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Stability Analysis and Support Design of Glandroud Coal Mine Tunnel

K.G.Goshtasbi & S.F.Dehghan
Department of Mining Engineering, School of Engineering, Tarbiat Modares University, Tehran, Iran

ABSTRACT: This paper reports the results of a research study which was carried out in order to analyze the stability of a tunnel at Glandroud coal mine, which is situated in northern Iran. The tunnel, with dimensions of 3 x 3.2 meters, was excavated at a depth of 150 meters below the surface. A numerical method was used to analyze the stability of the tunnel. Due to the structural, features and geology of the area, the distinct element method was used and the code utilized according to this method was UDEC. The results obtained from the numerical analysis show that instability in the tunnel is due to block falls from the roof and sidewalls. In view of this, various support systems were analyzed. This analysis shows that a combination of grouted rock bolt and shotcrete is the most suitable support system in Glandroud coal mine tunnel.

1 INTRODUCTION

The excavation of tunnels in coal mines causes instability, which may occur as a result of roof falls, wall failures or a combination of both. Therefore, in order to conduct safe mining operations, the stability of such tunnels is very important The prime concern in excavations is the control of displacements in the rock surrounding the excavation. In each excavation the design objective is to ensure that displacements of the rock around the excavation do not interfere with specified engineering activities (Pan et al. 1991).

Computer modeling for strata control and in rock mechanics has developed significantly in recent years. There are various numerical methods and codes available for stability analysis of tunnels. One of these methods İs the distinct element method, which has been developed for deformation and stability analysis of multiple-jointed rock masses around underground structures. Due to the structural features and geology of the Glandroud area, the distinct element method was used for stability analysis. The code utilized according to this method was UDEC. Many researchers have found UDEC to be a very powerful code when analyzing underground structures in various rock masses.

2 GEOLOGY

The Glandroud coal mine is İn the northern part of the Alborz Mountains, situated in northern Iran. Exploration studies have revealed that there are 14 coal seams which can be extracted (Glandroud & coal deposit 1998). These seams range from 0.5 to 1 meter in thickness. The lithology mainly consists of roof siltstone, coal and floor siltstone.

Field investigations were carried out and the general trend and characteristics of the joint structure were then determined. The analyzed data show that there are two joint sets in the floor and roof siltstones and a bedding plane in the coal seam. Table I shows the dip and dip directions of these joint sets regarding the roof siltstone, floor siltstone and coal seam. These details were then used İn model generation.

Table I. Joint directions in roof siltstone, coat seam and floor siltstone.

Formation	Joint set	Dip O	Dipi direcnon O	Spacing (m)
Roof Siltstone	11	55	124	0.54
	J2	81	187	0.85
Coal Seam	J1	70	14	0.33
Floor Siltstone	J1	55	127	0.38
	J2	82	24	0.65

3 GEOMECHANICAL PROPERTIES

Laboratory investigations were carried out in order to determine the physical and mechanical properties of the rocks and joints. Mechanical and physical tests were carried out on samples from the roof siltstones, floor siltstone and coal seam. With this consideration, uniaxial, triaxial and shear strength tests were carried out İn accordance to 1SRM suggested methods (Brown 1981). Table 2 shows the material properties used in model stability analysis.

Table 2. Geo mechanical properties

Property	Roof siltstone	Coal	Floor siltstone
U.C.S. (MPa)	11.3	5.85	10.7
Young's Modulus (MPa)	900	1300	850
Possion's ratio	031	0.28	0.33
Cohesion (MPa)	2.15	1.90	2.43
Friction angle (deg.)	25	30	23
Tensile strength (MPa)	1.65	1.15	1.4
Unit weight (KN/m^3)	26	13.1	27

4 NUMERICAL ANALYSIS

There are various numerical methods and programs available, each of which has its own applicabilities regarding the rock mass and discontinuités encountered in underground structures.

The universal distinct element code (UDEC, Itasca 1992) is a powerful numerical method for analyzing the stability of structures in jointed rock masses. In UDEC, the rock mass is presented as an assemblage of distinct blocks having joints between the blocks. Each block can be modeled with either rigid or deformabie materials. The rigid blocks represent me medium as a set of distinct blocks which do not change their geometry as a result of applied loading. Deformabie blocks are internally discretized into finite difference elements, with each element behaving according to a prescribed linear or non-linear stress-strain constitutive relationship. UDEC uses time-marching finite difference schemes to solve the force equations of morion in the system.

