Stability Analysis of Backfill and Underground Pressure Control in the Large-Scale Deep Mining

Fan Wenlu and Xia Changnian
China ENFI Engineering Corporation, Beijing, China

ABSTRACT

For the reason that Anhui Shapinggou Molybdenum mine with large-scale deep mining appears obvious underground pressure, the arch facade sequence mining and subsequent backfilling are designed for controlling the frequent underground movement. The numerical analyses of arch facade mining sequence and conventional upward horizontal slice mining sequence are carried out respectively, and static calculation and dynamic calculation are carried out for the stability of backfill. The analytical results show that the maximum principal stress distribution is uniform in the arch facade mining, and the arch facade mining has smaller degree of stress concentration and less plastic area than those of conventional sequence mining. Because of a better supporting role arising from the vaulting, the surface subsidence displacement caused by arch facade mining is smaller than that caused by conventional sequence mining. The operating range of blasting vibration influences the variation of plastic zone and displacement for backfill. When the blasting dynamic loading is applied near the backfill, the distribution area of backfill plastic zone is expanded obviously. If the curing time of backfill is insufficient, the backfill is prone to collapse.

INTRODUCTION

The main ore body of Anhui Shapinggou molybdenum is thick. The ore body is 1400 m long and 1000 m wide in north-south direction. And its thickness is 550 m. According to the characteristics and distribution of ore body, the sublevel open stoping backfill mining is designed for Shapinggou molybdenum ore exploitation. Due to large scale of ore body, the largest mining depth is close to 1500 m. With the increase of mining depth, the ground stress and confining pressure also increase. At present, a lot of international scholars have made correlation research of deep mining ground pressure control, and accumulated a lot of achievements and experience. However, deep mine also faces a lot of problems of deep underground pressure. There are many challenging mechanics problems which should also be solved, such as, stope underground pressure distribution regularity in deep mining, dynamic disturbance effects on the stability of stope and backfill, and mechanics behavior of instable surrounding rock beyond the critical depth.

In the Shapinggou molybdenum mining, two facade mining sequence plans were designed. We respectively research the stope underground pressure for two different plans, and study the stability of the backfill under dynamic disturbance. Through the establishment of the numerical model of mining, we compare and analyze the underground stress and the change of plastic zone under two different facade mine plans. We obtain the optimization of mining sequence scheme that includes the ability to control underground pressure, and the intensity change rule of back fill under dynamic disturbance.

NUMERICAL MODEL SETUP

Ore Body Characteristics

The main ore body of Shapinggou molybdenum deposit is M1 ore body. M1 ore body is the largest ore deposits. The main ore body horizontal projection is like an irregular ellipse, and the major axis is nearly in an east-west direction. The model of ore body is shown in figure 1.

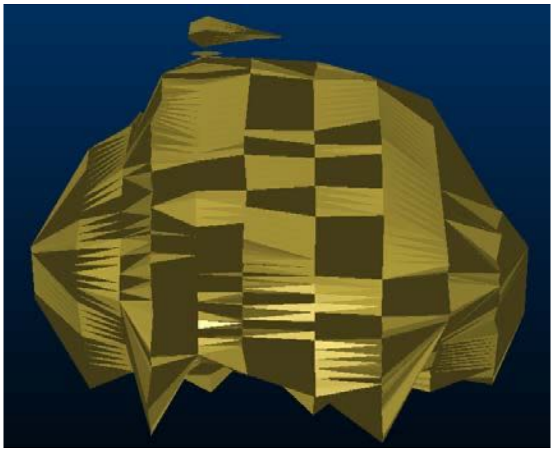

Figure 1. Ore body model

According to the occurrence conditions of ore body and the principal stress direction, the ore body is divided into bar stope room (the width is 40 m) along the east-west direction. Then the stopes are continuously mined. The length of main roadway is parallel to maximum principal stress direction. Stopes are divided into 40 m x 40 m square rooms in the plane,. The extraction level height is 100 m, and the drilling-blasting sublevel height is 50 m.

