# NUMERICAL MODELING OF NON-UNIFORM LOADING ON SUPPORT STRUCTURES DURING SHAFT SINKING IN COMPLEX GEOTECHNICAL CONDITIONS

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This study presents a comprehensive investigation of the shaft sinking process utilizing the ground freezing method, aimed at mitigating potential geomechanical risks in a challenging geotechnical setting. The research focuses on a site characterized by a complex geological structure, including a local disturbance near water-saturated rock layers within the excavation influence zone of the mine shaft (Fig. 1). The presence of geological complexities, such as folds and cavities, pose significant risks that require a careful approach to both the design and construction phases of the project.

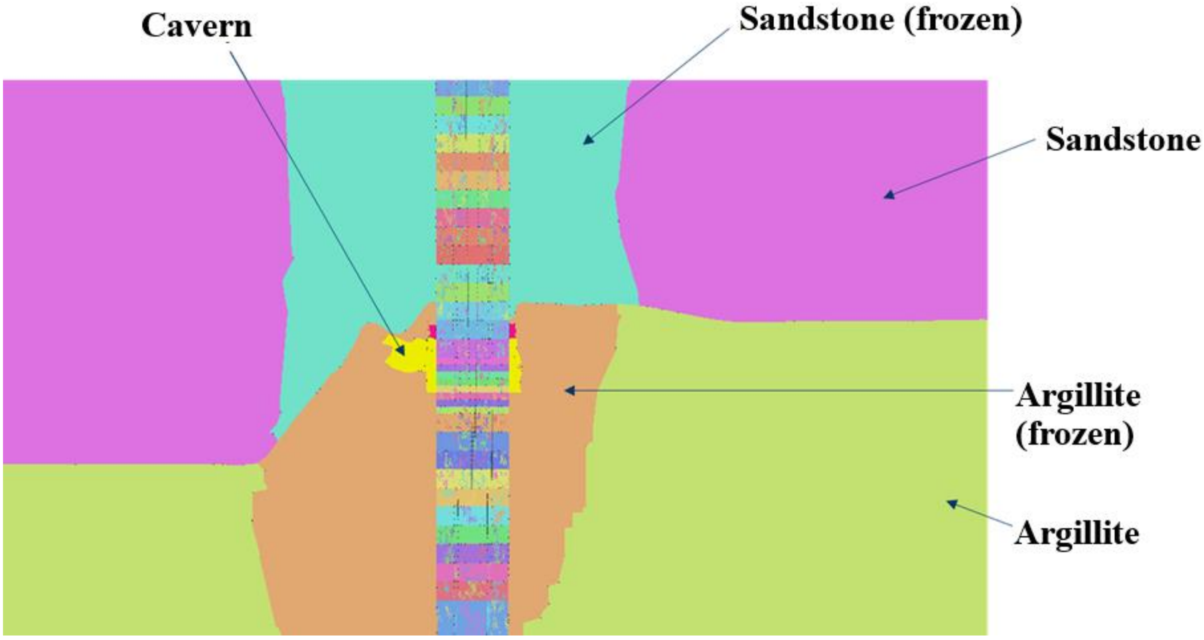


**Fig 1. Schematic layout of the geotechnical situation around the mine shaft**

As an initial data, a comprehensive investigation of this geological zone was conducted using a series of exploratory borings and various geophysical methods to provide a detailed understanding of its structural characteristics. Using the collected data, we developed a modified three-dimensional model that formed the foundation for thermophysical forecasts that included detailed consideration of the freezing wells configuration (Fig. 2). These predictions were extensively refined and calibrated against real-time monitoring data, achieving a high level of accuracy that formed the basis for further studies.

