NUMERICAL MODELLING OF LONG-TERM "ROCK-STRUCTURE" INTERACTION OF MINE SHAFT BEYOND DESIGN LIFE SPAN: A CASE STUDY

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This paper investigates the long-term interaction between mine shaft structures and surrounding geological formations, with a specific focus on recesses within the shaft designed for equipment installation. The analysis is conducted in the context of challenging geological conditions, specifically salt and salt-bearing rock formations such as rock salt, sylvinite, carnallite, anhydrite with rock salt inclusions. The study aims to predict the stress-strain state of these structural elements as they approach and exceed their original design life span. By assessing their serviceability during the anticipated period of structural degradation, the analysis also evaluates the impact of various reconstruction methods on the integrity of adjacent structures in the mine complex.

Initially, a comprehensive modelling prediction of the interaction between the mine structures and the surrounding rock mass was made, taking into account both the design life and the long period of operation thereafter. The modelling approach included the Mohr-Coulomb and Rankine criteria for time-independent plasticity of rock, alongside the Double Power Law for creep behaviour. For the reinforced concrete components, the Concrete Damage Plasticity model was employed to represent the concrete behaviour, while the Von Mises model was used to simulate the steel reinforcement response. Discrete rebar was modelled as embedded one-dimensional elements, while rigid reinforcement structures like I-beams and external columns were represented using shell elements.

As soon as the loading exceeded the design specifications, several defects in the structures were identified during modelling. These included buckling of some components (Fig. 1), severe damage to reinforced concrete (Fig. 2), including cracks of more than 15 mm in critical areas of the equipment foundations.

Fig 1. Buckling of columns in shaft recesses under increased loads

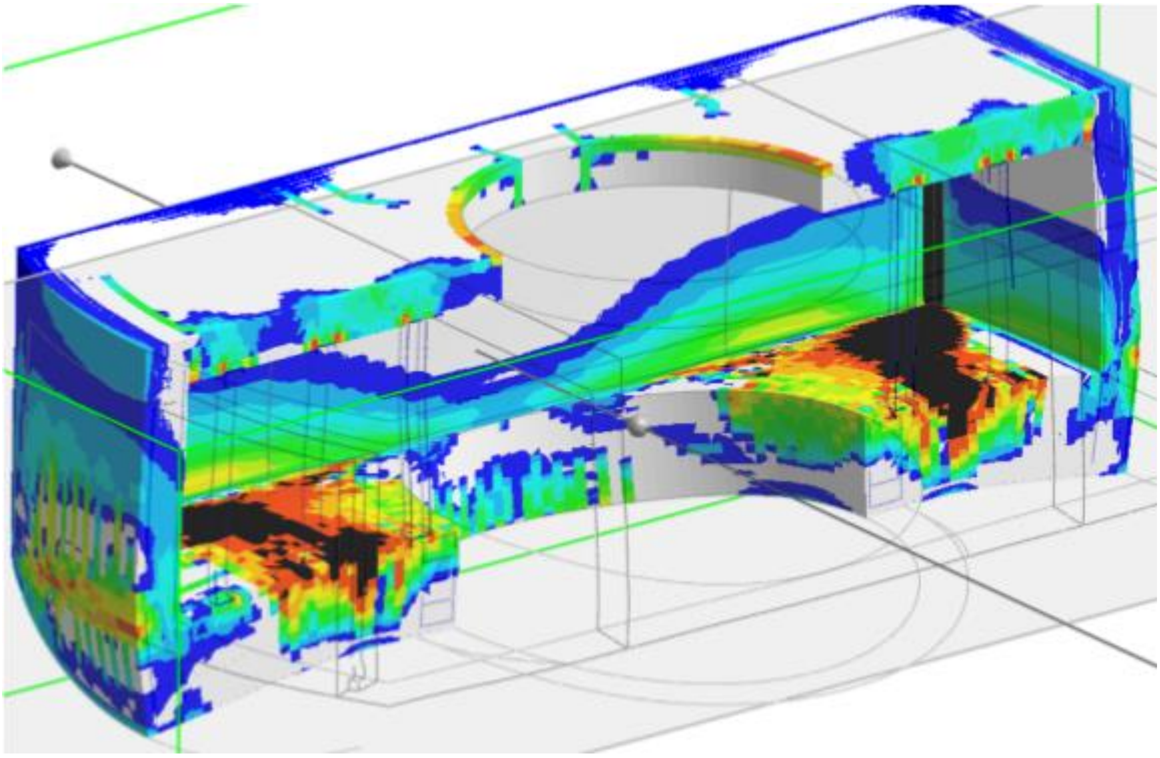

Fig 2. Crack development in reinforced concrete structure

An extensive analysis of shaft reconstruction scenarios was carried out, which included various methods of partial demolition of the damaged structures and/or modification of the design schemes with additional reinforcement of the remaining parts, as well as excavation of the access workings (Fig. 3). These scenarios were aimed to address both immediate safety concerns and the long-term stability of the mine infrastructure.

