CHAPTER 2

LITERATURE REVIEW

The overburden comprising of unconsolidated strata, weathered overburden, loose soil, and mega-thick alluvium has considerably reduced stiffness. Such strata formations are prone to develop higher surface deformation upon the caving of strata in depillaring workings. The effect of the softcover on the caving behaviour and load transfer of strata has been an area of interest for rational support selection and design of other control parameters for a safe depillaring in the mine workings.

The literature review has been conducted to compile the existing knowledge base in the areas pertinent to this research work. The salient findings and prevailing knowledge gap have been identified from this work to formulate a suitable research methodology for developing the requisite know-how for a meaningful realisation of the research objectives. The chapter is organised into five sections: Strata behaviour experiences, Mechanics of Caving and Load Transfer, Progressive goaf compaction, Performance of Goaf Roof Support, and lastly, the Effect of Softcover.

2.1 Strata Behaviour Experiences

The literature review shows that most studies of strata behaviour in the depillaring workings have focused on monitoring the front abutment stress (Fig. 2.1) at different depths of cover. Singh and Dhar (1996) obtained the maximum abutment stress and its range of influence in the depillaring panels at Govinda, Girmit, Porascole and East-Katras Collieries (Table 2.1). The results showed front abutment stress between 0.96 – 13.3 MPa near the goaf line below the cover depth of 50 – 146 m.

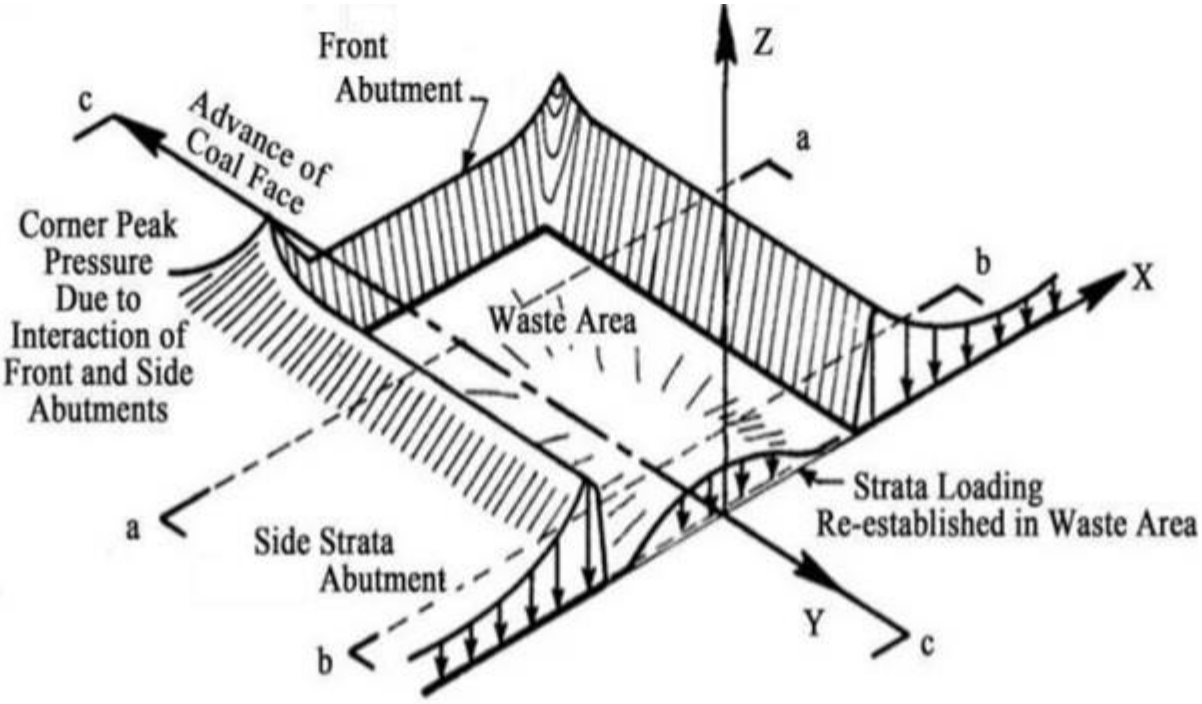

Fig. 2.1. Abutment stress distribution in the mine workings (Whittaker, 1974)

