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# Research on Bolt-Grouting Reinforcement Technology for Deep Soft Rock Roadways

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## ABSTRACT

With the continuous development of coal mining into deeper strata in China, the effective support of deep soft rock roadways has become one of the key challenges restricting safe and efficient mine production. In response to the complex engineering conditions of the deep soft rock at the 140505 working face of Kouzidong Coal Mine, a non-uniform bolting-grouting support technology was adopted, which combines conventional bolting and grouting reinforcement with additional strengthening at the shoulder zones. Numerical simulation results demonstrate that after the implementation of the bolting-grouting support, the maximum roof subsidence was reduced from 762 mm to 242 mm, and the floor heave decreased from 404 mm to 106 mm, indicating effective control of the surrounding rock deformation. This approach provides a reliable guarantee for safe and efficient mine production.

## KEYWORDS

Deep Mine; Soft Rock; Bolt-Grouting Reinforcement; Numerical Simulation.

## 1. INTRODUCTION

Soft rock roadways, deep roadways, and their composite types account for approximately 70% to 80% of all coal mine roadways in China [1], representing a significant proportion of underground engineering projects. Such roadways frequently experience failure during their service life, requiring repeated maintenance and repair. This not only substantially increases support costs and makes coal resource extraction considerably more challenging, but also poses serious threats to mine safety.

For roadways with weak surrounding rock and large loosening zones, rock bolting with shotcrete—typically employing uniformly distributed bolts—is commonly used both domestically and internationally. However, this method often proves inadequate in effectively controlling surrounding rock deformation [2, 3]. The primary reason lies in the fact that most bolts are installed within the limit equilibrium zone or fractured zone of the rock mass, where they cannot provide a reliable load-bearing foundation for the support system [4, 5]. As a result, the intended arching mechanism is often difficult to achieve. Therefore, further investigation into the control of surrounding rock in such roadways carries important theoretical significance and engineering value.

This study is conducted within the context of the Kouzidong Coal Mine operated by China Coal Xinji Energy Co., Ltd. Based on a comprehensive analysis of roadway deformation and failure mechanisms, a support strategy emphasizing "grouting reinforcement as the foundation with supplemental strengthening in critical areas" is proposed. The feasibility of this technique is validated through numerical simulations, providing a valuable reference for controlling surrounding rock in deep soft rock roadways under similar conditions.

## 2. ENGINEERING GEOLOGICAL CONDITIONS

The 140505 working face is situated at the -967 m level in the 1405(8) mining panel, serving as the fourth working face within this panel. It is bounded by the development roadway along the west wing to the south, the FS6 fault to the north, the DF31 fault to the west, and the goaf of the adjacent 140504 working face to the east.

Under the original support conditions, the surrounding rock of the 140505 maingate roadway at the Zhongmei Xinji Kouzidong Mine exhibited significant deformation. Monitoring data indicated that, at a location 350 m from the roadway entrance, the roof subsidence in certain sections exceeded 300 mm within four months after excavation, accompanied by fractures in the support straps. During a continuous 26-day observation period after excavation, the maximum convergence of the two sidewalls reached 520 mm, and the maximum roof-to-floor closure was approximately 820 mm, of which floor heave accounted for about 600 mm. Frequent floor heave necessitated floor dinting approximately every two months. Repeated dinting operations further compromised the overall stability of the surrounding rock, exacerbating both deformation and failure.

## 3. NON-UNIFORM BOLT-GROUTING SUPPORT TECHNOLOGY

Excessive horizontal stress is a critical factor leading to compressive failure in the roadway roof, which subsequently triggers overall instability of the surrounding rock. Therefore, effectively mitigating roof damage induced by horizontal stress is essential for achieving surrounding rock stability. Special attention must be paid to the shoulder area of the roadway, which is identified as a key zone for reinforcement. Conventional support methods, which typically employ uniformly distributed bolts, often fail to adequately counteract damage caused by horizontal stress. Instead, a targeted bolt arrangement strategy is required to achieve effective control. In response, a “non-uniform” support approach is proposed, emphasizing intensified reinforcement specifically in the critical shoulder regions, with the objective of enhancing the overall stability of the surrounding rock.

During the development of the roadway at the 140505 working face, a combined support system consisting of rock bolts, mesh, and cable bolts with cable beam suspension was employed. Based on the observed deformation and failure patterns of the surrounding rock in the maingate roadway of the adjacent 140506 working face, as well as the stress behavior of hydraulic props in the advanced support section, targeted reinforcement was applied to areas experiencing significant deformation, particularly at the shoulder zones of the sidewalls. Pre-grouting holes were drilled in both sidewalls and the roof, followed by injection of reinforcing materials to improve the stability of the surrounding rock.

Mine-type 12# I-beams were used to fabricate the cable suspension beams. The transverse beams measure 4000 mm in length, while the longitudinal beams are 4500 mm long. Each beam is equipped with four cable bolts spaced at 1200 mm intervals, with each cable bolt having a length of 9.2 m. Three rows of cable suspension beams were installed parallel to the roadway axis. The central row is positioned 145 mm to the right of the roadway centerline, and the two outer rows are located 1640 mm from the centerline on each side. The longitudinal cable beams were connected in an overlapping manner, with an overlap length of no less than 450 mm.

