

# Research and application on the horizontal tectonic stress influence on the stability of deep roadway

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**Abstract.** According to the test result of ground stress of -817.0m Horizontal shaft station in Huainan mine area, the stress field distribution characteristic of mainly with horizontal tectonic stress was analyzed, the deep roadway surrounding rock deformation and failure regularity under the situation of the maximum horizontal stress and roadway axis in the different angle were studied by using the FLAC<sup>3D</sup> simulation software, and then specific way of supporting and its parameters were designed combined with the shaft station layout conditions. The result shows that: the roadway stability is relatively good when its tunnel axis the maximum horizontal stress direction within 30° angle, surrounding rock deformation and the plastic zone at the top and bottom are significantly increasing along with the angle increased from 30° to 90°, the major form of deep soft rock deformation and failure is the floor heave. According to the simulation results, the conditions under the layout condition of the shaft station roadway, support methods and support parameters have been designed and determined. The supporting method can be referenced by the similar mines.

## 1. Introduction

The ground stress is the natural stress in the earth's crust, and its magnitude and direction have great influence on the stability of surrounding rock<sup>[1-3]</sup>. In order to determine the mechanical properties of engineering rock mass, to analyze the stability of surrounding rock and to realize the scientific design of underground excavation, it is necessary to study the distribution law of surrounding rock stress<sup>[4]</sup>. A large number of in-situ stress measurement and research results show that the horizontal tectonic stress in deep strata is generally greater than the vertical stress, and the horizontal stress has obvious directivity. And it is one of the important factors that affect the stability of the roof and floor<sup>[5-10]</sup>. For mine engineering design, the determination of the general layout of the mine, the selection of mining methods, and the optimum section shape, section size, excavation steps, support form, support structure parameter, support time and so on, the ground stress condition is the prerequisite<sup>[11-12]</sup>. Therefore, it is important to study the influence of the axial and horizontal tectonic stress on the stability of surrounding rock of deep soft rock roadway when the original rock stress field is certain.

## 2. General situation of engineering geology

### 2.1. Geological conditions of surrounding rock in deep tunnel

The coalfield in Huainan mining area is a totally hidden area covered by the loose layer of the



Cenozoic, which is a nearly east-west tectonic form. The north and south sides of the basin are hedged by imbricate-like nappe structure, and the basin is characterized by a gentle northwest-west syncline structure. The tectonic movement occurred mainly in the Indosinian and Yanshan period. The regional tectonics is formed by the push of the north-south direction. Syncline within the stratum dip gentle is generally  $9^{\circ}\sim 19^{\circ}$ , which is a series of gentle folds. In general, the mine strata formed in the Carboniferous and Permian sandstone, shale, mudstone lithology, experienced compressional and shear tectonic movement many times the role of the rock with mud cementation and katamorphic characteristics, and the occurrence of residual tectonic stress is higher.

According to the rock mechanical properties test results of long-term statistics, index of physical and mechanical properties of rock in the mine: Aluminum mudstone, mudstone and sandy mudstone and argillaceous sandstone in the natural water content under the condition of uniaxial compressive strength is 1.4~58.5MPa, is 3.3~7.9MPa, tensile strength 0.43~10.4MPa, shear strength was 2.1~10.9MPa; cements of sandstone is dominated by clay, so the strength is low.

### 2.2 Gound stress distribution characteristics<sup>[13]</sup>

In order to find out the law of stress distribution of the mine, we carried out in-situ stress test in the mine shaftbottom central air shaft -817.0m level, the test results are shown in table 1.

