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Modified ground support with alternative fill material for ground control at munsar underground manganese mine of moil limited, India

Ganesh Manekar, Dipankar Shome, Mukund Chaudhari
MOIL Limited, (A Government of India Enterprise),
MOIL Bhawan, Nagpur, **India**

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INTRODUCTION

The Munsar Mine of MOIL Limited is being worked since 1903. The total lease hold area of the mine is 140.49 ha. The mine is located in the Munsar town in Ramtek tehsil of Nagpur district in the Maharashtra state. It falls in the Survey of India Toposheet No 55 O/7. The latitude and longitude at the centre of the property is N 21°23'22" and E 79°17'14". The geological formations of the area belong to munsar formation of sausar group. The sausar fold belt is an important Mesoproterozoic (~1300 Ma age of Sausar Group) mobile belt in the Central India Peninsular Shield. Sausar belt extends for a length of over 215 km from Ramakona to Paraswada (Baihar) with an average width of 35 km and covers an area of about 7000 km² in the state of Maharashtra and Madhya Pradesh. It is an arcuate fold belt trending ENE-WSW with convexity to the south (Ramakrishna M and Vaidyanandhan, 2010). The lease area is undulating with highest level of 90 m towards north-west, and a general ground level of 315 m MSL towards south and east. The hillock is having almost NW-SE trend. At present, the manganese ore is being produced from the underground sections of 70'L, (-) 30'L and below levels (-) 130'L, (-) 230'L and (-) 330'L are under development stage. The level interval is 30 m. These levels are now attached with vertical shaft sunk at Ch. 2600. Horizontal cut and fill method of stoping with post filling by hydraulic sand stowing is being practiced. The lease plan of the mine is appended in Figure 1.

The opencast working was carried out in the eastern part of the property from surface 366 mRL to 309 mRL. The opencast working has been stopped since the year 1980. For the underground excavations, upper levels 270'L, 220'L and 170'L have been accessed by adit in the western part and central part of the property. Thereafter to access the 70'L incline has been developed in the western part. During the development of incline continuous fall of back and side walls of rock has been noticed and therefore incline was terminated at 70'L.

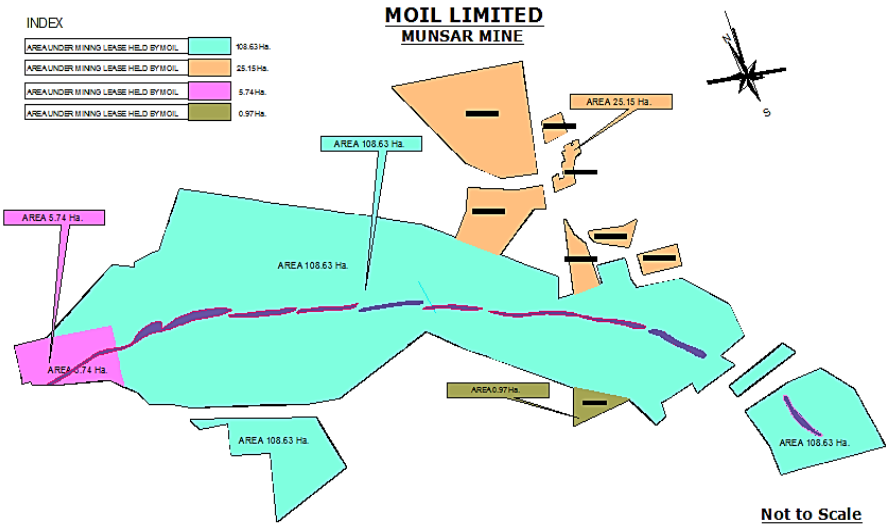

Fig. 1 Lease Plan of Munsar Mine

Longitudinal section of present mine working is mentioned in Figure 2.

