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Hazard Identification, Monitoring and Control in Blasting Operations

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Abstract: Blasting in mines is a hazardous operation and consists of considerable environmental, health and safety risk to miners due to dust, fumes, ground vibration, air overpressure and fly rock. Blasting also damages the structure or property in the vicinity of the mines or blasting area, and the main causes for such damage are air overpressure and ground vibration
To overcome the effects of Blasting Hazards, there are too many rules and safe operation procedures are framed as per Metalliferous Mines Regulation 1961 and D.G.M.S. Circulars. The one of the important factor in this is Blasting Zone. The Blasting Danger zone is 500 meters radius of the Blasting area. No person should enter in the Blasting zone during the blasting.
In certain circumstances it is very necessary to take a blasting operation in the place where occurrence of important buildings, plants or any infrastructures within the Blasting zone. In such cases we have take special blasting procedure to prevent fly rocks, ground vibration and also importance of safety.
To control the ill effect of ground vibration and air overpressure a proper risk assessment is necessary. After making the assessment guidelines could be framed for monitoring and controlling.
Keywords: Director General of Mines Safety (D.G.M.S) , Peak Particle Velocity (PPV) Detonation Pressure (D.P) , Risk Rating (RR), Safe Operating Procedure (SOP).

I. INTRODUCTION

Generally blasting is carried out in mines to excavate minerals in large scale. If hard rock exists in large quantity, and it is to be excavated, then drilling and blasting is the best method that can be adopted because drilling and blasting is the fastest and economical way of excavation of hard rock. The situation gets complicated when blasting is to be carried out near any structures. While blasting, it results in some adverse environmental issues, as a part of the total energy of the explosives used in blasting is consumed in breaking rocks while the rest is dissipated. The dissipated energy creates environmental problems in the form of ground vibration, air overpressure and fly rocks. Ground vibrations and air blasts are an integral part of rock blasting and are unavoidable. For that, accurate control must to be seriously considered to minimize blasting effect on people and environment. When a blast is detonated, some of the explosive energy not utilized in breaking rock travels through the ground and air media in all direction causing air blast and ground vibrations.

A. Objectives of the Study

1) To arrive at a suitable blast design parameters for rock blasting.
2) To arrive at a suitable muffling procedures to control flyrocks.
3) To monitor ground vibration and air overpressure near critical locations.
4) To get good fragmentation considering less ground vibration and Flyrocks.
5) To suggest procedures for control of air overpressure and ground vibration.
6) To recommend safe maximum charge per delay to keep vibration levels within the safe limits as per Director General of Mines Safety (DGMS), GOI recommendations.

II. EFFECTS OF BLASTINGS

A. Blast Induced Vibration

Explosive energy generated by the explosive must be adequate to overcome the tensile strength of the rock mass. This series of blast holes must then be detonated in a controlled sequence as to control the burden and spacing dimensions between adjacent holes. A well-designed blast will efficiently utilize the explosive energy in order to result in optimum fragmentation and burden movement. One of the negative impacts of blasting is ground and air vibration. Proper burden spacing design dimensions maintained through

accurate field controls typically will yield reduced ground vibrations as the energy is used to fragment and move rock and not to create excessive ground vibrations through energy over-confinement.
Vibrations generated by blasting that are transmitted through the ground are typically referred to as elastic vibrations
Elastic ground vibration is wave motion emanating outward from a blast much like ripples in water as a pebble is dropped in to a pool.
Elastic ground particle motion of this type is generally classified into two major categories.

1) Surface waves are elastic vibrations that are transmitted through the geology at the earth's surface. Surface waves are further classified into these types of vibrations.
   a) Vertical and Horizontal shear waves-back and forth motion
   b) Rayleigh waves-Rotational motion
   c) P and S waves-Compressional and shearing motion
2) Body waves are transmitted deep into the earth's crust and are returned back to the surface through a phenomenon called Refraction or Reflection. These reflected signals effectively change the characteristics of the surface wave.

