CHAPTER 8.
RESULT & ANALYSIS

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8.1 General

Systematic support design is important to restrict roof failure in the working area. Goaf edge support system, i.e., RBBLS, is also being used to control the caving of the immediate strata inside the goaf. Other relationships for estimation of required support load density near the goaf edge of a conventional depillaring are also not applicable for mechanized depillaring mainly because of change of pace and manner of extraction.

Monitoring data of the instrumented rock bolt obtained from field investigation indicates the status of the axial load developed on the bolt during depillaring operation. RLH has been observed from the results of the simulated models. A suitable support system during depillaring operation has been proposed based on the field and numerical simulation study. The information of bolt in terms of its length and yield strength used in support at a different location during mechanized depillaring operation has been discussed based on the set criteria in the methodology chapter.

The optimum support design selection is determined using various support patterns (bolt density) combinations used. The behaviour of the roof in terms of RLH and axial load on the bolt has been observed.

Finally, on the basis of different correlations under the detailed study of strata mechanics phenomenon, the generalized mathematical relationship is developed for the design of the required support system in mechanized depillaring operation.

8.2 Simulation Results of Parametric study

One hundred and forty four models have been simulated considering key parameters. The detailed discussion has been covered in the previous chapter. The nomenclature scheme illustrated in table 7.2 (Chapter 7) represents the numbers of models are considered for simulation.

The model response has been observed in the development and different stages of depillaring operation. In this study, two cases have been discussed, i.e., simulation without support and simulation with support using rock bolt. The support pattern using variable bolt density has been taken into consideration, as discussed above.

The simulated studies have revealed that induced stress on pillars increases rapidly during extracting the third row and two pillars, as shown in figure 8.1. The main fall will generally occur in this zone. So, the focused study area is taken into consideration for all the stages of operation as marked in red and expressed by locations 1 and 2 shown in figure 8.1 given below. Location 1 is termed as tri-junction, and Location 2 depicts a junction near the goaf edge. These two locations are also responsible for accidents in the mine due to insufficient support design. The manpower and types of machinery are travelled in this area during the extraction process. Therefore, the response of roof behaviour in terms of yield zone (RLH) and bolt in terms of the axial load has been observed in all the cases.

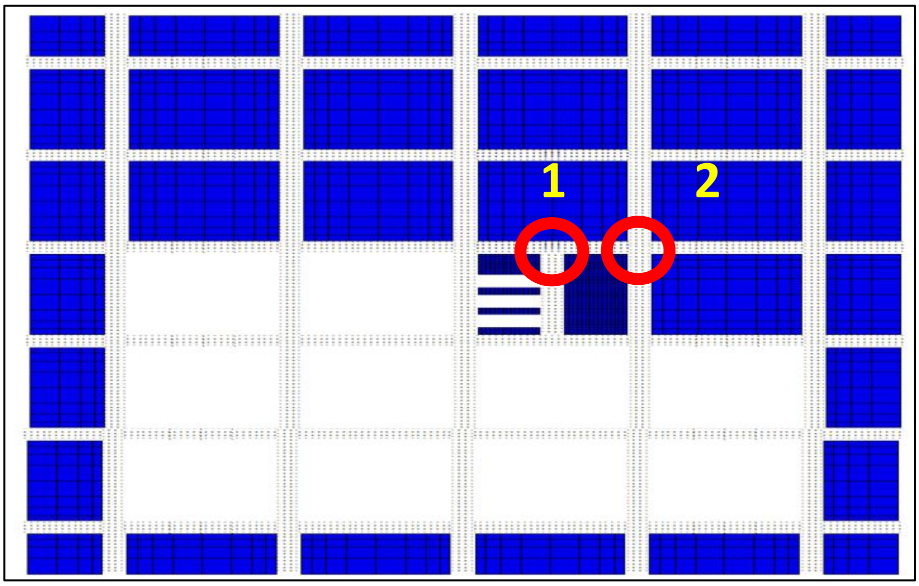

Figure 8.1 Typical example of final depillaring stage representing focused location

Discussion of total one hundred and forty-four numbers of models is very difficult in this thesis. So, a typical example, ABCX, is taken for detailed discussion for all the stages of operation, illustrated in Table 8.1, where X has been taken as variable bolt density, and other parameters are constant. The other model results have been tabulated in the APPENDIX.

Table 8.1 Cases for detail discussion with variable bolt density

Depth in m (A)	Gallery Width in m (B)	RMR (C)	Bolt density (m^2/bolt) (X)
200	6.0	40	Without bolt - 1
			4 m^2 /bolt - 2
			2.25m^2/bolt - 3
			1.44^2 /bolt - 4

8.3 Results of RLH and Axial Load Stage wise

8.3.1 Case ABCX$_1$

In this section, the yield profile of the roof and coal pillar has been discussed. Figure 8.2 shows the yield profile of the coal pillar at the final stage of depillaring considered in this study. Two rows of pillars are completely extracted. Two pillars have been completely extracted in the third row. The third pillar has been split and one fender has already been extracted using the slicing method.

The third pillar in the third row is in our focus, and the detailed study is being done here. The yielded zone is observed at the corner of each pillar and barrier pillar.

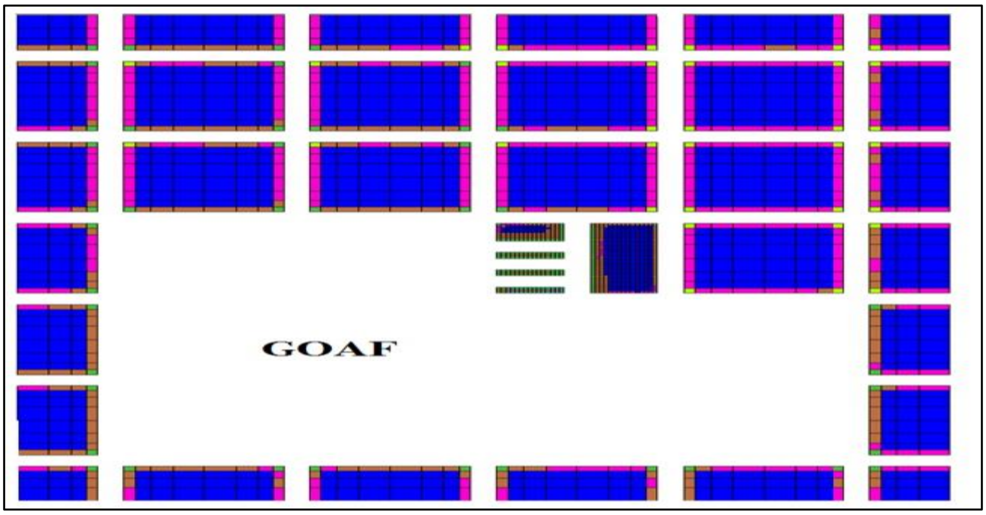

Figure 8.2 Yield profile of coal pillar at final stage of depillaring

a. Roof Yield (RLH)

Location 1 and 2 is the focused area where RLH is monitored continuously during all stages of depillaring shown in Figure 8.2. Figure 8.3 shows the yield profile in terms of RLH of the immediate roof without any support (rock bolt) along sections C-C' and D-D'. RLH is maximum 3.5 meters at location 1, out bye of tri-junction of the split gallery. Location 2 represents the junction point of the study area near the goaf edge and has observed RLH 2.5 meters.

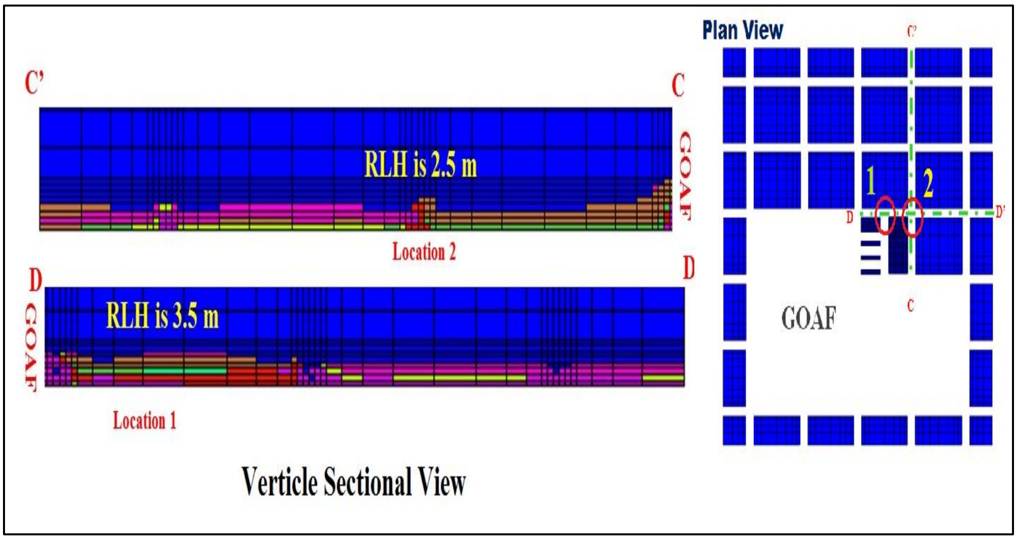

Figure 8.3 Yield profile of immediate roof at along section C-C' and D-D' at Final Stage

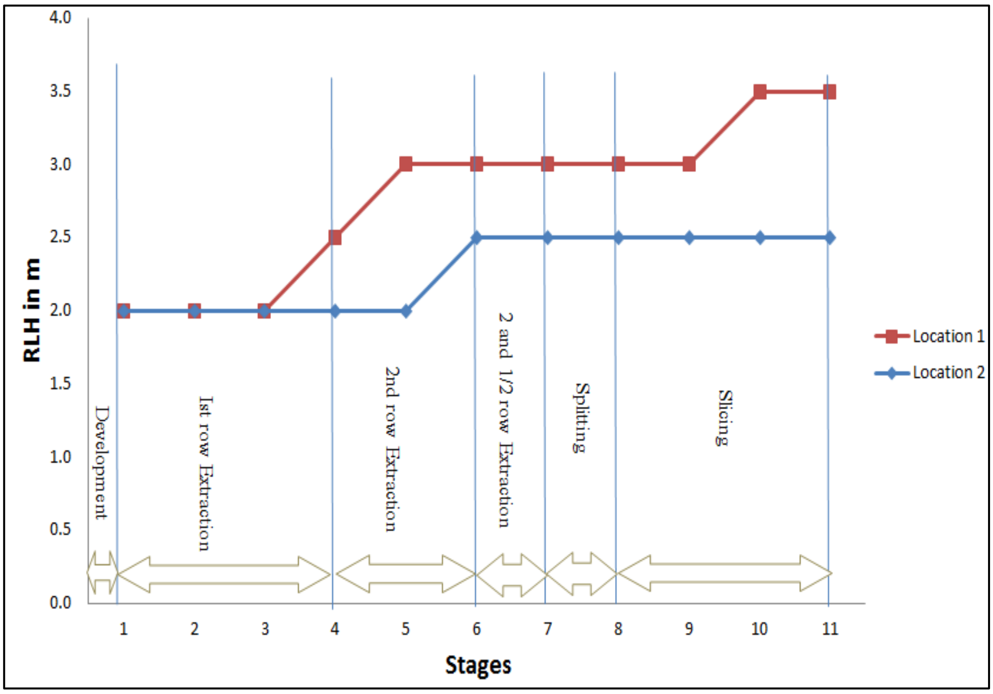

Figure 8.4 RLH at Location 1 and 2 for different stages of operation

Figure 8.4 depicts the rock load height (RLH) at different stages of operation, starting from the development stage. The graph represents the increasing order of RLH from development stage to last depillaring stage at focused study area defined as Location 1 and 2. In the slicing stage of operation higher value of RLH has been observed.

