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3-D Estimation of Stresses Around a Longwall Face by Using Finite Difference Method

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ABSTRACT: There is a considerable amount of lignite reserve in the form of thick seams in Turkey. It is rather complicated to predict characteristics of strata response to mining operation in thick seams. However, a comprehensive evaluation of ground behavior is a prerequisite for maintaining an efficient production especially when top coal winning by means of caving behind the face method is applied. A comprehensive modelling of deformations and induced stresses is vital for the selection of the optimum production strategy. Induced stresses around a longwall face can be determined by in situ measurements, physical models and numerical modelling techniques. In this study, numerical studies as.sociated with numerical modelling of a longwall panel at Ömerler Underground Coal Mine have been carried out by using the software called $FLAC^{3D}$. A 3-D model of the M3 panel has been prepared and associated induced stresses around the panel have been calculated.

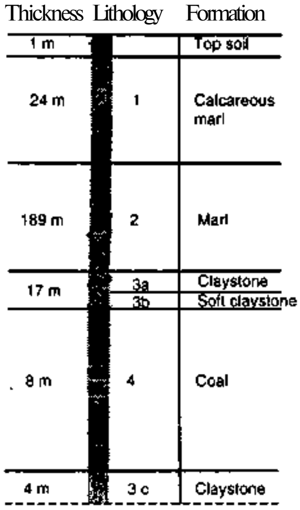
1 INTRODUCTION

Characteristics of primary stresses present prior to production and secondary stresses formed after mining activity are the key factors affecting the overal stability of especially gate roadways and the face. An efficient production can only be carried out if stability of the openings is properly maintained. For this purpose, understanding of the stress distribution characteristics around a longwall panel is of vital importance.

There have been numerous attempts in estimating primary and secondary stresses around underground structures depending mainly on in situ measurements, physical and numerical models. This paper briefly presents a part of a comprehensive 3-D numerical analysis of M3 panel at Ömerler Underground Mine. The numerical model was formed by using the commercially available software called $FLAC^{3D}$, based on the Finite Difference (FD) technique.

2 A BRIEF INFORMATION ON ÖMERLER UNDERGROUND MINE

Ömerler Underground Mine is located at the inner Aegean district of Turkey near Tunçbilek-Tavşanlı. The mine started production in 1985 and fully mechanized face was established in 1997. Average depth below surface is around 240 m and 8 m thick coal seam has a slope of 10°. A generalized stratigraphie column showing the coal seam together with roof and lloor strata is presented in Figure 1. There are three main geological units named as claystone, clayey marl and marl are present in the mine area. Physical and mechanical characteristics of coal and other units are presented in Table I.



Figuie I. A generalized stratigraphie column lit Omeiler Coal Mine

Table I. Physical and mechanical piupeiues of coal and surrounding rocks (Destanoğlu et ni, 2000; Taşkın, 1999)

Foim.ilion	Del umum LIKIC	Density (MN/m)	Unı.ı\ı.t! u>mpıessı\. slıenjuh (MP.ı)	Tensile SUCIIJJÜI (MP.ı ı	Iniein.il İmlimi an y le «0	Č óluşum » (MP.ı)	Motlıılıis ol cf.iMiLiiy - (MP.ı)	Ptitwm s r.ılıo v
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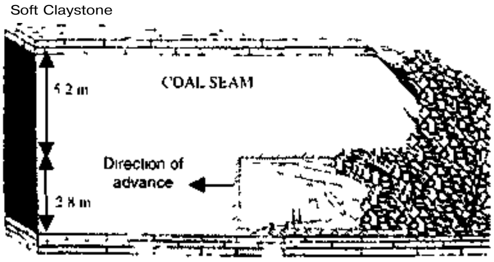
Coal	4	i n i n	|S>)		1S-2S		1711	0 2"i

The 8 m thick coal scam has been produced by means of longwall retreat with top coal caving pıoductıon method where a 2.8 m high longwall face is operated at the floor of the coal seam (Fig 2). Top slice coal having a thickness of 5.2 m ıs caved and pioduced through windows located at the top of shields. At the time of modelling, two adjacent longwall panels namely Ml and M2 had been completed and the production was carried out at M3 panel as shown in Figure 3



