Surface Deformation Mechanism Analysis of Village-under Repeated Mining of 12200 Stope in *Huancheng* Mine

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ABSTRACT

Under village mining scheme of 3_{up}# Coal (completely miming) and 12# Coal (strip mining) in Huancheng Mine was numerical simulated by UDEC. According to the results of numerical simulation, the two coal mining stress distribution, separation there parts, plastic development zone and surface movement and deformation value of strip coal pillar were analyzed. And the two layers of coal mining surface movement and deformation values are compared and analyzed. Through the borehole imaging shows the law of the pore of conglomerate layer increase, increase of body strain after mining in Huancheng Coal Mine. The conglomerate layer affected by mining of its migration rule, established the mathematical model of conglomerate layer energy and body strain, conglomerate layer energy and tg β, further reveals the principle of the conglomerate layer controls strata movement propagating surface, the settlement of ground surface is measured small.

KEYWORDS: conglomerate layer, UDEC, surface movement and deformation, borehole imaging, body strain, energy

INTRODUCTION

Huancheng Mine of Weishanhu Mining Group belonging to Weishan County is located in the northeast side of Huancheng town, Weishan County, Shandong Province. The mine was built in October 1970 and put into operation in October 1974. According to the approved, the annual production capacity is 600 thousand tons.

12200 stope located in the north of Huancheng Mine and 63-51 fault, the west of Zhifang fault and the east of 73-1 fault. As shown in Figure 1. The formation of mining area consists of Quaternary System, Jurassic System, Permian System, Carboniferous System and Ordovician System. And the main minable of it is 3_{up}# Coal and 12# Coal. The former characteristics are shown in Table 1 and the latter are shown in Table 2. The pressed coal under protective coal pillar of Yu Village, Ding Village accounted for the total reserves of coal mining area of 57.6%.

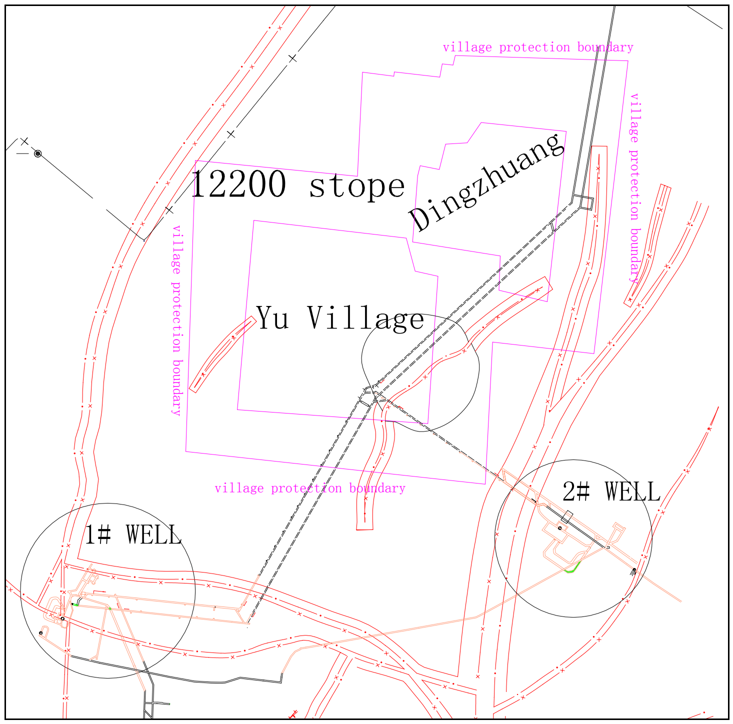


Figure 1: location schematic diagram of 12200 stope

Table 1: characteristics of 3_{up}# Coal of 12200 stope

Strike length (*m*)	Tilt width (*m*)	Average coal seam dip angle	Average coal thickness	Recoverable reserves	Average buried depth	Jurassic
1800	715	7°	1. 4	180. 6	270	102. 6

