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The Research on the Height of the 'Two zones' in Xiegou Mine Areas, Shanxi, China

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Abstract The basis of roof water controlling, excavation layout, coal pillars and gas drainage designed can be provided by confirming the height of the water conducting zone in roof. There are many methods can be used to determine the height of 'two zones', such as water injected and the leakage tested in overhead boreholes, transient electromagnetic detected and simulation method, or empirical formula. The results show that height of the water conducted fractured zone for No.8 coal seam in Xiegou is 74.8 m, height of the caving zone is 32 m, and height of the fractured zone is 42.8 m. Compared with results calculated by different equations in Coal Mine Safety Regulation (CMSR), it found that some equations in the CMSR were imprecise when being applied to predicting heights of 'two zones' at mining conditions for fully mechanized mining in median thick seams. Therefore, the CMSR should be modified appropriately.

Keywords fully mechanized mining, overburden strata movement, height of 'two zones', field test, FLAC^{3D} simulation

Introduction

The overburden strata will be disturbed during the mining activities which cause the gob to be formed. The gob can be divided into three parts which are caving zone, fracture zone and sagging zone, respectively.

The movement and destruction of the overburden strata is a complex and dynamical phenomenon and affected by factors including the mechanical properties and structure of the overburden strata, the gob area, the angle and thickness of coal seam, mining depth, thickness of the overburden strata, compaction time, repeat mining, mining methods, roof management methods. Scholars have done a lot of researches for decades, but there are still many issues left.

The empirical formula for predicting of water conducted zone is used in the 'Coal Mine Safety Regulations' (CMSR) which is based on following mining conditions: the excavation advance speed being about 40 m / month, mining thickness being 2 ~ 3 m (or slice mining) (Gui et al. 1997). With the development of technology, several kinds of new efficient mining methods are proposed, such as fully mechanized mining in median thick seams, top-coal caving mining, fully mechanized mining overall height at a time. Hence, it is necessary to find the developing law of the overburden strata movement and modify the prediction formula of water conducting zone height. Duo to the observational data limited, the unified empirical formula cannot be formed for fully mechanized mining in median thick seams.

In this paper, the empirical fitting formula was obtained based on statistics (Yang 2004), and was used in Xiegou mine. Compared the height of 'two zones' obtained by three methods, the formula by this paper, the formula by "Mine regulations in three special conditions" (Ministry of Coal industry, 2000) and the FLAC3D numerical simulation method (Ren et al. 2006 & Gao et al. 2003) the height obtained by empirical fitting formula is more precise. The formula will benefit the prediction of water conducted zone for fully mechanized mining.

Field tests

Xiegou mine is located at Hedong coalfield in Eastern Ordos Basin, Changxing County, in Shanxi province. The thickness of No.8 coal seam is 2.23 ~ 8.34 m and the average thickness is 5.8 m. The roof rocks are mudstone and sandy mudstone which is of medium hard rock. Fully mechanized mining method and full collapsing method to manage the roof was used in mining.

Water injection leakage measurement in overhead boreholes

During the injected and leakage tests(fig. 1), the water inflow is 0.5 ~ 0.65 m^3/h and 0.71 ~ 0.87 m^3/h when the drilling depth being 15 m to 45.7 m, and 45.7 m to 110 m respectively, the water pressure keep steady value of about 1 MPa. However, the water inflow reduces rapidly from 0.71 m^3/h at depth of 114 m to 0.07 m^3/h at depth of 115 m. It shows that cracks in surrounding rocks suddenly decreases and the drilling has passed through the water conducted zone, the height on the roof at that point is 74.8 m.

