CHAPTER 5

DESIGN CRITERIA

This chapter discusses the development of the design criteria for estimating the safe thickness of the parting strata (PS) and an optimal capacity of the goaf edge support for a controlled load transfer and a safer depillaring in the presence of the softcover. Transfer of load of the softcover in an uncontrolled manner could create considerable instability at the goaf edge, the premature failure of the rib pillars, and goaf encroachment or the over-riding of pillars, thus significantly affecting the safety and the overall efficacy of depillaring operation. Controlling the peak settlement rate of the parting strata within a threshold limit can ensure a gradual transfer of the dead load, thereby restricting degradation of the immediate roof and the rib pillar at the depillaring face.

The parametric study results revealed that the PS/SC plays a crucial role in defining the caving behaviour of the strata during the periods of major roof caving and vertical stress recovery in the goaf, in addition to controlling goaf edge convergence and the settlement of the parting strata. These parameters also reflect the severity of load transfer at the goaf edge and the associated strata control difficulty during progressive mining in a depillaring working.

A safe thickness of the parting strata helps in a controlled load transfer by maintaining an arching effect as it undergoes failure due to bending, followed by settlement of the softcover on the surface and the piles of caved goaf below ground. The parting strata undergo a very gradual failure. In such conditions, the peak load of the overburden does not get shifted very near to the face, thus avoiding excessive loading of the support and deterioration of the roof near the goaf edge.

A gradual bending of the PS also controls the rate of load transfer, avoiding excessive loading at the goaf edge, particularly during periods of major roof caving. As the parting strata fail reasonably away from the goaf edge, the effect of load transfer is not immediately realised by the goaf edge support. Hence, the deterioration of the roof remains under control enabling a safer working condition during progressive mining.

The softcover (SC) load transfer severity can be quantified by analysing the peak settlement rate and the location of failure of the parting strata (PS) from the goaf edge. The overall influence is manifested in terms of the peak convergence at the goaf edge. Once the safe thickness of the PS is decided for a given thickness of the softcover, an optimal capacity of the support can be selected for a controlled peak convergence to an acceptable limit and maintaining a sustainable roof control during progressive depillaring in the given condition.

5.1 Estimation of Safe Parting Thickness

The minimum thickness of parting strata (PS) for a safer load transfer of a given thickness of the softcover can be decided in terms of the PS/SC ratio, considering an acceptable value of the maximum goaf edge convergence slope (MGECS). The MGECS is the maximum of the goaf edge convergence slope observed during progressive depillaring at different PS/SC at a given cover depth, as depicted in Figure 4.26, Section 4.5. The compilation of the values for different depths of cover (Table 5.1) shows a higher convergence for a lower PS/SC ratio, implying conditions for thin parting strata and a very thick softcover. In contrast, lower convergence was observed for a high PS/SC ratio, representing thicker parting strata and relatively thinner softcover.

Table 5.1. Maximum goaf edge convergence slope for varying PS/SC at the cover depth of 150-350 m

Depth, m	Softcover, m	Parting strata, m	PS/SC	MGECS, mm/m
150	112.50	13.50	0.12	120
	100.00	26.00	0.26	85
	75.00	51.00	0.68	62
	50.00	76.00	1.52	52
	37.50	88.50	2.36	49
250	187.50	38.50	0.21	102
	166.70	59.30	0.36	91
	125.00	101.00	0.81	71
	83.30	142.70	1.71	62
	62.50	163.50	2.62	55
350	262.50	63.50	0.24	91
	233.30	92.70	0.4	88
	175.00	151.00	0.86	67
	116.70	209.30	1.79	54

The plot of the MGECS as a function of the PS/SC (Figure 5.1) shows that the maximum convergence at the goaf edge is strongly related to the ratio of the PS/SC for a given geo-mining condition. For a meagre value of the PS/SC, the convergence is exceptionally high. However, with an increase in the value of PS/SC, the convergence reduces following a hyperbolic trend and finally becomes almost constant after a particular PS/SC. With this note, the minimum thickness of the PS can be determined by considering 75 mm/m of the maximum allowable convergence for containing the deterioration of the roof during the peak loading cycles of progressive mining within an acceptable limit, as suggested by Singh and Singh (2009a) for longwall workings, considering the fact that the mining cycles of the powered support longwall working are pretty similar to the mechanised depillaring involving mobile goaf edge support. No such study is exclusively reported for depillaring workings. With the above consideration, the PS/SC ratio of 0.57, which corresponds to the peak goaf edge convergence of 75 mm/m of face advance, can be considered as the design criteria for deciding the safe parting thickness.

