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A STUDY ON BLAST INDUCED GROUND VIBRATIONS FROM AN OPEN CAST MINE

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Abstract

Blasting is a critical part of the mining process, and it necessitates the use of a lot of explosives. However, the blasting process and the use of explosives continue to pose a risk to both humans and the environment. According to various research, fragmentation contributes for only 20-30% of the overall kinetic force used. Ground vibration, fly rock, air overpressure, and noise are all ways that energy is lost. The human reaction to ground vibrations is the special difficulty linked with them. Vibrations from the blast may cause substantial damage to neighboring buildings or structures. This project involves conducting a blast vibration research and interpreting the results in light of the DGMS criteria. Geophones and the Blastmate8.0 programme were used in the research. First and foremost, blasting operations were observed using geophones placed at 100, 200, and 300 metres. The data from the instrument was analyzed by the Blastmate software, which produced a graphical representation. For each explosion, the maximum charge per delay, peak particle velocity (PPV), and air overpressure were measured. The numerous observations were then compared to the standards in order to arrive at a conclusion. When the appropriate quantity of charge per delay or safe charge per delay was utilized, the vibration level for the blasts was less than 5 mm/sec, according to the analysis of blast vibration at the mines. The measured air overpressure was between 114 and 127.6 decibels (L). The results determined from the project indicates that the peak particle velocity, air overpressure generated due to blasting were within the limits. The safe charge per delay for the blasting operation was determined from the study. The project's findings show that the peak particle velocity and air overpressure created by blasting were both within acceptable limits. The analysis found the safe charge per delay for the blasting operation

Keywords : Explosives, Blasting, Peak Particle, velocity, Vibrations, Fly rocks

INTRODUCTION

In mining and civil construction, the combination of drilling and blasting is still a cost-effective and practical approach for rock excavation and displacement. Blasting's negative effects are inescapable and cannot be totally eradicated, although they can be reduced to a safe level to avoid harm to the environment and existing structures Ground vibration is a key source of concern among planners, designers, and environmentalists. Several academics have proposed several strategies for reducing ground vibrations during blasting. The amount of explosive utilized , the distance between the blast face and the monitoring site, as well as the geological and geotechnical conditions of the rock units in the excavation region, all influence ground vibration.

Blast generated ground vibration is a problem that has historically been difficult to adequately control due to the usage of explosives. The equation contains a number of variables and site constants that, when added together, result in the production of a complicated vibration waveform caused by the constrained detonation of an explosive charge. If a welldesigned blast plan has been engineered, the use of adequate field controls during all parts of the drilling and blasting operation will help to reduce the negative effects of ground vibrations. This design would take into account the proper hole diameter and pattern for optimal usage and dispersion of the explosive energy put into the blast hole. It would also allow for the proper length of time between adjacent holes in a detonation to ensure that the explosive is contained to the maximum extent possible. The criteria that have the greatest impact on the composition of the ground vibration waveform once the explosion has been appropriately constructed are:

- Accurate timing between blast holes in a detonation series
- Geology between the blast site and the monitoring location The geological and geotechnical conditions, as well as the distance between the blast face and the monitoring point, cannot be changed, but the only factor that can be changed is the distance between the blast face and the monitoring point. , i.e. the amount of explosive that may be determined using empirical calculations presented by various researchers in order to keep ground vibrations to a safe level.

Indian Mining Industry :

The Indian mining industry, which exploits non – renewable resources for meeting the material needs of the society makes valuable contributions to society and the progress of the nation. This industry contributes over 3.5 per cent of the gross domestic product. Besides sizeable direct contribution to government revenue and significant export earnings, it also provides direct employment and over 2.5 million persons The mining industry has contributed significantly to the development of infrastructure in the nation and catalyzed extensive economic development of remote and backward regions. India's coal production has crossed 324 million tons per annum. Iron ore production at 120 million tons occupies the fourth rank in the world. Lime stone a production has increased to 154 million tons and bauxite to 10.95 million tons. Most non-metallic mines have also increased production Over 70 percent of coal production comes from surface mining whereas iron ore, limestone, bauxite and most non metallic minerals are produced by surface mining alone. Ever growing demand for coal and minerals and the pressure for cost reduction has compelled the mining industry to increase the scale of operations requiring large blasts to feed their high capacity earth moving equipment. This in turn has caused adverse impacts on environment in the form of ground vibration due to blasting, which are by and large controllable.

