Investigation and analysis of strata control problems in continuous miner workings

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Abstract

In India, bord & pillar and longwall mining methods have been adopted for the last several decades for extraction of coal from underground. In recent years, continuous miner technology has been introduced in several coalfields. This is a low capital intensive mechanized technology, and has the advantage of faster rate of production as well as safety.

The continuous miner was used both for regular depillaring in a bord & pillar panel with caving, and also for partial extraction using yield pillar technique. NIRM carried out instrumentation and strata behavior monitoring during the extraction using the continuous miner to evaluate the method under different geo-mining conditions. This paper details the results of the studies in three panels at SCCL, and discuses the strata conditions during the coal extraction vis-à-vis the instrumentation monitoring data.

1. Need for Mechanization in India:

Since nationalization in 1973, the Indian Coal Mining Industry has shown a phenomenal growth, but almost the entire growth is on account of opencast mining. The production from underground coal sector has remained practically stagnant for the last four decades. With economic liberalization and consequent reduction of import duty on coal, the coal mining industry in India is facing a new challenge and India can no longer rely on opencast mining alone. In view of this, Introduction of broad scale mechanization in underground coal sector in India has become imperative.

2. Mechanization with coal loading machines:

Replacement of the prevalent manual Bord and Pillar method of mining by semi-mechanised method of extraction in India with SDL and LHD has improved the percentage of extraction (Figures 1 & 2). In bord and pillar mining, application of SDLs for the purpose of loading, tramming and dumping of material on chain or belt conveyor has gained much popularity. It is obvious that even a marginal increase in the utilization of this large population of SDL machines will result in substantial economic benefit to the organization. To augment the production and productivity, face loading was identified

as one of the most important factors through SDL. Similarly LHD also shows the working flexibility while loading and transporting the coal in underground.

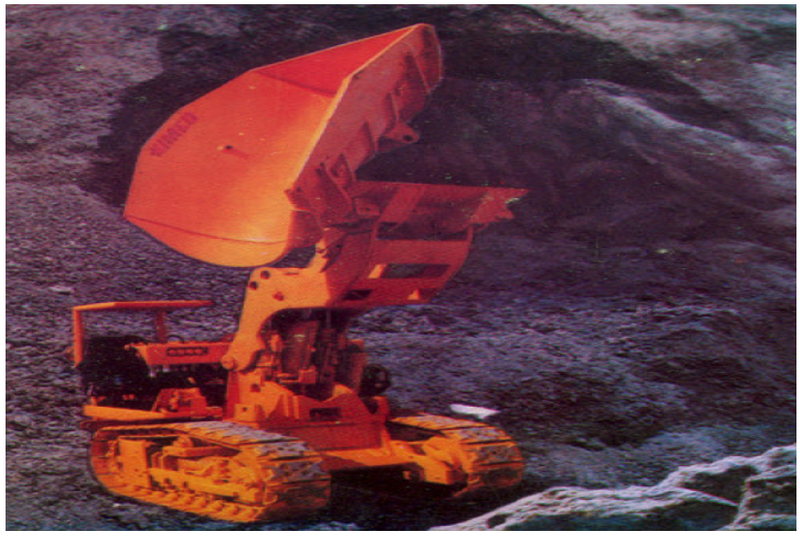

Figure 1 Side Discharge Loader (SDL)

Figure 2 Load Haul Dumper (LHD)

3. Mechanization with Longwall:

Longwall mining technology yields higher percentage of recovery (70% to 80%) with higher rate of output compared with other methods of underground mining. This method has been implemented in some mines of SECL, ECL and BCCL of Coal India Limited as well as in SCCL (Figures 3). However, due to difficult geo-mining conditions prevalent in India, large-scale adoption of this technology has not been possible.