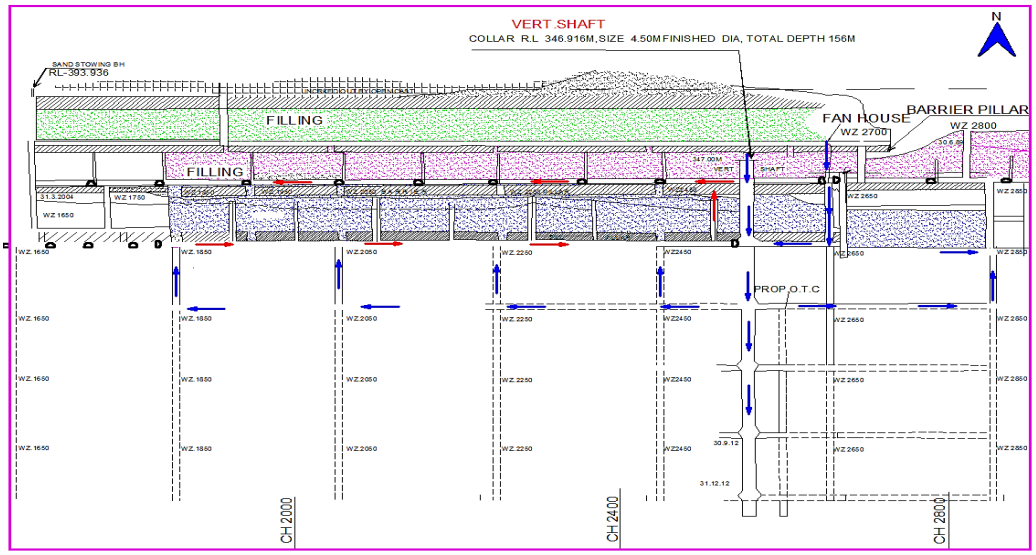

Fig. 2 Longitudinal section of present mine working at Munsar Mine

Moreover, in the eastern side, there was collapse of adit brow of 170'L. It was also anticipated during the development stage of incline that the rain water may enter in underground and hence to avoid the inrush of water in the underground stoping operations, haulage road is placed in the sill pillar and sill drive has been developed 5 m above the sill pillar to protect the 70'L (Lower level) and for the safety of 170'L (Upper level) barrier/crown pillar of 5 m thickness has been kept. In this method around 33% valuable manganese ore has been locked in the underground (Manekar G G, Shome D, and Chaudhari M P, 2018).

GEOLOGY OF AREA

The manganese deposits in the area are associated with rock of Sausar. These rocks are mainly meta-sediments composed of quartzites, various types of schist and gneiss. These are found at the base of the lower most Sausar Series of rock and have been involved in the movements along with the other rocks

and thus have developed certain features which make it difficult to identify them from the other rock of the Sausar Series. The ore bed in this area occurs in the Munsar formation of the Sausar rock belongs to the Dharwar met sediments and comprises of “various types of schists and gneisses, dolomitic marble” calgranulites and Biotite gneiss is found at the base of the lower most Sausar formation and it is involved in the movement with rocks of the same group. During this movement it might have developed some features which make it difficult to identify. Moreover, these rocks have undergone a high degree of metamorphism and the rocks are characteristically metamorphosed.

ROCK MASS CLASSIFICATION

The rock mass classification parameters namely, rock quality designation (RQD), joint set number (Jn), joint roughness number (Jr), joint alteration number (Ja), joint water reduction factor (Jw), stress reduction factor (SRF), uniaxial compressive strength (UCS), spacing of discontinuities, joints conditions, orientation of discontinuities and hydro-geological conditions, were estimated for ore as well as wall rocks using 3-D geological mapping and core logging. Based on these parameters, the rock mass has been characterized using Q-system (Barton, 1976) and RMR system (Bieniawski, 1973). Empirical estimation of support requirement for the modified stope design was made using the above two rockmass classification systems. It is observed that the foot wall and hang wall rocks have Q value of 4.75-9.37 and 6.06-9.38 respectively (Raju G D, NIRM, 2016), categorizing them both as “Fair”. On the other hand, the estimated “Q” value for the Ore is 22.5-66.67, which falls under ‘Good’ to ‘Very Good’ category as per the Q chart. Another widely used rockmass classification system, RMR is also examined. It is observed that the average RMR values of footwall, hang wall and ore body is estimated to be 44.5, 59 and 56 respectively (CMRI, 2001). Obtained Q and RMR value is presented in Table 1.

