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Comparative test and study on different types of anchor cable support in high stress deep rock mass

Yu haikuo[1], Zhang xiuyu[1]*, Li yuneng[1], Chi en'an[2,3], Pu hengqiang[1], Ming yue[1], Tang mingyuan[1], Lu shuang[1], Dai xianglong[1]

[1]Guizhou Guian Xinlian Blasting Engineering Group Co Ltd,Guiyang 550000,China.
[2]College of Ming,Guizhou University,Guiyang 550000,China.
[3]Poly Union Group Co Ltd,Guiyang 550000,China.

ABSTRACT

To study the grouting anchor cable, high strength anchor cable, constant resistance, large deformation of anchor supporting of coal roadway surrounding rock different control effect, first using drilling into instrument detecting roof inner fracture of surrounding rock and loose circle development situation, again USES the anchor dynamometer, the roof abscission layer meter, convergence rule of surrounding rock of roadway convergence deformation and stress monitoring and supporting artifacts related to data processing and analysis between the drivage and stoping different anchor rope supporting of roadway surrounding rock under the condition of deformation and stress change rule anchor rope.Through the above steps, the grouting anchor cable is found to be the best supporting method.

Keywords:Comparative test and study, different types, anchor cable support, high stress deep rock mass

***Correspondence to Author:**
Yu haikuo
Guizhou Guian Xinlian Blasting Engineering Group Co Ltd, Guiyang 550000,China.

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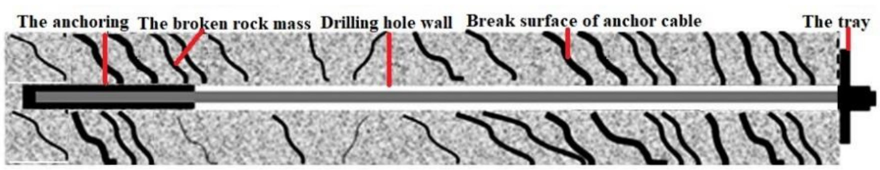
1. The introduction

As shallow coal resources depletion, China Eastern mine gradually to the deep development of high ground stress, the complex geological structure of surrounding rock of roadway caused by loose and broken phenomenon gradually increased, the stability of surrounding rock is often difficult to control, its main reason is that the existing supporting form provided by the support resistance is limited, can't offset the deformation of surrounding rock pressure. Xu mengguo, wang mingxu et al. [1] analyzed the pressure situation of different roadway through numerical simulation of different roadway support modes. Wang yufeng, cheng qiangong et al. [2] established model tests under different support conditions, and then analyzed the situation of instability. Chen hao, ren weizhong. [3]Model test and numerical analysis of bolt support under different supporting conditions. Wang qi et al. [4] established the mechanical model of "surrounding rock structural-roadway side support" based on the overburden movement law of cut roof and pressure relief, and deduced the calculation method of roadway side support resistance. Tao Zhigang, et al.[5] used numerical simulation and theoretical formula to study the stress distribution of the "short beam" formed by the cut top unloading autogenous roadway. The above scholars studied the rock support through theoretical calculation, numerical simulation and engineering test, and obtained good economic and social benefits in the application of coal mine, but did not compare different support methods.

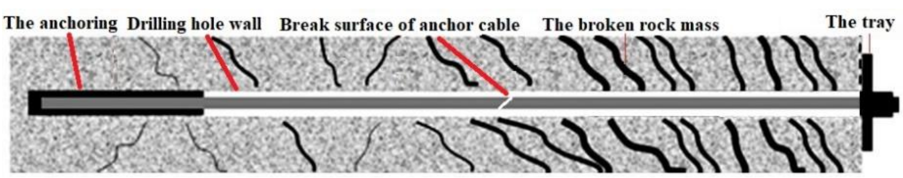
2. Project status

The coal mine is located in the central part of shandong province, China. The designed production capacity of the mine is 600,000 tons/year, and the approved production capacity is 1.2 million tons/year. The maximum vertical depth is 1501m.

The roadway of coal mine is mostly broken rock and supported by high-strength anchor cable. Although high-strength anchor cable support has the characteristics of simple technology, low cost and convenient transportation, its supporting effect is often not good in the face of broken rock[6].According to the analysis, there are mainly two reasons: (1) the rock mass in the anchorage section of the anchor cable is also broken, which leads to the lack of anchoring force, or even the removal of the anchor.(2) the rock mass of the anchorage section is complete, but the outer rock mass is broken and the surrounding rock is deformed. The degree of deformation exceeds the elongation of the anchor cable, leading to the fracture of the anchor cable[7].