Table 2: characteristics of 12# Coal of 12200 stope

Strike length (*m*)	Tilt width (*m*)	Average coal seam dip angle	Average coal thickness	Recoverable reserves	Average buried depth	Jurassic
1800	715	7°	0. 9	115. 3	420	102. 6

2 12200 Mining Scheme

In addition to being in accordance with the rules of “Regulations of buildings, railway, water, and main well lane leaving coal pillar and press coal mining”(2000) and relevant documents of the People’s Government of Shandong Province, the geological and mining conditions in 12200 stope, also experience of coal mining in Huancheng mine and under villages near the coal mine and results of surface moving should be taken into consideration. Finally, under Yu Village and Dingzhuang Village in 12200 stope mining scheme of mining 3_{up}# Coal completely and mining 12# Coal 60m of pressed coal with 60m left(strip mining) to avoid migrating the village was determined. The scheme was determined after prediction of surface deformation, economic efficiency contrast, social problems analysis, environmental impact assessment and saving coal resources[1].

3_{UP}# COAL (COMPLETE MINING) AND 12# COAL(STRIP MINING) NUMERICAL SIMULATION ANALYSIS

Building numerical model

UDEC is a two-dimensional discrete element numerical calculation program for the discontinuous medium model, which has been widely used[2-5]. Establish planar mechanical model by UDEC regarding the model as a two-dimensional model[6]. Build numerical model of 3_{up}# Coal (completely miming) and 12# Coal (strip mining) under villages based on geology of the working face. The model is 1200m×430*m*. And the mining height of 3_{up}# Coal is 1.4*m* while 12# Coal is 0.9*m*. 3# Coal is not allowed to mine. The numerical model is shown in Figure 2.

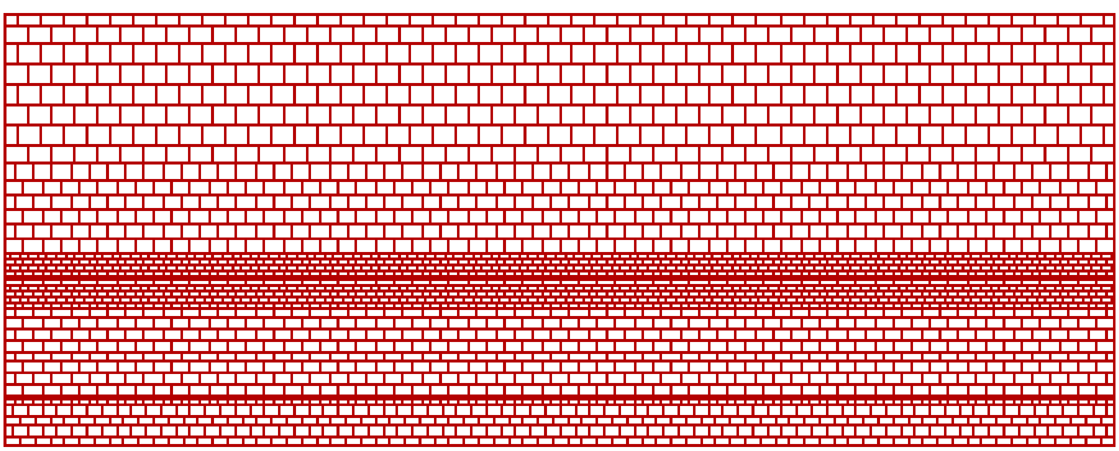


Figure 2: Numerical simulation model diagram

In the model displacement boundary conditions, both sides are fixed of the horizontal direction and free of the vertical direction. The bottom surface is limited of the vertical direction and free of the horizontal direction. Simulating from the top to the surface assuming the initial stress of rock is mainly caused by the self weight of the rock. In the calculation model range, combining rock stratum with small difference in physical properties and making it a single property of rock stratum. In the calculation, the constitutive relation of blocks uses Moore-Coulomb criterion. And joint model uses joint surface contact-Coulomb slip model, as described in the previous section[7].

Numerical Simulation Analysis

Simulating 3_{up}# Coal and 12# Coal according to the design of mining thickness. The excavation is carried out after calculating the model of balance. The plan is distributed excavation. Mining 3_{up}# Coal first, and mining 12# Coal after two-times-balance.