B. Effect of Blasting on Ground Instability

Part relevant research work has shown that peak velocity (PPV) correlates best with the degree of damage caused by blasting vibration can also give rise to long term ground movements which may contribute to structural disturbances. In practice, structural damage may result from a complex interaction mechanism and it is important to emphasize, that while PPV may be the single most valuable parameter to observe, ground motions propagation velocity and frequency must also be considered

C. Effect of Fly Rock

Fly rock is caused by a mismatch of the distribution of explosive energy, type of confinement of the explosive charge, and mechanical strength of the rock. Factors responsible for creating this mismatch include:

1) Abrupt change in the rock resistance due to presence of joints; cracks; layers of mud, silt, or soft material in the host rock; differential weathering of rocks near an outcrop; faults and slip planes; back breaks, overhangs, and uneven highwall face;
2) High explosive concentration leading to excessive localized energy density due to migration of explosive charge into fissures, caverns, voids, and mud seams;
3) Deviation of blast holes from the intended direction causing a reduction in burden or spacing;
4) Insufficient or improper stemming leading to stemming ejection and bench-top flyrock;
5) Inappropriate or poor blast design.

III. MINING AREA AND BLAST WORK

In the Mining area where a present situation occurred that the Mines area is encountered very Hard rock at the Top most Benches, in which without developing the Top most Benches, it is impossible to Work and progress the bottom benches. Hence it is necessary to remove the Top benches. But the hardness of the rock at Top benches is very high such that it cannot be removed by using Rippers and Dozers. Hence it is necessary to take the Drilling and Blasting works.
The Adjacent areas of the Topmost Hard Benches are very sensitive and critical areas. Since Petrol/Diesel Bunk were present very close to the Blasting area. Also on the other side Parking lot and Processing plant were also located closely. To carry out the Drilling and Blasting work at this particular area it is necessary to withdraw all the infrastructure/plants such that around 500 meters radius from Blasting place should be free from all the buildings. Practically it is not possible. Since the Processing plant is the main production unit for the mines.
To remove this top most benches without disturbing the other structures and plants, it is an important aspects to have controlled blasting techniques in which, the Top bench hard materials will be carried out drilling and blasting. But due to blasting no damage or harm will occur to the adjacent area for both men and properties.
So our Goal is

A. To carry out the Drilling and Blasting work which will reduce the other over head costs like ripping, dozing and Breaking of hard rock.

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B. To Get a good Fragmentation with least cost
C. To control the Vibration and Structure damage due to cracks.
D. To control and avoid the Cause of Fly rocks which is one of the most hazard in a Blasting work.

To fulfil the above said goal we have to carry out the Controlled blasting techniques in the Mining.

IV. RISK ANALYSIS AND HAZARDS

Risk Analysis is an important Safety aspect in case of the Control Blasting techniques. Since the Blasting area is very sensitive and have a permanent structures and parking yard were come across within the safety zone.

A. Risk Analysis

The safety zone of the Blasting area at A. Narrian mines consists of HSD bunk and Parking yard. Hence the detailed Risk assessment was carried and the same is tabulated below.

Sl. No.	Identified Hazard	Risk Rating			Total	Control Measures
		E	P	C		
1	Heavy ground vibration.	10	10	0.1	10	Less charging of shot holes and limited sub grade drilling
2	Back Breakage of Bench	5	7	0.1	3.5	Blasting carried out by presplitting
3	Fly rock	10	10	5	500	Operating by Control blasting techniques.
4	Damage criteria on Parking yard and Processing plant	10	10	5	500	Operating by Control blasting techniques.

B. Risk Assessment rating and its control measures

V. SAFE OPERATING PROCEDURES

A. Sop for Blasting Operations

1) The blasting operation is placed under the charge of assistant manager.
2) Blasting foreman, blaster, blasting helper & sentries are working under assistant manager for carrying out blasting operation.
3) The preparation of the charge & charging, stemming of the deep holes is carried out by the blaster & blasting helper under the supervision of the foreman.
4) Shots are fired by the blaster.
5) Every day or whenever the blasting is going to take place, a written information sent to the manager of neighboring mines through sentries to enable him to warn his all employees for TAKING PROPER SHELTER at the time of blasting. The written information is acknowledged by the manager or other authorized person.
6) Shot firing is carried out during the rest interval/between the shifts i.e. between 10.30am to 2.30pm.
7) Before commencing the charging the sentries are sent to all such place where men & machineries are working to evacuate them to safer distance.
8) Red flags are properly arranged, on the top of our check post & another 2-3 flags to block the entries & road & wherever required at least 30 minutes before firing of shots is to commence.
9) Hand siren 1km range is installed near check post & 10minutes before firing, siren is blown three times for one minute each at intervals of one minute & shots are fired when blasting in charge foreman has ensured that all persons have left the danger zone & taken adequate shelter.
10) "ALL CLEAR" signal is given by blowing a two minutes long siren and removing all red flags after completion of blasting operation.

