ISSN: 2710-0723

Research on In-situ Stress Measurement and Roadway Support Design in Coal Seam

Jiyu Zhao[1,2]

[1] State Key Laboratory of Coal Mine Disaster Prevention and Control, Chongqing 400037, China

[2] China Coal Technology and Engineering Group Chongqing Research Institute, Chongqing 400037, China

Abstract

Based on the existing situation of No.3 Coal Seam in Hengxing coal mine, the in-situ stress measurement was carried out at the two measuring points of the main inclined shaft bottom yard and the track roadway by using the core stress relief method, and the in-situ stress distribution characteristics of the measuring point area were obtained. Based on the measurement results, the numerical simulation software was used to simulate the support design of No. 3 coal seam roadway, and the deformation of roadway surrounding rock under different support methods and parameters was analyzed. The results show that the in-situ stress field in the second mining area of No.3 Coal Seam in Hengxing coal mine is mainly horizontal stress, the average maximum horizontal principal stress is 3.88MPa, and the average azimuth is 129°. The roadway support simulation shows that the bolt+anchor cable support method can effectively control the deformation of surrounding rock, and the displacement of roof and floor and two sides can be controlled within 100mm, meeting the production requirements. This study provides an important reference for the safe mining of No.3 coal seam in Hengxing coal mine.

Keywords

Coal Mine; In-situ Stress Measurement; Core Stress Resolution Method; Roadway Support; Numerical Simulation.

1. Introduction

With the increase of coal mining depth, the influence of in-situ stress on roadway stability is increasingly significant [1]. Accurately mastering the distribution characteristics of in-situ stress in mining area is of great significance for reasonably designing roadway support scheme and ensuring coal mine safety production [2-3]. No.3 Coal Seam in Hengxing coal mine is the main minable coal seam, its in-situ stress characteristics and roadway support design are directly related to the safe and efficient mining of the mine. The purpose of this study is to provide a scientific basis for the roadway support design of No.3 coal seam in Hengxing coal mine through in-situ stress measurement and numerical simulation analysis.

Scholars at home and abroad have carried out a lot of research on in-situ stress measurement and roadway support. Wang Chuanying et al. [4] proposed a new in-situ stress measurement method based on borehole morphology analysis. Zhao Shankun et al. [5] developed a hole bottom strain gauge for small aperture cone type hole bottom bushing in-situ stress test. Liu Xiangyang et al. [6] used the hydraulic fracturing method to measure the in-situ stress of No. 6 coal seam in Maiduoshan coal mine, and defined the stress distribution and zoning characteristics of Maiduoshan mine field. In terms of roadway support, Ding Lipei et al. [7] analyzed the surrounding rock damage and stress distribution under different support conditions, and obtained that under the tectonic stress field, the roadway deformation is very

ISSN: 2710-0723

small, the roadway support effect is good, and the roof separation phenomenon is basically eliminated. Bai Xinyuan et al. [8] found that when the thickness of top coal was 3.5m, the combined support mode of "bolt anchor cable shotcrete" was adopted, the displacement of roadway roof and floor changed little, the maximum subsidence of roof was 20 mm, the roof control effect was good, and the roadway did not have large-scale roof caving or rib spalling. Sun Xiaodong et al. [9] studied that under the action of high ground stress in deep mining, the surrounding rock of roadway showed obvious rheological phenomenon, and analyzed the influence of shotcrete thickness, bolt length, bolt row spacing and bolt diameter on the support effect. However, the specific research on No.3 coal seam in Hengxing coal mine is still insufficient. Combined with field measurement and numerical simulation, this study systematically analyzes the in-situ stress characteristics and roadway support design in this area, which provides an important reference for the safe mining of No.3 coal seam in Hengxing coal mine.

2. In-situ Stress Measurement Method and Result Analysis

In this paper, the in-situ stress measurement of No.3 coal seam in Hengxing coal mine is mainly carried out by using the core stress removal method [10-11]. This method can accurately calculate the stress state of the original rock by measuring the three-dimensional expansion deformation of the core after stress relief and combining with the determination of the elastic modulus. According to the current development level and the existing mining and geological conditions of Hengxing coal mine, the in-situ stress measurement is carried out at the bottom of the main inclined shaft and the track roadway.

