Chapter 7

CONCLUSIONS AND SUGGESTIONS

The bord and pillar system is the most commonly used method of underground coal mining in India, in which the mining operation is commenced in two phases, i.e., development and depillaring. The galleries are formed during the development phase leaving pillars, whereas splitting/slicing the pillars has to be carried out in the depillaring phase. A variety of extraction patterns have been adopted during mechanized depillaring operations using *CM* technology. The intact pillars and remnant pillars (ribs/snook) are the critical elements of a depillaring panel, and the stability of these structures governs the global and local stability in the panel. An attempt has been made in the study to design the bord and pillar panel for mechanized depillaring using numerical techniques ($FLAC^{3D}$). The study has been carried out in two phases, i.e., a) Designing of the panel and b) Designing of the remnant pillars. The following conclusions have been made in the study:

1) Coal is a strain-softening material; hence, incorporating appropriate material properties (mainly strength parameters) for the coal is a prime requirement in adopting the numerical techniques. Failed and stable cases of coal pillars from Indian coalfields have been chosen for assessment of the strength parameters using hit and trial approach. The cohesion of the coal has been found to be the most critical parameter. Based on the analysis, peak cohesion of the coal mass has been observed linearly dependent on the *UCS* of the coal (Eq. 3.3):

$$C = 0.034 \times (UCS) + 0.153 \ (MPa)$$

2) Three cases of Indian coalfields where *CM* technology has been used during depillaring have been selected for validation of the numerical model. The depillaring operation discontinues in two of the cases (‘Case A’ and ‘Case C) due to excessive side spalling and poor strata conditions, whereas difficult mining conditions arise in one of the cases ('Case B'), which enforces partial extraction of the pillars. The model shows similar mining conditions as observed in the field. The working pillar yields entirely in 'Case A' and 'Case B,' and the *FOS* of the next immediate pillar 'N' has been calculated as 1.1 and 1.2, respectively. The working pillar is marginally stable in ‘Case B’ and shows the *FOS* of about 1.3. It has been concluded from the analysis that the *FOS* of the working pillar should not be less than 1.3 (preferably more than 1.5) for safe depillaring operation.

3) Strata instruments have been used in the selected field cases to access the strata behavior and stress conditions on the pillars during the depillaring operation. It has been analyzed from the records of *AWTT* that the average stand-up time of the final snook is about 45 hours.

4) The designing of the panel has been commenced by preparing a bord and pillar panel of sufficiently large size and simulated at a critical depillaring stage (at which advancement length is equivalent to the panel width) for different combinations of pillar widths and depths of cover. The term '*Stress Ratio'* (i.e., ratio of average vertical stress during depillaring and development, has been coined in the study to assess the stability of the pillars during depillaring (Eq. 6.1). The analysis shows that the '*Stress Ratio (SR)'* for the working and barrier pillar shows a linear relationship with the *FOS* of the

pillar during development as expressed through Eq. 6.2 and Eq. 6.3, respectively:

$$SR_W = 0.5\ x\ FOS_{Development} + 0.6$$

$$SR_B = 0.45\ x\ FOS_{Development} + 1.3$$

5) Based on the analysis, a nomograph has also been proposed in the study to depict the suitable size of the pillar for a mechanized depillaring panel under different depths of cover and extraction heights (Table 6.13), assuming *UCS* of the coal as 40 MPa.

Depth of cover (m)	***Extraction height (m)***					
	3	*3.5*	*4*	*4.5*	*5*	*5.5*
	Optimum width of the pillar for CM working					
100	18	20	20	22	23	24
150	25	29	30	32	34	36
200	29	35	35	38	41	44
250	33	39	39	44	46	49
300	35	43	43	47	51	54
350	38	46	46	50	54	58
400	40	49	49	53	58	62
450	41	51	51	56	60	65

6) The remnant pillars (ribs/snook) are formed during the final extraction of coal, and their role is to provide temporary support to the immediate strata (overhang). The required stability of a remnant pillar is to provide temporary support to the overhang until the depillaring advances to a safe distance. The term *'Strength factor (SF)'* has been proposed in the study to assess the stability of the remnant pillars. *SF* is the ratio of the residual strength of the remnant pillars and the weight of the overhang (Eq. 3.1).

$$SF = \frac{Residual\ strength\ of\ the\ remnant}{Weight\ of\ the\ overhang}$$

7) A criterion has been set in the study to design the remnant pillars such that the *SF* of the working pillar/remnant (‘W’) should be greater than 1.0 and *SF* of the previously extracted pillar/remnant ('P') should be less than 1.0, at a depillaring stage where the last slice has been taken out from the working pillar ('W'). The optimum remnant pillar design has been considered to be the one that satisfies Eq. 6.5 and Eq. 6.6 at a depillaring stage where the last slice has been taken out from the working pillar/remnant ('W'):

$$SF_W > 1.0$$

$$SF_P < 1.0$$

8) The design of the remnant pillar has been commenced by preparing a model of the panel for each selected pillars and simulated at a critical depillaring stage and depth of cover. It has been analyzed from the simulation results that the load-bearing capacity of the remnant pillar shows an exponential relationship with its area (Eq. 6.4):

$$L = 54.51\ x\ e^{(0.003\ x\ A)}$$

Where, L is the load-bearing capacity of the remnant pillar in kT, and A is the area of the remnant pillar in m^2.

9) It has been concluded from the analysis that the average residual strength of the working pillar/remnant ('W') and the previously extracted pillar/remnant ('P') is about 0.6 MPa and 0.4 MPa, respectively, during the depillaring stage where the last slice has been taken out from the working pillar ('W').

10) The analysis of the simulation results shows that the percentage of extraction is about 80.77% for pillar width of 26 m, whereas for pillar width of 35 m, the percent of extraction is about 81.39%. The percentage of extraction for pillar width of 45 m, and 48 m has been calculated as 78.82% and 79.38%. It has been concluded from the analysis that the percentage of extraction is nearly 80% for an optimum remnant pillar design.

11) The analysis of the simulation results shows that the optimum area of snook is about 4.7% of the pillar in the case of fish-bone extraction pattern (having pillar width of 26 m), whereas for split and fender pattern (having pillar width of 35 m), the optimum area of the snook is about 8.4%. The optimum area of the snook in the case of double split and fender pattern is about 7.3% (for pillar width of 45 m) and 7.2% (for pillar width of 48 m). It has been concluded from the analysis that the area of final snook is about 5% for the smaller pillar and about 8% for larger pillars.