Fıguıe 2 Longwall with top coal caving method ut Omeıleı Undereiound Mine

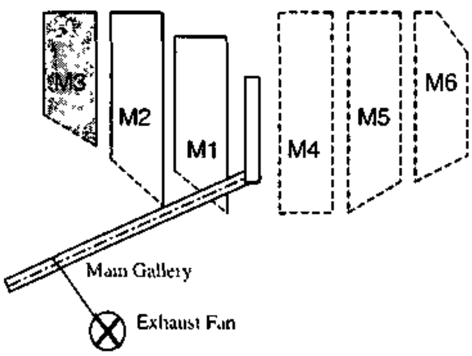


figure 3 Plan view of Ömerler Underground Mine (Akdaş et al 2000)

3 MODELLING PROCEDURE IN GENERAL

Finite Difference method can be better applied to modeling of stress distribution around underground mining excavations in comparison to other numerical techniques. FLAC[3D] is a commercially available software that is capable of modeling in three dimension.

Modeling for estimation of stresses around the longwall panel is performed in five steps. The steps called A. B. C, D and E are as follows:

A- Determination of boundaries and material properties,

B- Formation of the model geometry and meshing
- Determination of the model behavior,

C- Determination of the boundary and initial conditions,
- Initial miming of the program and monitoring of the model response,

D- Réévaluation of the model and necessary modifications,

E- Obtaining of results.

Model geometry and meshing refer to physical conditions of the district to be modeled. Model behavior is the response of a model under a certain loading condition. By means of boundary and initial conditions, physical limits of the model and original conditions are explained. At the beginning of the analysis, the model was in the form of a solid block in which gale roadways, the face and other structures were later created in the form ot modifications. The modeling process is presented in Figure 4 in the form of a flowsheet.

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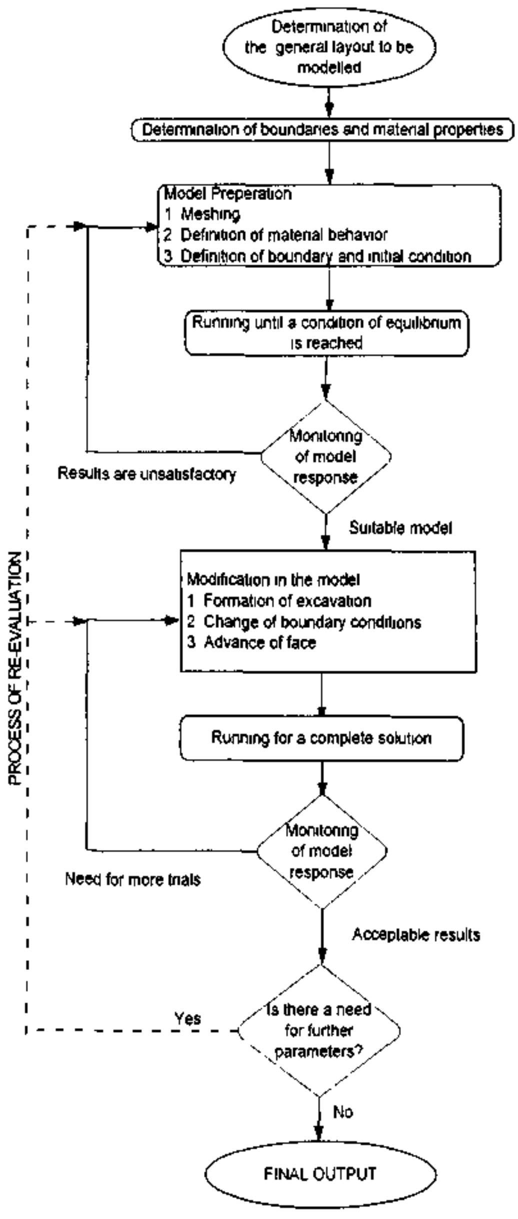


