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Underground Drilling and Packer Test in Fault F16 of Wugou Coal Mine

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Abstract Fault F16 of Wugou Coal Mine is located in the north-west direction of the mine, which is a large normal fault. With a fall of 30-150 m, strike length within the coal mine is about 2.24km. Air roadway of the 1031 working face's mechanical lane is near F16 normal fault, tunneling along the anti-pillar line of the fault's hanging side. Because of the influence of F16 normal fault, distance between coal mine of the 10th mine seam in the hanging side and the limestone of Taiyuan Formation in the heading side was further reduced. There is certain danger of water inrush of Taiyuan Formation due to the mining. Location, throw, and water transmissibility of the F16 fault was further detected by means of underground drilling and pressure water test, hydro-geological parameters of permeable rate and osmotic coefficient of F16 fault are obtained, giving the key basis for the setting up of the coal pillar for F16 fault in a reasonable way.
Keywords fault, packer test, hydrological parameters

General situation of fault F16

F16 is located in the north-west direction of the mine, and in the north of the 1031 working face, it is a large normal fault. Three-dimensional seismic ground control: the 5th coal seam leaped to Ordovician limestone, with a NNE strike and a SSW tendency, with a strike length of 2.24 km in the mine, dip angle of 70°m, fall of 30-150 m. The east and Wugou fault intersect, controlled by drilling holes of J1-6, J1-4, and Bu22. The Bu 22 drilling hole revealed the F16 fault, the fault zone is located at the drilling-hole's depth of 355.10 m, with a fall of 80m. Pumping test was performed with osmotic coefficients respectively 0.8333 m/d, 0.9562 m/d, 1.0554 m/d.

The fault is almost paralleled to the 1031 working face, about 84-141 m from the air way of the working face, there is no practical data at present. Working face is at the hanging side (downthrown side) of the fault. The effective water-resisting layer between baseboard in the 10th coal seam and limestone in Taiyuan Formation is further reduced even connected.

To further control the location, fall, and water transmissibility of the F16 fault, 2 sets of searching drilling holes are designed to perform searching and pressure water test so as to provide geological proof for the safety recovering on the 1031 working face.

Geological and hydrogeololgical conditions of the construction section

Geological and coal seam condition of the construction section

Construction section is located in the TZ3 drilling site of 1031 air way, near hanging side of the normal fault F16. Secondary faults and fractures may be more developed near the fault.

10th coal seam is in the middle of Shanxi Formation. It is 42.95-60.99 m away from the aluminum mudstone of the lower Shihezi formation, and 33.15-51.55 m from the limestone of Taiyuan Formation. Thickness of coal is 2.44-5.47 m.

The direct roof of the 10th coal seam gradually turns from siltstone into fine-grained sandstone. The upper roof is consisted of light gray fine-grained sandstone, interbedding with the dark gray mudstone showing an horizontal bedding. Carbonaceous components are shown in the bedding planes.

The direct baseboard consists of dark gray siltstone, mainly with aleuritic texture and containing line shaped light gray fine sand. The older baseboard is interbedded with sandstone and mudstone.11th coal seam is about 12-24 m under 10th coal seam. Thickness of the coal of 11th coal seam is 0.5 m.

Hydrological conditions of the construction section

Main influence of the construction section is from crevice aquifer of both top and bottom board in the 10th coal seam, as well as the aquifer from the limestone of the baseboard. Sandstone crevices in the sandstone aquifer are rarely seen, with a poor aquosity.

Coal seam of the hanging side connects with limestone from the opposite side due to the big fall of F16 fault. Gushing may occur because that aquifer in the opposite side may be drilled into when drilling hole going through F16 fault.

According to the real-time water level (-39.21 m) of the 6th water hole (Long observation holes in the limestone of Taiyuan Formation), max pressure water of the limestone of the test section is calculated as 3.45 MPa.Max gushing amount for a single drilling-hole is predicted to be 50 m^3/h.

