REPRESENTING SPALLING IN ROCK EXCAVATIONS WITH BBM

REPRESENTATION AV SPÄNNINGSINDUCERADE BROTT I TUNNLAR OCH BERGRUM MED BBM

Jessa Vatcher and Jonny Sjöberg

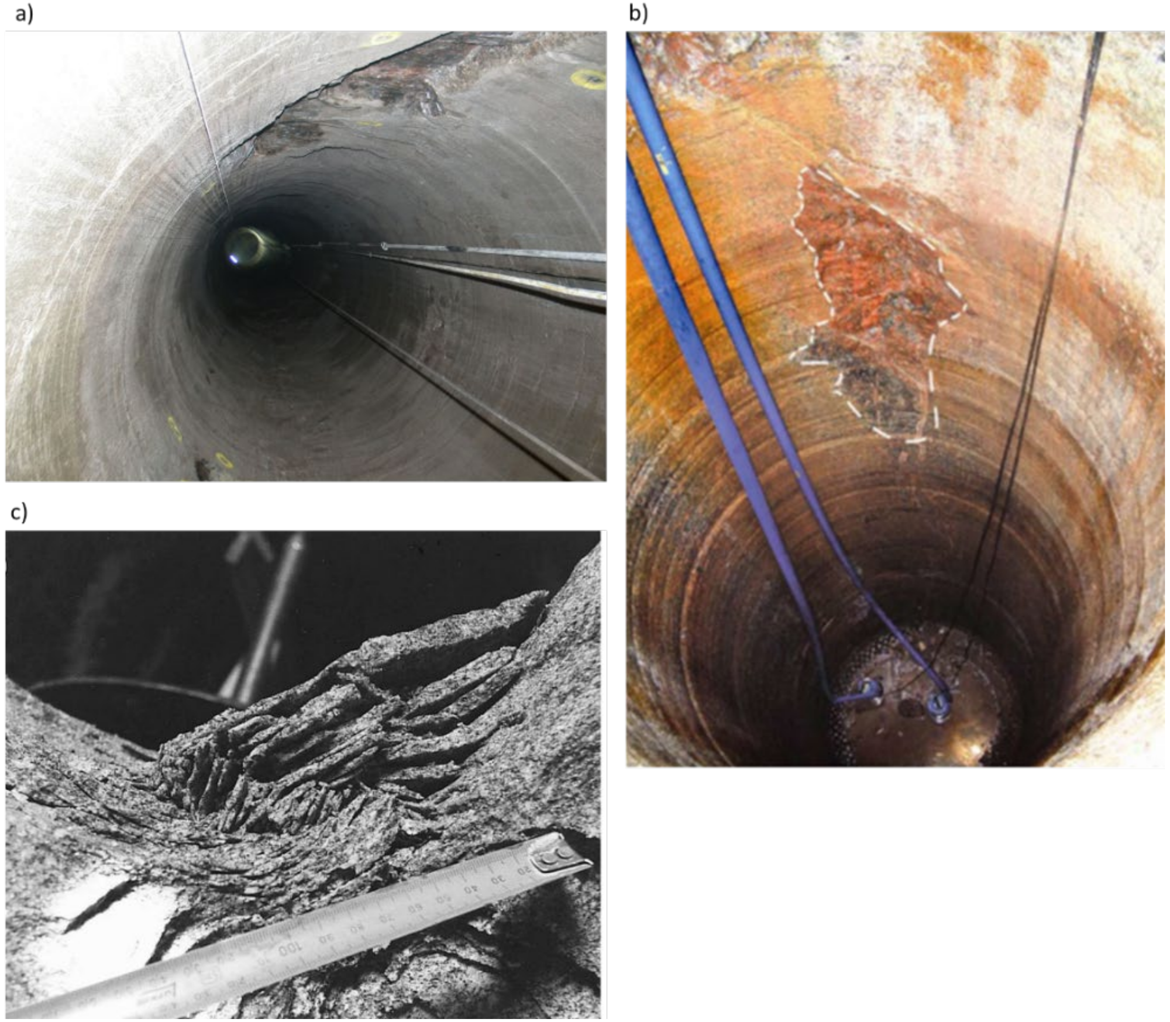
Itasca Consultants AB

2020-12

BeFo Report 212, 2020

Problem description and project objectives

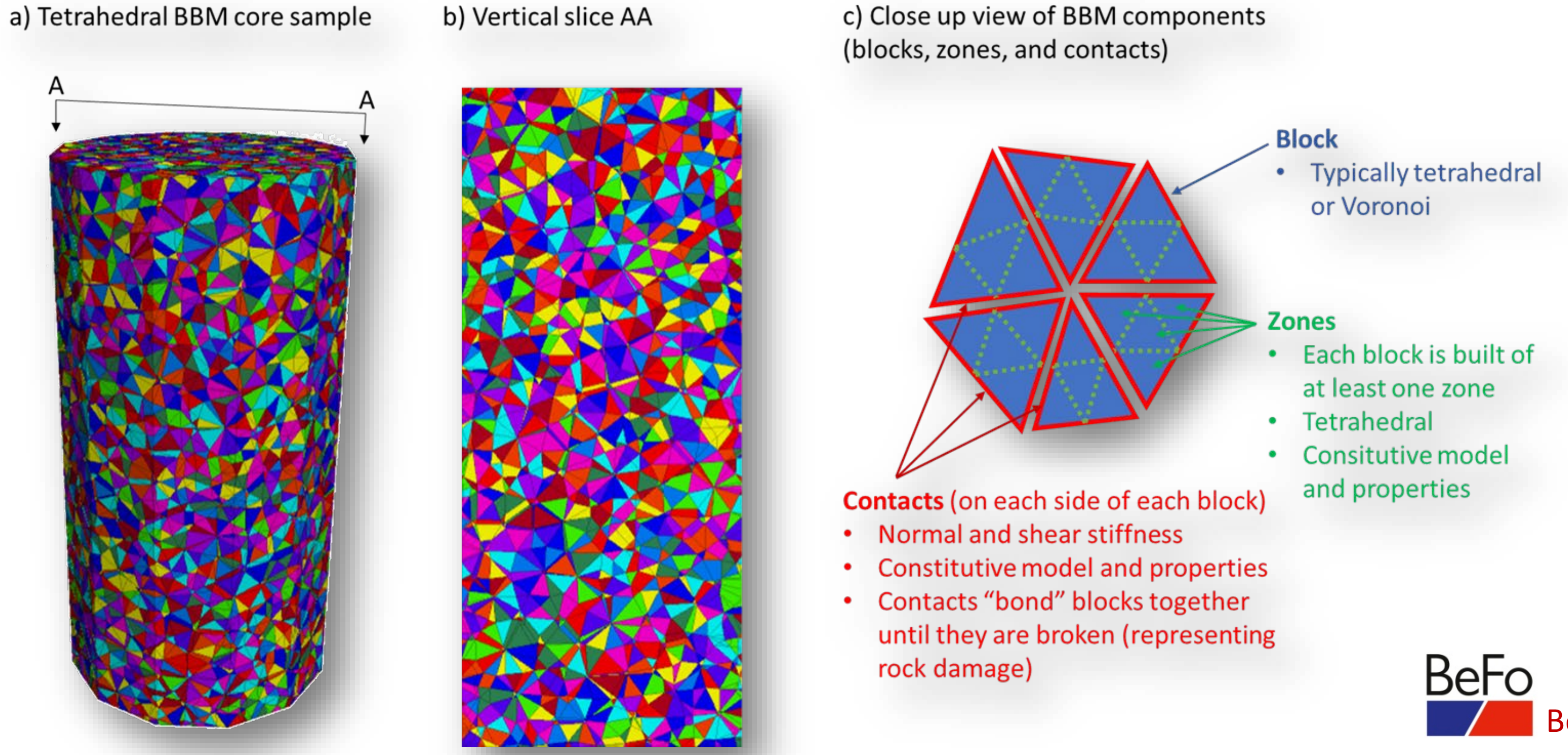
- Spalling occurs in Scandinavia, including in projects in the mining, infrastructure, and storage sectors.
- Spalling can be problematic as it may change the profiles of the excavations and rock mass transmissivity.
- Numerical modelling of spalling is complex. Typically, continuum models are used with strain softening constitutive models, but they are only a proxy for spalling. They are unable to capture the mechanisms underlying spalling, and they therefore work best as back analysis.
- This project studies the suitability of a new modelling technique to represent spalling in Scandinavia. The technique is called “Bonded Block Modeling” (BBM).
- The focus of this study is to give advice to practitioners who wish to use BBM in the future.



Examples of *in situ* spalling, where a) is a shaft in Garpenberg Mine (Edelbro, 2008), b) is a shaft exposed to thermal load to create spalling (Andersson, 2007), and c) is a close up of a cross-section of spalling in the tunnel in the Mine-by-Experiment (Martin, 1997).

What is “Bonded Block Modelling” (BBM)?

A numerical modelling technique that represents the rock mass as a conglomerate of blocks. Rock mass damage is represented by breakage of the contacts between blocks.