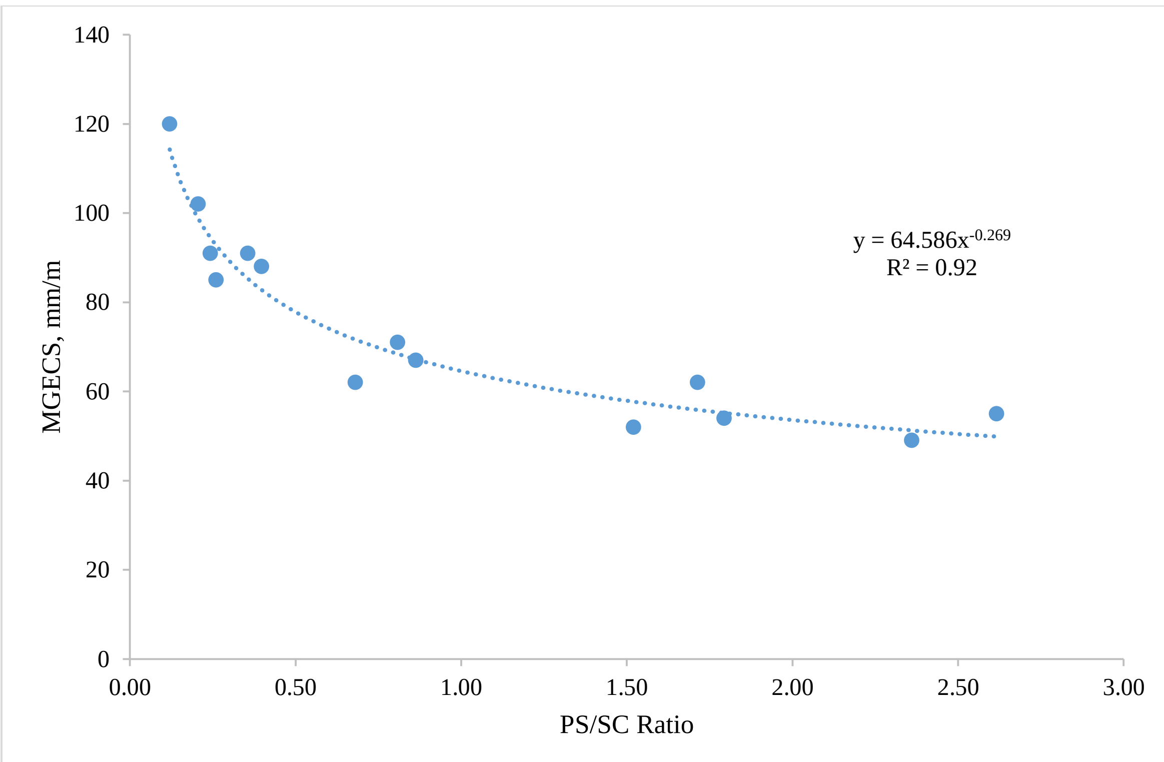


Fig. 5.1. Maximum goaf edge convergence slope for varying PS/SC at the cover depth of 150 – 350 m