Tıguıe 4 A general flowsheet of modelling process (Yaşıttı 20Ü2 Unverand Yasıllı 2002, Itasca 1997)

4 MODELLING OF GROUND STRESSES AROUND THE LONGWALL PANEL

A lull-scale model of the M3 longwall panel and its surrounding has been prepared as seen in Figure 4. Face length, panel length and depth below surface values were taken as 90 m. 450 m and 240 m, respectively. There was a 16 m wide rib pillar between M3 panel and the adjacent completed M2 panel. In order to efficiently estimate stress distribution around the longwall face, this area was divided in the form of a closer meshing in comparison to other regions (Fig.5).

Il r ciucial to properly assess material properties in oider to obtain acceptable results in modelling with FLAC . Therefore, physical and mechanical properties of each geological unit must be properly determined. In general, intact rock properties are found by means of laboratory testing. However, there is an important diversity between rock material and rock mass characteristics. It is compulsory to determine representative physical and mechanical properties of the rock mass instead of intact rock material. In this study, rock material properties were converted into rock mass data by using empirical relationships widely used in the literature, i.e. Hoek and Brown (1997) failure criterion, Bieniawski's (1973; 1989) RMR classification system and Geological Strength Index (GSI) (Hoek 1995, Sönmez 2001, Sönmez and Ulusay 1999).

Modelling of caved area is another important step that affect the results. It is a well-known fact that it is a rather difficult task to model the goaf material. Therefore, the goaf was characterized by using the following expression for modulus of elasticity as suggested by Xie et.al. (1999):

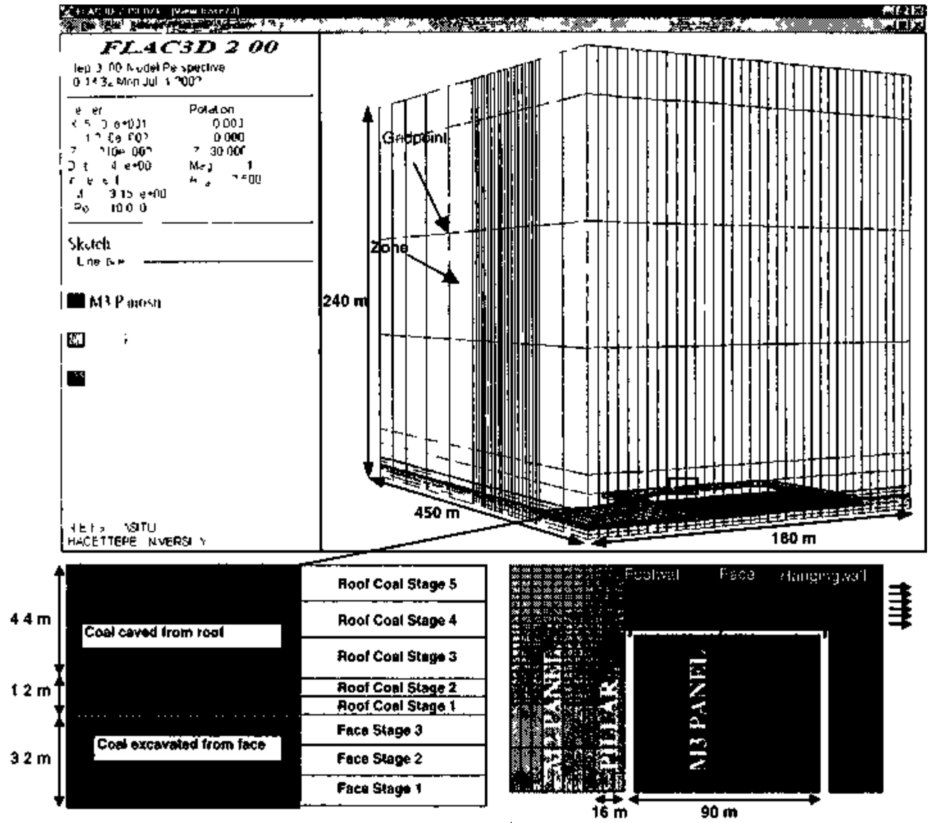
£ = 15 + 175(1-? '-·') (MPa) (1)

where, t is time in seconds

For the goaf material in Tunçbilek Region, Kose and Cebi (1988) suggested a modulus of elasticity interval of 15-3500 MPa, whereas Yavuz and Fowell (2001) suggested a Poisson's Ratio of 0.495. These values were used lor the characterization of goaf matenal throughout the analysis.