3_{up}# Coal in long wall mining and 12# Coal in strip mining are the plans. The latter is mining 60*m* with 60m left and excavating 5 strips in total.

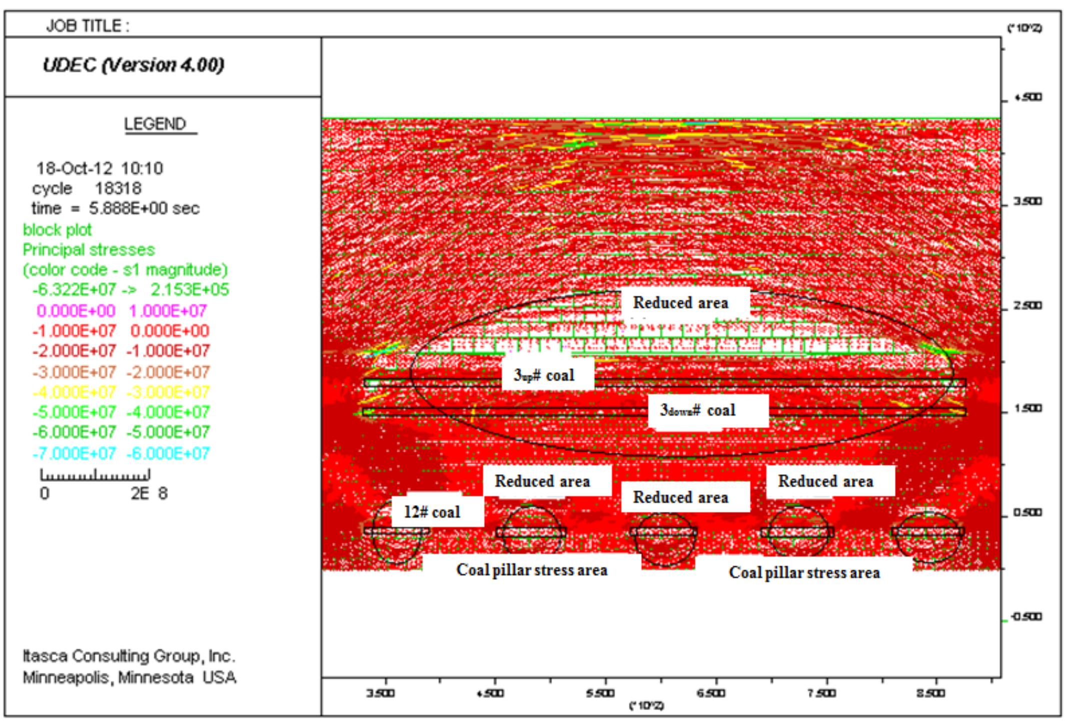


Figure 3: Stress arch evolution of 3_{up}# Coal (completely miming) and 12# Coal (strip mining)

From Figure 3 can be drawn that when mining 3_{up}# Coal completely, stress arch is formed in the upper part of the coal seam and elliptical arch is formed above the working face. The height of arch is about 60m. There is no obvious change in stress arch with the excavation of the lower working face of 12# Coal. Banded working face is located in the stress decreasing zone and stress is concentrated on strip coal pillar. So, it has less effect on the upper by mining 12# Coal.

