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BLAST VIBRATION MONITORING IN OPENCAST MINES

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ABSTRACT

Blast-induced ground vibrations in opencast mines pose significant risks to nearby structures, equipment, and the environment. Effective monitoring and control of these vibrations are essential to ensure safety and compliance with regulatory limits. This study examines blast vibration monitoring techniques, focusing on peak particle velocity (PPV), frequency, and attenuation patterns to assess their impact. Advanced seismographs and sensors are deployed to record vibration data, which is then analyzed using empirical models such as the scaled distance formula to predict and mitigate adverse effects. The findings highlight the importance of optimizing blast design parameters, including charge weight, delay timing, and geological conditions, to minimize vibration levels. Case studies from various opencast mines demonstrate successful implementation of vibration control strategies, ensuring operational efficiency while safeguarding surrounding infrastructure. The study concludes with recommendations for best practices in blast vibration monitoring to enhance safety and sustainability in mining operations. For the purpose of determination of the safe Charge per Delay a number of researchers have given various theories and equations. The feasibility of the CMRI equation is studied in this report. Also, there are various equipment's available globally for measuring the ground vibration and air blast. In the present study Minimate Blaster specification has been studied in detail. All the blasting operations were obtained at different- different distances. According graphs were plotted for the data's available from the blasting practices and the safe Charge per Delay and Peak Particle Velocity is determined for the mine in accordance with the DGMS regulations.

Keywords: Blasting, Vibrations, shock wave, seismographs

1. INTRODUCTION

Blasting operations in opencast mines are indispensable for rock fragmentation, but they generate ground vibrations that can potentially damage nearby structures, destabilize mine slopes, and cause environmental concerns. The propagation of these vibrations depends on multiple factors including charge weight, blast design, geological conditions, and distance from the source. To mitigate risks, blast vibration monitoring has become a critical component of mining operations, ensuring compliance with regulatory limits while maintaining operational efficiency. The primary parameter for assessing blast-induced vibrations is Peak Particle Velocity (PPV), which measures the maximum ground vibration velocity and serves as a key indicator of potential damage. Regulatory bodies worldwide, such as the Directorate General of Mines Safety (DGMS) in India and the Mine Safety and Health Administration (MSHA) in the U.S., have established threshold PPV limits—typically ranging from 5 to 15 mm/s for residential structures—to safeguard infrastructure and communities. Advanced monitoring systems employing seismographs, geophones, and accelerometers are deployed to record vibration data in real time, enabling immediate corrective actions if thresholds are exceeded. Empirical models like the USBM scaled-distance formula (PPV = K(√W/D)^n) are widely used to predict vibration levels based on charge weight per delay (W) and distance (D), with site-specific constants K and n derived from historical data. Beyond PPV, vibration frequency and duration are also analyzed, as low-frequency vibrations (<15 Hz) pose greater risks to structures due to their resonant effects. Effective vibration control requires optimized blast designs incorporating techniques such as staggered delay timing, reduced charge weights, and proper hole spacing. Geological factors, including rock type, joint patterns, and groundwater levels, further influence vibration propagation, necessitating site-specific studies. Case studies from various opencast mines

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demonstrate that real-time monitoring coupled with adaptive blast designs can reduce PPV by 20–40%, would also provide for the appropriate amount of time between adjacent holes in a blast to provide the explosive the optimal level of energy confinement. When the blast is properly designed, then the parameters that have the greatest effect on the composition of the ground vibration waveform are:

- Geology between the blast site and the monitoring location
- Accurate timing between blast holes in a detonation sequence

Geological and geotechnical conditions and distance between blast face to monitoring point cannot be changed but the only factor, i.e. quantity of explosive can be expected based on certain empirical formulae anticipated by the different researchers to make ground vibrations in permissible limit.

2. EXPLOSIVE

Explosives play a pivotal role in modern mining operations, serving as the primary tool for rock fragmentation in both opencast and underground mines. These high-energy materials undergo rapid chemical reactions, releasing large volumes of gases and shockwaves that break rock masses into manageable sizes for excavation and processing.

Fuels (or sensitizers) + Oxidizers (oxygen source) → Explosive

{Fuel oil (FO), TNT} {Ammonium nitrate (AN), Sodium nitrate}

Stabilizers such as magnesium and calcium carbonates are also used and sensitizers like metallic powders are used in explosive mixture. Explosives are classified into three categories:-

1. Low Explosive (LE)
2. High Explosive (HE)
3. Blasting Agent (BA)

2.1 Ammonium Nitrate: Ammonium nitrate (NH_4NO_3) is a white crystalline chemical compound widely used in agriculture as a high-nitrogen fertilizer and in industry as a key component of explosives. Its dual-use nature—supporting global food production while also serving mining, quarrying, and defense applications—makes it an economically and strategically significant chemical. However, due to its oxidizing properties, improper handling or storage of ammonium nitrate can lead to catastrophic explosions, necessitating strict safety regulations.