Introduction of Mining Sequence

Plan 1: Arched facade mining sequence

In the mining process of -450 m level, when the mining conditions of upper level are reached, then the -350 m level could start to mine and by analogy to other upper levels. And on the base of the above, this working face will become an arch facade. In this way, the arch facade is more conducive to the stability of the ore body in theory, and can effectively control the upper pressure. Arch facade mining sequence as shown in figure 2.

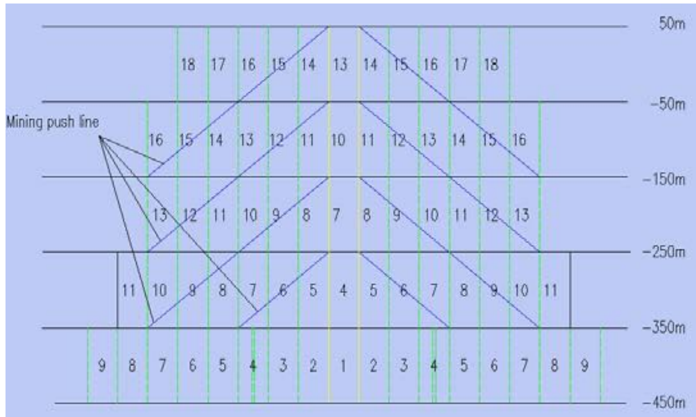

Figure 2. Arched facade mining sequence

Plan 2: Upward level facade mining sequence

The mining of ore body starts at the lowest level. When the lowest level ore body is removed, then the upper level ore body starts to mine, and by analogy to other upper levels. As shown in figure 3.

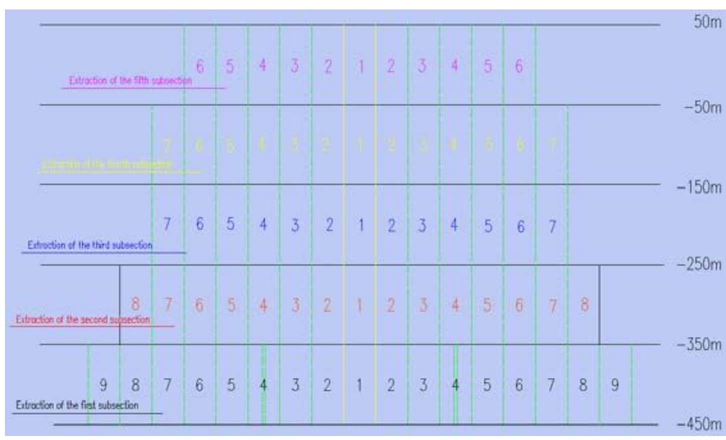

Figure 3. Upward level facade mining sequence

The mechanical parameters of ore body, surrounding rock and backfill are shown table 1.

Table 1. Mechanical parameters of rock mass

	Density(g/cm^3)	Bulk modulus, K(GPa)	Shear modulus, G(GPa)	Cohesion, C(MPa)	Internal friction angle, (deg.)	Poisson's ratio, v	Tensile strength (MPa)
Ore body	2590	23.08	14.20	3.69	45	0.25	3.04
Roof	2590	19.68	11.36	3.48	44	0.25	2.65
Floor	2700	24.35	15.84	4.68	46	0.23	3.35
Backfill	2100	0.56	0.37	0.45	40.15	0.27	0.2

According to the stress measurement results from Institute of Chinese Academy of Geological Sciences, as the depth increases, stress structure of this region changes. It shows a feature of the trend that vertical stress gradually plays a dominant role. The linear regression analysis of the measured data shows that maximum horizontal stress, minimum horizontal stress and vertical stress both increase linearly with change of depth. The rule of ground stress can be shown with following equations:

$$\sigma_{hmax} = 16.5+0.014H \quad (MPa)$$
$$\sigma_{hmix} = 8.12+0.013H \quad (MPa)$$
$$\sigma_z = 0.0265H \quad (MPa)$$