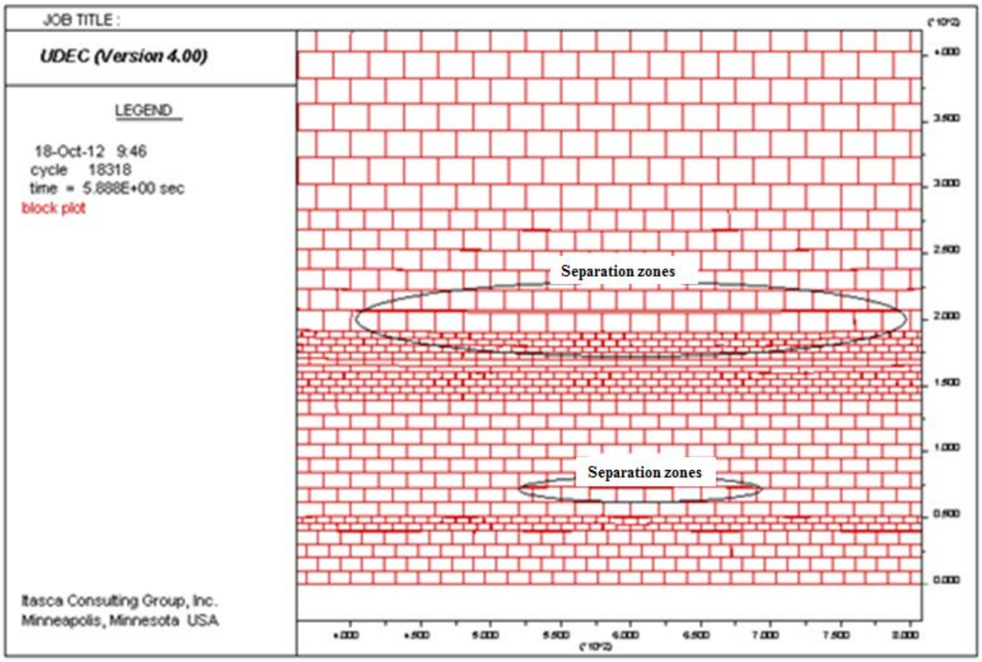


Figure 4: Deformation and failure of 3_{up}# Coal (completely miming) and 12# Coal (strip mining)

From Figure 4 can be drawn that the upper working face appears abscission layer when mining 3_{up}# Coal completely. And the abscission layer on top of the working face about 20*m*. There is no obvious change in 3_{up}# when mining 12# Coal. Meanwhile, the upper 12# Coal also appears smaller abscission layer.

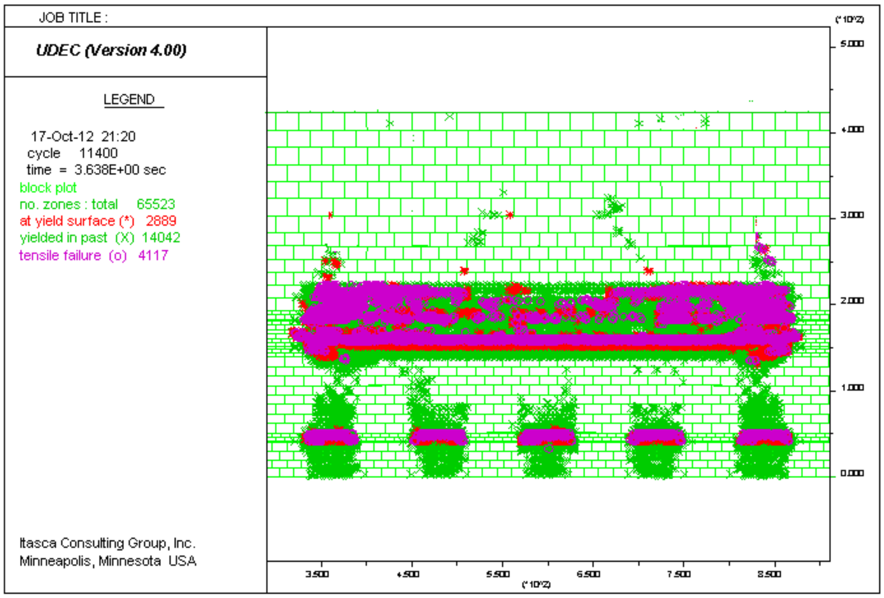


Figure 5: plastic zone distribution of 3_{up}# Coal (completely mining) and 12# Coal (strip mining)

From Figure 5 can be drawn that there is no obvious increase of plastic zone distribution of 3_{up}# Coal when mining 3_{up}# Coal(completely mining) and 12# Coal(strip mining). Smaller damage to the upper strata and coal seams because the interval between 12# Coal and 3_{up}# Coal measures about 108m. And the rock is hard and the plastic zone of the strip working face is not connected with the upper coal seam.

