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OPTIMUM UTILISATION OF CONTINUOUS MINER USED FOR PILLAR EXTRACTION IN BORD AND PILLAR MINING METHOD AND SUPPORT REQUIREMENTS IN VARIOUS ROOF CONDITIONS

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Abstract - *Continuous miner technology helps in achieving high production and faster rate of extraction with safety. Continuous miners and shuttle cars combination are used to transport the coal from face to a transfer point (feeder breaker).The present study has been aimed for optimum utilization of continuous miner by examines the performance analysis of continuous miner and also designing of support system under various roof conditions such as: At roadways and junctions, The area intersected with slips and faults, During depillaring. From the collection of borehole data at various locations of continuous miner panel different rock properties are drawn and for designing of support system CIMFR – RMR classification was used. From the performance analysis of continuous miner the reliability of continuous miner is 89.87 per cent and failure probability is 10.13 per cent was achieved and also different conclusions are drawn which shortly explains an overview of all work.*

Key Words: continuous miner, shuttle car, depillaring, support system, rock mass classification.

1. INTRODUCTION

To accomplish higher production and safe mining condition, require high automation in underground coal mines. The utilization of continuous miner in underground mines is increasing periodically, resulting in higher productivity and safe mining conditions. To meet the ongoing demand of coal in the country, immediate attention is required for improvement in the production from underground mines. India's coal ministry wants to better utilize land to meet a growing energy demand. The focus would be on making full utilization of underground resources by stressing on underground mining. As per recommendations of expert committee 'the Powered Support Longwall and Continuous Miner technology is being applied with success in many mines and there is a need to popularize and establish these as predominant underground technology especially for mass production.

1.1 Continuous Miner

The continuous miner technology in board and pillar mining is the ideal decision for achieving mass production in underground mines which does not require virgin areas; it can also be applied where development has already been done. Continuous miner technology helps in achieving high production and faster rate of extraction with safety. Continuous miners and shuttle cars combination are used to transport the coal from face to a transfer point (feeder breaker). From transfer point the coal is typically tipped onto the underground conveyor system, which transports the coal to the surface in order to be distributed to customers. Effective management of the cutting, loading, transporting and tipping cycle serves as a possible area for productivity improvement

1.2 Depillaring with Continuous Miner

Coal pillars of large dimensions are left out in underground coal mines to support the huge burden of the overlying strata for safe mining conditions. More than 3000 million tons of coal reserves are locked up in the form of coal pillars in India. Varying geo-mining conditions make it extremely difficult to extract more than 30 percent of the total coal reserve by Bord-and-pillar method, which is again the most popular method adopted in India. In fact, these reasons lead to enormous loss of coal, their spontaneous heating, and accumulation of poisonous gases and formation of unsafe working conditions. The obvious solution seems to optimize the dimensions of these pillars and retreat the coal by further de-pillaring or to applying artificial support system in lieu of these pillars, by using roof bolting system, cable bolts and truss system etc. Modified Navid system, split and fender, double split and fender, 1/3 split and fender are the basic pillar extraction pattern in different pillar dimensions.

1.3 Supports Requirements for Depillaring Areas

Support is known as the application of a reactive force to the surface of an excavation and includes techniques and devices such as timber, fill, shotcrete, wire mesh and steel or concrete sets or liners. Reinforcement, in other terms supporting is a means of conserving or improving the overall rock mass properties from within the rock mass by techniques such as rock bolts, cable bolts and ground anchors. In order to determine the system of support to be followed, Rock Mass Rating (RMR) is determined for the immediate roof, for this purpose, and generally, the following parameters are considered: Structural features Layer thickness, Rock weathering ability, Rock strength, and Ground water.