The model setup

According to geological characteristics, the length and width of model are both 4000m, and the height is 1400m. The boundary of the model ranges: x (0,4000m), y (0,4000m), z (-1000m, 400m), The numerical model is shown in Figure 4:

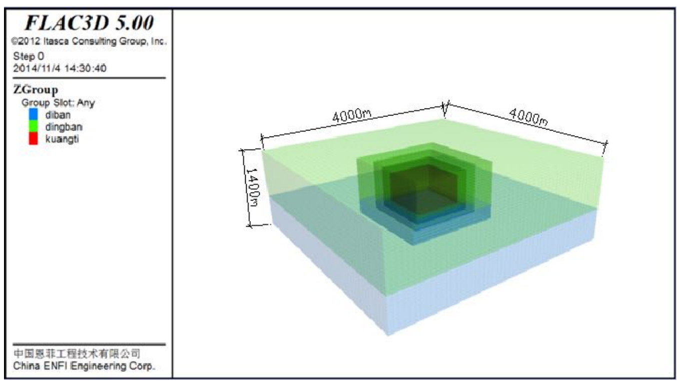

Figure 4. Numerical model

Excavation sequence simulation

According to features of two kinds of facade mining plan, two facade excavation numerical models are established. Arched facade mining sequence model is shown in Figure 5. Upward level facade mining sequence model is shown in figure 6.

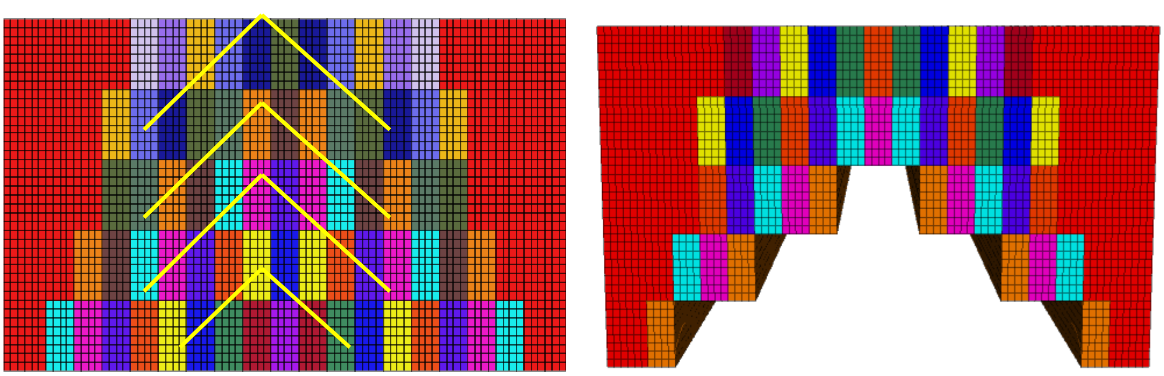

Figure 5. Arched facade mining sequence model (The same color block is mined at the same time)

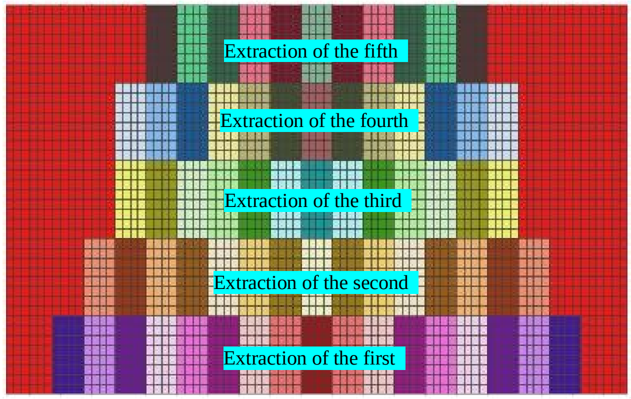

Figure 6. Upward level facade mining sequence model

MINING SEQUENCE RESULTS ANALYSIS

According to the numerical simulation, we compare and analyze the maximum principal stress, plastic zone distribution and displacement during excavation process.