Based on the results, it has been observed that, without any support, the rock load height is nearly 2.5 m and 3.5 m at the two locations mentioned above. That means the chances of roof fall is maximum.

8.3.2 Case $ABCX_2$

This case represents the different stages of operation using bolt density 4 bolt/m2 illustrated in Table 8.1. Three bolts in a row are installed in the gallery. The distance between two rows of the bolt is considered 2 meters. The observed yield profile of immediate strata and axial load exerted on the bolt at Locations 1 and 2 is expressed below.

a. RLH of immediate strata

Location 1 and 2 is the focused area where RLH is monitored continuously during all stages of depillaring, as shown in Figure 8.5 and Figure 8.6. It shows the yield profile in terms of RLH of the immediate roof without any support system along sections C-C' and D-D'. RLH has got a maximum value of 2.5 meters at location 1 (out bye of tri-junction of the split gallery). The maximum value of RLH has been observed as 1.5 meters at Location 2 (junction point of near the goaf edge).

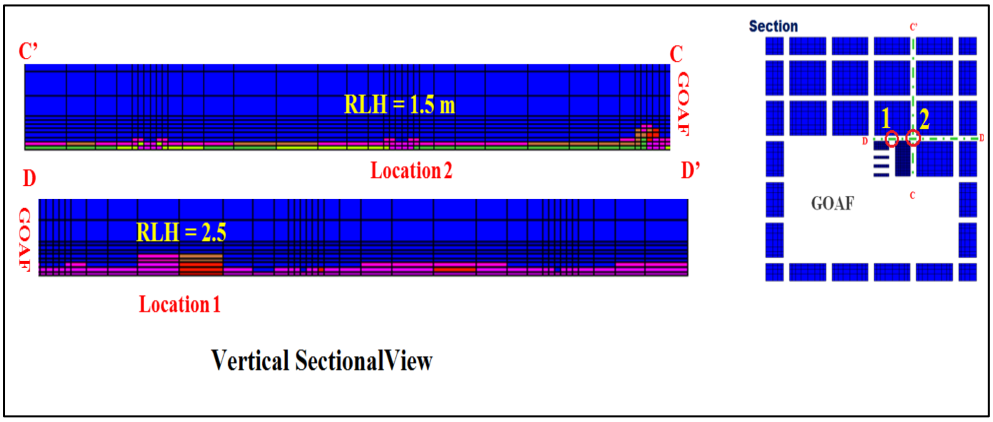

Figure 8.5 Yield profile of immediate roof at along section C-C' and D-D' at Final Stage (Case - $ABCX_2$)

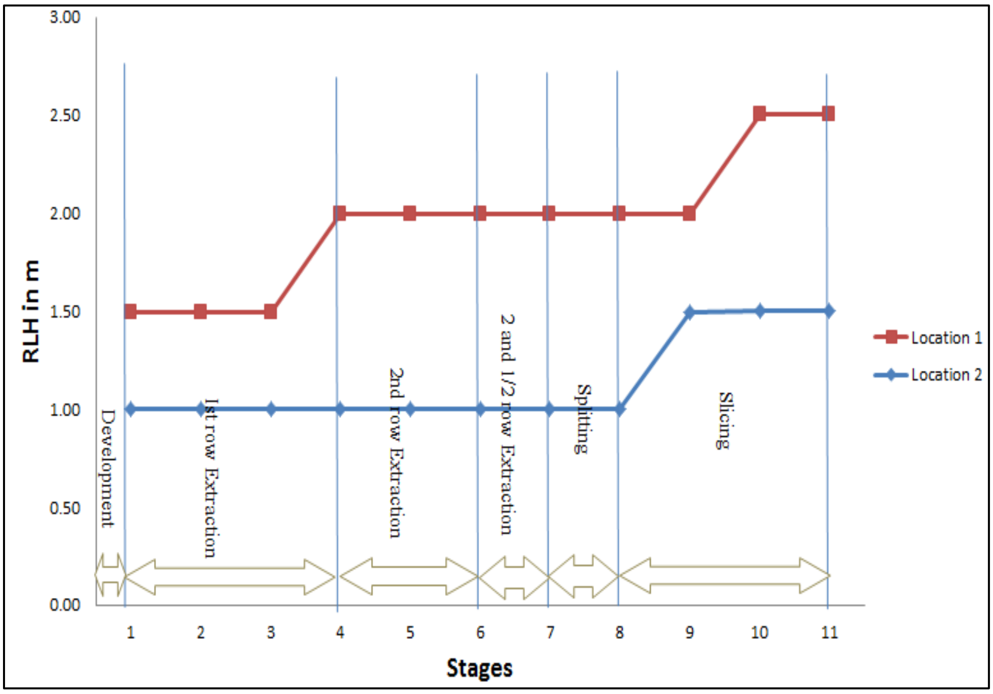

Figure 8.6 RLH at Location 1 and 2 for different stages of operation (Case - $ABCX_2$)

Figure 8.6 depicts the rock load height (RLH) at different stages of operation, starting from the development stage. The graph represents the increasing order of RLH from development stage to last depillaring stage at focused study area defined as Location 1 and 2. In the slicing stage of operation higher value of RLH has been observed.

RLH at the above locations has been observed as roughly 2.5 m and 1.5 m, with a support density of $4m^2$/bolt. It reveals that the roof yield crosses the bolt length at 1 and marginally below at location 2 (considering bolt length 1.8 m). It means, the chances of roof fall is maximum at location 2 and marginally low at location 1.

b. Axial Load on bolt

In this section, the maximum axial load exerted on the bolt has been observed during different stages of operation. The maximum axial load is observed at the middle of the bolt. The stage-wise observed value of the maximum axial load is shown in figure 8.7 at locations 1 and 2. Obtained value of peak axial load is around 12 tonnes in both the locations. So, to maintain the FOS>1, anchorage strength of the bolt is to be taken more than 12 tonnes.

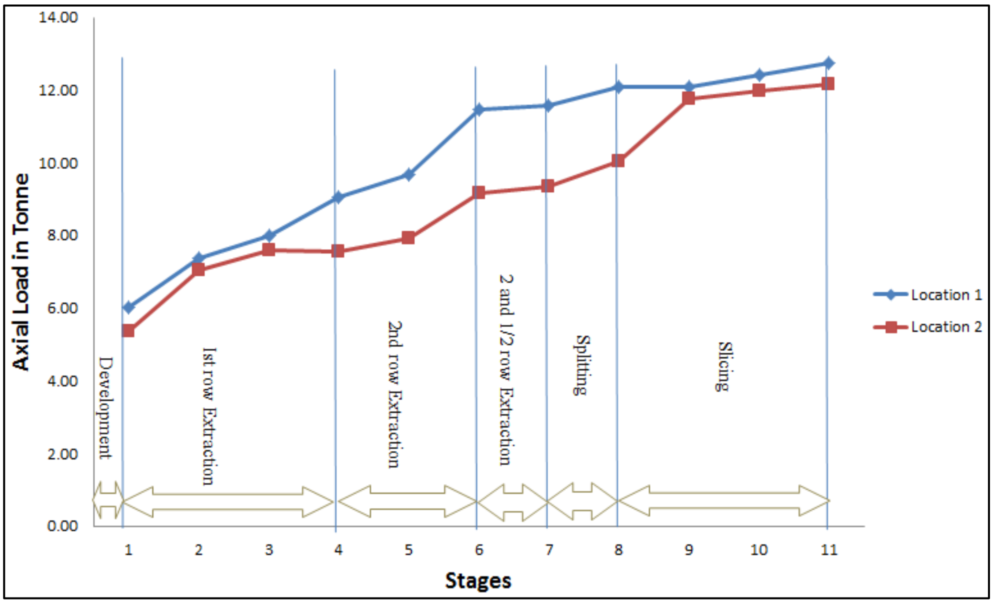

Figure 8.7 Axial loads on bolt at Location 1 and 2 for different stages of operation (Case - $ABCX_2$)

8.3.3 Case $ABCX_3$

This case represents the different stages of operation using bolt density 2.25 bolt/m2 illustrated in Table 8.1. Four bolts in a row are installed in the gallery. The distance between two rows of the bolt is considered 1.5 meters. The observed yield profile of immediate strata and axial load exerted on the bolt at Locations 1, and 2 is expressed below.

a. RLH of immediate strata

Location 1 and 2 is the focused area where RLH is monitored continuously during all stages of depillaring shown in figure 8.8. RLH is a maximum of 1.5 meters at location 1, out bye of the tri-junction of the split gallery. Location 2 represents the junction point of the study area near the goaf edge and has observed RLH 1.0 meter.