Table.1 -817.0m shaft station principal stress size and direction

	Stress /MPa	Dip / $^{\circ}$	Azimuth / $^{\circ}$
First Main Stress $\sigma_1$	24.89	66.64	150.14
Second Main Stress $\sigma_2$	19.64	20.19	1.77
Third Main Stress $\sigma_3$	16.88	11.24	267.57

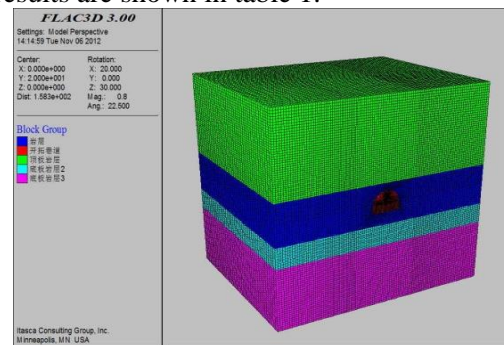


Figure1. Three dimensional numerical simulation model of FLAC<sup>3D</sup>

The stress test results also show that the maximum horizontal principal stress is 19.95MPa, 26.01MPa, 23.40MPa, and the vertical stress is 24.01MPa, 23.11MPa, 22.03MPa, and the stress level is higher. The maximum horizontal principal stress direction is 350.9 degrees, 310 degrees, 330 degrees and 319 degrees, which is close to NWN. Through a series of stress monitoring, the pore region of lateral pressure coefficient is slightly greater than 1. We can deduce that the test area is mainly based on the horizontal tectonic stress.

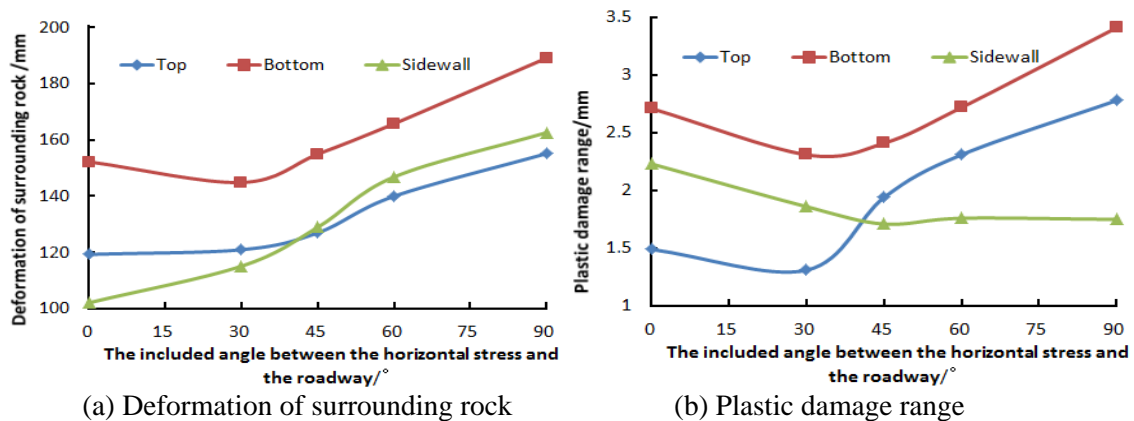
## 3. Numerical analysis of horizontal stress on roadway stability

### 3.1 The establishment of numerical calculation model

In order to obtain the influence degree distribution of horizontal tectonic stress and the deformation of surrounding rock plastic zone and the extent of damage, based on the mine shaftbottom central air shaft -817.0m level as the engineering background, the simulation numerical model is established by using FLAC<sup>3D</sup> numerical software. Using the Mohr-Coulomb model as failure criterion, the model of maximum horizontal stress and the axial angle of roadway at 0, 30, 45, 60 and 90 degrees were established. Three dimensional numerical model is established as shown in figure 1.

### 3.2 Numerical simulation results

The distribution of surrounding rock deformation and plastic zone in the surrounding rock of the maximum horizontal stress and the axial direction is shown in Figure 2.



(a) Deformation of surrounding rock (b) Plastic damage range  
Figure 2. Displacement and plastic zone of surrounding rock with different maximum horizontal stress and axial direction of roadway

As shown in Figure 2 :

(1) When the angle between the maximum horizontal stress and the axial direction of the roadway is  $0^\circ$ , the two sides displacement is 102.14mm, and the damage range of plastic zone is 2.23m; the subsidence of roof is 119.32mm, and the damage range of plastic zone is 1.49m; the floor heave volume is 152.25 mm, and the damage range of plastic zone is 2.71 m. It is not difficult to see the deformation of roadway surrounding rock and plastic area is relatively small.