4.1 *Model simulation*

Glandroud coal mine tunnel no. 630, with dimensions of 3 x 3.2 meters, was excavated at a depth of 150 meters below the surface. The model geometry was built up in accordance with the joint dip and dip directions given in Table 1. All the models analyzed had dimensions of 17 x 17 meters. Figure 1 shows the model geometry of Glandroud coal mine tunnel. The block material properties were used from the properties given in Table 2.

The UDEC's Mohr Coulomb plasticity model was used to simulate the intact rock of the blocks. However, for simulating discontinuities the joint area contact-Coulomb slip model was used.

The main objective of the model simulation was to model effectively the important behavior mechanism and modes of rock failure occurring in the tunnel under study. Thus, numerical models were analyzed under various horizontal-to-vertical stress ratios (k), ranging from 0.5 to 2. The analyzed data show that the models with a horizontal-to-vertical stress ratio of 1.5 produced very close findings compared to the observations and measurements that were taken in the mine. Therefore, this stress ratio was utilized for stability analysis and support design.

The model simulation process was checked by die resulting unbalanced force. The model converged to an equilibrium state when the unbalanced force in the model reached an acceptable value.

5 STABILITY ANALYSIS

The results of the UDEC distinct element analysis are obtained in terms of stress and displacement contours. Many models were analyzed under various in-situ stress fields. The minimum and maximum displacements occurred in models wim k=0.5 and k=2 respectively. However, the displacements obtained from the model with k=1.5 were very close to those measured in the Glandroud coal mine tunnel. Therefore, the results below are from models withk=1.5.

Figure 2 and Figure 3 show the displacement vectors and principal stresses respectively after excavation of the tunnel. The maximum displacements in the roof and floor of the tunnel were 48 and 23.5 centimeters respectively. The maximum displacements in the left and right sidewalls were about 20 centimeters. The results also show that minor block falls occurred in the roof and sidewalls. Therefore, supports were needed in order to control the displacements and block falls. Many support systems were analyzed, and die most suitable support system was found to be a combination of reinforced shotcrete and rock bolts. The bolt spacing was 2 meters in tie roof and 1 meter in the sidewalls. The thickness of the reinforced shotcrete was 20 centimeters. Figure 4 shows displacement vectors after support installation, clearly indicating that very little displacement occurred in the model. Figure 5 and Figure 6 show me shear force and axial force on the support system. The forces on the structure clearly indicate that no yielding occurs and therefore the tunnel is stable with this support system.

6 CONCLUSIONS

This investigation has shown that the distinct element method and the UDEC code can successfully model and analyze the stability of tunnels in coal mines.

This can best be achieved if the in-situ stress, geomechanical properties and joint structure are properly measured. The numerical analysis showed that the stress ratio of k=1.5 produced displacements which were in close agreement with measurements from the Glandroud coal mine tunnel. The maximum displacement was 48 centimeters, which occurred in the roof. The UDEC code has the capacity to model various support systems. The designed support system was 20 centimeters of reinforced shotcrete and rock bolts in the roof and sidewalls. This support system proved to be suitable in controlling block falls and displacements in the tunnel. Therefore, this support system is recommended for stabilizing the tunnel in Glandroud coal mine.

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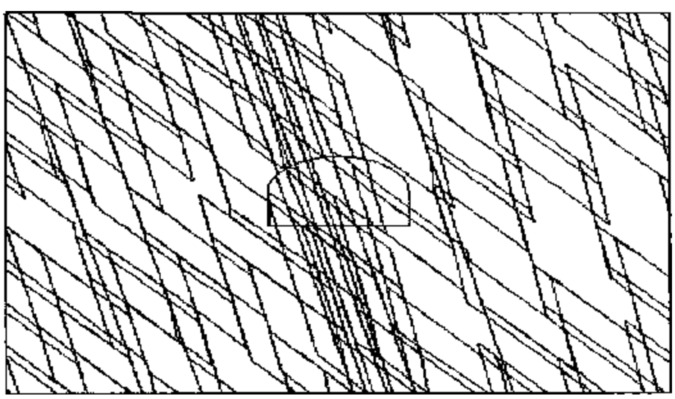


Figure İ. UDEC model geometry.