Initial Stress Results

Initial stress calculation result is shown in figure 7. The level of the model bottom is -1000m where the maximum principal stress is 36MPa. Based on the in-situ stress measurement results in the geological stress measuring report, it shows that the initial stress calculation is consistent with the measurement results.

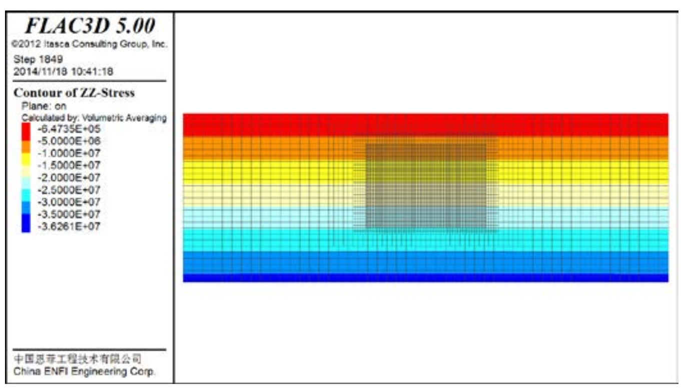

Figure 7. Initial stress

Maximum Principal Stress Analysis

Comparing the result in figure 8 with the result in figure 9, the arch facade mining sequence calculation results show maximum principal stress distribution of surrounding rock in the arch facade roof is very uniform, and the mining sequence can effectively control roof pressure. The upward level facade mining sequence results show that maximum principal stress distribution is relatively concentrated, and maximum principal stress is larger than arch facade mining sequence.