Drilling:

Rock drilling is the first operation completed in the field of operation, and its objective is to drill holes or open holes with precise dimensions and distribution within the rock masses, where explosive material and their starting devices are stored. Rock penetration and rock fragmentation are two different types of this procedure. Drilling, cutting, boring, and more terms are used to describe this procedure.

The first activity of drilling the rock mass with the drill tool is percussion, in which the drill tool penetrates and fractures the rock surface. After the drill tool spreads the breaking, it continues to penetrate with the drill bit rotating or cutting continuously with a push or percussive force. The drill bit or drill tool uses a thrust force or impact force to penetrate and break the rock surface; this is the primary mechanism of mechanical rock breakage. The drilling machine used in the open cast mining can be classified as :

1.Depending on the principle of working:

a). Percussive drilling

b). Rotary drilling

c). Rotary-percussive drilling

2. Depending upon the type of prime movers:

a).Fuel driven drilling machine

b).Electrically driven drilling machine

3.Depending upon the means of power transmission:

a). pneumatically operated

b). Hydraulically operated

c). Electrically operated

Blasting:

Blasting is the technique of utilizing explosives to break apart a hard rock mass into loose fragments. The explosives are injected into the hard rock via a drill hole. Blasting is also used to remove overburden from the earth's surface in order to excavate a mineral deposit through the creation of an opencast mine.

Explosives Used For Blasting :

An explosive is a solid or liquid substance or a mixture of substances which, in a short period of time after applying a flame, heat or shock (explosion), the mixture coverts to large volume of gases at high temperature and pressure. The explosive substance may be the mixture of various elements none of which is explosive by itself or a chemical compound.

An explosive contains, apart from the explosive substance.

The following materials:

1. Combustible material (wood, fibre, charcoal etc.).
2. Oxidation agents (Ammonium nitrate, Sodium nitrate, etc.).
3. Stabilizers (Magnesium and Calcium Carbonates).
4. Antisetting agents (Preventing the caking of salts).
5. Sensitizers (Metallic powders)

According to explosives the explosives can be classified into two categories:

1. Low Explosives
2. High Explosives

Low Explosives:

Low explosive means a mechanical mixture of two or more substances. It includes a supplier of fuel and oxygen. When burned, it burns but when confined, it explodes. It burns comparatively slowly and explodes by direct ignition. This gives the shattering effect when the explosion explodes. Low explosive: Gun powder (It is a common and earliest known explosive of low explosives). The constituents of Gun powder are Charcoal 15%, Sulphur 10% and Potassium nitrate 75%.

High Explosives:

A high explosive is a chemical compound and combines directly with the fuel and oxygen atoms. These explosives are exploding at velocities of 1500 to 8000 m/s and produce large volume of gases at considerable heat and high pressures. These are classified into two categories, depending upon their composition and explode rate:

1) Primary Explosives and

2) Secondary Explosives

Primary explosives:

Primary explosives are characterized by their sensitivity to impulses such as weak mechanical shock, spark or flame, the use of which allows the explosive compounds to be easily detonated from the deflection state. These explosives are used in starting devices such as detonators to initiate charges. Examples of these explosives include mercury fulminate, lead azide, lead stifnate, tetra zine and other alloys.

Secondary explosives:

Secondary explosives of this type are military explosives such as TNT, RDX, PETN, and Tetrile, and industrial explosives such as nitroglycerine, emulsion, slurries, water gels, ANFO and other powder explosives.

Environmental Impacts of Blasting in Mining

Blasting is the most used way of breaking up rock in mining and building projects all around the world. This is likely owing to various advantages such as cost-effectiveness, efficiency, ease, and the capacity to crush even the toughest of rocks. However, only a small fraction of the overall energy of the explosives used in blasting is utilized in shattering rocks, with the remainder being wasted. Ground vibration, air overpressure, and flyrock are all examples of the dissipated energy causing environmental issues. Ground vibration has become a serious environmental issue as mining and building operations have increased in places close to human settlements, causing human irritation and structural damage .

Blast Accessories:

Geophones :

A geophone is a device that converts ground movement (velocity) into voltage which may be recorded at a recording station. The deviation of this measured voltage from the base line is called the seismic response and is analyzed for structure of the earth. The majority of geophones are used in reflection seismology to record the energy waves reflected by the subsurface geology. In this case the primary interest is in the vertical motion of the Earth's surface. However, not all the waves are upwards travelling. A strong, horizontally transmitted wave known as ground-roll also generates vertical motion that can obliterate the weaker vertical signals. By using large areal arrays tuned to the wavelength of the ground-roll the dominant noise signals can be attenuated and the weaker data signals reinforced.

