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An experience of designing supports in newly opened Belgaon underground coal mine

Belgaon block is located in the northern most ends of explored coal block of the eastern limb of Wardha Valley Coalfields (WVC). WVC is well known for its complexity like complex geological structures, strata control problems while dealing with thick coal seam, fire and water problem etc. The Belgaon mine of SUNFLAG is however separated from Majra block in the south by a down throw fault. Designing of roadways and junction support in newly opened underground coal mine was a challenge due to its complex geology. To arrive at suitable support system, various experiments using cement as well as resin bolting were carried out. The pulls out tests were carried out on rock bolts grouted with cement as well as resin. The proposed paper deals with significance and importance of resin grout over cement and other issues related to strata control etc.

Introduction

Sunflag Iron and Steel Co. Ltd. (SISCO), have been allotted Belgaon block in the state of Maharashtra to meet the coal requirement for 3 lakh tonne capacity expansion of sponge iron production and augmentation of captive power generation by 10 MW from the existing 15 MW capacity power project at their plant located in Bhandara about 60 km from Nagpur.

Belgaon coal block is located about 95 km south of Nagpur by Nagpur-Chandrapur state highway No. 264. The project site is approachable at a distance of 5 km by an all-weather metallic-tar road connecting Tembhurda on SH-264.

At Belgaon coal mine project, bottom seam, 3.5 m thick and dipping 1 in 6.25 and 1 in 20 due NNE to ESE is being developed by bord and pillar method of working. The gallery width is 4.8 m and working height is 3 m. Pillars are 25m × 25m centre to centre in size and also 25m × 20m to 40m × 40m in dimension. The depth of cover was 25-30 m only.

For stability evaluation and support design of underground mine roadways rock mass rating (RMR) and rock load were determined applying CMRI Geomechanical Classification System. RMR provides useful information for selection of support system and rock load values were used for optimum support design and again reviewed in view of the change in rock mass conditions.

The most challenging problem faced in extracting coal at varying depths and different geo-mining environments in underground coal mines relates to ground control. National statistics of accidents reported that some 35 to 45% of fatal accidents from underground coal mines in India were due to roof and side falls. Injuries and fatalities, cost on cleanup labour and material, cost of resupporting, production losses, cost due to lost production, the demoralizing impact of accidents on personnel and the psychological impacts of working under potentially unstable roof on workers underscore the heightened problem dimension. Prevention of roof fall accidents has thus been one of the most intractable and challenging problems of underground mining.

The cement grouted roof bolting is well accepted for its cost effectiveness and for easy manual installation. But the changing prospective of mechanization which is aimed for speedy mining and at geological disturbances at great depth under high stress condition, then the resin grouts were preferred. However, after using the resin grouts the production, productivity of the mine increased and losses are reduced in comparison with cement grouts (Neeraj Kumar et al).

Geology

The general strike line of the coal seam as determined from the floor contour plan of composite seam is NW-SE to NNW-SSE in the northern part and N-S in the southern part. Dip is towards NE to ENE and E. The dip ranges between 2.8° to 9° (1 in 6.25 to 1 in 20) steeper in the NW part of the block as compared to the rest of the blocks. 12 faults have been interpreted in this block out of which two faults viz. F1-F1 and F6-F6 are major faults with maximum throw of 100 m and mark the northern and southern boundaries of the block. F1-F1 separates the block from Talchir while F6 separates it from adjacent Majra block.

Field studies

Laboratory studies were carried out to determine basic geo-technical parameters for the coal measure rocks mainly

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sandstone and shale. To arrive at CMRI Geomechanics Classification for coal measure rocks, field investigations were carried out and data collected were layer thickness, structural features, groundwater seepage etc. To arrive at suitable grout type for rock bolting, anchorage testing of rock bolts was carried out using cement and resin capsules. Based on the laboratory and field investigations, RMR was determined at 42, describing III-A FAIR Rock. Keeping in view and giving due consideration to strong rock mass layer above the immediate roof is presently at only 4-5 m, the support system was devised as follows:

PERMANENT ROADWAYS

1. Full column grouted bolts of 1.6 m length at spacing 1.2 m c/c with quick setting resin based grouts. The side bolt should be inclined at 45^0-60^0 drilled at a distance of 0.3 to 0.4m from the pillar so that it should provide support to the pillar rib.
2. ISMB -150 steel girders at spacing of 1.2 m in the roof and to be supported by vertical steel girder at both the side walls (goal post support).

AT JUNCTIONS

1. At junctions the bolt density increased by 25%.
2. It was recommended to provide full column grouted bolts of 1.6 m length at spacing of 1.2 m c/c with quick setting resin based grout.
3. Steel cross bars set into pillars or on steel props for permanent roadway junctions.
4. Four steel girders supported on vertical props on both sides.