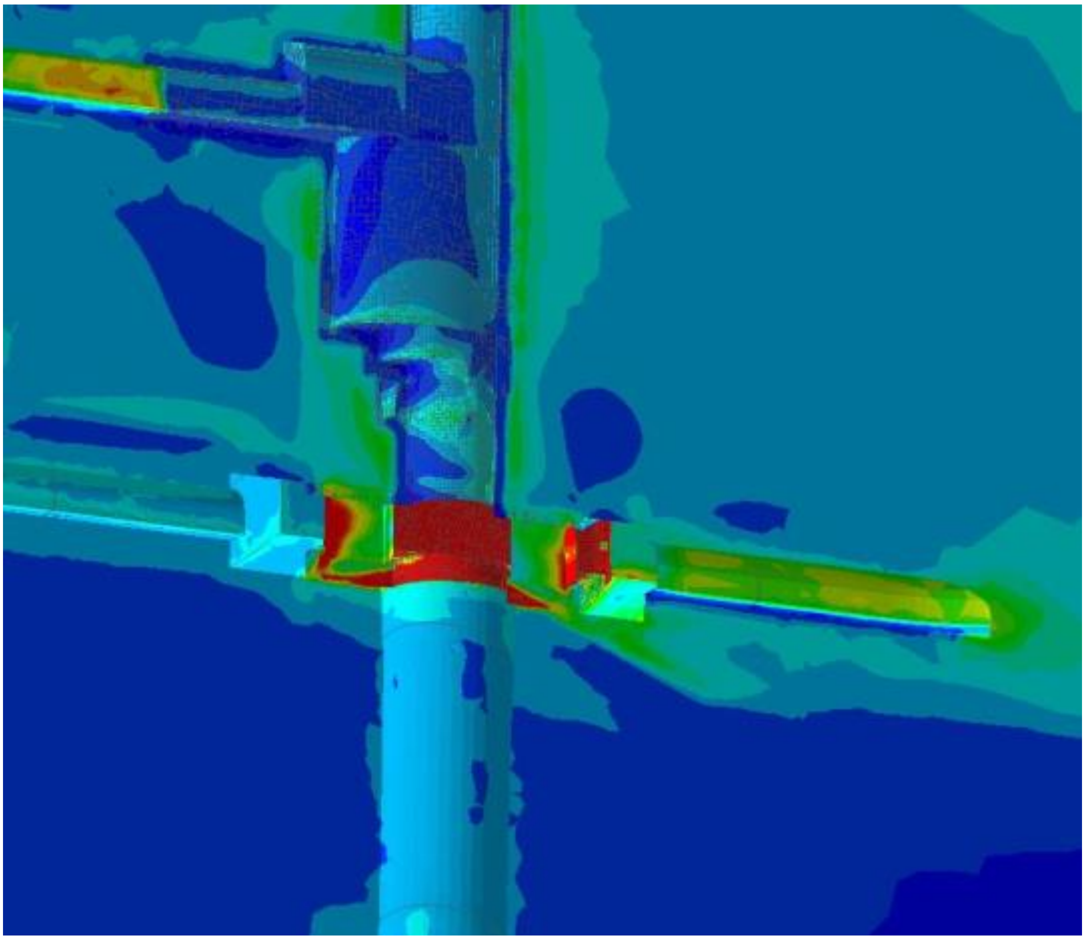

Fig. 3. Prediction of geomechanical processes and the influence of the reconstruction works on the shaft junction

A detailed processing of the numerical modelling results was carried out to identify potential failure modes and assess the potential for instability under different conditions and their scenarios. The study analysed multiple failure mechanisms, taking into account factors such as progressive deformation, creep effects and long-term degradation of material properties. Particular attention was paid to the impact of these failure scenarios on the overall stability of the mine and the relationship with the upper level structures (Fig. 4).