2.2 Ammonium Nitrate and Fuel Oil: Ammonium Nitrate and Fuel Oil (ANFO) is a widely used industrial explosive mixture, primarily employed in mining, quarrying, and construction due to its cost-effectiveness, stability, and ease of use. Composed of 94– 96% porous ammonium nitrate (NH_4NO_3) prills and 4–6% fuel oil (typically diesel), ANFO is a non-ideal explosive that requires a high-energy booster for reliable detonation. Its low cost and safe handling characteristics make it the most common bulk explosive in open-pit mining, accounting for ~80% of explosives used in North American surface operations.

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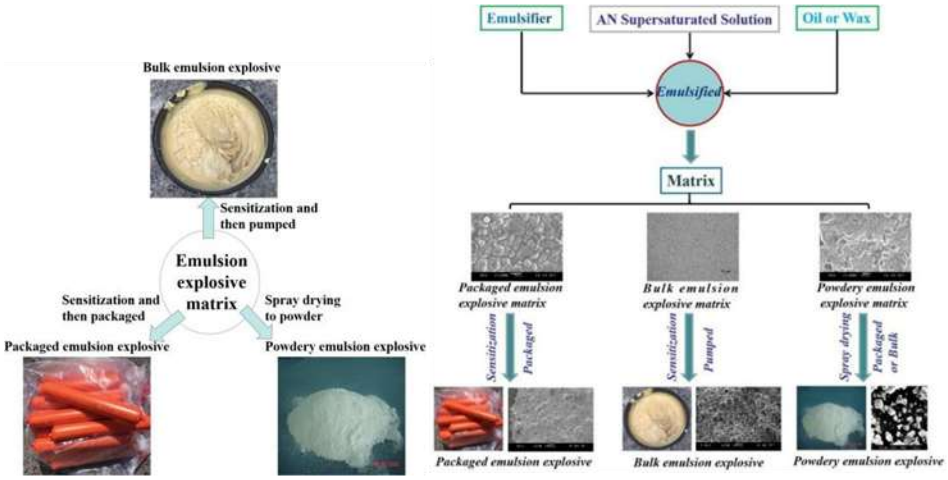

Figure 1 Emulsion explosive

2.3 Site Mixed Slurry: Site-mixed slurry explosives (also known as bulk slurry explosives) are a class of water-based industrial explosives prepared on-site for mining and construction blasting. They consist of a saturated oxidizer solution (typically ammonium nitrate) mixed with fuels, sensitizers, and gelling agents to form a thick, pumpable explosive. Unlike pre-packaged explosives, site-mixed slurries offer customizable energy output, better water resistance, and cost efficiency for large- scale operations.

2.4 Emulsion Explosive: Emulsion explosives represent a major advancement in commercial blasting agents, offering superior safety, performance, and versatility compared to traditional explosives like ANFO and dynamite. These water-in-oil (W/O) based explosives consist of microscopic droplets of an oxidizer solution (usually ammonium nitrate) dispersed in a fuel matrix, stabilized by emulsifiers. Due to their high energy density, water resistance, and reliability, emulsion explosives dominate modern mining, quarrying, and construction blasting operations. It ensures uninterrupted charging. It is recommended that 500 gm.

Table 1 Characteristics of SME

Site Mix Emulsion Explosive		
SL.NO	**Characteristics**	**Values**
1.	VOD (m/s)	4500m/s
2	Initial density	1.35g/cc
3	Final density	1.15g/cc
4	Bulk strength	1.37-1.47
5	Water resistance	Excellent
6	Specific energy	750-900
7	Wt. strength	1.00-1.05
8	Pumping rate	120kg/min
9	Booster %	0.1-0.2
10	Sleep time	2weeks

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2. 5 Choice of explosive depends on the following factors:

2.5.1 Strength: This is a measure of amount of energy released by an explosive during blasting and hence its ability to do useful work. The total energy released from the detonation of explosives includes both useful energy (energy that causes fragmentation or rocks) and waste energy (ground vibration, air vibration, light, heat).

2.5.2 Velocity of Detonation (VOD): It is the rate at which the detonation wave passé through a column of explosive and this is of consideration importance as the shock energy of detonation increase rapidly with this velocity. Most of the high explosives, slurry explosives and permitted explosives.

2.5.3 Density: The density is important when selecting an explosive for a particular use. With a high-density explosive, the energy of the shot is concentrated- a desirable feature in tunneling and mining operations. On the other hand, when the output of lump coal from mine is important, it is advisable to use a low-density explosive, which distributes the energy along the shot hole.

2.5.4 Loading Density (LD): An explosive loading density is defined as the weight of explosive per unit length of borehole at a specified diameter of hole.

$$\mathbf{LD = W/L \text{ or } LD = 0.3405£D^2}$$

2.5.5 Water Resistance: The ability of an explosive to withstand exposure to water without either losing power or becoming desensitized is termed as water resistance explosives. The detonation energy of ANFO mixtures that have been exposed to water in blast holes is far less than that of such mixtures placed in dry holes.

2.5.6 Fume Class: Fume class is a measure of amount of toxic gases, primarily CO and NO_X, produced by the detonation of an explosive. Slurry explosive and AN based explosives are preferable to the NG based explosives. Any factor that may change the chemistry of an explosive during detonation (such as balance of fuel to oxidizer).

2.5.7 Temperature: Extremely low temperatures can affect the performance of water- based explosives, the ingredients of which can solidify and aggregate, thereby reducing the particle surface area available for reaction. At high temperature, the crystal structure of AN cab be affected.