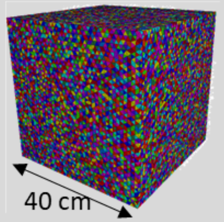
Project's methodology

- A literature review and an application of BBM to laboratory tests and *in situ* spalling av an actual case from LKAB's Malmberget Mine.
- Very small blocks were used (approximately grain size), since spalling occurs at the grain level.

Malmberget ventilation Öde 8E raise

1. Calibration process

1. Create large BBM volume to sample from

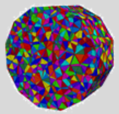


All future models make use of this volume (or similar volumes) with random sampling

2. Experiment with UCS tests to achieve correct elastic behaviour

Adjust contact shear stiffness (jkn) and contact normal stiffness (jks)

3. Experiment with Brazilian tests using results from 2 to achieve correct tensile behaviour

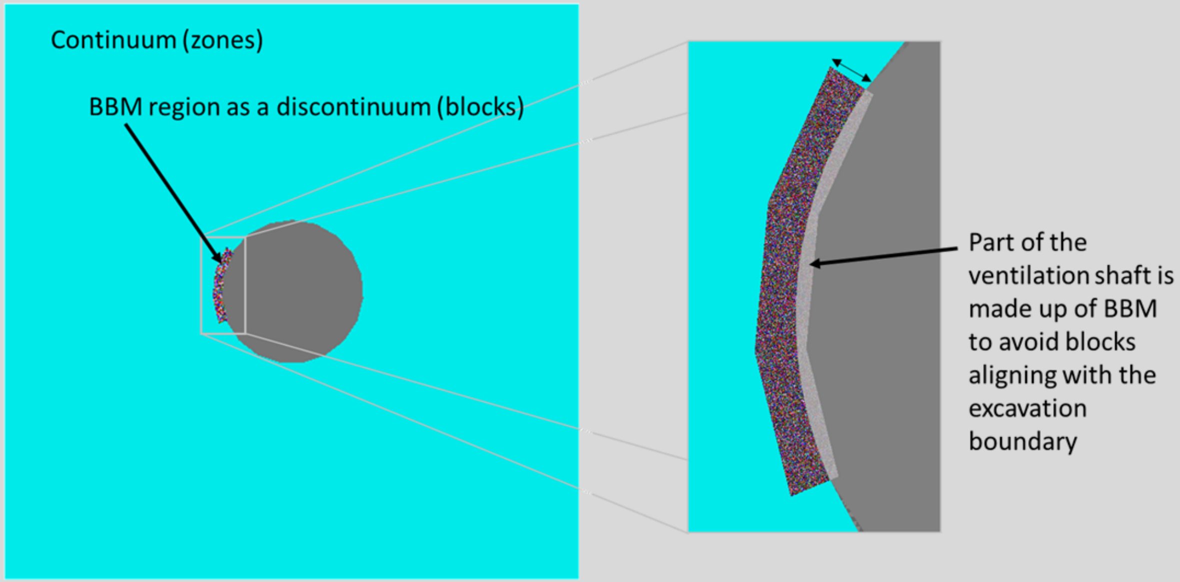


Adjust contact tensile strength

4. Check plastic behaviour using results from 2 & 3 with UCS tests

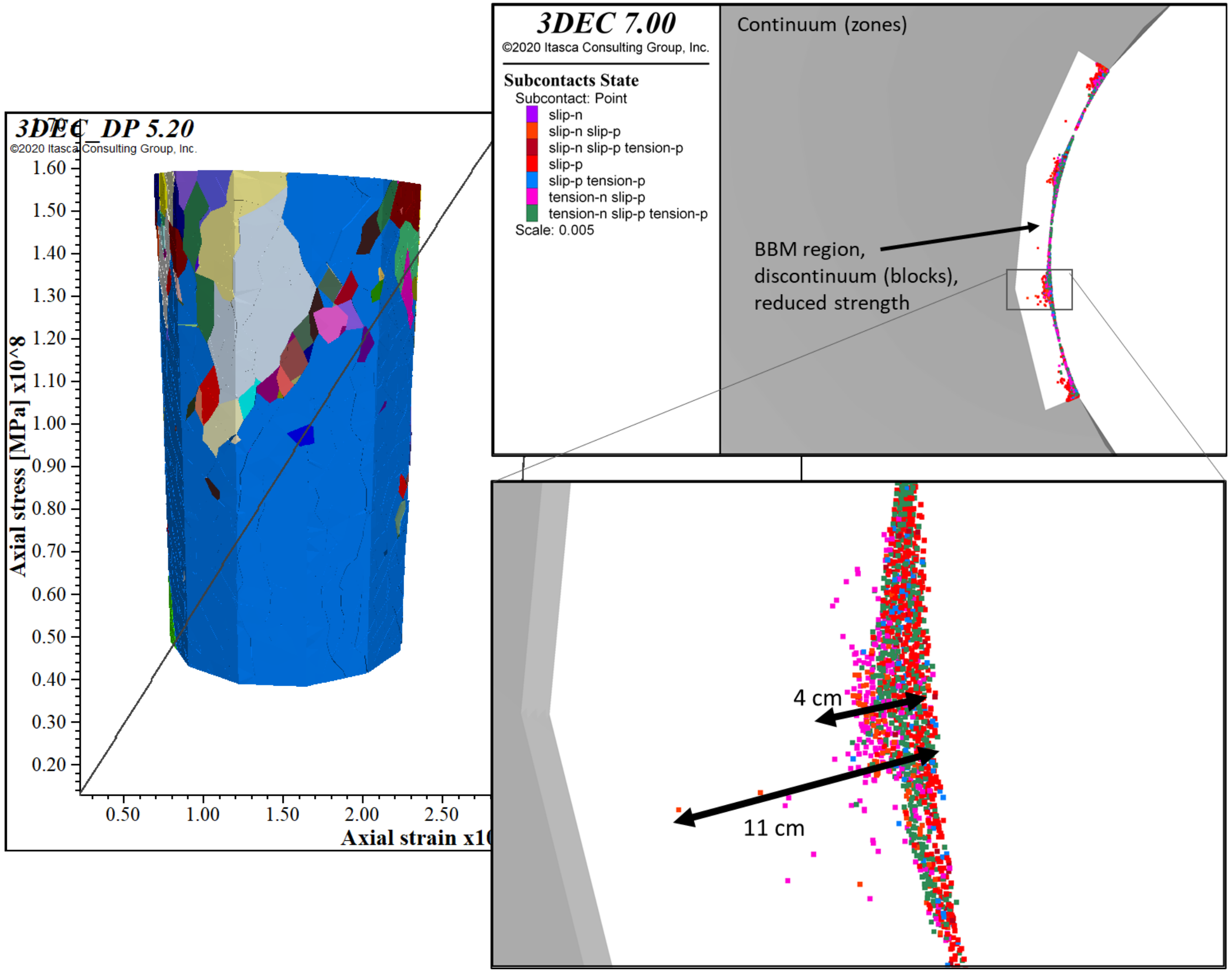
2. *In situ* testing process

5. Experiment with approved properties from calibration process and compare the spontaneous behaviour of the models to actual spalling behaviour



Results

- Increasing amounts of literature, many unanswered questions about the details of modelling.
- Material calibrated to laboratory testing data created. Difficulties occurred find a set of model properties that satisfied the UCS and Brazilian targets. UCS was prioritized since behaviour during a UCS is similar to the conditions under which spalling occur.
- *In situ*, quasi-3D models using the calibrated material showed some spalling, more spalling when the strength of the material was reduced. The depth and form did not match *in situ*. This may be due to boundary effects from the coupling of the continuum and discontinuum portions of the models, the lack of ability of intragrain breakage, lack of strength heterogeneity of the material, and/or lack of the true stress path.



