ELIMINATION OF GROUND VIBRATIONS AND FLY ROCK: A CASE STUDY OF AN OPENCAST MINE

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ABSTRACT

Signgareni Collieries Company Ltd. is operating the JK Opencast Project, at Yellandu, with a rated annual capacity of 1.6 Mt of coal with an average stripping ratio of 4.3. This opencast coal project is having three working sections, OC-II block, C-Block and D-Block These workings are operating in close proximity to the JK-5 Longwall Shed, 26-Dip Incline, other structures of 26-Dip, and a Township. There were complaints about ground vibrations and fly rock problems caused due to blasting operations, especially in OC-II and D-Blocks. In view of this, studies were taken up to eliminate the problems of ground vibrations and fly rock.

Ground vibrations were studied by using blast vibration monitors. Modifications were effected in the pattern of initiation. Air-decks were introduced in the blastholes, resulting in a decrease in explosive charge per blast. Later, tests with true bottom initiation, using Raydets and Excels, were conducted. In the final stage, studies were carried out with the blastholes covered by 1m x 1m wire meshes overlain by sand bags of 25kg. Change in the initiation pattern from earlier V-pattern to the straight-line pattern and reduction in charge weight per delay, resulted in elimination of ground vibrations problem. Adoption of straight-row pattern of initiation with a clear free face, introduction of air deck, bottom initiation of blastholes and muffling of individual holes with wire meshes overlain by sand bags of 25 kg resulted in complete elimination of fly rock.

INTRODUCTION

Now a days, mining projects are approaching the habitated areas, in turn posing the problems of ground vibrations, fly rock and noise to the surroundings. The JK Opencast Project, Yellandu, Singareni Collieries Co. Ltd., is facing these problems, due to nearness OC-II and Block-D workings to many sensitive residential and industrial structures. For OC-II Block workings, Shantinagar village and residential school of Shantinagar are in close proximity. Longwall shed, 26-Dip Incline and other structures and a village on east and north-east sides are the sensitive structures in the vicinity of D-Bock. In these two blocks, medium size blasts consuming 2-3t of explosives are being conducted regularly. Due to the nearness of workings to surrounding structures there were complaints from the neighbours about ground vibrations and fly rock. The Singareni Collieries Co. Ltd. has always been conscious of the development process with environmental awareness. Therefore, as a part of controlling the side effects caused due to blasting operations in JK Opencast Project, a systematic and scientific investigation programme was taken up to deal with the problems mentioned above.

ABOUT THE MINE

JK Openscast project of the Singareni Collieries Co. Ltd., operating in Yellandu, is having three working sections namely, OC-II-Block, C-Block and D-Block. In all these blocks, as the seam is steeply dipping, slicing method of extraction is being adopted. Of these three blocks of working, the OC-II Block workings are very near to the Shantinagar village and a Residential School which was within 150m from the boundary of workings on south side. Quarry Floor Boundary in OC-II Block varies from 170m to 240m, whereas the Quarry Surface Boundary varies from 280m to 320m. In D-Block, the Quarry Floor Boundary is about 290m. Coal seam in the D-Block was already developed by Board and Pillar method in bottom section. D-Block workings are surrounded by Longwall Shed, 26-Dip Incline, other structures of the mine and a village on north and north-east sides in close proximity to the workings.

Method of Mining

Thickness of the coal seam extracted in JK Opencast Project is varying from 7m to 16m. Dip of the seams 1 in 4.5-5.5. Horizontal slicing method is adopted for stripping the OB in order to expose coal seam. Overburden in OC-II and D-Blocks is being handled by hydraulic shovels of 1.1cu.m capacity. In accordance with this, the bench height was restricted to a maximum of 5-5.5m. Blastholes of 150mm diameter are used.

Blasts consuming explosives to the tune of 2-3t are regularly conducted in these benches. These blasts are suspected to be the cause of instability to the structures surroundings the workings. Fly rock also was reported earlier from OC-II Block workings endangering the nearby Shantinagar Village. Disposition of various structures of importance with respect to the workings of OC-II and D-Blocks are given below:

Structure	Distance from workings (m)			
	From: OC-II workings		D-Block workings	
	Present	Future	Present	Future
• Shantinagar village	320 m	70m	-	-
• Residential school	320 m	170m	-	-
• Longwall shed	-	-	180 m	60 m
• 26-Dip incline	-	-	220 m	120 m
• Cycle Stand of 26-Dip	-	-	125 m	60 m
• Township	-	-	250 m	200 m

A burden to spacing of 3.5m x 3.5m was being used in this project. V-pattern of initiation was in practice. The total number of holes blasted in a round was ranging up to 250-300. Whenever the total number of blastholes was large, blastholes were divided into two V-pattern layouts, but initiated simultaneously, in turn increasing the charge per delay, in spite of providing sufficient delays in the blast round.

