Engineering, 2010, 2, 201-204
doi:10.4236/eng.2010.23029 Published Online March 2010 (http://www.SciRP.org/journal/eng/)

Study on the Law of the Movement and Damage to Slope with the Combination of Underground Mining and Open-Pit Mining

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Received October 10, 2009; *revised November* 21, 2009; *accepted November* 26, 2009

Abstract

Under circumstances in which both underground mining and open-pit mining are employed, the mining effects of two approaches will be superposed and the mining slope will receive several induced stress fields, which makes the sliding mechanism and deformation law of slope rock mass more complicated. This paper, targeting at the east slope of Antaibao Mine with the joint employment of underground mining and open-pit mining, aims to study the moving law of the slope rock mass and the damage mechanism to the overburden of the goaf by numerical simulation. It is supposed that models of possible damage to the slope could be explored for guidance to safety-production of the mine.

Keywords: Combination of Underground and Open-Pit Mining, Mining Damage, Deformation Mechanism, Numerical Simulation

1. Introduction

Underground mining will damage the balance of the ground stress and cause the surface movement of rock mass, leading to mining damage in these areas. However, in cases where both underground mining and open-pit mining are employed, the mining slope will receive integrated superposition according to the corresponding relation of the extraction level and the superposition process of mining effect. It exhibits as a kind of mining effect which interferes or acts to another balanced system, making two types of excavation body arouse and interfere mutually, and constitute a complex dynamic system. Many domestic and abroad scholars have participated in the study of Strata Movement and Mining Subsidence, one of the bases in mining, and made many valuable research results. Some coal-producing countries in Europe carried out a systematic research on Strata and surface movement in 1930s. Ever since the 1950s, studies on Strata and surface movement have been developed vigorously. The methods of entire filling stoping, segmental mining, concerted mining and strengthening building are used in Germany, Poland, Russia and the United Kingdom, which have overcome the hazards of mining effect and thus succeeded in coal mining under buildings and railways, with the establishment of a series of rock and ground movement theory [1].

The number of mines in foreign countries switching to underground mining from open-pit mining approximately doubles every 20 years. Owing to their abundance of natural resources in the United States, Canada, Australia, there is less necessity for underground mining in their mines. Therefore, the main researches focus on when the switch happens. While many domestic large and medium-sized mines have of the need for deep mining, China is facing the problems associated with the process of switching as well as joint exploitation of surface and underground extraction. Yet, joint exploitation hasn't drawn enough attention in mining-developed western country [2].

Based on the investigation about the east slope of Antaibao Mine with the combination of underground mining and open-pit mining, the article mainly studies the moving law of the slope rock mass and the damage mechanism to the overburden of the goaf during different stage, with the expectation of systematically exploring models of possible damage to slope and offering scientific guidance to safety-production of the mine.

2. Project Summary

Pingshuo Coal Industry Corporation is a large modernized coal production base constructed in 1985. The Corporation built Antaibao and Anjialing open-pit mine succession. Joint employment of underground mining and open-pit mining was approved by original State Development Planning Commission in November 2002. Anjialing mine included two shafts in the mining field according to the document of approval and practical situation: Shangyao and Antaibao Mine, which are developed respectively. In the second quarter of 2003, the two shafts were constructed and started test extraction. During the course of test extraction, the impacts of underground mining on surface appeared as surface deformation, cracking and subsidence that would affect safety-production of the mine. Especially for the initial extraction area in Antaibao Mine, of which north and west is slope of open-pit, mining effect is considerably complicated. It is imperative to determine the law of displacement, and possible manners of destruction and subsidence aroused by mining. Integrant prevention and control measures should be done to make sure the safety of surface and underground engineering at the same time.

3. Three-Dimensional Finite Element Numerical Model

Numerical simulation of finite element could simulate a variety of project activities under circumstances of complex structure, complex boundary and loading. It is a simulation research method widely used in geotechnical engineering, which allows for repeated simulation experiments with low cost [3].

Finite element numerical simulation is used in the study to analyze the law of rock slope movement and damage to overburden of East slope of Antaibao in B901 integrative mining face where both underground mining and open-pit mining are employed. B901 integrative mining face is located 70-110 m beneath the mine slope, and in the middle of the slope in spatial relations. Finite element model is an orthogonal hexahedron. As is shown in **Figures 1** and **2**, Y axis stands for the vertical direction, X, Z axis for "East – West" direction and "South – North" direction respectively, with the dimensions of three axis

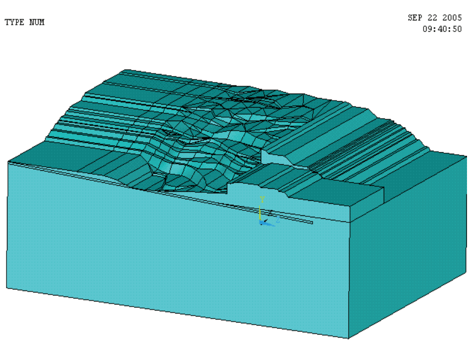

Figure 1. Three-dimensional finite element model.

