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The Change Law and Application Research of Surrounding Rock Loose Circle Based on Visualization Test

Liang Chen

Chongqing Research Institute co.Ltd of China Coal Technology and Engineering Group Corporation, Chongqing 400037, China
lelechen131452@163.com

Because the loose circle is an important basis and parameter for designing the tunnel support and estimating whole stability, how to determine its area accurately and fast has become all issues of concern. In this paper, combined with the actual situation, and used the visualization technology, we test the surrounding rock loose circle of roadway, which in 10-1# and 8# coal seam. The test results show that the measurement of surrounding rock loose circle borehole camera technology is reliable, and the thickness of the broken rock zone varies with the measuring position within a cross section of the roadway. And the 10-1 # coal seam loose ring size is 1.1 -1.6 m, 8 # seam loose ring size is 1.4~1.8 m, safe coal loose circle range between loose circle in the big and loose circle. Besides, the study results have some consult effects on the similar engineering.

1. Introduction

With the increasing scale of coal mining, the deterioration of engineering geology condition brings great difficulty to roadway support(Zhao et al., 2017).Loose circle is a generally state of physical and mechanical exists in underground engineering, its size is an important basis for stability evaluation of surrounding rock and supporting design and it plays a vital role in production safety of a mine enterprise (Dai et al., 2015).China is a nation of coal, the mine safety problems followed with the coal production, year by year. For the design of roadway support parameter, and use the surrounding rock loose circle to design supporting parameters, many scholars conducted in-depth research (Li and Li, 2005; Wan et al., 2012; Zhang et al., 2016). In tunneling activities, the coal and rock in equilibrium state with the three-dimensional stress, before roadway excavate. Formed in artificially excavated coal and rock roadway, the stress of surrounding rock of roadway will occur two significant changes: one is the peripheral radial stress is reduced to zero, the surrounding rock strength decreased obviously; and stress concentration phenomenon of the surrounding rock will be occur, general concentration factor greater than 2. If the stress concentration less than the strength of rock, then the surrounding rock will be in a state of elastic-plastic stability. Otherwise, roadway surrounding rock will be the first to destruction, and gradually expand to the deep, until the surrounding rock is an equilibrium state with three-dimensional stress. Then, the surrounding rock has transition to a broken state. The fracture zone of surrounding rock defined as the surrounding rock loose circle. Referred to as "loose circle. Its mechanical properties for stress reduce performance. Out of loose zone, there are plastic limit equilibrium zone and elastic zone. The size of the surrounding rock loose circle mainly related to the strength and the original rock stress of surrounding rock.

The distribution of tunnel surrounding rock loose circle not only associated with the level of the surrounding rock, but also with the size of the supporting force have a close relationship. With the increase of supporting force, the scope of the loose circle is gradually reduced; As level variation of surrounding rock loose circle range is gradually enlarged (Wang et al., 2017; Liu et al., 2015).The main test method of loose circle contains geological-radar (Xu et al., 2013), multi-point displacement (Luo et al., 2017) and ultrasonic (Dai et al., 2015). Borehole imaging test method simple operation, can be observed visually different depths in the borehole drilled in the deformation of fractured rock.

Because of the complexity of the deep rock mass, which seriously affects the stability of the roadway and the safety of the mine operation, thus the scope of the accurate measurement of roadway surrounding rock loose

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circle for specification of roadway supporting method, ensure the stability of roadway, increase the service life of has important practical significance (Yang et al., 2017).In this paper, based on the borehole imaging testing methods, testing the Huaan coal mine roadway surrounding rock loose circle, to study the change law, and provide accurate technical parameters for roadway support.

2. Testing scheme

2.1 Mine general situation

Huaan coal mine is in the southwest edge of the Tash mining area, between Bazhou mine three and Harman gully two, on the north by Tash coal field two, 22 km from Korla and 7 km from Tash. Its coordinate is east longitude86°12′37″~86°13′36″, north latitude 41°51′30″~41°52′19″. The mining area is about 1.06 km wide from east to west, 1.11 to 1.75 km in length from north to south and has an area of 1.5998 km2.

The coal resource in mining area is Jurassic Tash. The maximum depth of stratigraphic control is 240.81 and adds up to 9 layers including three coal measures from 8 to 10. There are three layers can be extracted (8#, 10-1#, 10-2+3+4#). The total thickness of the coal seam is 17.64 m on average, and the total extractable thickness of the coal seam is 10.46 m on average.