(a) anchor cable of broken rock mass in anchorage section



(b) the complete outer rock rock breaking anchor cable of the anchorage section

Figure 1 anchor cable type with poor supporting effect

The poor supporting effect of roadway caused by the above reasons is shown in figure 2.

Figure 2 roadway surface with poor support

3. Solutions

In view of the above reasons for poor supporting effect, it is particularly important to find out a new supporting method which can fix the anchor segment or extend the anchor cable to avoid breaking[8][9][10].

Grouting is a common disposal method for broken rock mass. Through compaction, filling and splitting, the slurry can be fully diffused in the established strengthened area. After that, with the condensation and solidification of grout, friction and interlock are formed between the grout and rock interfaces, and the strength of the grout and rock interfaces is increased, thus changing the failure mode of rock mass and delaying the occurrence of failure. At the same time, due to the injection of grouting materials, the compaction action caused by the change of the original stress propagation path, so that the overall performance of the rock mass is greatly improved. After grouting, the anchorage section of the anchor cable can be effectively fixed, so that the surrounding rock of the roadway remains stable and the outer rock mass can be effectively filled and reinforced, as shown in figure 3.

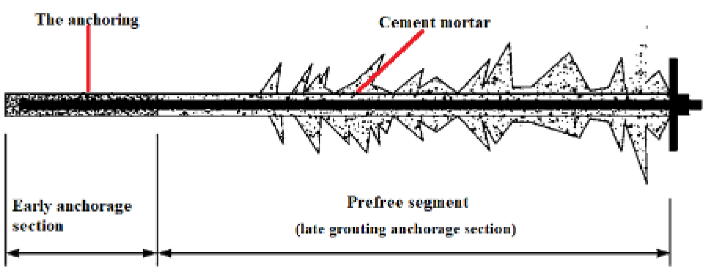


FIG. 3 schematic diagram of grouting structure and principle

In view of the situation that the rock mass in the anchorage section is complete, but the outer rock mass is broken and the surrounding rock is deformed, and the deformation degree exceeds the elongation of the anchor cable, which leads to the fracture of the anchor cable, an anchor cable with a higher elongation can be used for supporting. In the supporting process, the rock mass pressure can be offset by the deformation of the anchor cable, so as to play a better supporting effect. The anti-poisson's ratio material can meet the above requirements. The design constant resistance of large-deformation bolt with constant resistance is 80% ~ 90% of the yield strength of the bolt body, which ensures that when the constant-resistance device plays its role, the bolt body will not be plastic deformation due to the external load exceeding its yield strength.

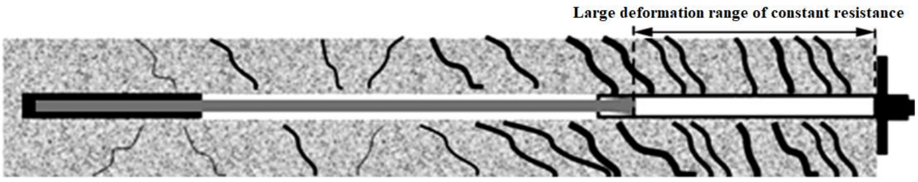


FIG. 4 working principle diagram of large deformation anchor cable with constant resistance

4. Contrast test

The 11120 working face of coal mine is located in the first mining area after -800 meters horizontal level in the south area of the mine field. The east working face has a strike length of 132.8 ~ 203.6m, an average strike length of 190.96m, and a tilt width of 125.1 ~ 145.6m.The elevation of the roadway on the working surface is -748.0 ~ -750.2m, and the elevation of the lower roadway is -794.3 ~ -800.1m.During tunneling, the test section of the lower entry adopts the support method of trapezoidal section "anchor net belt + anchor cable", which is arranged in the coal seam. The roadway section has a net width of 4.2m, a net height of 3.4m on the upper side and a net height of 2.3m on the lower side. The row spacing between roof anchor cables is 950×800mm, the row spacing between upper side anchor bolts is 950×800mm, and the row spacing between lower side anchor bolts is 900×800mm.