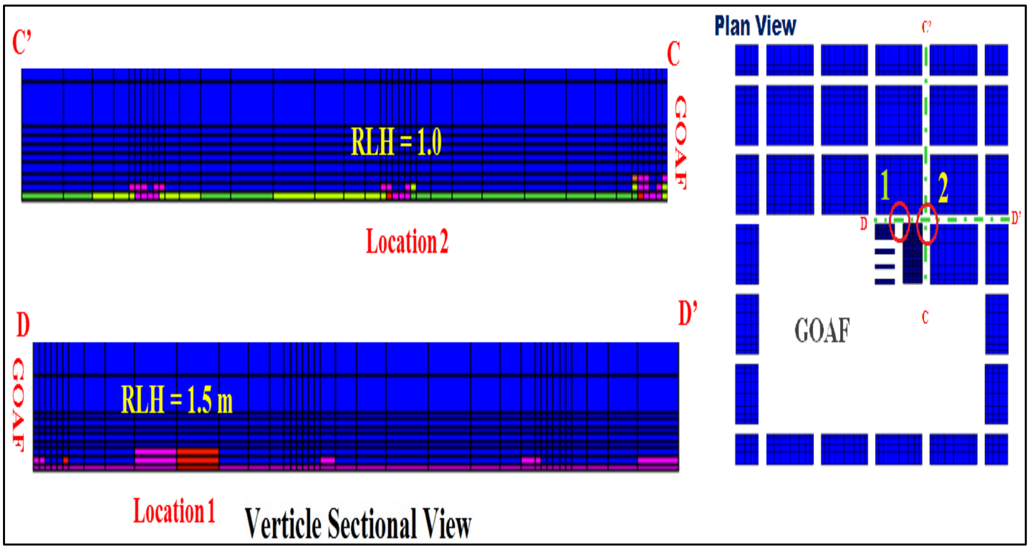

Figure 8.8 Yield profile of immediate roof at along section C-C' and D-D' at Final Stage (Case – $ABCX_3$)

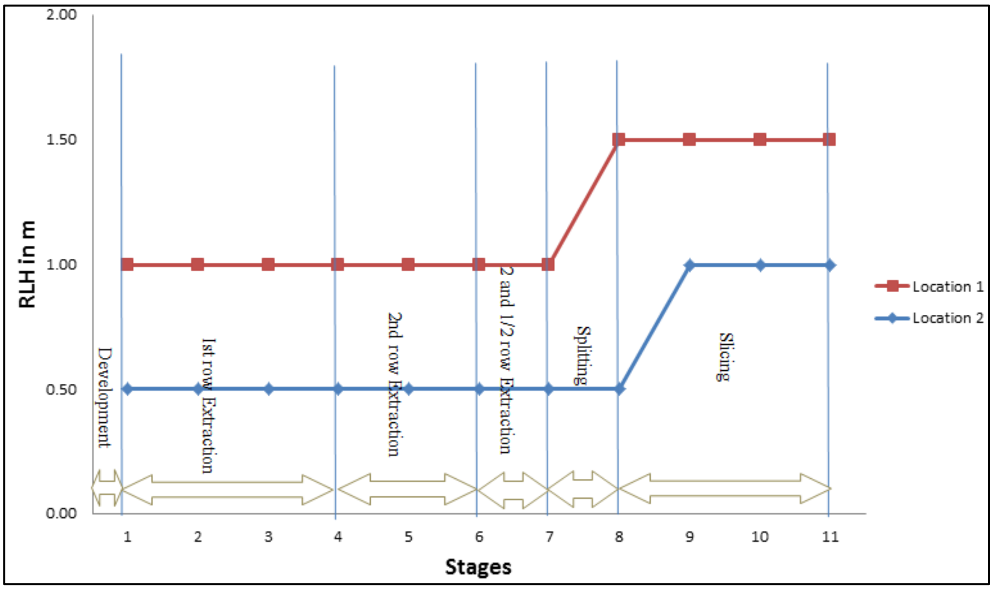

Figure 8.9 RLH at Location 1 and 2 for different stages of operation (Case – $ABCX_3$)

Figure 8.9, depicts the rock load height (RLH) at different stages of operation starting from development stage. The graph represents the increasing order of RLH from development stage to last depillaring stage at focused study area defined as Location 1 and 2. In the slicing stage of operation higher value of RLH has been observed. In this case RLH has been observed 1.5 m and 1 m at the mentioned locations. The yield profile of the roof is marginally low at location 2 and well within at location 1. Therefore, based on the results it can be expressed that the chances of roof collapse is very low in this case.

b. Axial Load on bolt

In this section, the maximum axial load exerted on the bolt is observed during different stages of operation. The maximum axial load is observed at the middle of the bolt. The stage wise observed value of the maximum axial load is shown in figure 8.10 at locations 1 and 2. Obtained value of peak axial load is around 10 tonnes in both the locations. So, to maintain the FOS>1, anchorage strength of the bolt is to be taken more than 10 tonnes.

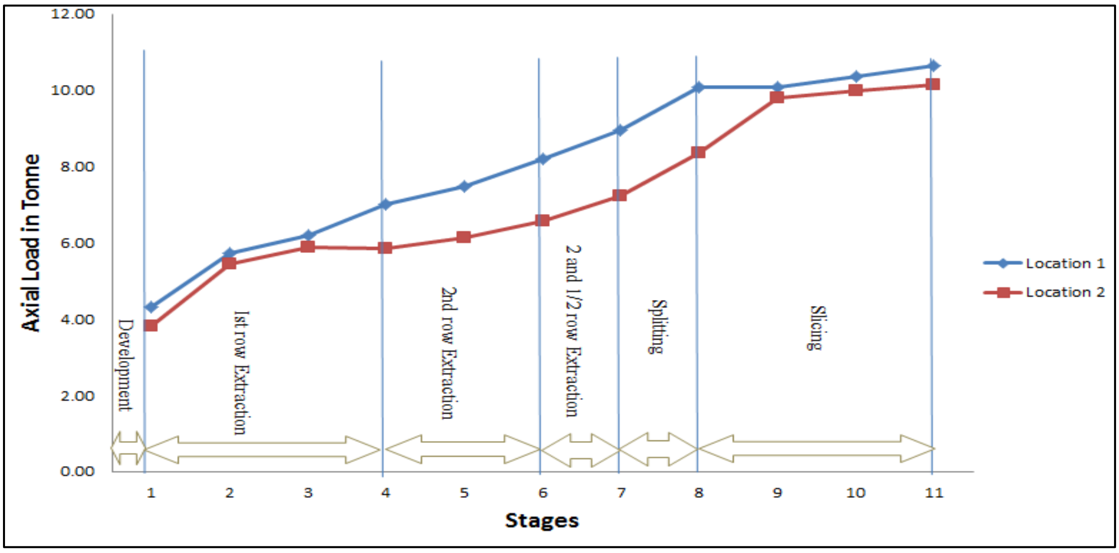

Figure 8.10 Axial loads on bolt at Location 1 and 2 for different stages of operation (Case $ABCX_3$)

8.3.4 Case $ABCX_4$

This case represents the different stages of operation using bolt density 2.25 bolt/m2 illustrated in Table 8.1. Four bolts in a row are installed in the gallery. The distance between two rows of the bolt is considered 1.5 meters. The observed yield profile of immediate strata and axial load exerted on the bolt at Locations 1, and 2 is expressed below.

a. RLH of immediate strata

Location 1 and 2 is the focused area where RLH is monitored continuously during all stages of depillaring shown in figure 8.11. RLH is a maximum of 1.5 meters at location 1, out bye of the tri-junction of the split gallery. Location 2 represents the junction point of the study area near the goaf edge and has observed RLH 1.0 meter.

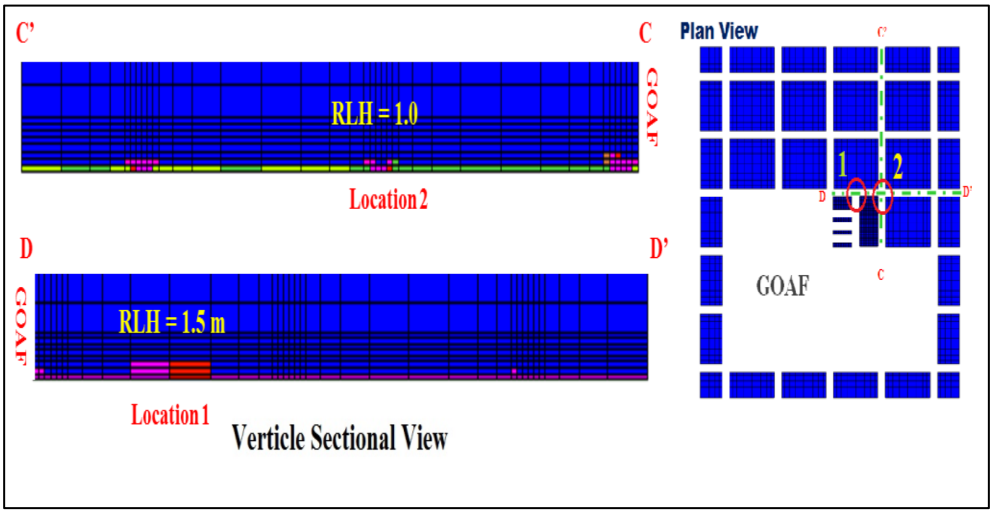

Figure 8.11 RLH at Location 1 and 2 for different stages of operation (Case $ABCX_4$)

Figure 8.11 depicts the rock load height (RLH) at different stages of operation, starting from the development stage. The graph represents the increasing order of RLH from development stage to last depillaring stage at focused study area defined as Location 1 and 2. In the slicing stage of operation higher value of RLH has been observed. In this case observed value of RLH is 1.5 and 1 m. The yield of roof is not crosses the length of the bolt in both the locations. Therefore, the risk of roof failure is very low using this pattern of roof bolt.

