Design of Roof Bolting System in An Underground Coal Mines- A Numerical Modelling Approach

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Abstract: To improve the safety in underground coal mines working the insertion of roof bolting on the rock layering is a vary popular method of roof supporting system. The estimation of rock load from the strata and its distribution over the underground mine workings is of prime importance, as it will justify the types of roof bolts used under different strata conditions. In this paper, an attempt has been made to design the roof bolting system based on numerical simulation approach. The parameters which taken into consideration were Bolt length, grout condition, presence of geological (such as dykes, sills, etc.) and geotechnical parameters (such as folds, faults, joints, uncertainties in rock, etc.). The numerical design is done to analyze the maximum load bearing capacity, stiffness of support and residual strength and Axial load on the immediate roof. Design parameters used in this paper is truly based on the assumption of the simulated underground coal mines condition.

Keywords: *Underground coal mines, Geotechnical parameters, Stiffness of support, Grout condition, Axial load.*

I. INTRODUCTION

Mining is a world which has very huge experience of accidents [1]. Roof fall is one of the major factors which decides the accident frequency in any underground coal mines [2]. Roof falls are the major hazards in underground bord and pillar mining method in India [3]. The complexity of geological deposit (such as dyke, slices, folding and faulting) and variability of mining parameters (i.e., mine layout, method of working, hydrological condition, etc.,) leads to the occurrences of unwanted roof falls. Thus, a proper and systematic approach is required for controlling the roof fall events in mines which can further improve the safety of the mining operation. In an underground coal mines, most successful and economical approach to support the underground rock strata is roof bolting. In roof bolting technology, roof bolts are used mainly for supporting roadways in bord and pillar workings [4]. The term mine support system explains method which adopt to improve the stability and maintained the load bearing capacity of rock layering structure. This support method of underground rock strata is more effective and efficient than other methods (such as steel arch support, cog support, chock support etc.,) because of its active behavior and also it utilizing the rock to support itself by applying internal reinforcing stress. The roof bolts support system bins the thin strata together and thus increases the effective thickness of the roof beam and it suspends the strata from the thrust of immediate roof structure. The main action of roof bolting is to hold the rock layering, by resin grouted tensioned rock bolt, that may break off. To keep the rock layering structure by roof bolt system the balanced lumps structure is maintained on both the abutments and anchors [5].

The prime objective of resin grouted roof bolt supports system is to enhance the inherent strength of the rock strata in order to make it self-supporting. The resin-grouted roof bolts are used as a means of support in order to redistribute stresses and reestablish equilibrium in the rock mass. It represents another improvement over the mechanical bolts and getting much attention in both academic and industrial research. In this paper, an attempt has been made to understand and analyses the roof behavior with roof bolting system by using a resin grouted technique which is based on the numerical simulation approach. A three-dimensional (3D) model of the depillaring panel with support design using roof bolt technology is complicated to simulate [6]. Therefore, the simulation is done near the goaf edge, where maximum chances of roof failure are likely to occur. An elastoplastic model has been taken for study considering physio – mechanical properties, geo-mining condition, roof bolt and grout properties as an input parameter.

II. ROLE OF ROOF BOLT SUPPORT SYSTEM IN UNDERGROUND COAL MINES

The primary function of roof bolts support system is to inhabits the rock movement and retards the rate of advancement which acts as enhancing agent of the inherent strength of rock in which it is installed. The principle of the action of roof bolts are, to improve the tensile, shear and flexural strength of the rock mass, and to consolidate the blocks or layers of rocks to form reinforce zone adjacent to the surface of the rock mass. In general, there are two types of roof bolts system are applicable in underground coal mines. First, point loaded bolts which act by linking a point deep in the rock with the plane of the exposed rock surface and their success depends on the mechanical strength characterstic of the rock deep inside the mass. The second one is distributed load bolts in which bolt stems are bedded in polyester resin. The polyester resin cement with accelerator is packed in a fluid state in thin paper or easily breaker able (glass) cartridges which are pushed to the bottom of the hole by means of stemming rod. The variety of research carried out over the world on the application of roof bolt supporting system which incorporates the different types of roof bolts [7]. In the resin grouted support system, bolts reinforce the rock by maintaining friction on bedding plane, key together blocks of fractured rock and controlling the dilation of failed roof layer. To determine the minimum required thickness of the beam is the first consideration in the design of resin grouted supporting system. An important consideration in beam theory is that the top and bottom surfaces of the beam are free of shear stress, and the shear stress distribution across the beam is parabolic. The schematic representation of the mechanism of resin grouted supporting is shown in Figure 1.