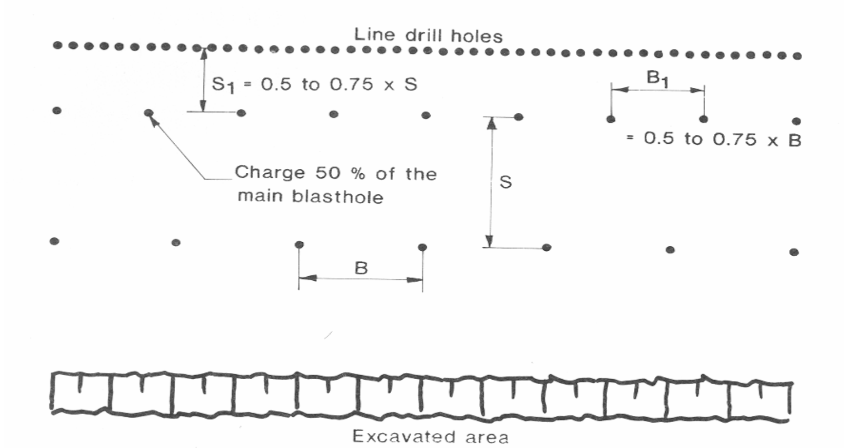
Responsibility: Blaster, Foreman, Asst.Manager and Manager

VI. CONTROLLED BLASTING

To reduce the damage or ill effect of blasting on the nearby structures and properties and to control ground vibration and air overpressure, controlled blasting technique was introduced. The different types of controlled blasting are.

A. *Line Drilling*

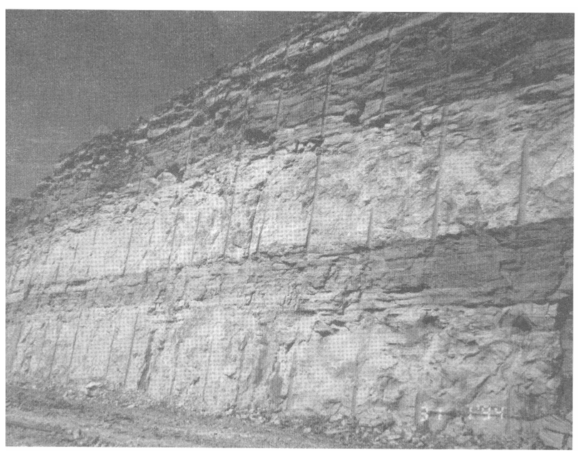
Line drilling is the earliest controlled blasting method used. The purpose of line drilling is to create a plane of weakness by drilling closely spaced, small diameter holes along the perimeter of the excavation to which the blast can break. Line drill holes are usually not over 75 mm in diameter and the spacing is 2 to 4 times the diameter of the hole. The hole depth should not be more than 12 m, since deviation in longer holes may produce adverse results.



Line Drilling

B. *Presplitting*

This is the most successful and widely adopted controlled blasting method and creates a plane of shear on the desired line of break, exposing the half barrel of the blast hole after excavation



Pre Splitting

VII. METHOD OF WORKING

A. *Field Study of Mines*

1) The Mines area is encountered very Hard rock at the Top most Benches, in which without developing the Top most Benches, it is impossible to Work and progress the bottom benches

2) Hardness of the rock at Top benches is very high such that it cannot be removed by using Rippers and Dozers. Hence it is necessary to take the Drilling and Blasting works.
3) The mine management were actually planned to relocate the Parking yard and Workshop from the existing place for safety. This will cost very high and also take more time. Mean time the works were delayed

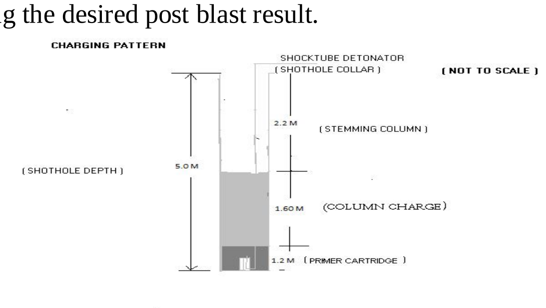
B. Drilling Pattern
Based on the area to be cut and the designed blast geometry and dimension, required Nos. of vertical shot-holes of 110 mm. diameter are drilled and fired in 1 to 2 patches of 12-20 shot-holes(approximately) with Crawler mounted drill machine as per designed spacing, burden and shot-holes depth to give the desired size of rock. The depth of the shot-holes varies from 5.0 to 7 m depending on bench height. The burden and spacing varies from 2.25 to 3.25 m and 2.50 to 3.50 m respectively

C. Charging Pattern
As per required size of rock, taking the geological factors (nature of formation of rock, density and hardness of rock etc.) affecting the blast and size of desired rock, all the drilled shot-holes are charged with predetermined quantity of latest developed Emulsion Explosives of 83 mm. diameter and 2.78 kg. of weight to suit the shot-hole diameter of 110 mm. The Emulsion Explosives are much safer in handling, usage and transportation with optimum energy and strength to break the rock, has no any detrimental effect on health and thus are Environment friendly.