4.1 Stress distribution around the longwall face

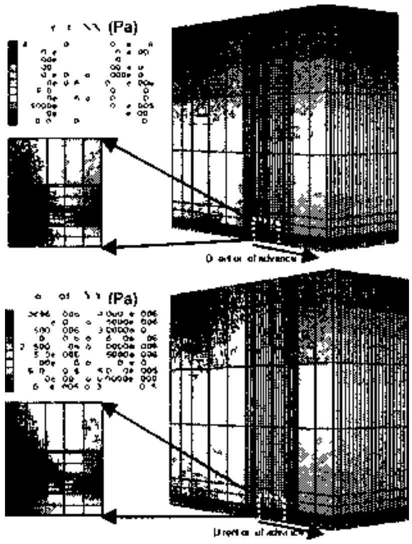
After formation of the model ol M3 panel together with its surroundings, rock mass properties were entered and the model is solved until an equilibrium state was leached. Resulting stress distributions in horizontal (x and y) and vertical (z) directions are presented in Figure 6 and 7, respectively. Distribution of vertical stresses in front of the face at various distances such as 3.5, 7, 10.5, 14, 17.5 and 21 m at eight different levels of the coal seam are presented in Figure 8. As shown in Figure 8, front abutment pressures increase until a distance of 7 m from the face line reaching to a maximum stress level of 13.5 MPa. The front abutment stress was found as 2.35 times of the initial field stress of 5.75 MPa.



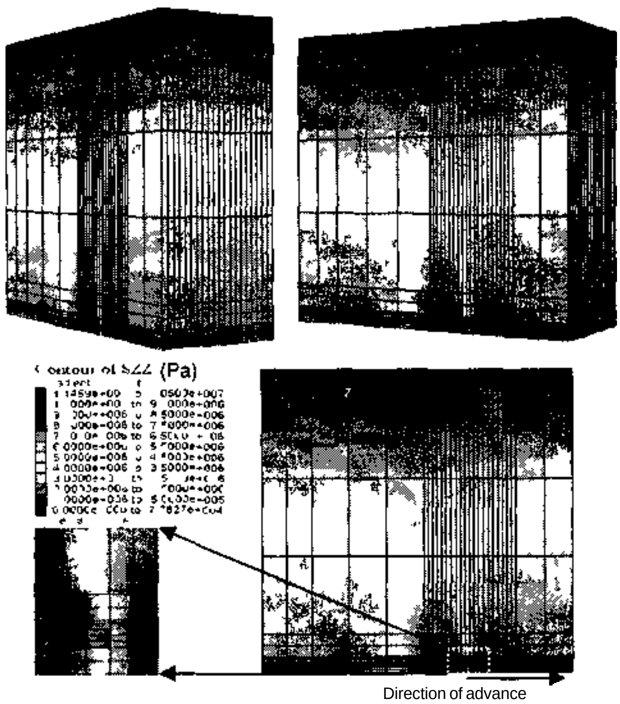
FiguiL S Omet lei Undugıound Mine model lonstıuıttd in FLAC^{4D} (Yaşıtlı 2002)