The PS/SC ratio was obtained from the MGECS using Equation (5.1), which derives the value of 0.57. This safe value of PS/SC is used to determine the minimum safe thickness of the parting strata under the maximum softcover from the Equations 5.2 – 5.4 :

$$\mathrm{MGECS} = 64.586\ (\mathrm{PS/SC})^{-0.269} \qquad \ldots(5.1)$$

$$\mathrm{PS}/SC = 0.574 \qquad \ldots(5.2)$$

$$(\mathrm{PS} + \mathrm{SC})/SC = 1.574 \qquad \ldots(5.3)$$

$$\mathrm{H} - \mathrm{t_{cav}} = 1.574\mathrm{SC} \qquad \ldots(5.4)$$

Where, t_{cav}= caving height, 24 m, and

H= depth of working, m

For a mine working having an extraction height of 3 m below the cover depth of 150 m, the limiting thickness (maximum) of the softcover is 80 m while the thickness of the safe parting (minimum) is 46 m. For a similar working at 250 m depth, the limiting thickness of softcover is 144 m while the thickness of the safe parting is 82 m. As the cover depth increases to 350 m, the requirement of minimum parting thickness increases to 119 m enabling the maximum softcover thickness of 207 m. These estimates consider the caving height of 24 m and the average strength and layer thickness of strata as considered in the parametric study.

5.2 Peak Settlement Rate of the Parting Strata

The settlement of the parting strata was monitored with progressive face advance at the cover depth of 150 – 350 m for different PS/SC, as depicted in the previous chapter. The observation could identify the face position during which the failure of the parting strata was indicated during the progressive depillaring. The resultant settlement of the parting strata initiated at the point marked by the beginning of its increased vertical deformation (termed as initial deformation). It could also locate the face position when the deformation of the PS stabilised (termed as final deformation), as it received contact with the pile of the caved goaf.

In this dissertation, Peak Settlement Rate (PSR) is defined as the ratio of the difference of the final deformation and the initial deformation of the parting strata to the difference of face position at these two stages. These deformation and face location values correspond to the first failure of the parting strata (PS). The settlement rates for different PS/SC is compiled in Table 5.2a–c.

Table 5.2a. PSR for different PS/SC at cover depth of 150 m depth

PS/SC	Initial face Position, m (a)	Final face position, m (b)	Initial deformation, m (c)	Final deformation, m (d)	PSR, mm/m [e = -1000×(d-c)/(b-a)]
0.12	44	46	0.197	1.341	572
0.26	43	45	0.167	0.732	282
0.68	43	50	0.086	0.611	75
1.52	49	73	0.082	0.716	26
2.36	51	58	0.111	0.288	25

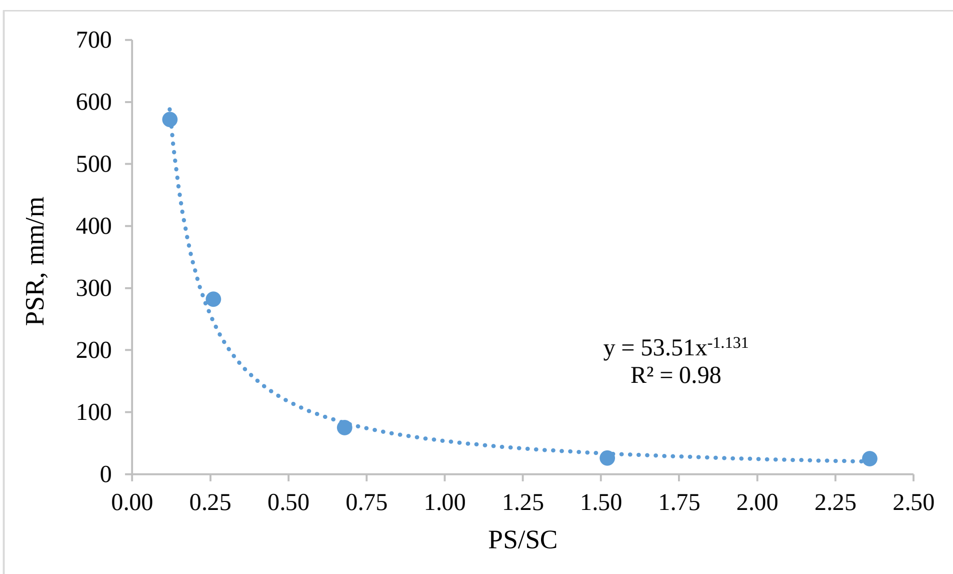
Table 5.2b. PSR for different PS/SC at cover depth of 250 m depth

