Underground extraction of contiguous coal seams/sections consisting thin parting: a case study

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Synopsis

Underground depillaring of contiguous coal seams/sections is a difficult problem, which becomes even more complex if the interburden/parting between them is thin. Conventionally, the depillaring with caving of contiguous seams/sections is done in descending order. However, if the parting is thin, the influence of the top sections/seams working over the standing pillars of bottom the sections/seams becomes extremely important for the safety and optimal exploitation of coal. Field investigations were carried out at Nowrozabad East mine where superimposed pillars of the Johilla top section were depillared above the developed pillars of the Johilla bottom section with a 3 m thick parting between the two sections. The competency of the 3 m thick parting (which consists of alternate layers of shale, sandstone and shaly sandstone) was improved by reinforcement (underpinning). The strata control investigations did not show any considerable instability problem of the 3 m thick reinforced parting and pillars of the bottom section due to top section depillaring. On the basis of this field investigation and a laboratory study on simulated models, simultaneous extraction of both the sections, along with reinforcement of the parting, was suggested for the geomining conditions of the Johilla top and bottom sections. Adopting the suggested simultaneous depillaring process, two sub panels of Johilla top and bottom sections have successfully been extracted without any strata control problem. This paper presents this case study along with the results of the strata monitoring conducted to evaluate performance of the underground structures during the field trial.

Introduction

In India, if two coal seams/sections are situated within 9 m distances of each other then they are termed contiguous seams/sections (CMR, 1957). The contiguous seams/sections are termed difficult coal seams/sections because the extraction of any one of them normally influences the safety of the other. As per the Coal Mines Regulations (CMR, 1957), development of contiguous seams/sections can be done with superimposed pillars and galleries formation. However, the parting thickness between the two superimposed developments of contiguous seams/sections should not be less than 3 m as per the regulation (CMR, 1957). If the parting between the contiguous seams/sections is only around 3 m, the underground mining of the seams/sections is difficult due to strata control problems like collapse of the parting and pillar load transfer. For such a situation, the conventional method of extraction with caving is to complete depillaring of the top seams/sections, first keeping the bottom section virgin. Once the depillaring in the top seam/section is complete, one waits sometime and allows the caved strata of the top seam/section to settle down. In fact, no standard procedure is available to check the status of the caved strata and, therefore, the commencement of depillaring in the bottom seam/section is generally delayed. During the working of the bottom seam/section with 3 m thick parting below the caved goaf of the top seam/section, the chance of strata control problems increases due to stress concentration over the remaining ribs inside the goaf of the top section/seam. Chances of heating, gas and water accumulation inside the goaf of the top section also influence the safety of the bottom seam/section working due to the presence of the thin parting/interburden between the two seams/sections.

An extensive study on simulated models was undertaken by CMRI (CMRI, 1999) to visualize safety during contiguous seams/sections, working. It was concluded during this study that the simultaneous depillaring of superimposed pillars of contiguous seams/sections provides better safety. Further, on the basis of the study on simulated models, it was observed that the safety of the 3 m thick parting could be improved by the rock mass reinforcing technique during the simultaneous extraction. Due to presence of working space in the top seam/section, the reinforcement of the parting is found (Singh *et al.*, 1999) to be comfortable, taking advantage of gravity. Although,

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laboratory investigations were supporting simultaneous extraction of contiguous seams/sections under the thin parting, field study of parting behaviour was thought to be necessary before going for a full-scale field trial of the simultaneous extraction. Considering all these facts, CMRI undertook the responsibility to conduct the parting stability study in the field for simultaneous depillaring of Johilla top and bottom seams/sections. In the first sub-panel, it was decided to extract the top section only, with caving keeping pillars of the bottom section intact. This exercise was planned to examine the influence of the top section depillaring over the parting of 3 m thickness and over the standing pillars/galleries of the bottom section. For this experiment sub-panel B of panel TE-14 was selected. After successful depillaring of the top section in the sub-panel B, simultaneous depillaring of Johilla top and bottom sections was carried out in the other two sub-panels, C and D, of panel TE-14, without any strata control problem. This paper details the results of the strata monitoring investigation conducted in different sub-panels of the Nowrozabad East Colliery (Figure 1).

Geology

The workable seams of Johilla Coalfield are under the Baraker formation of the Damuda super group. The generalized stratigraphical succession of the region is shown in Table I. Further, the workable seams of the Baraker formation are immediately over the Talchir deposits. The borehole sections of the overlying strata, as encountered in MPN 4 and SBH No. 3, are shown in Figure 2.

The Johilla seam of the Johilla area of South Eastern Coalfield Limited (SECL) is split into two sections, Johilla top and bottom, with an average thickness of 3.5 m and 2.8 m respectively. Thickness of parting between the two sections of the seam varied from 2 m to 4 m at the colliery and it consists of alternate layers of shale, sandstone and shaly sandstone. A number of panels in the Johilla top section have been depillared in the leasehold area of the mine in past 15 years. Six panels were extracted by normal caving method and ten panels were depillared by narrow panel method (Sheorey *et al.*, 2000) to avoid subsidence, since the area was under the highest flood level of the Johilla River and

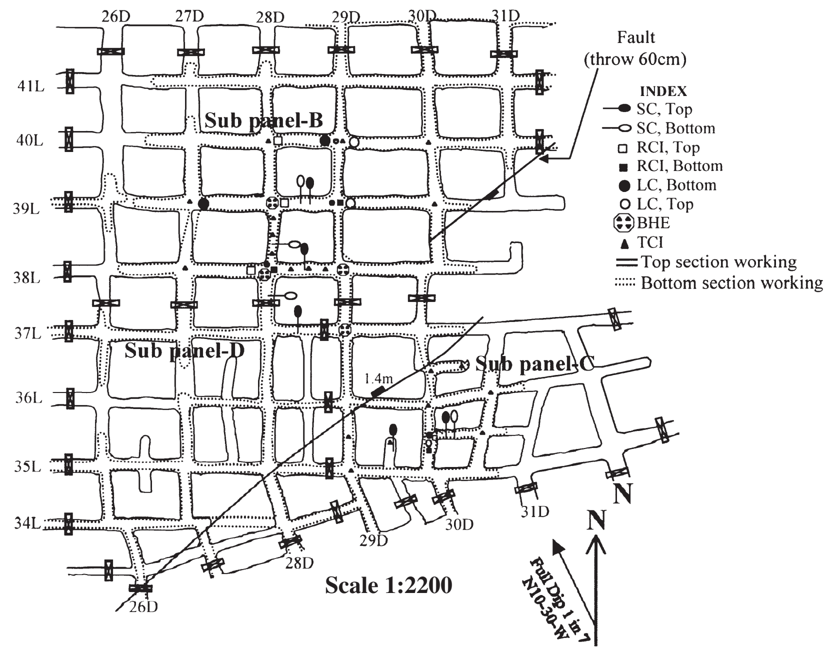


Figure 1—Plan of the observational sub-panels B, C and D (Panel TE-14), depicting instruments, position