Table 2.1. Front abutment stress in shallow depth depillaring workings

Mines	Mining Area	Depth, m	Working Height, m	Max. induced stress, MPa	Range of influence, m
Govinda	Jamuna and Kotma, SECL	50	3.0	7.08	4.5
Girmit	Sripur, ECL	54	3.0	1.66	20
Porascole	Kajora, ECL	60	4.5	4.71	30
East-Katras	Jharia, BCCL	146	2.5	10.1	40

Singh et al. (2011a) reported the monitoring results of the front abutment stress in sixteen depillaring panels extracted by the continuous miner below the cover depth of 40 – 252.5 m under massive overlying strata. The study revealed front abutment stress of 0.668 – 36.2 MPa within the influence zone of 20 – 200 m from the goaf edge (Table 2.2) in different depillaring workings at the cover depth of 40 – 250 m. The maximum abutment stress of 36.2 MPa was observed at Churcha Mine, SECL at the cover depth of 244 m, while the minimum abutment stress of 0.67 MPa was observed in South Jhimar Mine, SECL at the cover depth of 48 m.

Table 2.2. Front abutment stress in Continuous miner depillaring workings

Mine	Mining Area	Depth, m	Working Height, m	Max. induced stress, MPa	Range of influence, m
Madhusudanpur	Kajora Area, ECL	40	7	1.37	40
GDK-5	RG-1 Area, SCCL	44.3	4.0	1.6	50
South Jhimar	Hasdeo Area, SECL	48	2.3	0.668	20
RK-8	Srirampur, SCCL	65	1.8	2.5	55
SRP-3	Srirampur, SCCL	73.5	1.8	3.9	30
Somna	Hasdeo Area, SECL	77	1.9	11.8	55
Nowrozabad	Johila Area, SECL	80	3.5	3.7	60
Chirimiri	Chirmiri Area, SECL	91	12.5	14.6	70
Anjan Hill	Chirmiri Area, SECL	93.5	3.9	9.8	60
SRP-1	Srirampur, SCCL	95	2.0	1.6	40
SRP-3A	Srirampur, SCCL	102.5	6.0	4.1	50
Rajnagar	Hasdeo Area, SECL	172.5	2.6	12.4	60
GDK-2	RG-1 Area, SCCL	235	1.6	34.3	70
Alkusa	Kustore Area, SECL	238	6.7	21.3	130
Churcha West	Baikuntha Area, SECL	244	3.0	36.2	200
GDK-8	RG-2 Area, SCCL	252.5	10.5	7.1	65

Sheorey and Singh (1988) highlighted different challenges of pillar extraction observed in Satpura Colliery I and II, WCL, Sudamdih Colliery BCCL and Bankola Colliery, ECL. The depillaring working in Satpura Colliery faced caving difficulty due to sandstone rock formation exceeding 80% of the total overburden. The strata formed large overhangs in the goaf, causing goaf control problems apart from the poor stability of rib pillars in the slices. In Sudamdih Colliery, the depillaring working in a coal seam of 3.85 – 4.35 m thickness dipping at 26.5° faced the problem of rib instability at the cover depth of 130 m due to the higher gradient of the coal seam and lower width of the rib pillar. The depillaring workings in the Jambad Seam of 3 – 7.8 m thickness at Bankola Colliery also faced caving difficulty due to hard sandstone in the overlying roof.

Singh et al. (2011b) reported pillar spalling of 1.5-2 m and abutment stress of 34 MPa within 20 m from the goaf edge in depillaring workings below the cover depth of 300 – 350 m at VK-7 Incline and GDK 10 Incline Mines of SCCL. The monitoring work at Anjan Hill Mine, SECL below cover the depth of 120 m showed abutment stress of 10 MPa within 10 m from the goaf edge (Singh et al. 2011c).

At GDK-8 Incline Mine, SCCL, abutment stress of 4.27 MPa at 6.5 m from the goaf edge was observed after goaf exposure of 13,382 m^2 while working a seam of 10.5 m thickness below the cover depth of 298 m, wherein almost 85% of the overburden comprised of massive sandstone (Singh 2004). Kumar et al. (2015) reported severe goaf settlement at 12,380 m^2 of goaf exposure under similar geo-mining conditions at GDK-10 Incline.