PS/SC	Initial face Position, m (a)	Final face position, m (b)	Initial deformation, m (c)	Final deformation, m (d)	PSR, mm/m [e = -1000×(d-c)/(b-a)]
0.21	47	50	0.142	0.978	279
0.36	48	52	0.107	0.740	158
0.81	47	51	0.069	0.284	54
1.71	57	63	0.063	0.284	37
2.62	62	64	0.131	0.180	24

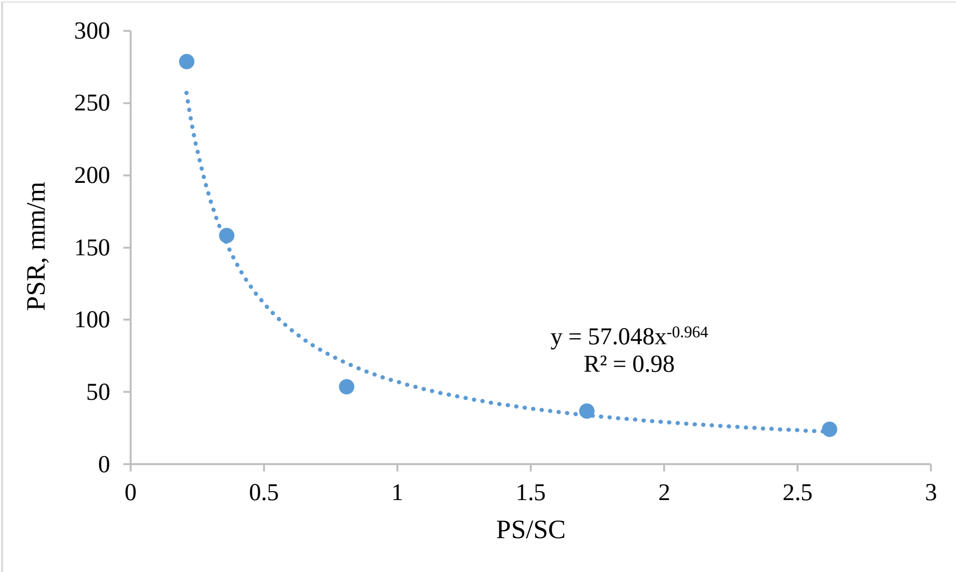
Table 5.2c. PSR for different PS/SC at cover depth of 350 m depth

PS/SC	Initial face Position, m (a)	Final face position, m (b)	Initial deformation, m (c)	Final deformation, m (d)	PSR, mm/m [e = -1000×(d-c)/(b-a)]
0.24	39	49	0.091	0.642	55
0.4	43	55	0.1	0.402	25
0.86	53	63	0.073	0.233	16
1.79	83	107	0.098	0.221	5

Figure 5.2a – c shows the trend of the PSR for varying PS/SC ratios at the cover depth of 150 – 350 m. The settlement rate is very high for a lower PS/SC ratio, but it reduces with an increase in the PS/SC ratio following a non-linear trend. It signifies that a controlled load transfer of the softcover occurs only after a cut-off settlement rate that corresponds with the safe PS/SC ratio.



(a)