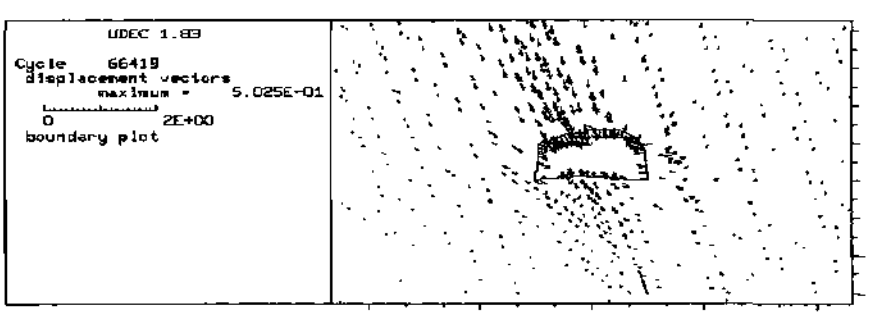
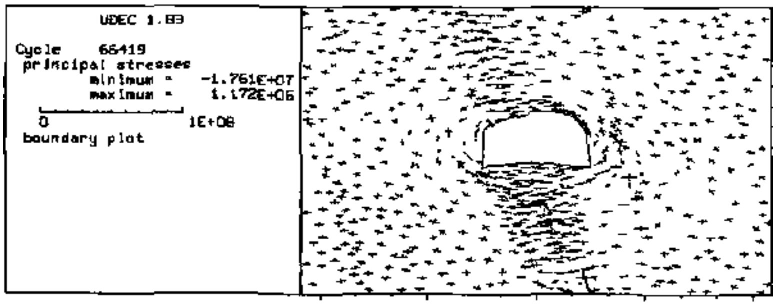


Figure 2. Model displacement vectors.



Fi Türe 3. Mode! principal stresses.

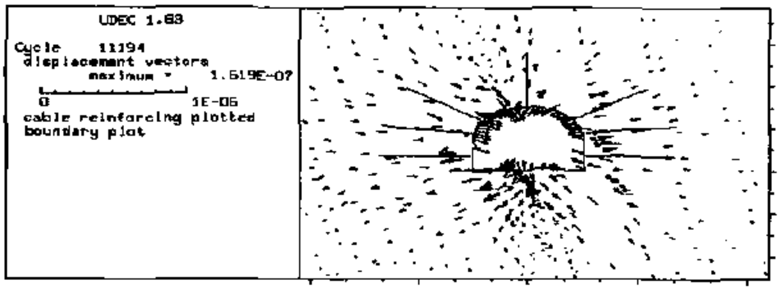


Figure 4. Displacement vectors after support installations.

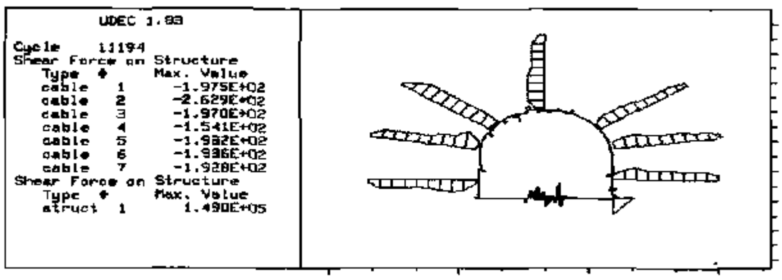


Figure 5. Shear forces on supports.

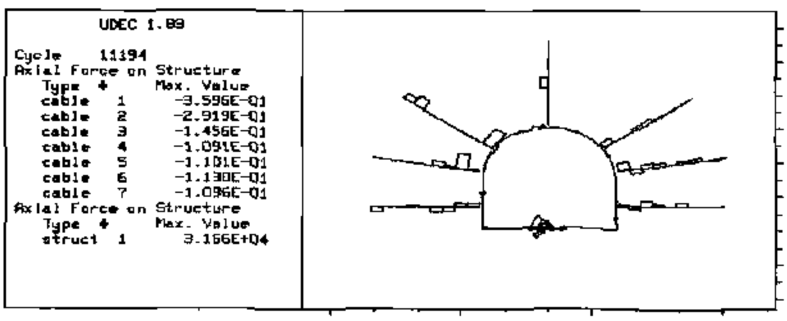


Figure 6. Axial forces on supports.