2.5.8 Shelf Life: The chemical stability and performance of an explosive change with age. The extent of instabilities and rate of aging will depend upon the formulation and storage conditions of the explosives; accordingly.

2.5.9 Sensitivity: The term sensitivity, as it pertains to explosives, has two meaning, the first meaning of the sensitivity as it relates to explosives refers to various safety aspects and describes the ease with which an explosive may be detonated or its sensitivity to accidental detonation from shock.

2.5.10 Fragmentation and Moving: A proper blast design will yield adequate fragmentation, which will lower downstream costs related to hauling, equipment maintenance and crushing. Fragmentation distribution can be determined by running a particle distribution on the muck pile.

2.5.11 Muck profile: The shape and location of the muck pile is an important element of shot design. Requirements range from a need to extreme throw for example, to cast overburden under a coal- stripping scenario; to buffer shooting, where the muck pile is confined to a certain area by rock that has been previously blasted.

3. GROUND VIBRATION

3.1 Blast Vibration

Blast vibration refers to the ground-borne vibrations generated by the detonation of explosives, commonly used in mining, quarrying, construction, and demolition activities. These vibrations propagate through the earth as seismic waves, characterized by parameters such as peak particle velocity (PPV), frequency, and displacement. While controlled blasting is essential for efficient rock fragmentation, excessive vibrations can lead to structural damage in nearby buildings, annoyance to residents, and potential environmental disturbances. Regulatory agencies worldwide impose strict limits on permissible vibration levels to mitigate risks, often measured in millimeters per second (mm/s) or inches per second (in/s).

3.2 Ground Vibration

Ground vibration refers to the oscillatory movement of the earth's surface caused by natural or human-induced activities, such as earthquakes, construction, mining blasts, heavy machinery, or traffic. These vibrations propagate as seismic waves, with their intensity and effects depending on factors like the energy source, distance, geological conditions, and frequency. Geophones are only able to respond to vibration in one dimension and so to capture the complete signal it is necessary to have three geophones arranged orthogonally (at right angles). One will always be vertical and the other two will be horizontal, but the horizontal geophones can either be aligned with the cardinal points of the compass or they can be arranged with reference to the blast position. In the latter case, one geophone would be set along the line from blast to monitor (this is known as the longitudinal or radial) so that the other would be perpendicular to this line (this is known as the transverse).

3.3 Generation of blast vibration

The generation of blast vibration occurs when explosives detonate, releasing a sudden burst of energy that fractures rock and transmits seismic waves through the ground. As the explosive charge ignites, it creates a high-pressure shockwave that expands outward, compressing and displacing the surrounding rock mass. This energy propagates as stress waves, primarily in the form of P-waves (primary/compressional waves) and S-waves (secondary/shear waves), along with surface waves like Rayleigh waves that contribute to ground shaking. The intensity of these vibrations depends on factors such as the explosive type, charge weight, blast design, geological conditions, and distance from the source. Larger charges and confined detonations produce stronger vibrations, while rock type and soil composition influence wave propagation—softer soils tend to amplify vibrations, whereas hard rock may transmit them more efficiently over longer distances. Proper blast planning, including controlled delay timing and scaled distance adjustments, helps minimize excessive vibrations, ensuring compliance with safety regulations and reducing the risk of structural damage or environmental impact.. The area in which this sensation happens is On the off chance that these attenuated waves are not reflected from a free face, then they may cause vibrations in the rock. However in the event that a free face is accessible, the waves reflected from a free face bring on additional breakage in the rock mass affected by the dynamic tensile stress.

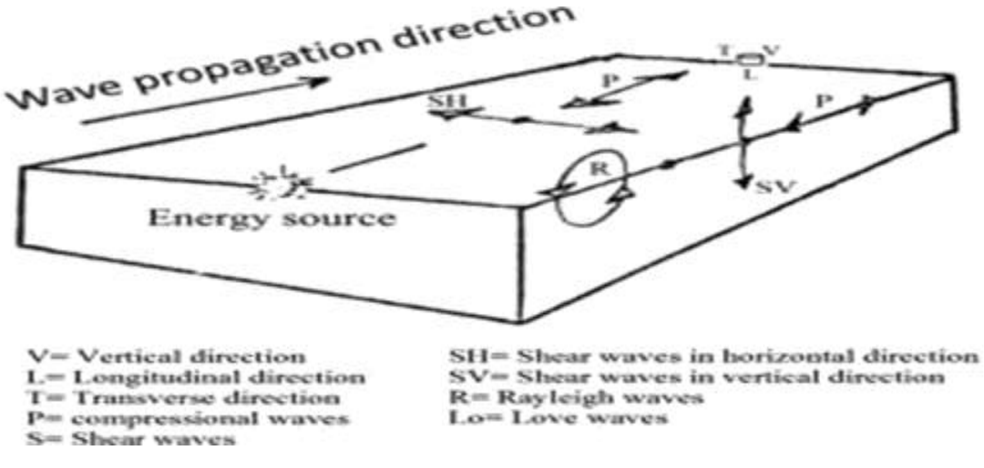

Figure 2 movement of particles by blast induced ground vibration

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3.4 Energy balance

It is valuable to view the blasting process as an 'Energy Balance' as indicated in the outline beneath. Basically, the chemical energy of the explosives must be dispersed as fragmentation, rock development, vibration and air overpressure. Not many rates of an explosive is continuously used for breakage of rock mass i.e., something like 15 to 20% relying on the blasting technique. Rest of the most extreme energy of the explosive is waste as vibration and air overpressure i.e. around 40% in each one case.

