

## ABSTRACT

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The trend of Indian underground coal mine is going into mechanisation by adopting continuous miner technology in Bord and Pillar working. The machine has operated in wider gallery size up to 6.6 m for the smooth maneuvering of the machine and fast retreating during the depillaring stage. The conventional method of mining using Load Haul Dumper (LHD)/ Side Discharge Loader (SDL) machine requires gallery size up to 4.8 m. One of the roof support design is established on empirical expression based on geo-mechanical classification of the roof. Various researchers proposed the geo-mechanical classification of roof (Terzagi, 1946, Bieciawski, 1989, 1976 and Barton et al., 1974). CMRI-ISM RMR (Venkatesvarlu et al., 1989) proposed the geo-mechanical classification of roof based on statistical analysis for various underground coal mines in India. The applicability of any empirical approach is limited within the range of the dataset. At that time, the maximum width of gallery 4.8 m was taken into consideration for computed the empirical relationship. Therefore, an extensive exercise is required for designing the support system in the greater width of the gallery. Numerical simulation is one of the appropriate tools for designing roof support.

Rock bolting is more economical than other support systems used in an underground mine, and also its installation is easy compared with others. It saves material and manpower consumption to improve the productivity of the mine. It also reduces the hindrance in the gallery, particularly in continuous miner (CM) operation. Many researchers have been done in support design in the form of mathematical, empirical and numerical approaches. The three-dimensional numerical simulation gives a reasonable understanding to analyse the complex roof strata and bolt interaction. The numerical model indicates that the roof bolts can significantly affect the vertical stress

distribution in the bolted area. So, the development of the three-dimensional roof bolt model can substantially benefit the studies on bolt-grout-rock interaction (Cheng, J et al., 2014). Roof support design in mechanised depillaring panels is a challenge due to the faster extraction rate, complex mining structure, and dynamic loading of the overlying strata.

Kushwaha et al., 2010 have conducted an extensive study through numerical simulation in conventional depillaring operations. In this design methodology, a generalized empirical equation has been developed using numerical simulation technique to estimating the required support load density at different places of the face based on geo-technical parameters of the mine and physico-mechanical properties of the immediate roof rocks during mechanised coal pillar mining. The equation depends on various parameters such as RMR, depth, gallery width and stress ratio. The elastic model has been used to estimate the rock load height using a numerical simulation approach. The minimum and maximum principal stress  $\sigma_{1i}$ ,  $\sigma_{3i}$  around an excavation are computed, the rock load height can be estimated by safety factor at different points and drawing its contour. In this method, the factor of safety is taken as  $\leq 1.5$ .

The design of support requirements and roof behaviour is dependent on number of parameters. It has been observed that depth, RMR, gallery size and bolt density are the most prominent factor in the stability of the roof based on the literature survey.

The interaction of rock-bolt-grout with the advancement of the goaf line is understood using three-dimensional modelling. The response in terms of axial load exerted on the bolt has been investigated. Roof behaviour has also been analysed at each stage of operation. The study critically investigates roof behaviour at various stages of depillaring operation in Bord and pillar panel.

Critical parameters have been chosen for the assessment of the roof behaviour under varying roof bolt density (bolt pattern) and geo-mining conditions. The methodology has been developed to formulate the simulation scheme for analyzing the stability of the roof under varying geo-mining parameters. The steps involved to achieve the objective of the thesis are preparation of three-dimensional model of bord and pillar panel, calibration of material properties used in the model, validation of the model for two different case studies of mechanised underground coal mining using continuous miner and semi-mechanised SDL/LHD and study of the impact of various parameters. A focused study area is being chosen near the goaf where maximum induced stress is observed. Simulation of the model has been carried out to analyse rock load height during different stages of depillaring operation. Axial load developed on the bolt has also been observed for different bolt patterns. Influences of various geo-mining parameters such as RMR, size of the gallery, depth of seam and different combinations of bolt patterns have been studied. Optimum required rock bolt density at various locations in depillared area has been observed based on the following set criteria

- ❖ Bolt length should be more than 30 cm of maximum observed value of RLH.
- ❖ Bolt capacity (anchorage strength) should be more than factor of safety (FOS) i.e., 1.5 times of observed axial load developed on the bolt from simulation.

Statistical analysis of data observed by simulated model results gives the mathematical expression of required support load density at a critical location near goaf edge.

A Three-dimension numerical simulation of the bord and pillar system of mining has been carried out to evaluate the performance of the roof bolt. Two cases have been chosen of Indian coal mines worked by bord and pillar system of mining. The representative model of these cases has been simulated and validated with the help of the observed monitored value of instrumented rock bolt during field observation. Total

One hundred and forty four models have been constructed considering different geomining parameters, i.e., depth, RMR, gallery width, and bolt density. The response on the bolt in terms of axial load and roof yield has been monitored during depillaring stages. Based on the number of data observed from simulated models, the criteria for suggesting the optimum support design have been proposed based on rock load height and axial load developed on the bolt.

The numerical simulation approach provides an opportunity to develop a guideline for support design. The design guideline has been developed based on the field and simulated study. The result of numerical modelling is analysed using a simple statistical approach to identify the major influencing parameters. The technical relevance of this analysis is examined through the observed facts of the field studies. Finally, on the basis of different correlations under the detailed study of strata mechanics phenomenon, the generalised empirical relationship is developed for the design of the required support system in mechanised depillaring operation.