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# Rock mass characterisation and stability analyses of excavated slopes

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Excavated slopes in fractured rock masses are frequently designed for open pit mining, quarries, buildings, highways, railway lines, and canals. These slopes can reach heights of several hundreds of metres and in cases concerning open pit mines slopes larger than 1000 m are not uncommon. Given that deep-seated slope failures can cause large damage or even loss of life, the slope design needs to incorporate sufficient stability. Thus, slope design methods based on comprehensive approaches need to be applied. Excavation changes slope angle, groundwater flow, and blasting increases the degree of rock mass fracturing as well as rock mass disturbance. As such, excavation leads to considerable stress changes in the slopes.

Generally, slope design rely on the concept of factor of safety (FOS), often a requirement by international or national standards. A limitation of the factor of safety is that time dependent failure processes, stress-strain relationships, and the impact of rock mass strain and displacement are not considered. Usually, there is a difficulty to estimate the strength of the rock mass, which in turn is controlled by an interaction of intact rock and discontinuity strength. In addition, knowledge about in-situ stresses for the failure criterion is essential. Thus, the estimation of the state of stress of the slope and the strength parameters of the rock mass is still challenging. Given that, large-scale in-situ testing is difficult and costly, back-calculations of case studies in similar rock types or rock mass classification systems are usually the methods of choice. Concerning back-calculations, often a detailed and standardised documentation is missing, and a direct applicability to new projects is not always given. Concerning rock mass classification systems, it is difficult to consider rock mass anisotropy and thus the empirical estimation of the strength properties possesses high uncertainty.

In the framework of this study an approach based on numerical discrete element modelling (DEM) in combination with limit-equilibrium (LE) methods are presented. The advantage of DEM methods is that failure and displacement of discontinuities and the intact rock for the investigation of failure mechanisms and slope deformations are considered. Furthermore, DEM methods have its strength when rock masses are highly anisotropic and slope failure is structurally controlled. Herein DEM methods are applied to model potential failure geometries, which in turn serve as basis for further investigations by limit-equilibrium methods. LE-methods are used to determine the factor of safety for the pre-defined failure geometries where a sliding mechanism with a discrete and pre-defined basal shear zone is the most likely kinematical failure mode. In this study a parameter variation was performed to find the most reliable FOS based on field estimated strength parameters and the critical strength parameter where a FOS is equal to one (i.e. the lower limit for the parameters). Furthermore, the sensitivity of the shear strength parameters is studied, which enables plausibility checks with field measurements and back-calculated values.

The combined approach can help to gain a better insight into failure processes and deformation mechanisms and facilitate to perform a parameter-variation study at a reasonable time frame.