As the disturbance passes at a given point an individual particle of the medium is displaced from its rest position. One can record or measure this particle displacement; alternatively, one may record the particle velocity or acceleration. Though the three quantities are related, it is not a simple matter to deduce one from another because the wave is not a simple one. It is required therefore to measure the quantity that is most merely and generally related to damage.

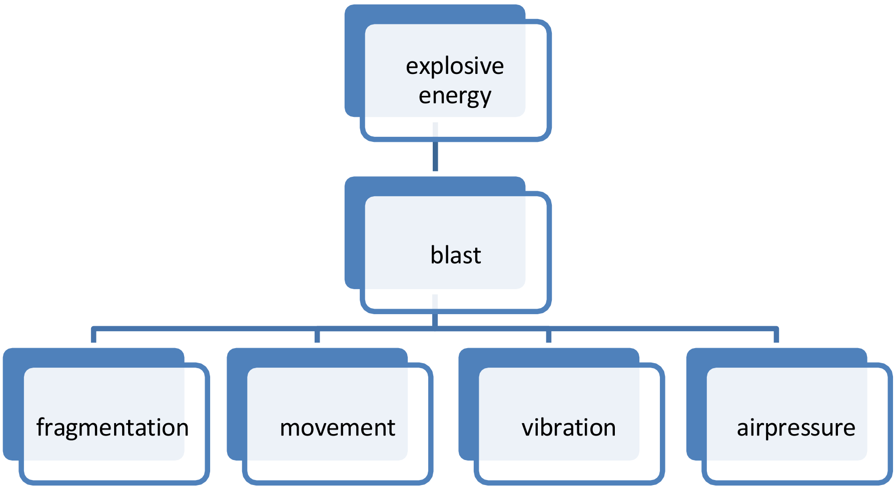

Figure 3 Different mode of release of energy from blasting

3.5 Natural Frequencies

Elements of building construction such as sprung floors, stud partition walls, ceiling and windows can all react as mass-spring systems; each with its own natural frequencies of about 4- 24 Hz (low frequencies). The risk of damage increases as the Ground vibrations at these frequencies amplified by the structures. When the low frequency ground vibration and natural frequency coincides with each other the structure resonance is originated.

The resonance is a state in which the structure absorbs most energy increasingly becoming deformed with time, until plastic deformation takes place. Therefore, even the low peak particle velocity of ground vibrations at natural frequency of structure is more damaging to the structure. Natural frequencies of brick and concrete structure generally vary from 8- 16 Hz.

3.6 Shock wave propagation causing vibration

3.6.1 Properties of blasting waves

At the instant spot of an explosion the disruption takes the form of a single pulse, whose peak amplitude and duration depend on the properties of the medium and the properties and size of the explosive charge. The resulting elastic wave generally has a strong initial build-up, which is followed by an irregular series of oscillations.

3.6.2 Types of Waves Generated by the Blast

As an explosive is detonated in borehole, energy is transferred into the surrounding rock as a result of the generated shock and gas pressures. Initially it is found that the pressure of the shock wave is higher than that of the compressive strength of the rock and the rock which is present

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around the borehole is crushed. However the shock pressure declines quickly to the values below the compressive strength. At this stage it is noticed that the shock travels inside the rock without breaking it in compression. Rock failure is a result of tension through the tensile component of the shock wave or when the tensile wave is reflected back as a tensile wave at the media boundaries. As the distance progresses the shock waves attenuates into an elastic wave. In this case it is observed that the stresses make the particles of the rock to oscillate about their rest positions as a spring-mass system. There is no huge movement or transport of matter during the time of wave motion. The initial shock front applies a force to the rock in such a way that it will compress it and reduce its volume which is causing a wave similar to a sound wave. Its property is that which compresses and expands the rock by particle vibration along the direction of propagation.

There are two types of wave:

1. Body wave
2. Surface wave

Body wave: it is the seismic wave which travels through the interior of the earth rather than across the surface of the earth. Body waves usually have smaller amplitude and shorter wavelength.

- **P wave (Compression and Tension Waves):** This wave type is basically termed compressional, dilatational, longitudinal or primary and is usually designated by the letter P (P-wave).
- **S wave:** It is another type of wave which is generated by the initial pressure pulse and the later P wave which is intermingling with discontinuities in the rock is the S-wave. Such type of wave is generated when the medium particles oscillate perpendicular to the direction of propagation. Sometimes it is referred to as shear, transverse or secondary wave.

Surface wave: Introduction of one or more boundaries across which there are differences in elastic properties can cause the introduction of other types of waves. Surface of the earth is considered to be the most significant boundary. There exist two basic surface waves. These waves are basically guided by the surface and are characterized by an exponential decrease in particle oscillation amplitude with the increasing distance from the boundary and by the propagation of the wave from along the boundary. Raleigh waves and the Love waves are the two fundamental surface waves.

