Roadway rock pressure appearance law of roof-cutting and pressure-relieving retaining roadway in medium thick seam

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Abstract: Through long-term monitoring of the displacement of the roof and the pressure changes of various supporting methods along the retaining section of No. 9 coal seam in the Dianping coal mine, the mechanical characteristics of the displacement of the roof and various supporting methods were analyzed. It has been found that the top layer of the roadway section has a longer aging effect and a lower value than the roof subsidence. The maximum pressure and average pressure of the side support side of the roadway are slightly lower than the pressure of the left side of the upper roadway. The initial pressure and cycle of the roadway side are slightly higher than the roadway side of the upper roadway. The constant resistance large deformation anchorage is more adaptable to the fluctuation of the roof pressure in a wide range than the door bracket.

1. Introduction
Retaining lanes along the goaf means that during working face extraction, the original mining roadway is maintained along the edge of the goaf, and no coal pillars are left. Roadway retaining technology can avoid the use of coal pillars, improve coal resource recovery rate and mine service life, ease the contradiction of mine production succession, reduce the handling and installation time of comprehensive mechanized equipment on the working face. This can effectively prevent spontaneous combustion of the coal seam in the mined-out area and is beneficial to the safe production of the mine and the improvement of economic mining technology.

Han Bendao\cite{1,2} believed that the roof sinking speed is maximum at a weighting step distance behind the working face. The load of the single pillar and the approaching amount of the top and bottom plates increase sharply, the support is deformed and damaged causes increased roof cracks or loose fractures. Li Huamin et al\cite{3} believed that the amount of roof subsidence on the side of the goaf was about twice as large as near the roadside. The amount of roof subsidence in the retained roadway is proportional to the width of the roadway and the overhang distance. Sun Henghu et al\cite{4} proposed that the support cannot completely prevent the roof from drastically sinking, but the large cutting height can make full use of the bearing capacity of the falling vermiculite, so that the roadside support and surrounding rock can reach a new balanced state as soon as possible to reduce the amount of roof subsidence. Jiang Jinquan et al\cite{5} believed that the direct top can fill the goaf and the old top rock layer can be balanced, which is conducive to the maintenance of the roadway along the goaf. Yang Yongjie\cite{6} proposed that it is difficult for the support to prevent the roof settlement caused by the overlying rock layer, but sufficient support resistance can prevent the direct roof from rupturing severely and does not cause a large separation from the roof.

Through the long-term monitoring of the top roof pressure and the displacement of the roof, this
paper analyzes the pressure of the working face support and door-type support, the force of the constant resistance anchor cable and the lateral pressure state of the meteorite in the goaf, studies the amount of roof subsidence and the variation law of the separation layer, so as to optimize the technology of roof cutting at gob-side entry retaining in similar geological conditions.

2. Basic conditions of retained roadway along the goaf

2.1 The basic conditions of the working surface
The 202 working face of the Dianping coal mine is located at the left-wing of the second mining area of the 830 level, it adjacent to the 200 working face in the north, the south of it is the 204 working face (Figure 1). the average coal thickness of No. 5 coal seam is 3.1m and its dip angle is 4°; The false roof is a sandy mudstone with a thickness of 3 meters; The direct top is sandstone with a thickness of 6.1 m; The old top is mudstone sandy with a thickness of 2.1 m. The buried depth of working face is 225~360 m. The strike length is 1200m and the inclined length is 220m.

![Figure 1. 202 working surface and mine pressure monitoring arrangement](image)

2.2 Mine pressure monitoring content and its location

| Monitoring location | 10m from the lower lane | 110m from the lower lane | 15m from the upper lane | 100m from the cutting hole | 500m from the cutting hole | 800m from the cutting hole |
|---------------------|-------------------------|-------------------------|------------------------|---------------------------|---------------------------|---------------------------|
| code                | YJP1                    | YJP2                    | YJP3                   | MJP1                      | MJP2                      | MJP2                      |
| content             | the pressure of working face support | the stress of constant resistance anchor cable | the lateral pressure of the goaf zone | the displacement of the top plates | the separation value of the roof | the coal door-type support |

The mine pressure monitoring content includes displacement and pressure in the retained roadway. The monitoring location is mainly located in retained goaf-side and mining face. The displacement monitoring includes the displacement of the top and bottom plates and the separation value of the roof. The pressure monitoring includes the stress of constant resistance large deformation anchor cable, the pressure of working face support, the coal door-type support and the lateral pressure of the goaf zone (Table 1).
2.3 The support of retained roadway
According to the law of mine pressure appearance and the needs of roadway layout, the support of roadway is divided into three zones: the advanced support zone, the temporary support zone and the stability zone. The support of advanced support area adopts single hydraulic support and π type steel beam joint support (1 beam, 4 columns and 1 meter row); temporary support area adopts self-circulating door type hydraulic support, single hydraulic support and U-shaped steel Joint support, the distance between the door-type support is 1.5 m, and the width of U-shaped steel is 500mm on the side of the goaf, the distance between the single pillars and the shrinkable brackets is 250mm; The self-circulating door type hydraulic support and the single hydraulic support are removed in the stable zone, but the U-shaped bracket and the steel mesh are retained to block the waste rock.