(1) The stress measuring point of the main inclined shaft bottom car yard is located in the main inclined shaft bottom car yard, and a hole is opened on the left side of the roadway. The measuring point is located in the roof of No. 3 coal seam of the main inclined shaft bottom car yard. The in-situ stress sensor is installed in the siltstone of the roof. The geostress borehole is constructed at an elevation of 18° and an azimuth of 270°. The diameter of the pilot hole is 110mm and the drilling length is 9.3m. The diameter of the geostress sensor mounting hole is 38mm and the length is 0.47m. The installation depth of the stress sensor is 9.7m, the deflection angle of the sensor is 0°, and the elevation of the measuring point is about 960m.

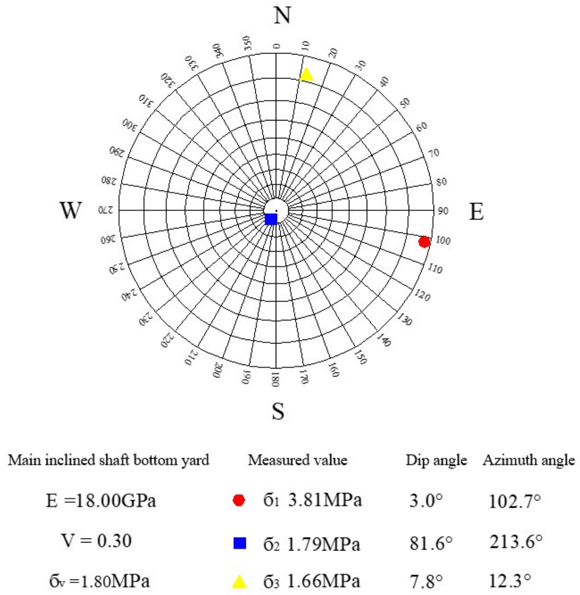
(2) The in-situ stress measurement point of the track roadway is located in the track roadway, 20m away from the turning point of the track roadway in the East, and a hole is opened on the left side of the track roadway. The measurement point is located in the roof of No. 3 coal seam of the track roadway. The in-situ stress sensor is installed in the argillaceous siltstone of the roof. The geostress borehole is constructed at an elevation of 15° and an azimuth of 0°. The diameter of the pilot hole is 110mm and the drilling length is 10.1m. The diameter of the geostress sensor mounting hole is 38mm and the length is 0.47m. The installation depth of the stress sensor is 10.5m, and the deflection angle of the sensor is 180°.

After the adhesive was cured for about 24 hours, the core stress of the rock mass with hi stress meter was relieved. After the stress in the casing is relieved, the elastic modulus of the core bonded with hi stress meter is calibrated, and then the measured data are processed by using the special data processing software. The stress stereogram is shown in Figure 1.

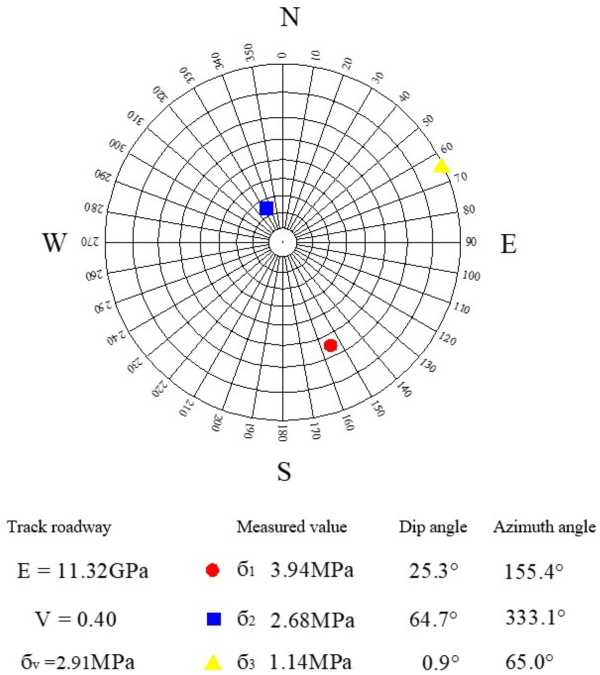
According to the measurement results in Figure 1, the in-situ stress field in the second mining area of No. 3 coal seam in Hengxing coal mine is mainly horizontal stress. The average maximum horizontal principal stress is 3.88MPa, and the average azimuth is 129°. The average minimum horizontal principal stress is 1.40MPa, and the average azimuth is 38.7°. The maximum horizontal principal stress and the minimum horizontal principal stress of the two measuring points are basically vertical in orientation, and the difference is about 90.4°. The intermediate

ISSN: 2710-0723

principal stress is close to the vertical direction and can be regarded as the vertical stress component of the in-situ stress field.