D. Charging Pattern for 110 mm. Hole
1) Shot-hole Diameter –110 mm.
2) Burden – 2.25 to 3.25 m
3) Spacing –2.5 m to 3.50 m
4) Shot-hole Depth –5.0 m to 7.5 m(Including Sub grade)
5) Explosives –Solarprime/column ,83 mm. – 7-12 Cartridges x 2.78 Kg =19.46 Kg to 33.36 Kg..
6) Charge Length – 2.80 M to 4.80 M
7) Stemming Column – 2.2 M. to 2.7 M.
8) Initiation –Electric Detonators, Non-electric shocktube detonators,TLD – 3.0 M to 4.0 M. long, TWINDETS.
9) Initiation Pattern – Staggered and row by row connection for better fragmentation

E. Initiation (Firing) Pattern
In hard rock of homogeneous nature TWINDETS are used with various surface and down-line delay-timings. There are various delay range in TWINDETS which are site and blast-specific and are decided at the time of procurement as per requirement of the blasts. The specification of the TWINDETS & TLD used so far is mentioned in the blasting pattern and in the Explosives consumption detail for your reference.

The methodology of Drilling & Blasting is given in Annexure-A .The methodology given in annexure-A1 to A-4 comprises some of the standard patterns which are subject to change during actual Drilling and Blasting depending upon various site specific factors affecting the desired post blast result.



Drilling and charging pattern

Laying of blasting pads by hydra

F. Risk Assement after Control Blasting

With due control blasting measures by reducing the risk from fly rocks and vibrations are drastically suppressed to bear minimum. The below table indicates the Risk Assessment score after control blasting applications.

Sl. No.	Identified Hazard	Risk Rating			Total
		E	P	C	
1	Heavy ground vibration.	0.5	3	0.0001	0.00015
2	Back Breakage of Bench	0.02	1	0.0001	0.000002
3	Fly rock	2.5	1	0.1	0.25
4	Damage criteria on Parking yard and Processing plant	2.5	1	0.1	0.25

Risk assessment after control blasting

The above table shows the minimum level of risks in each activity due to blasting.

VIII. DISCUSSION AND RECOMMENDATIONS

A. The blasts carried out during the field investigation period were safe with respect to ground vibration, air overpressure and fly rock.

B. The recommended hole diameter for further excavation is 110mm. The total number of holes in a blast shall not exceed 30 and the number of rows in a blast shall not exceed three. The burden and spacing shall not exceed 1m. The depth of the holes should be restricted to 6 m and the charge per hole shall not exceed 33 kg. The recommended initiation system is non-electric shock tube initiation system (250ms DTH and 17, 25, 42ms TLDs) and the recommended explosive is small diameter slurry/emulsion (125gm per cartridge).

C. The blast designs followed during the field investigation period may be continued for further excavation.

D. The recorded frequency of ground vibration is greater than 10Hz. The recommended safe peak particle velocity for the structures around the excavation site is 5mm/s as per the DGMS guidelines and the permissible air overpressure is 133dB.

E. No blasting shall be carried out within a distance of 10m from the structures and the maximum charge per delay suggested in table 7 may be adhered while blasting from 11 to 17m from the structures. For distances 18m and beyond a safe maximum charge per delay of 0.375kg is recommended.

F. It is recommended to monitor ground vibration near the structures when blasting is carried out at a distance of 10 to 50m form the structure.

G. The orientation of the blast faces should be designed in such a way that the structures close to the blasting site falls in front of the blast face (void side) or to the side of the blast.

H. The blasting area shall be muffled with sand bags, link mesh and blasting mats to restrict fly rock and to mitigate air overpressure as practiced during the field investigation period. No damaged link mesh, sand bags and rubber mats shall be used as this could lead to fly rock and excessive air overpressure.

