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Study on the Deformation Law and Support of Mining Roadway Under the Influence of Mining

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Abstract

Under the influence of mining disturbance, the deformation of roof, floor and two sides of roadway increases. Taking the 2506 working face mining roadway of Chensilou Coal Mine as the research background, the influence of working face advance on the deformation law of surrounding rock of roadway was studied through experiment and numerical simulation. The results show that when the depth plane of the monitored roadway section is close to the working face, the roadway is greatly affected by mining. The roadway displacement and stress concentration degree increase greatly, and the surrounding rock yield deformation is large. In order to control the deformation of surrounding rock, combined with theoretical calculation and numerical simulation, the supporting design of 2506 working face mining roadway was carried out. The simulation results show that the second scheme can effectively control the deformation of surrounding rock and maintain the stability of roadway itself.

Keywords

Mining effect; Surrounding rock deformation; Numerical simulation; The roadway supporting.

1. THE INTRODUCTION

Mine mining is the main mode of coal mining in China. Large scale roadway engineering needs to be excavated underground [1]. Most of the coal mines excavated by well workers excavated mining roadways [2], many mining roadways occurred accidents because of improper support. It is necessary to strengthen the study of roadway support. The stability of roadway surrounding rock is related to the surrounding rock occurrence environment, but mainly depends on the continuous mining influence caused by the continuous advancement of the working face. Under the influence of mining disturbance, the roadway is more prone to the deformation and failure of roadway surrounding rock, which affects the efficient and safe production of the mine [3]. Zhang qi etc[4]studied the deformation law of the surrounding rock of the mining roadway in Jinjie Mine, and the stress distribution law of the surrounding rock under the influence of mining was mainly studied. The supporting parameters of the supporting structure of the surrounding rock of the roadway were re-optimized. Xie Xiaoping etc[5]studied the influence of multiple mining in the close coal seam of Cuijiazhai Coal Mine, and the mining roadway was seriously deformed and damaged. Combined with theoretical analysis and numerical simulation, the reasonable position of the close mining roadway under the influence of mining was analyzed. Wang Weijun etc[6] studied the distribution law of surrounding rock stress field under the action of mining loading and unloading, and the mechanism of large deformation and instability of floor roadway under dynamic pressure was revealed. The proposed control method guided the field engineering practice. On the deformation law of roadway surrounding rock and roadway support problem, many scholars and experts in our country have carried out systematic research with various methods, including theoretical analysis and physical similarity simulation method [7-10]. The support research of mining roadway has always been a hot topic of academic researchers, and the support effect of such roadway is very important for efficient and safe mining of working face [11-13]. Both sides of the 2506 working face mining roadway are coal bodies, which are affected by the mining of the working face, and the roadway deformation is large and difficult to control. Different geological environments have different supporting modes of the roadway. Through theoretical and numerical simulation research, the supporting mode of the roadway suitable for Chensilou coal mine was designed, in order to provide guidance for similar projects.

2. ENGINEERING GEOLOGY

The geographical location of the 2506 working face is in the No.5 mining area. The corresponding ground elevation of the working face is + 34.70m, and the elevation range of the working face is -423.1 ~ 672.8 m. The strike length is 980.5 ~ 1080.8m. The inclination length is 97.4 ~ 324.7 m, and the total area can reach 304740 m2. The working face to the north is not yet mined solid coal and its own protective coal pillar, and the south is –720 orbit dark deviated well, -720 belt dark deviation and -720 return air dark inclined shaft and its own protective coal pillar, east to the south rail alleys, south leather alleys and its own protection coal pillar, 2301 old empty district, F30 fault and its own protective coal pillar, and west is not yet mined solid coal. The villages of Liuzhuang, Qiuhuangzhuang and Wangfanpeng are the corresponding surfaces of 2506 working face, and the facilities on the surface were affected by the surface collapse of the working face mining.

Based on the variation of coal seam thickness of 2509 working face and the actual measurement of coal seam thickness in 2506 working face roadway excavation, the coal seam thickness has little change, obvious change rule and simple structure. The coal seam in the inner part of the working face is a little thin, and the overall influence is small. The maximum coal seam thickness is 3.0 m, and the minimum coal seam thickness is 1.5 m. The average coal seam thickness is 2.56 m. The coal seam on the working face as a whole is a stable coal seam.

3. PETROPHYSICAL AND MECHANICAL PROPERTIES

Table 1. Rock physical mechanics test table

The lithology	Density/Kg• m^{-3}	Wave velocity/m•s^{-1}	Uniaxial compression test			Uniaxial tensile test
			Compressive strength /MPa	Elasticity modulus /GPa	Poisson's ratio	Uniaxial tensile strength /MPa
Fine sandstone	2714	4059	96.49	9.64	0.16	4.54
Sandy mudstone	2544	2650	46.32	4.63	0.21	3.96
Medium grained sandstone	2561	3646	53.10	7.06	0.20	1.66

Drilling core sampling was carried out on site for surrounding rock of roadway, sealed, and transported to the specimen processing plant of Henan Polytechnic University. After processing, the physical and mechanical tests were carried out on the rock, and the density, wave velocity, tensile strength and compressive strength of the rock were measured, so as to provide numerical basis for the subsequent numerical simulation. The resulting data are shown in Table 1.

4. NUMERICAL SIMULATION

4.1. Establishment of Numerical Simulation Model

Model is shown in figure 1. According to the geological conditions of roadway, setting up a 200 m long, 60 m high, 3D numerical simulation model of depth is 75 m long. Constitutive model selected Mohr-Coulomb model, the roadway surrounding rock and its nearby cell encryption processing, which made the calculation more accurate. The field away from the roadway did not affect the simulation precision of the grids, and the size of grids could enlarge appropriately. Model node number is 1339260, and zone number is 1299800. The direct roof of working face coal seam is gray-black sandy mudstone, and the thickness ranges from 5.30 m to 7.40 m, with an average of 5.88 m. The basic roof is a light gray fine sandstone, and the thickness ranges from 4.33 m to 19.20 m, with an average 16.67 m. The direct bottom is dark gray sandy mudstone, and the thickness ranges from 4.52 to 9.93 m, with an average 5.58 m. The base bottom is light grey medium grained sandstone, and the thickness ranges from 2.69 to 11.32 m, with an average 8.95 m. According to the rock physical mechanics test, the rock physical mechanics parameters of the roof and floor of coal seam are shown in Table 2.