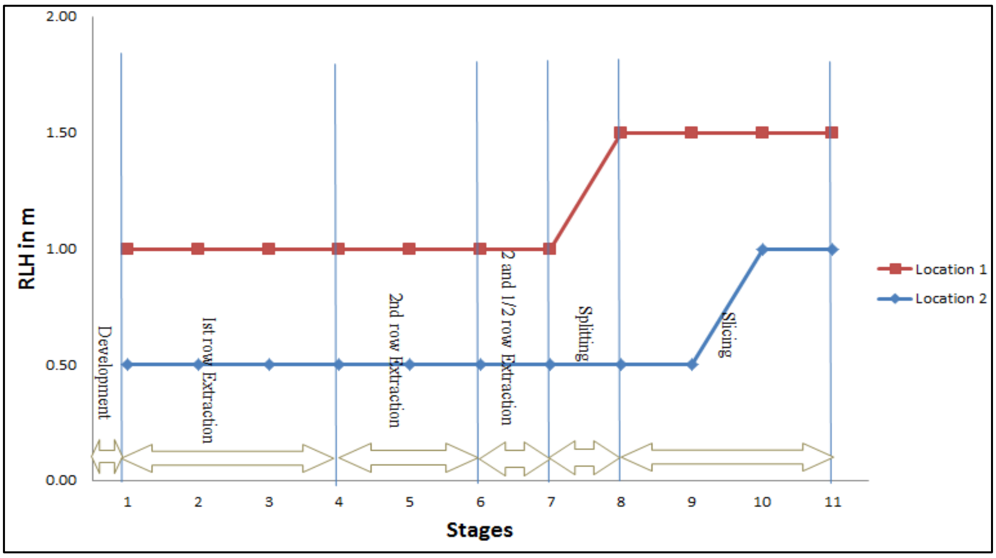

Figure 8.12 RLH at Location 1 and 2 for different stages of operation (Case $ABCX_4$)

b. Axial Load on bolt

In this section, the maximum axial load exerted on the bolt is observed during different stages of operation. The maximum axial load is observed at the middle of the bolt. The stage-wise observed value of the maximum axial load is shown in figure 8.12 at locations 1 and 2. Obtained results of peak axial load is around 7 tonnes at both the locations. It depicts that to provide the optimum support in this case, anchorage capacity of rock-grout taken more than 7 tonnes.

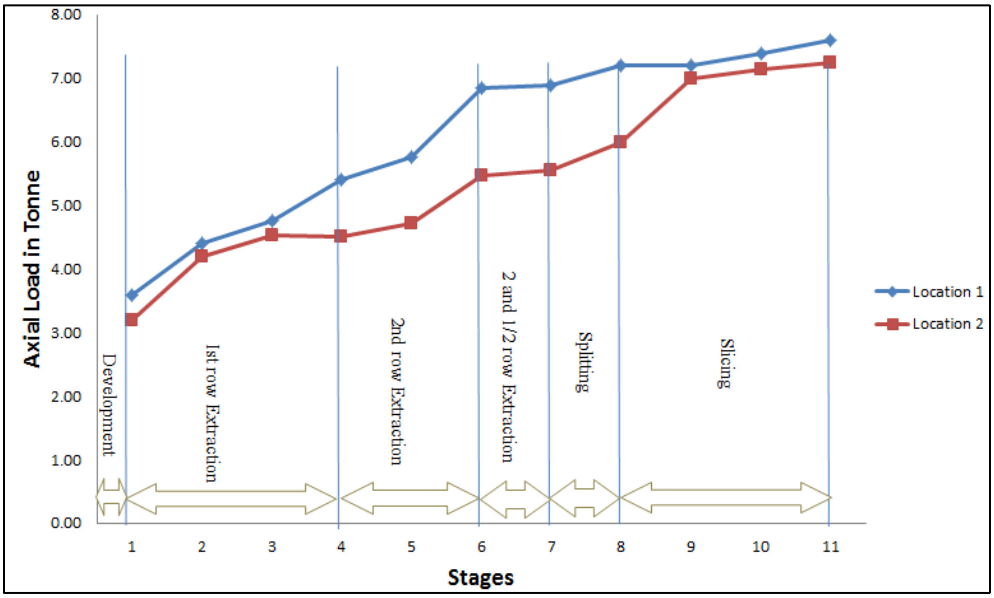

Figure 8.13 Axial loads on bolt at Location 1 and 2 for different stages of operation - Case $ABCX_4$

8.3.5 Comparison of RLH for different cases

In this section, observed RLH has been discussed of all the cases $ABCX_1$, $ABCX_2$, $ABCX_3$, and $ABCX_4$, at different stages of the mining operation. The graph is shown in Figures 8.14, and 8.15 shows the variation of observed RLH at locations 1 and 2, respectively, for a different combination of bolt density starting from without support to the different combination of the bolt. The observed RLH gives an idea about the effect of different support systems on roof failure. Based on representing values of RLH at locations 1 and 2, for cases using 4 bolt patterns and 5 bolt patterns, there is not much variation. So, results show in this particular case optimum support pattern is selected 4 bolts based on RLH.

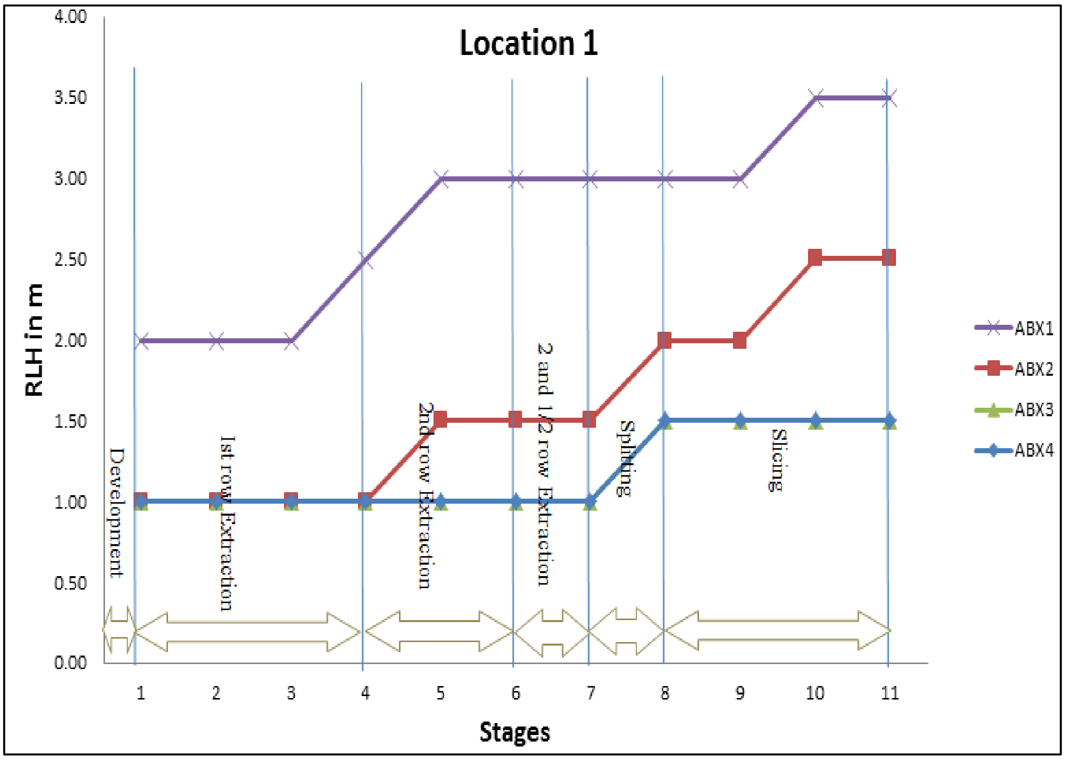

Figure 8.14 RLH for different support pattern at numerous stages of operation at Location 1

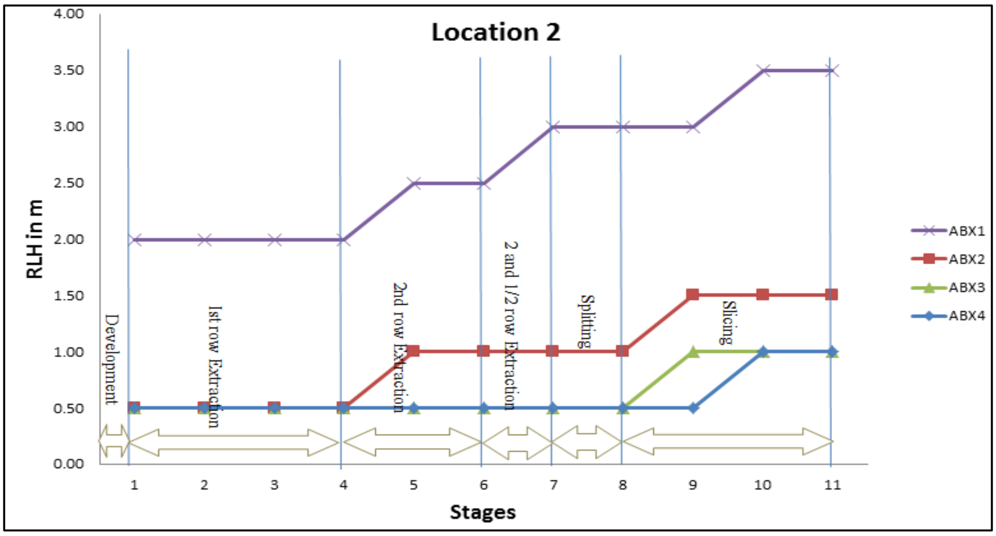

Figure 8.15 RLH for different support pattern at numerous stages of operation at Location 2

8.3.6 Comparison of axial load for different cases

In this section, the observed axial load exerted on the bolt has been discussed of all the cases $ABCX_1$, $ABCX_2$, $ABCX_3$, and $ABCX_4$, at different stages of the mining operation. The graph is shown in figures 8.16 and 8.17 shows the variation of observed axial load at locations 1 and 2, respectively, for a different combination of the bolt using 3 bolts, 4 bolts and 5 bolts in a row. The observed peak axial load gives the idea about the effect of different support pattern in the bolt. Using these values, the capacity of bolt is selected easily, based on its anchorage strength value.