Kumar et al. (2016) reported maximum goaf edge convergence of 9.7 – 18 mm in the depillaring panels K-9C and K-12A at Madhusudan Colliery below the cover depth of 48.1 – 50.4 m. Mishra et al. (2013) reported the occurrence of main fall after goaf exposure of 6,784 m^2 in a continuous miner working at Jhanjhra Mine, ECL below the cover depth of 110 – 140 m. Ram et al. (2017) observed that the pillar spalling in the presence of the massive roof was higher than that in the weak and laminated formation. The results of strata behaviour monitoring at Johila Top Seam of 3.5 m thickness at the cover depth of 75 – 85 m showed the main fall after goaf exposure of 4900 m^2 (Singh et al. 2004). The maximum convergence of 39 mm and front abutment stress of 1.4 MPa were observed 15 m behind the goaf edge. Mandal et al. (2008) reported an increase in the front abutment stress from 0.8 to 1.8 MPa and convergence from 20 to 68 mm as the goaf edge approached towards the monitoring station initially located 20 m away in the depillaring working of 3.0 – 3.5 m thick Top section in Zero Seam at Chirmiri Colliery, SECL. A similar monitoring work conducted at Nowrozabad Colliery during extraction of 3 – 4 m thick Johilla Seam below the cover depth of 75 – 85 m showed front abutment stress of 0.84 MPa and convergence of 14.8 mm at a distance of 5 m from the goaf edge (Singh et al. 2012).

Sahoo et al. (2016) and Galav et al. (2017) reported the maximum convergence of 3 to 5 mm at a distance of 7.25 – 11.86 m and stress of 7.2 MPa at 10 m from the goaf edge in the depillaring working of 2.2 – 2.9 m thick Upper Patpahari Seam at the cover depth of 42 m at Bhatgaon Colliery, SECL. The first local fall was observed at 5000 m^2 of goaf exposure, while the main fall occurred after 11300 m^2.

2.2 Mechanics of Caving and Load Transfer

A gradual transfer of load due to the gradual reduction in pillar size during extraction of the developed pillars, along with controlled caving of strata in the goaf, is vital for a safe and sustainable depillaring operation. Merwe (2006) reported a large scale collapse of the mining area below the cover depth of 137 m at Coalbrook Mine, South Africa. The collapse of the overburden originated due to the failure of a weak pillar that triggered the cascading failure of the adjacent pillars (Zipf and Mark 1997). Salamon (1970) stated that the stiffness of the immediate roof and floor should be greater than the post-failure stiffness of pillars to enable controlled failure. A lower stiffness of the loading system gives rise to uncontrolled and violent pillar failure, signifying its abrupt inability to control the load of the immediate roof - floor. The stiffness of the overburden depends on the width of extraction, the thickness of the overburden, and the material type (Frith and Kavanagh 2000). Thus, the mode of pillar failure depends on the rate of decrease in its load-bearing capacity and the stiffness reduction rate of the overburden.

Coal pillar loading system in a typical bord and pillar working considers the w/h ratio and the factor of safety of the production pillar that drives the failure, according to the overburden characteristics such as width/depth ratio and the thickness of massive strata. The super-critical condition represents low overburden stiffness that tends to collapse up to the surface, causing sudden and violent failure of the overloaded pillars. The factor of safety (FoS) of the pillars exceeding 1.5 indicates its elastic state, while its lower values signify the plastic state with the gradual decrease of stiffness compared to the strength (Reed et al., 2017). Thus, the overburden settlement increases with the reduction in the overburden stiffness.

Singh et al. (2017) monitored the area of goaf exposure in different depillaring panels below the cover depth of 71 – 265 m. They estimated the area of goaf exposure in terms of compressive strength of the roof, the width of the rib pillar and the height of extraction (Table 2.3).