2. DESCRIPTION ABOUT STUDY AREA

2.1 Coal seams

In study area three seams such as Queen seam (Top seam), King seam and Bottom seam exist at varying depth cover of 62 m–357 m, 125 m-425 m and 149 m–298 m respectively. Top Queen Seam (9 to 11 m thick) was developed up to 98 levels and several Longwall (L/W) and Bord & Pillar (B&P) panels were extracted with 3.0 m height, leaving about 2 to 3 m inferior quality coal in the roof and floor both. The eastern boundary side area of the King seam was identified for the application of Continuous Miner (CM) technology. This seam is around 6 to 7 m thick in this sector, lying below Queen Seam at a parting thickness of 40-50 m. The King seam was developed on pillars more than 20 years ago along the roof with a working height of 2.8 m. The average width of the gallery is 4.2 m and pillar size is 45 m x 45 m (centre to centre). In the past, the extraction in King Seam was done in 5 panels with the application of Blasting Gallery method where seam thickness was 8-10 m and another 19 panels were extracted by conventional depillaring with caving.

2.2 Depillaring Practice Used in Study Area

In study area spilt and slicing mining method is used for extraction of pillars. By using this method, the previous thirteen panels CMP-5A, to CMP-10A(2) were found successful as per expectation from strata control point of view with an average percentage of coal recovery around 72 percent.

2.2.1Extraction sequence of a pillar

In case of panel CMP-10A(1) and CMP-10A(2) 1st pillar is divided into two parts by driving a level split keeping the working width 6.5 m and height 3.0 m along the roof in such a way it creates two stooks of 1/3rd and 2/3rd size of pillars. A ramp at 1 in 7 gradient in the split gallery is made from the out bye side of the first set of slices for facilitating extraction of slices. In the split gallery, from the bottom of the ramp up to the corner of the pillar deepened up to 4.6 m height by floor dinting. Slicing operation by slicing 6 m in the upper side (upper stook) and 13.5 m in lower stook (Fender-A) up to 4.6 m height is completed. Before starting the extraction of the next set of slices, the ramp made in a similar way as mentioned above. Similarly, the second set of slices extraction is done by leaving 3 m thick rib toward goaf. The third set of slices extraction is also done by leaving 3 m thick rib. These ribs are reduced carefully, as their reduction will facilitate the caving of goaf. The last snook in Fender-A (trapezoidal shape) of dimension 12.12 m x 8.37 m x 14 m x 15.37 m is left for its judicious extraction. The final size of the snook left at split gallery Junction in the goaf after judicious extraction is decided based on Auto Warning Tell-Tale blinking (installed near to the snook at the height of about 10 m and having a warning level 5mm and withdrawal level 8 mm deformation) and pressure coming over surrounding pillars, fenders and snook which can be judged by their side spalling.

2.3 Support system used in study area

The support recommendations suggested by CIMFR, Dhanbad for continuous miner panels in the study area are given below. These are implementing during widening & heightening and also during the extraction of the pillars

2.3.1Support of goaf edges (Breaker lines)

All the goaf edges are supported by two rows of non-retractable fully resin grouted tor steel roof bolts and the length of such bolts is not less than 2.4 m. in 0.75 m grid pattern.

2.3.2Roof support of original / split galleries

All the existing original galleries are widened up to 6.5 m with a height of 3.0 m, and they are kept supported by 1.80 m long fully resin grouted tor steel roof bolts. Distance between two bolts in the same row is not more than 1.50 m and between the two rows of bolts is not more than 1.50 m.

2.3.3Supporting of the sides

Along the North/Rise and South/Dip side of galleries and level split galleries, 1.5 m long GRP bolts grouted with quick setting cement capsule fixed at roof level to hold the plastic mesh up to height of 2 m from the roof level.

2.3.4Support of 6.5 m wide gallery junctions lying below goaf of top seam long wall /LHD caving Panels

The support system for 6.5 m wide roadways are four full column resin grouted roof bolts in a row of length 1.8 m; the row spacing is of 1.5 m.