Table 1 Obtained Q Value and RMR of Munsar Mine

Geo-technical Parameters of wall rocks and ore body for Q-system		
Location	Rock description	Q-Value
Hangwall	Mica schist/Quartz mica schist/Rhodonite with mica schist	6.06 – 9.38, (Fair)
Ore zone	Mn-ore body	22.5 – 66.67 - (Good – Very Good)
Footwall	Quartz mica schist/Mica schist	4.75 – 9.37, (Fair)
Geo-technical Parameters of wall rocks and ore body for RMR		
Location	Rock description	RMR
Hangwall	Mica schist/Quartz mica schist/Rhodonite with mica schist	59, (Fair)
Ore zone	Mn-ore body	51 – 61, (Fair – Good)
Footwall	Quartz mica schist/Mica schist	33 – 56, (Poor – Fair)

EMPIRICAL DESIGN

The maximum stope width of 7 m is considered for the modified stope design for the mine. The excavation support ratio (ESR) is taken as 1.6. It can be observed from the ‘Q’ chart, which is shown in Figure 3 that the region falls in unsupported area for 6 m stope width. However, considering the damage due to blasting and other unforeseen geological effects, systematic bolting is found

correct for new stope application in which the haulage road and cross cut is placed in the foot wall rock.

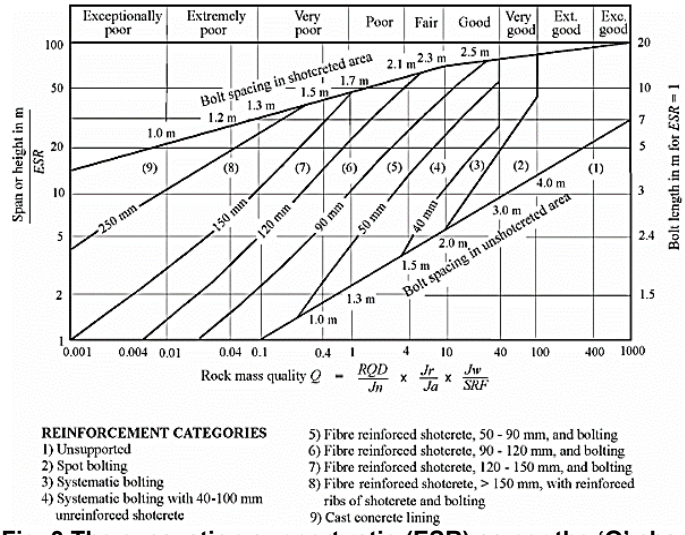

Fig. 3 The excavation support ratio (ESR) as per the 'Q' chart

MODIFIED STOPE DESIGN

Manner of extraction in sill pillar stopes, in earlier procedure of extraction in sill pillar through sill drive is described as below;

A stope drive not more than 2.4 m wide and 1.8 m high shall be made in the ore body between the two winzes leaving a block of ore 5m thick (called sill pillar) against 70'L drivage in ore, called haulage road. In the stope an ore pass and a man way at an interval of 30m shall be constructed between 70'L and stope drive. The ore pass chute shall be made of steel in segment and man way shall be made of steel/R.C.C. The man way shall be equipped for travelling with suitable platform and ladder way. The sill pillar and sill drive stopes was exhausted at 70'L from Ch. 800 to Ch. 2650 and the same stopes are under operation from Ch. 2650 to Ch. 3050 only in 70' L at Munsar Mine. Ch. 3050 onward at 70'L and below levels drift has been designed to be developed in footwall rock.

Now at 70'L from Ch. 3050 onward up to Ch. 4300, and lower levels (-) 30'L, the haulage drive of size 3.4 m x 2.1 m has been developed in footwall rock and is placed 20 m away from ore body and cross cuts of size 2.4 m x 2.1 m are driven from haulage road to intersect the ore body from foot wall to hang wall. The cross cuts are placed at an interval of every 30 m. Moreover, the raise/winzes is placed at 60 m interval. The modified strike length of stope is 60 m. In this modified stope along with the rock bolt support system has been applied.