Table 2.3. Critical area of goaf exposure in a few depillaring workings

	Depth, m	Extraction height, m	Rib width, m	Compressive strength, MPa	Area of exposure, m^2
Saoner	71	4.8	2	28	2100
Bankola	85	3.6	2.6	29	4232
Satpura	104	3	1.93	37	9000
Satgram Inc.	110	2.4	2.17	28	3600
Shyamsundarpur	131	3.6	2.47	30	3763
Nandan Mine	230	4.4	2.08	23	4000
Gorawari	243	4.5	2.28	31	3000
Muralidih	265	2.85	1.90	27.8	5400

2.3 Progressive Goaf Compaction

The piles of caved goaf material formed during progressive caving of roof in the goaf area work as an important supporting foundation for the super-incumbent strata. Salamon (1990) stated that the compaction of goaf material is influenced by bulking factor, initial modulus and the maximum compressive strain apart from the void ratio, porosity, and the rate of settlement of overburden. Peng and Chiang (1984) opined that the bulking factor is the crucial parameter for the goaf material and depends on the average fragment size, order of particle orientation, caving height, and the goaf pile's maximum compaction. Pappas and Mark (1993) observed that the more potent rock have a lower bulking factor than the weaker rocks. Hence, compaction in the caved goaf formed of stronger rocks is comparatively lesser.

Wilson (1981) proposed triangular stress distribution along the depillaring face in which the stress in the goaf material near the rib-side is zero and maximum at 0.3H distance from the rib, in a condition when the face length exceeds 0.6H agreeable for the depth (H) of 200 m. Yavuz (2004) concluded that in situ stress is attained in the goaf within the cover pressure distance of 135 and 226 m for cover depth of 400 and 600 m, respectively, in mine workings having extraction height of 1 – 4 m.

Bai et al. (2014) conducted a modelling study for a 9.1 m thick coal seam at an average depth of 574 m and obtained cover pressure of 14.35 MPa at 240 m behind the face. A similar study conducted by Li et al. (2015) for a coal seam of 6 m thickness at 390 m depth showed that 89% of the virgin stress was regained at the cover pressure distance of 0.23 times the depth of working. However, Wang et al. (2015) estimated the maximum stress recovery of 26 MPa for a working having seam thickness of 5 m at 900 m depth in Zhangshuanglou Coal Mine, China.

Zhang et al. (2015) reported the modelling results of the Yuwu Mine in Shanxi Province, China having an extraction height of 6.3 m at the cover depth of 575 m. The results showed 98% of stress recovery at the cover pressure distance of 0.18 times the cover depth. In a similar study for Yanzhou Coal Mine having extraction height of 3 m in the Shandong area, Zhang et al.(2018) obtained stress recovery of 93% at a distance of 0.11 times the cover depth of 560 m. However, Zhang (2019) observed cover pressure distance varying between 0.05 – 0.17 times the cover depth in a mine working having extraction height of 6 m at 400 m deep. Yet in another study for Yuncheng Coal Mine, Zhang et al. (2017) estimated 95% of stress recovery at a distance of 0.17 times the cover depth of 298 m, while for Zhaogu No.2 Mine in Shanxi Province, China. Wang et al. (2017) reported 80% of stress recovery at a distance of 0.29 times the cover depth of 160 m for extraction height of 2.2 m. For a shallow depth working at a cover depth of 100 m, Singh and Singh (2011) estimated maximum stress recovery of 25% of the in situ vertical stress just after the main fall that increased to 50% at a distance equal to the cover depth. The summary of these findings is given in Table 2.4.

Table 2.4. Stress recovery and cover pressure distance in different conditions

Researchers	Depth of mines, m	Stress recovery (%)	Cover Pressure Distance to depth, H
Yavuz (2004)	400 – 600	Complete recovery	0.37H
Bai et al. (2014)	574	Complete recovery	0.42H
Li et al. (2015)	390	89%	0.23H
Wang et al. (2015)	900	Complete recovery	-
Zhang et al. (2015)	575	98%	0.18H
Zhang et al. (2017)	298	95%	0.17H
Zhang et al. (2018)	560	93%	0.11H
Zhang (2019)	400	Complete recovery	0.05 – 0.17H
Jiang et al. (2017)	625	Complete recovery	-
Wang et al.(2017)	160	80%	0.29H
Singh and Singh (2011)	100	50%	-

Bai et al. (2014) conducted the modelling study of goaf material in conjunction with spalling at the coal face, while Li et al. (2015), Wang et al. (2015), Zhang et al. (2015, 2017, 2018) considered the behaviour of yield pillar in conjunction with the caved goaf, and Jiang et al. (2017) evaluated the stability of gate road. Wang et al. (2017) assessed the stress recovery during the periodic caving of strata, while Singh and Singh (2011) estimated maximum goaf stress recovery during main fall and periodic caving with progressive mining.