Analog geophones are very sensitive devices which can respond to very distant tremors. These small signals can be drowned by larger signals from local sources. It is possible though to recover the small signals caused by large but distant events by correlating signals from several geophones deployed in an array. Signals which are registered only at one or few geophones can be attributed to unwanted, local events and thus discarded. It can be assumed that small signals that register uniformly at all geophones in an array can be attributed to a distant and therefore significant event.

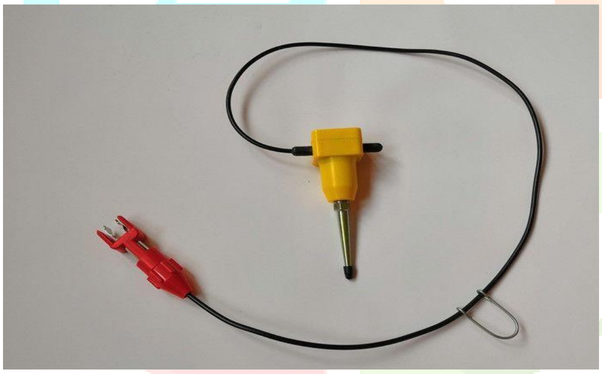

Fig 1. (Geophones)

Electric Detonators:

Electric Detonators have an electrical ignition system so that they can be fired with an electric current. An aluminium or copper shell 6mm in diameter has two insulated wires leading into one end. The ends of these wires are connected within the detonator by a short, very fine bridge wire of relatively high resistance. When a sufficiently high electric current is passed, this bridge wire becomes extremely hot and ignites an incendiary mixture. The flash of this mixture initiates, directly or via the delay composition, the primary explosive layer that, in turn, initiates the powerful PETN base charge. A rubber type plug, which surrounds 9 the lead wire just above the bridge wire, is securely crimped into the end of the shell. This forms a highly water-resistant closure, and firmly positions the bridge wire on the axis of the detonator. The lead wires are insulated with plastic.

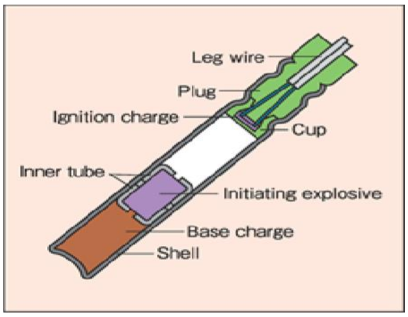

Fig 2. (Electronic detonator)

Non- Electric Initiating Devices:

Plain detonators: plain detonators are used with safety fuse for initiating a trunk line of detonating cord. They consist of small aluminium cylinders about 6 mm in diameter, closed at one end and loaded with a double layered charge, which is passed into the base. The upper (ASA) Primary explosive layer of this charge is ignited and detonated by the end spit of burning safety fuse; this, in turn, initiates the more powerful PETN base charge which provides the intense local shock required to fire the detonating cord.

Safety fuse: this product is a fuse through which flame is conveyed at a uniform rate to initiate a plain detonator. It consists of a core of gunpowder tightly wrapped in textiles, with layers of waterproofing materials like bitumen, and enclosed in a tough outer jacket. These coverings are designed to protect the gunpowder core from abrasion and the penetration of water and distillate. The nominal burning speed of these fuses varies between 100 – 145 seconds per meter.

Detonating cord: detonating cords are strong flexible cords, which, because of their high explosive core loads of PETN, detonate at high velocities (more than 6000 m/s). They are easy to handle and connect up using simple knots (fig). Detonating cords are relatively indensite to accidental initiation by ordinary friction, impact or shock. The use of detonating cord eliminates hazards due to stray currents and static electricity, which can effect electric detonators. For this reasons, it is a safe method of initiating explosives (e.g., Cordex, D-cord, Indocord).

Non-Electric Delay System:

Inter-hole or inter row delays can be obtained non-electrically with surface delays and/or down-the-hole delays using one or more of the following:

a) NONEL-type detonators (long delay series and/or short delay)

b) Cord relays

c) NONEL-type MS Connectors.

