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Field and numerical modelling studies for an efficient placement of roof bolts as breaker line support

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ABSTRACT

Depending upon the site conditions, field studies of roof bolt-based breaker line support (RBBLS) found that its positions need to vary from 0.5 to 2 m out-bye side from the goaf edge for a better performance. This variation is done to adjust the extent of spalling/loosening of sides of the surrounding natural supports. As per the studied site conditions of different mechanised depillaring operations, a detailed parametric investigation is conducted on the simulated models to estimate rock load height (RLH) for a given site conditions. Results of the static (elastic) simulation study are used for an estimation length of a bolt in the RBBLS. But the field measurements found that the bolts were subjected to dynamic loading during caving of the roof strata. Accordingly, the support resistance of the RBBLS is estimated considering the dynamic effect of caving, derived from the field measurements. On the basis of these investigations, empirical formulations are attempted among the relevant geo-mining parameters for the design of a RBBLS.

1. Introduction

The Indian coal mining industry has deployed a number of mechanised depillaring (MD) operations in recent past for efficient extraction of standing coal pillars.[1] Large variations in conditions of these depillaring sites bring a number of technical challenges[2,3] into consideration. One of these challenges is goaf encroachment[4,5] during caving of the competent roof strata. There is a possibility that the caving of roof strata, inside the goaf, extends into the working area, known as goaf encroachment. The goaf encroachment in a slice is controlled, mainly, by a suitable design of rib/snook.[6] However, the inherent existence of different rooms (openings) along the extraction line in a depillaring panel provides an easy path for the goaf to encroach the working area (Fig. 1). Each of these openings in a MD operation, along the extraction line, is supported by the roof bolt-based breaker line support (RBBLS) to restrict the goaf encroachment.

Commonly practiced empirical relationship[7] to support immediate roof strata in conventional room and pillar development encounters difficulties at the goaf edge because the influence of caving is not considered. Another relationship (Eq. (1)) for estimation of required support resistance at the goaf edge may be applicable for the conventional depillaring only.[8] First time in India, the roof bolts are applied at the goaf edge as breaker line support and called RBBLS in a continuous miner based MD.[9] In the beginning, three rows of roof bolts, each row with five bolts in 4.8 m wide gallery and seven bolts in 6.6 m wide gallery, were used as RBBLS (Fig. 2). But on the basis of field trial results, generally, two rows of roof bolts are now being used as RBBLS. Strata mechanics studies at different MD operations noticed that the performance of a RBBLS changes with the variations in the value of mining induced stress over the surrounding natural supports due to a change in the site conditions and dimension of the excavation. Experienced extent of the side spalling/loosening due to the high value of mining induced stress under difficult geo-mining conditions (competent roof strata and high depth of cover) is found to be site specific. Field observations at different depillaring sites found that the depth of cover and nature of overlying strata are two major responsible factors[10,11] for the value of mining induced stress:

$$SLD_{ge} = \frac{\gamma H^{0.54} K^{0.49} W^{0.89}}{R^{0.79}} \quad (1)$$

where SLD_{ge} is support load density (t/m^2), H is depth of cover (m), K is the ratio of horizontal to vertical in situ stress, W is the width of split or slice (m), R is the weighted average RMR (CMRS RMR classification) and γ is unit weight (t/m^3) of immediate roof rock.

A systematic parametric study in field for the design of RBBLS is difficult. Therefore, on the basis of the data and guidance provided by these field studies, a detailed investigation is conducted on simulated models for the existing range of geo-mining conditions of Indian

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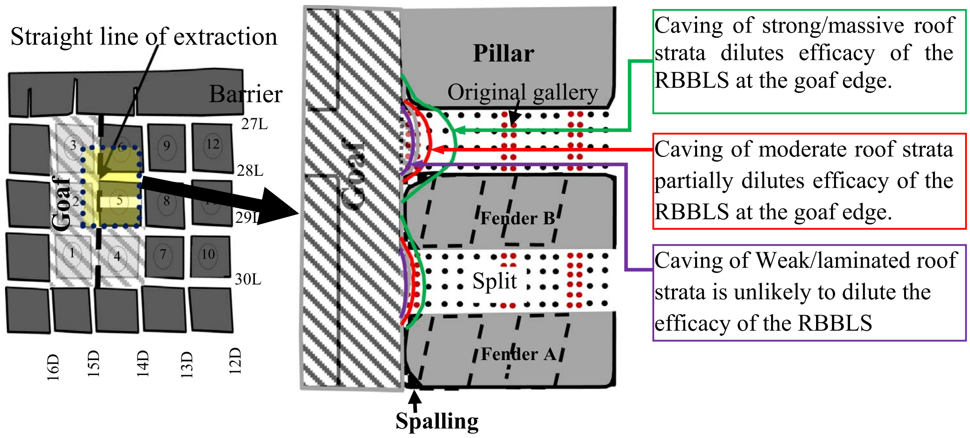

Fig. 1. Possibilities of goaf encroachment during caving of different types of roof strata (plan view).