Table I

Geological succession of Johilla Coalfield

Age	Formation	Lithology
Recent	Soil/Alluvium	Yellow to khaki coloured soils, boulders with loose sand.
Cretaceous	Lameta	Greenish to pinkish violet sandstone [not exposed/inter and nodular limestone (conglomeratic) intersected in the area] and clays.
		Unconformity
Late Triassic to Carnic	Supra Baraker	Medium to coarse-grained arkosic sandstone with shales and greenish to red mottled clays.
Lower Permian	Baraker	Fine to coarse-grained sandstone, grey shale, carbonaceous shale and coal-seams.
Upp. Carboniferous to Lower Permian	Talchir	Greenish sandstone and shales.
		Unconformity
		Pre-Cambrian gneiss's (not exposed/intersected in the area)

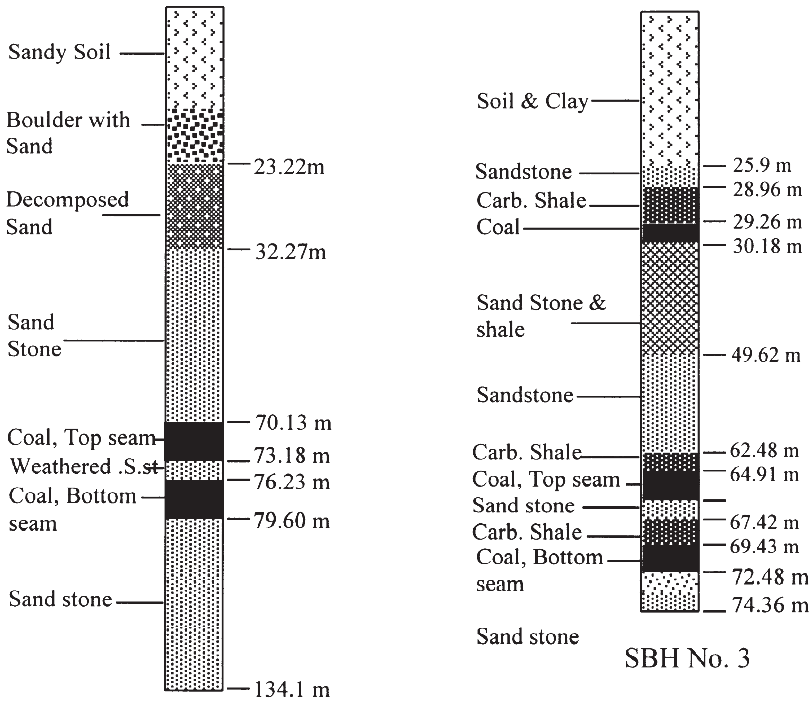


Figure 2—Sections of overlying rock strata encountered along borehole MPN 4 and SBH No. 3

Marzada Nallah. Nearly 1.57 million tons of coal reserve have been left in the bottom section under those depillared panels. In the panels TE-14 and TE-15, both top and bottom sections are developed on superimposed pillars and more than eighty pillars in each section are locked in pillars due to the contiguity problem. The rest of the leasehold area consists of the virgin bottom section under the developed top section.

Numerical modelling

CMRI study (CMRI, 1999) on simulated models showed that simultaneous depillaring of Johilla top and Johilla bottom sections are the best possible option for safe and economical exploitation of the top and bottom sections of the seam. However, the permission-granting authority of the country i.e. the Directorate General of Mines Safety (DGMS) expressed reservations about depillaring the two sections mainly due to the poor thickness of the interburden/parting between the two sections. Rock mass rating (RMR) (CMRI, 1987) of the parting was observed to be 41 only. Under the condition, the roof over the bottom section slice of 5 m width was likely to face instability problems. This instability could have endangered the safety of the workers and workings of both the sections, in addition to dilution of the coal quality. Reinforcement of the laminated parting was considered to overcome the parting instability problem for optimal extraction (Mandal *et al.*, 2002) of coal from the contiguous sections. In fact, application of reinforcement was to enhance the interface cohesion among the strata, resulting in an increase in the effective RMR of the roof rock mass. Underpinning* was thought to be the most effective means for meeting the above requisites. The banded roof of the bottom section i.e., parting was proposed to be pinned from the top downward through the development headings, splits, and slices of the top section. Full column grouted cables (using discarded haulage ropes) of around 19 mm diameter were used for the purpose at 1.2 m intervals. In this way, the banded parting could form a stable and strong composite beam. As no other yardstick was available to evaluate the impact of underpinning, efforts were made to use numerical modelling for this purpose.

Rock mass properties used for the modelling are given in Table II. Physico-mechanical properties of the parting and overlying roof rock mass for the modelling was obtained through core samples of the strata procured through a fresh borehole of 30 m length (Figure 3), drilled upward from the working horizon. This exercise also provided information about the caveability characteristic of the overlying roof rock mass for the proposed depillaring. A two-dimensional finite difference code, FLAC (Itasca, 1995), is used for this purpose. *In situ* stresses were simulated (Sheorey, 1994) according to the following equations:

$S_v = 0.025$ H MPa and $S_H = S_h = 2.4 + 0.01$H MPa

Where, H = depth cover in meter, S_v = vertical *in situ* stress, S_h = minor horizontal *in situ* stress and S_H = major horizontal *in situ* stress

As per Indian Coal Mines Regulations (CMR, 1957), the presence of a minimum 3 m thick parting between the two superimposed developments of contiguous seams/sections is a must. Generally stability assessment is carried out in advance for a parting of just 3 m thickness. At a few sites, parting instability problems were experienced during superimposed development of the two sections. The laboratory study on simulated models also indicated the need

*Application of a full column grouted cable bolt of suitable length in floor of the top section working

Table II

Material Properties as used in numerical modeling

Material	Young's modulus (MPa)	Poisson's ratio	Bulk modulus (MPa)	Shear modulus (MPa)	Density (Kg/m³)
Sandstone	6000	0.25	4000	2400	2548
Shale	5000	0.25	3330	2000	2200
Coal	2000	0.25	1330	800	1400
Caved rock	200	0.1	83	91	2000