Underground drilling of fault F16

Drilling site: TZ3 drilling site of 1031airway, shown in the pressure water test plan (Fig.1). Actually 6 searching holes are constructed, with a total work amount of 769 m. Of them, T6#: azimuth 328°, dip angle 11°, depth of hole 95 m, fractured zones with a width of 5m are seen at the depth of 85.5~91m, limestone from the heading side is seen at 91~95 m. Effluent rate of the final hole is 5 m^3/h. T6# is also the pressure water hole; T7#:azimuth 28°, dip angle 17°, depth of the hole 133 m, coal from footwall 11 is seen at 106.7~112.8 m; T8#: azimuth 28°, dip angle 0°, depth of hole 99 m, limestone from the heading side is seen at 97~99 m, effluent rate of the final hole is 10 m^3/h; T9#:azimuth 28°, dip angle -5°, depth of hole 107 m, limestone of the heading side is seen at 101.5~107 m, effluent rate of the final hole is 0.5 m^3/h.

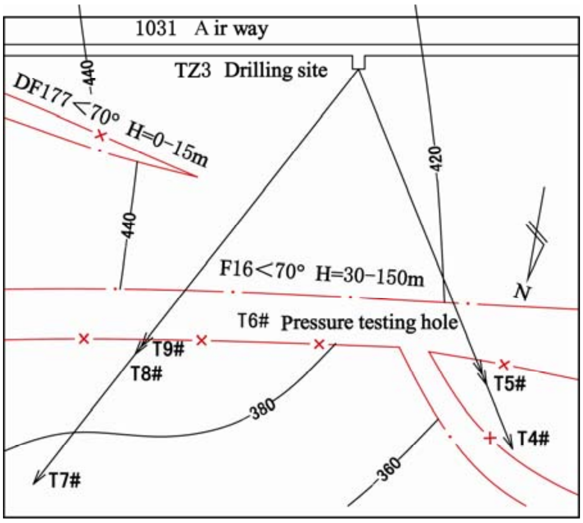

Fig. 1 *Plan of pressure water test*

Synthetic analysis of drilling: dip angle of fault F16 is 67~80°, fall of 75 m. Distance between air way and the intersecting line of fault and coal seam ranges from 77 to 95 m. Width of fault zone varies from 4 to 5 m. No water containing and flowing is seen in the fault. See the searching profile of fault F16 (fig. 2).

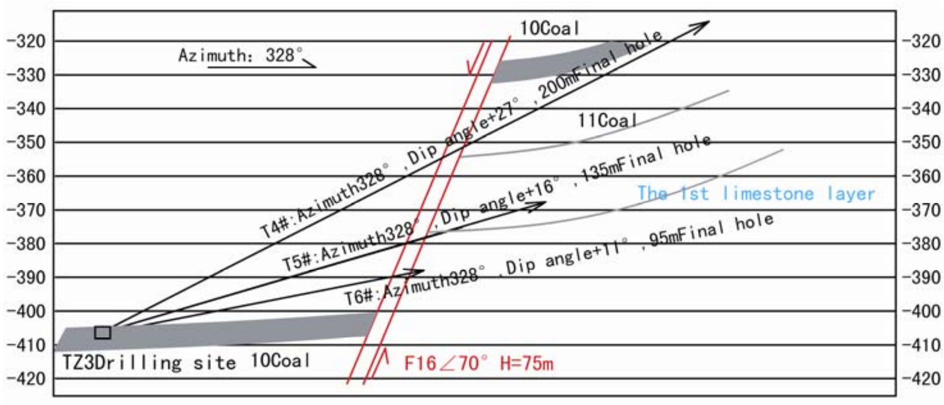

Fig.2 Searching profile of F16 fault

Pressure water test of fault F16

Trial objective

Pressure water test is to press water into the drilling holes by means of high pressure, an in-situ test according to the soakage of the rock body to calculate and know the development and water permeability of rock body. Specialized sealing equipment is applied in pressure water test to segregate off drilling test section with certain length, and then applied fixed water head to drill hole and drain water for this section. Water penetrates into the rock body through the crevices around the wall of holes. Penetrated water amount finally tends to be a fixed value. Intensity of water permeability can be determined according to the length of test section and water yield of stable penetration.

For this time, high pressure water test is done mainly in the fault zones. Length of test section is determined according to the width of faults that are actually drilled and searched. High pressure water test simulates the gushing and inrush from space as much as possible.

Test procedures

Considering the long construction period, high cost of the ground pressure water test, but since the effect of pressure water test is nearly as same as that on the ground. So it's determined to carry out the high pressure water test for fault F16 at 75-83 m within the drilling hole T6# , and underground airway 1031 drilling site TZ3.