Based on the analysis, recommendations have been formulated to identify the unacceptable repair strategies and operational solutions. A special emphasis should be placed on measures to change the monitoring scheme and frequency, which will not only prevent unacceptable deformation scenarios, but also optimise the implementation of proactive maintenance measures to extend the life of the mine shaft.

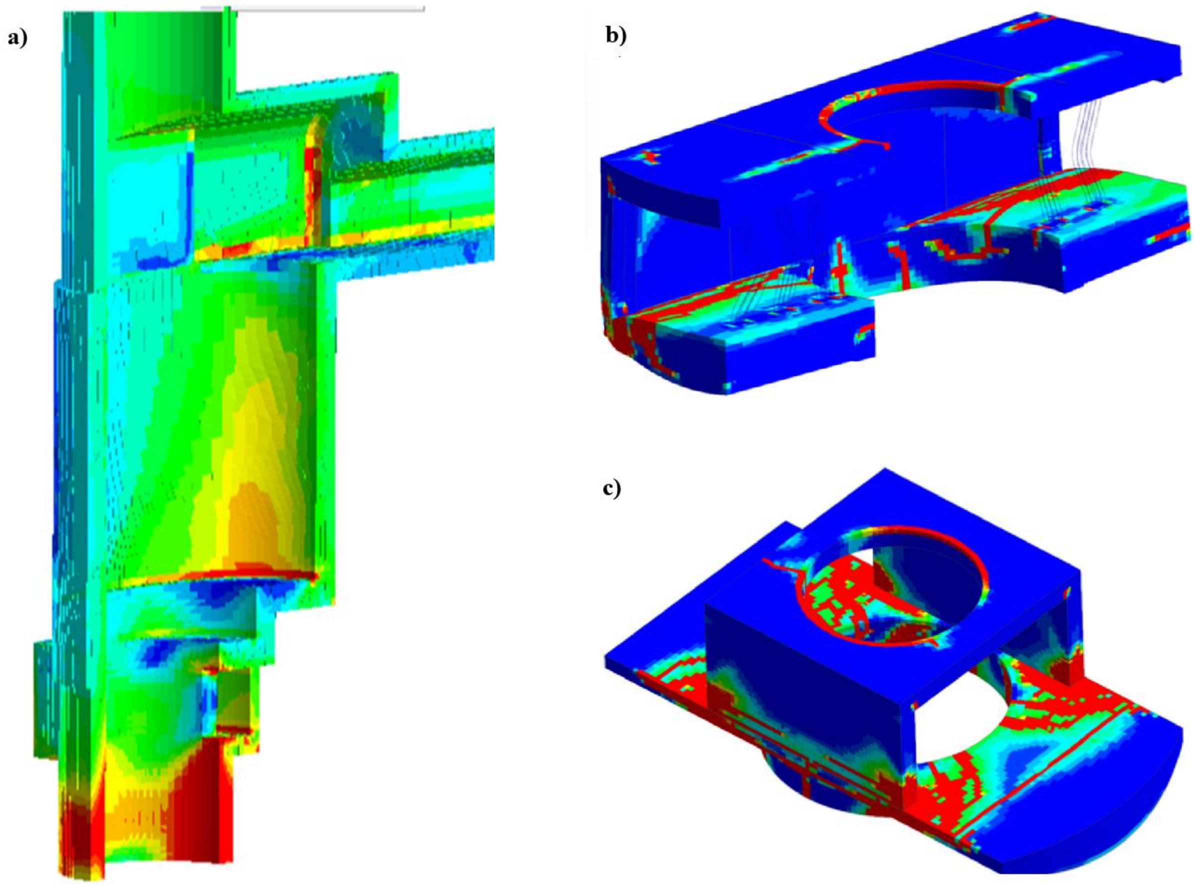

Fig 4. Typical patterns of additional deformation fields (a), predicted limit state scenarios of modified design schemes of shaft recesses (b, c)

The results of this study show experience in the successful application of advanced numerical modelling techniques to predict the long-term behaviour of rock-structure interaction. Furthermore, the proposed approach provides a framework for evaluating the effectiveness of different repair strategies to mitigate the risks associated with structural degradation beyond the design life of the mining infrastructure.

This study highlights the critical role of predictive modelling in the decision-making process, contributing to a more reliable assessment of structural integrity and the development of cost-effective solutions for extending the service life of mine shafts and associated underground structures.