CHAPTER 4.
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4.1 Background

The main objective of the study is to design the support system using three-dimensional numerical simulations using roof bolt technology. Simulation has been done during depillaring operation in bord and pillar mining method considering roof and coal pillar as strain-softening material. This objective could only be reached if acted upon with a planned approach. The first step towards a goal always starts with knowing everything about it. Therefore, extensive literature reviews were made using books, journals, papers referred to in this thesis. So far, the initial field visit gives an idea about the complex structure of underground coal mining. Discussion with mining officials encouraged us further in our work. On the basis of the initial field visit and extensive literature review the understanding is very effective to select the mine site and what are the important parameters need to be focused to achieve the objective. It was followed by extensive field investigation & collection of data from the field site.

In general, support design of the roof is suggested based on RMR as per the recommendation of the Paul Committee report. As per the report, the empirical relationship between RMR and gallery width gives the proper support design methodology at gallery and junction. The relationship was made based on extensive field data at various locations of underground coal mines. This relationship gives a suitable support design for gallery width up to 4.8 m.

In the present scenario, the underground working is changing drastically as compare to earlier working. The main challenge that has been observed in today's practices is to deal with highly mechanized working having wider gallery operation and fast retreating. To meet the challenges, many researchers suggesting a support system based on a

numerical simulation approach. The empirical design was developed by A. Kushwaha et al., 2010 during the depillaring operation. In this design methodology, a generalized empirical equation has been developed 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 mechanized 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, a factor of safety is taken as ≤ 1.5.

Initially, various studies have been carried out to reach the objective of the thesis. Primarily, the computational problems arise to simulate the model considering three-dimensional depillaring stages. An analogy has been established (Rizwan et al., 2016) to simulate the panel using two-dimensional analysis to replicate roof and bolt behaviour in three-dimension. Considering physico-mechanical properties of the immediate roof, geotechnical property of the mine and bolt and grout properties as an input parameter. The studies also try to simulate the laminated behaviour of roof strata using roof bolts based on beam building (Hasim et al., 2017). The simulation gives the idea about the bolt acting with layered strata for suitable design the number of bolts required to give stability on the roof. After the extensive study, an attempt has been established to simulate the model in three-dimensional development as well as depillaring stages of the mining operation.

So far, the behaviour of immediate roof strata and coal pillars is mainly behaving as strain-softening material, and the effect on the bolt in terms of the axial load has changed during the simulation process.

Therefore, an attempt is made to analyses the roof behaviour in terms of yield zone (RLH), including bolt performance in terms of axial load exerted on the bolt during the three-dimensional simulation process. It will be monitoring during the extraction of respective pillars. To suitable design of support pattern using roof bolt, the following steps are kept into mind. According to the thumb rule, the larger density of bolt will give effective support as compared to the lesser density of support. Still, at the same time, the study revealed that at some point of time, the yield zone remains constant irrespective of increasing bolt density. So, the study will give the idea of optimum support design to give the effective support design vis-á-vis to reduce the time for installing the support, which is not required.

Based on an extensive literature review and discussion with mining officials during the field visit, a detailed methodology was developed to achieve the prime objectives of the thesis.

4.2 Different steps of study

i. Model using FLAC^{3D} has been constructed. Strata (Coal seam and roof) were considered as strain-softening material. A systematic bolt pattern has also been installed in the panel.

ii. Validation of a model for two different case studies of mechanized underground coal mining using continuous miner and semi–mechanised using SDL/LHD technology.

iii. Parametric study of the models considering various factors such as RMR, gallery size, depth of seam, and different combinations of bolt patterns has been simulated.

iv. For analysis of different models, two set criterion has considered for support design methodology.

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

v. Maximum load on the bolt will encounter at the time where the goaf reaches near the bolt. The study area will focus on pillar exploitation after splitting and slicing, and it will be closely monitored.

vi. The development of mathematical expression will be based on a statistical analysis of data observed by different simulated models. It can be adopted by the industry as per their applicability.