The Application of High-Strength Yielding Bolt in −536 Air-Return Cross-Cuts

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Abstract The underground tunnel stress increased with the increasing of coal mining depth. And the support and stability of underground tunnel is more difficult in the areas of intense tectonic activity. The scientific support technology in soft rock environment with high geostress is the key factor to ensure the deep coal mining under the condition that the tunnel bolt support effect is not ideal in deep soft rock. In practice, mine support proved that the high-strength and high-pretension anchor bolts solved the supporting problems effectively in deep mines with high ground pressure.

Keywords Combined supporting • Deep soft rock • High geostress • High strength yieldable bolts

1 Introduction

In Wulong Mine Liujia section −536 of Fuxin Mining Group Co., Ltd, with ground level +179 m, the air-return cross-cuts facing very serious supporting problem during the excavation process. When digging the tunnel, the deformation of wall rock was severe, and the top plate and two sides were severely damaged, with large quantity of bottom squeeze (Yue Cai et al. 2004). After several times of renovated, it still could not control the deformation of tunnel. In most tunnels, the old method of digging in front and renovation behind were still used (Choi and Hee-Soon Shin 2004). Those kinds of process serious delayed the excavation speed and influenced the production safety. In order to solve the practical problems of tunnel deformation, the top plate were supported by full cable anchor (Qin zhengguang 2007; Kang

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Hong-pu 2000). This schema improved the support condition of tunnel, but the excavation speed was slow with high costs (Fan Ming-Jian and Kang Hong-Pu 2007). To solve the problem radically, we must study the supporting methods to explore a set of rational supporting schema (Dong Fangting et al. 1994, 1998).

The Liujia section −536 air-return cross-cuts were using semi-circular arch tunnel. The width of tunnel is 5,300 mm, and the height is 4,250 mm. The original top plates of tunnel were supported by bolt and strengthen anchor. The bolt interval was 800 × 800 mm, and the strengthen anchor interval was 1,200 × 3,200 mm. The two sides were supported by full cable anchor with interval 800 × 800 mm.

2 Geological Conditions

The surrounding rock of tunnel in Liujia section −536 air-return cross-cuts is interblended coal and rock. The Proctor coefficient of rock is 4 ~ 6. And the top plate of tunnel has a layer of thin seam. The surrounding rock histogram of air-return cross-cuts is illuminated as Table 1.

Table 1 The histogram of surrounding rock

Name of rock	Columnar	Layer thickness(m)	Cumulated deep(m)	Lithology description
Danks		0.9	13.28	Gray packsand
Packsand		2.4	12.38	Gray packsand
Coal		0.2	9.98	Black
Packsand		1.5	9.78	Gray and black
Danks		0.3	8.28	Gray and black slip surface
Packsand		1.0	7.98	Gray and black
Coal rock		0.5	6.88	Gray and black fragmentation
Packsand		1.9	6.38	Gray and black
Coal		0.1	4.48	Dark black
Packsand		0.8	4.38	Gray
Coal		0.15	3.58	Black
Packsand	Tunnel bottom plate	2.45	3.43	Gray
Coal		0.2	0.98	Black
Packsand		1.3	0.78	Gray and black
Coal		0.2	0.65	Black
Packsand		0.35	0.45	Gray and black
Coal		0.1	0.1	Black

3 Solution

3.1 Determination of Support Principle

Based on the underground observation analysis and geological conditions, the deformation type of tunnel is the typical appearance of highland stress. The supporting system could not control the expansion of the surrounding rock loose liquidity coil, and the phenomenon of anchor forces significant increased was not observed. It is said that the anchor supporting system did not play its due role (Hyett et al. 1992; Liu Quansheng et al. 2004).

There exist three problems. Firstly, the lack of anchor bolt installation load. Secondly, short of the anchor length. Thirdly, the surface control is not effective.

If we want the support system could control the expansion of broken area timely and effectively, the following principles must be meeting:

1. Support scope of anchor bolt. The length of anchor bolt should not be less than the range of the initial loose circle of tunnel excavation, and there should be at least 400 mm anchored in the stable area.
2. Installation stress of anchor bolt. The installation stress of anchor bolt is the important parameter to control the expansion of loose stave deformation coil of initial surrounding rock deformation. Too small installation stress will cause oversized early deformation in surrounding rock. Too big loose stove coil causing the roof broken, and the expansion of loose stove coil finally caused the bolt support failure.
3. Supporting strength. In condition of mining deep and high stress, once the prestressed anchor construction, the strength of anchor rod must be improved, which required the increased strength of single bolt.
4. Performance of deformable press-anchor. In order to prevent the bolt broken from excessive load, the bold must exist deformable yield pressure performance, and the pressure must be controlled in some extend. When anchor rod reaches the yield strength, the supporting system allow the yield pressure device let off the part surrounding rock deformation, play the role of protecting anchor bolt. At the same time, it ensured the stability of surrounding rock. Reasonable yield pressure performance should let the bolt has the stable yield pressure in a certain tonnage to ensure the support effect of tunnel and prevent the anchor from broken.
5. Surface control. In order to ensure the long-term stability of tunnel and prevent the anchor bolt failure, the surface control of tunnel is also very important.
6. Auxiliary support. Reasonable and effective auxiliary support could be integrated with the anchor bolt support to ensure the long-term effectiveness of tunnel, and adapted to the geological and mining conditions changes.

3.2 Determination of Bolt Support System Parameter

The anchor bolt parameter includes: the length of bolt, installation load of bolt, the arrangement of bolt, the diameter of anchor rod, interval of bolt, the extension yield pressure performance of bolt, the size and strength of tray, surface control, etc.

1. According the spot geological condition analysis, the air-return cross-cuts using bolt with the length of 2.4 m. And the bolt using across the faults and mudstone area is the length of 3 m.
2. The installation stress. For flow deformation surrounding rock, it must be have sufficient installation stress. According to the empirical analysis, the minimum bolt installation stress should be $5 \sim 6$ t, in order to prevent the expansion of loose flow area.
3. Diameter and strength of bolt. The bolt rod is using the D20HB500 high strength steel. Its yield strength is greater than 15.3 t, and the ensile strength is greater than 20.2 t.
4. Interval of bolts. The air-return cross-cuts has the array pitch of 900 mm, and the interval of 800 mm.
5. Yield pressure tube. Because of the large deformation of tunnel, the bolt supporting system will play its due role and resistant the deformation load of surrounding rock in condition of the suitable bolt length and installation stress. However, surrounding rock cannot be controlled. The high strength steel has low coefficient of elongation. The brittle rupture often happened in filamentosa. So the bolt system must have the ability of control yield pressure. Based on the selection of rod strength, the yield pressure of tube is $12 \sim 15$ t, and the length is 40 mm.
6. Anchorage length and anchor force. Each anchor selects 2 volume K2535 resin. The anchorage length is 1 m and the anchor force is greater than 23 t.
7. Size and strength of tray. The $150 \times 150 \times 8$ mm tray suitable to bolt was selected, and its strength is 23 t.
8. Surface control. The mental mesh and steel ladder is the methods of surface control to prevent the shedding of surrounding rock.
9. Guniting. The initial guniting is $30 \sim 50$ mm after tunnel excavation and the finial guniting is about 45 days. It is to ensure that the sprinkler body will not to be destroyed by the elastic deformation of tunnel.
10. Auxiliary support. In order to improve the service life of the tunnel to adapt the changes of geological conditions, the bolt cable is used as the auxiliary support. The length of bolt is 9 m. The anchor diameter is 17.78 mm and the interval is 1600×1800 mm.

3.3 Surface Control

The tunnel was excavated in soft rock with the influence of dynamic pressure; surface control has very important effect in give full play to the role of bolt

supporting system. The effective surface control system should guarantee against spalling and roof fall. Bolt and surface control systems together to form the best composite beam. Surface control include High-strength tray (it match bolt strength), steel strip (H section steel with bolt can become one, which has a good surface control effect), Metal net (it can prevent roof leakage; its self-deformation can control the deformation of the two sides); Combined with the bolt, steel strip to form a whole, the support system can be enhance (Jarred and Haberfield 1997).

3.4 Supporting Effect

After the application of High-Strength Yielding Bolt in −536 Air-return Cross-Cuts in Wulong Mine Liujia section, the deformation of tunnel's surface, roof separation and surrounding rock were monitored. The result of measuring shows that the deformation of tunnel is greatly reduced in the tunneling process. The decrement of deformation in tunnel's bottom is significantly. Compared with the old method of digging in front and renovation behind, the new of described in this paper does not require more renovation and more maintenance. The method of applying High-Strength Yielding Bolt is more to satisfy with the requirement of normal production.

4 Conclusion

Through the practice of underground construction, high-strength yieldable bolts are able to meet the requirements of high geostress, supporting quality and supporting strength of soft rock tunnel. In the construction process, the deformation of tunnel is reduced significantly, the supporting is very effective. The method mentioned above make the amount of tunnel renovation and maintenance and the cost of supporting cut down. Work safety is more guaranteed. Finally, the application of high-strength yielding bolt is worth popularizing.

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