2.4 Performance of Goaf Edge Support

In conventional depillaring workings, the goaf edge support comprises timber or steel chock/cog supports erected in combination with wooden/friction/hydraulic props to meet the requirement of high support density for avoiding goaf encroachment and over-riding of pillars. Cog supports are the conventional system of goaf edge support installed in the depillaring panels. The construction of the cogs for a depillaring face is described in

Regulation 124 of Coal Mines Regulation 2017 (DGMS, 2017). In some conditions, roof bolts have also been used, either single row or double row, to meet similar objectives. However, the withdrawal and installation of such support are pretty time-consuming, cumbersome, and impossible. Sometimes, it is not practically possible to deploy these supports immediately after the formation of the new goaf edge, causing a compromise in the overall effectiveness of their deployment. The support density provided by these supports is quite limited and primarily insufficient to act as an effective breaker line, particularly in massive strata formations. The mechanised mining system offers a faster rate of pillar extraction, which requires mobile goaf edge supports to enable their timely withdrawal and redeployment with moving goaf edge. Such supports provide compatible mobility, along with faster setting and withdrawal. They also offer a significantly high support density to meet the strata control requirement for safer depillaring in difficult to cave strata conditions. In general, the mobile roof support system is deployed in the retreat or depillaring panels of the Bord and Pillar workings, where the extraction is done using continuous miner. Mark and Zelanko (2001) also concluded that the MRS has better stiffness and higher capacity than the conventional goaf edge supports, providing safety to men and machinery at the goaf line from failure risk. Mark (2009) noted that 50% of the Room and Pillar workings in the U.S. having thicker seams at 228 – 670 m depth had deployed MRS. It provided better ground control in the mines at the deep cover, mainly prone to bumps. The support system assisted the rib in releasing the high stresses by controlling the line of caving along the goaf edge.

A mobile roof support (MRS) or mobile breaker line support (MBLS) initiates roof fall at the goaf edge without affecting the progressive face during its advancement. A typical

MRS has a base frame with four hydraulic legs, and a rigid canopy at the top altogether mounted on the crawler track assembly for movement. The canopy can move in transverse and horizontal directions. It was first deployed at Middlebult Mine, South Africa, in 1984, Cooranbong and Nebo Collieries, Australia, in 1987; and Donaldson Mine, West Virginia, in 1988. Over the period, its support capacity has been upgraded from 544 t to 1450 t (Thompson and Frederick 1986). Howe (1998) and Wilson (1991) also reported 600 – 800 t capacity MRS in U.S. and Austrian mines.

In India, IIT (ISM), in association with Jayabharat Equipment, has developed a two-legged Self-Advancing Goaf Edge Support (SAGES) which works in conjunction with stabilisers to provide the maximum support load density of 71.4 t/m^2 (Singh 2006). The support has been deployed in Bastacolla Colliery, BCCL and RK-7 Mine, SCCL. The support of 2 × 200 t capacity moves over a remotely controlled crawler-driven propelling unit. The closed and open heights of the support are 1.85 m and 3.2 m, respectively.

Barczak and Gearhart (1997) concluded that the vertical stiffness of MRS having two-stage hydraulic legs was higher as compared to the three-stage legs. The horizontal stiffness is height dependent and is lesser than the vertical stiffness. Chase et al. (1997) conducted a field investigation at Boone County Mine, West Virginia, where the fragile immediate roof caused the premature collapse of the pillars. A recovery rate of 85–95% could be obtained after the deployment of MRS along with the continuous miner. Maleki and Owens (1998) concluded that higher capacities and setting pressure of MRS were helpful in controlled load transfer of the main roof at the goaf edge during the periods of caving in the goaf. Maleki et al. (1999) noted that MRS could maintain the yield load to reduce roof-to-floor convergence to a significant amount. This support assists in the reduction of time-dependent roof fall when the mining cycle is faster. No roof fall could be recorded till the convergence rate was less than 0.5 cm/min. However, a convergence rate of 0.5 – 0.65 cm/min resulted in minor falls, while the critical roof fall had convergence rates exceeding 0.65 cm/min.