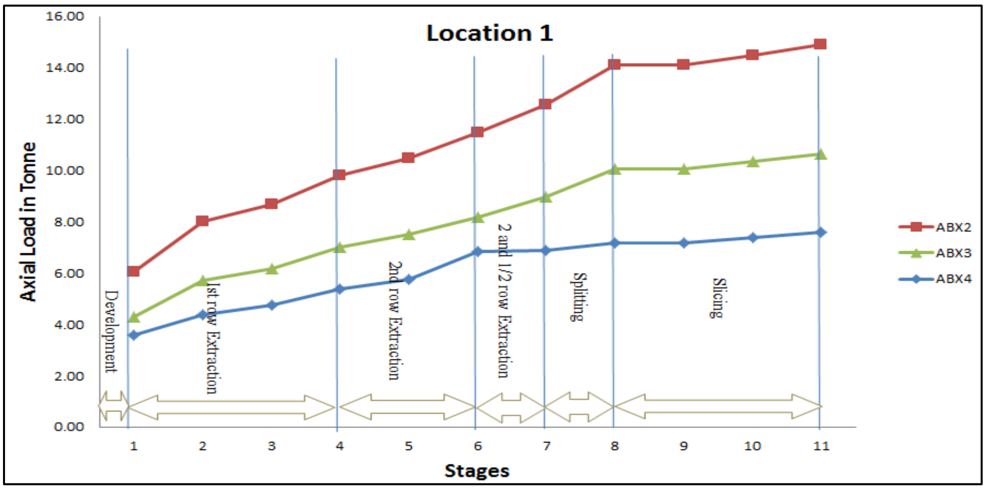

Figure 8.16 Axial Load for different support pattern at numerous stages of operation at Location 1

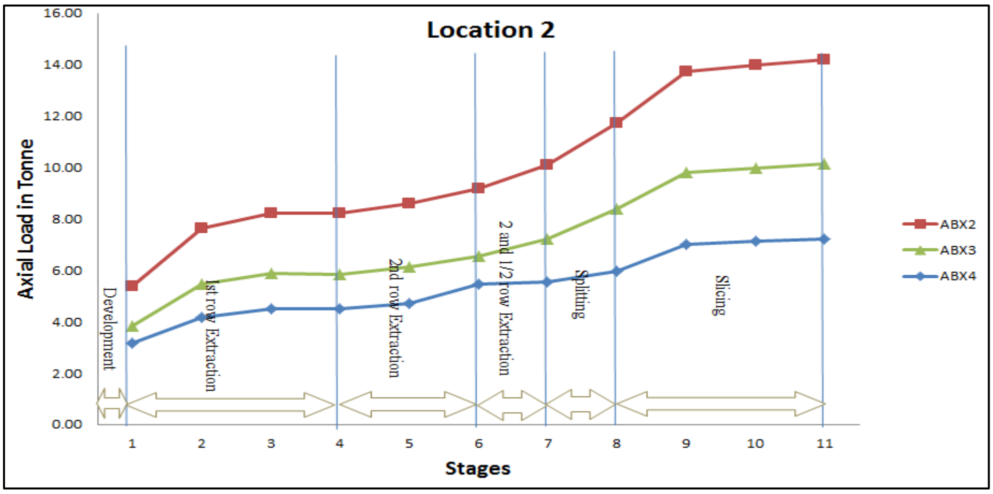

Figure 8.17 Axial Load for different support pattern at numerous stages of operation at Location 1

8.3.7 Optimum support Design for selected Case

As discussed in the methodology chapter, a set criterion has been considered for optimum design of support system using rock bolt. In this section, the optimum support design is evaluated considering above mentioned case. The selection of bolt depends on two parameters RLH and axial load. RLH gives the information regarding the selection of the length of the bolt, and suitable bolt capacity (anchorage strength) of the bolt will be taken based on the observed axial load on the bolt. The factor of safety (FOS) of the bolt is taken as more than 1.5. The calculation for the selection of optimum support design is expressed below.

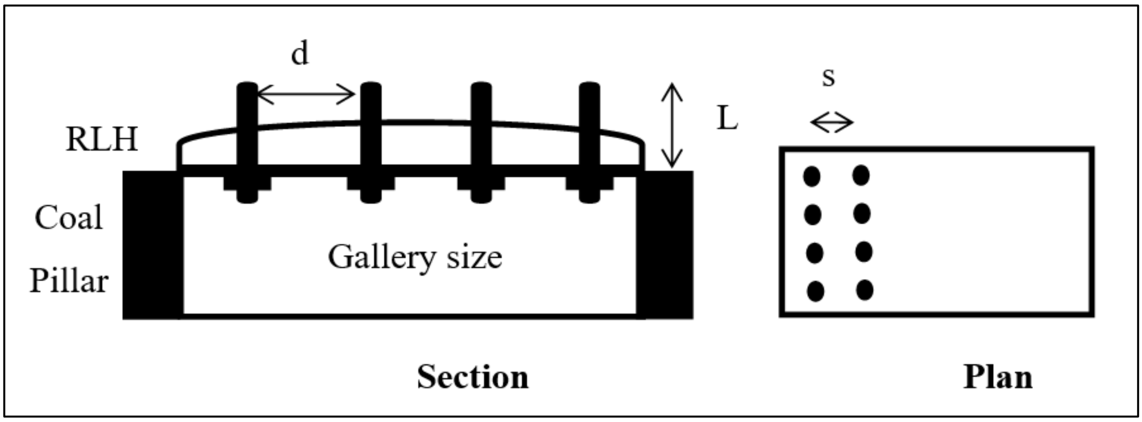

Figure 8.18 Schematic diagram of support pattern showing in plan and section view

The above figure 8.18 shows the plan and sectional view of the support pattern installed in the gallery. The numbers of rock bolt lengths are calculated with the help of observed RLH and the maximum axial load developed on the bolt. The design of the bolt is taken, where the maximum induced stress is observed near the goaf edge. The optimum design support pattern is a design based on input and output parameters which are expressed in Table 8.2 below:

Table 8.2 Input and Output parameters considered for optimum design of support system

Input parameters		**Output parameters observed from modelling near goaf edge**		
Parameters	Value	Parameters		Value
Gallery Size (m)	6.0	Max. RLH (m)	5 bolts in a row	1.5
Depth (m)	200		4 bolts in a row	1.5
RMR	40		3 bolts in a row	2.5
Anchorage strength of bolt using resin capsule (tonnes)	12	Max. Axial Load (tonne)	5 bolts in a row	7.6
Density of immediate strataγ(tonne/m^3)	2.5		4 bolts in a row	10.64
			3 bolts in a row	14.90

Based on the observed value of maximum axial load and rock load height, the optimum design of the support system is evaluated using the below expression.

Support load density (Rock load in tonne/m^3) is calculated with the help of RLH and the density of the rock strata.

$$Support\ Load\ Density\ (SLD) = \gamma \times RLH \quad (8.1)$$

Using the above expression, the required rock load (tonne/m^3) of the strata is calculated. The SLD gives the idea about the rock load required to be supported. RLH has been observed from simulation results for three different patterns of the rock bolt given in Table 8.2. The rock load is calculated for a different pattern of rock bolt is described below.

$$Support\ Load\ Density(SLD)_{3\ bolt\ in\ a\ row} = \gamma \times RLH \quad (8.1)$$

$$= 2.5 \times 2.5 = 6.25 \text{tonnes/m}^3$$

$$Support\ Load\ Density(SLD)_{4\ bolt\ in\ a\ row} = \gamma \times RLH \times s\ \times G_W$$

$$= 2.5 \times 1.5 = 3.75 \text{tonnes/m}^3$$

$$Support\ Load\ Density(SLD)_{5\ bolt\ in\ a\ row} = \gamma \times RLH \times s\ \times G_W$$

$$= 2.5 \times 1.5 = 3.75 \text{tonnes/m}^3$$

After calculation of rock load for different bolt patterns, the required support to be applied is calculated using the below expression.

$$Applied\ support\ load\ (ASL) = \frac{N_b A_s}{w R_s} \tag{8.2}$$

Where, N_b is Number of bolts, A_s is Anchorage Strength of the individual bolt in tonnes, w is gallery size in meter, R_s = spacing between two row of bolt in meter

So, applied support load for different bolt pattern (bolt density) is

$$ASL_{3\ bolt\ in\ a\ row} = \frac{N_b A_s}{w R_s} = \frac{3\ \times 12}{6\ \times 2} = 3\ tonne/m^2$$

$$ASL_{4\ bolt\ in\ a\ row} = \frac{N_b A_s}{w R_s} = \frac{4\ \times 12}{6\ \times 1.5} = 5.33\ tonne/m^2$$

$$ASL_{5\ bolt\ in\ a\ row} = \frac{N_b A_s}{w R_s} = \frac{5\ \times 12}{6\ \times 1.2} = 8.33\ tonne/m^2$$

Using SLD and ASL, factor of safety (FOS) is calculated to know the required support pattern used in this particular case using below expression.

$$Factor\ of\ Safety\ (FOS) = \frac{SLD}{ASL} \tag{8.3}$$

$$FOS_{3\ bolt\ in\ a\ row} = \frac{3}{6.25} = 0.48$$

$$FOS_{4\ bolt\ in\ a\ row} = \frac{5.33}{3.75} = 1.42$$

$$FOS_{5\ bolt\ in\ a\ row} = \frac{8.33}{3.75} = 2.22$$

Based on the above calculation, the support pattern is suitable for this case is either 4 bolts in a row or 5 bolts in a row because the factor of safety in both the cases is evaluated near to 1.5.

The maximum axial load exerted on the bolt will give information regarding the selection of the bolt. The type of grouting and its anchorage strength will be selected using the observed value of the maximum axial load on the bolt. The length of the bolt should be more than at least 30 cm of RLH.

Taking into consideration of all the above-discussed methodology, the optimum design of the support pattern is 4 bolts in a row having row spacing 1.5 meters. The distance between two bolts is also considered 1.5 meters. The length of the bolt should be taken at least 1.8 meters particularly for the case illustrated in above-mentioned Table 8.2.

8.4 Effect of depth of cover of coal seam on axial load and RLH

In this section, the effect of depth of cover at constant RMR and gallery size along with variable bolt patterns are represented in terms of RLH, and axial load exerted on the bolt.