These non-electric systems are the most modern delay devices in common use today, they are reliable, quick and easy to use, because they are very adaptable, their use assists greatly in controlling blast vibrations.

OBJECTIVES:

1. To study the blast vibration caused due to surface mine blasting.
2. Prediction of safe explosive charge for protection of surface structures

METHODOLOGY

Objective :

The mining industry is concerned with the extraction of valuable minerals from the earth. In any mining project, drilling and blasting are the first basic operations that are part of an integrated system and impact the results of subsequent operations in productivity and costs. The ill effects of blasting, i.e. ground vibrations, air blasts, fly rocks, back breaks, noises, etc. are unavoidable and cannot be completely eliminated but certainly minimize up to permissible level to avoid damage to the surrounding environment with the existing structure this process is achieved by taking of optimization process. The diameter of the drill hole, the number of holes, the depth of the holes, the peak particle velocity, the type of explosives used, the maximum charge per delay, the accessories utilized, the powder factor, and the volume of explosive used are all taken into account. After the blasting, various measurements such as blast fragmentation, throw, muck file, and fly rock are made in order to evaluate the blast vibration induced by surface mine blasting and to estimate a safe explosive charge for the protection of surface structures.

Data collection :

Estimation of ground vibration :

Peak particle velocity is a concept that can be used to measure ground vibration (PPV). There are numerous prediction formulae for calculating explosive weight per delay in order to achieve a certain peak particle velocity. There are a variety of predictors available, however we chose the US Bureau of Mines (USBM) predictor, which is based on ppv. The equation proposed by USBM is :

$$v = K[R/\sqrt{Q_{max}}]^{-B}$$

Where, v = peak particle velocity (mm/s)

R = distance between blast face and monitoring point (m)

Q_{max} = maximum explosive charge used per delay (kg), and K, B = site constants which can be determined by multiple regression analysis

For a better understanding of the effect of ground vibrations, data on peak particle velocity (PPV), distance from the blast site to the monitoring station, and explosive charge per delay for various blasts were investigated.

The data is represented by the following predictor equation in terms of scaled distance (x) and PPV (Peak particle velocity), which is proposed for use in estimating safe explosive charge per delay to keep the vibration level within acceptable limits.

$$\textbf{PPV} = \textbf{290.12 (Scaled distance)}^{-1.296}$$

Prediction Of Safe Charge For Surface Structures :

The quantity of ground vibration produced is proportional to the charge per delay employed in the blast holes. It has a critical value at which it produces the best results; any amount higher than that will cause more ground vibration. The resulting vibrations may cause structural damage to surrounding structures. The safe quantity of charge per delay is determined by observing ground vibration from a number of bursts.

Design methodology :

1. Literature review
2. Development of knowledge base. Finalization of parametric variation for the study.
3. Identification of the objectives of the study.
4. Study the various inputs in blasting operation.
5. Parameters like ppv(peak particle velocity),maximum charge per delay ,air overpressure are studied.
6. The data obtained is analysed with allowed norms.
7. Result and conclusion.

CASE STUDY

Location

An open cast coal mine in Raigarh is a captive which has a capacity of 1000 MW (4 x 250 MW). The block lies between the longitudes of 83°29'40" and 83°32'32" (E) and the latitudes of 22°09'15" and 22°05'44" (N) on topo sheet no. 64 N/12 (Survey of India). The block is administratively located in Raigarh District, Chhattisgarh's Gharghoda Tahsil.

Communication

The road connects the blocks well. Raigarh town, the district headquarters and nearest railway station on the Mumbai-Howra Main Line, is around 60 kilometres away.

General Geology of the Block

Geology

Only lower groups of Gondwana seams have been deposited in subblocks IV/2 and IV/3. The strata are slowly sloping southwesterly by 2 to 5 degrees. The seams in NW-SE have a general strike that is nearly uniform throughout the block. Based on the level difference of the seams' floors and the presence of several tiny faults of less than 5 m, two minor normal faults of small scale have been deciphered. Throw cannot be overruled.

Structure

The Mand Raigarh basin is a part of IB River - Mand - Korba master basin lying within the Mahanadi graben. Sub block IV/2 & IV/3 of Gare-Pelma area is structurally undisturbed except one small fault (throw 0-15 m) trending NE-SW with westerly throws. The strike of the bed is NW-SE in general with dip varies from 2° to 6° south-westerly. The strata shows rolling dip.