(a) Main inclined shaft bottom yard



(b)Track roadway

Figure 1. Main stress stereogram of Hengxing coal mine

3. Numerical Simulation of Roadway Support Design

Combined with the actual roadway surrounding rock situation in Hengxing coal mine, the roadway surrounding rock in Hengxing coal mine belongs to the unstable type. Above coal seam 3 is the goaf of coal seam 2, which is 8.60~21.85m away from coal seam 2, with an average of 14.77m. Under the condition of reasonable layout of roadway location, when the height of isolated rock pillar between coal seams is greater than 7.0m, it can be supported according to the general support method. The experimental borehole ZX1 of the mechanical properties of

ISSN: 2710-0723

the roof rock of No. 3 coal seam shows that the spacing between No. 3 coal seam and No. 2 coal seam is 4.4m. In addition, according to the on-site construction situation, the spacing between some areas is about 4~5m, indicating that the spacing between No. 3 coal seam and No. 2 coal seam is small in special areas, and special support research is needed.

Based on the in-situ stress measurement results, the numerical simulation software was used to simulate the roadway support of No. 3 coal seam. The size of the model is 60m×60m×20m, consisting of 5480 blocks and 6717 nodes. The mechanical parameters of model coal and rock stratum are shown in Table 1. The basic model is shown in Figure 2.

Table 1. Mechanical parameters of model coal and rock stratum

Name	Thickness/m	Bulk/10^9Pa	Shear/10^9Pa	Friction/°	Tension/10^6Pa	Density/ 10^3kg/m^3	Cohesion/10^6Pa
Siltstone	10	35	53	37	3.53	2.5	7.85
Fine sandstone	5	18	27	38	4.91	2.47	5.95
Mudstone	4	8	10	44	4	2.5	0.76
No.2 coal seam	1	6	9	30	3.7	1.4	1.7
Mudstone	5	8	10	44	4	2.5	0.76
Siltstone	5	35	53	35	2	2.57	15
Mudstone	4	8	10	44	4	2.5	0.76
No.3 coal seam	1	6	9	30	3.7	1.4	1.7
Mudstone	5	8	10	44	4	2.5	0.76
Siltstone	10	35	53	35	2	2.57	15
Fine sandstone	10	18	27	38	4.91	2.47	5.95

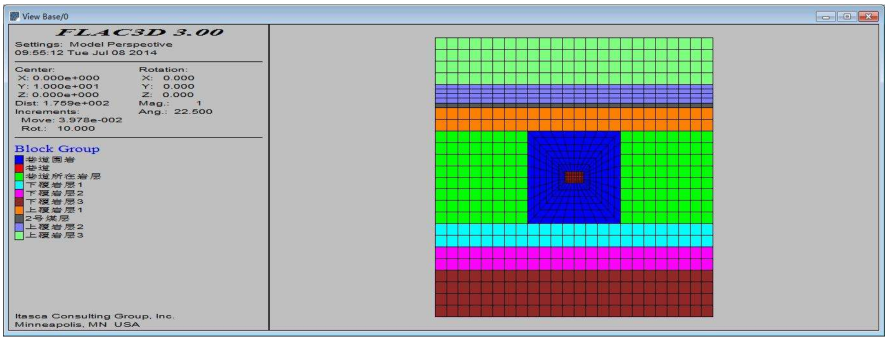
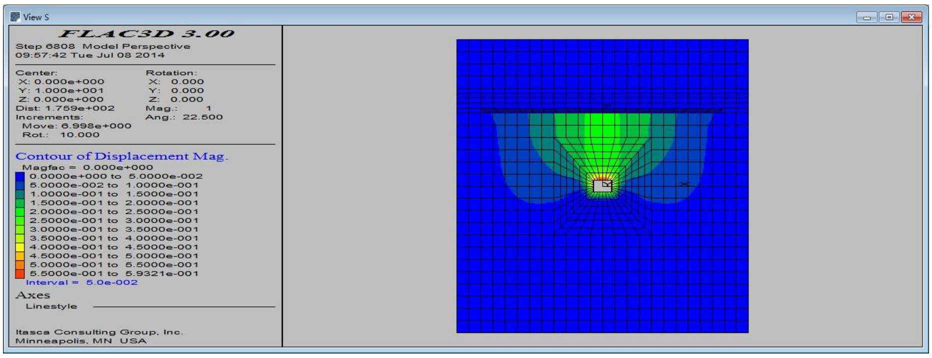