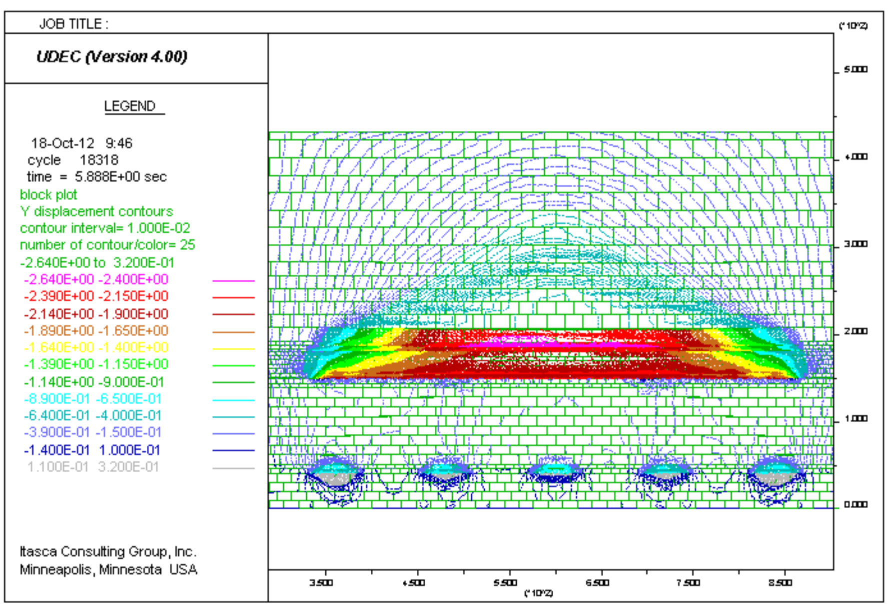


Figure 6: Displacement isoline of 3_{up}# Coal (completely miming) and 12# Coal (strip mining)

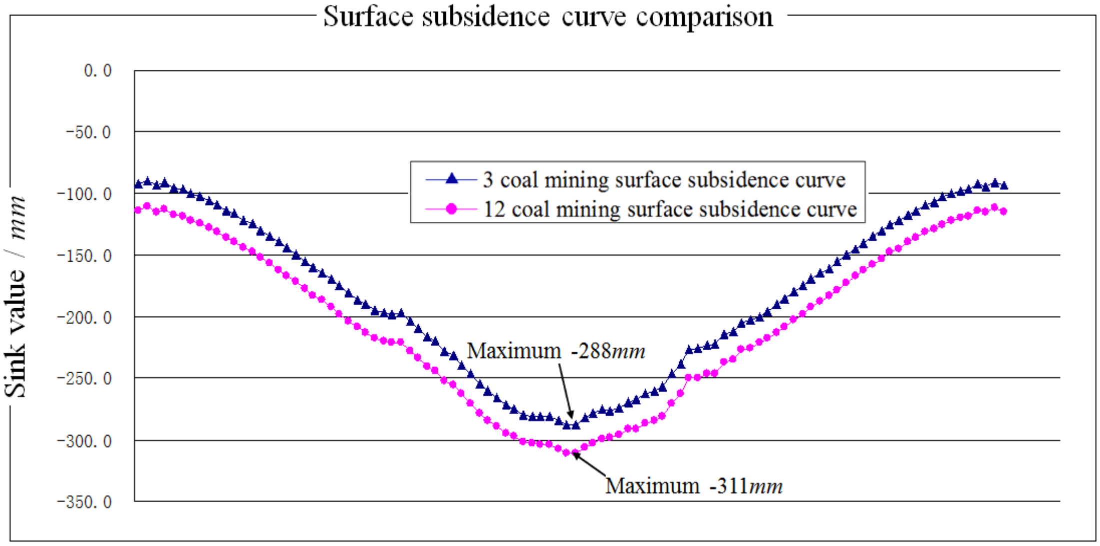


Figure 7: The surface subsidence curve contrast diagram

From Figure 6 and Figure 7 can be drawn that the maximal value of the surface subsidence is 288*mm* after mining 3_{up}# Coal. And the maximal value is 311*mm* after mining 12# Coal(strip mining). So, mining 12# Coal has little effect on the surface and won't cause the surface subsidence greatly.

