Research Article

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. Blasting accidents in the mining industry tend to result in critical injuries or fatalities. Accident reports and information collected from the Mine Safety and Health Administration (MSHA) and other government agencies provide supporting evidence. According to the data collected, blasting-related accidents (in mining) were 11 times more severe than all other types of mining accidents. Blasting accidents are not unique to mining operations - the same situation exists in the construction field. 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.

1. INTRODUCTION

Generally blasting is carried out in mines to excavate minerals in large scale. If soil or soft rock alone exists, they are excavated by using excavators. If weak or weathered rock is to be excavated and is in small quantities, it can be excavated using mechanical breakers like rock breakers, splitters etc. 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. Air blast and ground vibration from blasting is an undesirable side effect of the use of explosives for excavation. The effects of air blast and ground vibrations associated with blasting have been studied extensively. Particular attention has focused on criteria to control the vibration and prevent damage to structures. In order to control and protect the structures from deleterious effect of ground and air vibrations, regulations have been formulated in different countries. These regulations vary from country to country depending on the type and the construction material used.

2. 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.

3. MECHANICS OF BLASTING

The mechanics of blasting are treated in this chapter in a simplified manner to point out basic principles and conditioned. The word “explosive” has used here is defined as
chemical components or a mixture of components of that reacts to liberate heat or mechanical energy by decomposing rapidly into other components mostly gases.

3.1. PARTITIONING OF ENERGY

Although complicated, the general mechanics of blasting or now at least partially understood. Three main stages of blasting are pressure build up, wave transmission and blast.

Peak pressure and shock wave: explosion gases occupy a much greater volume at ordinary confining pressures than the original charge and are capable of building up transient peak pressure of 10 atmosphere (atm) or more in the vicinity of charge. A resulting shock wave generated within a few milliseconds (ms) following detonation propagates away from the explosive charge. Even the strongest rocks are shattered in the immediate vicinity.

Elastic (seismic) waves: work is performed in the crushing rocks surrounding the charge, and consequently the initial shock wave being to decay in intensity after leaving the point of detonation. At a relatively short distance the compress strength of the rock. From this point on rock crushing stops, but other pressure are primary (p) and shear(s) waves continue through the rock mass. The velocity of the p wave varies mainly according to the elastic properties of the rock. In weak rock, it will travel approximately 5,000 to 10,000 feet per second (fps) and in strong rock with little jointing, it will travel as fast as 20,000 (fps). The s-waves perform work by moving the rock particles longitudinally and transversely. For this reason, the waves will attenuate until they eventually die out until a free face is encountered. The distance of travel of these waves is measured in hundreds thousands of feet in construction blasting. These waves are of considerable importance in regards to damage and vibration control.

AIR WAVES: a portion of the energy that reaches the free face as a P-wave may be transferred to the air in the form of an air wave.

3.2. FRAGMENTATION NEAR EXPLOSION.

1. For a spherical charge or a section perpendicular to the axis of a cylindrical charge. The rock medium assumed for this illustration is essentially infinite in extent so that the effect of free boundaries is not included.

2. Four major zones can develop. The first is the explosion cavity (essentially the original charge cavity) where the process I hydrodynamic. The second and third zones are the crushed and blast fractured zones, respectively, where the shock pressure is rapidly reduced as a result of plastic low, crushing, and cracking. The fourth zone is the seismic zone, where the stress is below the elastic limit and no configuration occurs, except near free boundaries as discussed below.

3. Crushing and fracturing are functions of the explosives type, charge loading, and the rock parameters. The size of the crushed zone is usually larger in rocks of lower compressive strength. Use of explosive with low detonation pressures or decoupled charges (isolated from rock by air space) in competent rock may reduce crushed zones and control the extent of the blast fracturing. The crushed zone typically extends to about twice the charge radius. The radius of the blast fractured zone is typically six times the radius of the crushed zone, or about three to four times the radius of the crushed zone adjacent to a very large point charge. The spacing between fractures increases outward. Radial fractures develop from hoop stresses at the front of the divergent stress wave. A second and equally important type of fracturing in the blast-fractured zone is spalling as discussed below.

a. Spalling:

1. Natural joints and free faces promote paling fragmentation. First there are air-rock interfaces, i.e., the excavation surface or free face. Second there are multitude of open fissures, bedding planes, etc., that constitute internal free face.