Anchorge testing of bolts

To arrive at suitable grout type, anchorage testing was undertaken using cement as well as resin. The obtained results of anchorage testing in actual field conditions are provided in Table 1.

From the presented anchorage testing data in Table 1, it was found that since the rock mass condition comprised various geological disturbances like cleats, minor and major slips, it is recommended to fully grout bolts using resin based grout. Again, it was noticed that few cement grouted bolts mostly slipped after attaining 5-6 tonnes of load, hence keeping in view, geological disturbances, watery strata and presence of Kamthi water series above the roof, it is strongly recommended to use resin based grout. Similarly, it was observed by the DGMS that in a number of cases, the falls had occurred along with roof bolts and after testing of the installed bolts in the area, it was found that the bolts were failing at loads varying from 2 to 6 tonnes (DGMS (Tech.) (S& T)/Circular No. 3/703, dated the 14th August, 2008). Vide same circular, it was also pointed out that cement grout is being used in watery strata without assessing the water quality and compatibility with cement grouts in respect of its strength variation with respect to time. It shall be mentioned here that resin is also now being used for grouting the roof bolts which provides fast support at the working place especially in the green roof areas. In case of resin grouted bolts, experience from in-situ pull testing showed that high transfer loads can be achieved over short embedment lengths (Villaeseusa et. al., 2008).

Various types of resins including slow and fast setting types are being used in roof bolting. Since this is a quick setting type of supports suitable for green roof area. It is desired that the quality of the roof bolts and the resins should be ensured to have an effectives support in active working areas. DGMS suggested short encapsulation pull test should be conducted to ascertain the load bearing capacity of the support before use of every lot of resin capsules. According to above cited DGMS circular, during the course of inspection and testing of resin bolts, it was observed that:

TABLE 1: ANCHORAGE TESTING DATA

Setting time (hrs)	Grout type	Load taken (te)	Maximum displacement (mm)	Remarks
1/2	Cement (full column grouted)	6		Bolt slipped
1/2	Cement (full column grouted)	7	6.042	Testing stopped
1/2	Resin (2 capsules)	8	2.01	Testing stopped
1/2	Resin (1 capsule)	5	1.040	Testing stopped
1/2	Resin (1capsule)	7	1.050	Testing stopped
1/2	Resin+ cement (1capsule each)	8	0.030	Testing stopped
1/2	Resin+ cement (1capsule each)	8	2.010	Testing stopped
2	Cement (full column grouted)	8	3.040	Testing stopped
2	Resin (2 capsules)	7.5	0.086	Testing stopped
2	Resin (1capsule)	9	1.040	Testing stopped
2	Resin (1capsule)	5	2.090	Testing stopped
2	Resin + cement (1capsule each)	10	3.031	Testing stopped
2	Resin + cement (1capsule each)	10	5.030	Testing stopped

1. The roof bolts had failed from their threads.
2. The roof bolts were pulled at very low load due to non-setting of the resin.
3. The resin grouts had weathered and crumbled into powder form after elapse of 2 to 3 months thereby making the roof bolts ineffective.
4. The shell life of the resin capsule was less than the specified period.
5. Expired resin capsules were being used in roof bolting resulting in improper grouting thereby reducing the strength of the roof bolts.

This reveals that a good quality control measures is required to ensure the quality of resin as well as its strength characteristic profile with respect to time.

Review of the support system

At Belgaon coal project, bottom seam is being developed and immediate roof consists of coal and shaly sandstone. However, delay in implementing resin as a grout material and frequent occurrences of major/minor slips in the roof rock mass, posed strata control problems in development galleries and junctions. Roof falls occurred extending cavity in roof up to 1.5 m and Fig. 1 shows the support system provided using wooden slippers and ISMB steel girders. Due to problems as stated above, review of the support system were undertaken. The geotechnical review studies revealed that adjusted RMR comes to 40-Class IVB, describing "poor roof". As per DGMS (Tech.) (SOMA)/Circular No.1, dated the 4th January, 2008, for the roof category "poor", having value of RMR of 40 or less, or where there is excessive seepage of water from the roof strata, roof bolts exclusively with resin capsules shall be used to ensure adequate and immediate reinforcement of the strata. The rock load was determined at 5.24 t/m^2 for galleries.

