Block Erosion of Unlined Rock Spillway Canals

Blockerosion av utskov i berg

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Background

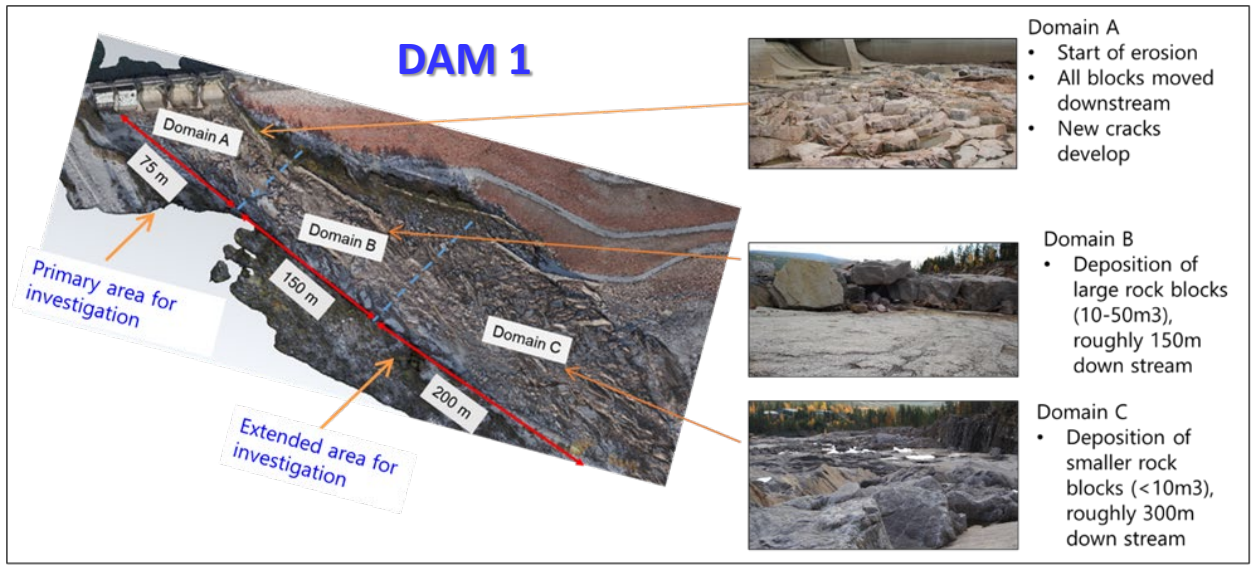
Spillways canals are generally designed to receive shock-like flows without damaging the dam or the rock foundation. However, as the current climate situation has resulted in increased amount of precipitation new guidelines on design flood calculations for flows have been established (e.g., Flödeskommitten 2007). This means that most of today's dams must be dimensioned to withstand higher flows than in the past. A larger flow also means that the spillways are exposed to more water. In many of the larger dams' outflow channels, block erosion is observed in the spillways.