(2) When the angle between the maximum horizontal stress and the axial direction of the roadway is  $30^\circ$ , and the two sides displacement is 115.17mm, and the damage range of plastic zone is 1.86m; the subsidence of roof is 121mm the damage range of plastic zone is 1.31m; and the floor heave volume is 144.91mm, and the damage area of plastic zone is 2.31m.

(3) When the angle between the maximum horizontal stress and the axial direction of the roadway is  $45^\circ$ , and the two sides displacement is 129mm, and the damage range of plastic zone is 1.71m; the subsidence of roof is 127mm, and the damage range of plastic zone is 1.94m; the floor heave volume is 155 mm, and the damage range of plastic zone is 2.41 m.

(4) When the angle between the maximum horizontal stress and the axial direction of the roadway is  $60^\circ$ , and the two sides displacement is 146.87mm, and the damage range of plastic zone is 1.76m; the subsidence of roof is 140mm, and the damage range of plastic zone is 2.31m; the floor heave volume is 165.82 mm, and the damage range of plastic zone is 2.72 m. Compared with the maximum horizontal stress is  $0^\circ$  to the axial direction of the roadway, and the displacement of the roof and the bottom plate and the displacement of two sides are obviously increased

(5) When the angle between the maximum horizontal stress and the axial direction of the roadway is  $90^\circ$ , and the two sides displacement is 162.63mm, and the damage range of plastic zone is 1.75m; the subsidence of roof is 155.17mm, and the damage range of plastic zone is 2.78m; the floor heave volume is 189.15 mm, and the damage range of plastic zone is 3.41 m. The damage range of plastic zone has reached the maximum value.

As shown in the numerical simulation results:

(1) When the angle between the maximum horizontal stress and the axial direction of the roadway is less than  $30^\circ$ , and the deformation amount of the wall rock at the bottom is slightly decreased and the deformation amount of the top and the two sides is slightly increased with the increase of the included angle. The plastic zone of the top, bottom and two sides is slightly reduced with the increase of the included angle.

(2) When the maximum horizontal stress and the axial angle of the roadway are in the range of  $30^\circ \sim 90^\circ$ , the deformation of the top and bottom plate and the surrounding rock increases significantly with the increase of the included angle. Compared to the top and bottom of the plastic zone of the surrounding rock increased significantly, the deformation of two sides decreased slightly. When the angle between the maximum horizontal stress and the axial direction of the roadway is  $90^\circ$ , the deformation and plastic zone of roadway roof, bottom plate and wall rock have reached the maximum

value. Among them, the floor heave is more serious in the total deformation of the roadway, which shows that the floor heave is the main form of the deformation and failure of the deep high stress soft rock roadway.

#### 4. Engineering practice

According to the ground stress test and rock physical mechanical properties test, the angle between -817 Horizontal track cross-cut direction and the direction of the average maximum principal stress is  $48.5^\circ$ . The ratio of horizontal stress to vertical stress is 0.97:1. The results of FLAC<sup>3D</sup> numerical simulation show that the horizontal stress in the included angle has a great influence on the surrounding rock stability. Therefore, in order to maintain the long-term stability of roadway surrounding rock, it is necessary to take into account the influence of horizontal stress on the stability of roadway surrounding rock when selecting roadway support mode and determining support parameters.

The results of numerical simulation show that the deformation of the roof and floor of the roadway is especially affected by the horizontal tectonic stress. Therefore, special strengthening method should be adopted to support the roof and floor of the roadway. Full-face ultra-high-strength pre-stressed anchor bolt with high-strength bolt-net support technology can effectively control the strong deformation of the soft rock roadway and maintain the stability of the roadway.

##### 4.1 Parameters of roadway support

Bolt layout: full-profile layout.

Support system: roadway surrounding rock support with a force of not less than 60kN ultra-high-strength prestressed bolt support system.

Treatment of special parts: The maximum plastic zone of the surrounding rock is the corner of the roadway where a row of bolts are arranged. Bolts are arranged in the straight wall and semicircular arch, the interval is 800mm × 800mm. The supporting section is shown in Figure 3.