2.3.5Support of 6.5 m wide galleries and junctions lying below panel barriers of top seam longwall/LHD caving panels

The support system for 6.5 m wide roadways lying below Top Seam barrier are four full column resin grouted roof bolts in a row of length 2.4 m; the row spacing is of 1.5 m. For 6.5 m wide junctions, the support system consisted of 2.4 m long resin grouted roof bolts on 1.5 m x 1.5 m grid pattern supplemented by 5 nos of 5 m long flexi bolts

2.3.6Support of more than 6.5 m wide galleries and junctions lying below goaf of top seam longwall /LHD caving panels

All the galleries and junctions of more than 6.5 m wide galleries lying below Goaf of Top seam LHD caving panels are kept supported by 2.40 m long fully resin grouted tor steel roof bolts in 1.5 m x 1.5 m grid pattern.

2.3.7Support system for the area intersected with slips and faults

All dykes, visible slips and breaks in the roof are supported with 2.40 m long fully resin grouted bolts in addition to the systematic support rule (SSR) for original galleries.

3. FIELD AND LABORATORY INVESTIGATIONS

The underground visit was carried out with underground manager and other mine employees and following observations are noted

- CMP-11 panel consisting of sub-panels CMP-11A(1), CMP-11A(2) and CMP-11A(3) are fully developed and standing on pillars.
- The geological anomalies observed are mostly faults and slips. The majority of the faults are minor in nature.
- Cracks are observed particularly at junctions.
- Localized spalling in the pillar sides and pillar corners were also observed in few places in the panels.

The above observed geological discontinuities, roof condition below Top seam B&P and longwall goaf and barrier pillars, widened junctions indicates that suitable support system at those locations are to be installed in advance, so that early bed separation can be prevented and thus, chances of roof fall over the workings and working faces can be restricted during depillaring. Data of the earlier two boreholes located at 67LN/16D and 20R/68L are used for determining the RQD, cavability Index, compressive strength, tensile strength.

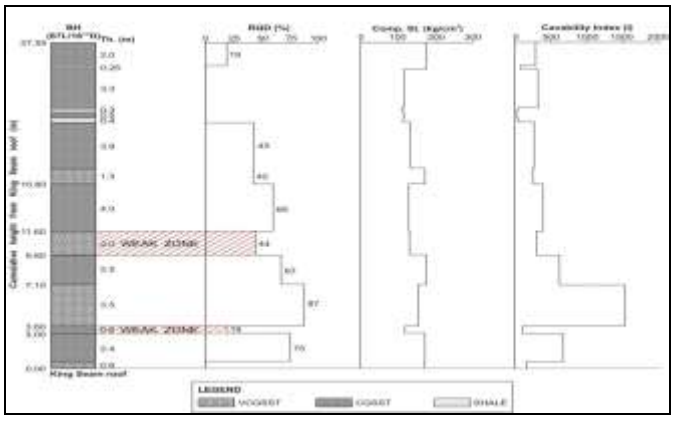

Fig -1: Compressive Strength, RQD and Cavability Index of immediate roof rock strata above King seam of BH located at 67LN/16D.

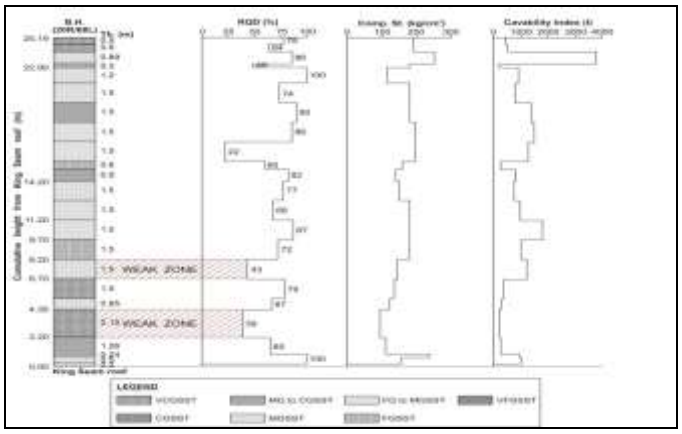

Fig -2: Compressive Strength, RQD and Cavability Index of immediate roof rock strata above King seam of BH location 20R/68L.