2. Spalling is caused by tensile stress resulting from interference between the tail portion of an incident compressional wave and front of the same wave which has been transformed on reflection at the free surface into a tensile wave. Rocks being strong in compression but weak in tension are particularly prone to spalling. They are able to transmit very high compressive stress, but when these are transformed on reflection into tensile stresses, the rocks may fracture or spall.

3. The higher the ratio of compressive to tensile strengths, the more extensive the spalling becomes. The ratio is sometimes known as blasting coefficient. The harder and more competent rocks are more susceptible to spalling.

These new cracks, in turn, serve as reflecting tensional waves. Thus, other parallel spalls form until attenuation subdues the tensional wave to below the destructive level (tensile strength of rock), or until the spalling has migrated back to the explosion cavity. The strength and blasting coefficient are not necessarily representative in general of the particular rock type.

b. Combined role of expanding gases: the combined effect of rock fracturing by compressional and tensional wave are greatly augmented by hot expanding gases that work their wave along fractures, churning pieces together and moving large block and masses. Fragmentation results in part from collision of pieces. The shock wave is responsible for only a part of the breakage. The whole process is a complex interaction of several processes.

4. MONITORING OF GROUND VIBRATION

In order to prevent the neighboring structures from the ground vibrations arising from a blast, it is necessary to monitor these vibrations and design the ideal blasting pattern.

Monitoring is an operation in which the frequency and the velocity of the seismic waves in transvers, vertical and longitudinal directions are measure. The corresponding peak particle velocity, peak acceleration, peak displacement and peak vector sum are determined from the event report. The monitoring instrument minimate is suitably placed nearby the
structure and monitoring operation is carried out for which the instructions are given on minimate face panel view. The geophone sensors placed inside the minimate detects the ground movements. These sensors emit electrical signals through the conductor wires and are recorded by the sensors. This constitutes the entire seismograph system. Now the computer system analysis the recorded signals through a modem and the event report is thus obtained through the printer. Based on the event report a conclusion can be made as to whether the vibrations are critical or not for which the appropriate blast pattern is determined which have been explained in the concluding chapter.

4.1 VIBRATION MONITORING EQUIPMENT

There are various instruments which are used to monitor the ground vibrations.

1) Instantel Minimate.
2) Seismograph.
3) ABEM Instrument.
4) SINCO.
5) Blastotronics.

Some of the instruments which are commonly used are listed below

1) Instantel Minimate.
2) Seismograph.

The detail about the Instantel Minimate and Seismograph are given below

4.1.1 INSTANTEL MINIMATE
Minimate consists of a geophone and microphone, in order to monitor the ground vibration level and noise level. There are two models of Minimarts

1. Consists of an internal Geophone.
2. Consists of an external Geophone.

4.1.2 KEY FEATURES
1.40 Full wave form event capacity.
2. Easy personal operation.
3. Multiple record modes offers you unlimited flexibility during monitoring operations single event, continuous, auto record time programmed start/stop and manual operation.
4. Full wave form event analysis:- Full field analysis of the event including peak particle velocity, peak air (sound) pressure, peak vector sum (PVS). Peak acceleration and peak displacement.

i. Compliance and national frequency Analysis standards.

4.2 EVENT MONITORING

Event monitoring measures both ground vibrations and air pressure. The monitor measures, vertical and longitudinal ground vibration. Transverse ground vibrations agitate particles in a side to side motion. Vertical ground vibrations agitate particles in an up and down motion. Longitudinal ground vibrations agitate particles in a forward and back motion progressing outward from the event site. Events also affect air pressure by creating what is commonly referred to “air blast”. By measuring air pressures, we can determine the effect of air blast energy on structures, measured on the linear “L” scale.