After leaching to its highest value front abutment siiesses tend to deciease away from the face The lesults ot numeiical modeling studies reveal that tiont abutment stiess aie formed at the center region ot the face Due to the pi esence ot the goat ot adjacent M2 panel front abutment stresses aie hıghcı aiound the tootwall side in comparison to solid hanging wall side as expected Figure 9 presents the stiess distribution on axes parallel to dıectıon ol advance as shown in Fıguıe 5 Distubution chaiacteustics and magnitudes ot lıont abutment stiesses aie found to be in good agieement with the results obtained by in situ measurements piesented in the lıteıatuıe Attei reaching to the highest lıont abutment pressuie of H 5 MPa at a distance ot 7 m m ti ont of the face, it decieases gudually to initial field stiess of 5 75 MPa at a distance of 70 m away from the face

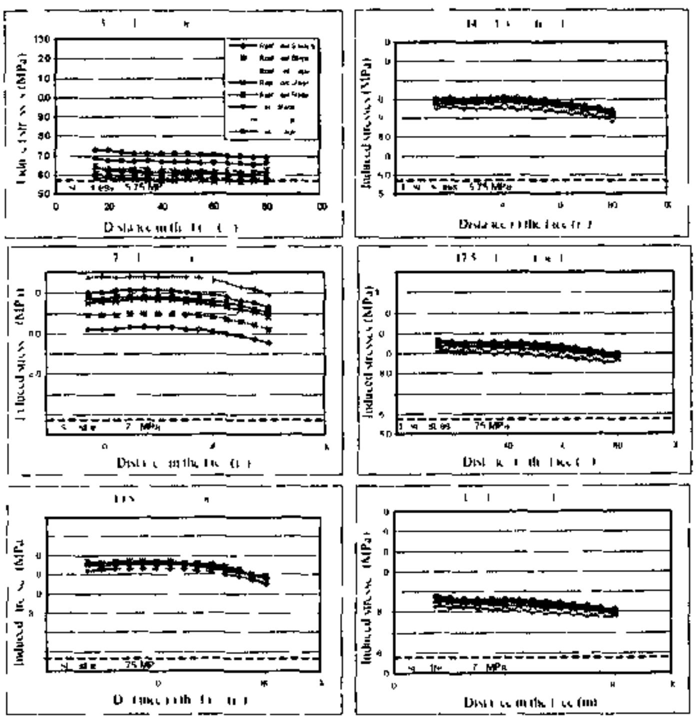
Stiesses in the goat behind the face deciease to 0 1 MPa levels and lends to increase at the stait line of the face in a sımılaı manneı with tiont abutment stiesses At the face stait line ot the panel, ıeaı abutment stresses reach to the highest level at 2-3 m inside the solid coal and decrease gradually to the field stress level at about 60 m inside the solid coal



Fıguıe 6 Secondary stiesses in hoiizont.il dıectıon (x and y dıectıon)



hguie 7 Stcondmy Miesses in vcrtic il diiLition *(i* direction)



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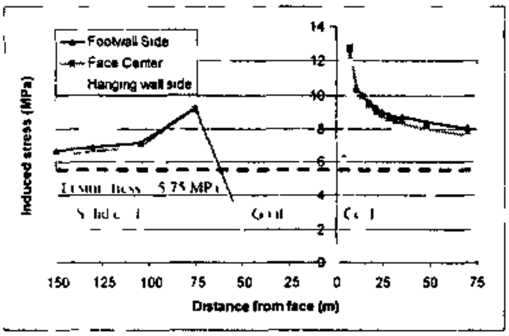

Figuic 9 Veitic.il Mioses tot med pat ale! to advance dncction it coal bottom

S CONCLUSIONS

In this study preliminary results ot a comprehensive 3-D modelling ot a longwall panel at Ömerler Undeıground Coal Mine are piesented In order to maintaining a realistic modelling ot stıesses and displacements matenal properties were derived tor lock mass instead ot ıock matenal by using Hoek&Biown failure critenon, RMR and GSI system and relevant empirical equations derived tiom the case studies The results show that stresses aiound longwall taces can be successfully modelled by using FLAC[1D] provided that ıock mass pioperties are input instead ot ıock material properties Realistic modelling of stresses would undoubtedly be of vital importance in understanding strata lesponse to production activity in undeıground opeıatıons This ıs ratheı important for thick seam coal mining where strata lesponse is moie complex due to top coal caving behind the face

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