SURFACE DEFORMATION VALUE

12200 stope was mined from March 2005 to December 2012. As shown in Table 3 to 5, the surface movement deformation values are calculated from the measured data of three observation lines. The maximum subsidence of surface is 152*mm* and building deformation is grade Ⅰ. There is no dispute with workers and peasants. Huancheng Mine mined the two coal mine under villages successfully.

Table 3: Movement and deformation values of the South-North Line 1(in Village)

Maximum Subsidence	Maximum Tilt	Maximum Curvature	Maximum Horizontal Movement	Maximum Horizontal Deformation
152*mm*	1.32*mm/m*	0.0043（$10^{-3}/m$）	49.9*mm*	1.20*mm/m*

Table 4: Movement and deformation values of the East-West Line 1(in village)

Maximum Subsidence	Maximum Tilt	Maximum Curvature	Maximum Horizontal Movement	Maximum Horizontal Deformation
152*mm*	2.74*mm/m*	0.0090（10^{-3}/*m*）	49.9*mm*	0.44*mm/m*

Table 5: Movement and Deformation values of the East-West Line 2

Maximum Subsidence	Maximum Tilt	Maximum Curvature	Maximum Horizontal Movement	Maximum Horizontal Deformation
148*mm*	2.46*mm/m*	0.0090（10^{-3}/*m*）	50*mm*	0.81*mm/m*

INTERPRETATION OF 12200 STOPE ROCK DEFORMATION BY BOREHOLE ACOUSTIC SCANNING IMAGING INFORMATION

A Digital Logging Station of Shandong built NO.SD1 drill in June 30, 2012 and had acoustic scanning imaging logging. Ultrasonic imaging logging is the use of the frequency of 1MHz, 20mm diameter wafer of piezoelectric ceramic transducer to transmit ultrasonic pulse to the wall. The transducer receives the transmitted pulse echo, measures the echo amplitude and propagation time. Ultrasonic transducer uses the external rotation scanning mode and contacts directly with the well fluid. It spins 5 circles per second and samples 300 points each circle (sampling frequency of 1500 *times / sec*). From the moment of aiming at magnetic north, the director scans a circle along the direction of north, east, south, west and north. With the increase of the down-hole instrument, the borehole wall can be scanned in a spiral way. Recording the changes of acoustic amplitude and travel time caused by blast hole wall rock and rock physical characteristics and borehole geometry change. It can be directly observed borehole lithology, fractures, bedding, caves and borehole geometry changes, depth and range[8]. Image interpretation results are as follows.

Stratum

The Quaternary - Dominated by sandy silt in light yellow. Thick is about 0~41.85*m*. The Quaternary has closed casing.

Jurassic –Dominated by fine sandstone in iron red. Thick is about 102.6*m*. The bottom of the depth is about 144.45*m*.

Permian – This is mainly to expose the Shihezi formation. Shihezi formation is dominated by sandstone, fine sandstone, silty mudstone and mudstone. And there are several separation zones.

Rock deformation interpretation

In Jurassic strata, the layered interface of the upper strata of the iron red sandstone is 90.20*m*. There is a weak layer in the image in the middle and upper part of the formation. Such as 61m and 85*m*, the bedding face is clear. In middle and lower strata, the cracks of fine sandstone and conglomerate are less, and the porosity is more. The unconformity surface of the Jurassic strata and underlying strata is clearly reflected.

There are three layers of fracture or separation development in the Shihezi formation. The first layer is from 155.85*m* to 170.50*m*. The second layer is from 190.50*m* to 210.50*m*. Crack is the main structure in the two strata. And the last layer id from 220.00*m* to 230.50*m*. Crack is the main structure in the stratum and the development of separation is in the second position. The main separation is from 240.30*m* to 254.80*m*. Since the separation concerns bedding plane, the occurrence of separation is small. The opening degree of separation is about 1*m*.