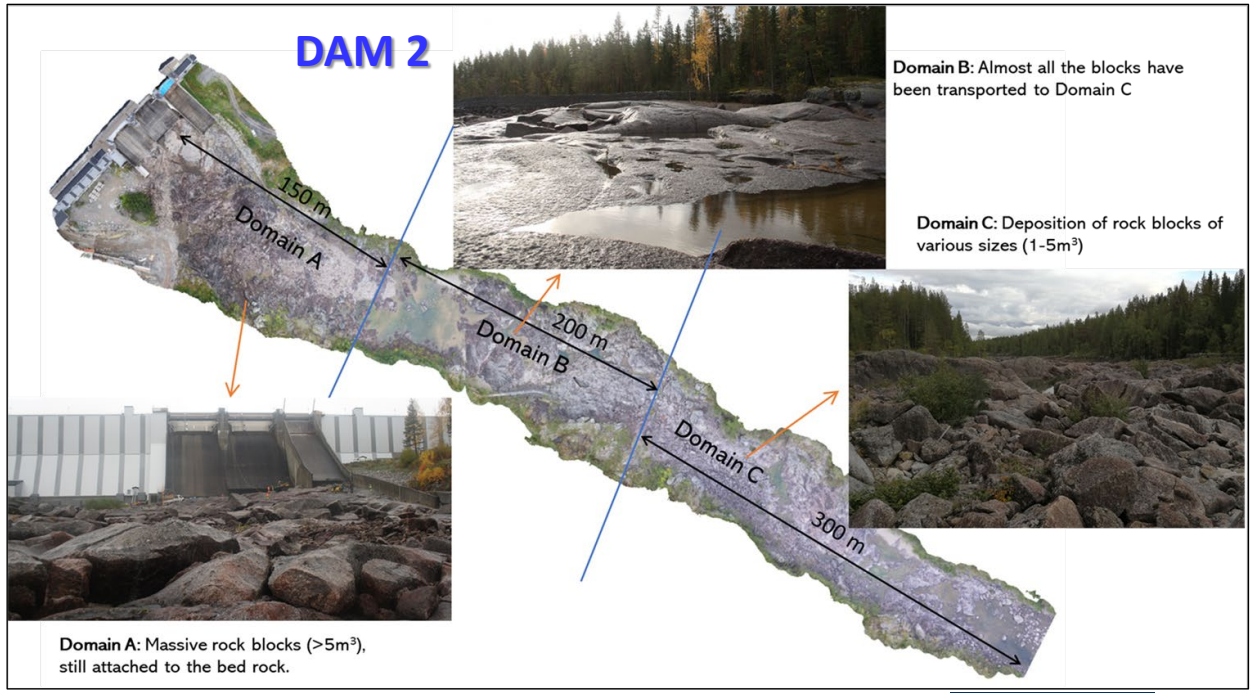
The main objectives this research are therefore (1) investigate how block erosion occurs in spillway canals, (2) investigate the mechanisms or governing factors involved in the block erosion, and (3) make recommendations to optimize the design of canals as well as corrective measures.

Two hydropower dams were investigated as case studies. Detailed rock mass characterisation was performed for the canals. These data was utilized in empirical and numerical analyses to investigated block erosion potential and mechanisms involved in the erosion.

Site Investigations

- Spillway canals of two hydropower dams, referred to as Dam 1 and Dam 2, were used as case studies.
- Geotechnical investigations were conducted and rock mass conditions of the two spillways established.
- Dam 1 spillway comprises moderately fractured and blocky rock mass, while Dam 2 comprises massive rock mass.
- Block sizes formed by fractures and fracture parameters were observed to dictate the mechanisms of block erosion