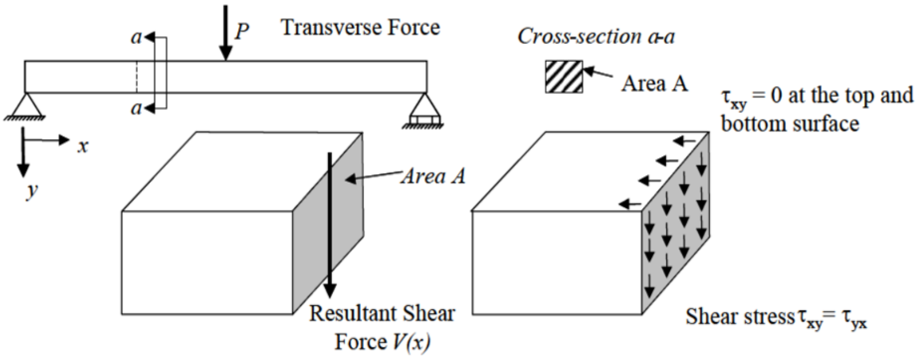

Fig.1 Mechanism of resin grouted supporting system

III. DESIGN OF ROOF BOLTING SYSTEM-A NUMERICAL MODELLING

It is difficult to simulate the three-dimensional (3D) model of the depillaring panel with support design based on the roof bolt technology. Therefore, to perform the simulation model the area selected near to the goaf edge, where maximum chances of roof failure may occur. The FLAC 3D design model was used during the course of the study and FLAC 5.0 numerical model was considered for the determination of stress formation in and around the working areas. The input parameters for the purposed numerical modelling is Tabulated in Table 2. The elastoplastic model has been chosen to perform the numerical modelling which consider the physio-mechanical properties, geo-mining condition, roof bolt and grout properties as an input parameter. In the underground coal mine scenario, the case of a depillaring panel was selected for this study. The available literature corroborates the fact that the induced stress on the pillar increases with the advancement of goaf. The three-dimension sectional view of the panel is shown in the Figure 2.

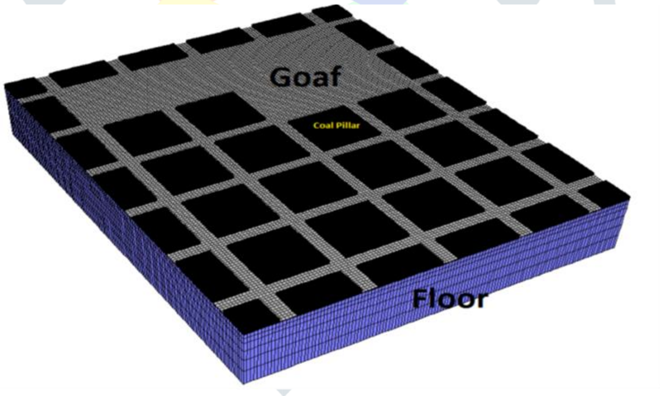

Fig.2 Three-dimensional Views of the Panel

The plan view of the area, where the study has been performed near goaf edge as shown in Figure 3. Also, three–dimensional discretizational view of the model is shown in Figure 4. It has been analyzed that the load on the model is continuously increasing with the advancement of the goaf edge and it has been observed maximum value varies from 7.0 – 8.0MPa in three- dimensional depillaring panel model which is shown in Figure 3. The axial load on rock bolt in an underground coal mines during the different stages is tabulated in Table 3.1.

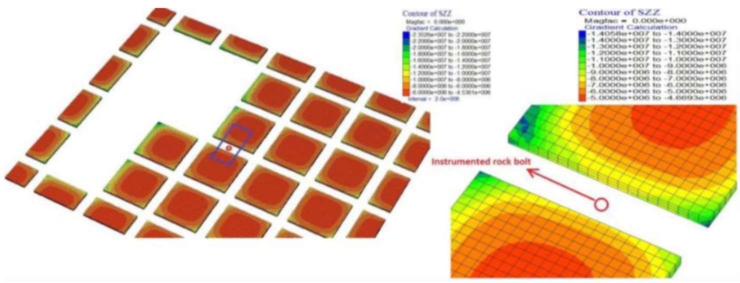

Fig.3 Plan View of Panel near Goaf Edge and Maximum Induce Stress Value

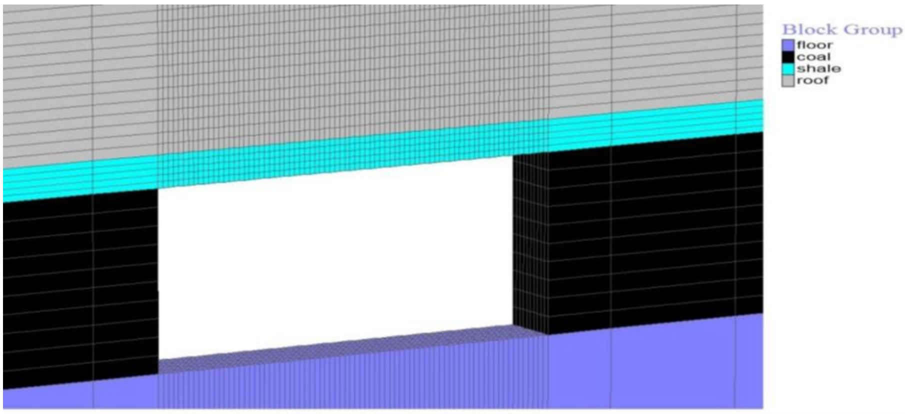

Fig.4 Three-dimensional Sectional View of the Model

Table 3.1: Axial Load on Rock Bolt in Different Stages of Mining

Mining Stages	Total Stress (MPa)	Axial Load in (tonne)	
		Instrumented Rock bolt result IRB (Field)	Instrumented Rock bolt result (Simulation)
Development stage		0.2	0.25
Depillaring Stage		-	-
Stage 1	5.87	-	0.45
Stage 2	6.37	-	0.49
Stage 3	6.87	-	0.54
Stage 4	7.37	-	0.58
Stage 5 (Near Goaf edge)	7.87	0.55	0.61