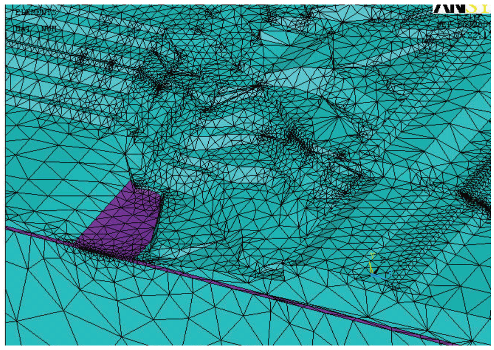

Figure 2. Finite element mesh map.

as 1785 m, 700 ~ 1000 m, 2500 m accordingly. Numerical simulation takes into account four different extraction states: original state, B901 integrative mining face retreating mining 500 m, B901 integrative mining face retreating mining 1000 m, B901 integrative mining face mining over. In the process of numerical simulation, the mined ore body is removed in the numerical model according to the speed of open-pit mining and underground mining, while the surface dump is forced on the model as external load. The model border restricts its horizontal displacement and its rotation; the bottom boundary limits vertical displacement in Y direction and its rotation. The rock mechanics parameters used in the finite element numerical model are selected according to field investigation and indoors rock mechanical experiments [4].

4. Numerical Simulation Results and Analysis

Finite element simulation calculates slope deformation and stress changes in underground excavating as well as open-pit mining under the four states. By comparing damage degree of mining slope rock mass in different states, we can directly determine the law of the movement and damage to slope with the combination of under ground mining and open-pit mining. Some of the finite element calculation results are listed as follows:

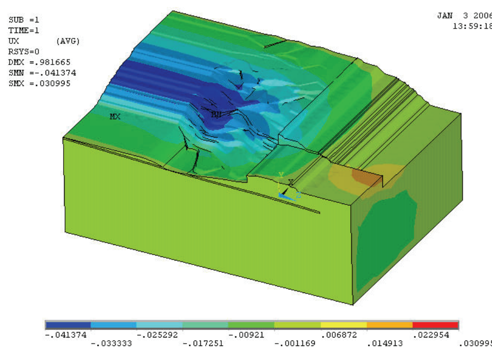

Figure 3. X direction displacement in original state.

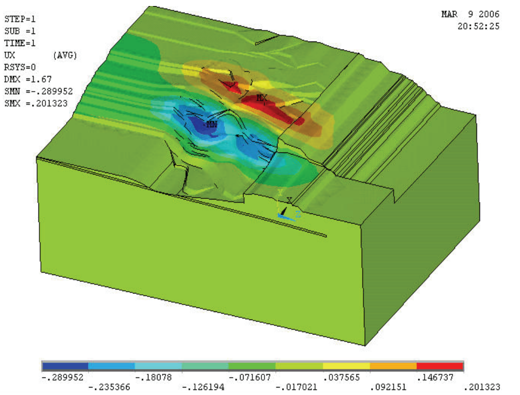

Figure 4. X direction displacement when B901 face mining was over.

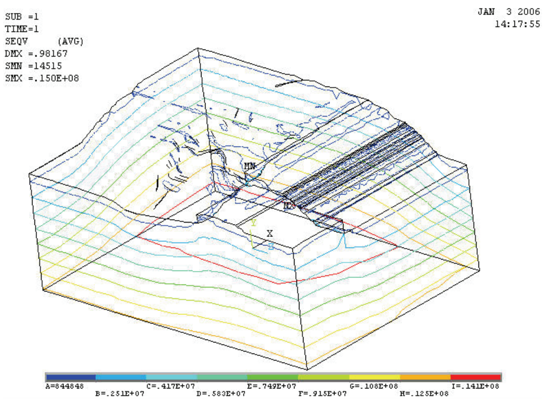

Figure 5. Average principal stress contour in original state.

