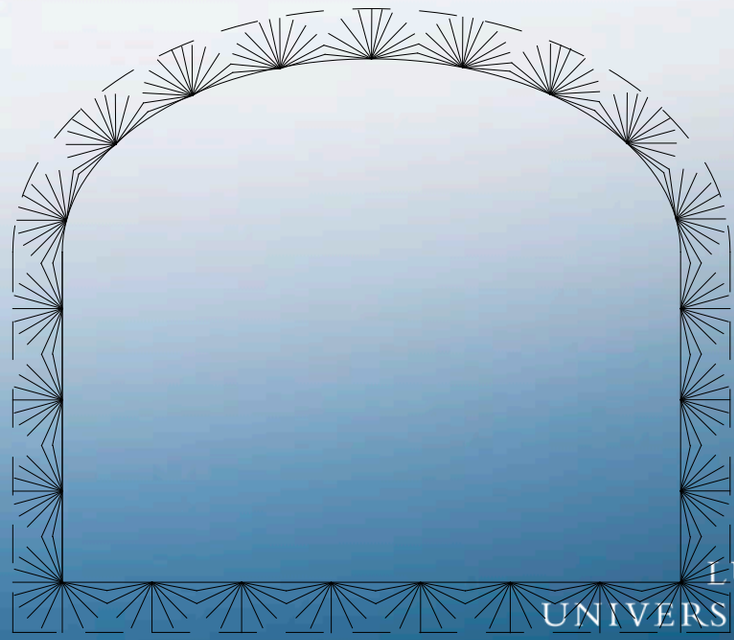
- Numerical study of BIDZ behaviour
  - Induced stresses were reduced by 50% on the boundary.
  - Maximum displacement increased by 10%.
  - Important parameters of damaged zone in order of significance are; stiffness, tensile strength and compressive strength.
  - Tensile strength of the damaged zone is important at shallow depth excavations, while shear strength deep excavation
  - Failure depth estimated to be between 0.05 to 1.2 m

Behaviour of BIDZ using coupled FLAC-PFC^{2D} model

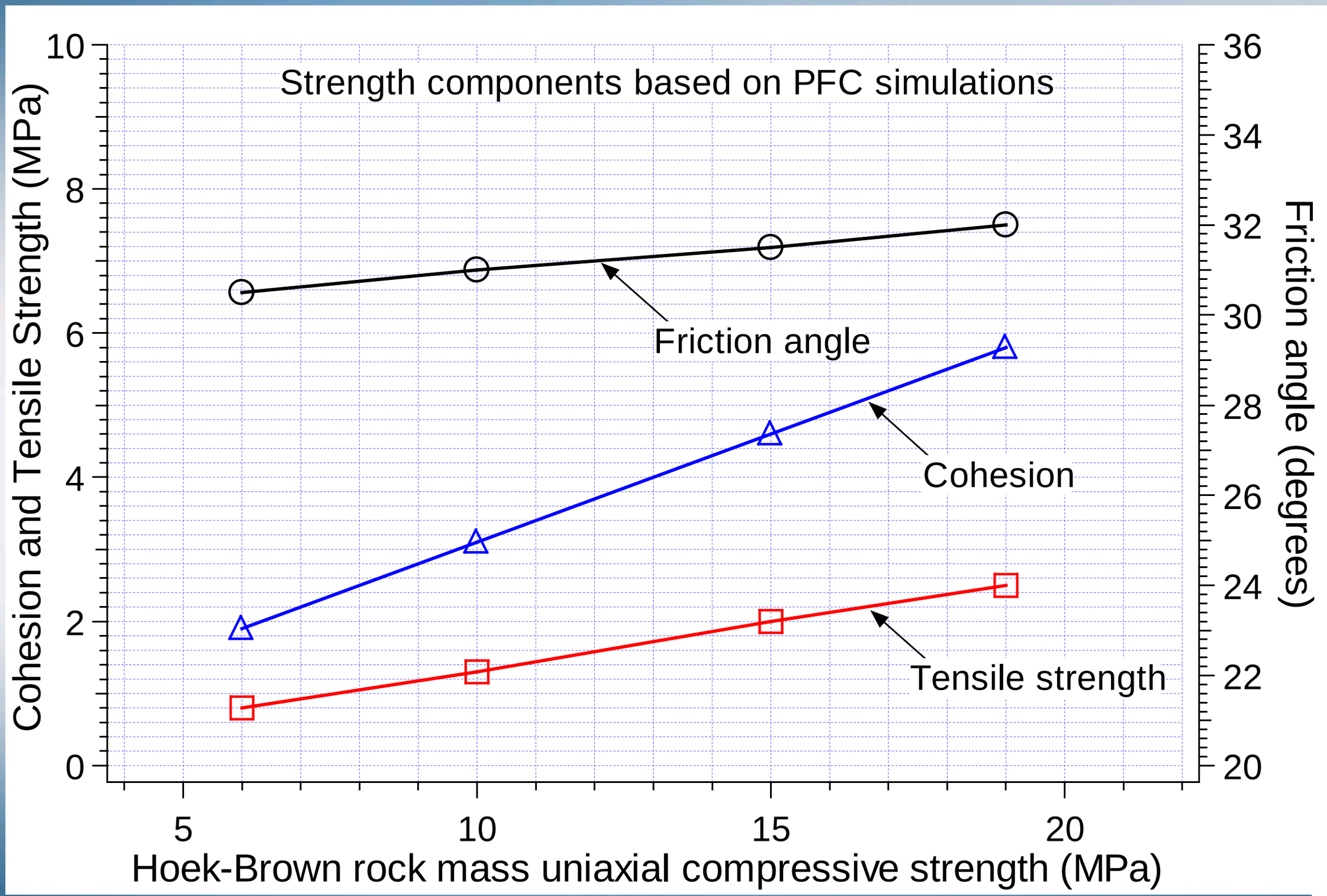
FLAC-PFC^{2D} coupled model







Inputs derived through PFC^{2D} modelling



MAIN CONCLUSIONS

Behaviour of the BIDZ

- The thickness of the BIDZ ranges between 0.1 m and 1.0 in many practical cases, with an average between 0.3 and 0.5 m.

- The modulus within the BIDZ can be reduced by 10 to 50%.

- The study did show that the presence of the BIDZ affected the response of the near field rock mass.

- The inherent properties of the BIDZ that affected its behaviour in order of significance are (i) Young's modulus, (ii) tensile strength and (iii) compressive strength.

- Tensile strength of BIDZ is important for shallow excavation.

- At shallow depth the rock pillar directly above a tunnel behaves like a beam. The BIDZ could reduce its thickness, thus risk its failure.

- The effect of BIDZ on tunnel safety must be considered subjectively.

Modelling of the rock mass

- Behaviour of rock mass is influenced by the failure process. Appropriate inputs must be used to capture these processes.

- Estimation of inputs based on HB-GSI empirical method is inadequate. PFC^{2D} can be used instead.

- Chart developed via PFC^{2D} modelling can be used as a tool to estimate inputs for a continuum model.

- Volumetric strain concentration is a better indicator for brittle failure than the usual plasticity indicators.

- Explicitly simulation of the BIDZ using the coupled FLAC-PFC^{2D} model show promising results.
  - depth failure estimated was within those in practical cases
  - changes in failure characteristics due to different mechanisms were also captured.

THANK YOU!

Bergforsk

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