I. No blasting shall be carried out within a distance of 30m from the hardening concrete and if blasting is in evitable, it should be carried out after 72hrs of poring of the concrete.

IX. CONCLUSION

Controlled blasting is possible in urban environment beyond a distance of 10m from the critical structures. Ground vibration and air overpressure can be controlled within permissible limits while blasting close to critical structures by adopting controlled blasting.

Fly rock can be controlled within the source by proper muffling procedures while blasting in urban environment or near any structures.

Back Break of the Bench may be controlled by presplitting method of blasting.

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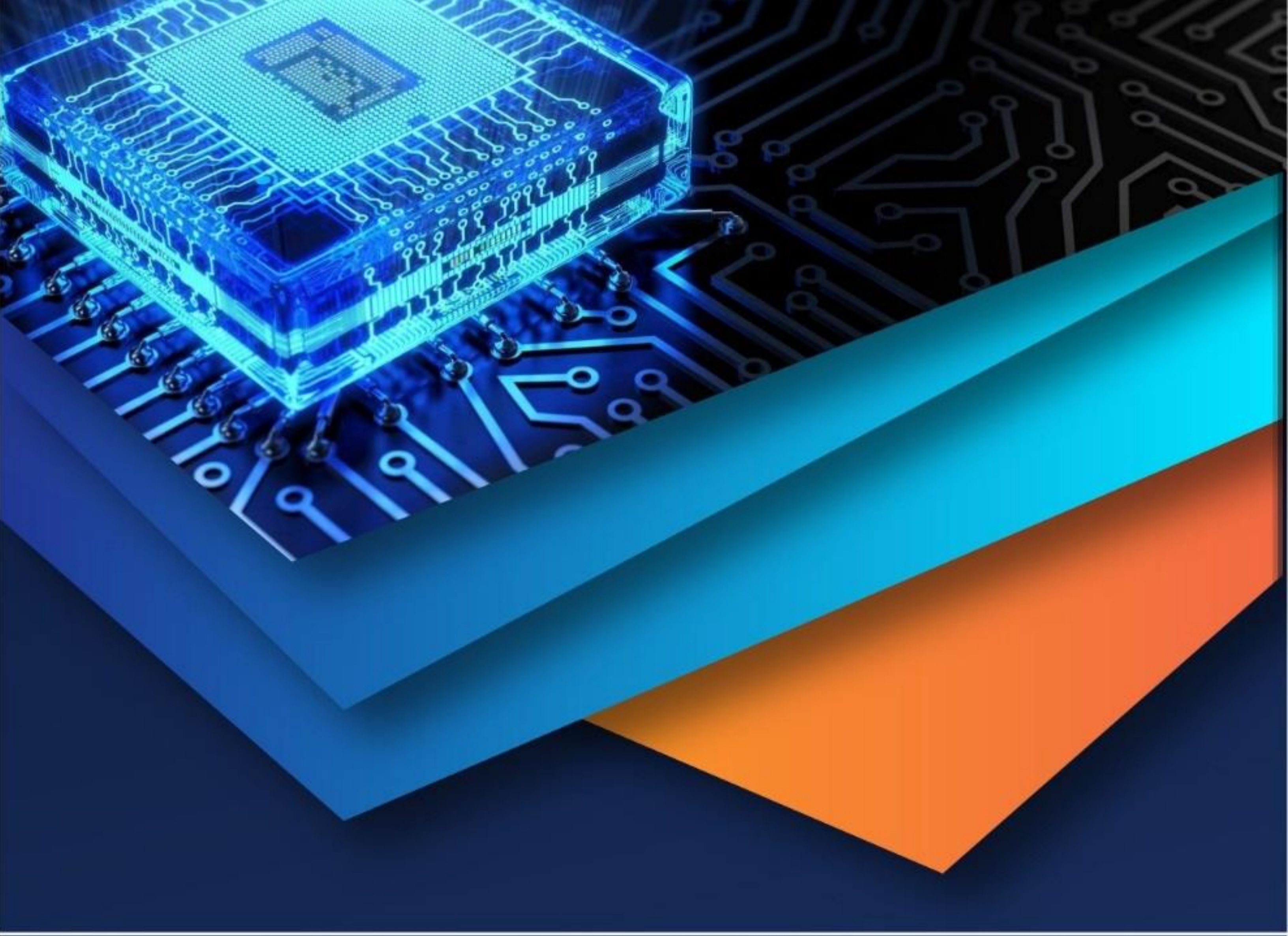

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