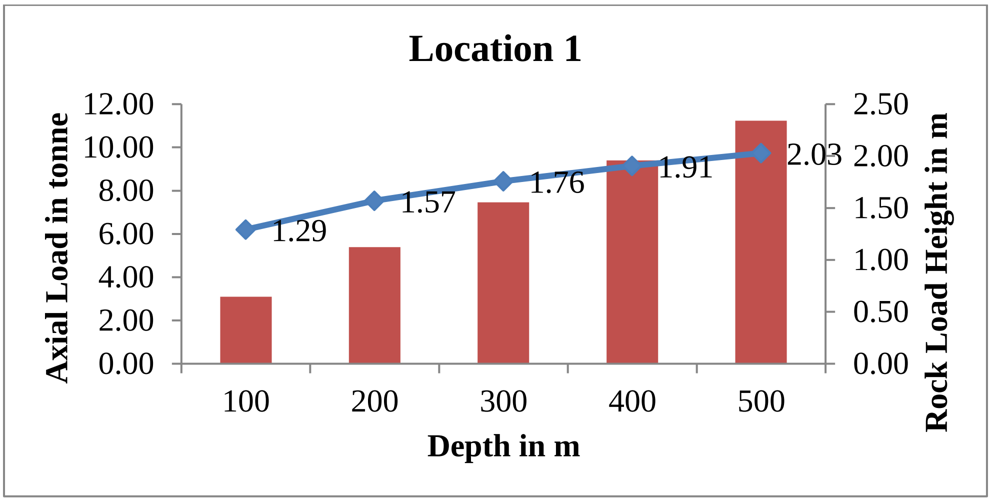

Figure 8.19 Effect of depth on RLH and axial load using 3 bolts in a row at location 1

Figure 8.19 gives the relationship between depth, RLH, and axial load. The above figure considered the observed value of RLH and axial load developed on the bolt at location 1 with variable depth of cover. The relationship will give the idea of RLH and axial load value with fixed RMR i.e., 60 and gallery size 5.5m, along with the variable depth of cover and bolt density.

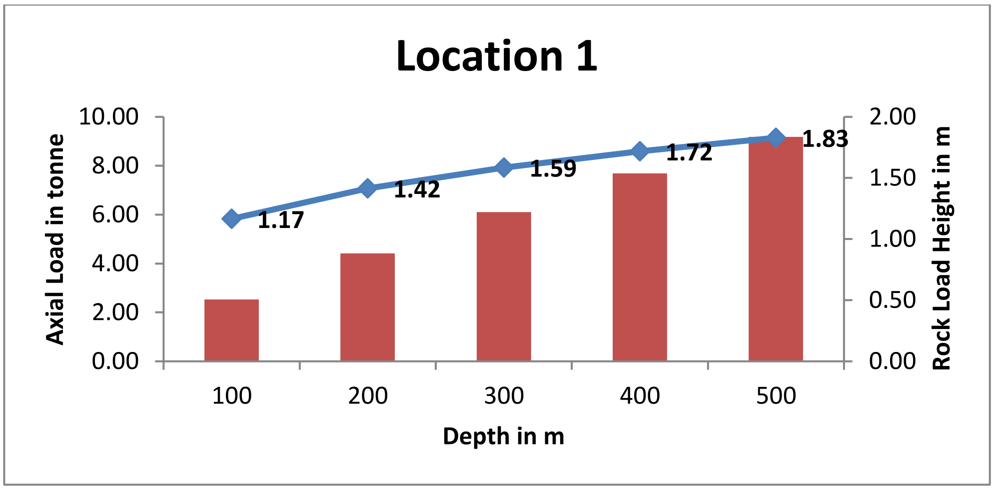

Figure 8.20 Effect of depth on RLH and axial load using 4 bolts in a row at location 1

Figure 8.20 gives the relationship between depth, RLH, and axial load. The above figure considered the observed value of RLH and axial load developed on the bolt at location 1 with variable depth of cover. The relationship will give the idea of RLH and axial load value with fixed RMR i.e., 60, bolt density 2.25 m2/bolt, and gallery size 5.5m, along with the variable depth of cover.

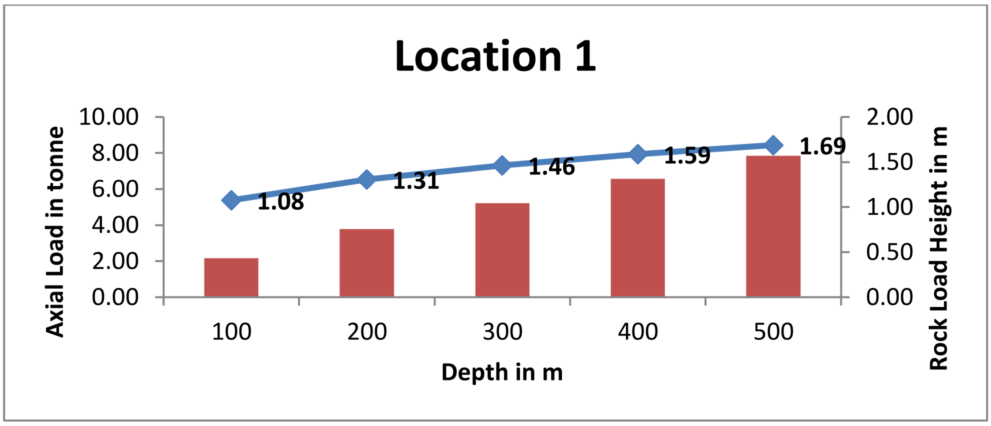

Figure 8.21 Effect of depth on RLH and axial load using 5 bolts in a row at location 1

Figure 8.21 gives the relationship between depth, RLH, and axial load. The above figure considered the observed value of RLH and axial load developed on the bolt at location 1 with variable depth of cover. The relationship will give the idea of RLH and axial load value with fixed RMR i.e., 60, bolt density 1.44 m2/bolt, and gallery size 5.5m, along with the variable depth of cover.

8.5 Effect of RMR on axial load and RLH

In this section, the effect of RMR at a constant depth of cover and gallery size, along with variable bolt patterns are represented in terms of RLH and axial load exerted on the bolt.

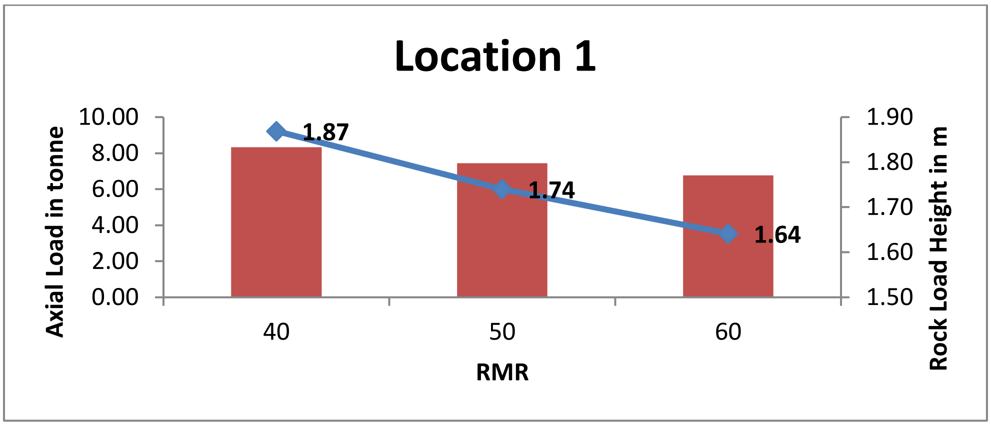

Figure 8.22 Effect of RMR on RLH and axial load using 3 bolts in a row at location 1

Figure 8.22 gives the relationship between RMR, RLH, and axial load. The above figure considered the observed value of RLH and axial load developed on the bolt at location 1 with variable RMR. The relationship will gives the idea of RLH and axial load value with a fixed depth of cover i.e., 300 mand gallery size 6m along with variable RMR of strata and bolt density using 3 bolt pattern.

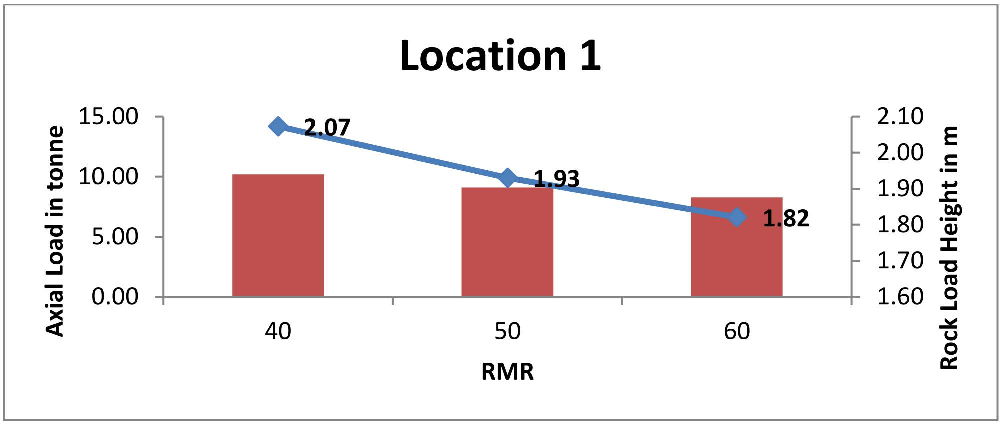

Figure 8.23 Effect of RMR on RLH and axial load using 4 bolts in a row at location 1

Figure 8.23 gives the relationship between RMR, RLH, and axial load. The above figure considered the observed value of RLH and axial load developed on the bolt at location 1 with variable RMR. The relationship will give the idea of RLH and axial load value with a fixed depth of cover i.e., 300 m and gallery size 6 m, along with variable RMR of strata and bolt density using 5 bolt patterns.

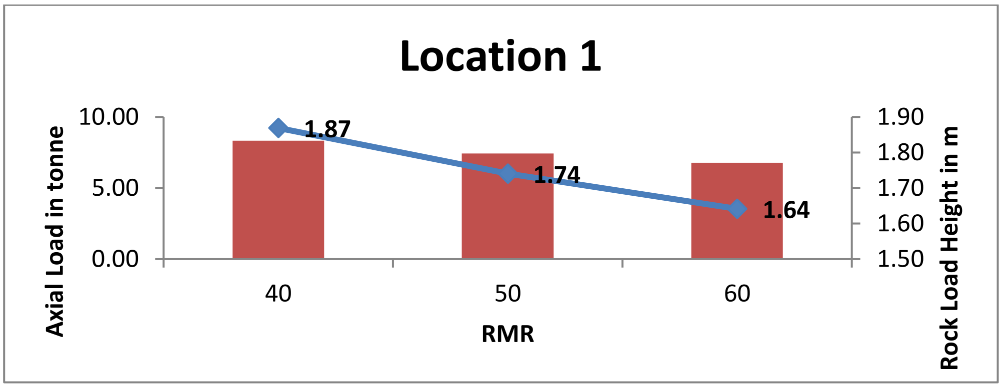

Figure 8.24 Effect of RMR on RLH and axial load using 5 bolts in a row at location 1

Figure 8.24 gives the relationship between RMR, RLH and axial load. The above figure considered the observed value of RLH and axial load developed on the bolt at location 1 with variable RMR. The relationship will gives the idea of RLH and axial load value with fixed depth of cover i.e 300 m and gallery size 6 m along with variable RMR of strata and bolt density using 5 bolt pattern.

