



Research article

Numerical Modeling for Determining the Optimal cable Bolt Pattern in the Stability Analysis of Underground Spaces

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Keywords

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English Extended Abstract

Summary

One of the most important challenges in underground excavation projects is ensuring stability in weak ground conditions. Cable bolts are widely used as a reinforcement system due to their high load-bearing capacity and flexibility in various geological environments. In this study, numerical modeling using FLAC3D was conducted to evaluate different cable bolt patterns, including conventional, short-long, and spiral arrangements. The results showed that the short-long pattern, with alternating bolt lengths of 5 and 7.5 m at a spacing of 1.5×2.2 m, reduced tunnel displacement from 7.0 cm (Sakurai's allowable limit) to 5.5 cm while lowering cable consumption by about 10% (equivalent to 175 m in a 28 m tunnel). The spiral arrangement using 7.5 m bolts achieved the lowest displacement (3.5 cm), although it required more complex installation. Overall, the short-long pattern was identified as the most practical and cost-effective option, balancing stability improvement and material savings, and is therefore recommended as the optimal support design in weak ground conditions.

Introduction

The stability of underground excavations is one of the most critical issues in mining and civil engineering. Among the available support systems, cable bolts are widely applied due to their high load-bearing capacity and suitability in weak ground conditions. However, inappropriate design or arrangement may lead to unnecessary material consumption or insufficient support. This study focuses on determining an optimal cable bolt pattern to enhance tunnel stability while minimizing material usage.

Methodology and Approaches

A continuous medium was numerically modeled using FLAC3D software to simulate the behavior of underground tunnels supported by cable bolts. Several bolt patterns were investigated, including the conventional arrangement, the short-long alternating pattern, and the spiral arrangement. The analysis considered tunnel displacement, plastic zone development, and material consumption to evaluate the efficiency of each support scheme.

Results and Conclusions

Simulation results showed that the short-long cable bolt pattern significantly reduced tunnel displacement compared to the conventional arrangement, achieving stability with about 10% less material consumption. The spiral arrangement further decreased displacement but required more complex installation. Overall, the short-long pattern was identified as the most practical and economical

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option, providing improved stability while reducing support costs.

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