Details of continuous miner panel 11A

Extraction Started On	: 11.04.2019
Panel Length / Width	: 170 m X 138 m
Panel Min/Max Depth	: 314 m /328 m
No of Pillars/Area of Panel	: 11/23500 Sq m
Coal Available in a Pillar	: 10,500 T
Extractable Coal in a Pillar	: 6,000 T
Extractable Coal in a Panel	: 145000 T
Expected per cent of Extraction	: 70 %
No Of Pillars Under The Barrier	: 9(4,5,6,7,8,8a,9,10,11)
Panel Completed On	: 19.08.2019.

4. RESULTS AND DISCUSSIONS

4.1 performance analysis of continuous miner

The percentage of breakdown classification for continuous miner and shuttle car in panel CMP 10 is given in Tables 1 and 2 respectively. Table 3 and Fig 3 represent the breakdown, idle and working hours of continuous miner.

Table 1 Percentage of continuous miner breakdowns in CMP10A

S. No	Classification of breakdown	Per cent
1	Electrical problem	6.81
2	Cutter problem	13.84
3	Conveyor problem	15.18
4	Gathering problem	39.53
5	Traction	6.09
6	Hydraulic	18.52

7	Chassis	0
	Total	100

Table 2 Percentage of shuttle car breakdown in CMP10A

S. No	Classification of breakdown	Per cent
1	Electrical problem	99.12
2	Conveyor problem	0
3	Traction	0.88
4	Hydraulic	0
5	Chassis	0
	Total	100

Table 3 Breakdown, idle, working hours (percentage) of continuous miner in CMP10A

S. No	Classification of hours	Per cent
1	Breakdown hours	7.59
2	Idle hours	17.40
3	Working hours	75

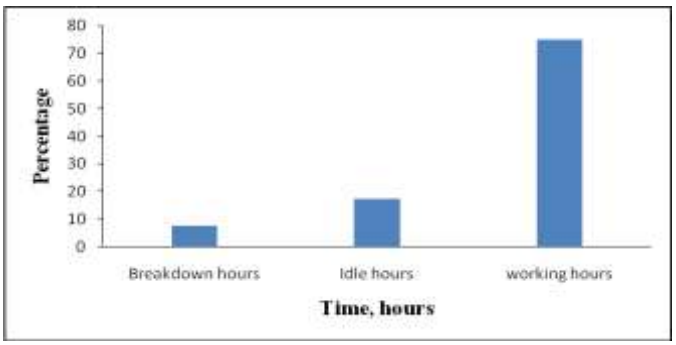

Fig. 3 Breakdown, idle working hours (percentage) of continuous miner in CMP11

4.1.1Breakdown Analysis

The detailed study of breakdown analysis of continuous miner indicates the following:

4.1.2Continuous Miner panel - 10A

The observed major percentage of breakdown in continuous miner is due to gathering problem i.e., 39.53 per cent. This includes gathering cylinder pin out, gathering head gear box, gathering spray nozzle jam. Apart from gathering problem, there are other problems like hydraulic and conveyor problems which accounts 18.52% and 15.18% of breakdowns respectively. Here the observed electrical problem is main in shuttle car i.e, 99.12 per cent

4.1.3Reliability Analysis

The Tables 4 and 5 are showing the breakdowns under various head in respect of the equipments of CM for CMP 11A panel in VK7 mine, which are elaborated as below.

Table 4 Reliability analysis of continuous miner

S. No	Classification of breakdown	Hours	Probability of failure P(F)	Per cent P(F)
1	Electrical problem	12.67	0.006900	69
2	Cutter problem	25.75	0.014005	14.0
3	Conveyor problem	28.25	0.015386	15.38
4	Gathering problem	73.54	0.040054	4.00
5	Traction	11.33	0.006171	6.17
6	Hydraulic	34.46	0.018769	1.87
7	Chassis	0	0	0
	Total		**0.101302**	

Table 5 Reliability analysis of shuttle car

S. No.	Classification of breakdown	Hours	Probability of failure P(F)	Per cent P(F)
1	Electrical problem	45.51	0.0162455	1.624
2	Conveyor problem	0	0	0
3	Traction	0.25	0.000086	0.008
4	Hydraulic	0	0	0
5	Chassis	0	0	0
	Total		**0.016332**	

Reliability of continuous miner = 1 – P (F) = 0.8987

Reliability of shuttle car = 1 – P (F) = 1 – 0.0163 = 0.9836

Percentage availability = 56.53 percent.