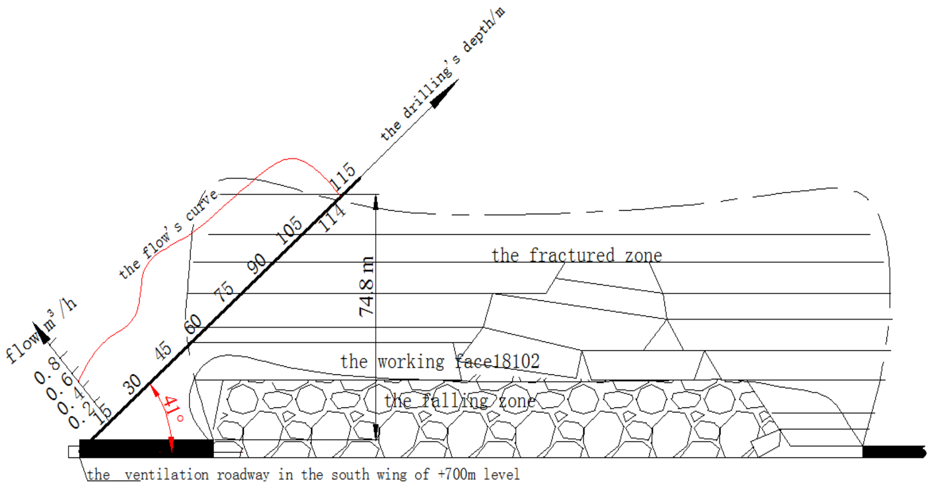

Fig. 1 *Water inflow observation in borehole on working face 18102 roof*

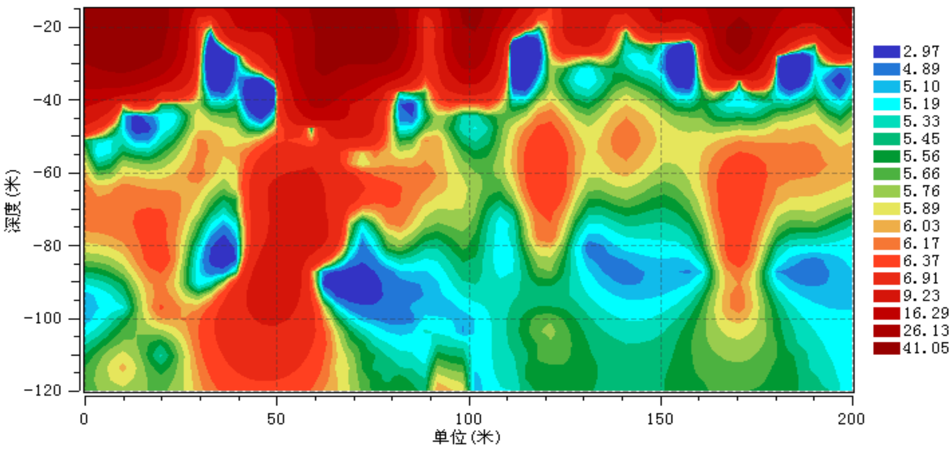

Fig. 2 *Apparent resistivity chromatogram along Inclined 60 degrees*

The transient electromagnetic method

The transient electromagnetic detection system was used for detecting height of water conducting zone at mining face 18102. As shown in fig. 2, there is a clear vertical high resistance region on stable high resistance yellow line in the horizontal direction. Obviously, there isn't any water in caving zone, thus the line is the dividing line of caving zone and fractured zone. The height of caving zone is 34.6 m and height of water conducted zone is 75.3 m in working face 18102 according to the analysis of chromatograms in different angles.

Mathematical statistic empirical formulas

By statistic analysis from the measured data (Yin et al. 2013), the empirical formula was got. The function relation between the reciprocal height of water conducted zone and coalseam thickness for medium hard overburden can be described as follow:

$$y = -0.0541x^2+0.098x-0.0009 \qquad (1)$$

The relation between height of caving zone and mining thickness is also of non-linear. The function relationship between the reciprocal height of caving zone and mining thickness for medium hard overburden can be described as follow:

$$y = -0.6256x^2+0.3206x+0.0067 \qquad (2)$$

The average mining thickness at face No.18102 in Xiegou mine is 5.8 m and the reciprocal is 0.172414. By applying appropriate empirical formula, height of the caving zone is 23.1 m and the height of water conducted zone is 75.2 m.

Numerical Simulation

The numerical simulation has been done by FLAC software. The strike length of the model is 400 m, the slope length is 292m and the height is 248 m. The coal seam angle is 11 degrees (fig. 3).

The simulation results were shown in fig. 4. The plastic failure area of surrounding rock will improve with the advancing of working face. Plastic failure zone is like a saddle. Shear failure appears on the overhang of the saddle while pull failure appears in the middle. The stress contour was shown in fig. 5. According to fig. 4 and fig. 5, the tensile stress area where shows obvious pull damage is the caving zone. The vertical height of plastic damage area is about 75 m and the height of caving zone is 32 m, the height of water conducted zone is 43 m.