4.1 Design of test scheme

The 11120 working face of coal mine adopts the common anchor cable support. Due to the large impact ground pressure, many roof support damages and roof net phenomenon are caused, which has a great influence on the control of surrounding rock on the construction site. Based on this, suitable areas were selected for grouting anchor cable, high-strength anchor cable and large-deformation anchor cable support test, and the most suitable support method for 11120 working face was selected[11].

Test to select 11120 face entry under 150 m coal roadway section 3 test area monitoring, monitoring test section design is divided into three 50 m, respectively to test section Ⅰ (ordinary anchor cable), test section Ⅱ Ⅲ test section (grouting anchor cable), constant resistance (anchor), as shown in figure 5.

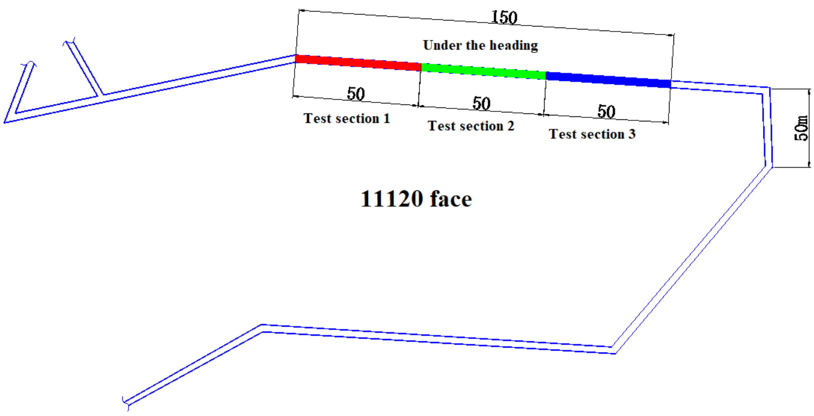


FIG. 5 layout diagram of each test section

4.2 Design of monitoring scheme

In the test section Ⅰ,Ⅱ,Ⅲ middle position each decorate A comprehensive monitoring, monitoring of convergence, anchor cable force, the roof abscission layer), notes for point A, B, C, respectively, on both ends of each comprehensive measuring point 15 m each arrangement of A convergence monitoring stations, respectively to convergence point A1, A2, B1, B2, C1 and C2, monitoring equipment layout is shown in figure 6.

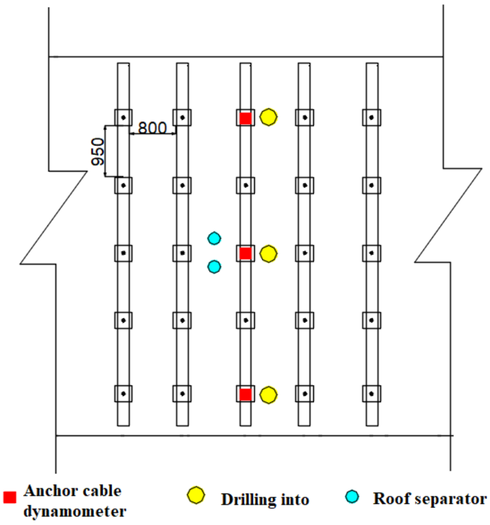


Figure 6 monitoring equipment layout

4.3 Borehole peep

In order to explore the range and development of surrounding rock loose fracture in the test section of the roadway under the 11120 working face of coal mine, and to provide a basis for the future analysis of the effect of different types of anchor cable support, it is now necessary to conduct an 8-meter borehole inspection near the monitoring anchor cable hole.

Test section development period, using the drilling peep instrument to detect internal fracture of surrounding rock, roof recovery period, the test section are influenced by mining, roof all have different degrees of fracture, again using borehole peep meter to peep of roof, the roof fracture of the testing section for the analysis of each, to map the roof fracture distribution is expected, as shown in figure 7[12].

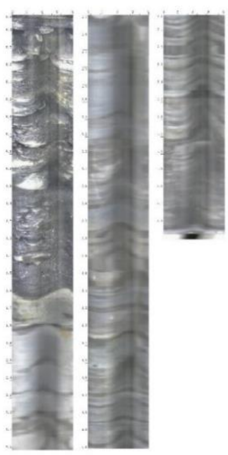


FIG. 7 distribution of roof cracks

The black filler in each borehole represents the location and extent of the fractured surrounding rock observed on the borehole wall. It is expected that after the detection results of each borehole are completed, the surrounding rock is divided into serious, medium and minor failure zones from the inside to the outside according to the degree of surrounding rock fragmentation, as shown in figure 8.