Percentage utilization = 33.33 percent.

4.2 Designing of support system under various roof conditions

The present study has been conducted to frame suitable support design guidelines for depillaring in CMP 11 A.

4.2.1 Design of support system at road ways and junctions

4.2.1.1 Below top seam caved goaf

The recommended support system for 6.5 m wide roadways are four full column resin grouted roof bolts in a row of length 1.8 m; the row spacing should be of 1.5 m. Similar support pattern needs to be adopted for the junction using 2.4 m long resin grouted roof bolt at a grid spacing of 1.5 m x 1.5 m as shown in Fig. 4. For galleries and junctions exceeding 6.5 m width, additional roof bolts of the same length and at same grid spacing are to be installed.

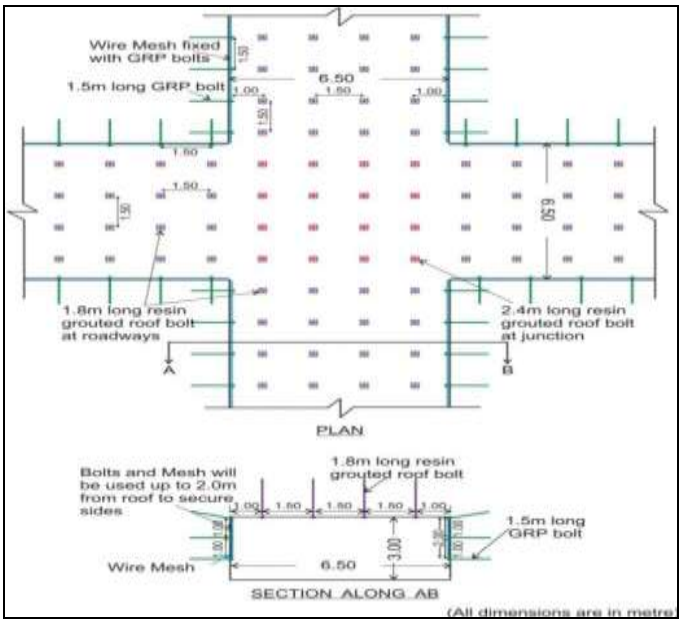

Fig. 4 Support system for 6.5 m wide gallery and junctions below top seam goaf

4.2.1.2 Below top seam barrier

The recommended support system for 6.5 m wide roadways lying below Top Seam barrier are four full column resin grouted roof bolts of length 2.4 m in a row; the row spacing should be of 1.5 m. For 6.5 m wide junctions, the recommended support system consisted of 2.4 m long resin grouted roof bolts on 1.5 m x 1.5 m pattern supplemented by five numbers of 5 m long flexi bolts, the bolt length crossing the weak zone at 2.2 m to 4.35 m above the seam and anchoring at stable zone. This is required due to high stresses in junctions below the barrier. For galleries and junctions exceeding 6.5 m width, additional roof bolts of the same length and at same grid spacing are to be installed as shown in fig 5.