According to the information provided by geological report, in general, the roof of number 8 coal layer is siltstone and some parts carbonaceous mudstone. In general, the floor is siltstone and some parts carbonaceous mudstone. According to the columnar contrast analysis of drill 8-1,7-1,7-2, the direct roof of number 8 is siltstone and the thickness is 2.13-6.27 m, its upper layers include coal line, are carbonaceous mudstone, siltstone and fine sandstone. They interbedded with each other. The floor is siltstone, fine sandstone and carbonaceous mudstone which interbedded with each other.

The roof of number 10-1 coal layer is siltstone and some parts are carbonaceous mudstone. In general, the floor is siltstone and some parts carbonaceous mudstone and coarse-grained sandstone. According to the columnar contrast analysis of drill 8-1, 7-1, 7-2, some parts of 10-1 coal layer has false roof, it is carbonaceous mudstone and its thickness is about 0-0.65m. The direct roof is fine sandstone, its thickness is 4.2-15.24, some parts interbedded with siltstone, carbonaceous mudstone coal line. The floor is siltstone, fine sandstone and glutenite.

According to the results of rock physical and mechanical tests and similar physical and mechanical test results of the same roof and floor in adjacent mines, the unidirectional compression strength of the siltstone of the roof for coal seam 8 is 6.01～31.13 Mpa in natural condition which is soft rock. The floor of coal seam 8 is siltstone and fine sandstone (the stability of floor depends on the parameter of siltstone). The siltstone is 30.13 Mpa in the natural condition which is soft rock.

The direct roof of coal seam 10-1 is fine sandstone and it is 10.31 MPa in the natural condition and it is soft rock. Its floor is siltstone, fine sandstone and glutenite (the stability of floor depends on the parameter of siltstone). The siltstone is 20.26 MPa in the natural condition which is soft rock.

It is found that the deformation and destruction of the deep roadway in the mine are more serious, and the roof of the roadway in local district is broken in symmetry. In addition, the deformation of the roadway is serious in other sections, and the rules of the fracture surface of anchor sprayed sections are poor. From the analysis, there are mainly subjective and objective factors following:

2.1.1 The influence of the crustal stress on the mining area is remarkable

The deeper the roadway is, the bigger the crustal stress is and the more serious the destruction of the roadway is. The destruction of roadway support is usually started from the weakest key support of the roadway. Once the roadway support is damaged, the deformation of the roadway accelerates rapidly and the roadway is seriously damaged because the roof of coal seam in Huaan coal mine is siltstone, parts are carbonaceous mudstone which is own physical and mechanical engineering properties are poor and has low supporting capacity. Therefore, if the support body is partially damaged, the roadway support should be repaired in time so that can present from the deformation of roadway accelerate rapidly. As far as the anchor sprayed roadway is concerned, the reinforcement of the sprayed body should be repaired in time.

2.1.2 Seriously affected by groundwater

The underground water inflow in Huaan coal mine is relatively large. Field investigation shows that the surrounding rock disintegration is serious in the flooded section. In the roof and the two sides of the roadway, especially the lower part of the two side of the roadway, the anchor will gradually lose efficacy because of the long erosion of the water, and the deformation of the two side of roadway is nearly inward moving. Rock bulge caused by water is an important factor for floor heave of roadway.

2.1.3 Relatively great influence on the mining pressure

Relatively great influence on the mining pressure, the roof of roadway will become crisp caused by pressure and the roof is relatively broken because of the repeated mining. The increase of destroy sections and ranges more obvious than the non-mining area.

2.2 Testing Scheme

ZXZ20 type rock stratum detection recorder is consist of ZXZ20-Z type host and ZXZ20-S type camera. On the basis of the television imager, the drilled imaging equipment which is specially improved and designed according to the special geological conditions and operating environment of the coal mine, is all intrinsically safe type (ExibI). The whole instrument is small in size and light in weight and easy to carry underground. The outer diameter of the camera is less than the size of the anchor hole and it isφ25 mm. It can directly detect holes by anchor rod. Compared with flameproof (ExdI) borehole detector, there is no need to match with other geological rigs, it can drill in the scene and it is convenient to detect.