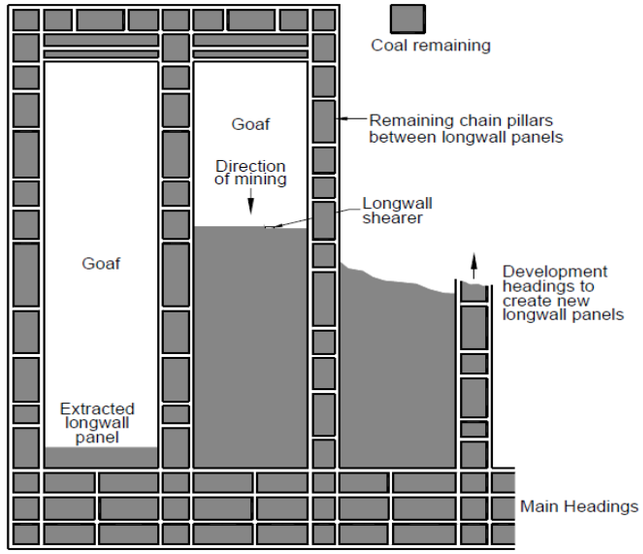

Figure 3 Layout of longwall Panels

4. Mechanization with Continuous Miner (CM):

Continuous miner technology, which has of late been introduced in India, is able to extract 60% to 70% of the coal in a panel depending upon the seam parameters as against 50% to 60% by semi-mechanized Bord and Pillar system of mining with SDL/LHDs. The rate of extraction by the continuous miner being high, it will be possible to create larger panels and thus reduce the coal lost in barrier pillars.

A continuous miner (CM) is an excavating machine capable of cutting soft rocks such as coal, potash or trona at high rates whilst simultaneously gathering the cut mineral and loading it onto a transport system such as a shuttle car or a belt conveyor. The main body of the continuous miner (CM) is similar to that of the road header, being compacted, crawler-mounted and with the same type of debris clearance system (Fig. 4). The cutting drum is much wider, however, at about 3.5 m and can be moved only in the vertical plane so that only a rectangular profile can be formed.

Figure 4 Continuous Miner

In India, continuous miner technology is used in various subsidiaries of Coal India Limited (CIL) and Singareni Collieries Company Limited (SCCL). In CIL, South Eastern Coalfields Ltd (SECL) has introduced, for the first time in the country, the "continuous miner" technology at zero seam underground mine of Chirimiri area in year 2002, Western Coalfield Limited (WCL) introduced CM technology at Tandsi project in the year 2002 and Eastern Coalfields Limited (ECL) introduced CM technology in Jhanjra project in the year 2007 and all the projects are running successfully. Similarly, SCCL introduced the same technology at Venkatesh Khani No.7 Incline, Kothagudem area in 2005, and till date three panels were extracted successfully and the fourth panel is progressing.

5. Experience while cutting with continuous miner in SCCL:

NIRM has studied the various parameters for introduction of continuous miner in the mines of SCCL. The continuous miner was used both for regular depillaring in a bord & pillar panel with caving, and also for partial extraction using yield pillar technique. Further, NIRM carried out instrumentation and strata behavior monitoring during the extraction using the continuous miner to evaluate the method under different geomining conditions.

5.1 Strata behavior in Caving Panel:

At VK-7 incline, the 4.6 m thick King seam has been developed mostly in the top section with sandstone as the roof. The strata in general are dipping at 7.6^{o} (gradient 1 in 7.5) due N 58½^{o} E. Earlier five panels were extracted by BG method from the bottom section taking the full thickness. Abutment stresses, bed separation, pillar dilation and pillar strain were monitored using geotechnical instruments during the extraction of pillar in the CMP-1 panel. The salient observations of strata monitoring for the period from September 2006 to October 2006 are as follows:

a) Stress over the pillars

For monitoring the abutment load on the pillars/stooks during the extraction, total seven vibrating-wire type stress cells were installed in the pillars including one in the barrier pillar. The abutment loads on this pillar increased gradually and remained within 300 KPa till the splitting operation was completed. Afterwards there was a significant increase in abutment loads and it recorded 561 KPa before it went inside the goaf (Fig. 5). This may be attributed to the abutment stresses acting on the small stook due to increase in the area of exposure.