Obviously, the thickness of conglomerate layer in the range of protective coal pillar of Yu Village and Dingzhuang Village is about 102.6*m*. The porosity of the conglomerate is increased and the volume of conglomerate layer is enlarged because of mining. That controls the movement of rock strata to the surface, slows down the surface deformation and the destruction of the house and the deformation value of the ground surface is small.

GRAVEL MIGRATION LAW OF CONGLOMERATE

Body strain of conglomerate

Conglomerate is composed of gravel. The internal stress of conglomerate layer is increasing because of overlying strata movement after coal seam mined, which makes the way of aggregation and disintegration of conglomerate changes. From borehole imaging, the pore size of the gravel is increased and the total porosity is decreased. This change can be described by the body strain.

$$\Delta = \frac{e_2 - e_1}{1 + e_1}$$

In the formula, e_1 – conglomerate rock mass porosity before mining, e_2 – conglomerate rock mass porosity

Conglomerate layer energy analysis

3_{up}# Coal of Huancheng Mine to the conglomerate layer spacing is about 70m. Fine sandstone in the conglomerate of 3_{up}# Coal is about 85%, and the rest is mudstone, etc. Overlying rock mass is broken, bending and other damage, but also the occurrence of energy transfer in the process of mining 3_{up}# Coal. According to the knowledge of rock mechanics, the energy produced by the conglomerate layer in the mining process is

$$W = W_0 + W_1 - W_2 - W_3 - W_4$$

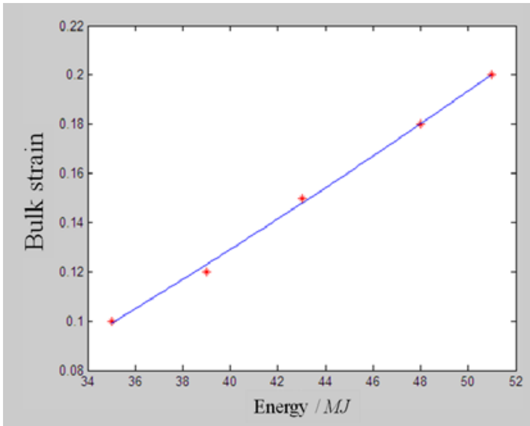
In the formula, W_0 – the work of the conglomerate layer on the rock stratum, W_1 – the work by the rock breaking and bending process, W_2 – energy consumption of plastic deformation of rock, W_3 – energy consumption of rock joints, W_4 – strain energy of rock stratum.

The energy of conglomerate layer can be obtained by the calculation of different rock strata thickness by fish function in UDEC software. The distance between coal and conglomerate layer is the main factor to determine the energy of the gravel layer.

The relationship between body strain and energy and between tgβ and energy

According to the geological and mining conditions of coal mining area of 3_{up}# Coal and 12# Coal of Huancheng Mine, the conglomerate layer were applied 35MJ, 39MJ, 43MJ, 48MJ and 51MJ energy by UDEC model. According to the simulation results, the relationship between the body strain and the energy and between the tgβ and the energy were plotted. Shown in Figure 8, Figure 9.

The mathematical model of body strain and energy(x) is$\Delta=2.907\times10^{-5}x^2+0.004x-0.071$. Model fitting error is 0.011.



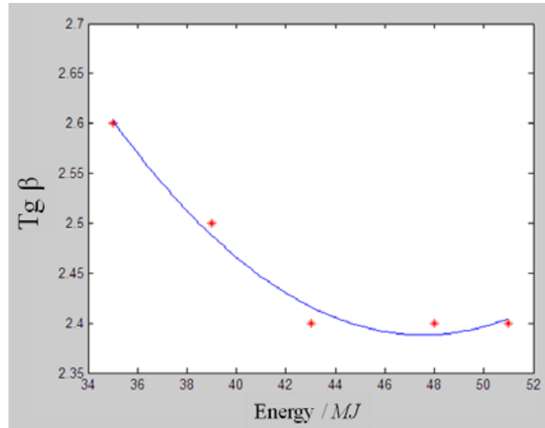


Figure 8: Relationship between energy and body strain Fig 9 Relationship between energy and tgβ

The mathematical model of tgβ and energy(x) is tgβ=$0.001x^2$-0.130x+5.480. Model fitting error is 0.004.