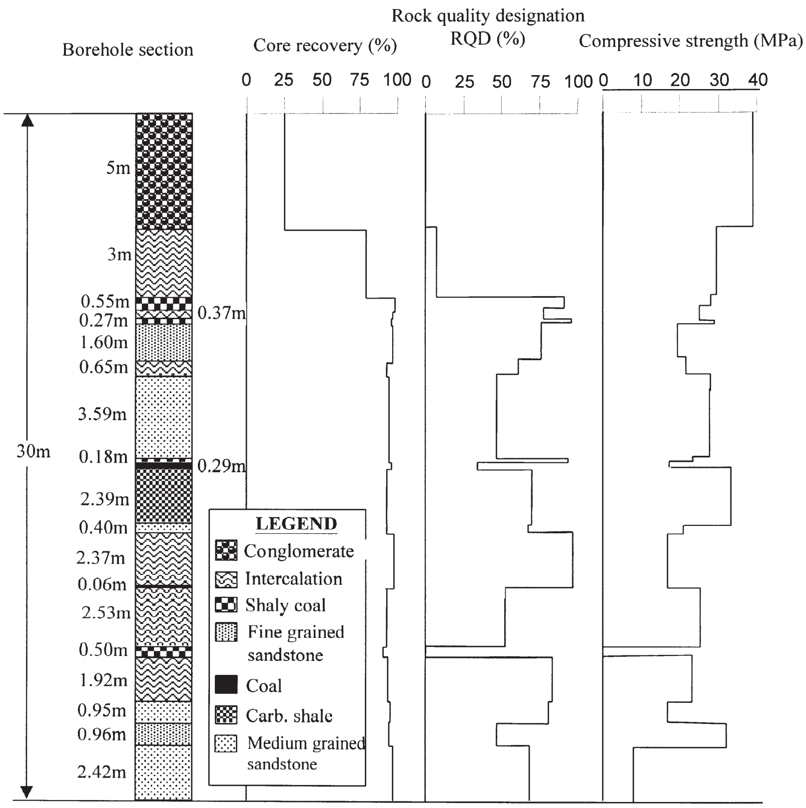


Figure 3—Geomechanical properties of the formation over the experimental panel

for reinforcement of the parting for better safety during working. Safety factor contours for the top and bottom section developments and for only the top section development in absence of reinforcement are shown in Figure 4a, while those for reinforced parting are presented Figure 4b. Inbuilt functions 'Struct' and 'Cabl' of Flac were used for simulation of the reinforcement. As demonstrated in Figure 4a, the almost complete thickness of the parting possessed one safety factor value after application of the coal evacuating machine (LHD/SDL) pressure over the parting. After adoption of the reinforcement (cable bolts), the safety factor of the parting improved (Figure 4b) and now almost the whole thickness of the parting possessed two safety factor values. These results of numerical modelling clearly demonstrated the potential of reinforcement to arrest the instability problem of the parting. In the absence of the reinforcement, progress of the depillaring process was likely to be hampered by the instability of the parting. Simulation of underpinning in numerical models indicated (Figure 4) that the pinned parting is competent enough for the short-term stability required for the depillaring. The numerical modelling was done in idealized laboratory conditions where exact simulation of the depositional conditions was difficult but the message of improvement in the parting stability was considered important. Taking advantage of this message, field studies were conducted at the actual site to visualize the competency of the 3 m thick reinforced parting for the depillaring.

Trial site

The study was conducted in panel No. TE-14 of Nowrozabad East mine, where top and bottom sections of the Johilla seam were developed on superimposed pillars. The incubation period of the coal was estimated to be six months. Considering this short span of the incubation period† and slow pace of the face advance, the panel TE-14 was divided into four sub-panels. In fact, intermediate mechanization was adopted for the depillaring as only the coal evacuation

†The time span between first roof fall and trace of fire in the goaf

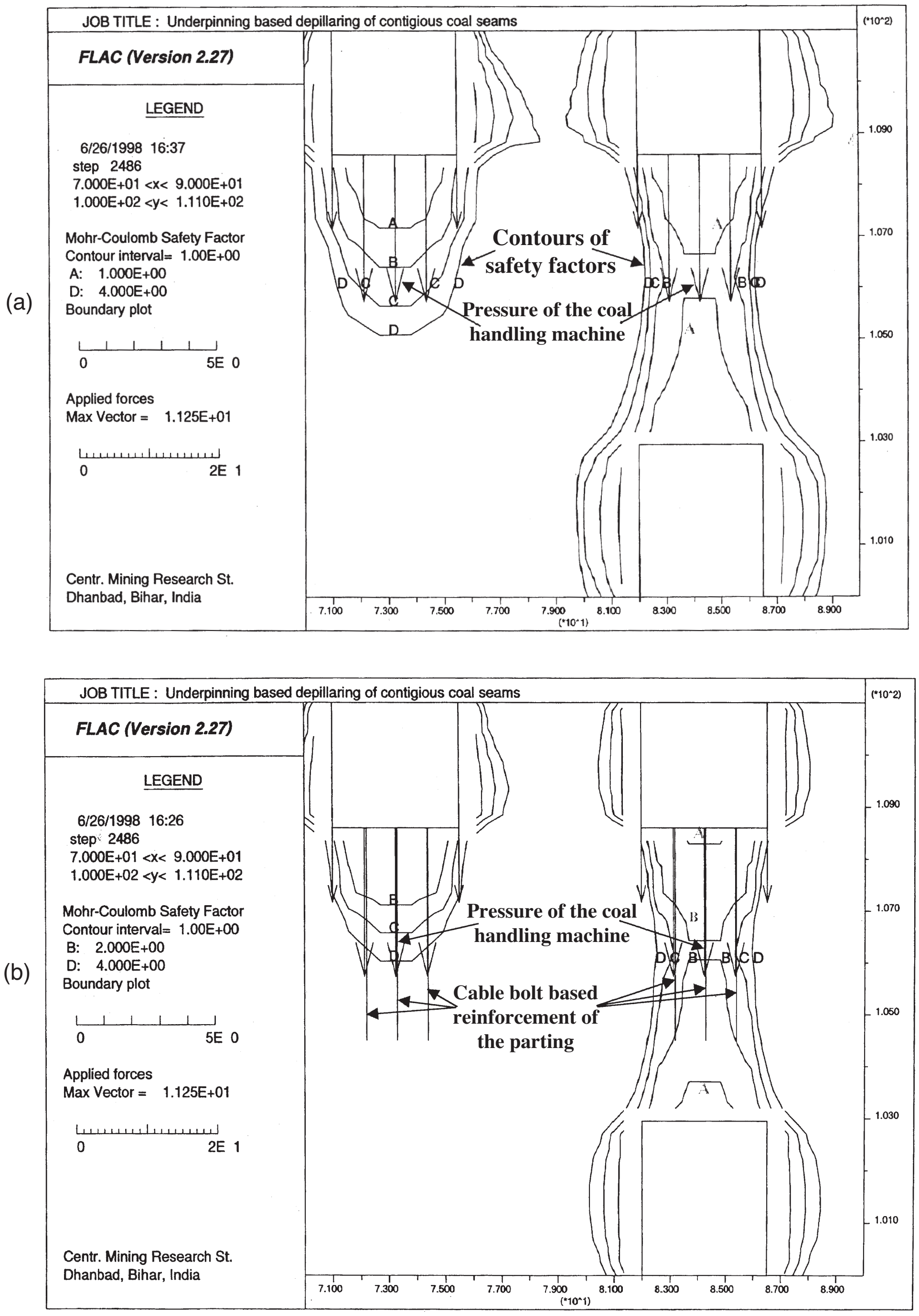


Figure 4—Simulation results for safety factor of parting without (a) and with (b) reinforcement

process was done through machines. A strata behaviour study was conducted in sub-panel B (Figure 1) where depillaring of the top section was done by caving while keeping the developed bottom section intact. Once the competency of the parting was proven, simultaneous extraction of both the sections was done in two other sub-panels-C and D. The strata behaviour study was also conducted during the simultaneous depillaring of top and bottom sections in sub-panels C and D. The operational parameters of the studied panel are summarized below:

Name of seam	: Johilla seam, split into Johilla top and bottom sections.
Name of the panel	: Panel TE-14 (sub-panels B,C and D)
Status of seam/working	: Top and bottom sections developed on superimposed pillars
Parting thickness	: 2 to 4 m, average 3 m
Seam thickness	: Top section 3 to 4 m, average 3.5 m Bottom section 2.6 to 3 m, average 2.8 m
Incubation period	: Six months

