International Symposium on Earth Science and Technology, CINEST 2012

Numerical Analysis of Interaction Effects in Double Extra-thick Coal Seams Mining

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Abstract

The interaction effects in multi-seam mining depends on many factors such as local geological and geotechnical conditions, mining depth, seam sequencing, and mining method employed, etc. The paper discusses preliminary study on the interaction effects in underground mining of double extra-thick coal seams in Mae Moh coalfield in Thailand. The Mae Moh mine is currently operated as open pit mine by EGAT (Electricity Generating Authority of Thailand) and it is the largest open-pit lignite mine in Thailand. In the near future, the final pit limit of the mine will be reached and underground mining will be commenced from the final highwall in the depth of 400-600 m from the surface. However, due to the challenges such as poor geological and geotechnical conditions, extra-thickness (20-30 m) of the coal seams and huge final pit slope, success probability for underground mining are being evaluated at the present. This paper discusses the ground response and possible interaction effects in the double extra-thick seams mining by means of numerical analyses using three dimensional finite difference code FLAC3D.

Keywords:

1. Introduction

The Mae Moh mine is located in Mae Moh district, Lampang province, about 630 kilometers north of Bangkok, Thailand. The location map of Mae Moh mine is shown in Figure 1. This mine is operated by EGAT (Electricity Generating Authority of Thailand), and it is the largest open-pit lignite mine in Thailand. The total geological and economical lignite reserves of the Mae Moh coal field are approximately 1,140 million tons and 825 million tons, respectively. The annual production is about 16 million tons (as of 2010), which represents 70 % of the total coal production of Thailand. 347 MT of lignite has been produced, and the remaining future reserve is about 478 MT (as of 2010). In the near future, the open pit limit will be reached and underground mine has been planned to be developed from the depth of 400-600 m from the surface. However, due to the challenges, such as poor local geological conditions, extra thickness of coal seams (20-30 m thickness) and weak mechanical properties of coal seam and its surrounding rock, possibility of underground mining and an
applicable underground mining system for Mae Moh mine is being investigated at the present (EGAT, 2011). In this paper, the ground response and possible interaction effects in the double extra-thick coal seams mining was discussed by means of numerical analyses.

2. Geological Setting of Mae Moh Mine

The generalized stratigraphic column of Mae Moh tertiary basin is illustrated in Figure 2. This figure presents three main geological formations, namely HuaiLuang (HL), Na Khaem (NK) and Huai King (HK), in the Mae Moh coalfield. HL formation mainly consists of red to brownish red semi-consolidated and unconsolidated claystone, siltstone and sand. NK formation composes lignite layers and gray to greenish gray claystone and mudstone. Five lignite seams, marked as J, K, Q, R and S seam, are found in NK formation. However, the J, R and S seams are considered as uneconomical seams due to the poor quality/thickness and depth of seam and thus major economical mineable seams are only K and Q seams. The thickness of K and Q seams range from 20 to 30 m and the interburden ranges from 20 to 25 m. HK formation consists of semi-consolidated fine to coarse sandstone, claystone, mudstone and conglomerate with green, yellow, blue and purple in color (EGAT, 2011).
3. Numerical Analysis

Numerical modeling was carried out by using a 3D finite difference codes “FLAC3D” to investigate the ground response around the underground mine and interaction in the double coal seams mining.

![Mesh and group of zones in the Flac3D model](image)

**Figure 3. Mesh and group of zones in the Flac3D model**

3.1. Model Construction

The numerical model is composed of 20 m thick double coal seams, K and Q, with the interburden of 20 m thick. The thickness of cover depth to K seam was taken as 100 m. However, additional loading 5.7 MPa, which implies overburden depth of 300 m, was applied at the top of the model. Therefore, the total depth of the overburden was assumed to be 400 m. To simplify the model, multi-layers were not considered and the materials except the coal seams were assumed as homogeneous claystone layers. The details of the model showing the geometry, density of grids and group of zones of the model is presented in Figure 3. The Mohr Coulomb elasto-plastic material behavior was adopted for this model. The mechanical properties of coal and claystone used in the numerical simulation are listed in Table 1. After constructing model, defining constitutive relation and material properties, in situ stress initialization and assignment of boundary conditions of the model, the model was run until the equilibrium state was reached (Itasca 2002).

| Mechanical properties of the materials used in the analyses | Coal | Claystone |
|-------------------------------------------------------------|------|-----------|
| Density (kg/m³)                                             | 1,430| 1,950     |
| Young’s modulus (MPa)                                       | 1,800| 2,100     |
| Poisson’s ratio                                             | 0.25 | 0.30      |
| Tensile strength (MPa)                                      | 1.0  | 1.0       |
| Cohesion (MPa)                                              | 1.0  | 1.0       |
| Frictional Angle (Deg)                                      | 30.0 | 33.5      |