Table 2. Physical and mechanical parameters of each rock layer

The lithology	Density/Kg• m^{-3})	Volume Modulus /(GPa)	Shear Modulus /(GPa)	Tensile strength /(MPa)	Cohesion/(MPa)	Internal friction Angle /(°)
Fine sandstone	2714	4.72	4.15	4.54	12.06	48.69
Sandy mudstone	2544	2.66	1.91	3.96	4	33
coal	1400	1.35	0.63	0.1	0.4	29
Medium grained sandstone	2561	3.92	2.94	1.66	10.82	40.63

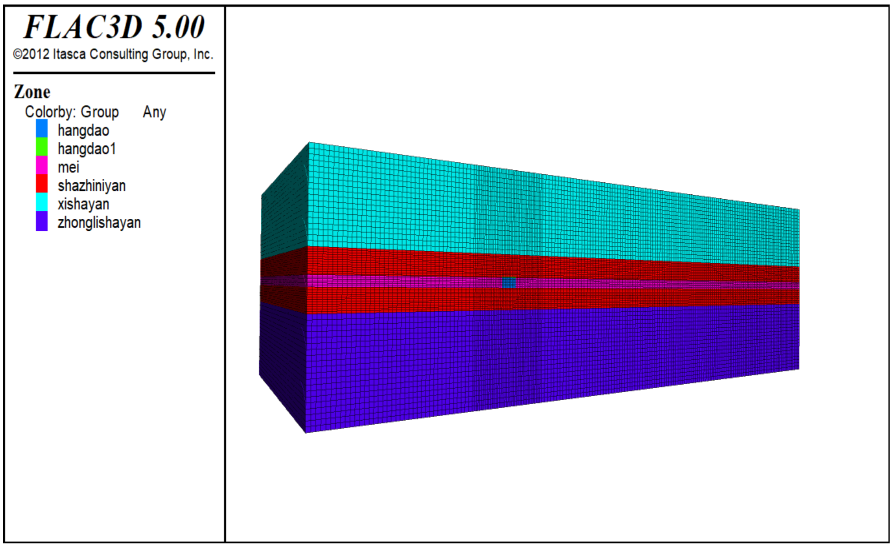


Figure 1. 3D model diagram of numerical simulation

4.2. Analysis of Simulation Results of Roadway Without Support

Figure 2 shows the displacement changing of the roof, floor and two sides when the monitoring points at the midpoint of the roadway roof, floor and two sides are different distances from the working face. The roadway was not supported in numerical simulation. As the working face keeps advancing, the roadway displacement, stress and plastic zone change continually, which provides a basis for subsequent support design. At the beginning of the mining, base plate displacement is 58.64 mm, and the displacement of the roof is 71.92 mm, and the right shift is 117.8 mm, and the left side shift is 115.71 mm. As the distance of working face and monitoring points constantly decreases, the displacement of roadway increases greatly, and roadway deformation is very severe.

Figure 3 shows the stress peak on the left and right sides and the distance between the peak value and the roadway edge. As the working face continuously moves forward, the peak vertical stress of surrounding rock increases accordingly, and the distance from the peak to the edge of the roadway is getting larger and larger. The influence of stress concentration range constantly to extension of deep surrounding rock, the ranges of stress peak on the left and right sides of the roadway are 22.5~26.4 MPa and 23.2~42.3 MPa respectively, and the distances between the vertical stress peak on the two sides and the edge of the roadway are 2.32~3.34 m and 2.7~3.89 m respectively. When the monitoring points in the middle of the left and right sides of the roadway are close to the working face, the stress peak value is large, and the peak value is far from the edge of the roadway. The roadway is affected by the mining of the working face, and the failure extends to the deep surrounding rock.