Figure 2. Schematic diagram of model

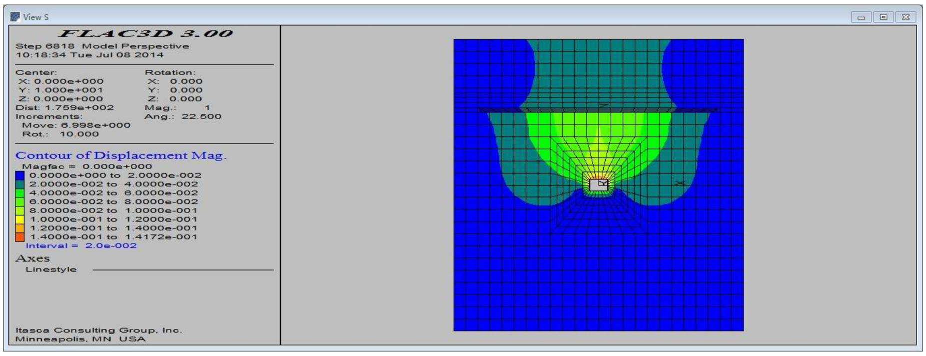
The surrounding rock deformation of roadway under four support modes, i.e. no support, bolt support, bolt+anchor cable support, bolt+anchor cable+shotcrete support, is simulated and analyzed. The specific results are shown in Figure 3. The simulation results in Figure 3 show that: (1) the surrounding rock of the roadway is severely deformed without support, with the roof and floor moving closer by 855mm and the two sides moving closer by 840mm. (2) The effect of bolt support on the deformation of roadway surrounding rock is very obvious, which can reduce the displacement by 75%, and reduce the displacement of roof and floor and two sides to 198mm and 217mm respectively. But under the condition of bolt support, the roof and floor displacement and two sides displacement are about 200mm, and the surrounding rock

ISSN: 2710-0723

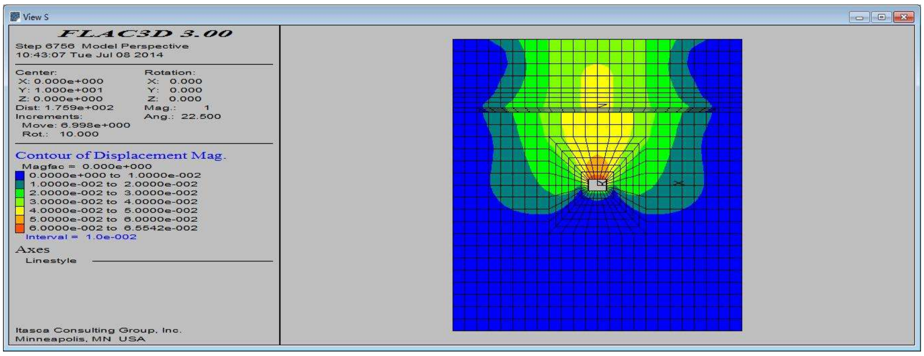
deformation of the roadway can not meet the production requirements. (3) The supporting effects of bolt+anchor cable support and bolt anchor cable shotcrete support are similar. When the roadway reaches the equilibrium state, the surrounding rock movement is about 100mm, which can meet the requirements of production and roadway surrounding rock control. However, the improvement of deformation control effect by further increasing shotcrete support is limited.



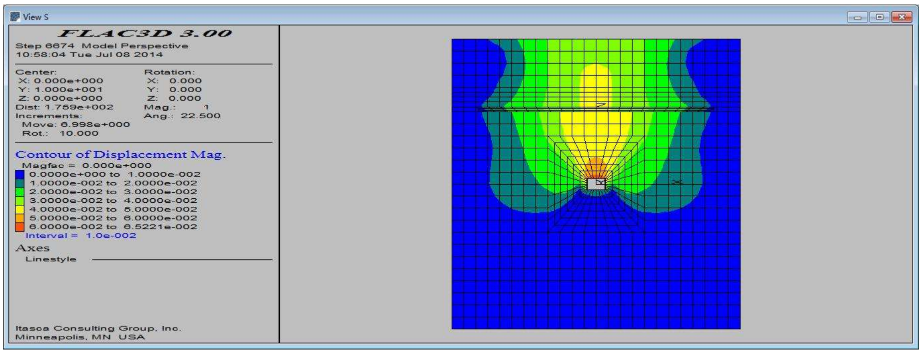
(a) Surrounding rock displacement of unsupported roadway