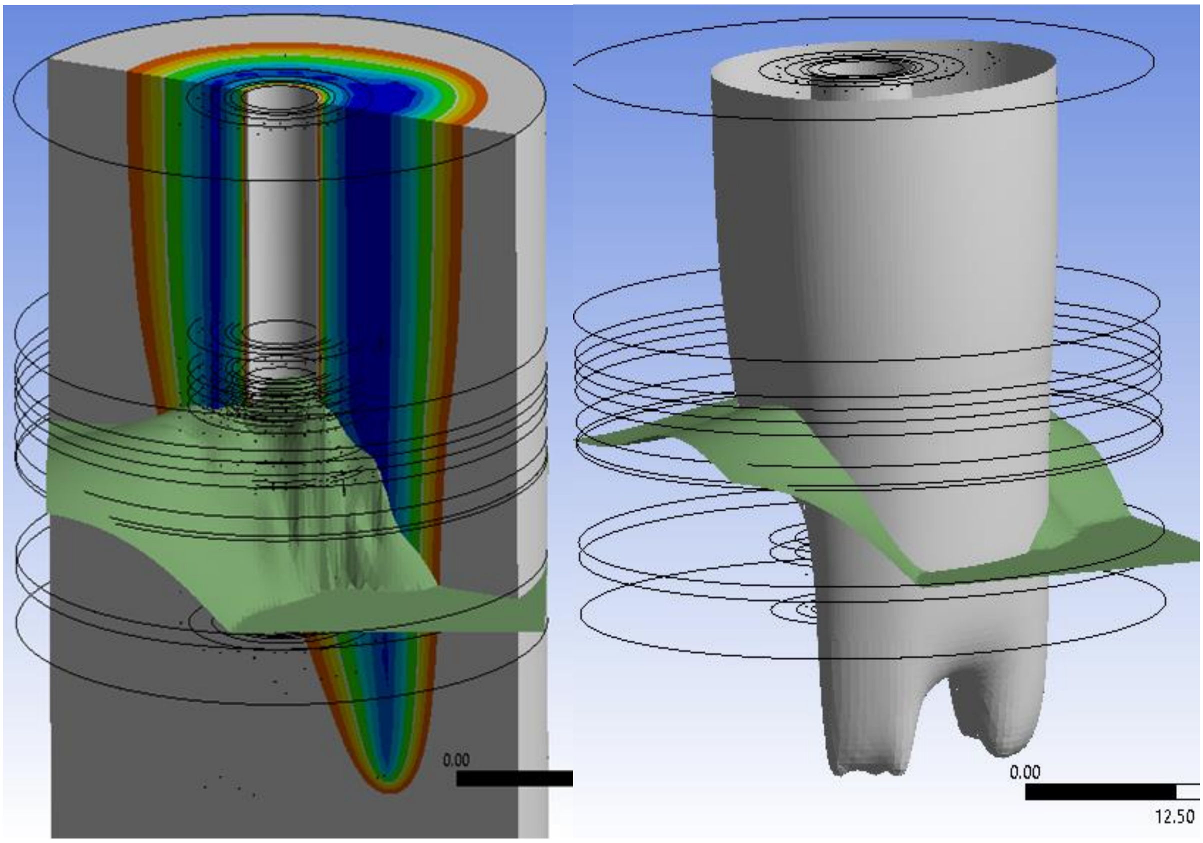


**Fig. 2. Temperature field inside the frozen zone (left) and its boundary surface for one of the stages (right)**

Central to this study is the analysis of the mechanical interaction between the shaft lining and the surrounding geological formations, especially under non-uniform loading conditions. The modelling process focused on the sequence of excavation phases and the time effects on rock stability (Fig. 3). This sensitive approach allowed for an in-depth study of the dynamic processes occurring in the geological environment during the excavation phase.

