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Experimental study on the bolt–cable combined supporting technology for the extraction roadways in weakly cemented strata

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ABSTRACT

Aiming at the characteristics of the poor steady ability, the short stable time and severe deformation behavior of weakly cemented soft surrounding rock around extraction roadway, a bolt–cable combined supporting technology was proposed. Numerical simulation was performed by using FLAC3D software to study the effects of different supporting systems. The simulation result proves that those supporting systems have good practical values. Based on real-time monitoring and analysis of the deformation of surrounding rock and the stress of supporting structure, real time information of deformation of surrounding rock and stress state of supporting structure of extraction roadway within weakly cemented strata was obtained. Monitoring results show that large deformation and failure of surrounding rock of extraction roadway within weakly cemented strata can be effectively controlled by the bolt–cable combined supporting technology, which ensures the long-term stability and safety of surrounding rock and supporting structure.

1. Introduction

As the coal resource in mid-east region of our country decreases each day, many mines relocate to the west region with time. For most part of the west region, Inner-Mongolia included, the main coal-bearing strata is the Cretaceous and Jurassic strata and the rocks of coal-bearing strata are mainly soft rock of layered structure which is characteristic of poor cementation, low strength, weathering, mudding and softening in water [1–3]. The physical and mechanical characteristics of this weakly cemented soft rock are situated between soft rock and hard soil. Because of the poor steady ability, short stable time and severe deformation behavior of weakly cemented soft surrounding rock around extraction roadway, the bolt and cable can be hardly set. The coal roadway is not stable. The roadway support equipment is difficult to install, and the roadway is hard to stay stable after frequent renovation. The frequent roof caving accidents in the coal roadway within weakly cemented soft surrounding rock have severe effects on the coal mining efficiency and safety. Thus the coal mining progress in west region and exploiting depth are greatly constrained.

The typical cross-sectional shape of the mining roadway is rectangle shape. This rectangle roadway shape is hard to form in the weakly cemented strata. Thus shaped steel bracket is needed to keep the shape of the roadway and constant maintenances should be made to the shaped steel bracket. Although many domestic experts had done some research on the theory [4–8], took engineering practice on selection of mining roadway and solved some supporting technology difficulties [9–21], little research has been made on the supporting theory and supporting technology of the mining roadway within weakly cemented soft rock strata. Based on engineering project of the Xiyi mine in Wujianfang coalfield in Inner Mongolia, this paper studied the supporting theory and technology of the mining roadway within weakly cemented soft rock strata. Many engineering practices have showed that, for the roadway surrounding rock and the supporting structure under complex hydro-geologic and engineering geologic condition, the deformation behavior of roadway and the stress variation laws of supporting structure can be obtained through in-situ measurements [22–26]. According to New Austria Tunneling Method, through the analysis of in-situ monitoring results, further optimization of the design, construction program and information construction can be achieved. Real time monitoring and analysis on the deformation of surrounding rock and stress of supporting structure provides real time grasp of deformation behavior of surrounding rock and stress state of supporting structure. So timely estimation of the supporting efficiency and adjustment of the supporting design can be applied, which ensure the long-term stability and safety of surrounding rock and supporting structure.

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2. Mining roadway supporting system design in weakly cemented strata

The Xiyi coal mine locates at southwest Wujianfang coalfield, West Ujimqin flag, Inner Mongolia, and is developed by inclined shaft. The main coal-bearing strata belong to the BayanHua Group of Cretaceous. The roof and floor of the roadway are mainly poorly cemented mudstone, siltstone and sandstone. The coal-bearing strata have low physical and mechanical properties, and the strength of the roadway roof rock is lower than that of the coal-bearing strata. Strength weathering, muddy and disintegration phenomenon as well as loosening in water or after weathering also exist. For this kind of weakly cemented soft rock strata, it is difficult to set the bolt, cable and other supporting systems, which are extremely detrimental to the stability of the roadway.

Considering the characteristics of the poor steady ability, the short stable time and severe deformation behavior of weakly cemented soft surrounding rock around extraction roadway, two supporting methods are provided in this paper based on coal bed thickness and roadway depth. The roadway cross section takes the tangential arch shape with straight wall. When the coal seam is less than 10.0 m, the coal seam is too thin to be stably set. Thus combining with supporting method, bolt mesh and shaped steel bracket is selected to make sure the roadway to be stable and safe. When the coal seam is larger than 10.0 m, the coal seam is thick enough for the bolt and anchorage cable to exert their full potential, so the roadway global stability and safety can be guaranteed. Thus the bolt–cable combined supporting system is selected to support the roadway, as shown in Fig. 1.