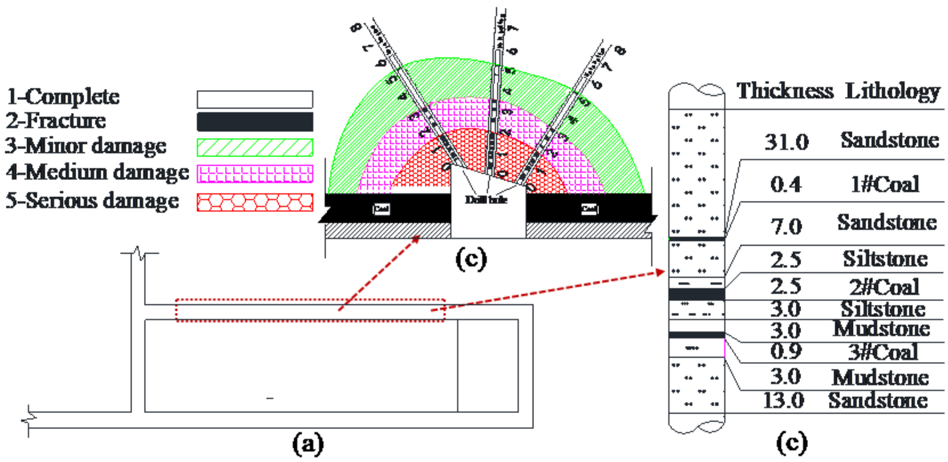


Figure 8 failure range of surrounding rock in section (unit: m)

From the above results, it can be seen that the fragmentation range of surrounding rock is large, and the law of minor failure zone and medium failure zone. The typical soft rock in this area, and the field observation found that the mudstone rock mass fracture development, resulting in the overall strength of surrounding rock is lower, bring great difficulty to the stability control of surrounding rock[13].

Main reasons for roadway failure are analyzed as follows:

(1) the upper part is a coal seam with a soft texture, so the surrounding rock has low strength and poor bearing capacity. Therefore, the deformation of the two sides is large.

(2) low roadway surface strength. Due to the lack of shotcrete on the roadway, the surrounding rock surface protection strength of the surrounding rock is low, the metal mesh is torn and the surrounding rock bulge is serious.

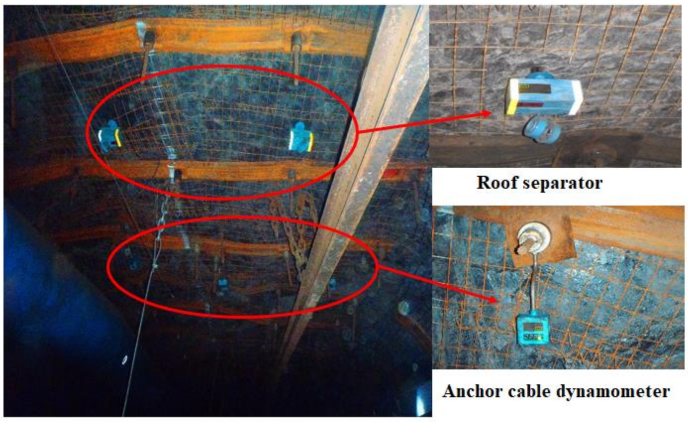
5. Monitoring the deformation of different types of anchor cable support sections on site

In order to solve the problems existing in the original high-strength anchor cable support, the underground roadway of 11120 working face with similar geological conditions was selected for the test of high-strength anchor cable, grouting anchor cable and large-deformation anchor cable support with constant resistance, and the control effect of each test section and the stress state of anchor cable were monitored.