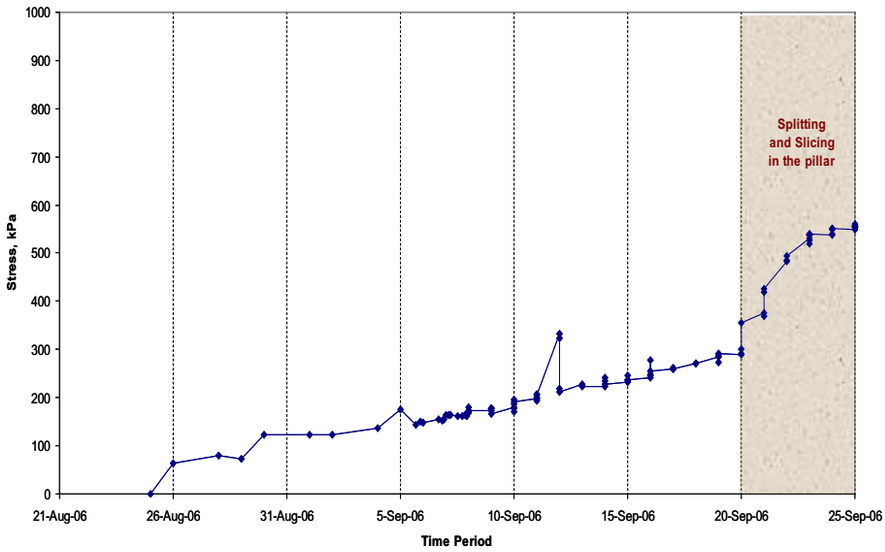

Figure 5 Stress observations in the panel

b) Pillar Dilation:

To monitor the pillar side spalling one magnetic ring borehole extensometer was installed in the pillar. The magnetic anchors were installed at 1 m, 2 m, 3 m and 3.5 m respectively inside the pillar. This extensometer recorded a movement of 31 mm within 3 m in the side and out of this 22 mm was in between 1 m and 2 m (Figure 6). There was no side movement recorded behind 3 m inside the pillar indicating its stability.

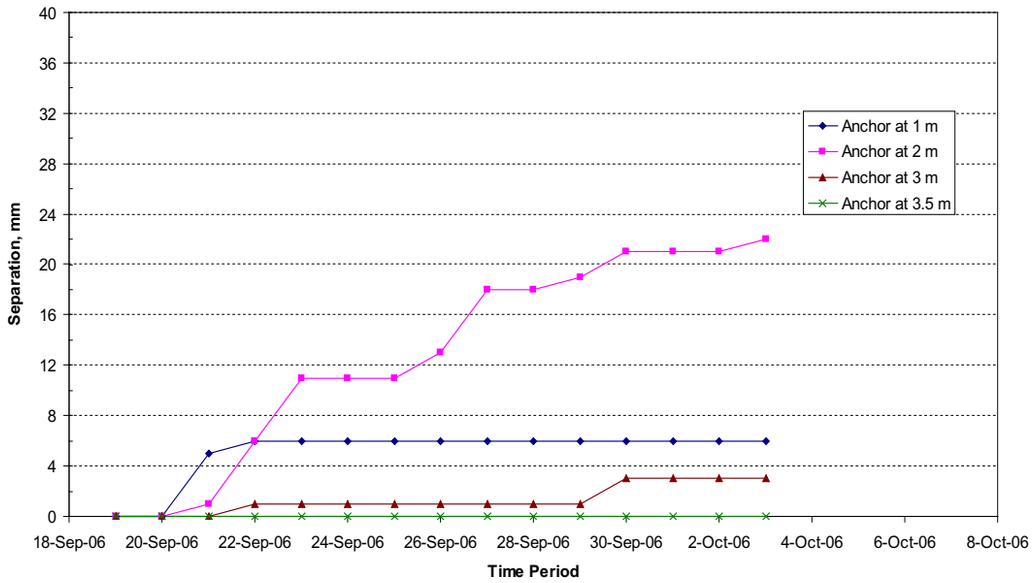

Figure 6 Pillar dilation in caving panel

c) Strain measurements in the pillars:

Four pillar strain meters were installed on the sides of first four pillars. The pillar strain meters are fixed over the bolts grouted at a depth of 1 m inside the pillar. The strain meter recorded a marginal increase in strain of 0.3 mm/m. The other strain meters did not record any significant increase in strain as the pillar sides are weak and dilating towards the gallery.

d) Bed separation:

Tell-tale type four point borehole extensometers were installed in the immediate roof in all the original junctions. The four anchors are kept in the roof at 1.5 m, 5 m, 10 m and 14 m respectively. These extensometers did not record any roof movement during extraction of the first pillar.

During and after the extraction of first pillar in this panel, the increase in abutment stresses were recorded over the pillars and also resulted in dilation of side of the pillars. However, there was no roof movement recorded during this monitoring period and no roof fall was observed inside the goaf. Due to this typical strata behaviour observation, induced blasting was done. This resulted in local roof fall inside the goaf out area. It is recommended to carry out induced blasting at regular interval to facilitate the roof falls inside the goaf.