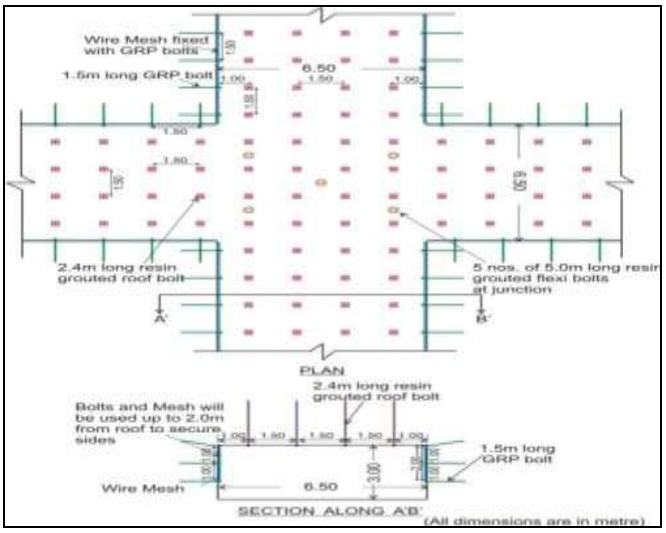

Fig. 5: Support system for 6.5 m wide gallery and junction below the top seam barrier

4.2.2 Support system for the area intersected with slips and faults

In case of slips and faults intersecting the galleries, additional supports of 2.4 m long resin bolts are to be provided as shown in Fig 6. Additional supports are also to be provided as and when required in form of wire netting, roof bolts with W-straps, cogs or other supports in old and newly formed cracks, fractured roof, deteriorating roof, excessive wide roadways and junctions etc.

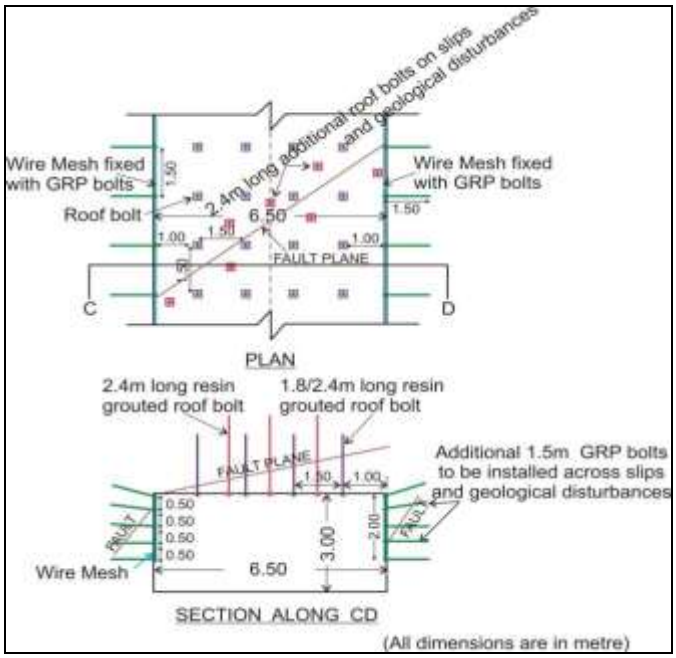

Fig. 6: Support system for the area intersected with slips and faults

4.2.3 Support design during depillaring

The support systems recommended for CMP-11A(1), CMP-11A(2) and CMP-11A(3) for 6.5 m wide galleries, junctions and goaf edges are shown in Fig. 7 and Fig. 8, 9 respectively. At level, splits and dip rise galleries, 16 numbers of 2.4 m long bolts having a load-bearing capacity 25 Ton at 0.75 m x 0.75 m grid pattern is used as a breaker line support as shown in Fig. 8 & Fig. 9.