- **Raleigh wave:** The Raleigh wave causes the surface particles to describe an elliptical counter clockwise orbit. These waves always exist in the vertical radial plane and have no transverse component.
- **Q wave:** The Love wave (Q-wave) is characterized by the particle vibration of the shear type and only in the horizontal transverse direction. These waves are confined to a shallow surface zone.

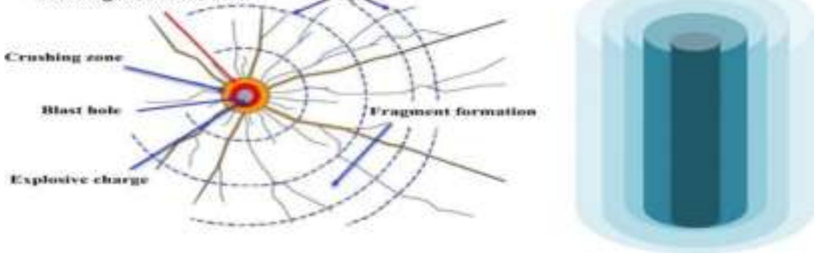

Figure 4 Vibration waves from a cratering charge (Bauer 1981)

Above Figure 4 shows the main types of waves which are associated with blasting. These waves are generated by a hypothetical cratering charge. The P-waves are moving faster than the S-waves which are moving faster than the surface waves.

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Table 3 Typical P and S wave Velocities of Rocks

Material	P Velocity, m/s	S Velocity, m/s
Granite	4000-6000	2000-3000
Basalt	5500	3000
Sandstone	2000-3500	1000-2500
Limestone	3000-6000	2000-3000
Schist	4000-5000	2500-3000
Soil	150-1000	100-700

In general, the S wave travels at a velocity of ½ to 1/3 of that of the P wave and the Raleigh wave at a velocity of 0.9 to 0.95 of that of the S wave (Oriard1996), (Bauer1981). All these waves arrive simultaneously at small distances while at greater distances they get separate and identification is possible. However, in mining most blasts comprises of a series of explosions which are delayed by millisecond delays. As a result of this overlapping of the waves takes place. For complete description of the motion, three perpendicular components are necessary. The longitudinal having the direction of a horizontal radius to the blast, the transverse which is perpendicular to the longitudinal on the horizontal plane while the vertical, which is perpendicular to both the longitudinal and the transverse.

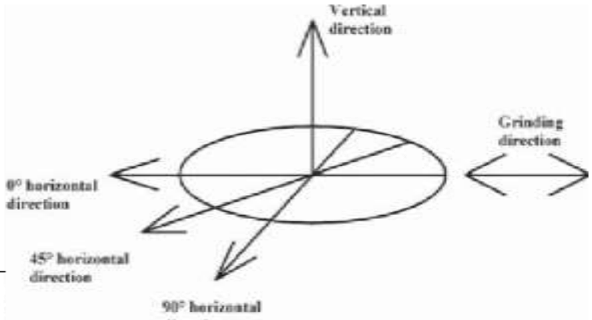

Figure 5 Vibration direction

3.7 Peak particle velocity

Peak Particle Velocity (PPV) is a critical parameter used to quantify the intensity of ground vibrations generated by blasting, earthquakes, or mechanical operations. It represents the maximum speed at which soil or rock particles oscillate in any direction (vertical, horizontal, or longitudinal) as vibration waves pass through the ground, measured in millimeters per second (mm/s) or inches per second (in/s). PPV is widely adopted in engineering and regulatory frameworks because it correlates closely with the potential for structural damage—higher velocities pose greater risks to buildings, pipelines, and underground utilities. Unlike acceleration or displacement, PPV provides a direct and practical measure of vibrational energy, making it essential for blast design, seismic monitoring, and construction safety protocols. Regulatory agencies set PPV thresholds (e.g., 10–25 mm/s for residential structures) to mitigate damage, while advanced seismographs and predictive models help optimize blast patterns and delay timing to stay within safe limits.

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3.8 Predictor equation for ground vibration

Extensive research has been conducted to determine the mathematical relationship between vibration level, charge size and distance. The relationship is known as the Propagation Law, developed in the

U.S Bureau of Mines Bulletin 656

$V = H [D/W\alpha] \beta$

Where,
V = Predicted particle velocity (in/s)
W = Maximum explosive charge weight per delay (lbs.)
D = Distance from shot to sensor measured in 100's of feet
(e.g. for distance of 500 feet, D = 5)
H = Particle velocity intercept
α = Charge weight exponent
β = Slope factor exponent

Table 4 Predictor equations by different researchers

SL.No.	Approach	Equation
01	Gupta et al (1988)	$PPV= K [D/\sqrt{W}]^{-\beta} e^{-\alpha(D/W)}$
02	P pal roy 1993	$PPV =\alpha + K (Q^{1/2}/D)^{-1}$
03	Temrock (1995)	$PPV = K (Q/R^{3/2})^{0.5}$
04	Ju & Vonppaisal (1996)	$PPV = BDI^*(\sigma cm/4)/d.c$
05	Belgin et al	$PPV =(D/\sqrt{W})^{\alpha} B^{\beta}$
06	(Ali kahriman 2004)	$PPV = K^*(SD)^{-\beta}$
07	Rai et al (2005)	$Q= K[PPV^*R^2]^B$
08	Hossaini and sen,2004,2006	$PPV= K.R^a.Q^b$

4. DAMAGE CRITERIA & DGMS REGULATIONS

The damage criteria was proposed by many organizations including USBM, DGMS, Indian Standards etc. based on the Permissible PPV in mm/s and Frequency of the ground vibrations for various types of structures. 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) as presented below in Table 05 is followed for the present investigations to estimate safe charge per delay to limit the ground vibrations within safe limit.