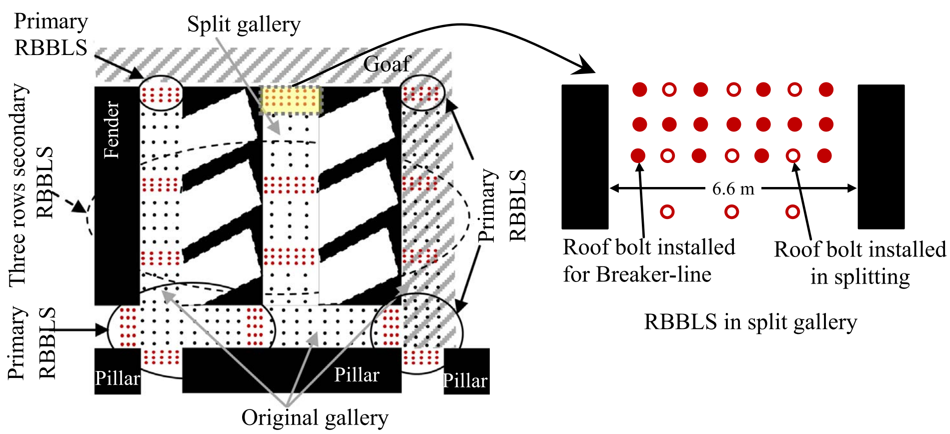

Fig. 2. : A plan view of RBBLS placement in different galleries to arrest the goaf encroachment.

coalfields. FLAC^{3D} is used for the simulation in association with the available empirical formulations for such site conditions. Using indigenously developed Sheorey's rock mass failure criterion,[12] an analysis of safety factors for different stages of a MD operation in simulated models provided significance of site conditions for the RBBLS design. Observed contours of the safety factor are used to estimate the RLH at different position at the goaf edge in simulated models. Estimated RLH values for different studied geo-mining conditions are used for the RBBLS design.

These obtained results of the models are validated through the results of the field investigations. The modelling results, more or less matched with the field observations for the length of the bolts but a large difference is observed between the two for the support resistance of the RBBLS. Most of the field observations noticed goaf encroachment during caving of the roof strata, where a dynamic loading (Fig. 3) phenomenon was also noticed. Quantifications of the dynamic loading phenomenon are done on the basis of mining induced stress measurements over the natural supports, in and around the goaf edge. An incorporation of the dynamic loading factor into the results of the static modelling is found to be in good agreement with the field results. Considering these observational facts of the field and numerical modelling studies, an attempt is made in this paper to provide relationships for the design of RBBLS under a given site conditions.

2. Field studies

Field studies are carried out in fourteen MD panels of three different coal mines (Table 1). Gallery width at all these sites remained around 6 m only. Performance of the applied RBBLS was monitored through visual inspection and, also, with the help of geo-technical instruments like stress meters and instrumented roof bolts. Samples were collected from these sites and their physico-mechanical properties (compressive and tensile strengths, density and modulus of elasticity) are determined in the laboratory as per the ISRM suggested methods.

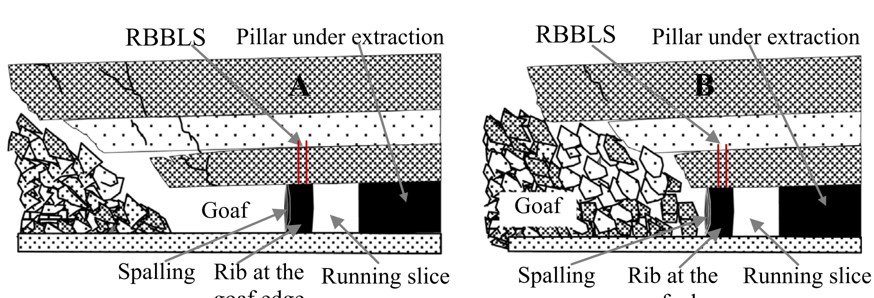

Fig. 3. : A sectional view of strata movement during depillaring: (A) large overhang inside the goaf posing a dynamic loading condition, (B) control of the goaf encroachment with the help breaker line support.