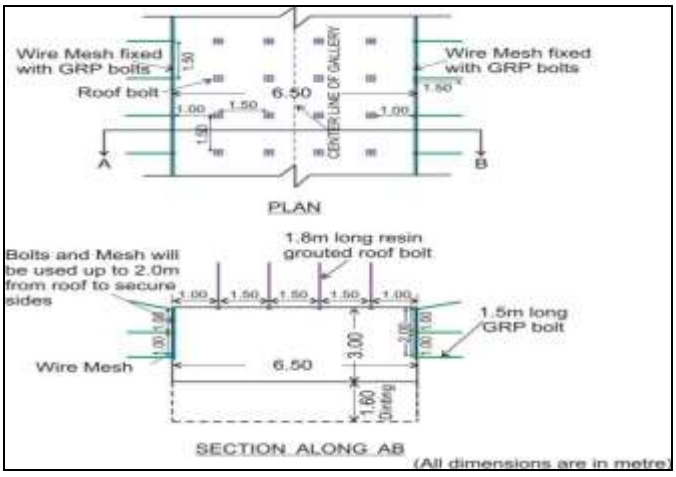

Fig. 7 Support design for level splits and sides of 6.5 m width

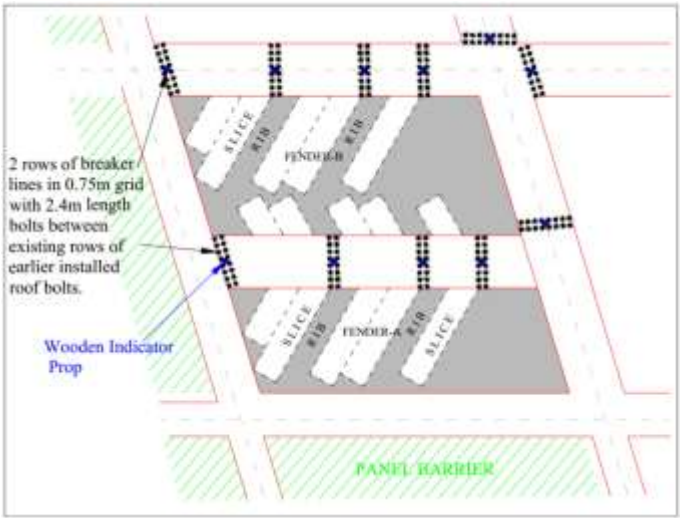

Fig. 8 Goaf edge breaker line support for original galleries & level splits of 6.5 m width in CMP-11A(1) & 11A(2).

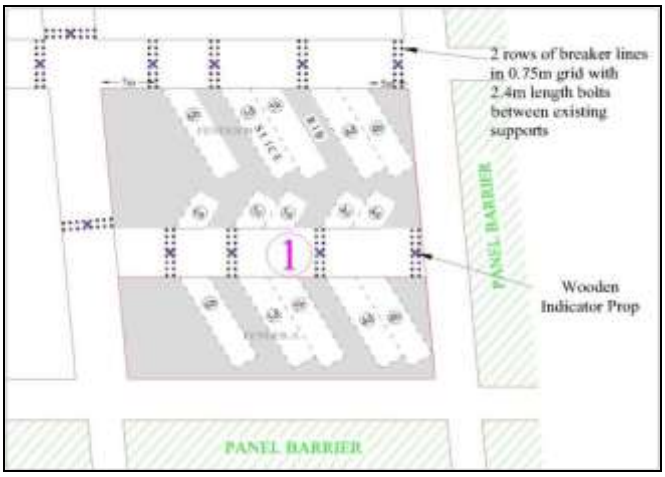

Fig. 9 Goaf edge breaker line support for original galleries & level splits of 6.5 m width in CMP-11A(3) panel.

5. CONCLUSIONS

- The reliability analysis of continuous miner shows that the machine reliability is 89.87 percent and failure probability is only 10.13 percent. Hence utilization of continuous miner increases production and productivity in underground mining both in caving and non caving method of mining will be enhanced.
- From the pillar stability analysis, it is found that the safety factors of all the pillars after widening considering 3 m height of roadways in panel CMP-11 are more than 2.0 and are suitable for depillaring with splitting and slicing method.
- The observed geological discontinuities in study area, roof condition below Top seam B&P and longwall goaf and barrier pillars, widened junctions indicates that suitable support system are to be installed in advance, so that early bed separation can be prevented and thus, chances of roof fall over the workings and working faces can be restricted during depillaring.
- During the extraction of King seam pillars below the Top seam barrier using CM technology, comparatively heavy pressure around the face can be experienced, which can be countered by providing additional supports in roadways, junctions and pillar sides. For the areas intersected with slips and faults additional support such as long resin bolts are to be provided.

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