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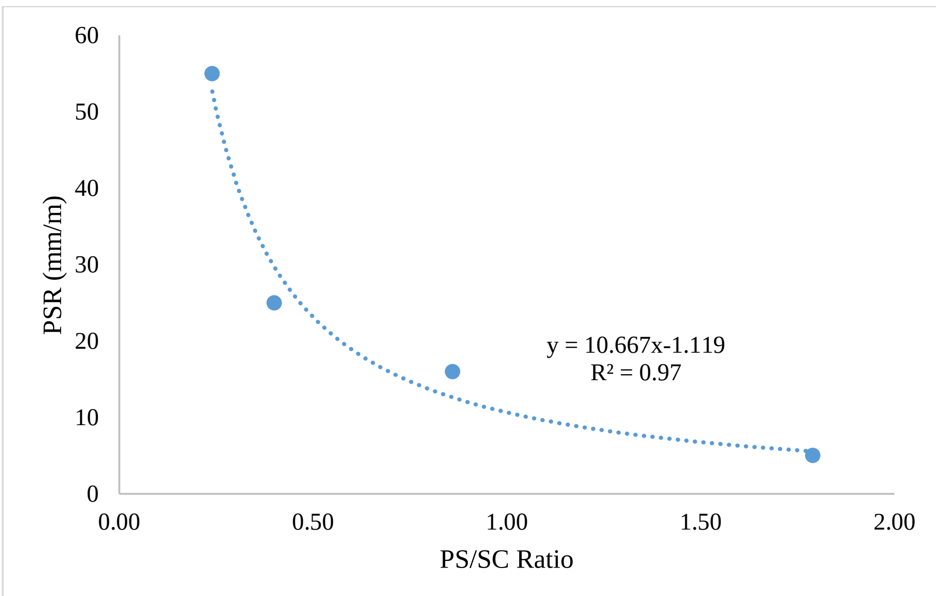

(c)

Fig. 5.2. Peak settlement rate for different PS/SC at cover depth of (a) 150 m, (b) 250 m, (c) 350 m

These plots confirm that the PSR is almost controlled beyond PS/SC of 0.57, revalidating the design limit of MGECS as discussed in the previous section. Thus, the cut off PSR for a given cover depth can be determined based on the safe PS/SC of 0.57. It denotes the point where the uncontrolled settlement of softcover could be transformed into a regulated and safely controlled manner. The PSR remains controlled beyond this limit, as depicted by an almost flat trend line with a further increase in the PS/SC. This ensures that the parting strata are capable enough to prevent its uncontrolled movement under the influence of the dead load of the softcover, thereby preventing adverse convergence at the goaf edge. The safe peak settlement rate at the cover depth of 150, 250 and 350 m was obtained as 100, 97 and 20 mm/m of face advance, respectively.

5.3 Location of the failure in the Parting strata

Table 5.3 compiles the location of the failure of the parting strata behind the goaf edge for different PS/SC at the cover depth of 150-350 m. The failure location corresponds to the distance behind the goaf edge at which the final deformation in the PS was observed upon its first failure during progressive mining. The trend line obtained from the data plot shows that for lower PS/SC, the failure of the PS takes place nearer to the goaf edge, thus transferring a higher load on support and convergence at the goaf edge. With the increase in the PS/SC ratio, the location of the failure occurs relatively away from the goaf edge, thus lowering the severity of load transfer in the depillaring working.

Figure 5.3 shows that the failure location in the parting strata increases following a non-linear trend with the increase in the PS/SC ratio. It was observed that the failure in PS is located at the distance of 30 m from the goaf edge corresponding to the safe ratio of PS/SC at 0.57. It shows that the failure in the parting strata should not occur at a distance less than 30 m from the goaf edge for controlled loading at the goaf edge while depillaring under softcover.

Table 5.3. Location of failure in the parting strata for different PS/SC

Depth, m	PS/SC	PS thickness, m	SC thickness, m	Failure Location of PS, m
150	0.12	13.5	112.5	14
	0.26	26	100	29
	0.68	51	75	32
	1.52	76	50	36
	2.36	88.5	37.5	42
250	0.21	38.5	187.5	24
	0.36	59.3	166.7	29
	0.81	101	125	32
	1.71	142.7	83.3	38
	2.62	163.5	62.5	46
350	0.24	63.5	262.5	27
	0.4	92.7	233.3	30
	0.86	151	175	35
	1.79	209.3	116.7	41