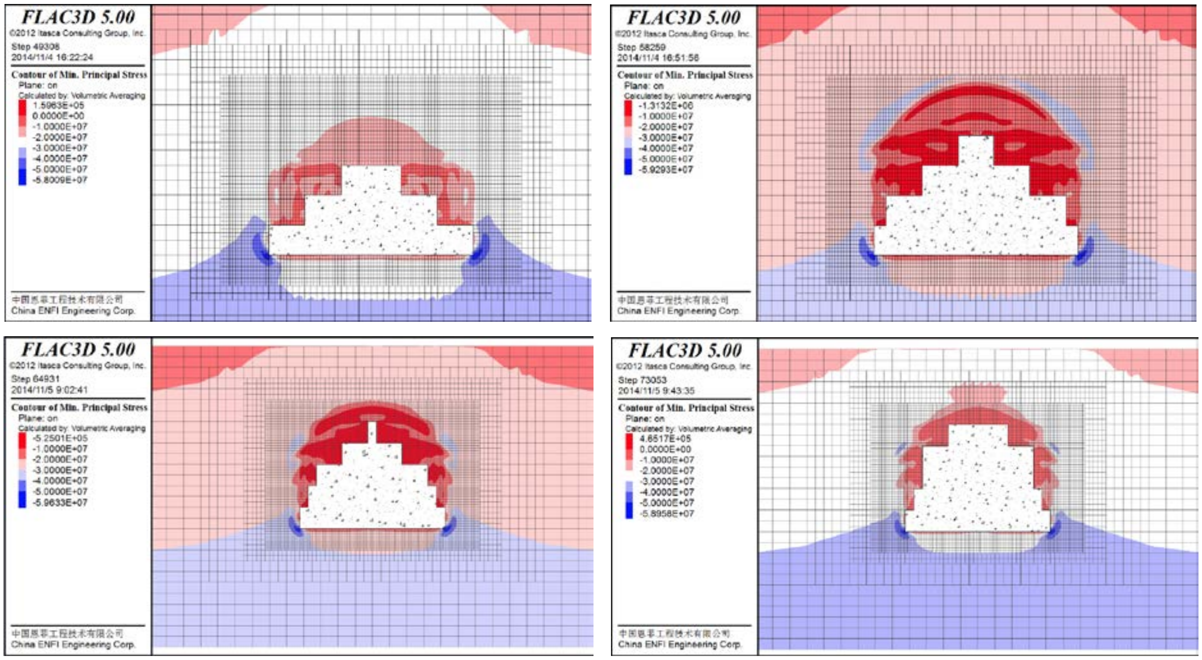

Figure 8. Distribution of maximum principal stresses in arch facade mining

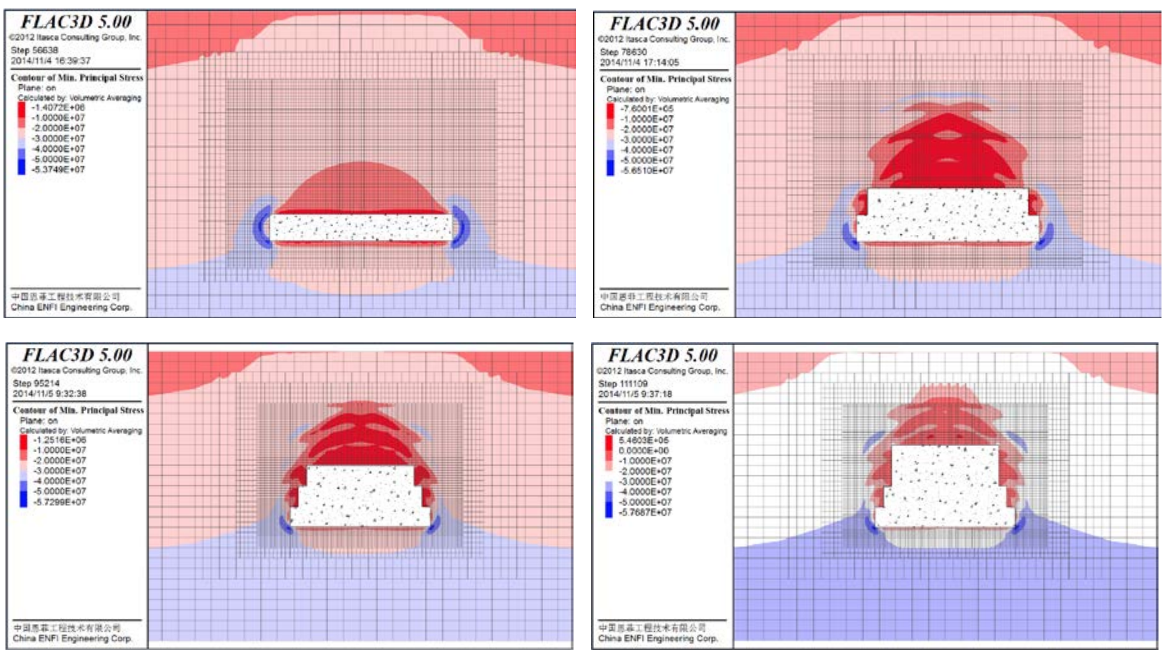

Figure 9. Distribution of maximum principal stresses in upward level mining

Analysis of Plastic Zone Distribution

Comparing plastic zone results of figure 10 and figure 11, it indicates that arched facade mining can form an arch roof that have a good support effect is good for stability of ore body and surrounding rock. Upward level mining sequence results show that this mining sequence presents triangular distribution, and generates obviously area of shear deformation and plastic zone more than arch facade mining sequence. The surrounding rock is prone to tension failure in upward level mining sequence.