Table 5 DGMS Damage criteria

Type of structure	Dominant excitation Frequency, Hz		
(A) Buildings/structures not belong to the owner	<8 Hz	8-25 Hz	>25 Hz
(i) Domestic houses/structures (kuchha brick & cement)	5	10	15

(ii) Industrial Buildings (RCC & Framed structures)	10	20	25
(iii) Objects of historical importance & sensitive structures	2	5	10
(B) Buildings belonging to owner with limited span of life			
(i) Domestic houses/structures (kuchha, brick & cement)	10	15	25
(ii) Industrial buildings (RCC & framed structures)	15	25	50

Table 6 Limiting blasting vibration criterion

Distance from blasting site (ft)	Maximum allowable peak particle velocity (in/sec)
0-300	1.25
301-5000	1.0
>5000	0.75

Table 7 Ground vibration limits

Sl.No.	**Distance**	**Scaled Distance**
1.	0-300m	50
2.	301-5000m	55
3.	Over 5000	65

Table 8 Effects of ground vibration on human beings

Peak Particle velocity (mm/sec)	**Effects**
0.1	Not noticeable
0.15	Nearly not noticeable
0.35	Seldom noticeable
1.00	Always noticeable
2.00	Clearly noticeable
6.00	Strongly noticeable
14.00	Very strongly noticeable

5. BLASTING SEISMOGRAPHS

5. 1 Blasting seismographs

Blasting seismographs are specialized instruments used to monitor and record ground vibrations generated by controlled explosions in mining, quarrying, and construction activities. These devices measure critical parameters such as peak particle velocity (PPV), frequency, displacement, and acceleration to assess the potential impact of blasts on nearby structures, infrastructure, and the environment. Equipped with high-sensitivity geophones or accelerometers, blasting seismographs capture seismic waves in three orthogonal directions (vertical, longitudinal,

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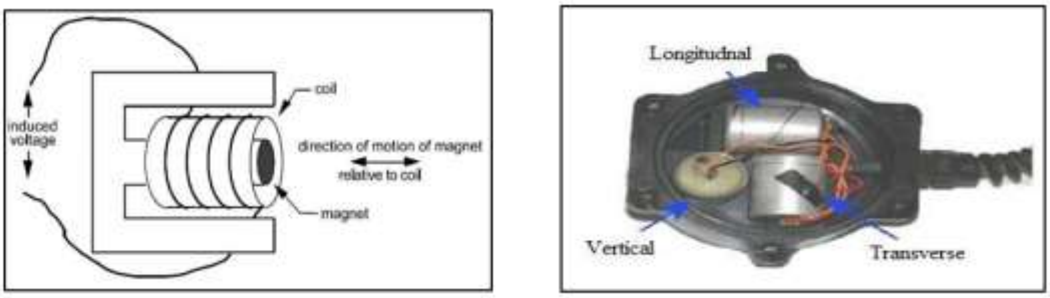
and transverse), providing a comprehensive analysis of vibration propagation. Advanced models feature real-time data transmission, GPS synchronization, and software for immediate analysis, ensuring compliance with regulatory limits (e.g., 5–25 mm/s PPV, depending on local standards). By correlating vibration data with blast design variables—such as charge weight, delay timing, and geological conditions—engineers can optimize explosive usage, minimize ground disturbance, and prevent structural damage.



(a) (b)

Figure 6 (a) Geophone sensor operation (b) A tri-axial geophone

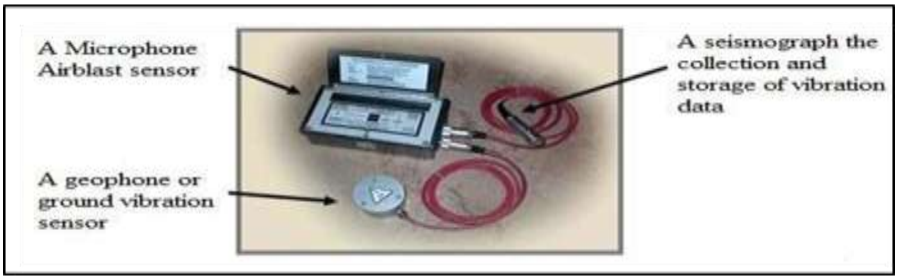


Figure 7 Parts of a seismograph

Some of the commonly used equipment's for measuring ground vibration due to blasting are as follows: Micro- Innovations: - PVM A6/Sinco ETNA 8., Blastronics: - µ MX, Instanel: - [Blastmate DS 677, Minimate Pro6, Minimate Pro4, Minimate Plus, Minimate Blaster, Blastmate III] , Datamaster: - Dynamaster Blast Monitoring System,Terrock: - Vibpak/CJ4/VIB Vibration Monitoring System.