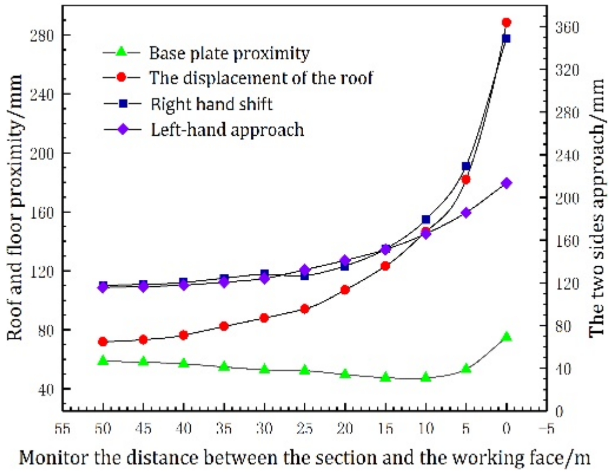


Figure 2. Surrounding rock approach curve of roadway

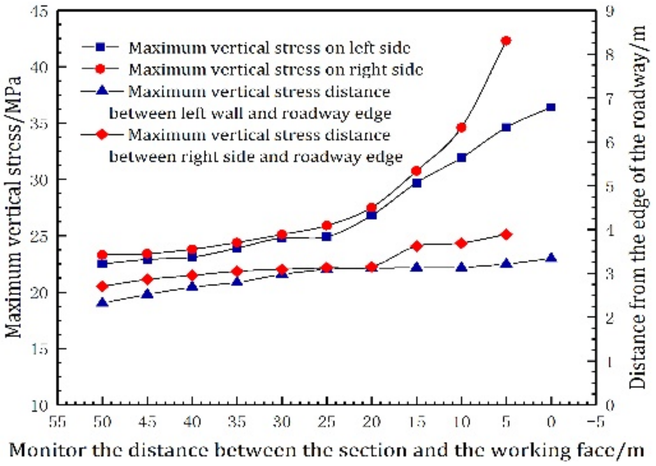
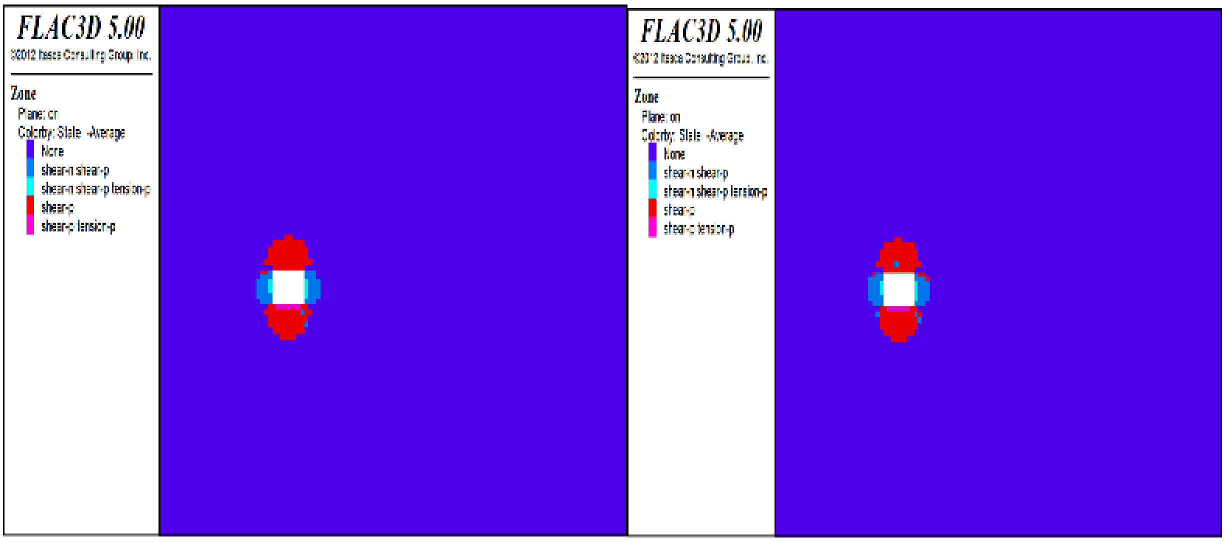
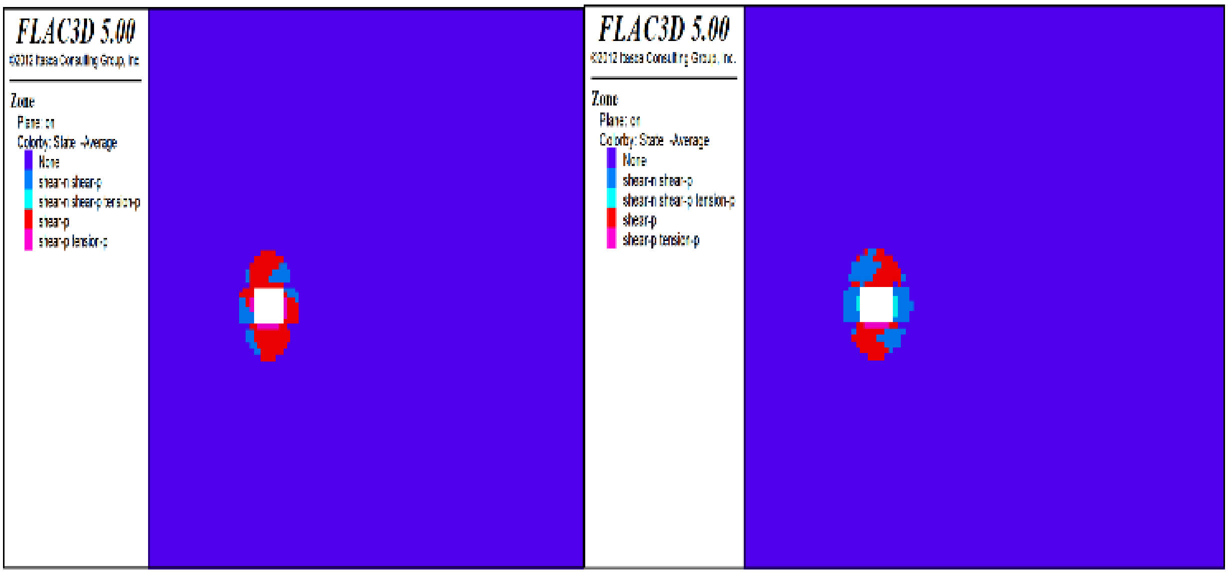