Applied Support System

- Rock bolt support system of 1.5 m long at 2 m spacing in haulage road, cross cut, ore drive and stope back in square pattern is being introduced.
- 5 m thick crown pillar is being designed with a safe conservative estimate with FOS of 1.5. Rock mechanics instrumentation work for installation of Multi

Point Bore Hole Extensometer (MPBX) from upper level 170'L and Strain Bar installation at lower level 70'L are in progress.

- The maximum stable unfilled volume at any point of the stopping operation is estimated to be 840 m³. This has generated new avenue for introduction of LHD for mechanical handling of ROM in the stope for better productivity.

ALTERNATIVE FILL MATERIAL OF OVERBURDEN

To replace the sand as fill material, MOIL used old OB material for experimental purpose, which is available at the mine in huge quantity for filling the underground voids by hydraulic transportation. Initially some pills/pellets of overburden material at Dongri Buzurg mine of MOIL Limited were developed in the month of November 2017 with various compositions. In these pallets, polymer and binder have been used and trials were conducted at Munsar Mine in the month of December 2017. During the trials it is found that only the following product mix shows partial success for hydraulic transportation in underground, which is given in Table 2 and shown in Figure 4.

Table 2 Product mix found suitable for hydraulic stowing operation

Mix No	Fine OB (< 2 mm)	Course OB (2 to 10 mm)	Sand	Clayey soil	Gypsum based Putty	Water Content
4	45%	45%	NIL	NIL	10%	9%

Fig. 4 Product mix found suitable for hydraulic stowing operation

Observed primary results during the initial trails at Munsar Mine found that:-

- The developed product mixes after heat treatment is suitable for underground hydraulic stowing purpose in underground mines.
- Some product mixes are rejected due to its non-compatibility and properties are not matching with sand.
- It is also concluded as the increase in temperature will cause the change in bond of the mix it will change the hardness also.
- It may kindly be noted that the developed product mix is prepared only for use of fill material in underground mines for hydraulic transportation.

Field trials after treatment of material

It was then recommended and suggested that final field trial on experimental basis should be conducted at Munsar Mine in underground for minimum quantity of around 30 m³ of the material to confirm the physical properties of the OB material as fill material by hydraulic transportation in underground for future industrial application in MOIL mines. The suggested developed product mix along with the photograph is given in Table 3 and Figure 5.

Table 3 Product Mix Used for Field Trials at Munsar Mine after heat treatment

Mix No	Fine OB (< 2 mm)	Course OB (2 to 10 mm)	Sand	Clayey soil	Gypsum based Putty	Water Content
4	45%	45%	NIL	NIL	10%	9%

Fig. 5 Product mix used for hydraulic transportation after treatment at Munsar Mine

The trails show that the developed product mix material of overburden dumps can be useful only when it will be treated with heat for change in the engineering properties of the material for hydraulic stowing purpose in underground mines of MOIL. From the literature (Christine Saiang, 2010), when the samples of the Schist, Granite and Mica tested at 400ºC, 750º and 1100ºC, it is found that after heat treatment the rock affects the mechanical behaviour. It is also assumed that the heat treatment will reduce the breaking of material and retention of water properties. On the basis of the above data, the product has been developed at Munsar Mine after treatment from the OB material and trial was conducted.

Over burden material of Munsar Mine is mica schist of meta-sedimentary rock formation contain sand particle and dolomite band intrusion. Most of the Overburden material having the characteristics of plastic type paste formation and sudden fragmentation rock particle connection with water. Overburden material is erodible with respect to water, air and temperature. This research program is carried out to use overburden material inside the underground and generation of land for infrastructure and plantation purpose same as sustainable solution to environment.