Table 3.2: Design parameters used in numerical modelling

Property	Coal	Sandstone	Clay band
Bulk Modulus	3.67GPa	6.67GPa	2GPa
Shear Modulus	2.2GPa	4.0GPa	1.4GPa
Density	1480 kg/m^3	2100kg/m^3	1650 kg/m^3
Tensile Strength	1.86MPa	9.0MPa	6MPa
Cohesion	1.85MPa	6.75MPa	5MPa
Friction angle	30^0	45^0	17^0

IV. Stress Distribution over Pillars/Stooks

Cumulative stress over the pillars and stooks in FLAC simulation of numerical modelling for different stages is shown in Table 4.1. The model was simulated with roof support, roof and side support and without support to comprehend the stress distribution over the pillars and stooks. In the study, three pillars with two stooks in each was considered for the simulation modeling. The detailed technical information of this is provided in Table 4.1, in which, maximum stress of 9MPa is experienced by the stook present next to the fourth gallery after excavation of 5 stooks. The maximum over the pillar remains more or less same for supported and unsupported roof because the rock load remains constant. But the stress distribution profile changes showing more stress enforcement at the side of the pillars for supported roof and sides.

Stage	Support	Pillar 1		Pillar 2		Pillar 3	
		Stook 1	Stook 2	Stook 3	Stook 4	Stook 5	Stook 6
Development of gallery	Without support	5		5		5	
	Roof Bolting	5		5		5	
	Roof and side bolt	5		5		5	
Development of Splits	Without support	5	5	5	5	5	5
	Roof Bolting	5	5	5	5	5	5
	Roof and side bolt	5	5	5	5	5	5
Extraction of Stook 1	Without support		8	6	5	5	5
	Roof Bolting		8	6	5	5	5
	Roof and side bolt		8	6	5	5	5
Extraction of Stook 2	Without support			8.5	7	5	5
	Roof Bolting			8.5	7	5	5
	Roof and side bolt			8.5	7	5	5
Extraction of Stook 3	Without support				9	7.5	6
	Roof Bolting				9	7.5	6
	Roof and side bolt				9	7.5	6
Extraction of Stook 4	Without support					9	8
	Roof Bolting					9	8
	Roof and side bolt					9	8
Extraction of Stook 5	Without support						9
	Roof Bolting						9
	Roof and side bolt						9

Table 4.1: FLAC Simulation – Stress Observation (MPa)

Maximum stress observed over the pillar at the stage of extraction of 5 stooks supported with roof and side bolts was 7.5MPa. The X-axis represents the stress in MPa and Y-axis represents the goaf edge distance in meters which is shown in Figure 5.

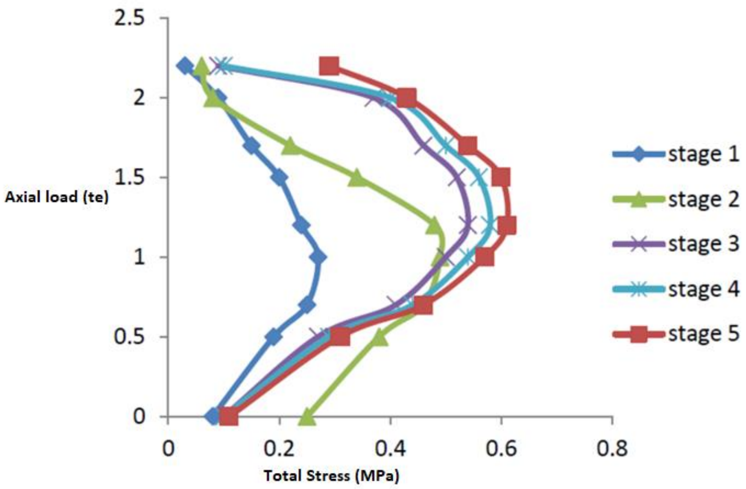

Fig.5 Axial Load in Different Depillaring Stages

V. CONCLUSIONS

Design of rock bolt support system is an essential factor to control the strata of the rock layering and to provide safe working condition in underground environment. The numerical modelling approach was applied to design the roof bolting system for an underground coal mines condition results which validated by substituting the design parameters. It was observed that the convergence trend was continuously increasing, indicating a major roof fall. Thus, the assumption in the design of support system was taken such that, the rate of convergence will decrease, reducing the impact of a fall occurring in underground mines. Since, the model parameters are based on assumptions, it can be used to predict the strata behavior of the working in advance.

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