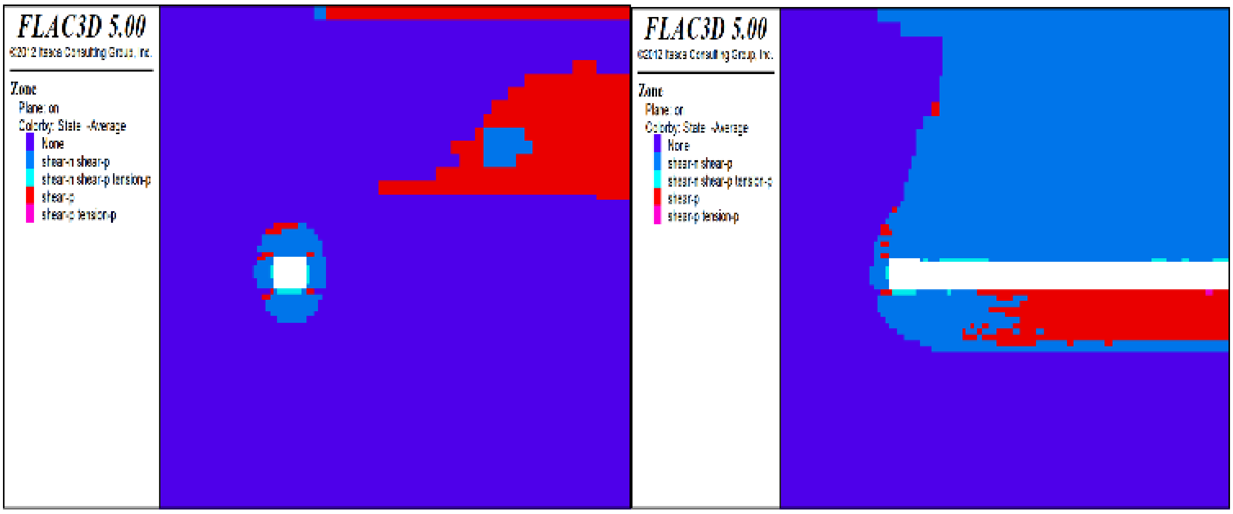
Figure 3. Curve of vertical stress in surrounding rock of roadway



(a) 50 m ahead of the working face (b) 40 m ahead of the working face



(c) 30 m ahead of the working face (d) 15 m ahead of the working face



(e) 5 m ahead of the working face (f) 0 m ahead of the working face

Figure 4. Yield failure diagram of surrounding rock of roadway

Figure 4 shows the change of plastic zone at the monitoring section of the roadway. With the decrease of the distance between the monitoring points and the working face, the change of plastic zone becomes larger and larger. The damage of roof, floor and two sides is serious, mainly for the shear failure and tensile failure. When the distance between the monitoring points and the working face is 40 m, the plastic zone of roadway is almost the similar to roadway excavation. When the working face advances to 30 m from the monitoring points, new changes appear in the plastic zone, and the plastic zone area increases, indicating that the mining disturbance of the working face has a strong influence on the stability of the roadway. When advancing to 5 m away from the monitoring points, a large range of plastic zones appear on the working face, and the leading stress produced by mining causes a large damage above the working face.

4.3. Roadway Support Design

Two kinds of roadway support schemes were designed through numerical simulation and theoretical research, and their supporting effects were compared and verified.

Scheme 1: Figure 6 is the schematic diagram of roadway cross-section support in Scheme 1, which adopts combined support of anchor bolt and anchor cable. The roof adopts Φ22×2200 mm high strength anchor bolt, and row spacing between anchors is 1000 mm×900 mm. Anchor cable specification Φ21.6×6300 mm, row spacing between anchor cables is 1600 mm×1900 mm. Roadway sides adopt Φ18×2200 mm high strength anchor bolt, and row spacing between anchors is 900 mm×900 mm.

Scheme 2: Figure 7 is the schematic diagram of roadway cross-section support in Scheme 2, which adopts combined support of anchor bolt and anchor cable and bolt-mesh. The roof adopts Φ22×2200 mm high-strength anchor bolt, and row spacing between anchors is 900 mm×800 mm. Anchor cable specification Φ21.6×6300 mm, row spacing between anchor cables is 1500 mm×1600 mm. Roadway sides adopt Φ18×2200 mm high strength anchor bolt, and row spacing between anchors is 800 mm×800 mm. Metal net is 1000×2500, Grid 70×70 mm, grid allowable deviation -5 ~ +7 mm, with 6# steel processing.