(1)The confirmation of testing water pressure

Water pressure of limestone in the strata of the test section is calculated as 3.45MPa, according to the real-time water level (-39.21m) of the 6th water hole (limestone in Taiyuan Formation). To make a true simulation of the limestone water, making use of existing equipments synthetically, testing pressure water of the high pressure is set to be 4Mpa. The 7 pressure stages of 1.0→2.0→3.0→4.0→3.0→2.0→1.0 are applied. Medium-speed method is applied as the way of boosting. Duration of each pressure stage is 30min.

(2) Experiment process

Drilling in→casing→coring→slip casting→drill-hole cleaning→drill-hole washing→

connection of pressurized water tube→performing observation of pressure and the pressed in water amount in the pressure water test stage→performing data arrangement and curve verification on site.

(1) Flush holes in positive cycle method. Hole-washing drilling tools should be drilled to the

bottom of holes. Flow rate should be the max output of the water pumps. Piston suction method is appropriate for the holes with severe blockage of rock powder. Standard for the accomplishment of hole flushing is that back water of the orifice is clean and thickness of sediments at the bottom is less than 0.2 m.

(2) Adjust the testing pressure to the index value and keep it stable. Then start observing the pressure and flow.

(3) The interval between pressure and flow observation is 1 or 2 min. On condition that pressure keeps the same, and there is no continuous growing trend, and the difference value between the max and the min values of all the 5 readings of the flow is less than 10% of the final reading or less than 1 L/min. Test of this stage shall be ended and the final value is taken as the calculation value.

(4) Repeat the testing processes above by following the pressure stage and corresponding pressure value until test of this stage is accomplished.

(5) If there is any back flow in depressurization stage, the back flow shall be recorded until the back flow stops and its flow rate reaches the required standard.

(6) During the testing period, water inflow near the testing holes shall be observed.

(7) After finishing the test, draw P-Q curves in order to check whether the test results are true.

Device installation and matters needing attention

(1) Installation diagram for devices

Diagrammatic drawing for installation of testing devices with high pressure water is shown as fig.3

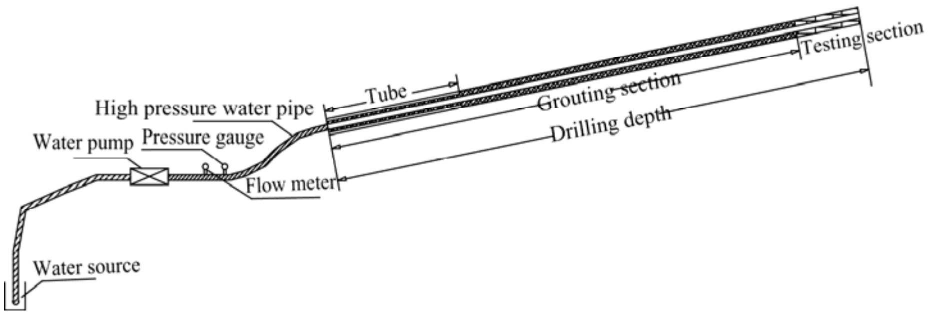

Fig.3 *Diagrammatic drawing of the installation for devices of pressing water in holes*

(2) Matters needing attention in the test

(1) Testing equipment and instruments shall meet the required regulations. Water pump shall be equipped with more than 2 cylinders and its pressure keeps stable. Flow during water injection and pressurization shall be no less than 120 L/min, effluent shall be well-distributed. Pressure gauge and water level gauge shall response quickly, working pressure shall be kept within 1/3-3/4 of the range of extreme pressure value.

(2) Joints shall be all well sealed. Otherwise, curves will deform due to the data distortion caused by water leakage.

(3) Holes shall be flushed clean. Otherwise, E type curves are easily seen, and the permeable rate is low.

(4) Pressure during the second grouting of T6# hole shall not be too high, so as to ensure that the fault zone will not be wholly blocked, which will affect the results of pressure water test.

(5) Diamond bits are allowed for use in priority if meeting the requirements of the strata, so as to make the wall of hole smooth and ensure the good quality of sealing up.

(6) No staying long near hole top and high pressure tube. People without fixed duties are prohibited to go close in case of accidents.