## 4. NUMERICAL SIMULATION

Based on the actual geo-mining conditions and spatial layout of the roadway at the 140505 working face in Kouzidong Mine, a numerical model was established as shown in Fig. 1. The dimensions of the model (length × width × height) were set to 356 m × 300 m × 40 m. The Mohr–Coulomb failure criterion was adopted for the simulation, and the working face was assumed to advance along the Y-axis.

The bottom and four lateral sides of the model were assigned fixed boundary conditions with zero displacement constraints, while the top surface was set as a free boundary. Given the average burial depth of the 140505 working face of 920 m, a vertical stress of 23 MPa, equivalent to the overburden pressure, was applied to the top of the model based on an estimated unit weight of 2.5 MPa per 100 m of depth. A lateral pressure coefficient of 0.8 was used to simulate the in-situ horizontal stress.

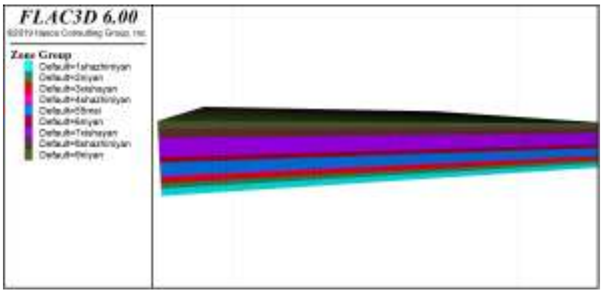
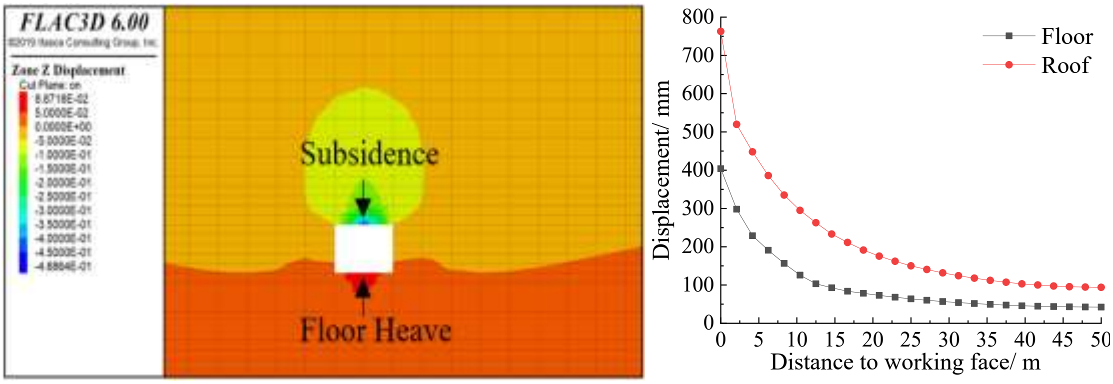



**Figure 1.** Numerical Simulation Model




(a) Nephogram (b) Curve

**Figure 2.** Vertical Displacement Distribution Without Grouting

The vertical displacement of the surrounding rock in the roadway is primarily manifested as roof subsidence and floor heave. As shown in Fig. 2(a), after excavation, the roof experiences noticeable sinking, with the maximum displacement occurring at the center of the roof. Similarly, the maximum floor heave is observed at the center of the roadway floor. Based on the nephogram of vertical displacement, it can be concluded that the surrounding rock of the coal pillar side exhibits significant overall settlement.

According to the analysis of Fig. 2(b), the maximum roof subsidence after excavation reaches 762 mm. Significant vertical displacement occurs within a range of 16.6 m from the roof surface, beyond which the displacement decreases sharply. The maximum floor heave is 404 mm, with considerable vertical displacement observed within 12.5 m of the floor surface. Beyond this depth, the vertical displacement of the surrounding rock diminishes significantly.

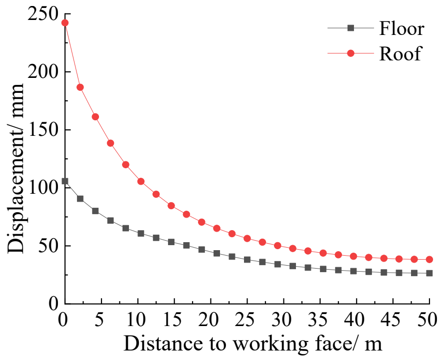



**Figure 3.** Vertical Displacement Distribution After Grouting

As shown in Fig. 3, after the implementation of the "non-uniform" grouting reinforcement technology in the 140505 maingate roadway, the maximum roof subsidence was reduced from 762 mm to 242 mm, a decrease of 68.2%. The floor heave decreased from 404 mm to 106 mm, representing a reduction of 73.8%. The surrounding rock deformation stabilized within 39.6 m ahead of the working face. These numerical simulation results demonstrate that the "non-uniform" grouting reinforcement technique effectively controls the deformation of the roadway surrounding rock, thereby ensuring safe and efficient mine production.

## 5. SUMMARY

After the implementation of the "non-uniform" grouting reinforcement technology in the 140505 maingate roadway, the peak roof subsidence was reduced by 68.2%, and floor heave decreased by 73.8%. This effectively controlled the deformation of the surrounding rock, providing crucial support for safe and efficient mine production.

## CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

## ACKNOWLEDGEMENTS

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