Numerical Simulation of Support Design Using Rock Bolt in Bord and Pillar Method

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Doctor of Philosophy

By

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CHAPTER 9.

CONCLUSIONS AND RECOMMENDATION FOR FUTURE WORK

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Roof bolting technology is widely and successfully accepted for support design in an underground coal mine. It is the only way to efficiently support the roof particularly in case of mechanised bord and pillar operation by continuous miner technology. It also reduces the hindrance for the smooth operation of machinery and manpower in underground working as compared to other support system used in mine. With this background, roof bolt technology is proved to be an effective support system at a number of mechanised operations in Indian coalfields.

The two important parameters i.e. rock bolt capacity and RLH has been taken for selection of optimum support design based on literature survey. Mining operation has been simulated by stage by stage operation and the behaviour of the bolt has been observed after each stage of mining in terms of axial load and roof behaviour in terms of RLH.

The study has been carried out by numerical simulation technique. Two field cases has been taken for validation of the model based on known value of geo mining parameters and observed value of instrumented rock bolt.

The study has been carried out to achieve the optimum design of rockbolt under varying geo – mining parameters such as RMR, depth of cover, gallery size and bolt density. Focused study area is being chosen near the goaf where maximum induced stress is observed. Two critical locations near goaf edge i.e tri - junction and main junction are important for safe mining operation. These two location are continuously monitored (RLH and axial load) at every stages of operation considering different combination geo – mining parameters.

On the basis of current research, the following conclusions have been drawn:

1. Two cases have been chosen of Indian coal mines worked by bord and pillar system of mining. CM6 panel of Pinora Mine, SECL is worked using mechanized operation by continuous miner (CM) and panel no. 31 of GDK – 5A Incline mine, SCCL having semi - mechanized operation using LHD/SDL. Both the panels were having instrumented rock bolt at different location in the panel.

   It is observed from the results from models that the maximum axial load at two location where instrumented rock bolt has being installed were IRB_1 is 4.38 tonne and IRB_2 is 8.74 tonne, reasonably matching the field observation 3.7 tonne and 8.21 tonne respectively in case of Pinoura mine.

   In GDK-5A Incline, SCCL observed results from model is recorded; maximum axial load at GSG1 is 11.8 tonne reasonably matching the field observation 13.4 tonne. The maximum RLH at these two locations has also being observed 1.5 m in both the cases. One can conclude that the numerical simulation technique can be applied for stability of roof analysis.

2. The criteria for suggesting the optimum support design has been proposed based on rock load height and axial load developed on the bolt as follows:

   - 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.

   Both the above-mentioned criteria should be satisfied for deciding the optimum support design.

3. It has been observed that the rock load height in the junction is more than 60% than the gallery near the goaf edge.
4. The results in terms of rock load height have been analyzed during depillaring stages. It is concluded that the rock load height increases with respect to the depillaring stages within the influence zone i.e, about one pillar from the goaf. It is concluded that the rock load height increases by about 60% towards the goaf edge w.r.t the development stage for junction.
5. The result in terms of maximum axial load on the bolts installed in a row has been analyzed for all the cases. It is concluded from the observation that the bolt installed in the middle of the gallery experience about 40% - 50% more load as compare to the bolt installed towards the pillar side.
6. It is observed from the axial load profile along the bolt length that the pickup length is approximately half of the rock load height.
7. The statistical analysis shows the relationship b/w maximum axial load on the bolt and rock load height and it is expressed as

$$Axial\ Load = 0.9 \times e^{0.05 \times RLH} \tag{9.1}$$

8. Two critical locations have been chosen near the goaf edge for stability of roof during the operation. These locations are tri junction and main junction. Mathematical expression has been made developed at these location in terms of RLH and axial load on bolt for varying geo - mining parameters such as bolt density (BD), depth of cover (D), gallery width (GW) and RMR is expressed below:

❖ **The generalized equation for RLH in m:**

- Tri – junction (Location 1)

$$RLH = \frac{0.52 \times BD^{0.18} \times D^{0.28} GW^{0.4}}{RMR^{0.32}} \tag{9.2}$$

- Main – Junction (Location 2)

$$RLH = \frac{0.11 \times BD^{0.3} \times D^{0.3} GW^{0.4}}{RMR^{0.45}} \tag{9.3}$$

❖ **The generalized equation for Axial Load in tonnes:**

- Tri – junction (Location 1)

$$Axial\ Load = \frac{0.05 \times BD^{0.35} \times D^{0.8} GW^{1.2}}{RMR^{0.51}} \tag{9.4}$$

- Main – Junction (Location 2)

$$Axial\ Load = \frac{0.06 \times BD^{0.40} \times D^{0.74} GW^{1.2}}{RMR^{0.51}} \tag{9.5}$$

9. Responses on the bolt in terms of axial load in the model under the varying depth of cover have been monitored up to 100 m from the goaf edge. It has been observed that peak axial load on the bolt decreases in an exponential manner as one moves away from the goaf edge and, it becomes nearly constant. The effect of the goaf can clearly be seen in the response of the bolts. This zone is called the *Influence zone (I_z).*

10. It is concluded from the results in terms of vertical stress profile that the influence zone lies within 40 m, 50 m and 75 m for a depth of 200 m, 300 m and 400 m respectively from the goaf edge. It is also concluded from the observation that the rate of influence zone increases with increasing depth of cover.

11. The response on the bolt in terms of axial load has been monitored during depillaring stages. It is concluded from the analysis that the peak axial load within a bolt is, maximum toward the goaf edge and reduces exponentially within the influence zone with respect to the distance of bolt from the goaf. It is also been concluded from the study that the range of influence zone depends on the working depth. The axial load on the bolt has been normalized with respect to maximum axial load observed at the goaf edge.

The following expression has been derived for normalize axial load in tonne with respect to the distance from the goaf edge.

$$Axial\ Load_{Normalize} = e^{(3\times10^{-5}-0.0235)\times Iz} \tag{9.6}$$

$$Actual\ axial\ load = Peak\ value\ of\ axial\ load\ for\ location\ 1\ and\ 2\ \times Axial\ Load_{Normalize} \tag{9.7}$$

RECOMMENDATION FOR FUTURE WORK

- It is suggested that geological disturbance along with more case studies may be included for fine tuning of the developed model.
- More data required to observe from instrumentation in various fields will gives the model validation in much accurate manner.
- Dip working of mine more than 500 m would be an interesting study.
- Using of robust system taking into account the finer zone size will gives something more interesting results.