Experimentation

A number of blasts were recorded in order to investigate various blast parameters related to overburden and coal bench blasting, as well as the impact of the blast on the surrounding structures. With suitable instruments in the field, the peak particle velocity and frequency of ground vibrations due to blast were measured at various distances from the blast site (vibroblast, geophone). The data collected from monitoring was analysed using the BLASTWARE software, and charts were created and studied. The blast vibration is to be estimated from the monitoring of the blasts provided by identifying the peak particle velocities associated with distinct blasts.

Damage criteria:

Many organizations, including USBM, DGMS, and Indian Standards, developed damage criteria for various types of structures based on the permissible PPV in mm/s and the frequency of ground vibrations. For the current investigations, the criteria based on the Permissible PPV in mm/s and Frequency of the ground vibrations for various types of structures as per DGMS (1997) are used to estimate safe charge per delay to limit the ground vibrations within the safe limit of 5 mm/sec as the frequency was within the range of 8 to 25 for the observations.

Table 1: Damage criteria of Buildings / Structures belonging to the owner

Type of Structure	Dominant Excitation Frequency		
	<8 Hz	8 to 25 Hz	> 25 Hz
a) Domestic Houses	10	15	25
b) Industrial Building	15	25	50
c) Sensitive Structure	2	5	10

Table2: Damage criteria of Buildings / Structures NOT belonging to the owner

Type of Structure	Dominant Excitation Frequency		
	<8 Hz	8 to 25 Hz	> 25 Hz
a) Domestic Houses	10	15	25
b) Industrial Building	15	25	50

Table 3: Type of Damage Due to Air over pressure

Structural Damage	Value in dB-L
Plaster Cracks	180
Loose Windows sash rattles	176
Failure of Badly Installed Window Panes	140-145
Failure of Correctly Installed Window Panes	Over 168
All Window Panes Fail	176

Table 4: Details of a Blast Vibration Study Report of an open cast coal mine in Raigarh

1	Blast number			**13**	
2	Location			VII Seam Coal	
3	Strata			Coal	
4	No of Holes			39	
5	Depth of Holes (Mtr)			3.7 to 5.0	
6	Burden x Spacing (Mtr)			4.0 x 5.0	
7	Diameter of Holes (Mtr)			159 mm	
	Explosives Used				
8	Powergel B- 1 (SME) in Kgs			927	
9	Primex (100gm pellets) in Kgs			3.9	
10	Total Explosives in Kgs			930.7	
11	**Accessories Used**			Detonating Fuse	
12				Electric Detonator Cord Relay (25 MS)	
13	Maximum charge/ Delay (Kgs)			102	
14	Volume Blasted (Cu. Mtr)			3510	
15	Powder Factor (Cu.Mtr/Kgs)			3.80	
	Post Blast Observations				
16	Blast fragmentation			Good	
17	Fly Rocks			Within 10Mtr.	
18	Throw			Normal	
19	Muck File			Good	
Distance (Mtr.)	**150**	**200**	**300**	**400**	**500**
PPV (mm/Sec)	8.89				
Frequency (Hz)	39				
Noise dB(L)	127.2				

Table 5: Peak Particle Velocity (PPV) observed for various blasts at an open cast coal mine in Raigarh

Sl no.	Distance(m) R	Charge/Delay (kg) Q	PPV(m/sec) P
1	200	50	3.75
2	200	50	4.75
3	200	83	4.06
4	200	70	3.75
5	300	70	2.35
6	200	52	3.05
7	150	102	9.14
8	150	25	2.1
9	150	30	4.95
10	200	30	5.97
11	200	25	1.65
12	150	35	7.87
13	150	102	8.89

Table 6: The safe charge per delay recommended to keep the vibration level below 5 mm/sec at various distances from the blast site at an open cast coal mine in Raigarh

Distance of the charge	Safe charge per delay (kg)
200	75.9
300	170.8
400	303.7
500	474.5

The ground tremors, frequency, and air overpressure created by the blast were all measured. To monitor the ground vibrations induced by the blast, the vibrograph was erected at predefined distances between the blast site and the monitoring station, ranging from 100 to 350 metres. Table 5 shows the peak particle velocity (PPV) for around 13 blasts as a function of distance from the blast site to the monitoring station, as well as the charge per delay for various blasts.

The damage criteria of OSMRE/USBM indicate that the ground vibrations vis-à-vis frequency content of vibration are within the safe limit for structures corresponding to a distance of about 150 m from the blast site.