4.3 MINIMATE OPERATING PRACTICAL FIELD NOTES

1. PURPOSE OF BLAST VIBRATION MONITORING
   • Document Compliance with established vibration guidelines
   • Protect Structures
   • Optimize Blasting & minimize risk of damage or annoyance
   • Protect yourself against claims and lawsuits
2. HOW TO PLACE GEOPHONE
   1) Spikes for Loose Soil, Mud Etc.
   2) Adhasives for Hard Rock
   3) Plaster of Paris (Pop) for Hard Rock
   4) Sand Bag for Hard Rock

3. OPERATION OF DS-077 MINIMATE:
   • Press (*) Key Once for Turning the Minimate “ON”
   Unit Displays the Following after Turning On
   • Hold (*) Key to Turn OFF The Minimate.

A) Setting up the MiniMate in CONTINOUS/SINGLE MODE for vibration monitoring:
   1. Press SETUP Key.
2. Select Record Mode as **CONTINUOUS/SINGLE** using arrow keys (↑ and →).
3. Press (*) key.
4. Select Trigger source as **GEOPHONE**.

**Geophone Trigger Level:**
1) MINIMUM RANGE 0.25 MM/S
2) MAXIMUM RANGE 127 MM/S

**Microphone Trigger Level:**
1) MINIMUM RANGE 106 db (L)

5. Select Trigger level with respect to Unit distance from the blast as follows using arrow keys (↑ & →) (Field tips suggested with our experience):

   **When Minimate is kept**
   - 50 mtr. to 100 mtr.
   - 100 mtr. to 300 mtr.
   - 300 mtr. to 500 mtr.
   - 500 mtr. to 1000 mtr.

   **Geophone Trigger Level**
   - 2 mm/s to 3.00 mm/s.
   - 1 mm/s to 1.50 mm/s.
   - 0.50 mm/s to 1.00 mm/s.
   - 0.25 mm/s

**Record Time:**
Set **Record Time** using the following formula with arrow keys (↑ & →).

\[ \text{Record time} = \text{TFT} + \text{D} \]

TFT (Total Firing Time) - 1 second for every 1000ms of firing time D (distance from blast) - 1 second for every 330 meter distance between Minimate and blasting holes.

**Example:** If you have a blasting pattern with total firing time of 560 ms and you are trying to record vibrations at a distance of 300m from the blast then set total record time as 2 second (generally we should keep record time of 3 second)

Press (*) key.

Text and Notes: Select “Blank text lines” using arrow keys (↑ & →).

### 5. 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.

In the A Narrian mines the Safety zone of the Blasting area is mainly consists of a HSD Bunk and a parking yard. Hence to blast the Mine Benches we have to find out the Risk and Hazards and its controlling measures.

#### 5.1. 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.

#### 5.2. SAFE OPERATING PROCEDURES

##### 5.2.1 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

##### 5.2.2 SOP FOR CHARGING OF DRILL HOLE

1. Before charging of drilled hole/shot hole should ensure that it allows a clearance of at least 3mm over the diameter of cartridge of explosive.
2. No shot hole shall be charged before it is thoroughly cleaned.
3. Explosive shall be delivered first to the hole so as to avoid person walking among piles of explosives.
4. The process of charging, stemming etc., shall be carried out under the personal supervision of blasting foreman.
5. Not more than one hole shall be in the process of being charged.
5.2.3 PRECAUTIONS AGAINST ELECTRICAL STORM DURING CHARGING

- No explosives, particularly detonators shall be handled.
- If the charging operations have begun the work shall be discontinued until the storm has passed.
- If the blast is to be fired electrically all exposed wires shall be coiled up if possible placed in the mouth of the holes or kept covered by something other than a metal plate.

Responsibility: Blaster, Blasting foreman and Assistant Manager.

5.2.4 SOP FOR STEMMING OPERATIONS

1. Every shot hole shall be stemmed with sufficient & suitable non-inflammable stemming so as to prevent the shot being blown out.
2. Only loosely filled-in sand or soft clay or compact mixture of sand & clay shall be used as stemming.
3. The stemming material should be compact but not hard.
4. The size of the stemming rod should slightly exceed the size of the cartridge.
5. Sufficient supply of stemming material should be provided as near to the working place as practicable.