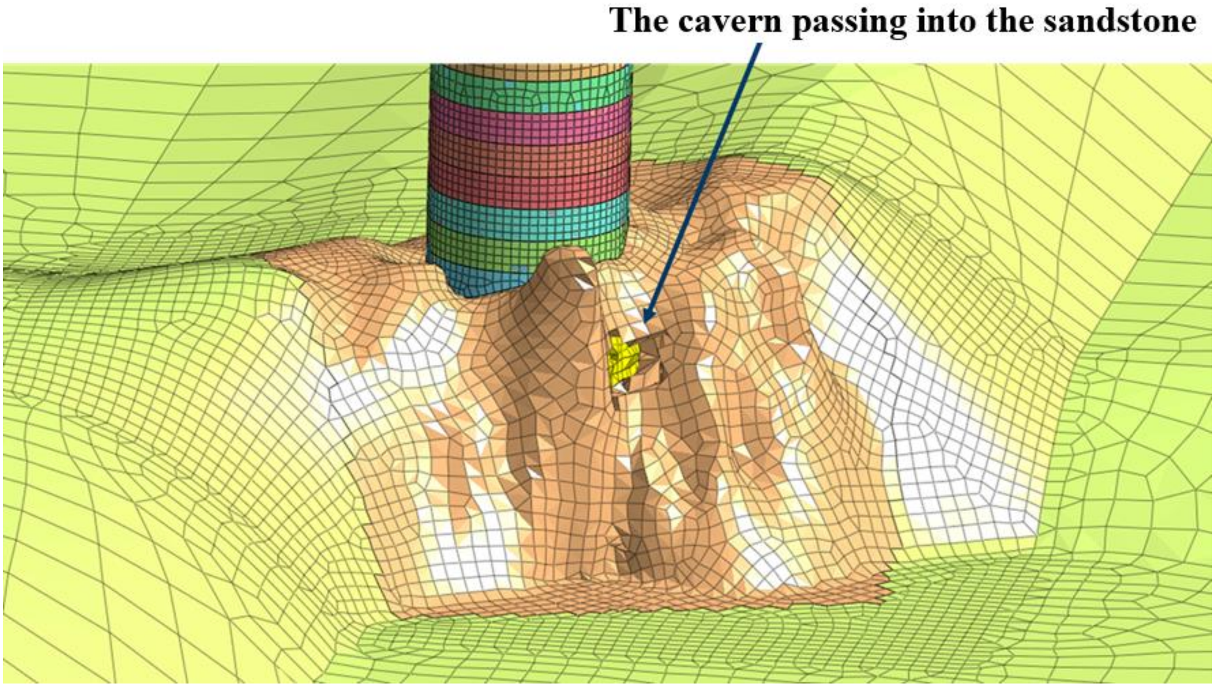

**Fig 3. Fragment of finite element mesh in the area of a cavern**

As the main practical value, the initial design solutions proposed by third-party organisations were reviewed, focusing on the reliability of the lining, the acceptable deformation limits of the surrounding rocks, and the identification of potential risks and negative scenarios caused by geomechanical processes in this zone. The results revealed specific mechanisms of interaction between the lining and the surrounding rocks (Fig. 4), which allowed the development of focused recommendations aimed at optimising design solutions to improve shaft stability in the face of complex geological challenges.

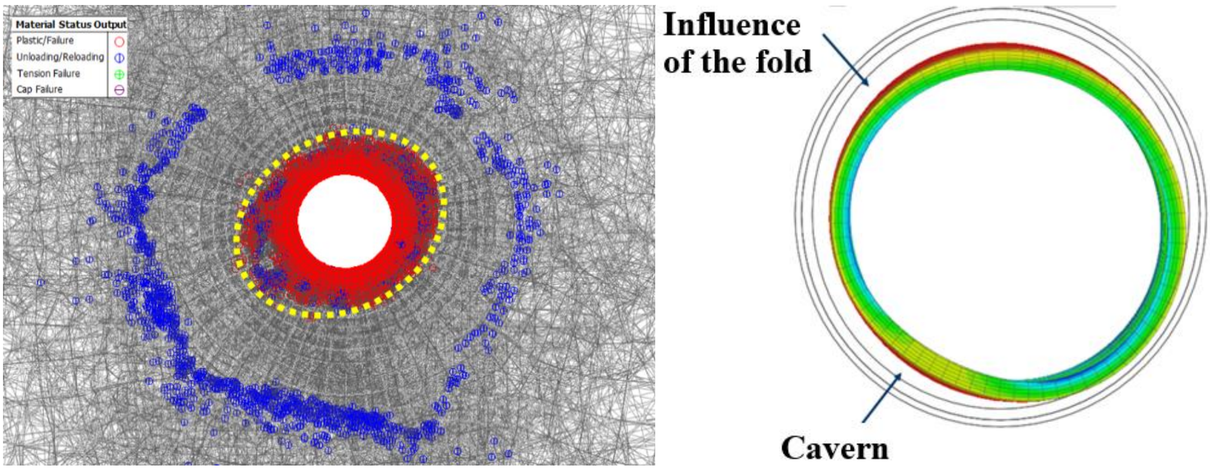

**Fig 4. Plastic zones in the rock at one of the intermediate stages (left) and deformed mesh of one of the cast-iron support rings (right, displacements scaled)**

In conclusion, the findings from this research highlight the critical need for a comprehensive strategy to address the multidisciplinary challenges associated with shaft sinking in geotechnically challenging environments, and the need to develop advanced input data for such numerical studies. Using a combination of field methods, re-interpretations of results from various operations and advanced thermophysical modelling, a robust underlying dataset for detailed mechanical analysis of lining-rock interaction has been provided. This framework not only improves our understanding of geomechanical processes, but also significantly reduces the risks associated with excavation, contributing to safer and more efficient mining operations.