5.2 Specifications of Minimate Blaster

Currently in this mine, ground vibration monitoring is conducted with the help of the equipment Minimate Blaster of Instantel. The monitor incorporates an eight-key tactile keypad and on- board LCD, with a clearly structured, menu-driven interface. Specification of the equipment is listed below in the Table IV.

Table 9 Specification of the vibration monitoring equipment - Minimate Blaster

General Specifications	**Minimate Blaster**
Channels	Microphone and Tri-axial Geophone
Vibration Monitoring	
Range	Up to 254 mm/s (10 in/s)

Resolution	0.127 mm/s (0.005 in/s) or 0.0159 mm/s (0.000625 in/s) with built-in preamp
Accuracy	+/- 5% or 0.5 mm/s (0.02 in/s), whichever is larger, between 4 and 125 Hz
Transducer Density	2.13 g/cc (133 lbs/ft3)
Frequency Range	2 to 250 Hz, within zero to -3 dB of an ideal flat response
Air Overpressure Monitoring	
Weighing Scale	Linear
Range	88 to 148 dB (500 Pa (0.072 PSI) Peak)
Resolution	0.25 Pa (0.0000363 PSI)
Accuracy	+/- 10% or +/- 1 dB, whichever is larger, between 4 and 125 Hz
Frequency Range	2 to 250 Hz between -3 dB roll off points

Event monitoring measures both ground vibrations and air pressure. The monitor measures transverse, vertical and longitudinal ground vibrations. Transverse ground vibrations agitate particle in a side-to-side motion. Vertical ground vibration agitate particle in an up and down motion progressing motion. Longitudinal ground vibration agitates particles in a forward and back motion progressing outwards from the event site. Events also affect the air pressure by creating what is commonly referred to as "air blast". By measuring air pressure, we can determine the effect of air blast energy on structures offering a measurable PPV range of 0.1–254 mm/s and an airblast overpressure range of 110–143 dB. Equipped with real-time GPS synchronization, the Minimate Blaster ensures precise time- stamping and location tracking, while its rugged, weatherproof design (IP67-rated) allows operation in harsh environments. Additional features include long battery life (up to 30 days standby), USB/Wi-Fi/Bluetooth connectivity, and user-friendly software for instant data analysis and regulatory reporting. Its lightweight, handheld design makes it ideal for field use, providing critical insights to optimize blast designs, minimize environmental impact, and ensure compliance with safety regulations.