Responsibility: Blaster, Mate & Blasting foreman.

5.2.5 SOP FOR FIRING OPERATIONS

1. Only properly drilled, charged & stemmed shot holes shall be fired by blaster as far as practicable shots shall be fired by the same blaster who charged it.
2. The blaster should himself attach the detonator leads to the firing circuit & leave the face where the shot is to be fired.
3. The firing of shot holes should not exceed 80 nos if fired electrically.
4. Where large number of shots has to be fired, the firing shall as far as practicable carried out between the shift or during the rest interval or at the end of work for a day.
5. The blaster shall ensure that before a shot is fired all persons other than his assistants have taken proper shelter & further ensure that all the inadvertent entries shall be properly avoid by posting guard at all possible entry.

Responsibility: Blaster, Blasting foreman & Blasting Assistant Manager

5.3 SOP FOR DRILLING OPERATIONS

PRECAUTIONS WHILE DRILLING:

1. The position of deep hole to be drilled shall be marked by the foreman/site in charge.
2. No drilling shall be commenced in an area where shots have been fired until the blaster has made a thorough examination & clearance.
3. Drilling & charging of holes shall not be carried out in the same area & at the same time.

6. 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.

6.1 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. These holes are not charged.

6.2 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 (figure 5.2).
7. ANALYSIS OF PPV AND GROUND VIBRATION

7.1 Estimation of Peak Particle Velocity

For a new area in which the seismic transmission characteristics are unknown, site constants are determined by monitoring the ground vibration at different distances for known drilling and blasting parameters. In the present case, the vibration records generated by blasting at an opencast iron ore mine were used for regression analysis. In total, 137 sets of readings were used for regression analysis and Figure 7.1 shows a plot of peak particle velocity against square-root scaled distance on a log-log graph. The following predictor equation (Equation 2) was derived with a correlation coefficient of −0.76 at 50% confidence level.

\[
V = 432.03 \frac{D}{Q}^{1.337}
\]

Where,
- \(V\) is peak particle velocity (mm/s),
- \(D\) is distance (m),
- \(Q\) is the maximum charge per delay (kg)

![Figure 7.1: Shows that plot showing peak particle velocity versus square root scaled distance.](image)

From the Figure 8.1 it is observed that the permissible limit of ground vibration (5mm/s) was restricted with in the distance of 36m from the blasting site. In fern paradise area the maximum ground vibration recorded is recorded is 2.64mm/s at a distance of 35m from the blasting site. The vibrations recorded behind the blast can be reduced further by changing the orientation of the blast face.

7.2 Frequency of Ground Motion

The frequency of the ground vibration was determined by analyzing the records of the blasts using the software provided with the instruments. As shown in Figure 7.2 the Frequency of ground vibration in and around the excavation area is greater than 10Hz.

![Figure 7.2: Shows that plot showing Frequency versus distance.](image)
7.3 Estimation of Air Overpressure

The measured 137 sets of air overpressure levels were plotted against cube root scaled distance (Figure 8.3). The cube root scaled distance is the distance divided by the cube root of the maximum charge per delay. Statistical analysis for air overpressure was not carried out as the data is scattered.

![Figure 7.3: Shows that plot showing air overpressure versus cube root scaled distance](image)

7.4 Permissible Level of Ground Vibration

Vibrations from blasting are of transient nature but the disturbance may result in permanent damage to property/structure. Preventive measures lead to restraints on the working method that besides incurring additional costs, in extreme circumstances may lead to the curtailing of activity. For the recorded frequency range (greater than 10Hz), the permissible particle velocity as per the DGMS circular happens to be 10mm/s. Although 10 mm/s is permitted as per DGMS Circular, considering higher factor of safety, the recommended permissible particle velocity is 5mm/s for the structures located near the blasting sites.

![Figure 7.4: Plot showing peak particle velocity versus distance.](image)

7.5 The Estimation of Maximum Charge per Delay

The most practical method of controlling ground vibration is to restrict the maximum charge per delay. This can be achieved by delay blasting which permits to divide the total charge into smaller charges. Substituting the permissible vibration level of ground vibration (5mm/s) and the distances in equation 2, the safe maximum charge per delay for different distances is estimated and is presented in Table 7.1.