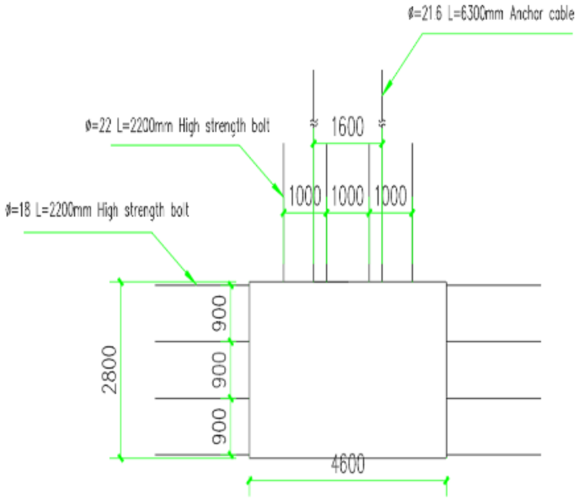


Figure 5. Support Schemes 1

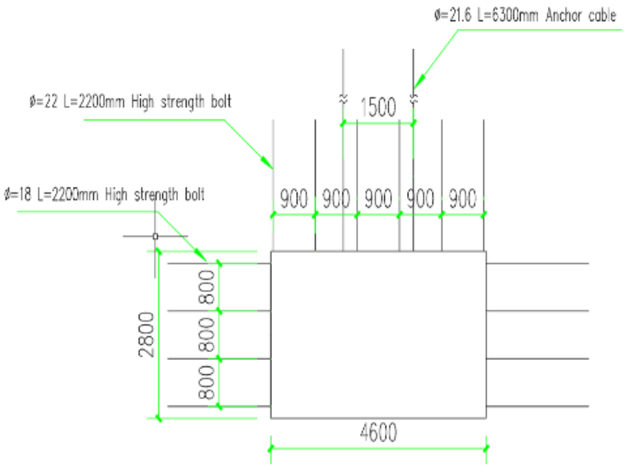
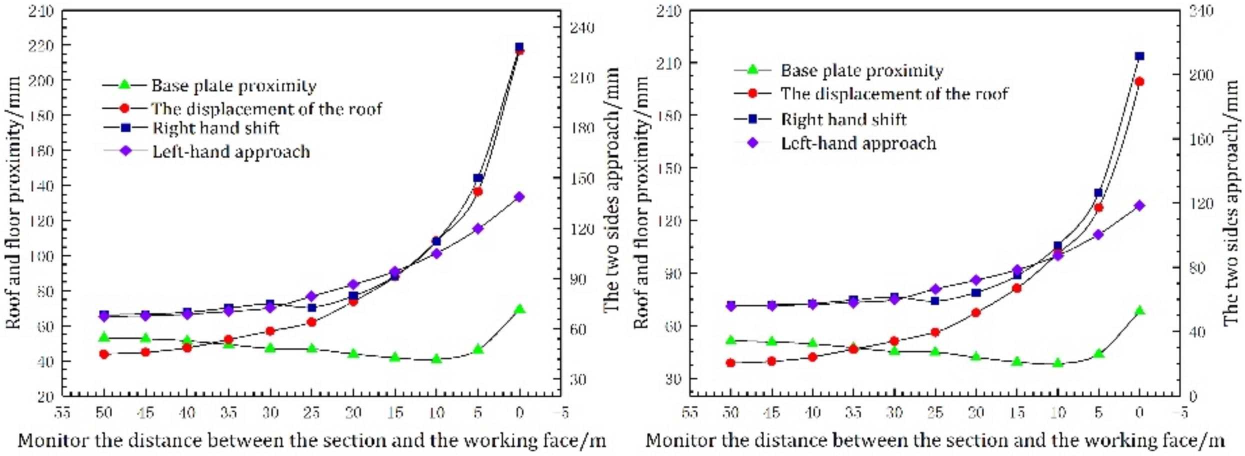


Figure 6. Support Schemes 2

4.4. Analysis of Numerical Simulation Results of Different Support Schemes

Figure 7 is the curve of surrounding rock movement under the two support schemes.

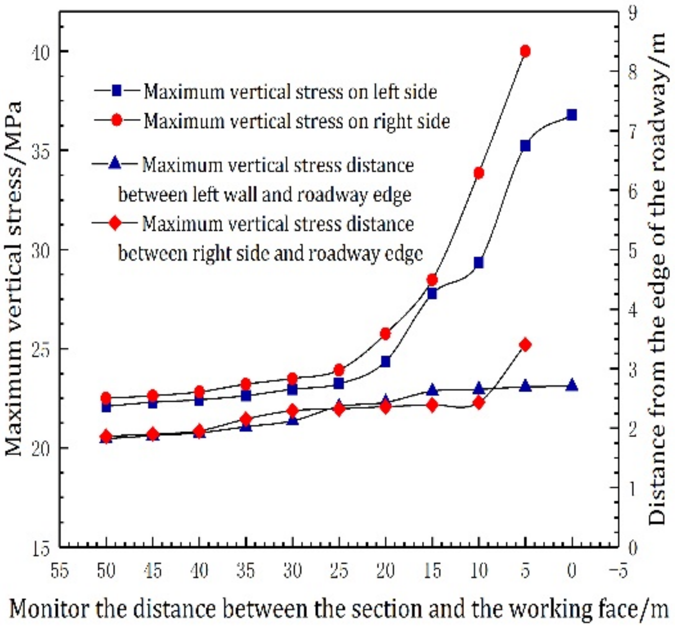
Scheme 1 was adopted for roadway support, which made roadway deformation under certain control. When the working face is 50 m away from the monitoring points, base plate displacement is 53.1 mm, and the displacement of the roof is 43.84 mm, and the right shift is 68.42 mm, and the left side shift is 67.43 mm. With the working face advancing continuously, when the working face is close to the monitoring section, the roadway deformation is severe. When the supporting scheme 2 is adopted, the roadway deformation is effectively controlled by the support. When the working face is 50 m away from the monitoring points, base plate displacement is 51.3 mm, and the displacement of the roof is 38.6 mm, and the right shift is 56.4 mm, and the left side shift is 55.1 mm. The closer the distance to the monitoring points of the roadway section, the roadway deformation is severe, but the range is small, in a controllable range. It can effectively control the deformation of roadway surrounding rock and ensure the safe construction ahead.



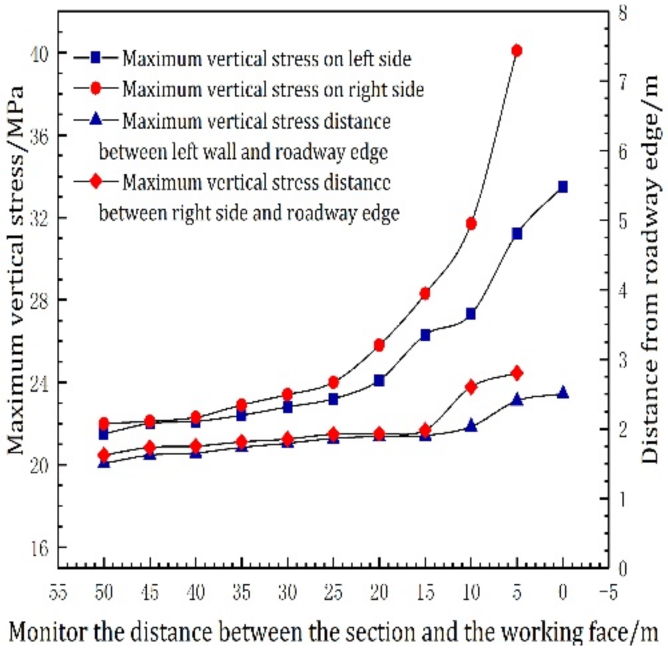
(a) Support Schemes 1 (b) Support Schemes 2