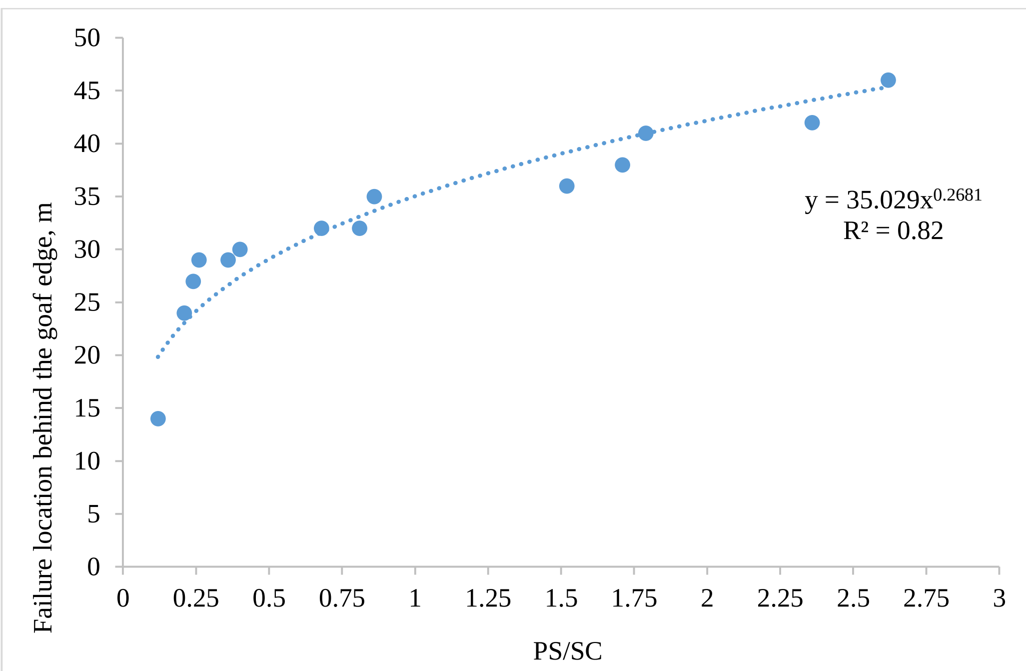

Fig. 5.3. Location of failure in the PS for variation in PS/SC at the cover depth of 150-350 m

5.4 Summary

This chapter analysed the convergence characteristics at the goaf edge for variation in the thickness of the parting strata and the softcover for the average strata condition as considered in this study. The maximum goaf edge convergence slope (MGECS) varied from 120 – 49 mm/m for variation of PS/SC from 0.12 – 2.36 at the cover depth of 150 m. For cover depth of 250 m, the MGECS varied from 102 – 55 mm/m for an increase in PS/SC from 0.21–2.62. The convergence reduced from 91 – 54 mm/m for PS/SC of 0.24 – 1.79 at 350 m cover depth.

Combining these observations for different PS/SC ratios at cover depth of 150 – 350 m, the safe PS/SC ratio of 0.57 is estimated for controlling the goaf edge convergence to its maximum allowable limit of 75 mm/m of face advance. According to this criterion, the safe thickness of parting strata at 150 m depth was 46 m, while the limiting (maximum) thickness of the overburden dump was 80 m. At the cover depth of 250 m, the minimum parting thickness for the safe depillaring was 82 m, while the maximum allowable thickness of softcover was 144 m. The estimated thickness of parting strata at the cover depth of 350 m was 119 m, while the maximum permissible softcover was 207 m. These estimates consider the caving height of 24 m and the average strength and layer thickness of strata in the parametric study.

The peak settlement rate (PSR) of parting strata is determined for different PS/SC at the cover depth of 150 – 350 m. PSR reduces with the increase in PS/SC following a non-linear trend. The PS/SC of 0.57 represents the point for a controlled and safe load transfer at the goaf edge, ensuring that the parting stratum of the minimal safe thickness is capable enough to arrest its uncontrolled movement. Otherwise, it might adversely affect the rate of load transfer and resultant convergence at the goaf edge. The safe settlement rate of the parting was obtained as 100, 97 and 20 mm/m for the cover depth of 150, 250 and 350 m. The rate of the maximum allowable settlement decreases with the increase in the cover depth.

The location of failure of the parting strata increases with the increase in the PS/SC ratio. A distance of 30 m was estimated as the safe location of failure from the goaf edge for the average strata condition considered in the study.

Figure 5.4 shows the flow diagram of the recommended design and implementation steps for assessment of the softcover and the optimal capacity of the goaf edge support.