From the field studies it was observed that no blasting shall be carried out within a distance of 10m from the existing structures and the maximum charge per delay suggested in Table 8.1 may be adhered to while blasting from 11 to 17m distance from the structures. For distance 18m and beyond a safe maximum charge per delay of 0.375kg is recommended. By using this maximum charge per delay for the remaining excavation, the vibration could be restricted within the

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8. METHOD OF WORKING

8.1 Field study of A Narrian mines:

- 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
- 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 mine management were actually planned to Relocate the Parking yard and Workshop from the existing place for safety. This will cost very high

<table>
<thead>
<tr>
<th>Distance (m) from the blast</th>
<th>Computed safe maximum charge per delay, kg</th>
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<td>16</td>
<td>0.37</td>
</tr>
<tr>
<td>17</td>
<td>0.37</td>
</tr>
</tbody>
</table>
and also take more time. Mean time the works were delayed. The location of parking yard, workshop and Blasting area were marked in the Google Map 8.1.

Figure 8.1 showing the Blasting area which includes sensitive area

8.2 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

The reasons for opting 110 mm. diameter holes are followings:

- The minimum depth of excavation required at the mine is 5.0 m to 7.0 m as per plan submitted by mine officials.
- To utilize maximum area out of total available area to facilitate multiple working points to get speedy progress in work and to give sufficient work-space to the mucking team to deploy as many Nos. of excavators and dumpers as required. 110 mm. shot-holes need 83 mm. diameter explosives cartridges with 2.78 kg. Weight which is readily available at the Explosive’s manufacturers and Explosive’s dealers, whereas any bigger or smaller diameter and weight explosives cartridges become specific requirement, which require advance planning both for the users and the manufacturers/ dealers. Hence this may create a problem of availability of material on time.

8.3 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. The typical charging pattern is shown in Annexure-A1 to A-4.

CHARGING PATTERN FOR 110 mm. HOLE

1.0 Shot-hole Diameter –110 mm.
2.0 Burden – 2.25 to 3.25 m
3.0 Spacing –2.5 m to 3.50 m
4.0 Shot-hole Depth –5.0 m to 7.5 m(Including Sub grade)
5.0 Explosives –Solar prime/column .83 mm. – 7-12 Cartridges x 2.78 Kg =19.46 Kg to 33.36 Kg.
6.0 Charge Length – 2.80 M to 4.80 M
7.0 Stemming Column – 2.2 M. to 2.7 M.
8.0 Initiation –Electric Detonators, Non-electric shocktube detonators,TLD – 3.0 M to 4.0 M. long, TWINDETS.
9.0 Initiation Pattern – Staggered and row by row connection for better fragmentation

8.4 INITIATION (FIRING) PATTERN:

In hard rock of homogeneous nature TWINDETS are used with various surface and down-line delay-timings. There is 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.

8.2 Laying of blasting pads by hydra
8.3 Laying of blasting pads by hydra

Fig: 8.4. Blasting Area consists of Parking yard and plant at the adjacent

Fig: 8.5 Parking yard and plant area after blasting

8.6 RISK ASSESSMENT 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.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Identified Hazard</th>
<th>Risk Rating</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>E</td>
<td>P</td>
</tr>
<tr>
<td>1</td>
<td>Heavy ground vibration</td>
<td>0.5</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Back Breakage of Bench</td>
<td>0.02</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Fly rock</td>
<td>2.5</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Damage criteria on Parking yard and Processing plant</td>
<td>2.5</td>
<td>1</td>
</tr>
</tbody>
</table>

9. DISCUSSION AND RECOMMENDATIONS

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

2. 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).

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

4. 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.

5. 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.

6. 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.

7. 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.

8. 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.
9. No blasting shall be carried out within a distance of 30m from the hardening concrete and if blasting is inevitable, it should be carried out after 72hrs of poring of the concrete.

10. 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.

11. REFERENCES


[8] Hydroelectric Project, Bhutan” (2004), NIRM Project Report Nos. RB 02 03C & RB 03 02C (Un-published)