Gradient of seam	: 1 in 7
Depth of working	: 75 to 85 m
Method of working	: Bord and pillar method (the pillars were developed by conventional drilling and blasting)
Pillar size (centre to centre)	: Top section 30 m × 30 m Bottom section 30.2 m × 30.2 m
Gallery height	: Top section 3.5 m Bottom section 2.5 m
Gallery width	: Top seam 5.0 m Bottom seam 4.5 m
RMR of parting	: 41
Compressive strength of coal	: 30 MPa
Compressive strength of parting	: 18.1 MPa (weighted average)

Splitting and slicing was adopted for depillaring in the panel and the manner of pillar extraction is shown in Figure 5. The conventional system of drilling, blasting and manual loading was adopted for winning of coal from the panel. The support system for working places, goaf edges, galleries and splits for the depillaring of the sections/seams at Nowrozabad Colliery was designed as per Systematic Support Rule (SSR) (CMR, 1957). Steel cogs (made of G.I. pipes) and wooden props and cogs were erected at different places with different frequencies to meet the required support density of the workings. To strengthen the parting, top section floor stitching and bottom section roof stitching are done using haulage rope of around 19 mm diameter. Taking advantage of available roadways in the top section of the seam, parting was supported by floor stitching (underpinning) of 1.5 m length as shown in Figure 6. The interval between two rows of roof stitching was kept at 1.2 m. At least a 1.5 m length of the rope was anchored inside the pillars at an angle of 45° on both sides. Old haulage ropes were used for the stitching of the parting.

Instrumentation

An extensive strata movement monitoring programme was undertaken to understand the interaction between top section working and standing pillars of the bottom section. The following instruments were installed at different observation stations of the experimental panel TE-14 (Figure 1) to study the strata control parameters:

- Remote convergence indicator (RCI, potentiometer type, accuracy—0.3 mm).
- Stress meter (SC, vibrating wire type, accuracy—0.002 MPa).
- Electronic Load cell (LC, accuracy—0.001 ton).
- Borehole extensometer (BHE, accuracy—0.5 mm).
- Telescopic convergence indicator (TCI, accuracy—0.5 mm).

Before the commencement of extraction in the top section, the observation sites were selected in both the sections and instrumented with these instruments. To reduce the barrier effect, the observation sites were selected from the middle row of the pillars and their positions were chosen in such a way that they were expected to experience maximum abutment loading/convergence during different stages of the extraction. Stress meters (vibrating wire type) were installed in horizontal holes across each observation pillar. All these stress meters were installed vertically inside the hole and so the induced stresses measured and discussed in this paper are the vertical ones only. The position of a stress meter inside the pillar was chosen in such a way that it remains in the centre of the stooks/ribs even after splitting and stooking of the pillars. Stress meters were also installed inside the solid coal pillars of the bottom section to study the stress development over these pillars due to top section working. The distance of the bottom section instrument from the goaf edge of the top section was easily estimated as both the sections had almost superimposed pillars and galleries.

Measurement of roof to floor convergence was done in two steps. When the area was accessible the measurement was done by telescopic convergence indicator (TCI). When the

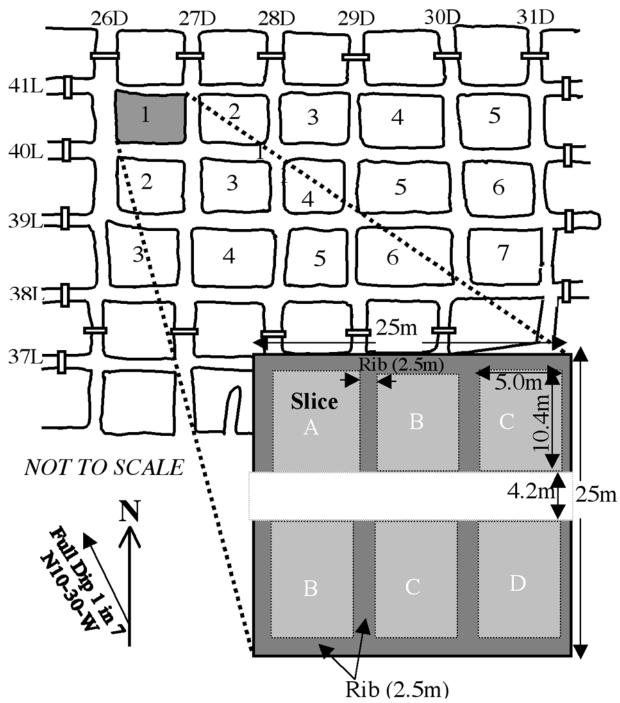


Figure 5—Manner of slicing for final extraction of a pillar from sub-panels B

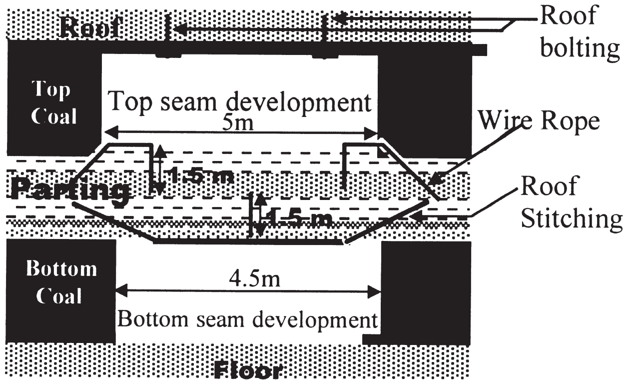


Figure 6— Reinforcement pattern of the parting for simultaneous depillaring

observation point went inside the goaf, then the measurement was done by remote convergence indicators (RCI) at the same observation point. RCI is nothing but a simple spring- loaded potentiometer, erected against roof and floor with a telescopic arrangement. A number of stations were installed in both the top and bottom sections for TCI to monitor roof to floor convergence along the accessible areas of the gallery and gallery junctions. Once these observation stations reached near the goaf edge with face advance, RCIs were installed at all these observation stations and their leads were taken out to a safe observation place in the panel to extend the study inside the goaf edge. These RCIs were installed in top and bottom sections. To measure the load on props/chocks load cells, (LC) were installed (Figure 7) over the props/chocks in the top and bottom sections. These load cells were shifted to new locations as the goaf edge advanced from dip to rise, maintaining the diagonal line of extraction. To monitor bed separation of the parting, different anchors of borehole extensometers (BHE) were installed at different depths inside the parting at four different junctions of the bottom section. One anchor of these extensometers was installed in the lower layer (roof of the bottom section) and other anchors were installed at 2.25 m, 1.5 m and 0.75 m inside the parting, as shown in Figure 8. Observations of these instruments were taken regularly since commencement of the depillaring in the panel and continued till close of the panel.

Top seam depillaring

With the advance of the depillaring face, occurrences of roof falls were regular, with similar characteristics, and did not exert untoward incidence over the working face and ahead of the working. The pillars and bords of the bottom section, below the caved area of the top section, remained undisturbed and were easily accessible even after the main fall in the top section. Visual inspection of parting from the galleries of the bottom section (exactly below the caved goaf of the top section) noticed no physical damage in the parting and was found intact even after the roof falls in the top section. During the monitoring period in the panel, no considerable surface subsidence was noticed over sub-panel B. The history of the roof falls in sub-panel B is given in Table III. Generally, after roof falls, there was always an overhang of the cantilevered strata over the goaf, which is also obvious from figures given for the cumulative area of exposure and cumulative area of fall in Table III.