Maleki et al. (2001) noted that the MRS could achieve the yield load of 21 MPa during excavation of the final lift of the pillar. The average loading rate greater than 44 kN/min signified the roof fall in which the continuous miner and MRS get buried. In the lower range between the 22 – 44 kN/min, the roof is under pressure which might pose some strata control problems due to structural instability in the overlying roof strata. However, the range below the 22 kN/m was the safe range in which no roof fall was observed, and the problems of pillar stability were relatively low. Lind (2002a) noted that MRS deployed at the breaker line provides improved safety during depillaring as compared to the timber props. However, they cannot prevent goaf flushing during coal extraction. Lind (2002b) observed that the extraction percentage increased from 25 to 80 after incorporating three MBLS in a continuous miner working. In contrast, workings with timber props could obtain the maximum extraction percentage of 45 only.

2.5 Effect of Softcover

It is understood that the stiffness of the overburden plays a crucial role in the caving behaviour of strata and the severity of load transfer during the periods of major roof caving. Hence, a proper understanding of these issues is required for safer extraction of the pillars in workings having a considerable softcover in the overburden.

The study conducted by Sharma et al. (2020) for Kuiya and Phularitand Collieries in the Jharia Coalfield below the cover depth of 93 – 112 m for extraction height of 3 m showed that the FoS of the support pillars reduced in the presence of 42 – 49 m thick softcover. Liu et al. (2020) reported excessive stress concentration before the collapse of the roof at the goaf edge while working below the cover depth of 860 m having 649 m thick unconsolidated overburden at Zhaolou Mine in the Shanxi Province.

The coal mining regions in Huaibei, Huainan, Yanzhou, Datun, Jiaozuo, Pingdingshan, Yongxia, Kailuan and Xingtai, China, are under the thick cover of alluvium (Industry SBOC 2004; Liu et al. 2012). Yang and Xia (2013) reported severe roof collapse within the shortest settlement time in the depillaring panels at Lu'an Coal Mine under 198.95 m thick loose soil and thin hardcover of 10.35 m over the 3.5 – 5 m thick coal seam in the Shanxi Province. The maximum abutment stress occurred 5 – 15 m behind the working face. With an increase in thickness of the hardcover, the point of maximum abutment stress shifted 15 – 25 m ahead of the face (Yang and Xia 2018). Ju and Xu (2015) reported discontinuous subsidence during extraction of 7.2 – 16.4 m thick coal seam at Taian Coal Mine below the cover depth of 133.9 –177.7 m under 83.9–98.7 m thick loose soil and 50–80 m hard rock. The stepped subsidence was produced at the surface during the breakage of the parting strata. Prakash et al. (2018) reported maximum surface subsidence of 2.06 m above the depillaring working of Maheshpur Colliery below the cover depth of 54 m in the Jharia Coalfield. The extraction height of the coal seam was 3.05 m, whereas the overburden consisted of 34 m thick hardcover and softcover comprising of overburden dump of 20 m height.

The results of the numerical modelling study conducted by Zhao et al. (2019) for Zhaoguyi Coal Mine in Jiaozuo Coalfield below the cover depth of 493 m comprising 450 m of alluvium and 40 m of hardcover showed increased subsidence with an increase in the thickness of alluvium. The maximum subsidence decreased with the increase in cohesion and the angle of friction.

Guo and Zhao (2021) proposed a π-shaped rectangular model to explain the subsidence mechanism due to thick alluvium at the Zhaogu Coal Mine. The surface subsidence increased with the increase in bulk density of the stratum and the mining height but decreased with an increase in bulking factor and modulus of the goaf material.

Zhu et al. (2020) considered the case study of Heze coal area in the Shandong Coalfield with the unconsolidated layer of the average thickness of 651 m covered on the bedrock of 59.75 m thick had estimated the thickness of the transition zone as 262 m over the mine workings of the thickness of 10 m. They have termed the transition zone as the layer consisting of hard soil and soft rock and ascertained that the subsidence increases with the decrease in the bedrock and transition zone. Thus, the transition zone is the compacted layer inherited with cushioning effect to prevent uncontrolled deformation due to the load of the unconsolidated soft soil. Subsidence in the softcover condition is more significant than the intact overburden condition, as observed by Yang and Xia (2013), Ju and Xu (2015), Wang et al. (2019c) and Guo and Zhao (2021). The study of mining-induced subsidence reported by Prakash et al. (2021) also confirmed 1.58 times higher subsidence over the 60 m high dump than the intact condition during working in Adriyala Mine at the cover depth of 410 m.