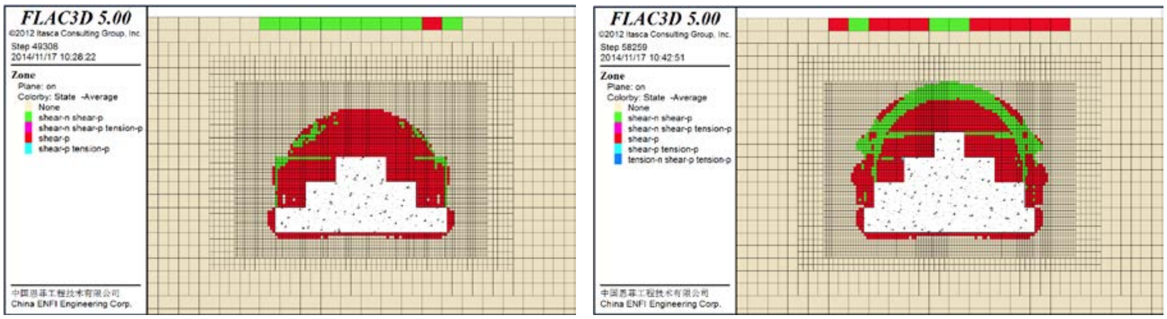

Figure 10. Distribution of plastic zone in arch facade mining

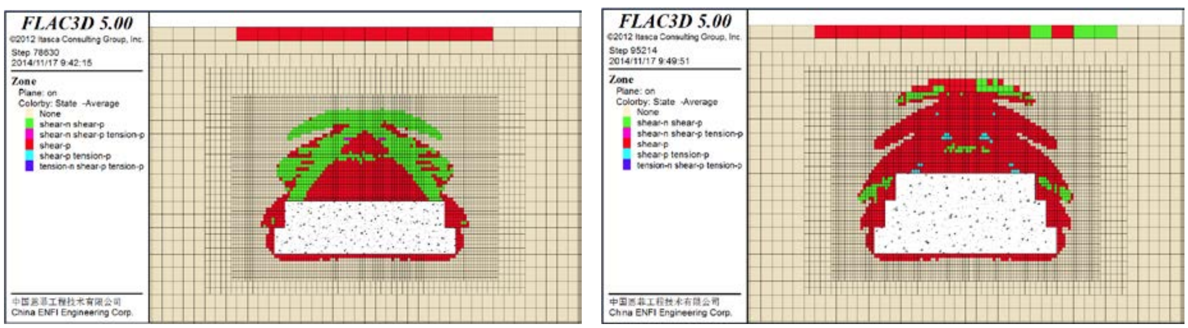

Figure 11. Distribution of plastic zone in upward level mining

Subsidence Analysis

Comparing subsidence displacement results of figure 12 and figure 13, it indicates that, due to the support effect of an arch, arched facade mining leads to smaller surface subsidence displacement than upward level mining. The largest subsidence displacement that is caused by arch facade mining is 0.39 m, and the largest subsidence displacement which is caused by upward level mining reaches 0.58 m.