Strata behaviour study

The strata control study was conducted only for reinforced parting because the permission granting authority, i.e. DGMS, did not allow working without reinforcement in view of their past experience of parting failure.

Stress variation

The stress meters in the top section recorded a nearly uniform rate of increase of stress as they approached close to the goaf edge. The observed changes in stress over

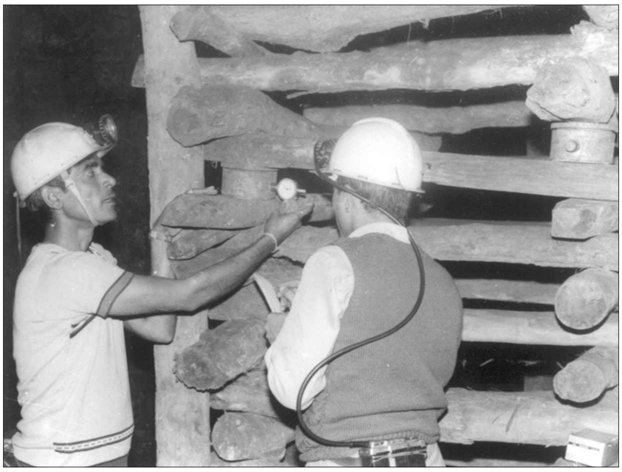


Figure 7—A load cell (mechanical type) installed in the wooden chock

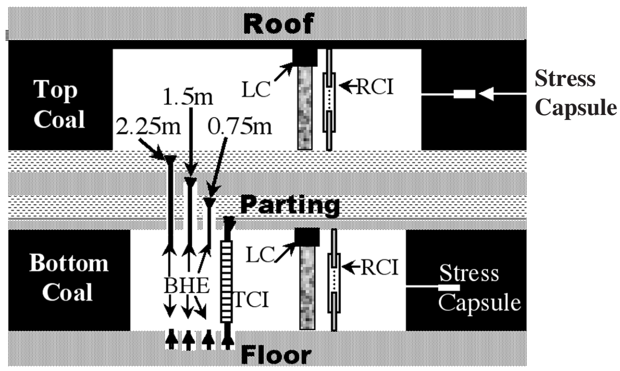


Figure 8— A typical sectional view of different instruments in the top, bottom and parting of the Johila seam

Table III

History of roof falls in sub-panel B of panel TE-14

Roof fall	Date	Description	Cumulative area of exposure (m^2)	Cumulative area of fall (m^2)
1st roof fall	04.7.2000	Local	1,700	300
2nd roof fall	20.7.2000	Local	3,038	1,140
3rd roof fall	29.7.2000	Main	4,062	2,800
4th roof fall	03.8.2000	Local	4,440	3,040
5th roof fall	08.8.2000	Local	5,065	3,980
6th roof fall	22.8.2000	Main	6,358	5,496
7th roof fall	08.9.2000	Local	8,615	6,430
8th roof fall	23.9.2000	Main	9,732	9,102
9th roof fall	27.9.2000	Local	11,355	9,627

pillars/stooks/ribs of the top and bottom sections of the seam with respect to face advance during depillaring of the top section are depicted in Figure 9. A rib of 5 m × 10 m dimension was left with each stress meter to observe the stress change within the goaf. During the first main fall the stress meter of the top section at 15 m distance from the goaf edge, recorded a stress change of 1.4 MPa and the other two stress meters, at 30 m and 50 m away from the goaf edge, recorded a stress increase of 0.09 MPa and 0.037 MPa, respectively. In the bottom section, the stress meter, 14 m ahead of the top section goaf edge, recorded a stress change of 0.28 MPa at the time of the main fall in the top section. Whereas the other two stress meters in the bottom section at 27 m and 46 m away from the top section goaf edge recorded no change in stress. Before the second main fall, the stress meter at the goaf edge of the top section recorded a stress change of 2.7 MPa, whereas the other two stress meters, at 19 and 35 m away from the goaf edge, recorded stress increases of 0.3 MPa and 0.18 MPa, respectively. Before the 7th local fall, a stress meter near the goaf edge recorded 0.6 MPa of induced stress. Thereafter a small release of stress was noticed due to the roof falls. After that stress started gradually increasing over it. When the stress meter was around 15 m inside the goaf edge, it recorded a maximum stress of 3.7 MPa just before the third main fall. The other stress meter, which was at the barrier pillar, recorded a stress change of 0.86 MPa during the main fall, while in the bottom section, one stress meter, 10 m inside the goaf edge of the top section, recorded a stress change of 0.8 MPa. This value of mining-induced stress reduced to zero after the main fall in the top section when this station was nearly 10 m inside below the top section goaf. In the bottom section, the other two stress meters, 5 m and 24 m away from the top section goaf edge, recorded cumulative stress increases up to 0.4 MPa and 0.12 MPa, respectively. In the bottom section the stress meter in the barrier pillar recorded no change of stress during the main fall in the top section. However, the maximum observed value of stress increase over barrier pillar of the bottom section was 0.37 MPa only.

Convergence variation

The average value of convergence observed by telescopic convergence indicator in the top section was 7 mm. On the other hand, the average value of convergence recorded by the telescopic convergence indicator in the bottom section was 1 mm only. In fact, remote convergence indicators were installed near the goaf edge to monitor roof-to-floor convergence inside the goaf. A typical observed variation roof-to-floor convergence in the top section with face advance is shown in Figure 10a. Here, the RCI recorded a cumulative convergence of 39 mm, before being damaged by the roof fall around 15 m inside the goaf edge. Just before the roof fall, this RCI picked up 15.5 mm of convergence in one day. The remote convergence indicators installed in the bottom section gallery junctions recorded a cumulative convergence of 2.72 mm and 1.52 mm respectively during the first main fall when they were 5 and 43 m away from the top section goaf edge (Figure 10b). During the second main fall these two remote

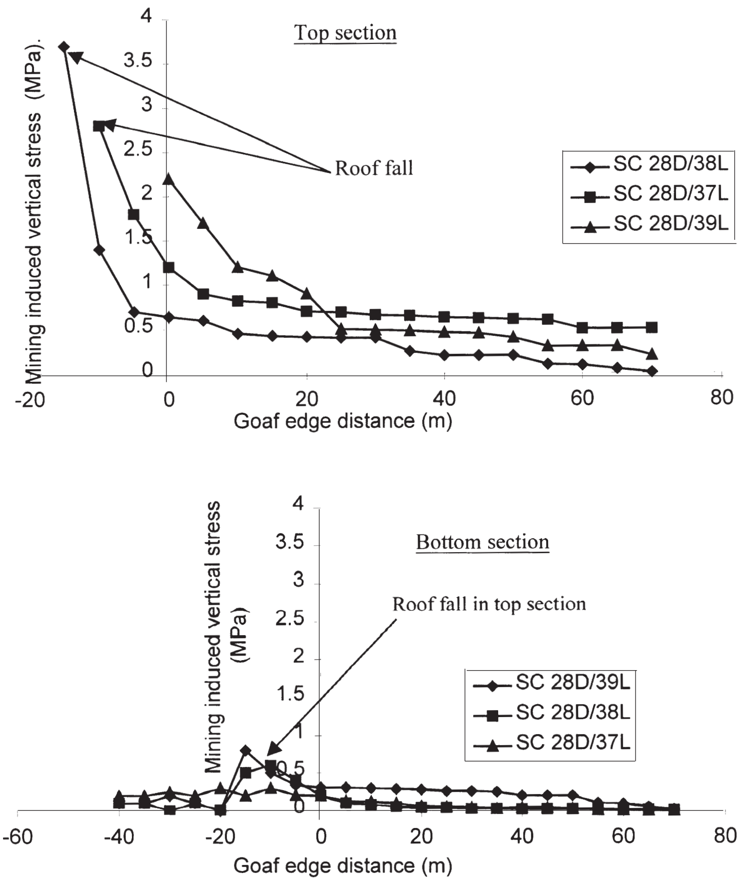


Figure 9—Development of mining-induced stresses over pillars/stooks/ribs of the top and bottom sections with face advance