Figure 7. Surrounding rock approach curves under different schemes

Figure 8 shows the vertical stress diagram of surrounding rock under the two support schemes. Under the support condition of Scheme 1, the vertical stress peak of the roadway is concentrated at the middle line of the two sides of the roadway, which is a certain distance from the edge of the roadway. The ranges of stress peak on the left and right sides of the roadway are 22.1~36.8 MPa and 22.5~40 MPa respectively. The distances between the vertical stress peak on the two sides and the edge of the roadway are 1.82~2.7 m and 1.86~3.4 m respectively. The closer the working face is to the monitoring points of the roadway, the stress peak is constantly rising and the distance from the edge of the roadway is also increasing. Under the support condition of Scheme 2, the vertical stress peak of the roadway is concentrated at the middle line of the two sides of the roadway, which is a certain distance from the edge of the roadway. The ranges of stress peak on the left and right sides of the roadway are 21.5~33.5 MPa and 22~39.3 MPa respectively, and the distances between the vertical stress peak on the two sides and the edge of the roadway are 1.5~2.3 m and 1.62~2.3 m respectively. The closer the working face is to the monitoring points of the roadway, the stress peak increases and the distance from the edge of the roadway also increases. However, compared with the support scheme 1, the peak range is smaller and the influence range is relatively small. The second scheme can effectively control the peak stress of surrounding rock and its influence range during mining.



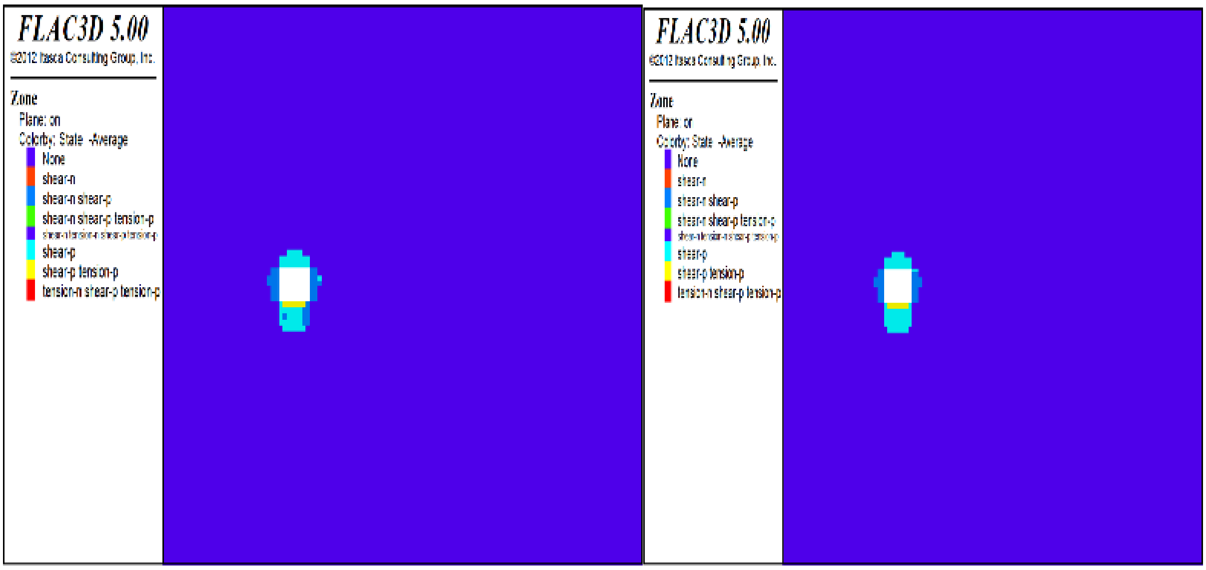
(a) Support Schemes 1



(b) Support Schemes 2

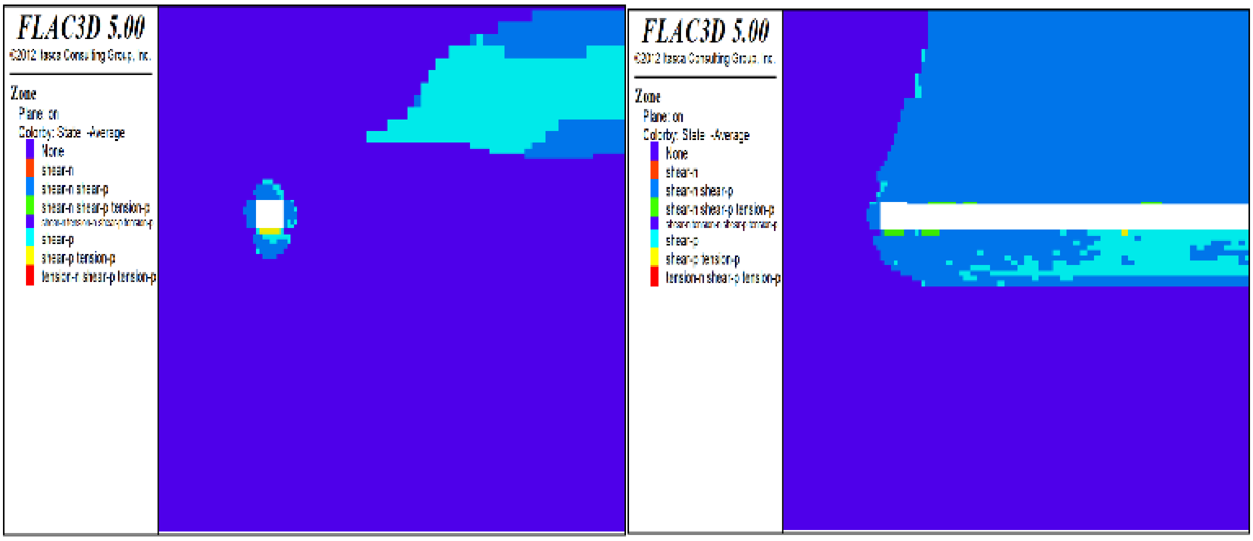
Figure 8. Vertical stress curves of surrounding rock under different schemes

Figure 10 and 11 show yield failure of roadway surrounding rock under the different support schemes. Adopting the scheme 1, the plastic zone is large When the distance between the monitoring points and the working face is 50 m. When the working face advances to 15 m from the monitoring points, the plastic zone of the two sides fundamentally envelopes the whole length of the anchor bolt. The deformation of anchor bolt is large, and the deformation and damage of roadway are serious. When the working face advances to 5 m from the monitoring points, the plastic zone of the two sides envelopes the whole length of the bolt, and the bolt is deformed and failed. Adopting the scheme 2, when the working face reaches the monitoring points of roadway section from 50 m away from the monitoring points, the depth of plastic failure of roadway roof and two sides is less than the anchoring depth, and the roadway can maintain its own stable state.