INVESTIGATIONS

A. Ground Vibrations

Ground vibrations generated from the blasts were monitored by Microprocessor based Seismographs, Blastmate DS-477, Series II of Instantel, Canada (one no.) and Minimate DS-077, Series II of Instantel, Canada (two Nos.). Monitoring in general was done near the surface structures surrounding the D-Block of JK Opencast Project, like longwall shed, cycle stand of 26-Dip, entrance of 26-Dip, officers colony, nearby village etc. in addition to other points. Fig.1 shows the details of the positioning of blasts in D-Block and monitoring stations. In total, 38 ground vibration events were recorded and 17 blasts were studied for making experiments with air decks, change in pattern of blastholes, introduction of air decks, muffled blasting etc.

Regression analysis was performed to obtain best wave propagation equation for the given project site. The best fit for present case was, therefore, found to be USBM equation with square root scaled distance as:

V – 120 (D/W*0.5)*-1.125

Where, V = Peak particle velocity, mm/s

D – Distance between blast site and structure, m

W = Maximum explosive charge per delay, kg

Intensity of ground vibrations was in general found to decay quickly in this project site. This may due to the thick soil cap existing in the area and also the large grained argillaceous sandstone overburden. This also might be the reason that for almost all the blasts monitored from a distance of 50m and above from blast site, frequency of ground vibrations was below 20 Hz in general. From this wave propagation equation, Safe Charges that can be detonated per delay to keep vibrations within safe limits were computed. Some more blasts were conducted to verify the validity of these safe charges.

B. Fly Rock

It was observed that in the benches with a height of about 5m, a pattern of 3.5m x 3.5m being used. This seems to be of a higher order considering the ratio of bench height to burden (approximately 70%). Excessive burden distance results in increased stiffness of the bench, leading to ground vibrations and fly rock problem. Keeping this in mind, the pattern was changed from 3.5m x 3.5m to 3m x 3.5-4m. Another point always to be considered while conducting a blast is that the spacing between holes should always be greater than burden. In case these values are equal, premature splitting of blastholes takes place resulting in the escape of explosive energy from the blastholes causing fly rock. The new pattern was suggested to take care of this problem.

Another main point of concern was the charging of explosives in the blastholes. It was decided in the first step to divide the explosive column into two decks, the idea of which was to ensure proper distribution of explosive energy in the total length of blasthole.

Accordingly, first blast was conducted in D-Block by using decked charges. Tape was used to measure the exact length of explosive and stemming columns in the decks.

Theory of air decking suggests that the air deck in blasthole enhances the time period over which explosive pressure front acts on the surrounding rock mass. This results in an increase in crack network in the rock mass in front of blasthole. Studies made by High Speed Photography indicated that the blasts with air deck charges result in lesser movement of material from the blast site. Based on this, it was also suggested that whenever material movement is required, like the case in cast blasting, air decks may not be used. It was also concluded from some earlier studies that the blasts with air decks also minimize back-break problem. This is another significant point of concern in D-Block workings especially in top benches, where back-break is also one of the main problems.

Experiments were conducted by introducing one air deck (top column) of 0.5m length over the explosive charge (below the stemming zone) as shown in Fig. 2. On an experimental basis, the charge in blasthole was reduced by about 0.5m length, i.e. 9.375 kg. Results indicated that there was no effect on fragmentation, which was registered by the loading operations. Fragmented material could be loaded normally by 1.1 cu.m hydraulic shovels, without any problem. The problem of fly rock was also found to decrease. In fact, in some of the blasts, no pieces of rock were found on the floor of the bench as well (Fig. 3). In total, four blasts were conducted with air decks.