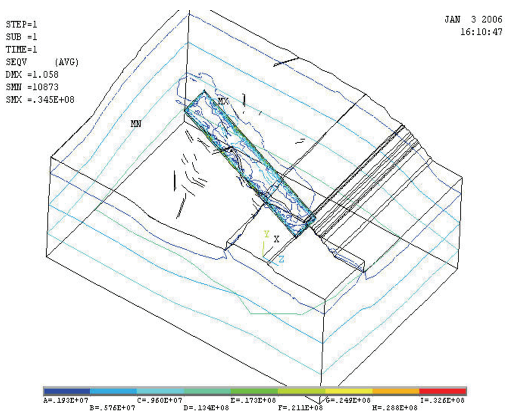

Figure 6. Average principal stress contour when B901 face mining was over.

4.1. Displacement Deformation Analysis

The graph of horizontal displacement deformation shows that in original state the east-west displacement will slide down along the East Slope of Antaibao under the influence of rock slope self-weight stress. With both underground mining and open-pit mining carried on, the mining effects are superposed. The east-west displacement mainly appears in the middle of the East Slope of Antaibao in two forms: surface rock mass sliding in the upper and middle part of slope; horizontal displacement accompanied with mining subsidence of the overburden of the goaf in the middle and lower part of slope. The horizontal displacement region is in parallel with the B901 and exhibits as large-scale band distribution, while its movement direction is opposite to that of rock mass sliding. As the horizontal displacement is caused by surface subsidence in underground mining, rock mass that falls down will fill goaf and thus helps to increase the rock slope stability of Antaibao. Therefore in the process of B901 mining, more attention should be paid to the local landslide damage in the middle and upper part of the east slope of the Antaibao Mine.

The graph about vertical displacement deformation shows that vertical displacement of rock slope mainly exhibits as surface subsidence. The largest subsidence region changes dynamically right over the goaf in underground mining. The final decline basin is located right over the goaf and is oval-shaped in horizontal surface. It is identical to surface movement basin formed in the use of long-wall caving.

While the mining work in B901 face is over, the maximum horizontal displacement (28.99 cm) is located in the upper part of the east slope, while the maximum vertical displacement (269.14 cm) is located right above the mining area. The data is similar to the result monitored by GPS in this region.

4.2. Analysis of Stress Change

While not being affected by underground mining, rock mass in the original state mainly maintains a sliding trend with small tenslie stress of about 0.83 MPa. In the process of joint mining, stress in rock mass is redistributed, and induced stress constantly generates and superposes each other. When the mining work in B901 is over, the average principal stress shows the appearance of high accumulation of tensile stress ranging from 9 to 17 MPa in goaf boundaries, the accumulation of compressive stress ranging from 50 to 80 MPa in the top of non-mining area, and tensile stress of about 1.32 MPa in the upper and lower part of slope. According to the physical and mechanical indicators of mining rock, we can judge that the goaf formed in underground mining will be naturally caving and filling because of existence of stretching destruction from rock mass of two sides, while the slope above goaf will be destroyed by partial compressive stress, which will not happened in most other part of slope. If the goaf formed in underground mining is not caving and filling in time, the sudden damage of slope and refuse dump by high tensile stress may cause a large subsidence area in the whole slope as a basin. If surface soil and rock mass effect mutually, it may lead to the occurrence of large-scale landslide in Antaibao East Slope. Therefore, we should make goaf overburden fall and fill itself as much as possible.

5. Conclusions

We can obtain the following conclusions based on the study about the four states of East Slope of Antaibao by finite element numerical simulation.

1) Rock mass movement patterns of slope are complex under the joint employment of underground mining and open-pit mining. In fields bordered by the strike of underground mining goaf, the sliding trend of rock mass in uphill of goaf is more apparent, while rock mass in dip head of goaf slides into goaf reversely. In the process of combinational mining, safety monitoring to upper rock mass of mining slope should be strengthened.

2) Mining damage caused by underground mining occurs firstly, then the two sides of goaf and roof are destroyed and the damage spreads upside to surface slope, resulting in the formation of caving zone, fault zone and bending zone. So slope movement in combinational mining mainly exhibits as the deformation caused by underground mining.

3) Stress balance in slope rock mass is a dynamic adjustment process in the condition of combinational mining. The major damage region of slope rock mass is mainly located in the overlapping areas affected by both mining systems.

4) With the implementation of underground mining and open-pit mining, the main damage region in the mine slope approximately parallels to strike and dip of main sectional plane in underground mining area. Thus, accurate grasp of the spatial relationships between mining area and mining slope enables the effective understanding of the law of mining slope movement.

5) In order to prevent large-scale landslide from occurring in mining slope as the result of mining effect, for subsidence pit in slope surface, bulldozers should be used to fill cracks punctually so as to avoid infiltration of rainfall which may affect the stability of slope.

6) Backfilling the refuse in slope side is conducive to slope stability. In the production processes, for Antaibao slope, the section paralleling to B901 mining face in strike is proposed to be given priority in terms of backfilling.

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