2.2.1 Testing principle

Drilling holes of 42 mm or 32 mm in the rock layer and wash away the rock fragments which in the hole. The CCD probe, power supply and digital video recorder of the detector are connected through the cable, and the CCD probe is installed on the supporting circular pipe. After sending the CCD probe to the hole, opening the system power and turning on the video switch. The instrumentation plan is shown in Figure 1, and the specific measurement steps are as follows:
(1) Drilling in the roadway and the roof of the selected roadway are not less than 32 mm in diameter, and blow the rock powder with the pressure wind and rinse the hole with normal pressure water.
(2) Preparing the notebook and recording the location of the holes. The camera is sent into the drill hole with metal rods until the camera reaches the bottom of the drill hole. Connect the plug, open the power, open the record button, start collecting the image, and record the time to collect the image in the notebook and the distance between the camera and the hole.
(3) Slowly move the camera outwards and record the time of collecting the image every 0.1 m until there is a drilled hole. Or the position of the hole is moved to the bottom of the hole.
(4) When the camera reaches the borehole, close the record to ensure that the data is stored correctly and prepare for the measurement of the next borehole.

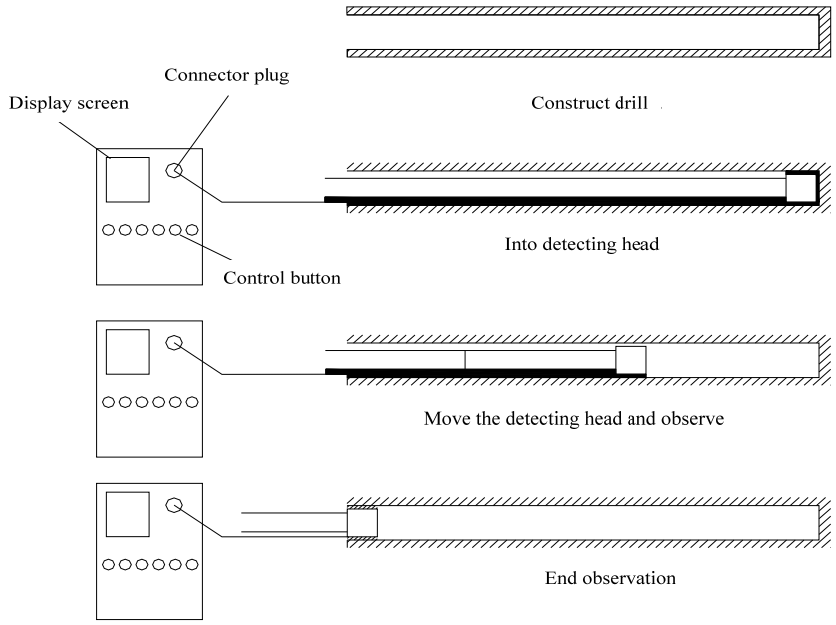

Figure 1: Instrumentation plan

2.2.2 Data processing

In the detection of hole testing hole, the video files collected by the rock layer detector are stored on the hard disk of the host by the data format, and the host is connected to the computer via the communication data line.

The video captured in the detection can be replayed on the microcomputer, and the video is played through the special image processing software and Image processing.

2.2.3 Scheme design

The layout of the borehole is measured by the loose ring, and the distance between 20~30 m and a test point is adopted to avoid the principle of the influence of the geological structure belt, so that the layout of the measuring point can reflect the size of the loose circle of the roadway more comprehensively, and make the measurement more reliable. According to the existing development layout and the roadway conditions of the work-face in Huaan coal mine. A total of 4 measuring points are arranged in 10-1# east return air return way and 8# return wind down hill. The detailed location is: 10-1# coal seam is in the 20m (the first test point) and 50m (the second test point) within the +800 air return way. 8# coal seam is below 20m (the first test point) and 50m (the second test point) of +765 air return way. Along the roadway, each roadway has 1 observation sections at intervals of 30 m, and each section has 3 boreholes and 2 boreholes on each side of the roadway, and a total of 7 boreholes. The borehole diameter is 32 mm and the side side is 42 mm. The drilling depth is greater than the range of loose circle. It is known by 3.4 analysis that the range of the moving circle of the pine is more than 150 cm, and the loose circle range of the general roadway is within 2 m. The drilling depth can be designed with the design of the mine, and the drilling depth is designed to be 4 m. The design layout consists of 4 measuring points, 28 boreholes, 27 actual holes, and the specific parameters of drilling are shown in Table 1.

