NUMERİCAL ANALYSİS OF DİSPLACEMENT AND PRESSURE DİSTRİBUTİON AROUND A LONGWALL PANEL İN STEEP COAL SEAM

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Abstract: Pressure distribution and methods of estimating cover pressure distance in the goaf of longwall coal mines has always been challenging because the waste area is not accessible. When a longwall panel is excavated, the overburden strata are disturbed differently from the immediate roof towards the surface. The immediate roof behind the longwall face collapses at a distance that can change depending on the properties of the rock, the thickness of the immediate strata, and the type and nature of strata. To date, extensive attempts have been made for a comprehensive understanding of the stress and deformation state of the caved and fractured zone in horizontal working faces but few researches have studied steep coal seams. In the present study, stress and displacement redistribution and cover pressure distance in the longwall steep coal mines at angles about 43 degrees were analyzed by the 3D finite difference method and the result was compared with previous studies. In general, deformation and stress redistribution pattern is in accord with earlier research. Cover pressure distance was determined to be 198 m which shows a close agreement with the literature. Support system was evaluated by Sakurai's critical strain for underground excavations and tunnels. Finally, the lower part of the stopping and the conveyance roadway were determined as critical locations.

Keywords: Longwall, Numerical method, Steep coal seam, Stress distribution, Caving zone, Critical strain.

1- INTRODUCTION

Due to the decrease in coal reserves, extraction of coal seams with a moderate or steep slope and thus the feasibility studies of the steep coal stopes are necessary. Compared with more successful results in gently inclined coal seams, failures in steep coal seams or complex conditions happen because of various difficulties and the insufficiency of theoretical studies. To date, efforts have been made to comprehensively understand the stress and the deformation state of longwall coal stoppings. In situ monitoring of stress and displacement in immediate roof and caving zone has always been a problem due to inaccessibility of the waste area. Therefore, assumptions have been put forward by investigators in the past. All of these assumptions are based on indirect methods of prediction, i.e. numerical or analytical methods rather than in situ measurements. Distribution of stress in the caving area and cover pressure distance in horizontal stopes has been discussed in detail by Yavuz (2004). Based on previous field and experimental studies, Yavuz presented the stress-strain relationship of goaf material with its effective parameters, namely, the depth and thickness of the coal seam, the bucking factor and compressive strength of caved rock sand, then the relationship was verified by a numerical model. In 2017, Wang et al. presented an

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analytical model in a logarithmic form based on the stress-strain characteristics of the caved area for the stress stabilization distance, which was confirmed by a laboratory model. Also in 2017, Dongfeng et al., investigated the behavior of the roof strata in longwall top coal caving in a thick and steep coal seam. The results showed that the pressure variations of the roof layers in the strike direction were not significant, while in the dip direction the measured support pressure increase from the bottom upwards. In 2018, Rezaei presented a long-term analytical model for stability analysis of distressed zone at the top of the longwall extracted coal panels, then the most influential parameters were identified based on the sensitivity analysis results. In 2014, Yuehua and Shouqan examined the state of pressure and displacement around the longwall steeply inclined coal seam using a numerical model. They found that the movement behavior of the stope roof is quite different from horizontal roofs, and the support pressure at the bottom of the stope may cause serious damages and separations to the immediate roof. Bai and Elsworth proposed some empirical relationships in 1990 to determine the extent of the caving and fracture zones in steep mining conditions. Zhenyu et al. presented a research on the height of the caving and fracture zone with a combination of finite difference and empirical formulas in 2016. In 2017, Zhang et al. examined the behavior of roadways after mining in different roof conditions. An overview of the available literature suggests that few researches have been published on longwall steep coal mines. Using the theoretical analysis and field experiments, the present study attempts to numerically simulate the mining process in K12 Eastern Alborz coal mine.

2- METHODS
In the present study, the analysis of stress and deformation distribution around the steep coal seems makes it necessary to use 3D numerical simulation. FLAC3D, as a proper professional software in geotechnical engineering, has been used in several papers, including Yuehu and Shoqan's research in 2014. The software is a three-dimensional finite difference calculation procedure which provides 11 types of structural models for different materials, based on the non-linear method, and adapts to different conditions and the demands of strata movements during and after mining.

3- FINDINGS AND ARGUMENT
Stress and displacements of the rocks surrounding longwall steeply inclined coal seams during mining operation were analyzed. Generally, by extracting the coal seam, the pressure on the roof is reduced, causing excess pressure on the side tunnels, which is clearly more pronounced at the bottom of the tunnel and coal pillars. The structure and movement behavior of the longwall steeply inclined coal seams are quite different from those of horizontal types. First, the gob, which lies in the lower end along the tilt direction of the working face, needs to be filled to prevent the roof falling. Therefore, a large room is produced in the upper end of the inclined working face into which the roof above the gob can collapse and fall into. The maximum vertical strain is concentrated on the lower part of the working face which leads to make an unsymmetrical roof, loose at the upper end and thick at the lower end. Caving rock blocks in the working face roof move along the bedding plane and the upper zone of the roof in the gob is damaged by shearing and tension, while the lower part is damaged by shearing. With excavation being resumed, the stress is redistributed and the highest vertical and horizontal stresses appear in the surrounding rock around the conveyance road. Pressure and displacement distribution in the stope was compared with Sakurai's critical strain criteria (Sakurai, 1997) and critical areas were identified.

4- CONCLUSIONS

The pressure and displacement of the surrounding rock in the roof of a thin and steep coal seam, K12 Eastern Alborz, during mining has been analyzed and compared with allowed values. The displacements in the middle section of the working face and the conveyance tunnel were10.4 and 35.1 mm respectively, higher than Sakura's limit. Nevertheless, the shear strain did not exceed the permissible range. Movements and vertical stresses of gob area gradually return to the initial state. The experimental formula developed by Yavuz, predicts a cover distance value of 200 m according to the parameters of this study, which is in good agreement with the distance obtained by the numerical model in the lower section of the working area (198 m). The upper and lower coal pillars experience an increased vertical stress up to 3times as the initial state. Achieving success in a steep coal seam depends mainly on good maintenance and stability of the conveyance road behind the working face, which is different from the stopes in gently-inclined coal seams.

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