The developed product mix has been tried earlier at Munsar mine for hydraulic stowing but it was suggested to go for heat treatment for better results. Accordingly, in house developed kiln has been used for heat treatment of the material of product mix. The final field trial on experimental basis has been

conducted at Munsar Mine in the month of February 2018 at underground for quantity of around 30 m³ of below developed product mix material to confirm the physical properties of hydraulic fill in underground for future industrial application in MOIL mines. The product mix along with the photograph is given below in Fig. 6 and Fig.7;

Fig. 6 Initial trial run for 30 minutes at Munsar Mine

Fig. 7 Compact filling of OB material after 2 hrs at Munsar Mine

The treated materials used as fill material in place of sand have following advantages:

- The material does not retain the water. The retaining capacity is very less than the sand.
- Minimum expansion of OB material floor with higher load in compares with sand fill
- OB fill floor is easy for movement of men and machines
- Old refuse material can be utilized for hydraulic transportation in underground.

CONCUSIONS AND RESULTS

In the modified stope design of Munsar Mine underground lateral development has been increased for stope preparation and production from the underground has been increased considerably. After implementations of the roof bolt support system, roof bolt 1.5 m long at 2 m spacing in square pattern in haulage road, cross cut and in stope back, the progress of the underground development quantity has increased. However, in turn it has improved the minable reserves

in underground as sill pillar of 5 m thickness at lower level has been totally eliminated. The production from underground has been shown improvement at Munsar Mine of MOIL Limited. Improvement in underground production and underground development progress for the year 2006-07 to 2008-09 and 2014-15 to 2018-19 is given in Table 4.

Table 4 Production of Manganese Ore and Drift Development in underground at Munsar Mine

Year	Prod from U/G in T	U/G Development in Running Meters
2006-07	8693	49
2007-08	8503	69
2008-09	14246	40
2014-15	14905	451
2015-16	15562	865
2016-17	21710	659
2017-18	30409	844
2018-19	49930	916

After the introduction of alternative fill material of OB in place of sand for hydraulic transportation to fill the voids in the stope, the floor of OB stowed material is more compact and non-expansion in nature. It will improve the face productivity by basket loading manually in comparison with sand floor and modern mobile underground equipment's could be used for drilling in stope and loading, transportation of ROM in the stope by side discharge loaders or load, haul and dump machines. With the rock mechanics instrumentation program of Multi Point Bore Hole Extensometer (MPBX) and strain bars and continuous monitoring may reduce the thickness of barrier pillar from 5 m to 4 m in coming years. This will help to conserve the manganese ore locked in underground.

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Abstract.
MOIL Limited is operating 7 underground and 3 opencast mines in central India and producing annually more than 1.3 million tonnes of various grades of manganese ore. The underground mines are operating at shallow – 90 m at Munsar mine to moderate – 353 m at Balaghat mine below the surface with horizontal cut and fill (HCF) or its variant method of stoping with post filling by hydraulic sand stowing. The Munsar mine is being worked underground since 1903. The opencast mining is presently stopped. The ore body below the opencast quarry is geological continuity of the area excavated in past by opencast method of mining. The underground mining is done through the adit in three levels i.e. 270'L, 220'L, 170'L and by incline in western part of the property at 70'L. The horizontal drift development has been developed in the manganese ore body with sill drive of 5 m above the sill pillar in lower level at 70'L and barrier pillar of 5 m thickness is left for protection of upper level at 170'L. Valuable mineral has been locked in sill pillar and therefore rock mechanics investigations have been carried out. On the basis of study now the drift development has been carried out in footwall rock at 70'L, (-) 30'L and below levels and it has improved the minable manganese ore by about 20%. In this modified HCF stope design, an alternative fill material in place of sand, which has been developed in house by use of overburden (OB) material after treatment, has been used for hydraulic stowing. The experimental trials find out that the alternative fill material of OB is more compact and forms a non-expansion floor for the men and machines in the stope. This will certainly help in the introduction of mobile underground mining equipment for drilling in the stopes and mechanical mucking, transportation and loading of the ROM. The paper presents rock mechanics investigations and future use of alternative fill material of overburden material after heat treatment for better safety and productivity at Munsar Mine of MOIL.

Keywords: Cable Bolting, Heat Treatment, Overburden, RMR, Stowing