Table 1: The test drill parameters of surrounding rock loose circle in Huaan coal mine

Coal seam	Drill location	Number of drill	drill parameter		Coal seam	Drill location	Number of drill	drill parameter	
			corner(°)	depth(m)				corner(°)	depth(m)
10-1#	Return air roadway of 1002 Working-face	side-1#	180	4	8#	8# return airflow	side-1#	180	4
		side-2#	180	4			side-2#	180	4
		side-3#	0	4			side-3#	0	4
		side-4#	0	4			side-4#	0	4
		roof-1#	135	4			roof-1#	135	4
		roof-2#	90	4			roof-2#	90	4
		roof-3#	45	4			roof-3#	45	4
		side-5#	180	4			side-5#	180	4
		side-6#	180	4			side-6#	180	4
		side-7#	0	4			side-7#	0	4
		side-8#	0	4			side-8#	0	4
		roof-4#	135	4			roof-4#	135	4
		roof-5#	90	4			roof-5#	90	4
		roof-6#	45	4			roof-6#	45	4

3. Results and discussion

3.1 The test results of 10-1# coal seam

3.1.1 Roof test result

Through the comparative analysis of the observation of two measure points and six roofs, it is found that the integrity of top covers is relatively good and joint fissure in partial sections develop well but no shear failure is found. A number of weak intercalations with great damage range from 0.4 to 1.1 meter. Distinct bed separation is found in partial area. 4# drill hole shows that there are minor faults above the coal bed. The observation of roof shows that the size of the roof broken rock zone is about 1.4 meter.

3.1.2 Two sides of rock formation test results

10-1# coal bed has placed all together two measure points, eight drill holes and eight constructions. Actually, seven drill holes are observed because of the equipment failure. As is seen from the observation results that the left surrounding rock is more complete, partial joint fissure develops incompletely and looseness range is not obvious. Drill hole shows that the maximum damage depth of the left coal body is 1.4 meter, and the exterior rock body is relatively complete. The area exists in this scope. The maximum damage depth is 1.6 meter, extending to near the hole edge. The tensile and shear failure mode are main mode of failure. Therefore, it is analyzed that the bolt length is not less than 1.6 meter and the anchorage zone must be 1.6 meter far from coal body. The right surrounding rock has a severe damage and a high degree of looseness

ranging from 0.38 to 1.6 meter. The looseness range should be not less than 1.6 meter. The right bolt length should be not less than 1.6 meter and the anchorage zone must be 1.6 meter far from coal body. Considering the coal body near the coal the coal pillar, it is suggested that the bolt length should be increased. The overall probe results show that the range of 10# loosen zone of coal bed is: tunnel roof is from 1.1 to 1.3 meter. The both sides are ranging from 1.5 to 1.6 meter. Therefore, the length should be not less than 1.7 meter. The right bolt length can be properly increased. The test results is shown in Figure 2.

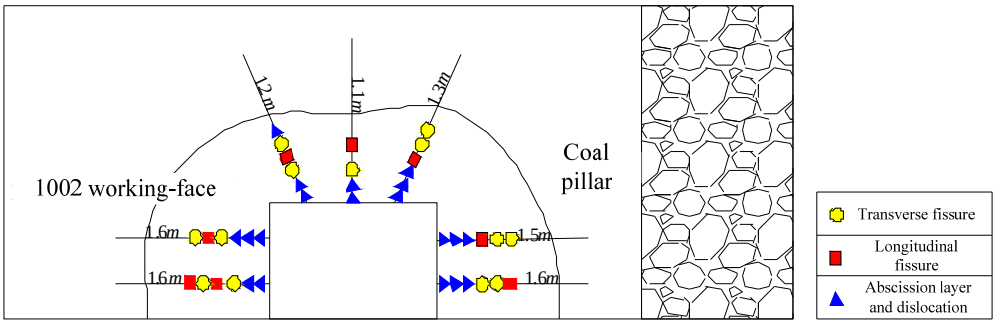

Figure 2: The test results of loose circle at No.1 measure point in 10-1# coal seam

3.2 The test results of 8# coal seam

3.2.1 Roof test result

Coal seam placed two test points and constructed six drill holes. All coal holes take advantage of rock formation detection recorder to carry on probe test with borehole camera. From the analysis of probe results, we can know that the integrity of 8# roof coal seam is relatively bad. The fracture form can be divided into the horizontal fracture and vertical fracture and the separation layer, misplacement and fracture zone evolved from horizontal and vertical fracture. Take 500mm as a basic measure level and get the development condition of the roof fracture. From the picture we can know that the roof fracture basically have the symmetry feature. The scope of fracture is about 1.8 meter. The fracture mainly consists of horizontal fracture, separation layer and misplacement. Partial drill hole fracture can be divided into shallow part (0-1.5m horizontal fracture/separation layer development area) and deep part (1.5-1.8m vertical fracture development area).