From the Figure can be drawn that corresponding to different energy, the size of the average body strain increases gradually with the increase of the energy. tgβ increased gradually with the increase of energy but the growth rate is not large. When the energy reaches a certain value, tgβ will not change.

The above analysis reveals that the movement law of the conglomerate layer is affected by mining. The deformation of overlying strata caused by coal mining is absorbed by the body strain of the conglomerate layer. And that controls the spread of the strata movement to the surface, so the subsidence is small. That's why the surface deformation is small after mining 3_{up}# Coal and 12# Coal under the condition of thick 102*m* gravel stratum in Huancheng Mine.

CONCLUSION

1 Such a conclusion can be drawn through the simulation of mining 3_{up}# Coal and 12# Coal. When mining 12# Coal (strip mining), little change in the position of the stress arch and the top absciss layer, and the range of plastic zone. The maximum surface subsidence value increases is only 23*mm*. Apparently, there is little influence on 3_{up}# Coal that empty and the surface when mining 12# Coal (strip mining).

2 The maximum surface subsidence is 152mm after mining 3_{up}# Coal and 12# Coal. The building deformation is grade Ⅰ. And the successful experience of two layers of coal mining under the building has been made.

3 After mining 3up# Coal and 12# Coal, NO.SD1 drill was built in the empty stope and had acoustic scanning imaging logging. From the drilling image can be drawn that a large number of

pores are emerged after mining 12200 stope. That slows down the surface deformation and the damage to the building, and explains the cause of small surface deformation values.

4 Analyzing the movement law of conglomerate layer influenced by mining. The energy calculation formula of the conglomerate layer in the process of mining and the energy solution method of UDEC software are presented. Based on the simulation results and the Matlab software, the mathematical model of body strain and energy, tgβ and energy of the conglomerate layer is established, which further reveals that the conglomerate layer controls the propagation of the satrata movement to the surface, what explains the cause of small surface deformation values.

REFERENCES

[1] Zou YouFeng, Deng Kazhong, Ma WeiMin. Mining subsidence engineering [M]. Xuzhou: China mining university press, 2003.

[2] Xie L, Yan E, Gao L, et al. Rock strata's equal thickness characteristic research in bending and toppling of rock slopes [J]. *Electronic Journal of Geotechnical Engineering*, 2013, 18:4947-4957.

[3] Ajalloeian R, Dardashti A F. Evaluation of fluid flow from a dam foundation using numerical modeling technique by UDEC software [J]. *Electronic Journal of Geotechnical Engineering*, 2013, 18:1787-1800.

[4] Pu Y. Study on Dynamic Distribution of “Three Zones” at Fully Mechanized Face with Thick Coal Seam and Composite Roof[J]. *Electronic Journal of Geotechnical Engineering*, 2014, 14:9987-10005.

[5] Ming Y, Jianliang G, Xiaomin J. Study on Porosity Distribution of Porous Media in Mine Gob Based on UDEC[J]. Electronic Journal of Geotechnical Engineering, 2014, 19:4619-4630.

[6] Peng Wenbin. FLAC3D practical tutorial[M]. Beijing: mechanical industry press,2009.

[7] Wu Chongfu, Liu Dongyan, Fang Zhi. The application of stability analysis in mined area using FLAC3D[J]. Henan university of physics and engineering journal,2007,26(2):134-140

[8] Hyuck M.Kwon, Theodore G.Birdsall. Digital waveform codings for ocean acoustic telemetry. IEEE Journal of Oceanic Engineering, 1991,16(1):56-65.

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