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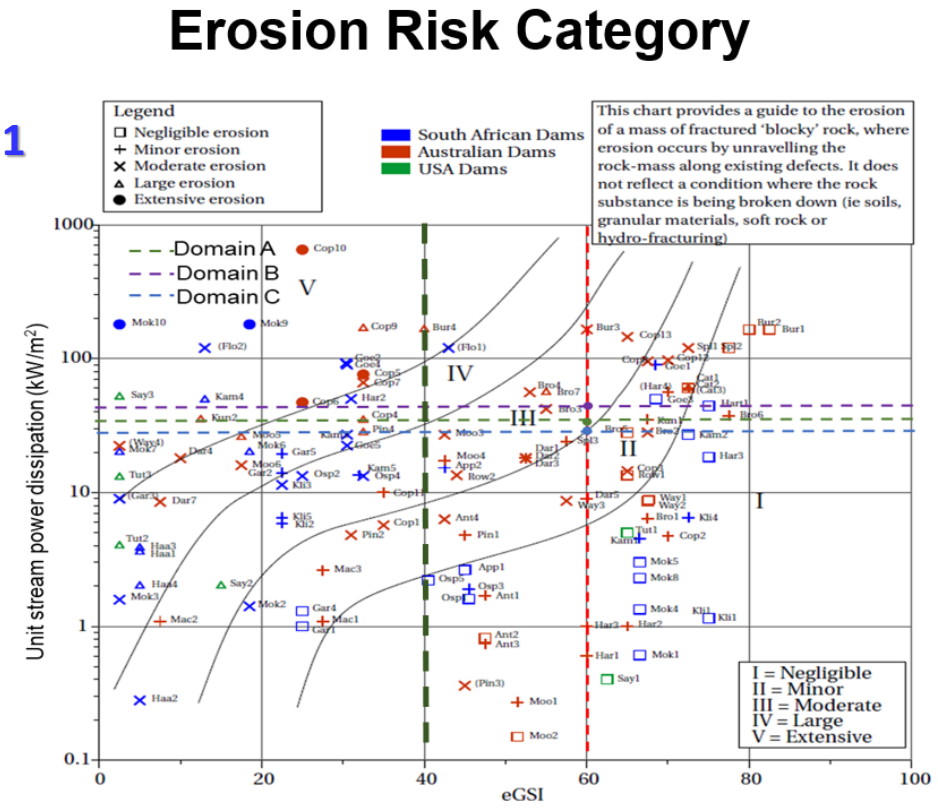
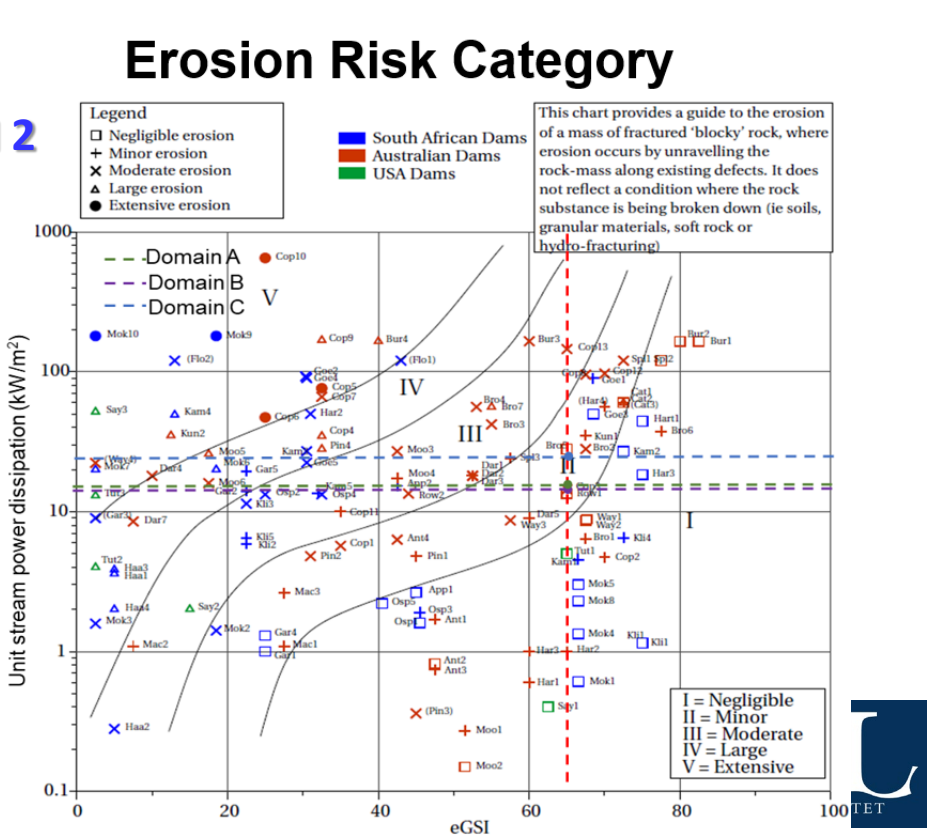
Empirical Analyses

- Using the geotechnical information obtained from site investigation and hydraulic parameters supplied by the owners of the two dams, empirical analyses were conducted using two established empirical methods, Annandale and Pells, to assess erosion potential of the dams.
- Of the two empirical methods the results from the Pells method are shown below. Pells method describes erosion potential in terms of risk and is therefore considered as best erosion potential assessments.
- Dam 1 is in 'Category III' (moderate erosion risk) and Dam 2 is in 'Category II' (minor erosion risk). The results also confirm field assessments.