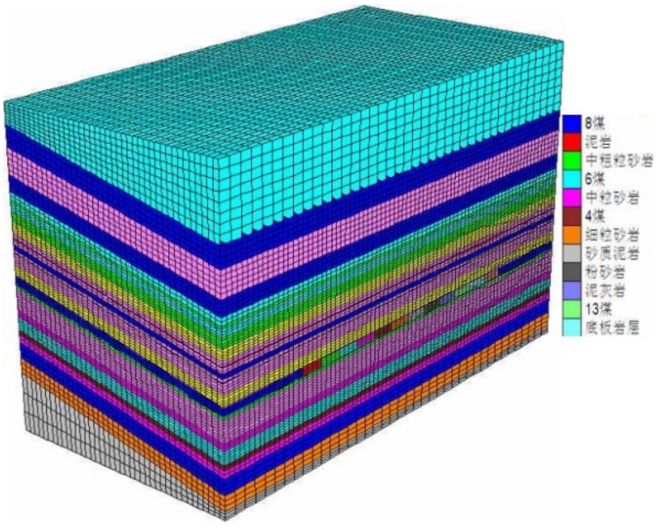

Fig.3 *Mathematical model*

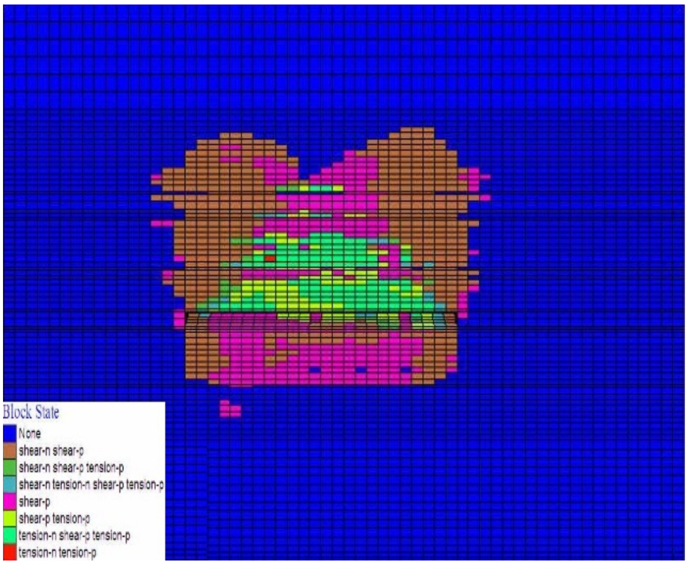

Fig.4 *Cloud chart of plastic failure at 120 m in work in working face*

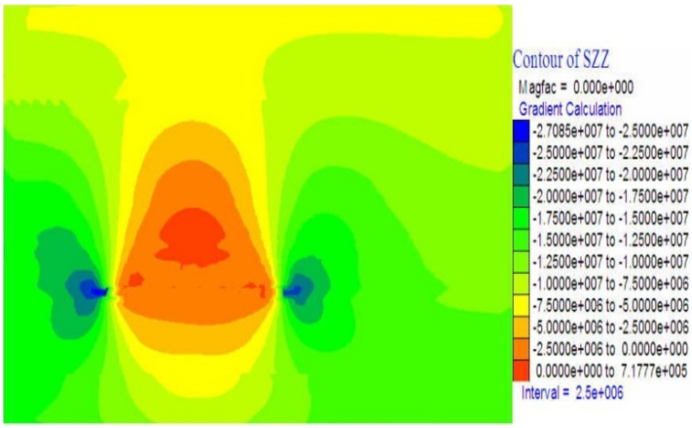

Fig. 5 *stress cloud chart of surrounding rock at 140 m in working face*

Comprehensive analysis

Comprehensive analysis

In conclusion, for working face No. 18102, the height of caving zone is 32 m, and the height of fractured zone is 74 8 m. The ratio between the height of caving zone and the mining thickness is 6.42:1 while the ratio of the fractured zone and the mining thickness is 12.89:1.

Comparative analysis with formula from the CMSR

The height of caving zone and water conducting zone can be calculated by the formulas from the CMSR.

$$H_m = \frac{100\sum M}{4.7\sum M + 19} + 2.2 \quad (3)$$

$$H_{li} = \frac{100\sum M}{1.6\sum M + 3.6} + 5.6 \quad (4)$$

In the formula:

H_m—the caving zone height(m);

H_{li}—water conducting zone height(m);

M—mining thickness(m).

The results show that the average thickness of No.8 coal seam is 5.8 m, the height of caving zone and water conducted fractured zone are 14.7 m and 50.63 m respectively. Compared with the results obtained by our research, the height values of caving zone and water conducted fractured zone obtained by the CMSR are 52.1% and 32.4% smaller respectively.

Table 1 *Height of "two zone" in working face 18102 by numerical modeling and geophysical exploration test and field test*

Methods		Caving zone height/m	fractured zone/m	Ratio of caving and mining	Ratio of fractured and mining
water injected and the leakage test		30.7	74.8	6.42	12.89
Transient electromagnetic method	Experimental value	34.6	75.3	6.7	12.98
	Comparation with field test（%）	13	0.6		
FLAC numerical simulation	Simulation value	32	75	6.7	12.93
	Comparation with field test（%）	3.5	0.2		
Empirical formula	calculaed value	23.1	75.2	3.98	12.97
	Comparation with field test（%）	-24.8	0.5		

Conclusions

According to the results of calculation by empirical formula, field tests and numerical simulation, the height of caving zone is 32 m, and the height of fractured zone is 74.8 m in working face No.18102 in Xiegou coal mine. Compared with the results got by our research, the values of caving zone height and water conducted fractured zone got by the CMSR are 52.1% and 32.4% smaller respectively. It shows that the empirical formula in the CMSR is not very suitable for the height predicting of 'two zone' under fully mechanized mining.

According to field tests from domestic mining, under the condition of fully mechanized mining, for medium hard overburden, the ratio between the height of caving zone and mining thickness is about 2.2:1 ~ 7.5:1, the ratio between height of fractured zone and mining thickness is about 10.8:1 ~ 17.9:1. The ratios are 6.42:1 and 12.89:1 respectively in the paper, so, the results are appropriate.

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