8.6 Effect of Gallery size on axial load and RLH

In this section, the effect of gallery size at a constant depth of cover and RMR along with variable bolt patterns are represented in terms of RLH and axial load exerted on the bolt.

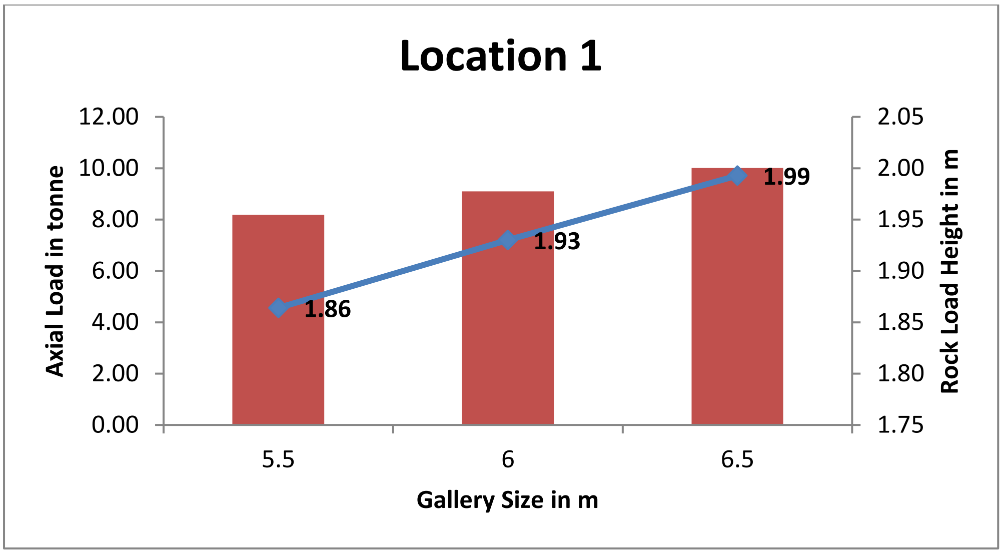

Figure 8.25 Effect of Gallery size on RLH and axial load using 3 bolts in a row at location 1

Figure 8.25 gives the relationship between gallery size, RLH, and axial load. The above figure considered the observed value of RLH and axial load developed on the bolt at location 1 with variable gallery size. The relationship will give the idea of RLH and axial load value with a fixed depth of cover i.e., 300 m and RMR50, along with variable gallery size of strata and bolt density using 3 bolt pattern.

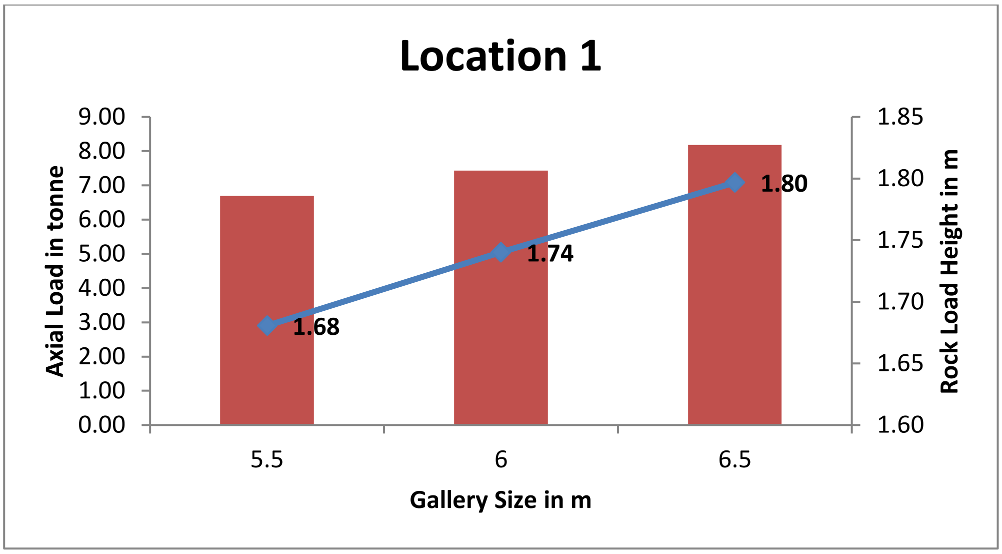

Figure 8.26 Effect of Gallery size on RLH and axial load using 4 bolts in a row at location 1

Figure 8.26 gives the relationship between gallery size, RLH, and axial load. The above figure considered the observed value of RLH and axial load developed on the bolt at location 1 with variable gallery size. The relationship will give the idea of RLH and axial load value with a fixed depth of cover i.e., 300 m and RMR 50, along with variable gallery size of strata and bolt density using 4 bolt pattern.

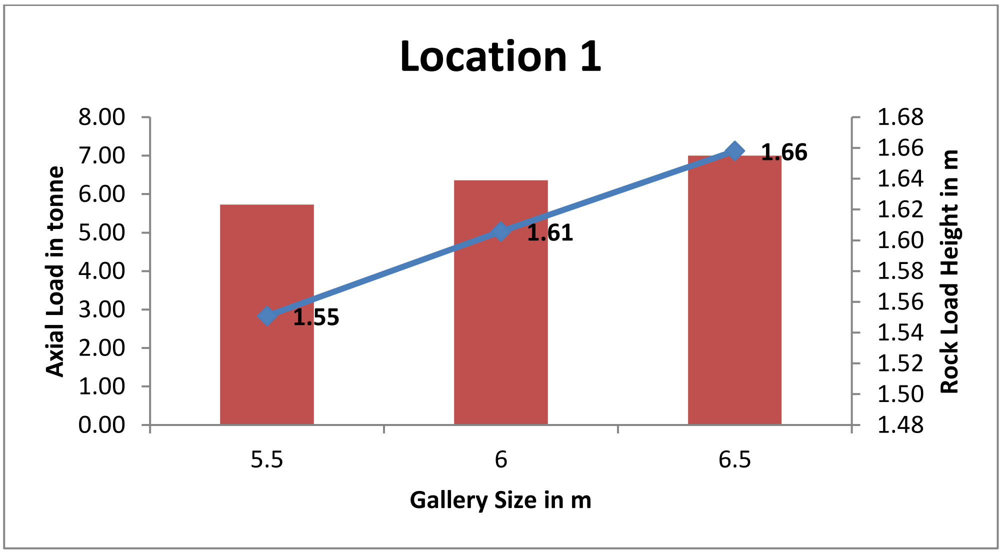

Figure 8.27 Effect of Gallery size on RLH and axial load using 5 bolts in a row at location 1

Figure 8.27 gives the relationship between gallery size, RLH, and axial load. The above figure considered the observed value of RLH and axial load developed on the bolt at location 1 with variable gallery size. The relationship will give the idea of RLH and axial load value with a fixed depth of cover i.e., 300 m and RMR 50, along with variable gallery size of strata and bolt density using five-bolt patterns.

8.7 Pick up length Vs. Rock Load Height

The axial load along the bolt has been observed during various stages of the mining operation. The observed axial load has been analysed two folds on each bolt, i.e., the maximum axial load exerted on the bolt and axial load profile along the different horizons of the bolt. The relationship between RLH and axial load along the bolt length has been observed based on the results. In general, it has been observed the maximum axial load is at the middle point of the bolt. It has also been observed that the maximum observed RLH is also at the same location. The bolt length from collar of the bolt to maximum axial load vale termed as "pick-up-length" of the bolt. The graph shown figure 8.28 the one typical example observed from simulation results.

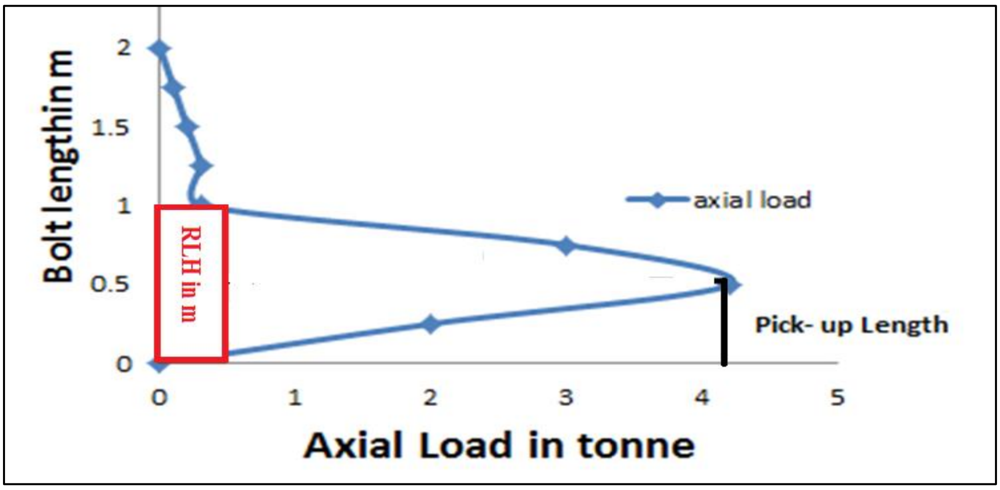

Figure 8.28 Graph showing pick up length

8.8 Axial load Vs. Influence zone with variable depth of working

The response on the bolt has been monitored upto 100 m from goaf edge with an interval of bolt spacing. The axial load exponentially decreases as one moves away from the goaf edge. However, it becomes constant at a certain point. The area between the goaf edge and the above point has been termed as the *Influence Zone* (*Iz*). Figure 8.29 shows the area of the influence zone at a depth of 200 m and 40 m from the goaf edge. The axial load decreases exponentially in this area.