DAM 1

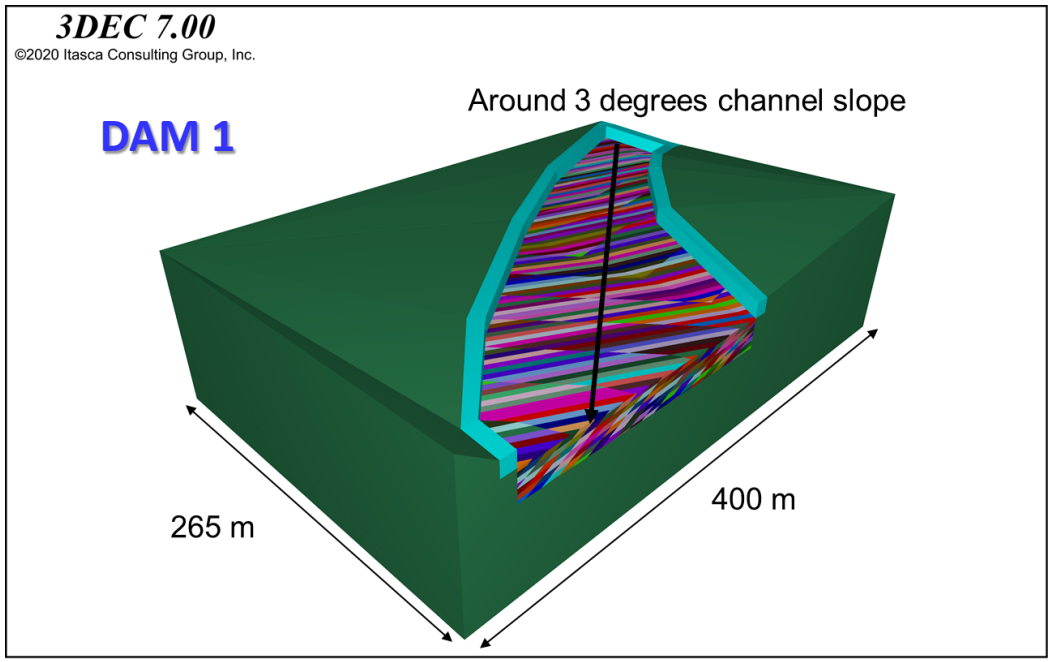


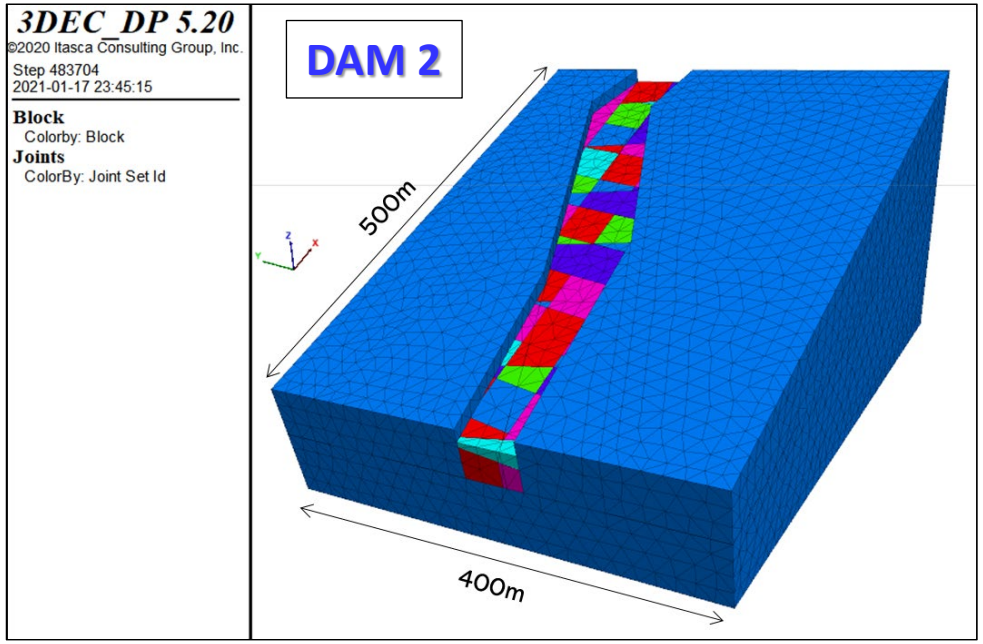
DAM 2



Numerical Analyses

- Hydro-mechanically coupled 3DEC models were constructed to further study block erosion potential of the two dams' canals. The models are shown below.
- The models are build on the actual topographic profiles of the canals. And mapped joints were added to model to create the fractured rock mass in the canals
- Prior to that a series of parameter study was conducted on a single block to assess sensitivity of hydraulic and rock mass parameters.