5.2 Strata behaviour in Non-caving:

In CMP-2, the first phase of development of the panel, the 4.2 m wide galleries were widened to 6.5 m, and then the roof was supported with 2.4 m long resin-grouted roof bolts (using the Quad-Bolter). After all the galleries were widened, extraction was started in the dip-most pillar by floor dinting in the dip direction to increase the height from the existing 2.8 m to 4.6 m (full seam height) and forming a ramp, and then cutting 13 m long and 3.3 m wide slices (Figure 7).

Only the two out by sides of the pillar were thus extracted, leaving a remnant pillar of 25.5 m x 25.5 m in size as the “yield pillar” (which is expected to yield slowly over a long period of time), and also a 8m x 9m stook at the corner as a “chowki” pillar (“policeman” / “indicator”). Pillar no. 2 was then extracted in a similar way, and straight line extraction was adopted. In the panel width to height ratio maintained as five.

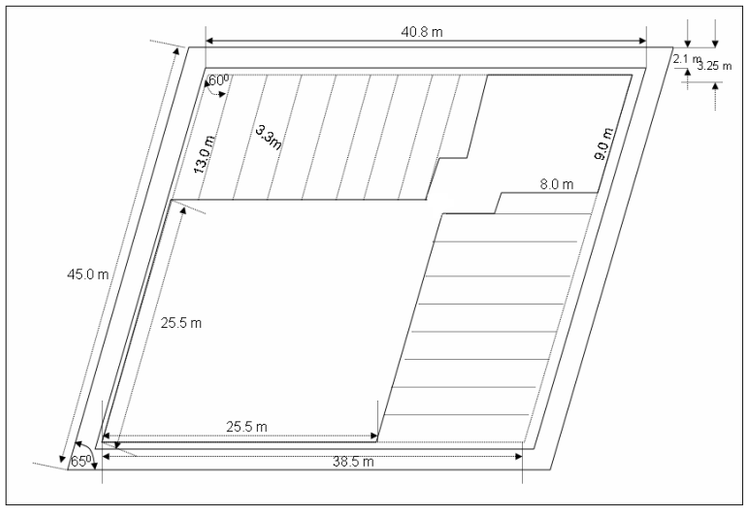

Figure 7 Method of extraction of the pillars in the "yield pillar"

a) Stress over the pillars:

In CMP-2 panel, for monitoring the abutment load on the pillars/stooks during the extraction, ten vibrating-wire type stress cells were installed in pillars and one in the stook. These instruments were monitored till the completion of the panel (NIRM, May 2010). The highest stress measured was 3.1 MPa (Figure 8).