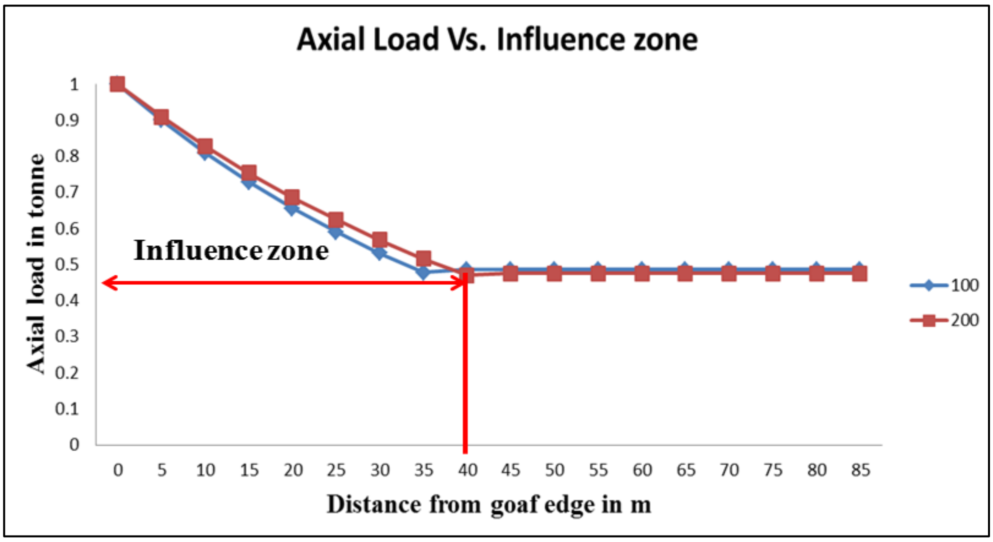

Figure 8.29 Graph between axial load bolt distances from goaf edge up to 200 m depth

In case of 300m, it is observed from the results the area of influence zone increases as compared to a depth less than 200 m. The influence zone is about 50 m from goaf edge at 300 m depth of cover. After this point the value of axial load is remains same as shown in the graph in figure 8.30.

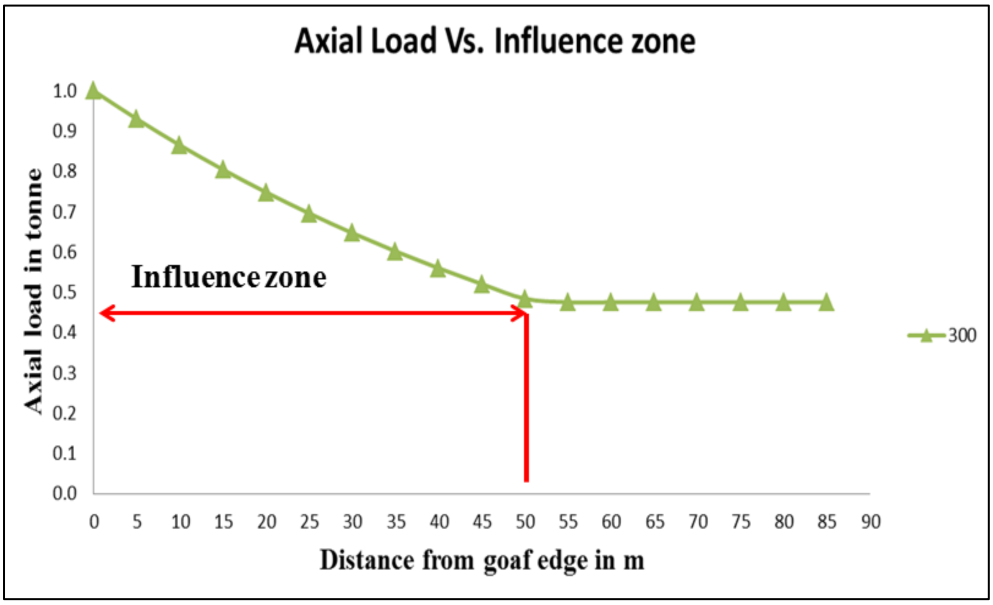

Figure 8.30 Graph between axial load bolt distances from goaf edge up to 300 m depth

In case of 400m, it is observed from the results the area of influence zone increases as compared to depth less than 300 m. In this depth of cover (400 m) the influence zone is about 75 m from goaf edge. After this point the value of axial load is remain same as shown in graph in figure 8.31

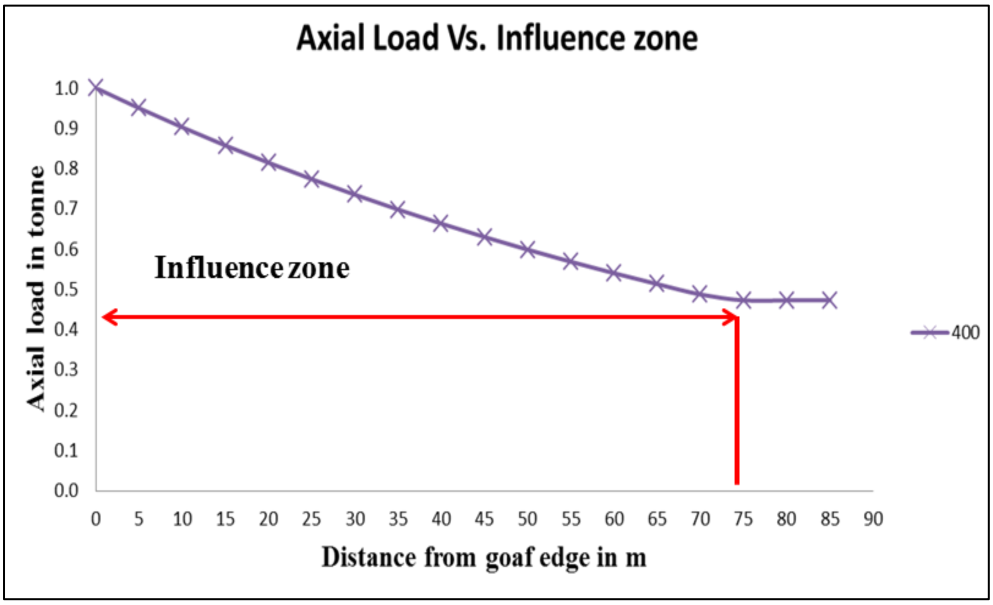

Figure 8.31 Graph between axial load bolt distances from goaf edge up to 400 m depth

Based on above results it is concluded that the influence zone is directly depends upon the depth of cover, as the depth is increasing the point of influence zone is increases.

$$Axial\ Load_{Normalize} = e^{(3\times10^{-5}-0.0235)\times Iz} \quad (8.4)$$

$$Actual\ axial\ load = Peak\ value\ of\ axial\ load\ for\ location\ 1\ and\ 2 \times Axial\ Load_{Normalize} \quad (8.5)$$

8.9 Mathematical expression derived by using Statistical analysis

In this section mathematical expression is derived considering all the variable geo-mining parameters based on simulated models. The statistical analysis used "multi variant regression analysis" in this study. The effect of two keys parameters is taken into consideration for design optimum support system as per variable parameters in Indian coalfields. The expression is deduced using statistical analysis represented in below paragraph.

❖ **Rock load Height (RLH)**

Two critical locations have been chosen near the goaf edge for the stability of the roof during the different stages of the depillaring operation. These locations are tri-junction and main junction. Mathematical expressions have been developed at these locations in terms of RLH and axial load on the bolt for varying geo-mining parameters such as bolt density (BD), depth of cover (D), gallery width (GW), and RMR is expressed below. The RLH results have been observed at these locations in different stages of operation. The generalised expression has been formed to estimate the RLH at these two critical locations expressed below.

The generalized equation for RLH in m:

- Tri-junction (Location 1)

$$\mathrm{RLH} = \frac{0.52\times \mathrm{BD}^{0.18}\times \mathrm{D}^{0.28}\mathrm{GW}^{0.4}}{\mathrm{RMR}^{0.32}} \quad (8.6)$$

- Main – Junction (Location 2)

$$RLH = \frac{0.11 \times BD^{0.3} \times D^{0.3} GW^{0.4}}{RMR^{0.45}} \tag{8.7}$$

❖ **Axial Load (tonne)**

The Axial results have been observed at these locations in different stages of operation. The generalised expression has been formed to estimate the axial load at these two critical locations expressed below.

The generalized equation for Axial Load in tonne:

- Tri-junction (Location 1)

$$\text{Axial Load} = \frac{0.05 \times BD^{0.35} \times D^{0.8} GW^{1.2}}{RMR^{0.51}} \tag{8.8}$$

- Main – Junction (Location 2)

$$\text{Axial Load} = \frac{0.06 \times BD^{0.40} \times D^{0.74} GW^{1.2}}{RMR^{0.51}} \tag{8.9}$$

8.10 Summary

Numerous models have been simulated considering important geo–mining parameters for proper selection of support systems in mechanized development and various depillaring stages. Based on the literature study, two key factors RLH and bolt capacity have been taken to design the proper support system using rock bolt technology. So, the chapter discussed the effects of various geo–mining parameters on these two factors, which will contribute to giving the optimum support system. Based on extensive literature review and field observation, the focused study area has been selected near the goaf edge. The study also revealed the maximum roof failure and load developed on the bolt near the study area. This chapter discussed in detail, taking one typical example and suggesting the suitable support design along with the capacity of the bolt to be chosen.

This section also examined the effects of various geo–mining parameters such as depth of cover, RMR, gallery size, and different bolt density on RLH and axial load at various stages of the mining operation. Based on the observed results from simulated models, the effect of roof failure and axial load is perceived maximum at a particular point, and then it follows the saturation line. This defined point is called the influence zone, and after this point, the roof failure is constant using any combination of the bolt pattern. This point will give the idea of optimum support provided in the mine. The influence zone is directly affected on the different depth of cover of the seam. The chapter also evaluated the value of the influence zone into the different depth of cover. The generalized mathematical expression has been developed considering all the geo – mining parameters using statistical analysis to gives the value in terms of RLH and axial load developed on the bolt. The expression has been evaluated at two selected focused area near goaf edge. The two pints are at tri-junction of split gallery and main junction.