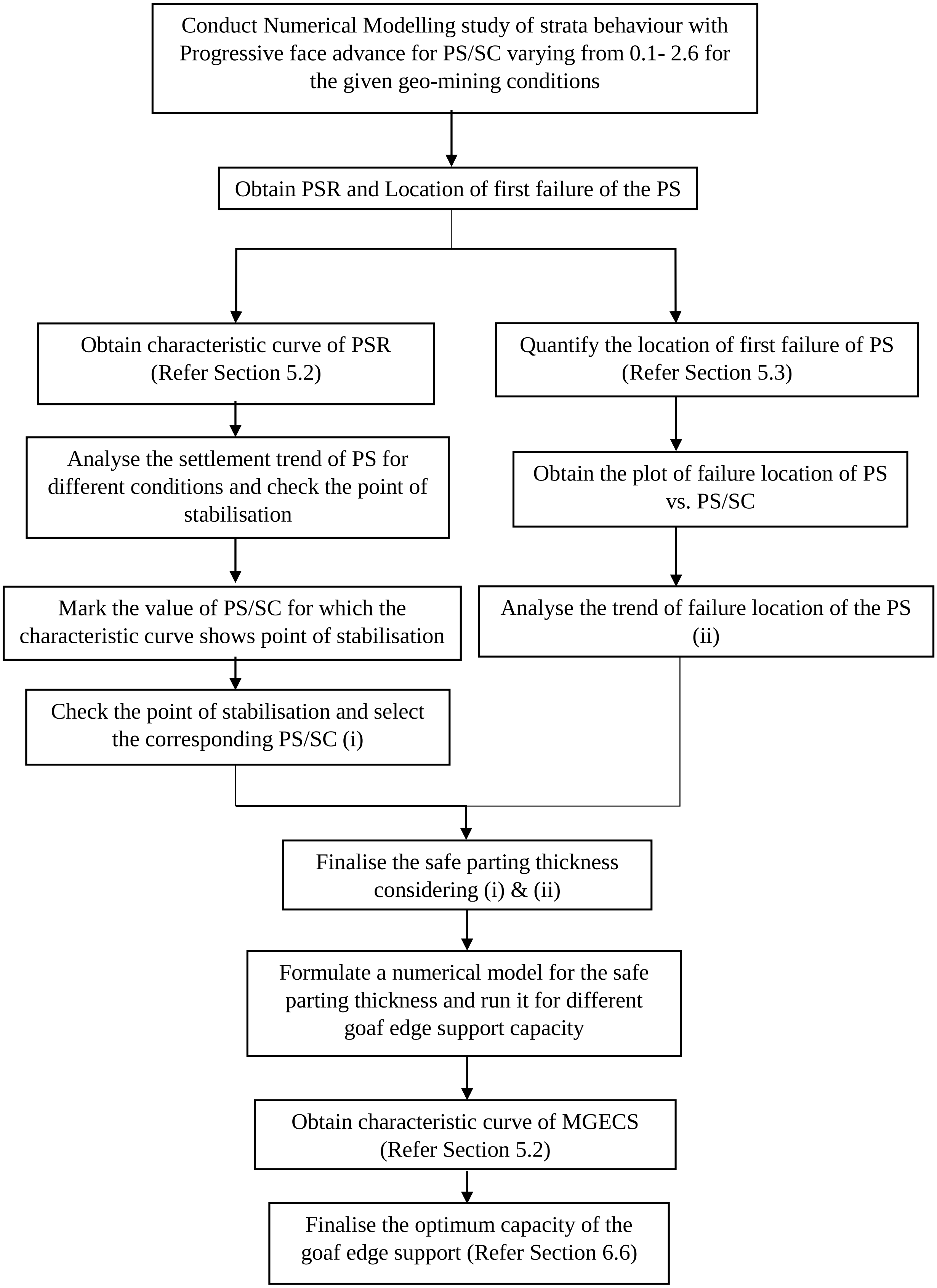

Fig. 5.4. Flowchart showing recommended design and implementation steps