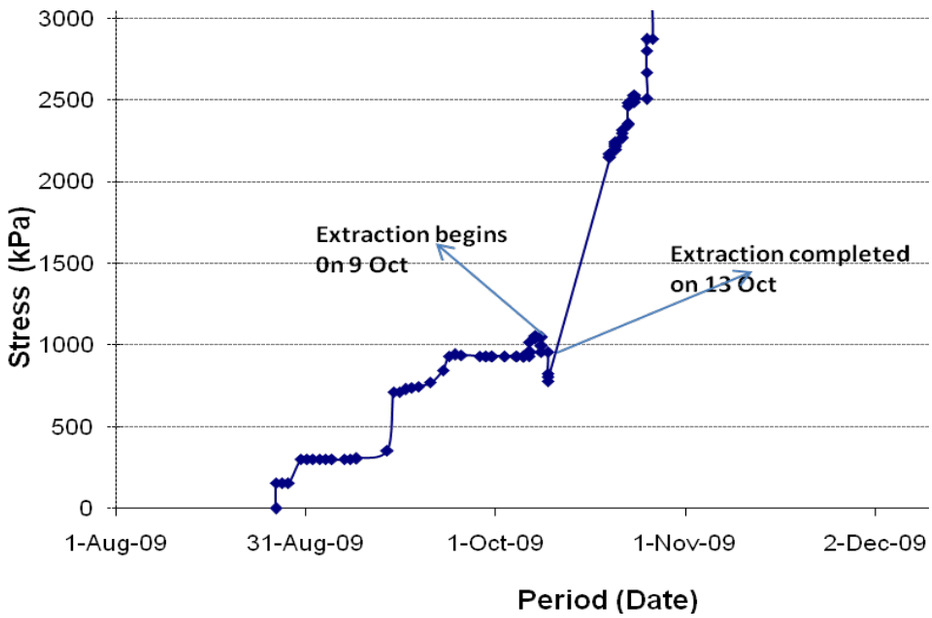

Figure 8 Maximum Stress observed in CMP-2 panel

In CMP-3 panel, total 17 vibrating-wire type stress cells were installed. Eleven stress cells in pillars and six in barrier pillars (NIRM, Nov. 2010). These instruments were monitored till the end of the panel. The highest stress measured in the pillars was 2.3 MPa and in barrier pillar was 3.7 MPa.

b) Roof-to-Floor Convergence:

In CMP-2, 12 Remote Convergence Indicators (RCI) were installed at different locations to monitor the convergence from roof to floor. All the RCI were installed in the goaf after extraction of the adjacent pillar. The convergence recorded by these instruments is due to both roof movements and floor heaving. The maximum convergence recorded was 286 mm (Fig. 9). Since the roof strata have been hard, most of the closure is attributed to the floor heaving (NIRM, May 2010).

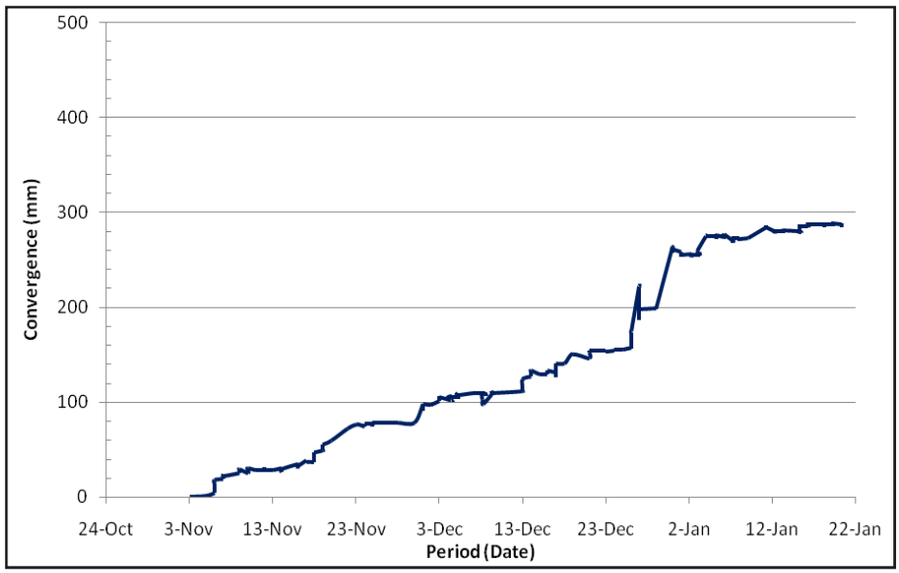

Figure 9 Maximum convergence observed in CMP-2 panel

In CMP-3, 9 remote convergence indicators (RCI) were installed at different locations in the working area and 11 RCIs in advance of the working. All the 9 RCIs were installed in the goaf immediately after extraction of the adjacent pillar. The total convergence (closure) recorded was more than 300 mm. The RCI which were placed ahead of the extraction, indicate cantilever action of the roof showing the trend of up and down movement ahead of the working (NIRM, Nov. 2010).

6. Conclusion:

The impact of continuous miner on panel is same as in other depillaring methods. Continuous miner allows faster rate of extraction, and results in high productivity. It is worth mentioning here that SCCL achieved a record production of 4810 t in a day in one of the current panels, which is a national production record.

Fast rate of extraction is always advantageous from safety point of view. Stress behavior while extracting is in the range of 3-10 MPa and roof to floor convergence varies from 200 to 400 mm. In view of this, using continuous miner, higher percentage of extraction can be achieved even in non-caving methods.

Reference:

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2. NIRM (2010a): Strata control investigations in panel no. CMP-2 during extraction by continuous miner at VK-7 incline, Kothagudem area, SCCL. *Unpubl. Rep.*, National Institute of Rock Mechanics, KGF, Karnataka, India (May, 2010).
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