Bolt :Diameter is 22mm, length is 2.5m, yield strength is more than 700MPa, elongation is more than 10%. The construction prestress of the bolt should reach 7 ~ 8t; using high-strength spherical type pallet with thickness of 8mm and area of 150mm × 150mm and standard high-strength torque nut with cover.

Steel mesh: reinforced with diameter of 8mm welding, the mesh grid size specifications: 110mm×110mm, mesh: 1650mm×850mm.

Injection method: a full cross-section injection, jet thickness: 120mm.

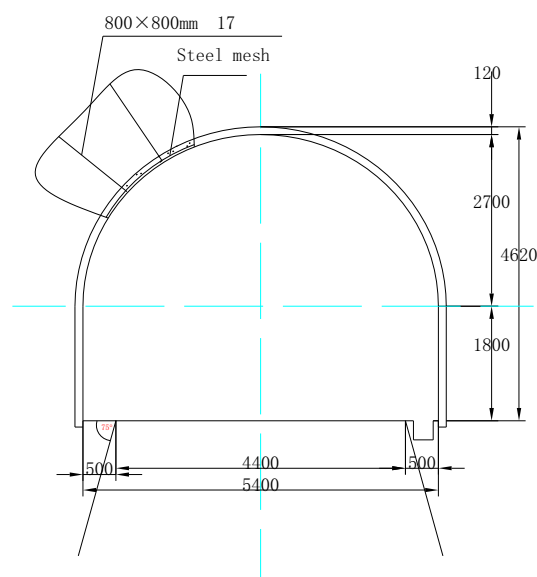


Figure 3. section of roadway support

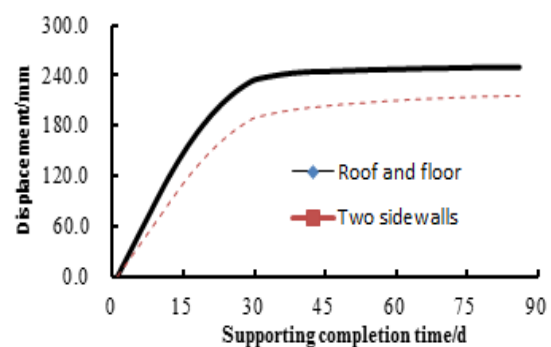


Figure. 4 curve of surface displacement of Roadway

#### 4.2 Analysis of supporting effect

After supporting the roadway, the deformation of surrounding rock of roadway is monitored by 90d, and the observation results are shown in Figure 4.

As shown in Figure 4, after the roadway surrounding rock is supported, in the roadway surface displacement observation period, the surrounding rock deformation is not large, the maximum displacement of two to help the near 215.8mm, the top floor of the maximum displacement of 250mm, consistent with numerical simulation results After 30 days, the deformation speed of the surrounding rock began to slow down, and after 35 days, the deformation velocity was 0.6mm/d and finally stabilized. It can be explained that the support scheme effectively controls the strong deformation of high stress soft rock roadway and maintains the stability of roadway. It is also verified that the numerical simulation study on the maximum horizontal stress and the axial angle of the roadway can play a good guiding role.

#### 5 Conclusion

Through Flac<sup>3D</sup> numerical simulation study, the deformation and failure law of surrounding rock of soft rock roadway under different angles are obtained. And successfully applied to the deep roadway support engineering practice, maintaining the stability of the roadway surrounding rock, the effect is good. The main conclusions of this paper are as follows:

(1) The distribution of stress field in deep mine, which is mainly caused by horizontal tectonic stress, is an important influence on the stability of deep roadway, especially in soft rock tunnel.

(2) The numerical results reveal that the maximum horizontal stress direction affects the stability of roadway surrounding rock, and when the angle between the roadway axial and maximum horizontal stress direction was 30°, the stability is relatively good. When the angle was in the range of 30°~90°, with the increase of the angle, the deformation of surrounding rock and plastic zone at the top and bottom are significantly increased. The floor heave is the main form of deformation and failure of deep high stress soft rock roadway.

(3) The engineering practice shows that the high strength bolt net support increasing the whole section of the corner bolt technology is adopted, which can effectively control the strong deformation of the high stress soft rock roadway and maintain the stability of the roadway

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