For all coal seams in China, the exploiting depth is less than 1500 m. As roadway depth increases, the effect of gradually increasing in-situ stress on the deformation, stress and failure zones around roadways located in soft strata, increases. In addition, it can be observed that the instability of the roof increases, and the ribs fracture and the floor heave happen. Thus the floor, roof and ribs of the roadway require reinforcement.

The materials and its parameters of the bolt–cable combined supporting technology scheme are as follows: The bolt is 20 mm in diameter and 2400 mm in length with inter row spacing of 700 mm × 700 mm and the initial pretension value is not less than 50 kN. The bolt pallet is arch-shaped and has high strength, the specifications of which are 150 mm × 150 mm × 8 mm. The metal mesh is rhombic and made from Φ6.5 mm cold-drawn iron wire with inter row spacing of 50 mm × 50 mm. Steel backbar is made of round steel by welding and is used in the full face of the roadway. Two longitudinal steels are welded with spacing of 60 m in the bolt installation position. Anchor cable is produced by high strength and low relaxation pre-stressed steel strand with diameter of φ17.8 mm and length of 6000 mm. The layout is 3-2-3 with inter row of 1600 mm × 2100 mm. The pre-stress of anchor cable is not less than 150 kN. Anchor cable tray is high strength arch-shaped tray with specifications as 300 mm × 300 mm × 16 mm. The floor of the roadway is reinforced by injecting concrete with strength level of C35. The thickness of concrete in the floor and in the wall is 300 mm and 200 mm, respectively. One medium 2360 type and one slow 2360 type chemical resin sausages were used for the bolt; one medium 2360 type, one slow 2360 type and one super-slow 2360 type chemical resin sausages were used for the anchor cable. The floor concrete thickness is 300 mm and wall foot concrete thickness is 200 mm. The concrete strength level is C35.

3. Numerical study on the bolt–cable combined supporting technology

3.1. Numerical simulation model

FLCD^{3D} software is used to carry out the numerical simulation study on bolt–cable combined supporting technology in the extraction roadways within weakly cemented strata. The model scale is 60 m × 60 m × 60 m (length × width × height). And the model has 141600 elements and 147681 nods (See Fig. 2).

Both the bottom and lateral displacement are fixed in this model and gravity stress is applied on the surface according to

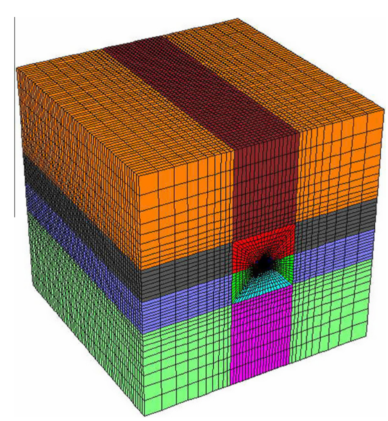
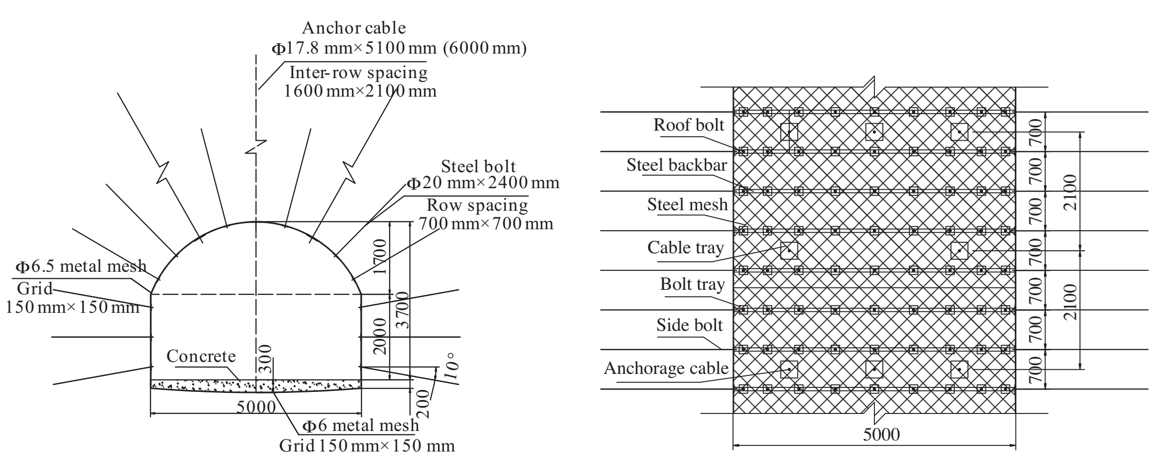


Fig. 2. Three-dimensional numerical simulation model established by FLAC3D.



(a) Front view (b) vertical view

Fig. 1. Combined supporting technology solutions of anchor wire rope in gateway.