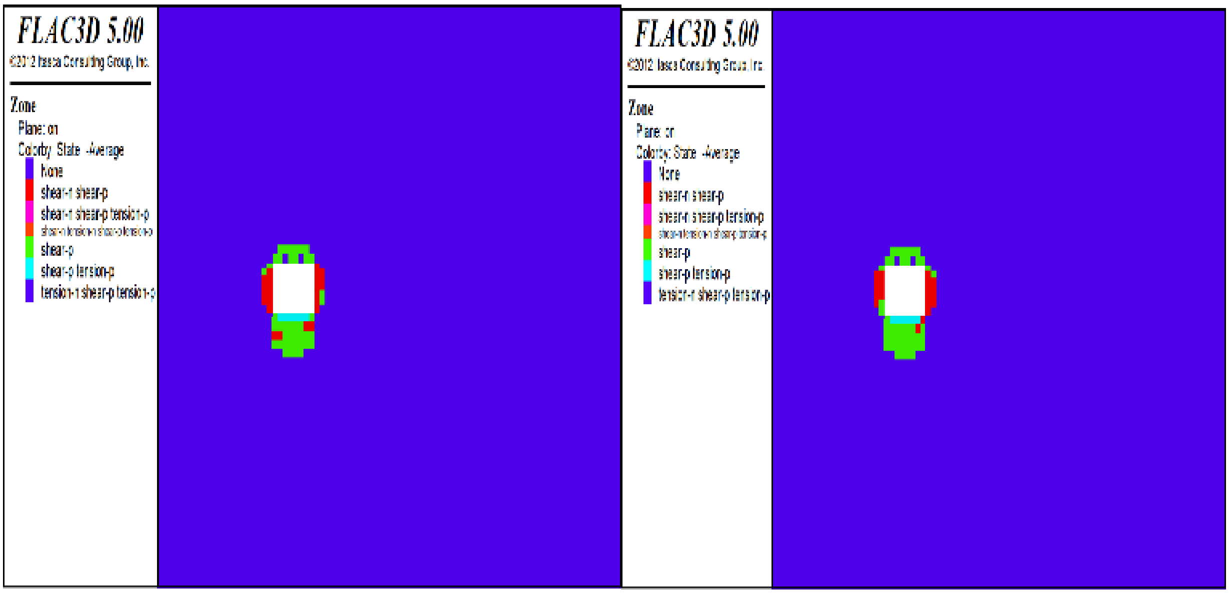
(a) 50 m ahead of the working face (b) 40 m ahead of the working face