3.2.2 Test results of the sides of roadway

Coal layer has placed two test points and there are seven actual pore-forming. Due to water in rib, six drill holes are actually observed and all of them are coal holes.

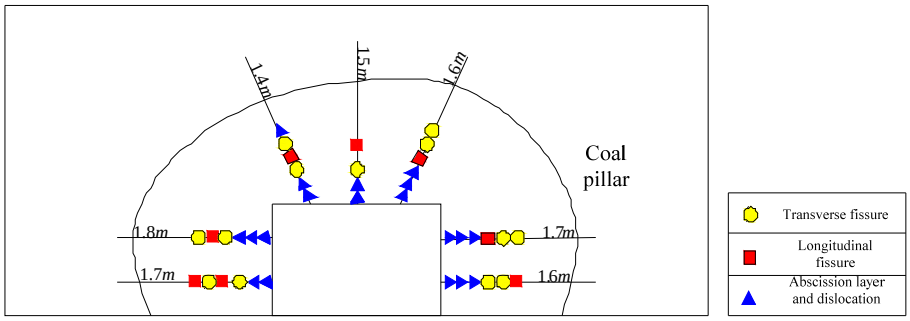

Figure 3: The test results of loose circle at No.1 measure points in 8# coal seam

The left surrounding rock is relatively cracked. Partial joint fissure develop completely. The range of looseness is relatively distinct. The shallow part mainly includes separation layer and misplacement. Partial vertical fracture can be seen in deep part. Drill holes show that the maximum damage depth of the left coal body is 1.8 meter, which extends to the area near the hole edge. Tensile and shear failure are main modes of failure. Therefore, it is analyzed that the length of the left rock bolt is at least 1.8 meter and the anchorage zone should lie in coal body 1.8 meter away. The right surrounding rock is damaged severely and has a great

degree of looseness ranging from 0.15 to 1.68 meter. The probe result shows that the coal body is relatively cracked and the exterior coal body is relatively complete ranging from 0.3 to 1.54 meter. Obviously, it is analyzed that the length of right rock bolt should be at least 1.7 meter and the anchorage range should lie in the coal body 1.7 meter away. According to the probe results, it is easy to find that the broken rock zone of 8# coal layer is: roof (1.4-1.6m), both sides (1.5-1.8m, 1.5-1.7m). Therefore, the length of mining roadway roof should be at least 1.6 meter, the length of left rock bolt should be more than 1.8 meter and the right rock bolt should be at least 1.7 meter. The test results is shown in Figure 3.

4. Conclusions

According to the field measurement results and the actual situation of the mine, and combined with the collected mine support and geological data. After comprehensive analysis, the surrounding rock loose circle of the coal seam is determined, and the following conclusions can be obtained through the field measurement.

(1) The size of loose circle in air return way of 10-02 high-grade general work-face in Huaan coal mine is determined: The first test point is 1.1 to 1.6 m, and the second test point is 1.2 to 1.6 m. the first test point of coal seam air return way down to hill of loose circle is 1.4～1.8 m and the second test point is 1.5～1.6 m. Taking the maximum between the two, the diameter of the loose circle in the 30 m is 1.1～1.6 m in the +800 m way of the 10-1# coal seam. The loose circle of +765 of 8# coal seam +765 is 1.4～1.8 m. The Huaan coal mine loose circle is located between the middle pine moving circle and the large loose ring.

(2) There are no large faults in the work-face and thick coal seam in the working face and the 10-1 #coal has thick gangue in the working face from the analysis of the coal seam occurrence and geological condition during the heading of the working face. From the measured loose circle range, the anchor length of the bolt length of 2 m in the 10-02 high grade working face of Huaan coal mine and the roadway support system in the 8-02 fully mechanized caving face can be satisfied. Existing support projects need to be properly reinforced in case of local geological structure.

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