5.1 Implementation of monitoring program

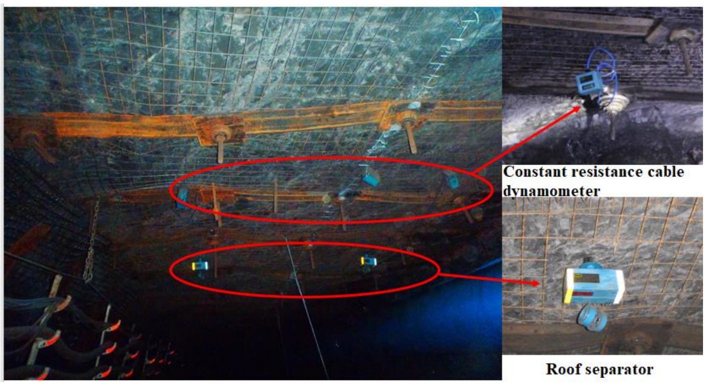
The implementation of the scheme was carried out in three test areas of high-strength anchor cable, grouting anchor cable and large-deformation anchor cable of 150m coal roadway under the working face 11120. Figure 9 shows the implementation effect of each scheme.

Three stations are arranged in each test scheme to monitor the surface displacement of roadway, roof separation and anchor cable stress. According to the different layout of each support system, the concrete monitoring scheme is designed.



Scheme 1: high-strength anchor cable support

Scheme 2: grouting anchor cable support



Scheme 3: anchor cable support with constant resistance and large deformation

Figure 9 field implementation diagram of each support system

5.2 Monitoring of surrounding rock convergence

Asymmetric monitoring method is adopted to monitor the convergence of roadway surrounding rock. The layout section of measuring points is shown in FIG. 8 (b).Four measuring points were arranged in each monitoring section to monitor roof subsidence, left (right) side displacement and bottom heave.

The convergence of roadway was measured every 3 to 5 days in the first two weeks, and then every other week. When the convergence and deformation of roadway tended to be stable, the measurement was stopped. According to the acquisition of high strength anchor cable, constant resistance large deformation of anchor cable and grouting anchor average convergence value data, map the two sides of roadway deformation and roof and floor move and face on mining and the changes of location under the condition of different anchor cable, map out the convergence deformation of roadway, is expected to monitoring of displacement of two-time curve diagram as shown in figure 10.

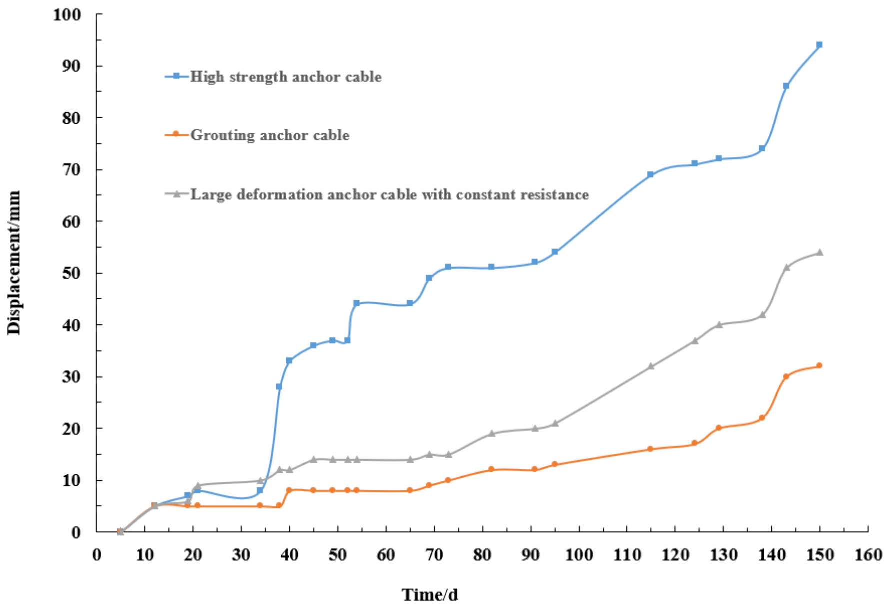


FIG. 10 two-sided displacements - time curve of the monitoring point

As can be seen from figure 10:

(1) grouting anchor cable support and large-deformation anchor cable support with constant resistance are better than high-strength anchor cable support. The settlement of roof and the displacement of two sides are respectively 60% ~ 80% and 50% ~ 83% of the high-strength anchor cable support scheme.

(2) the overall effect of grouting anchor cable support is better than that of the constant resistance large-deformation anchor cable support scheme. Compared with the latter, the settlement of the roadway roof and the displacement of the two sides are reduced by 20 ~ 25% and 23 ~ 40%.

(3) grouting anchor cable support is the best choice in the mining support scheme, and the roadway deformation is effectively controlled.