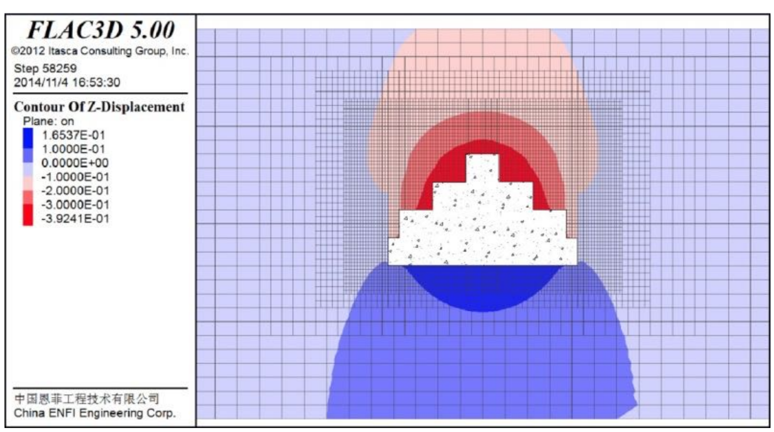

Figure 12. Distribution of subsidence displacement in arch facade mining

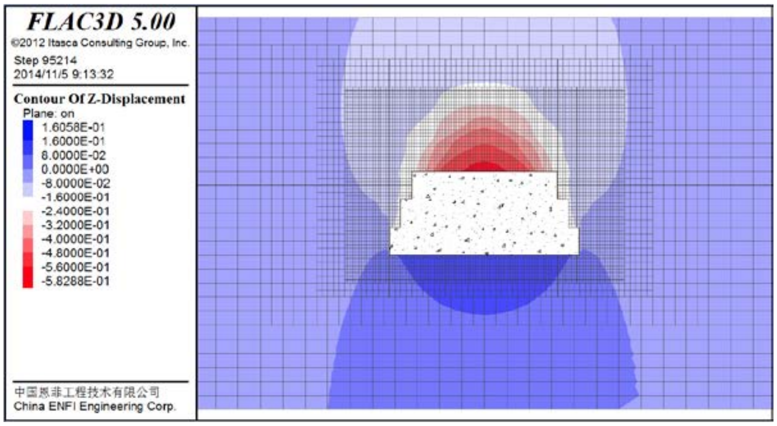

Figure 13. Distribution of subsidence displacement in upward level mining

Through the comparison of mining sequence plan calculation results, it clearly shows that the arch facade mining plan is good for controlling underground pressure and maintaining stability of surrounding rock.

ANALYSIS OF BACKFILL STABILITY UNDER BLASTING VIBRATION

According to scientific research test, we developed the high strength cement filling material. Strength parameters of backfill are shown in table 1. At the same time, in order to obtain the blasting vibration data, blasting vibration field test study is made on Shapinggou molybdenum. Relevant researches and practice have proved that the vibration of the seismic intensity can be expressed by three physical quantities: particle vibration displacement, velocity and acceleration. Vibration velocity can reflect the amount of vibration energy, and is also proportional to the dynamic stress caused by blasting. It is convenient and reliable to test, so particle vibration velocity is the main observation quantity. Blasting vibration velocity time history curve shows the main parameters, frequency is 5.64Hz, vibration time is 1.00s, and large amplitude is 0.1812m/s.

In consideration of advantages and solving dynamic characteristic problem in rock and soil mechanics with $FLAC^{3D}$, it makes $FLAC^{3D}$ can solve the problem of nonlinear dynamic analysis. Thus, we also apply $FLAC^{3D}$ to analyze backfill stability under dynamic load. The calculation results are shown as follow.