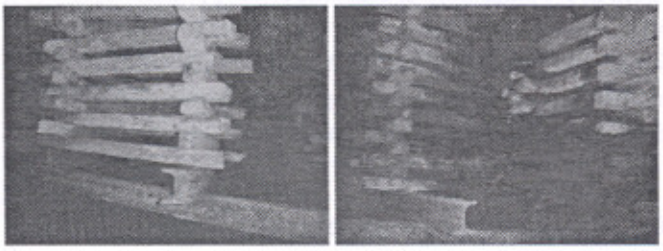

Fig.1 Roof falls extending cavity in roof and the support system provided using wooden slippers and steel girders

Based on the studies, galleries would be supported with new support system comprising four bolts along with W-straps in a row at an interval of 1.2 m leaving 0.6 m space towards the pillar on both sides and the bolting rows would be spaced at 1.2 m (Fig. 2). The side bolts should be inclined at 60^0 towards the pillar from the roof level. The bolt length of 1.8 m is recommended. All bolts should be fully grouted with slow setting (setting time 2-3 mins) resin capsules. The support resistance offered by suggested support system was determined at 6.94 t/m^2 with a safety factor of around 1.5.

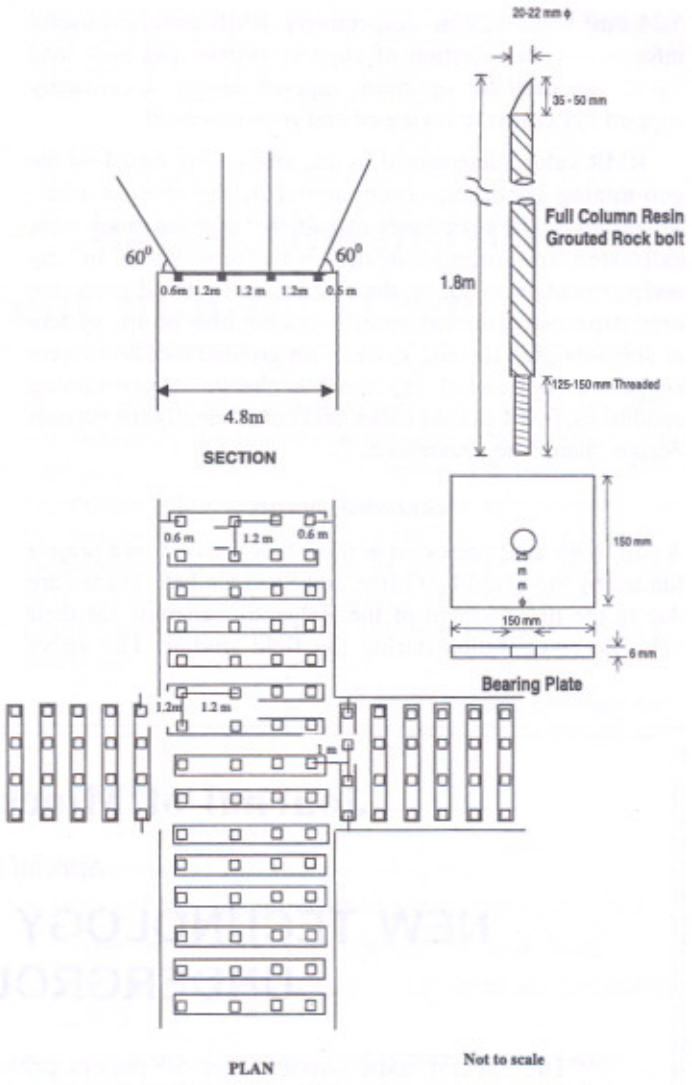

Fig.2 The outline of the support system suggested

However, where hard cover is less than 15 m, in addition to resin roof bolting goal post support at a spacing of 1.2 m interval between the bolted rows were suggested.

Design of support for junctions

From the RMR, the rock load at junction is determined at 5.82 t/m^2. Hence, the junction to be supported with four bolts in a row at 1.2 m interval along with W-strap and the row would be spaced at 1.2 m. Thus, five rows would be required to support the junction of 4.8 × 4.8 m (Fig.2). Support resistance offered at junction, which was found to be 8.68 t/m^2 with safety factor of around 1.5.

Conclusion

For stability evaluation and support design of underground mine roadways in Belgaon coal project RMR and rock load were determined applying CMRI Geomechanical Classification System. The RMR of the roof rocks was 40 (poor roof) and the rock load for galleries and junctions were

5.24 t/m^2 and 5.82 t/m^2 respectively. RMR provided useful information for selection of support system and rock load values are used for optimum support design, accordingly support system were reviewed and recommended.

RMR values determined in this study were based on the geo-mining conditions encountered in the studied areas. Accordingly, the rock loads in galleries and junctions were estimated and support design was formulated. In any underground excavations, the stability of roof and sides, not only depends on the nature of rocks but also on the system of supports used therein, since, resin grouted roof bolts were suggested. In case of any notable change in geo-mining conditions, RMR of roof rocks, and consequently the support design should be reassessed.

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