(b) Surrounding rock displacement of bolt supported roadway



(c) Surrounding rock displacement of bolt+anchor cable supporting roadway



(d) Surrounding rock displacement of bolt+anchor cable+shotcrete support roadway

Figure 3. Simulation results under different support conditions

ISSN: 2710-0723

4. Conclusion

Through the in-situ stress measurement and numerical simulation analysis, the following conclusions are drawn:

(1) The in-situ stress field in the second mining area of No.3 coal seam in Hengxing coal mine is dominated by horizontal stress, the average maximum horizontal principal stress is 3.88MPa, and the average azimuth is 129°. The distribution characteristics of in-situ stress have important guiding significance for roadway excavation and support design.

(2) The numerical simulation results show that the bolt+anchor cable support can effectively control the deformation of roadway surrounding rock, and the further increase of shotcrete support has limited improvement on the deformation control effect.

(3) This study provides an important reference for the safe mining of No.3 coal seam in Hengxing coal mine, but it still needs to be further verified and optimized in the actual project. Future research can be combined with more on-site monitoring data to improve in-situ stress measurement and roadway support design methods, and provide more reliable technical support for safe and efficient mining of deep coal mines.

Acknowledgments

The study was supported by Key science and technology plan of the Emergency Management Department (2024EMST070703), Major science and technology projects of Guizhou Province (Qiankehe Key Special Project Document [2024]029).

References

[1] Dong Jun, Wu Yunjie, Si Huaru, et al. Deformation Characteristics and Surrounding Rock Stability Control of Soft Rock Roadway under High Structural Stress in Xin'an Coal Mine[J]. China Mining Magazine, 2024, 33(08): 147-157.

[2] Wang Wenfei, Gao Baobin, Zhang Longyang, et al. Research on the Mechanism and Technology of Coordinated Integrated Control of Surrounding Rock in High-Stress Soft Rock Roadway[J]. Coal Engineering, 2024, 56(11): 103-109.

[3] Yue Xizhan, Yang Ziyi, Li Yingfu, et al. Surrounding Rock Control and Support Design for Deep High-Stress Roadways[J]. Coal Technology, 2024, 43(06): 37-42.

[4] Wang Chuanying, Wang Yiteng, Han Zengqiang, et al. Research on In-Situ Stress Measurement Method Based on Borehole Morphology Analysis[J]. Rock and Soil Mechanics, 2019, 40(S1): 549-556.

[5] Zhao Shankun, Gao Guiyun, Wang Chenghu, et al. Small-Diameter Cone-Type Bottom Hole Overcoring Stress Relief Method and Experimental Research[J]. Journal of China Coal Society, 2021, 46(S1): 74-83.

[6] Liu Xiangyang, Liu Yonghao, Zhang Shunfeng, et al. In-Situ Stress Measurement and Stress Field Characteristics Analysis in Maiduoshan Coal Mine[J]. China Safety Science Journal, 2023, 33(S2): 91-95.

[7] Ding Lipei, Tang Tao, Liu Guoqing. Research on Roadway Support Parameter Design Based on In-Situ Stress[J]. China Energy and Environmental Protection, 2019, 41(06): 113-116.

[8] Bai Xinyuan, Gao Dengyan, Chen Jianhua. Research on Roadway Layout and Support under Shallow and Extremely Close Goaf[J]. Coal Engineering, 2025, 57(01): 52-59.

[9] Sun Xiaodong, Zhang Yi. Research on Secondary Support Timing and Support Parameter Optimization for Deep High-Stress Roadways[J]. Coal, 2025, 34(01): 18-22.

[10] Li Yang, Huang Wenlong. Application of Overcoring Stress Relief Method in In-Situ Stress Measurement of a Deep-Buried Tunnel[J]. Journal of Hebei GEO University, 2021, 44(03): 92-97.

ISSN: 2710-0723

[11] Wu Peinan, Zhang Qiang, Li Yapeng, et al. Calibration Analysis of Elastic Modulus of Eccentric Core in In-Situ Stress Measurement by Stress Relief Method[J]. Chinese Journal of Rock Mechanics and Engineering, 2024, 43(12): 2956-2967.