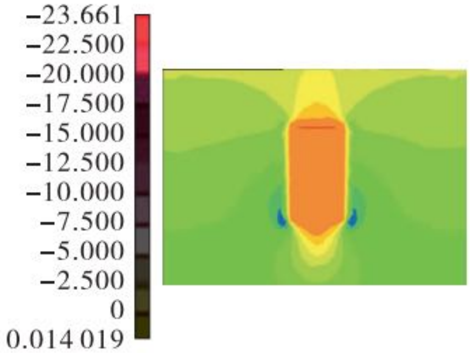

Figure 14. Distribution of maximum principal stresses

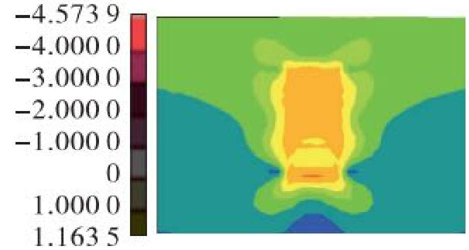

Figure 15. Distribution of minimum principal stresses

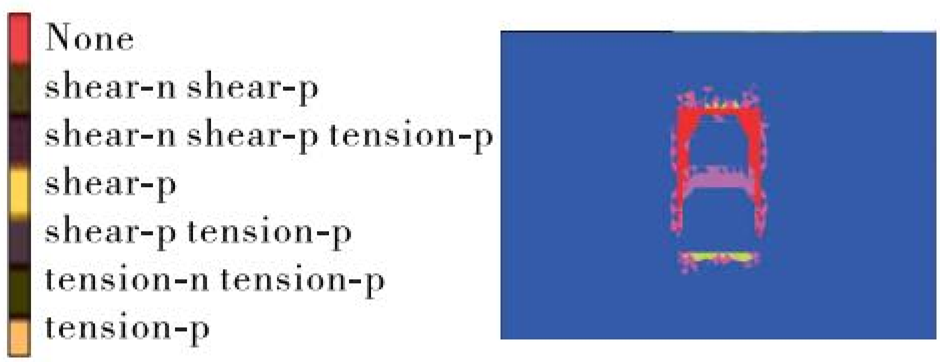

Figure 16. Distribution of plastic zone

Based on multi perspective section views of the model, comprehensive analyses of backfill stability are conducted on maximum principal stress, minimum principal stress and plastic zone. The results show that backfill nearby blasting vibration area suffered large stress that is more than backfill ultimate strength under the effect of blasting vibration. After the excavation, adjacent backfill has a transfixion of plastic zone surrounding the backfill, but when a stoping interval exists, vibration effect is not obvious on backfill. Thereby, the blasting vibration weakens support ability of backfill. In this case, backfill maybe is unstable and needs strengthening to support it. However, we can use pre-splitting blasting or non-coupling charging structure to reduce the influence of blasting vibration on backfill.

CONCLUSIONS

(1) Maximum principal stress distribution is uniform in the arch facade mining, and the arch facade mining has smaller degree of stress concentration and less plastic zone than upward level sequence mining.

(2) Because of a better supporting role arising from the vaulting, surface subsidence displacement caused by arch facade mining is smaller than that caused by conventional upward level sequence mining.

(3) The operating range of blasting vibration influences the variation of plastic zone and displacement for backfill. When blasting dynamic loading is applied near the backfill, the distribution area of backfill plastic zone is expanded obviously. If the curing time of backfill is insufficient, the backfill is prone to collapse.

There is a potential damage of backfill influenced by blasting vibration, so pre-splitting blasting or non-coupling charging structure can be used to reduce the influence on backfill stability.

REFERENCES

1. Itasca Software Comp. Theory and back ground, constitutive model: theory and implementation [P]. User Manual of FLAC3D 2.0, 2002.
2. Hock E. Practical rock engineering[M]. Rotterdam: A. A: Balkema Publishers, 2000.
3. Zhixin, Wang Yonghe, Jiang Ping, et al. Study on measurement of blast-induced seism and building safety criteria[J].Chinese Journal of Rock Mechanics and Engineering, 2003, 22(111:1 907-1 911.(in Chinese))
4. Chunling, Qi Shengwen, Tong Liqiang, et al. Stability analysis of slope under earthquake with FLAC30[J]. Chinese Journal of Rock Mechanics and Engineering, 2004, 23(16): 2 730-2 733. (in Chinese))
5. Hustrulid, W.(2000). Method selection for large-scale underground mining. Proc. Massmin 2000, Brisbane(ed. G. Chitombo), 29-56. Aust. Inst. Min. Metall.: Melbourne.
6. Brady, B.H.G. and Brown, E.T.(1985) Rock Mechanics for Underground mining,1st edn. Allen & Unwin: London.
7. Li Xiangyang, Li Junping, Zhou Chuangbing et a1. Comparative studyon numerical simulation and similarity simulation of overburden deformation in abandoned stope[J]. Rock and Soil Mechanics, 2005, 26(12): 1907-1912.
8. LI Zhongkui, Dail Rong, JiangYiming et a1. Improvement of the generation of the initial stress field by using FLAC3D and application in a huge understand cavern group[J]. Chinese Journal of Rock Mechanics and Engineering, 2002, 24(Supp): 2387-2392.
9. Yin Xiangang, Li Shulin, Tang Haiyan, et al. The tests and studies of physical mechanical properties of the rocks from Changba lead-zinc mine[J]. Mining Research and Development, 2003, 23 (51: 12-14. (in Chinese))