When a coal seam is extra thick that exceeds 10 m, its extraction usually involves slicing the coal block a number of slices/lifts and each slice/lift is extracted with a longwall or bord-and-pillar using continuous or conventional mining methods. In this practice of mining, the longwall caving system is the preferred practice; but, the material produced requires a large expense to compensate for surface/subsurface damage (K. Matsui et al., 2011).
Considering the situation of Mae Moh mine, however, the application of conventional longwall method has limited potential since the rocks are weak and coal seams are extra-thick that might occur serious ground disturbance/subsidence and slope instability. Therefore, in this study the application of bord-and-pillar method was firstly considered. The models were firstly created for two slicing orders of extraction, in descending and ascending order. For descending model, firstly and then lower slices extractions were followed downward sequentially whereas the extraction was begun along the floor of the coal seam and the extraction were done upward sequentially for the ascending model. The bord was considered as 6 m in width and the extraction heightwas 3 m. The 18 m wide square pillars were left between the openings. The panel dimension was taken 102 m in width and 120 m in length. The detail of the bord-and-pillar model is shown in Figure 4.

In order to investigate the interaction effects in the double seams mining, the models were created for two cases, undermining and overmining. For the undermining model, the upper seam, K, is extracted first by multi-slice bord-and-pillar method followed by the extraction of lower seam, Q, while the lower coal seam is done first and the possible interaction effects on the upper seam was investigated for the overmining model.

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4. Results and Discussion

4.1. Comparison of Descending and Ascending Orders of Extraction

Figures 5(a) and (b) show major principal stress distribution after the first slice extraction along the mine roof (for descending case), and along the floor of coal seam K (for ascending case) respectively. In these figures, it can be seen that in-situ stress field is redistributed after developing the panel; stress relief zones are formed above and below the openings while highly stressed zones are formed around the pillar. In comparison with these two results, it was found that stress concentration occurred around mined-out panel (gob) in ascending model is much greater than that occurred in descending model. In addition, stress transformation to the working areas in the next slice seems to be faster and higher in the case of ascending order and thus the strata control might be more difficult. In descending order of extraction, the safer operation would be achieved as the next slice extraction can be done in/under the stress relief zones.

Figures 6 (a) and (b) show the contours of displacement in descending and ascending models. It was found that the induced displacement occurred in ascending model was much larger than that occurred in descending model. The coal seam roof was displaced about 10 cm in average after the first slice extraction and the displacement zones at the roof were relatively larger in the ascending model. Therefore, the strata control may be more difficult in comparison with descending of extraction.
Figure 5. Distribution of major principal stress after extracting first slice
(a) descending model and (b) ascending model

Figure 6. Contours of displacement after extracting first slice
(a) descending model and (b) ascending model

4.2. Comparison of Undermining and Overmining

Figure 7(a) and (b) show the distribution of major principal stress after extracting K seam (for undermining model) and after extracting Q seam (for overmining model), respectively. In the case of undermining, it could be seen that stress relief zones formed above and below the mined area; the stress decreased into 4-6 MPa, it evenly distributed at the mine roof, interburden and lower coal seam and this formation of destressed zones can be beneficial to lower seam mining in terms of safety. In the case of overmining model shown in Figure 7(b), it could be seen that the zones at the central part of the interburden and the upper seam are extremely destressed, this can be explained as the occurrence of arching loading at the upper seam, and this may result the vicinity of these zones highly loaded and the pillar and ground control problems at the upper seam mining might be occurred.

Figure 8(a) and (b) show contour of displacement after extracting K seam (undermining model) and after extracting Q seam (overmining model) respectively. The displacement contours of 10-20 cm are found at the
interburden and the lower seam, this can be considered as heaving condition, in undermining model. In the case of overmining, the displacement contours of 40-50 cm are found at the interburden and the upper seam and this can be considered as subsidence condition. Therefore, the overmining would be faced more difficulties in ground control in comparison with undermining due to the subsidence and lowering/shearing of the coal seam and the interburden.

![Figure 7. Distribution of major principal stress after extracting (a) K seam (undermining model) and (b) Q seam (Overmining model)](image)

![Figure 8. Contours of induced displacement after extracting (a) K seam (undermining model) and (b) Q seam (Overmining model)](image)

### 5. Conclusion

According to the results of a series of numerical analysis, it can be concluded that the extraction in descending order would be better than that in ascending order for the given ground condition in terms of safety and ground control and interaction between the seams would be relatively less in the undermining of the seams comparing with overmining of the seams.
Acknowledgements

The authors would like to express their gratitude to the managers, engineers and miners of EGAT Mae Moh lignite mine for arranging our site investigation and providing information. All opinion and comments stated in this paper are those of authors and do not necessarily represent those of the institutions or the mine.

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