5.3 Monitoring of internal displacement of roof

When tunneling deep thick top coal roadway, the middle roadway roof is the key part of roadway surrounding rock control. In order to monitor the bending and settlement of roadway roof, two roof layer separators are arranged in the same section of the roof of three kinds of support schemes, with base depth of 8 and 4 m respectively. This paper focuses on the comparative analysis of the monitoring data of the depth of roof separation.

Data can be collected once in the well at an appropriate time, and 6 groups of data can be collected each time. After calculating the average value, the separation values under different anchor cable support conditions can be compared, including the beginning time of separation and the size of separation values. When significant separation occurs, in order to clarify the position where the separation occurs, drilling holes can be made at the place where the separation occurs to peer into the internal conditions of the surrounding rock of the roof and draw the relation diagram between the internal displacement and time change of the roof. The expected internal displacement and time curve of the roof is shown in FIG. 11.

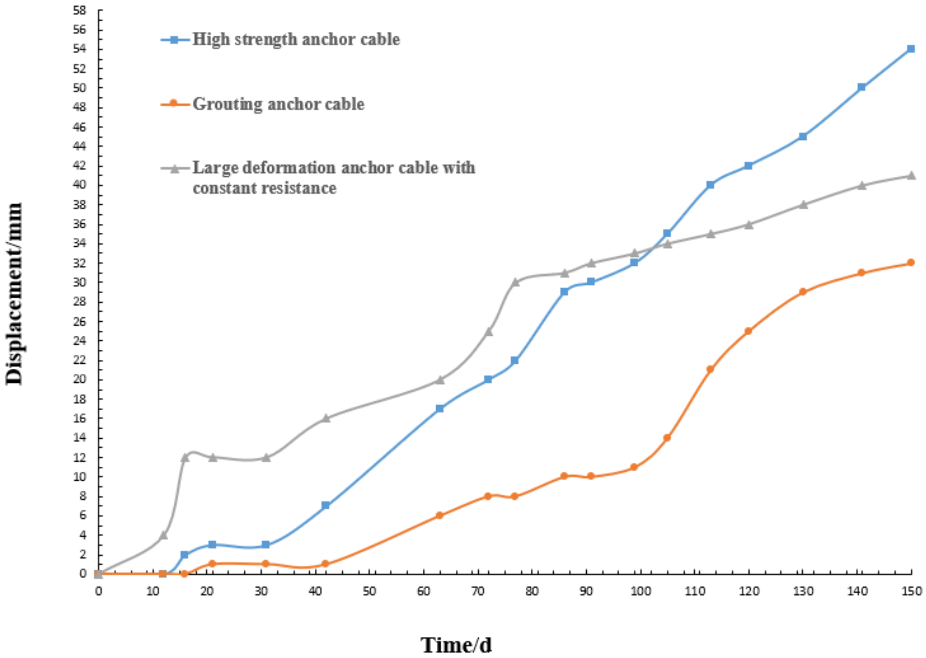


FIG. 11 displacement - time curve of roof interior

FIG. 11 shows the monitoring curve of separation amount of roof of high-strength anchor cable, grouting anchor cable and large-deformation anchor cable with constant resistance. Among them, time 0 refers to the moment when the roof separator penetrates the overlying strata and first reads after the roadway heading head excavation. Monitoring results show that:

(1) in the early stage of roadway excavation, roof separation increases rapidly. This is because the stress redistribution of surrounding rock caused by roadway excavation, the roof coal seam changed from a three-direction stress state to a two-direction stress state, and the tangential force support was lost. The coal seam burst from the out-side to the in-side caused the rapid increase of roof separation in the early stage of roadway excavation. With the roadway driving, the support system plays an effective supporting role and the roof separation tends to be stable.

(2) among the three support methods, the amount of roadway roof separation of grouting anchor cable and large-deformation anchor cable with constant resistance is only 33.8% ~ 49.7% of that of high-strength anchor cable support scheme. At the same time, the roof separation amount of grouting anchor cable support is less than that of constant resistance large deformation anchor cable.

5.4 Stress monitoring of anchor cable

In order to understand the development trend of surrounding rock deformation and the stress state of bolt and anchor cable supporting components, the typical stress curve of bolt and anchor cable in each program was selected for analysis.