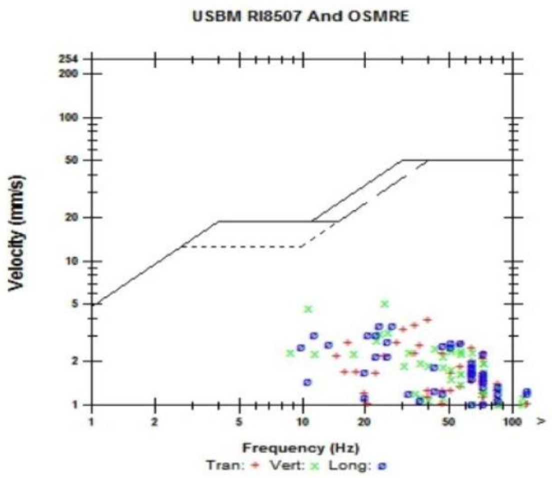

Fig 3. (Frequency vs velocity graph showing OSM and USBM RI8507 limits)

The OSM (Office of Surface Mining) and USBM RI 8507(United States Bureau of Mines,Report of Investigations 8507) standard is widely used in monitoring vibrations.The velocity and frequency properties of various components of vibrations are indicated by data points.

RESULT

PPV Predictor Equation for the mine

For studying the influence of ground vibrations generated by blasting at an open cast coal mine in Raigarh, ground vibration data including Peak particle velocity (PPV), distance from the blast site to the monitoring station,and explosive charge per delay for various blasts were investigated.

The data is represented by the following predictor equation in terms of scaled distance (x) and ppv (peak particle velocity),which is proposed for use in estimating safe explosive charge per delay to keep vibration levels within safe limits.

$$\textbf{PPV} = \textbf{290.12 (Scaled distance)}^{-1.296}$$

For the geomining circumstances of an open cast coal mine in Raigarh, the safe charge per delay advised to keep the vibration level below 5 mm/sec is shown in Table 6. The air overpressure measured during blast monitoring at an open cast coal mine in Raigarh ranged from 114 to 127.6 dB(L), which is within the safe limits listed in Table 3.

Safe charge for protection of structures

The quantity of ground vibration produced is proportional to the charge per delay employed in the blast holes. It has a critical value at which it produces the best results; any amount higher than that will cause more ground vibration. The resulting vibrations may cause structural damage to surrounding structures. The safe quantity of charge per delay is determined by observing ground vibration from a number of bursts.

CONCLUSION AND RECOMMENDATION

Conclusion :

Peak Particle Velocities (PPVs) for various blasts were calculated using blast vibration data. The PPV for various blasts was discovered to vary with and be related to the charge per delay connected with the blast. The PPV remained within the limits in most of the explosions, as indicated in tables 1 and 2. This is due to the fact that each blast has a different amount of charge per delay. As a result, for a blast hole, a certain quantity of charge per delay should be specified in order to keep the PPV and air overpressure generated by the blast within the DGMS's limits. Table 6 illustrates the amount of safe charge per delay that should be used to maintain vibrations below the limitations, i.e. 5 mm/sec. When the appropriate quantity of charge per delay was employed for blasting, the vibration levels were determined to be less than 5 mm/sec, which is within the limitations. The observed air overpressure levels ranged from 114 to 127.6 dB (L), which is well within safe limits.

Recommendation :

While there can be no compromise in terms of protecting surface structures from ground vibration, permitted vibration levels should not be overly restrictive, putting mining activities at risk. The DGMS vibration levels may be changed as a result of this research. The maximum particle velocity is used to determine the allowable amounts. The practical measures that can be adopted to control ground vibration are:

1 Reduce the maximum charge per delay by:
- Utilizing the maximum number of delays
- Using in-hole decking with two or more delays
- Reducing the blast hole diameter
- Reducing the bench height

2 Utilizing a combination of field observation and computer modelling, optimize the delay interval using the linear superposition of waves.

3 Allow for maximum relief and free faces for the successive rows to be blasted.

4 Experiment with different sorts of explosives or the same type from various manufacturers.

5 Use the best specific charge possible, as both a low and a high specific charge will enhance ground vibration.

6 Whenever possible, ensure that the blast hole initiation sequence moves away from the structure.

7 Optimize blast design parameters for a given site condition.

8 Only use specialized procedures like as presplitting or trenching as a last option.

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