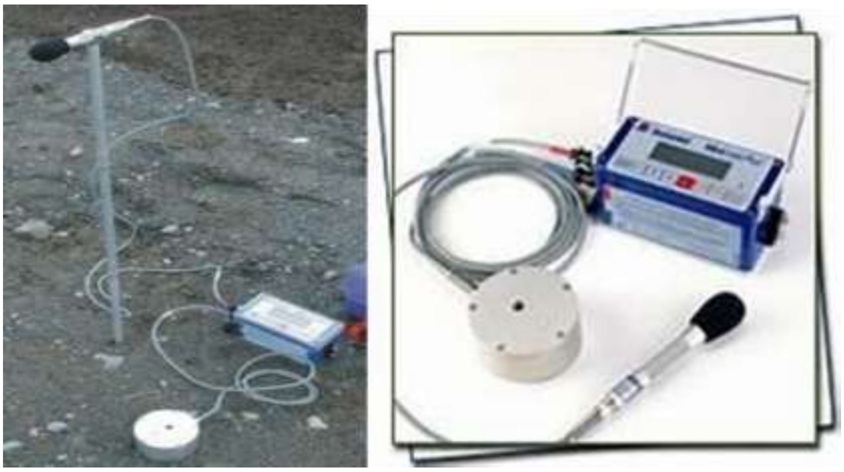


Figure 8 Minimate blaster

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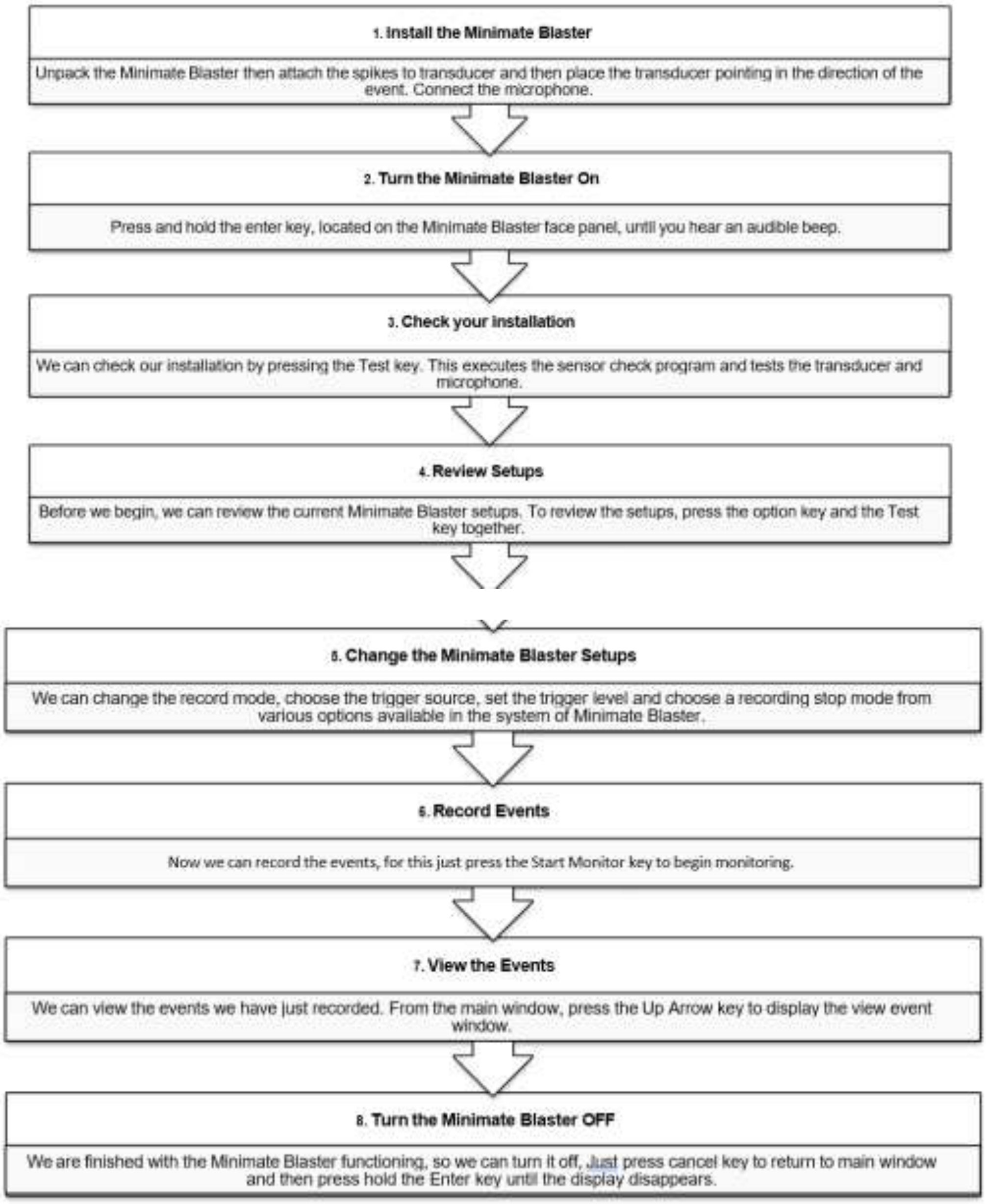
5.3 Procedure for Monitoring



1. Install the Minimate Blaster

Unpack the Minimate Blaster then attach the spikes to transducer and then place the transducer pointing in the direction of the event. Connect the microphone.

2. Turn the Minimate Blaster On

Press and hold the enter key, located on the Minimate Blaster face panel, until you hear an audible beep.

3. Check your installation

We can check our installation by pressing the Test key. This executes the sensor check program and tests the transducer and microphone.

4. Review Setups

Before we begin, we can review the current Minimate Blaster setups. To review the setups, press the option key and the Test key together.

5. Change the Minimate Blaster Setups

We can change the record mode, choose the trigger source, set the trigger level and choose a recording stop mode from various options available in the system of Minimate Blaster.

6. Record Events

Now we can record the events, for this just press the Start Monitor key to begin monitoring.

7. View the Events

We can view the events we have just recorded. From the main window, press the Up Arrow key to display the view event window.

8. Turn the Minimate Blaster OFF

We are finished with the Minimate Blaster functioning, so we can turn it off, Just press cancel key to return to main window and then press hold the Enter key until the display disappears.

Figure 9 Flow chart for Procedure for Monitoring

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6. CONCLUSIONS

Analysis of the blast vibration data of the Peak Particle Velocities (PPVs) for various blasts was recorded. It was found that for the different blast PPV varies and it is related to that of the charge per delay. In most of the blasting operation PPV is found to be within the limits. It is possible because of the use of different amounts of charge per delay for each blast. In this project, vibrations generating from the blasting practices and how it will affect the nearby structure is studied. According to the DGMS circulars the safe PPV for industrial buildings under the frequency range of 8 to 25 Hz is 20mm/sec. In the present study the measured PPV and frequency matches this configurations, in which industrial building such as Plant and crusher will have no adverse impacts. A safe charge per delay is determined in accordance with the regulations issued by the regulatory authority DGMS (Director General of Mine Safety), Government of India.

Moreover, real-time vibration data enables proactive risk management, reducing the likelihood of slope instability, flyrock, and overbreak. By integrating **predictive modeling and geotechnical analysis**, mines can enhance blast planning and adapt to varying geological conditions. Ultimately, systematic blast vibration monitoring fosters **sustainable mining practices**, balancing productivity with environmental stewardship and community relations. Continuous advancements in **seismic sensors, wireless telemetry, and AI-driven analytics** promise even greater precision in vibration control, reinforcing the industry's commitment to safety and operational excellence.

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