(c) 30 m ahead of the working face (d) 15m ahead of the working face

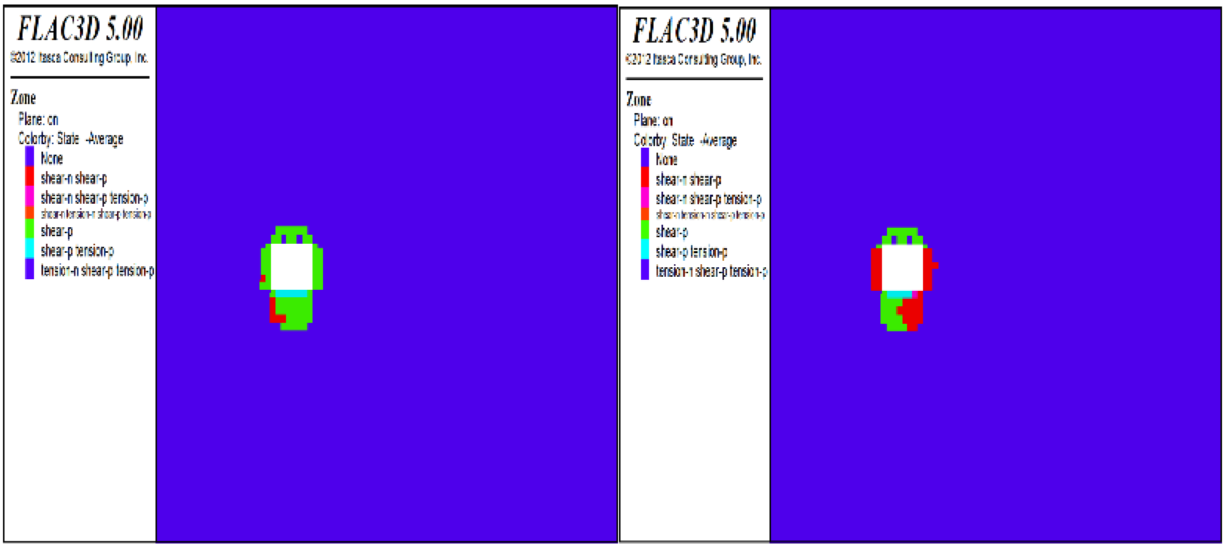


(e) 5m ahead of the working face (f) 0m ahead of the working face

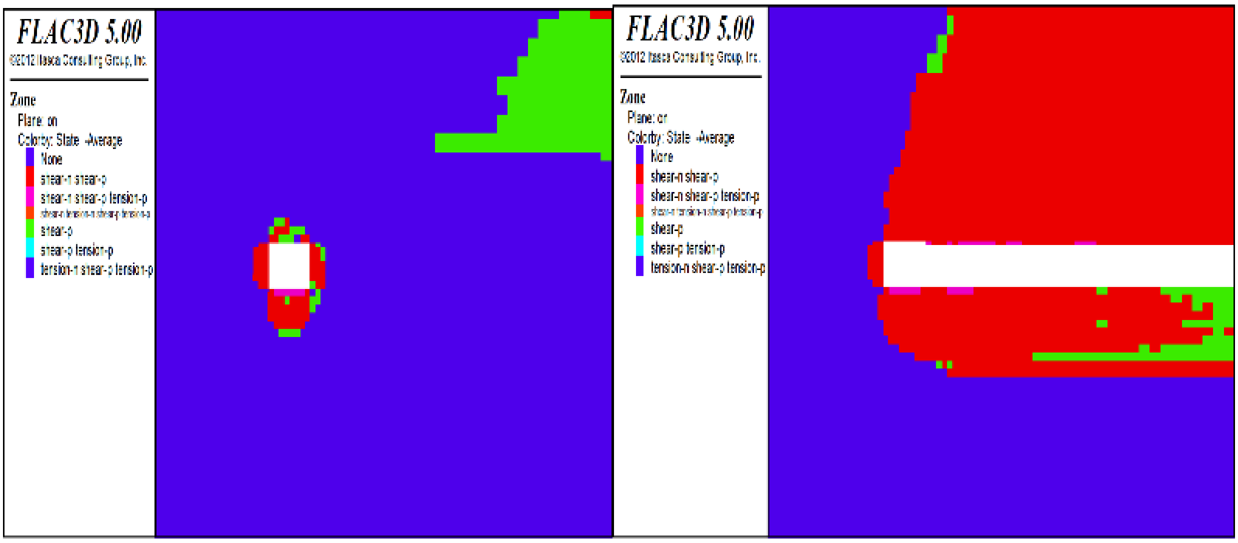
Figure 9. Yield failure of surrounding rock of roadway in support scheme 1



(a) 50 m ahead of the working face (b) 40 m ahead of the working face



(c) 300 m ahead of the working face (d) 50 m ahead of the working face



(e) 50 m ahead of the working face (f) 50 m ahead of the working face

Figure 10. Yield failure of surrounding rock of roadway in support scheme 2

5. CONCLUSION

1) With the continuous advance of the working face, the closer the working face is to the monitoring section of the roadway, the greater the displacement, stress and plastic zone of the surrounding rock will be.

2) Finally, the second support scheme is determined as the final support scheme. The numerical simulation shows that this support scheme can effectively control the deformation of surrounding rock of the roadway. The depth of plastic failure of the roof and both sides of the roadway is less than the anchoring depth of the anchor bolt, and the roadway can maintain its own stable state without affecting the construction ahead of the working face.

REFERENCES

[1] Kang Hongpu. The Development of Mine Roadway Surrounding Rock Control Technology in Coal Mine in China in 70 years and its prospect [J]. Chinese Journal of Rock Mechanics and Engineering, 2021, 40(1): 1-30.

[2] Wang Longfei, Chang Zechao, Yang Zhanbiao. Combined support technology of mining roadway under mined-out area of deep well near coal seam group. Journal of Mining & Safety Engineering, 2018,35 (4): 686-692.

[3] Li Yunpeng, Cui Feng, Yang WenhuaYuChi Xiaoqian. Parameters design and effect evaluation of roadway support in broken surrounding rock under the influence of mining [J]. China Mining Magazine, 2020, 29(Suppl. 2): 265-270.

[4] Zhang Qi, Yang Xiao, Qiao Boyang. Failure characteristics of surrounding rock and optimization of support parameters of mining roadway in Jinjie Mine [J]. Safety in Coal Mine, 2019,50 (6): 219-223

[5] Xie Xiaoping, Su Jing, Wei Zhongju, Xu Guang. Surrounding Rock Control Technology of Near Mining Roadway under the Influence of Multiple Mining [J]. Safety in Coal Mines, 2019,50 (3): 81-88.

[6] Wang Weijun, Yuan Yue, Yu Weijian. Failure mechanism and control of inclined shaft under the influence of mining [J]. Journal of China Coal Society, 2014,39 (8): 1463-1472.

[7] Wen Zhijie, Lu Jianyu, Xiao Qinghua. Failure mechanism and support technology of floor heave in soft rock mining roadway. Journal of China Coal Society, 2019,44 (7): 1991-1999.

[8] Tang Qingbao, Yang Gang, Zhang Qi. Failure characteristics and support parameter optimization of mining roadway in Bulianta mine [J]. Safety in Coal Mines, 2019,50 (4): 223-227.

[9] Yu Weijian, Like, ZhangJing. Analysis of deformation characteristics and controlling factors of deep buried soft rock roadway under the influence of mining [J]. Coal Science and Technology, 2020, 48(1): 125-135.

[10] Song Yanqing, Zhang Jianwei, Hou Siyu. Optimization of Supporting Scheme of Roadway in Crushed Zone under the Condition of Acidic Water Corrosion in Mine [J]. China Mining Magazine, 2019,28 (9): 91-96.

[11] He Feng, Wang Zhenyu, Yu Yang. Research on Steel Beam Support in Over-broken Roof Area of Multiple Mining Roadway [J]. Coal Science and Technology, 2019,47 (7): 115-120.

[12] Li Aijun. Research on active support technology of soft crushing roadway along goaf in deep mine [J]. Coal Science and Technology, 2015,43 (S1): 59-63.

[13] Du Yunhang. Dynamic combined support technology of the broken surrounding rock mining roadway under the old kiln failure area [J]. Coal Engineering, 2018,50 (4): 35-42.