Conclusions & recommendations to practitioners (I)

- BBM is a promising technique to represent spalling.
- Attempting to model the exact process of spalling using BBM is currently difficult due to computational limitations restricting minimum block size. Larger blocks should be currently used in practice.
- Adequate time for the calibration process is important, as it is not always straightforward.
- Block configuration during the calibration process is important.
- Contact shear and normal stiffnesses are less significant than the other properties, such as cohesion and tension in models of laboratory tests.
- The use of a ratio between tension and cohesion is appropriate until proven otherwise.

Conclusions & recommendations to practitioners (II)

- A distribution of the tensile strength (and therefore cohesion) across all contacts may help better represent the variance of UCS tests. Correlated random fields should be considered.
- Start *in situ* modelling with simplistic models (continuum) to check model behaviour and identify exactly where in the model the BBM region should be built.
- Contact stiffnesses in in situ modelling between the BBM region and the continuum should likely be based on zone size, not the values from calibration. These stiffnesses may result in problems with the stresses in the model, and time and effort may be required to find values that work.
- It is inconclusive if a reduction of the BBM material strength is required when the block sizes are near grain size. However, it is still postulated that this strength reduction is required for larger blocks. It is proposed that this is due to a combination of 1) rock mass strength being less than intact strength, 2) the lack of strength heterogeneity of the material, and 3) the lack of damage build-up possibly caused by the stress path.