2.4 Parameters of concentrated energy blasting
To ensure convenient construction and the penetration effect of the coal seam roof, The directional collapse of the roof is realized by bilateral cumulative blasting technology. The pre-cracking blast-hole has an angle of 15° with the vertical direction, the diameter of the hole is 48 mm, the spacing is 500 mm, and the depth is 9000 mm. The tube used in bilateral cumulative blasting has an outer diameter of 42 mm, inner diameter of 36.5 mm, and the length tube is 1500 mm. The optimum dosage of a single hole explosive is 3.2 kg. The specification of the drug roll is 27×300 mm in diameter, and the mass of each roll is 200 g. Five tubes are used in each hole, the length of the hole is 2.25m.

3. Roof deformation displacement change

3.1 The variation law of roof subsidence
To observe the variation law of the roof subsidence of the 9-2022 retained goaf-side entry, the cross-point measurement points are arranged at the distances of 100m, 500m and 800m from the cutting hole (Figure 2). Analysis of roof change law by monitoring the displacement of the roof.

After the analysis, When the working face advances within 50m, the top plate of the retained goaf-side has the largest amount of roof subsidence at 100m and 500m from the cutting hole. When the working face advances 50m to 120m, the roof subsidence becomes smaller. When the working face advances more than 120m, the roof subsidence tends to be stable, and the maximum subsidence of the top plate is about 150 mm; When the working face advances within 35m, the top plate of the retained goaf-side has the largest amount of roof subsidence at 800m from the cutting hole. When the working face advances 35m to 120m, the roof subsidence becomes smaller. When the working face advances more than 120m, the roof subsidence tends to be stable, and the maximum subsidence of the top plate is about 200 mm.

3.2 The variation law of roof separation
The roof separation layer mainly monitors the separation value within the anchor cable or bolt support range. It mainly composed of a base point anchor head, a measuring rope, a casing, a outer and inner measuring cylinder. the deep base anchor head is fixed in the deep stable bedrock (11 m), the shallow base point is fixed at the end of the bolt (2 m). The top layer monitoring point is installed 500 m away from the cutting hole. The deep and shallow base points are both in the constant resistance large deformation anchor hole. The deep base point at the bottom of the hole, The shallow base point is 2m from the hole (Figure 3). the variation of the roof separation is as follows:

1) The advance of the working face affects the separation of the roadway roof, generally about 30 m in advance. According to the monitoring data of the 9022 retained goaf-side entry, when the working face starts to advance, the roof of the roadway is separated from the floor. When the working face advances to 38m, the variation of roof separation is the largest.

2) When the working face advances 38m to 150m, the roof separation layer becomes smaller. When the working face advances more than 120m, the roof separation layer tends to be stable.
4. The pressure of support and anchor cable force change law

The monitoring of the support pressure includes the working face support and the door-type support pressure of retained goaf-side entry. The pressure monitoring of the work face support is mainly to study the effect of the top pressure relief. The pressure monitoring of the door-type support is mainly to understand the variation of the support pressure of the retained goaf-side entry after the working face is advanced. The monitoring of the stress of the anchor cable is mainly to study that change law of anchor cable force in the front section and the retaining section of the working face.

4.1 Variation law of working face support pressure

The pressure monitoring of the working face support is mainly composed of mine intrinsically safe pressure sensor KJ385-G, monitoring substation KJ385-F2, monitoring main station KJ385-F1, transmission interface KJ385-J and KJ27 surrounding rock dynamic monitoring and analysis system. The monitoring position includes three locations: from the retaining section 10 meters, the middle of the working surface and 15 meters from the upper lane, which respectively represents the cutting effect affected area, the central unaffected area, and the uncut top affected area.

Table 2. Support pressure and pressure step in three positions of working face

| position               | the maximum pressure/MPa | the average pressure/MPa | first weighting interval/m | periodic weighting step distance/m |
|------------------------|--------------------------|--------------------------|----------------------------|-----------------------------------|
| 10m from the retained roadway | 32.8                     | 20.3                     | 46                         | 31                                |
| Middle of working face | 38.4                     | 33                       | 38                         | 18                                |
| 15m from the upper Lane | 33.7                     | 24.5                     | 42                         | 25.5                              |

According to table 2, the maximum and average pressure of the intermediate support of the working face is significantly higher than that of the retained roadway side and the upper roadway side. The maximum and average pressure of the roadway side support is slightly lower than that of the upper roadway without cutting the top of the roadway; The cycle step is lower than the roadway side and the upper roadway side. The retained roadway side is increased by 4m for the first weighting interval and the periodic weighting step distance is increased by 5.5m. The increase of periodic weighting step distance at the end of the working face indicates that under the influence of the top blasting, Direct top drop height is large and the block is small (the coefficient of bulging is large), and The formation of shattered meteorites can fill the goaf, so the space for the basic top to rotate is smaller; Because the angle of rotation is small, the deformation of the rotation is also small, resulting in the basic top not being easy to break, and the pressure generated on the direct top of the roadway along the space is also small.