convergence indicators, 12 m inside and 27 m away from the top section goaf edge, recorded a cumulative convergence of 4.40 mm and 1 mm, respectively. Regular monitoring of convergence in bottom section gallery junctions revealed that there was no considerable convergence between the parting and bottom section floor when they approach near the goaf edge. However, some convergence (max. 4.4 mm) was recorded in bottom section due to strata movement in the top section. The observed variation of convergence between the parting and bottom section floor became almost stable (Figure 10b) deep inside the goaf. Roof-to-floor convergence in the bottom section was observed mainly below the active region of the goaf of the top section.

Load variation

In the absence of hydraulic steel supports, natural supports i.e. pillars/stooks/ribs played an important role during the depillaring. As per the manner of pillar extraction, a rib of 2.5 m width was left against the goaf for each slice of 5.0 m width. These ribs were found effective for the required short-time stability due to a relatively higher value of compressive strength (30 MPa) of the coal. However, the slices and goaf were also supported by wooden props and chocks. The load cells were installed below these wooden props/chocks, which offered poor stiffness and a low value of setting load, so the observed value of the load remained relatively low. During the top section workings the maximum change in load recorded at the goaf edge was 8.2 ton before roof fall. At the gallery junctions of the bottom section, the observed maximum loads on two props were 2.2 and 1.7 only (Figure 11) when these props were around 15 m inside the goaf edge of the top section.

Parting separation

The borehole extensometer installed in the parting, to monitor separation in the parting layers over different gallery junctions, recorded no bed separation during the depillaring of the top section. In fact, the little roof convergence noticed in the bottom section galleries was due to bending of the parting as a whole. There was not much freedom given to the parting as the span of the bottom section gallery was 4.5 m only and they were put under a situation of a clamped beam. No crack or loosening of the parting material was noticed during the entire period of top section depillaring.

Few pillars of the bottom section experienced side spalling (max. 1m deep) when they came directly below the top section goaf. This spalling was limited to those pillars, which consisted of slip planes close to the edge of the pillar.

Simultaneous depillaring

Underground instrumentation and monitoring of strata control parameters in both the sections during depillaring of the top section in sub-panel B revealed competency of the reinforced parting to sustain the dynamic load of successive roof falls in the top section. No considerable impact of top section caving over the standing pillars/galleries of the bottom section was observed during the study. However, the depillaring of the bottom section below the caved goaf of the top section was an extremely difficult task. Conventionally, a bottom section can be depillared after settlement of the top

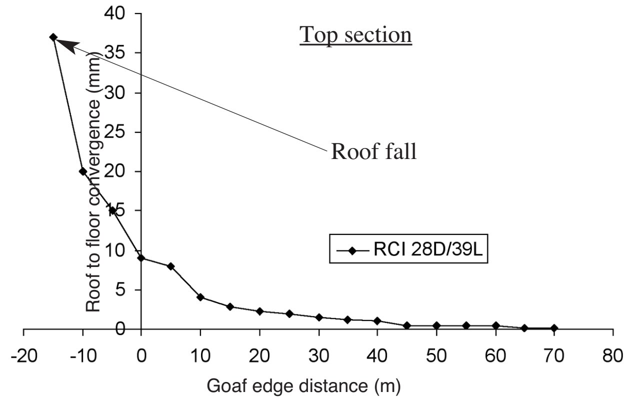


Figure 10a—A typical variation of roof-to-floor convergence with face advance in the top section of sub-panel B

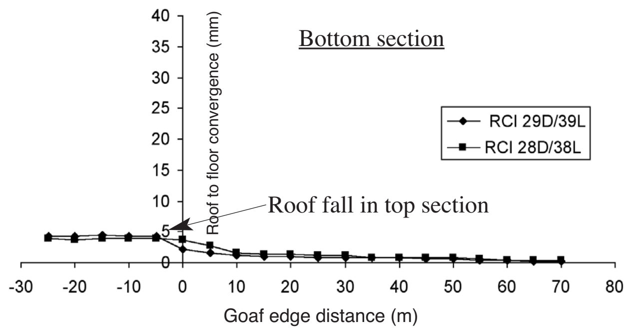
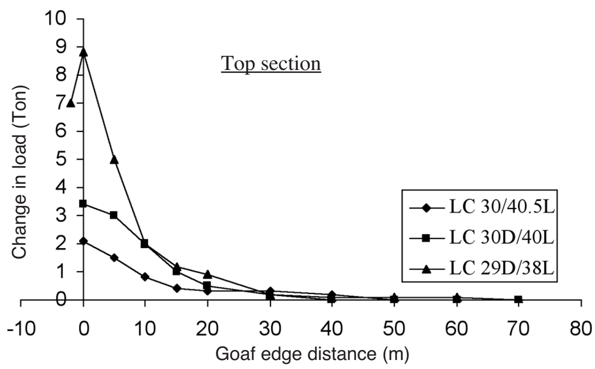


Figure 10b—Convergence observation in the developed bottom section during top section depillaring in sub-panel B



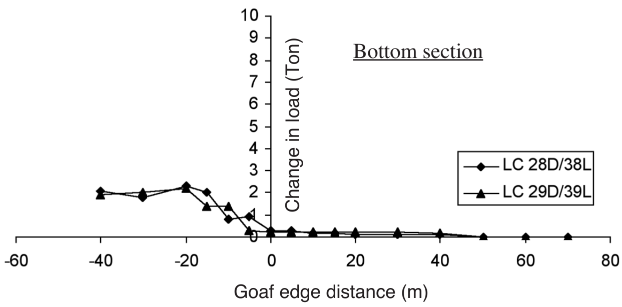


Figure 11—Variation of load on support with face advance during top section depillaring in sub-panel B

section goaf. However, the poor thickness of the parting, along with other safety problems, mentioned above, restricted the depillaring of the bottom section below the goaf of the top section.