The numerical modelling and field study conducted by Zhou et al. (2015) showed increased subsidence and goaf compaction under 200 – 300 m thick rock strata overlain by 160 – 500 m thick alluvium in the North zone of Huainan Coal Mine, as compared to the

South zone working under 20 – 40 m thick alluvium and 180 – 260 m hardcover. A similar study conducted by Zhang et al. (2016) in the Baodian mining area under the alluvium thickness of 207 m showed decreased deformation and fracture at the surface with the increase in thickness of the hardcover. The span of main fall and periodic caving decreased with a reduction in the thickness of the hardcover. Zhu et al. (2016) observed the front abutment stress of 37 MPa at 45 m ahead of the working face below the cover depth of 900 m at Xinjulong Mine in Shandong Province, China, under the highly thick alluvium of 600 m.

Wang et al. (2019a) considered the bottom part of the unconsolidated layer located above the parting strata as an arch structure in the overburden. They noted an increased lateral thrust and decreased shear force that resisted the load transfer of the voluminous softcover while working a 4.98 m thick coal seam in Shandong Province below the cover depth of 258 – 324 m. The overburden comprised 209 m thick unconsolidated strata and 85.29 m thick hardcover. A similar finding was made for the Shanxi Province working with 16.39 m thick coal seam below 83.95 m thick unconsolidated layer and 50 m hardcover. The interval of periodic fracture increased while the abutment stress at the working face decreased with the increasing thickness of the parting strata. Wu et al. (2020) also made a similar observation at Baodian Mine in the Shandong Province below the cover depth of 184.24 m comprising 142.98 m thick alluvium, 10 m aquifer and 31.26 m parting strata.

Wang et al. (2019b) concluded that the arch structure of the unconsolidated layer and the parting strata restrict fracturing of the overlying strata below the unconsolidated overburden. Wang et al. (2019c) noted the formation of stepped pressure arch causing a shorter weighting interval and higher abutment stress at the face at Daliuta Mine in the

Shandong mining area, having an extraction height of 5.4 m at the cover depth of 115.4 m, comprised of 14.8 – 50 m thick hardcover and 96 m thick softcover. The discrete element model showed that the rotating pressure arch in the 1.7 – 9.6 m thick immediate roof protected the stepped pressure arch in the goaf, causing reduced weighting severity during periodic caving.

Li et al. (2022) conducted a field study in the Guoton Coal Mine located in the Juye mining area, China, wherein hardcover varying from 35 – 110 m was overlain by the softcover of 590 m. Workings under the 53 m hardcover measured higher subsidence of 5.4 m, as compared to 2.46 m in the thicker hardcover. The hydraulic supports were also subjected to severe loading and a higher frequency of yielding in thin hardcover, as compared to the thick hardcover condition.

Xu et al. (2020) concluded that the thickness of the hardcover should not be less than 35.74 m to prevent the dead loading of the 48.4 m thick softcover in the Wulanmuhun Mine located below the cover depth of 97.77 m.

2.6 Summary

Based on the outcome of the literature study, it is understood that the depillaring workings in the Indian geo-mining conditions are mostly overlain by intact overburden. The influence of softcover on the loading behaviour of support pillars and the failure mechanism of the hardcover is not properly investigated. The studies conducted elsewhere show that softcover in the overburden significantly influences the severity of loading and deformation of the roof in depillaring workings. The support pillars are exposed to an increased load in the presence of the softcover. A suitable method of pillar extraction using continuous miner

(CM) and mobile goaf edge support (MGES) could enable faster extraction of pillars for improved recovery and safety in the working.

As the span of major fall increases and the front abutment stress reduces with an increase in thickness of parting strata and a simultaneous reduction in thickness of the softcover, a safe thickness of the parting strata between the caved zone and the softcover is essential for a controlled load transfer of the overburden and safer performance of the goaf edge support during progressive mining.

An in-depth understanding of the caving and load transfer mechanism of the hardcover under the influence of the softcover could be helpful in the development of design criteria for ascertaining the minimum thickness of the parting strata and the optimal support requirement at the goaf edge for effective goaf control enabling safer mining in such geo-mining conditions.