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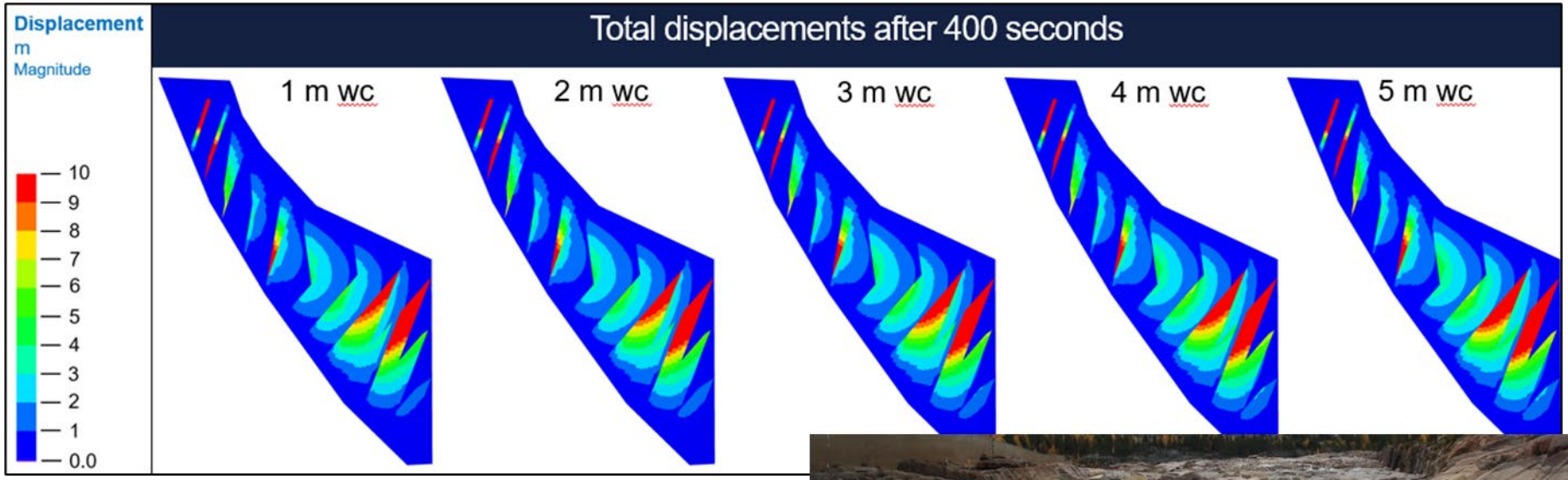
Numerical Analyses

Results from Dam 1 model shows that:

- Slaps formed by shallow dipping joints in the direction of flow significantly influence block erosion
- The change in channel geometry and profile downstream also affects erosion potential, with flow occurring favourably to the shallow dipping rock blocks.
- Displacements observed from 100 and 400 seconds flow time are similar in magnitudes, indicating that much of block displacement occurs within several minutes (2-3 minutes)



Numerical Analyses

Results from Dam 2 model shows that:

- Increased displacements are observed in areas where joints intersect to rock blocks.
- It was observed that blocks sizes of less than 0.5 m3 highly vulnerable to erosion
- Like Dam 1 most of displacements occur within several minutes (2-3 minutes)
- Dam 2, however, shows higher erosion risk than Dam 1.

This photo was taken at the location where the channel makes a bend. ‘Coincidental or not’, it precisely matches the location the 3DEC model shows high displacements around a wedge formed in that area

Conclusion

- Block erosion observed at the two dam canals involved 3 mechanisms, (i) abrasion , (ii) plucking and (iii) fracturing. And three factors affect block erosion, (i) canal rock mass characteristics (ii) canal geometry and (iii) hydraulic parameters.
- Both, Annandale's and Pell's methods show that there is a potential for erosion at the two spillways. Empirical analysis in this work shows that Pells' method is preferred for spillway erosion potential assessment.
- Block erosion in a spillway canal is a process affected by the coupled effects of hydraulic and mechanical parameters. A fully coupled hydro-mechanical model (as done in this study) best captures interaction between the hydraulic and mechanical factors.
- The single block model indicated some important controllers for block erosion which include: This includes the effect of (i) block size (ii) flow velocity (iii) water column height and (iv) slope gradient
- Results from simulation of the two spillways show that much of the erosion occurs under 10 minutes, in fact the first 2 to 3 minutes are critical.
- Two ways to control erosion are (i) put controls on factors that influence erosion, mainly hydraulic factors and canal geometrical factors and (ii) controls on the basis of erosions mechanisms, such rock bolting, concrete reinforcement, engineered erosion, etc.