Testing data arrangement

(1) ***Calculation of pressure loss in the high water-pressure test***

Grouting section is served as the working tube for this drilling-hole water-pressure test, with the same inner diameters of 75 mm.In this water-pressure test, water column pressure shall be considered because that both the testing device and water source are not at the same elevated height(height difference is 15 m) as those of testing section.

$$P_S=\rho gh=0.15\ \text{MPa}$$

(2) ***Data compilation***

35 groups of data are acquired in this test. After analyzing, checking and synthetically considering the influence that grouting will do to pressure water test and after deducting the pressure loss, respectively third group data from all the five groups of data from every data stage is shown in table 1:

Table 1 *Data sheet of packer test*

Pressure（MPa）	0.00	0.85	1.85	2.85	3.85	2.85	1.85	0.85	0.00
Flow rate（L/min）	0.00	18.77	38.52	58.83	77.36	58.63	38.09	19.48	0.00

P-Q curve for high pressure water test was drawn as fig.4:

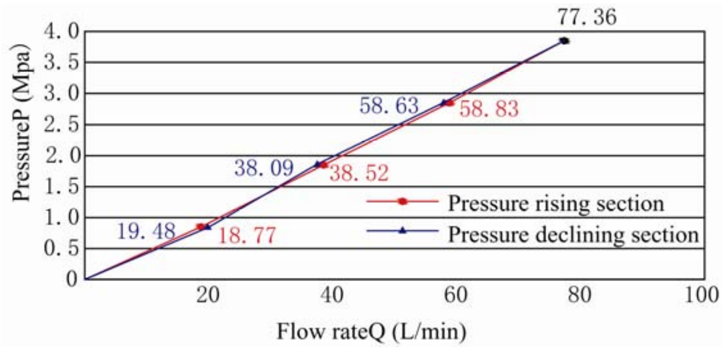

Fig.4 *Curve chart of flow rate and pressure for high pressure pressure water test*

Permeability analysis

(1) ***Permeable rate***

Length of testing section is 8m.Permeable rate is calculated by taking the pressure value (*P4*) and the flow value (*Q4*)of the max pressure stage (the 4th stage)(1), calculated permeable rate of the testing section was 2.51Lu.

$$q = \frac{Q_4}{LP_4} \tag{1}$$

Where, q—permeable rate of the testing section Lu; L—length of testing section, 8 m; Q_4—calculated flow amount of the 4th stage, 77.36 L/min; P_4—testing pressure of the 4th stage, 3.85 MPa. Two significant figures are taken for permeable rate of the testing section.

(2) ***Osmotic coefficient***

According to the *Drilling Pressure Water Test Procedures of Water Resources and Hydropower Engineering*, on condition that permeable rate is low (less than 10Lu), data of the max pressure stage is taken as osmotic coefficient in the pressure water section in the rock body of the crevices and calculated as per equation (2). The calculated osmotic coefficient is 3.1×10^{-2} m/d.

$$K = \frac{Q}{2\pi HL} \ln \frac{L}{r_0} \qquad (2)$$

Where, K—osmotic coefficient of rock body (m/d); H—testing waterhead (385 m); Q—press-in flow amount(111.4 m^3/d); L—length of testing section (8 m); r_0—radius of the drilling hole (0.0375 m).

Results analysis for the high pressure water test

From *P*-*Q* curves of this high pressure water test, we can see that, boosting curve is a straight line going through the original point, the depressurizing curve nearly overlaps with the boosting curve(under the same pressure while boosting or depressurizing, they can be identified as almost overlapped if the absolute difference of the flow rate is less than 1L/min). It works out that in the whole pressure water test, permeable state of the testing fine-grained sandstone section is laminar flow, and generally there is no difference in the crevices; according to the synthetic analysis of permeable rate and osmotic coefficient that the permeable rate of this rock body shall be classified as low permeable rate with good integrity of the rock body in the fine-grained sandstone.

Conclusion

According to the seismic exploration data, ground drilling and underground drilling data, dip angle of F16 fault is further verified at around 70°,with a fall ranging from 30 to 150 m; permeable rates are respectively 0.8333 m/d, 0.9562 m/d, 1.0554 m/d according to the pumping test for the Bu 22 drilled holes on the ground. Permeable rate of the testing section is 2.51Lu through pressure water test, while osmotic coefficient of the testing section is 3.1×10^{-2} m/d, according to the synthetic analysis of permeable rate and osmotic coefficient that the permeable rate of this rock body shall be classified as low permeable rate with good integrity of the rock body in the fine-grained sandstone. Hydrogeological parameters such as permeable rate and osmotic coefficient of F16 fault provide key basis for setting up anti-coal pillars of F16 fault in a reasonable way.

References

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