Postprint: Study on Mechanical Response of Tunnel Excavation in Deep Soil-Rock Mixture Backfill Using Discrete-Continuous Coupling Method

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Abstract

Southwestern China is widely underlain by deep and thick strata of coarse-grained soil-rock mixture (SRM), which pose serious threats to construction and operational safety due to their loose structure, high porosity, and abundant rock blocks. Tunnel excavation in such deep-buried, fractured, and highly heterogeneous backfill materials often exhibits complex mechanical responses, rendering conventional design and prediction methods inadequately applicable. In light of this, this study employs a coupled finite difference method and discrete element method (FDM-DEM) framework to systematically investigate the mechanical responses induced by tunnel excavation in SRM. The analysis focuses on the influence of excavation methods (full-face method, bench cut method, and core soil reserved method), burial depth, tunnel diameter, and stone content on surrounding rock stability. Additionally, the role of pipe roof support parameters (pipe diameter, spacing, and installation angle) in suppressing deformation and fracture propagation is evaluated. The results demonstrate that the core soil reserved excavation method provides more significant control over surrounding rock deformation and stress concentration under conditions of greater burial depth. Increased burial depth induces a crown-dominated failure mode and substantially increases displacement. Increased stone content can alter the load transfer path and enhance overall structural stability through strengthened particle interlocking, while simultaneously causing migration of failure locations. Larger tunnel diameter intensifies excavation disturbance, necessitating more robust support measures to ensure crown stability. Furthermore, pipe roof support with larger pipe diameter and smaller spacing significantly reduces grouting body fracture and improves deformation control capability. The installation angle exhibits a nonlinear influence on support effectiveness: support performance is optimal at moderate inclination angles, whereas excessive inclination angles tend to induce stress concentration at the crown-sidewall junction. The research findings can provide theoretical support and engineering guidance for optimizing tunnel construction and support design in deep-buried coarse-grained SRM backfill, contributing to enhanced structural stability and reduced construction risk.

Full Text

Mechanical Effects of Tunnel Excavation in Deep Soil-Rock Mixed Backfills Based on a Discrete-Continuum Coupled Approach

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Abstract

In southwestern China, deep strata composed of coarse-grained soil-rock mixture (SRM) are widely distributed. Due to their loose structure, high porosity, and substantial rock block content, these formations pose serious threats to construction and operational safety. Tunnel excavation in such deep-buried, fractured, and highly heterogeneous backfill materials often exhibits complex mechanical responses that conventional design and prediction methods cannot effectively address. In view of this challenge, this study employs a coupled finite difference method and discrete element method (FDM-DEM) framework to systematically investigate the mechanical responses induced by tunnel excavation in SRM.

The analysis focuses on the influences of excavation methods (full-face method, bench cut method, and core soil retention method), burial depth, tunnel diameter, and rock content on surrounding rock stability. Additionally, the role of pipe roof support parameters (pipe diameter, spacing, and installation angle) in suppressing deformation and fracture propagation is evaluated. Results indicate that the core soil retention excavation method demonstrates superior control over surrounding rock deformation and stress concentration under greater burial depths. Increased burial depth induces a vault-dominated failure mode and significantly amplifies displacement. Higher rock content alters load transfer pathways and enhances overall structural stability through improved particle interlocking, while simultaneously causing migration of failure locations. Larger tunnel diameters intensify excavation disturbance, necessitating more robust support measures to ensure vault stability.

Furthermore, pipe roof support configurations featuring large pipe diameters and small spacing significantly reduce grout body fracture and improve deformation control capability. Installation angle exhibits a nonlinear influence on support effectiveness: moderate inclination angles yield optimal support performance, whereas excessive inclination angles tend to induce stress concentration at the vault-sidewall junction. The research findings provide theoretical support and engineering guidance for optimizing tunnel construction and support design in deep-buried coarse-grained SRM backfills, thereby helping to improve structural stability and reduce construction risks.

Keywords: soil-rock mixture; loose strata; numerical simulation; tunnel excavation; pipe roof support