The above mentioned problems of independent working of the two sections can easily be eliminated through simultaneous depillaring of the Johilla top and bottom sections. Results of strata control observations conducted in both the sections during depillaring of the top section in sub-panel B and the results of the numerical modelling study (CMRI, 1999), both favoured simultaneous extraction of the two sections. Considering these facts, simultaneous depillaring of the Johilla top and bottom sections was carried out in sub-panel C. To understand the performance of the simultaneous depillaring, a strata behaviour study (similar to that conducted in sub-panel B) was conducted during the simultaneous working in this sub-panel. The first roof fall in sub-panel C occurred in the top section after an area of exposure of approximately 2 200 m^2 and it packed the extracted area of approximately 1 900 m^2. In fact, not all the exposed area experienced roof fall; this is mainly due to overhang and cantilevering of the roof strata. The second roof fall occurred after additional exposure of a nearly 1 700 m^2 area. After an exposure of 4 400 m^2 of area, a major roof fall took place. Due to the broken nature of the depillaring face it was difficult to keep the two faces exactly superimposed. In fact, it was observed to be safe to keep the top section face, at least, half pillar ahead of that of the bottom section. The practice of keeping the top section face ahead of that of the bottom section was a must for the working. The size of sub-panel C was kept small, mainly due to apprehension about the success of the simultaneous depillaring and short incubation period of the coal. The size of the panel influenced the observed values of strata control parameters. There was not a single incidence of parting and pillar failure, and the underpinned parting was found competent enough to resist the impact of the main fall in the top section.

Strata behaviour study

The stress meter, which was at the goaf edge of the top section, recorded a stress change of 0.31 MPa during the first roof fall. Maximum stress recorded at this location was 0.84 MPa when the instrumented stook/rib was 5 m inside the goaf. The other stress meter in the top section, 12 m away from goaf edge, recorded a stress change of 0.23 MPa during the first roof fall. Observed maximum stress change at this location was 0.48 MPa before the stress meter was damaged by the roof fall. In the bottom section the nature of variation of mining-induced stress was observed to be similar to that of the top section. The maximum recorded amount of induced stress was 0.32 MPa only when the instrumented stook/rib was 5 m inside the goaf. The bottom section face remained below the distress zone of the top section working, which might have resulted in a low value of mining-induced stress in the bottom section. Observed changes in induced stress are shown in Figure 12.

The observed value of the convergence ahead of the face remained low in both the sections. The maximum recorded value of convergence by telescopic convergence indicator in the top section was 5 mm. On the other hand, the maximum

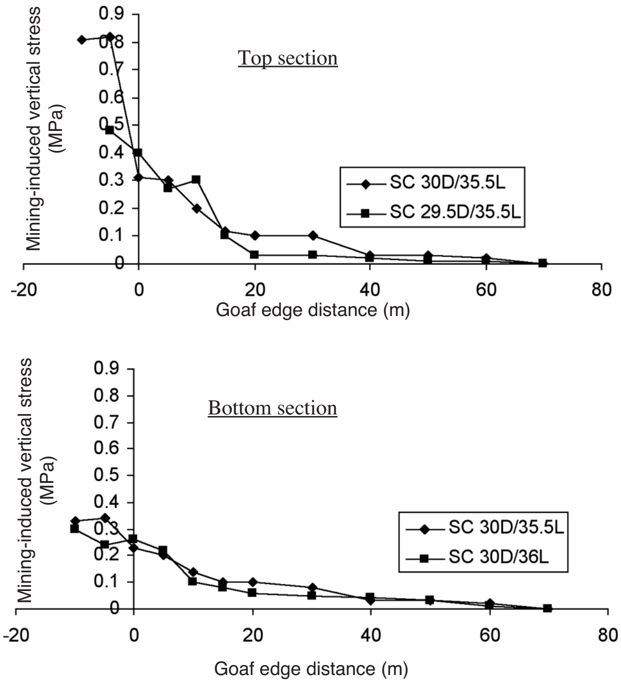


Figure 12—Development of mining-induced stresses over pillars/stooks/ribs in sub-panel C during simultaneous extraction of top and bottom sections

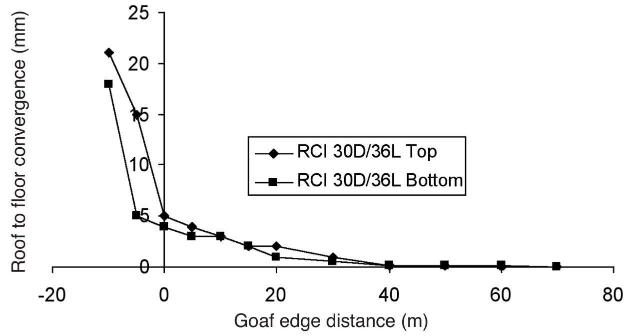


Figure 13—Convergence observation in sub-panel C during simultaneous extraction of top and bottom sections

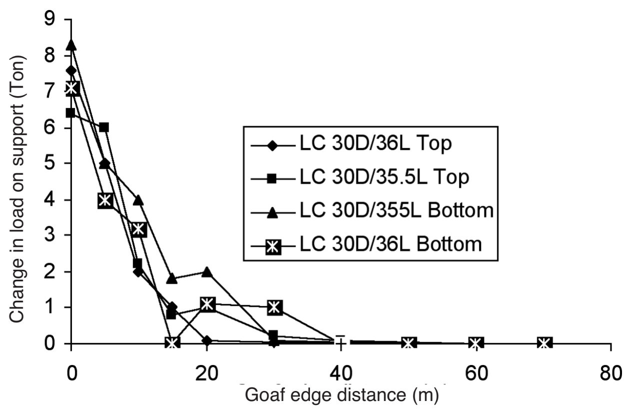


Figure 14—Load observation in sub-panel C during simultaneous extraction of top and bottom sections

recorded value of convergence by telescopic convergence indicator in the bottom section was 4 mm only. Once the observation point went inside the goaf, the convergence increased rapidly. Remote convergence indicators (RCI), installed at the top and bottom sections, recorded maximum cumulative convergence of 16 mm and 14.8 mm, respectively before getting damaged by a roof fall. A typical observed convergence variation in the top and bottom sections is shown in Figure 13.

Variation of load on support with face advance in the top and bottom sections was observed through mechanical-type load cells. This measurement was done only up to face line as the load cells were also withdrawn with the support. The value of the load increased with face advance and, generally, the load cells close to the face and just before the roof fall, observed a maximum value of load. During the first roof fall, two load cells of the top section recorded 1.45 t and 3.89 t loads when their distances from the goaf edge were 8 m and 6 m, respectively (Figure 14). Maximum observed load in the top section was 7.5 t while for the bottom section this value was 8.2 t.

Generally, after every 2–3 local falls in the top section, fall of the parting in bottom section took place. It was also noticed that the main fall of the top section did not propagate through the parting instantaneously. The parting between the two sections was able to sustain the impact of even main falls. After a local or main fall in the top section, parting failed generally after a period of 8 to 12 days. There was no perceptible spalling in pillars facing goaf lines. Ribs near the goaf edges were judiciously reduced to the minimum for the safety of the workings and at most of the places was blasted and withdrawn, except stump near the split. After each main fall almost 50–70% packing of goaf was noticed by the visual observations. Parting instability problems, generally faced during independent working of the two sections, due to stress concentration over the left out ribs/fenders inside the goaf of the top section, remained absent during the simultaneous working.