Data can be collected once in the well at an appropriate time, and 6 groups of data can be collected each time. After calculating the average value, by comparing the stress of anchor cable dynamometer under different supporting conditions, the supporting effect of different types of anchor cable can be analyzed, and the relationship between the stress of anchor cable and time can be drawn. The stress of anchor cable - time curve is shown in figure 12.

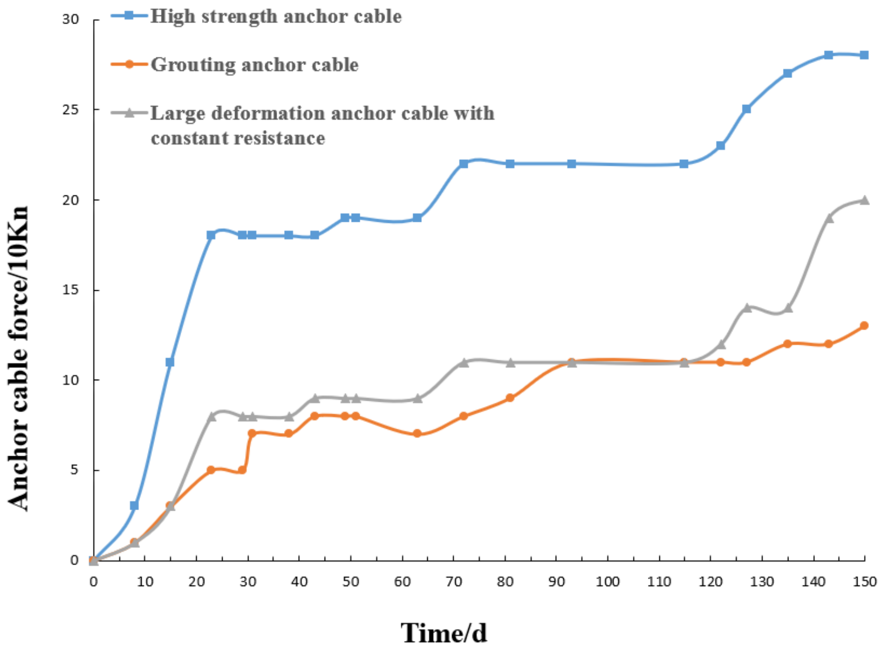


FIG. 12 stress - time curve of anchor cable

As can be seen from figure 12:

(1) in the early stage of roadway tunneling, the anchoring force of bolt and cable increases rapidly, and the growth of anchoring force slows down when the surrounding rock of roadway becomes stable, and then basically becomes stable with the stress of anchor cable in roadway tunneling.

(2) because the grouting anchor cable support improves the rock crack, the anchoring force is obviously at a low level. Because the grouting anchor cable cancels out part of the rock impact energy, the anchoring force also changes slowly.

(3) the effect of grouting anchor cable support and large-deformation anchor cable support in controlling surrounding rock is obviously better than that of high-strength anchor cable. Compared with the two, the effect of grouting anchor cable support is also better than that of large-deformation anchor cable support. Therefore, grouting anchor cable support can effectively control the deformation of surrounding rock[14].

6. Monitoring summary and field application

6.1 Monitoring summary

(1) in view of the unsatisfactory supporting effect caused by the use of high-strength anchor cable support in coal mine, different control effects of grouting anchor cable, high-strength anchor cable and large-deformation anchor cable support on surrounding rock of coal mine roadway were studied respectively.

(2) field test monitoring of surrounding rock control effect shows that: grouting anchor cable support and large-deformation anchor cable support have better control effect on surrounding rock than high-strength anchor cable support; Moreover, the effect of grouting anchor cable support is better than that of constant resistance large deformation anchor cable support.

(3) the stress monitoring results of anchor cable show that the grouting anchor cable support improves the situation of rock mass cracks and enhances the supporting effect. The large defor-

mation anchor cable with constant resistance counteracts part of the surrounding rock deformation and enhances the supporting effect. Compared with the grouting anchor cable, the stress is smaller and the effect is better.

(4) combined with the results of different anchor cable support, it is suggested to adopt grouting anchor cable support in coal alley with similar geological conditions.

6.2 Field application

In the first section of roadway, all grouting anchor cables are used for support, and the effect is very obvious.

(a) before anchor cable support (b) anchor cable support

Figure 13 before and after effect of anchor cable support

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