Subsequently, studies were conducted by changing the initiation patterns. During the investigations it was found that the delay timing used earlier was not proper. In addition, V-pattern of initiation was followed in the mine. It was also observed that blasts with 200-300 holes were being divided into two separate networks with two V-patterns and blasted simultaneously. This effectively increased the charge per delay Number of rows blasted will be more with V-pattern compared to a straight-line pattern, which results in more confinement of charges. The connection of delays also is simple in the latter. Keeping these two points in mind, initially a large blast with 193 blastholes was conducted with one portion initiated with straight-row pattern and the other connected with V-pattern of initiation. It was observed that the portion having straight-row pattern of initiation gave better results. Later, some blasts were conducted with straight-row pattern, gradually reducing the number of rows to 5-6 using cord relays. There was significant improvement in fragmentation, no trace of fly rock and decrease in ground vibrations as well due to this. Cord relays used in the blasts were increased, to minimize the explosive charge on any given delay. Steps were taken to initiate one, two or maximum three holes at a time controlling the charge per delay. These blasts indicated significant reduction in ground vibrations and fly rock. Details of the blasts studied in D-Block workings are shown in Fig. 1.

Later, experimental blasts were conducted in OCII – Block, with muffling of blastholes, in order to avoid the fly rock problem totally. This is due to the nearness of the Shantinagar village and the 100% safety to be achieved in such conditions. As a part of this programme, wire meshes of 1m x 1m size were prepared from old haulage ropes. Each blasthole was covered with these wire meshes. Sand bags weighing 25 kg were kept on these blastholes covered with wire meshes. Fig. 4 shows the arrangement of the muffling system adopted to eliminate the fly rock problem in OCII Block workings. Pattern of the hole initiation was straight-line with two or three holes on each delay. There was no trace of any fly rock even on the backside of the portion that was blasted. Results of these blasts showed complete elimination of fly rock, which can be judged by Fig. 5. Same technique has been used by the author to carry out blasting operations in close proximity to the charged pipelines carrying LPG, Petrol, Naphta etc. in Mangalore Refinery and Petrochemicals Ltd. premises at Mangalore.

Peak particle velocity near the Shantinagar village was contained to below 6.25 mm/s, as per the norms suggested by DGMS authorities. To minimize the noise problem, blasts were conducted with Excel system of initiation. This showed a considerable decrease in noise levels by about 10-15 dB at distances of 100-125 m.

Based on the studies, blast pattern for every bench was prepared for controlling fly rock and ground vibrations giving details about burden, spacing, stemming, number of rows, number of delays with timing, pattern of initiation etc.

CONCLUSIONS

- It may be asserted that out of various criteria for establishing safe ground vibration limits, measurement of peak particle velocity (PPV) is considered to be the best. In accordance with this criterion, a PPV of 25 mm/s may be considered safe for the structures of modern construction (RCC structures like the officers colony, longwall shed, Residential school near Shantinagar village), 12.5 mm/s for old structures and structures standing on improper foundation and in poor repair condition, and 6.25 mm/s for houses with mud walls like the houses in Shantinagar village. This classification takes care of the lower frequency ground vibrations, whose frequency falls within resonance frequency range of structures. These safe limits are quite conservative.

- Blasts conducted with modified explosive columns, changed pattern of initiation (straight-row pattern) and increased delays between rows compared to earlier ones and restricting the number of rows to a maximum of 5 eliminated the ground vibrations problem. Ground vibration level near the houses in Shantinagar village was restricted to below 6.25 mm/s, by adopting above mentioned improvements in the execution of blasts.

- Controlled blasting practice with muffling of individual blastholes by 1m x 1m wire mesh overlain with sand bags, completely eliminated the fly rock problem in OC-II Block.

- Another important point observed during the studies is the cost saving involved with air decking. Introduction of air deck of 0.5m length in a blasthole of 5.0-5.5m resulted in a direct saving of 9.375 kg explosive. There was no negative impact of this air decking on fragmentation, at least in top three benches where experiments were conducted, with a positive influence noted in decreasing ground vibrations and fly rock problems.

Reduction or elimination of environmental effects of blasting requires a good coordination between driller, foreman and the blasting engineer. Careful drilling according to the markings made in the filed and judicious charging of holes and their initiation are the major factors which require much more attention. Studies conducted in JK Opencast Project may be a good beginning towards achieving the goal of eco-friendly mining. Controlling of environmental problems indirectly saves significant sums of money to the organization, in the form of avoiding public protests, closure of workings etc. Confidence in the neighbours about mining operations could be considerably improved by taking up such studies, whenever there is problem or at regular periods of time, which is also a very important aspect from mine management point of view. Good interaction between Industry-Institute is essential for overcoming such trivial problems faced by the industry in general and mining industry in particular.

ACKNOWLEDGEMENTS

Author is thankful to the management of The Singareni Collieries Co. Ltd., Andhra Pradesh, India, for funding the studies. Views expressed in this paper are of the author and not necessarily of the organization he represents.