Conclusions

The competency of the reinforced parting could be established through the strata behaviour study during depillaring in the top section, keeping the pillars of bottom section intact. Here, pillars/galleries of the bottom section did not experience any instability problem, even after they were directly below the top section workings and goaf. The observed value of mining-induced stress in the top section went up to 3.7 MPa over the pillar/stook, while the maximum value of the induced stress in the bottom section was 0.8 MPa only. Even this value of mining-induced stress over the pillars of the bottom section got released soon after the roof fall above in the top section. Further, the instruments of the bottom section did not notice any dynamic pillar load transfer phenomenon due to the top section working. On the basis of these field results, and also as per the laboratory studies on simulated models (CMRI, 1999), simultaneous extraction of top and bottom sections was found most suitable for the geomining conditions of the Nowrozabad East Colliery and adopted successfully in sub-panel C. The observed value of strata movement and mining-induced stress over pillars during the simultaneous extraction remained relatively low and the working did not face any strata control problem. Simultaneous extraction of the contiguous sections may be adopted at other sites with similar geomining conditions.

Acknowledgements

The authors thank the Director, CMRI, for his permission to present this paper. The results of this paper are partially based on a Science and Technology (S&T) project funded by the Ministry of Coal (Government of India) and supported by the Central Mine Planning and Design Institute Limited of Coal India Limited. The authors are obliged to the colliery management of SECL for their valuable co-operation during the field observation. The views expressed in this paper are those of the authors and not necessarily of the institute to which they belong.

References

1. CMR. The Coal Mines Regulations 1957. (ed.), L.C. Kaku, Lovely Prakashan, Dhanbad. 2000.
2. CMRI Report (unpublished). Feasibility of extraction of Johilla top and bottom seams at Nowrozabad (East) Colliery, 1999. 23 pp.
3. CMRI Report (unpublished). Geomechanical classification of coal measure roof rocks vis-à-vis roof supports 1987. 125 pp.
4. ITASCA. *Fast analysis of continua in two dimensions*. Itasca Consulting group Inc., Minnepolis, Minnesota, USA. 1995.
5. MANDAL, P.K., SINGH, A.K., SINGH, O.P., BURAGOHAIN,J., and SINGH, R. A novel method of mining for underground winning of contiguous sections of a coal seam under fragile parting, *Journal of Mines, Metals and Fuels*, vol. 50, nos. 1 and 2, 2002. pp. 25–33.
6. SHEOREY, P.R., LUI, J.P., SINGH, K.B., and SINGH, S.K. Ground subsidence observations and modified influence function method for complete subsidence prediction. *International Journal of Rock Mechanics and Mining sciences*, vol. 37, 2000, pp. 801–818.
7. SHEOREY, P.R. A theory for *in situ* stress in isotropic and transversely isotropic rock. *International Journal of Rock Mechanics and Mining Sciences*, vol. 31, no. 1, 1994. pp. 23–34.
8. SINGH, T.N., MANDAL, P.K., and DUBEY, B.K. Technology for extraction of clean coal from contiguous seam sections under fragile formation, *Clean Coal: proceedings of the international symposium of Clean Coal Initiatives* (CCI - 99), 22–24 January, New Delhi, (eds.) T. N. Singh and M. L. Gupta, Oxford & IBH Publishing Co. Pvt. Ltd, New Delhi, India, 1999. pp. 111–121. ◆

New deal to optimize local mining productivity*

Reid and Mitchell are to distribute Tritronics Production-Monitoring products in South Africa.

In terms of a recently signed agreement, the Johannesburg-based company will gain exclusive local rights to the Production Monitoring brand, providing comprehensive local technical support to customers, and using knowledge of South African mining operations to further penetrate the market.

Australian-based Tritronics has led the way in the design and installation of mine machine monitoring and information systems since 1975.

The company was recently bought by Leica-Geosystems, a leading company in spatial data management and the manufacture of systems and solutions for modelling and visual representation of collated data.

The Tritronics family of products combines powerful reporting and analysis software with radio telemetry, GPS-based navigation, and relation databases to deliver near real-time information on the location and operating parameters of draglines, haul trucks, loaders, shovels, bulldozers and blast-hole drills.

User-friendly reports enable mine managers to make informed decisions on improving productivity.

Tritronics has installed equipment at 52 mines in four countries including South Africa, where a KwaZulu-Natal minerals extraction company uses the system in an asset management application to monitor mining equipment utilization and to optimize fuel consumption.

Commenting on the South African distribution agreement, Reid and Mitchell engineering manager Boris Breganski said that by combining an excellent product with his company's extensive experience of local mining operations, the stage was set for dramatic improvement in mining machinery productivity.

'In essence the systems give mines information to manage. Instead of wasting fuel, for example, you are able to maximize the use of assets to mine the maximum possible tonnage,' Breganski said.

'I believe that the Tritronics product family is unrivalled.

'Mines worldwide have seen these products deliver an increase in productivity linked closely with the very high quality of information that the products make available,' Breganski said.

The Tritronics product suite is modular in design, and comprises four lines, all of them open-architecture and designed around real-time reporting.

On major products, common hardware platforms reduce the number of spares to be carried.

First in the family is the fleet monitoring system (FMS), designed for opencast mining and using GPS to deliver accurate production statistics and vital signs, monitoring.

Each payload is tracked from loading to dump, and the system can automatically manage load materials and detect queuing and loading of trucks fitted with weighing systems.

Shovelpro, the second product in the suite, is designed to integrate electric shovels with FMS, accurately monitoring shovel loads and delivering to management instant feedback on production rates, current dipper weight, and what is required to load the haul truck to its targer weight.

The system allows operators to evaluate their performance against their peers by using key performance indicators as part of the screen presentation to the operators.

The third product, the 9000 Series-3 Dragline Monitor, uses leading technology to deliver comprehensive information about each dragline cycle, including production rates and the accurate measurement of repetitive weights in each bucket.

Tritronics claims System 9000 to be the most advanced dragline monitor in the world, using newly developed algorithms to calculate bucket weight during the swing cycle. Blasting can be quantified owing to the accurate measurement of fill time, drag distance, production and a digability index developed by reference to the original blast hole.

There are a number of add-on options to System 9000, including Duty Meter, Dragline Navigation, and Boom Anti-Tightline protection systsems.

Duty Meter facilities stress management of the boom, a vital component of the dragline, while Dragline Navigation aids the environmental management of the opencast mine, allowing first-time operators to see in real time the actual position in relation to themselves.

It also allows planners to plot production and use a telemetry system to download these maps directly to the dragline operator.

DrillNav Plus, the fourth product in the family, is a drill navigation system that uses advanced GPS technology to design drill patterns in the office and download them to the drill.

As the drill navigates around the pattern, the map moves on the operator's display, showing him where each hole should be drilled and the location of holes drilled previously. DrillNav Plus eliminates the need for surveyors or drillers to stake a pattern, and reduces losses by over-or under-drilling.

Reid and Mitchell have spent the last quarter of 2003 preparing the workshops and technical support necessary to effectively implement the Tritronics product distributorship.

Geoff Baldwin, former managing director of Tritronics and now vice president, machine automation for Leica-Geosystems, has put his full backing behind the Reid and Mitchell agreement.

'We feel that it is important to have local people with local knowledge based in local areas distributing and supporting our products. Reid and Mitchell have an excellent track record in the industry and we believe they have the right credentials for success in South Africa. We are very excited about the agreement,' he said.

Active marketing of the products is to start in 2004. However, Breganski has said that Reid and Mitchell are already in contact with a number of potential customers, and emphasized that products are available. ◆

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