4.2 Variation law of door-type support pressure

The door-type support model is ZMX410 / 220, its length is 3200mm, width is 300mm, height range is2200~4100mm, the retractable length is 500mm, working resistance of the support is 2040kN (28MPa). The pressure sensor is used to record the pressure change of the door-type support. By comparing the monitoring data of the constant resistance anchor cable, the support of each stage is
played to analyze the stability of the roadway.

It can be seen from Figure 4 that there is a certain initial supporting force of door-type support about 20-25 MPa. After the working face is passed, the support pressure gradually increases, and the average increase rate is close to 0.45 MPa/m; the working surface is advanced at about 20 m. The pressure is basically stable or exhibits a small oscillation, about 40 MPa. This shows that the door bracket can adapt to the change of the roof pressure of the retained roadway section, and it works well (Figure 5).

Figure 4. Pressure change of door-type support

Figure 5. Supporting effect of roadway in retained roadway section

4.3 Force resistance of large deformation anchor cable

The constant resistance anchor cable is one of the main supporting methods for the retained roadway. During the coal roadway excavation, the side of the goaf is strengthened by the constant resistance large deformation anchor cable, and the adjacent side of the 9-204 working face is strengthened by the long anchor cable. The anchor cable dynamometer is embedded in the three locations 100m, 500m and 800m from the cutting hole to monitor the change of the cable tension and compare with the press change of the door-type support. The dynamometer consists of a tray-type closed oil-filled pressure cell with a central hole and a pressure gauge connected to it. During installation, the pressure box is placed between the tray and the nut at the outer anchor end, which can detect the axial force change. Pre-stress the anchor cable before use and record the value of the pressure box. Thereafter, the pressure value is regularly recorded.

Figure 6. The stress of constant resistance anchor cable

Figure 6 shows the change of the force of the constant-resistance large deformation anchor cable at the three positions 200m, 400m and 700m from the cutting hole. It can be seen from the figure:

(1) The advanced concentrated stress generated by the advancement of the working face affects the stress of the anchor cable. Its influence range is 32 ~ 35m, with an average of 33m. This is basically consistent with the range of influence of the leading bearing pressure measured by the cross point.
(2) The anchorage of the retained roadway section is forced to lag behind the working face by about 25m. With the basic top periodic fracture, the anchor cable stress decreases; within the 60m range of the lag working surface, the anchor cable stress will fluctuate due to the movement of the roof plate, and the deformation of the surrounding rock increases with the increase of the deformation of the surrounding rock; After 150 meters, the anchor cable will eventually become stable.

(3) According to compare the tensile force of the constant-resistance and large-deformation anchor cable and the pressure change of the gantry bracket, it can be seen that the pressure of the gantry support in the retained roadway section is about 20 meters, and the tension of the constant-resistance large-deformation anchor cable changes most during this period. After the roadway section is 120 meters, it will enter a stable state. Therefore, the constant resistance anchor cable is an indispensable support method for the roadway section.

5. Conclusion
In this paper, through the long-term monitoring of the roof plate and its support pressure and roof displacement changes, the mechanical characteristics of the roof displacement and various support methods are analyzed, and the following conclusions are obtained:

(1) The roof of the retained roadway section shows the emergence time of the roof separation is longer than the roof subsidence. After the working face is passed to 150 meters, the roof is stable, and when the working surface is advanced to 50 meters, the roof sinking is basically stable; The maximum sinking amount of the top plate is significantly higher than the top plate separation value, the maximum sinking amount is 200mm, and the maximum separation value is less than 50mm.

(2) The intermediate support pressure of the working face is higher than the upper and lower ends, and the pressure step is lower than the upper and lower ends. The retained road has less influence on the support pressure of the working face near the side of the retained roadway, and the maximum and average pressure of the retained side is slightly lower than the upper roadway. The first weighting interval and periodic weighting step distance are slightly higher than the side of the upper roadway.

(3) In the retained roadway section, the door-type support pressure reaches a steady state when the working face advances at a distance of 20m. However, the constant resistance anchor cable is in a state of turbulent fluctuation within 60 meters from the working face; After entering the retained roadway section from 120~150 m, the anchor cable tends to be stable, which indicates that the constant resistance large deformation anchor cable is an indispensable support method for the retained roadway.

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