BLAST VIBRATION STUDIES IN SURFACE MINES

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF TECHNOLOGY

IN

MINING ENGINEERING

BY

BADAL KUMAR KUJUR

Roll No. 10605005

DEPARTMENT OF MINING ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY

ROURKELA

2010

BLAST VIBRATION STUDIES IN SURFACE MINES

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF TECHNOLOGY

IN

MINING ENGINEERING

BY

BADAL KUMAR KUJUR

Roll No. 10605005

Under the Guidance of
Prof. S. Jayanthu

DEPARTMENT OF MINING ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY

ROURKELA

2010

National Institute of Technology
Rourkela

CERTIFICATE

This is to certify that the thesis entitled, "**Blast Vibration Studies in Surface Mines**" submitted by Mr. Badal Kumar Kujur in partial fulfilment of the requirement for the award of Bachelor of Technology Degree in Mining Engineering at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance. To the best of my knowledge, the matter embodied in the thesis has not been submitted to any University/Institute for the award of any Degree or Diploma.

Date:

Prof. S. Jayanthu
HOD. Deptt. Of Mining Engineering
National Institute of Technology
Rourkela – 769008

ACKNOWLEDGEMENT

The most pleasant point of presenting a thesis is the opportunity to thank those who have contributed to it. Unfortunately, the list of expressions of thank no matter how extensive is always incomplete and inadequate. Indeed this page of acknowledgment shall never be able to touch the horizon of generosity of those who tendered their help to me.

First and foremost, I would like to express my gratitude and indebtedness to Dr. S. Jayanthu for his kindness in allowing me to do work in the present topic and for his inspiring guidance, constructive criticism and valuable suggestion throughout this project work. I am sincerely thankful to him for his able guidance and pain taking effort in improving my understanding of this project.

An assemblage of this nature could never have been attempted without reference to and inspiration from the works of others whose details are mentioned in reference section. I acknowledge my indebtedness to all of them.

And my sincere thanks to all my friends who have patiently extended all sorts of help for accomplishing this undertaking.

Date:

Badal Kumar Kujur

Dept. of Mining engineering

National Institute of Technology

Rourkela – 769008

CONTENTS

ABSTRACT

Blasting is very important process for mining operation and a lot of explosive is used for this purpose. The blasting process and usage of explosives, however, remain a potential source of numerous human and environmental hazards. Various studies indicate that fragmentation accounts for only 20-30% of the total amount of explosive energy used. Rest of the energy is lost in the form of ground vibration, fly rock, air overpressure and noise. The specific problem associated with ground vibrations represents the human response to them. Blasting vibrations may also cause a significant damage to nearby buildings or various structures. In this project blast vibration study is done and it is interpreted for its effects in reference to the standards set by DGMS.

The study has been done with the help of geophones and Blastmate8.0 software. First of all the blasting operations were monitored through geophones at distances of 100m, 200m and 300m. The data obtained from the instrument were interpreted by Blastmate software and the graphical output was obtained from it. The **Peak Particle Velocity** (PPV), maximum charge per delay, air over pressure was recorded for each blast. After that the various observations were compared with the standards to determine the conclusion.

From the analysis of blasts vibration at the mines it was determined that the vibration level was less than 5 mm/sec for the blasts when recommended amount of charge per delay or safe charge per delay was used. The air overpressure value determined was in between 114 & 127.6 dB (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.

LIST OF TABLES

LIST OF FIGURES

CHAPTER - 1

INTRODUCTION

Drilling and blasting combination is still an economical and viable method for rock excavation and displacement in mining as well as in civil construction works. 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 structures . Among all the ill effects, ground vibration is major concern to the planners, designers and environmentalists. A number of researchers have suggested various methods to minimize the ground vibration level during the blasting. Ground vibration is directly related to the quantity of explosive used and distance between blast face to monitoring point as well as geological and geotechnical conditions of the rock units in excavation area.

Blast induced ground vibration is an impact from the use of explosives that has historically been an extremely difficult problem to effectively mitigate. There are many variables and site constants involved in the equation that when combined, result in the formation of a complex vibration waveform generated by the confined detonation of an explosive charge. The application of proper field controls during all steps of the drilling and blasting operation will help to minimize the adverse impacts of ground vibrations, providing a well designed blast plan has been engineered. This design would consider the proper hole diameter and pattern that would reflect the efficient utilization and distribution the explosives energy loaded into the blast hole. It would also provide for the appropriate amount of time between adjacent holes in a blast to provide the explosive the optimum level of energy confinement. After the blast has been properly designed, 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 altered but the only factor, i.e. quantity of explosive can be estimated based on certain empirical formulae proposed by the different researchers to make ground vibrations in a permissible limit. An appropriate and rock friendly blasting can be only alternative for smooth progress of the rock removal process.

1.1 Objective of the Project

To study the blast vibration caused due to surface mine blasting, and prediction of safe explosive charge for protection of surface structures.

CHAPTER - 2

LITERATURE REVIEW

Explosive energy produces the following effects:

- Rock shattering and displacement.
- Ground vibration.
- Air vibration.

The energy contained in explosives used in mine blastholes is designed to break and displace rock and the more energy available which can be utilised for that purpose, the more efficient the blast. However, some of the energy cannot be utilised in breaking rock and creates vibration in the surrounding rock and air. As a general principle, both air and ground vibration increase with increasing charge (explosive) mass and reduce with increasing distance.

2.1 Ground Vibration

The movement of any particle in the ground can be described in three ways; displacement, velocity and acceleration. Velocity transducers (geophones) produce a voltage which is proportional the velocity of movement, and can be easily measured and recorded. They are robust and relatively inexpensive and so are most frequently used for monitoring. It has been shown in many studies, most notably by USBM that it is velocity which is most closely related to the onset of damage, and so it is velocity which is almost always measured. If necessary, the velocity recording can be converted to obtain displacement or acceleration. Each trace has a point where the velocity is a maximum (+ve or -ve) and this is known as the Peak Particle Velocity (or PPV) which has units of mm/s. 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).

2.1.1 Generation of blast vibration

When an explosive charge detonates, intense dynamic waves are set around the blast hole, due to sudden acceleration of the rock mass. The energy liberated by the explosive is transmitted to the rock mass as strain energy. The transmission of the energy takes place in the form of the waves. The energy carried by these waves crushes the rock, which is the immediate vicinity of the hole, to a fine powder. The region in which this takes place is called shock zone. The radius of this zone is nearly two times the radius of the hole. Beyond the shock zone, the energy of the waves gets attenuated to some degree which causes the radial cracking of the rock mass. The gas generated as a result of detonation enters into these cracks and displaces the rock further apart causing its fragmentation. The region in which this phenomenon takes place is called transition zone. The radius of this zone is twenty to fifty times the radius of the hole. As a result of further attenuation taking place in the transition zone, the waves although cause generation of the cracks to a lesser extent but they are not in a position to cause the permanent deformation in the rock mass located outside the transition zone. If these attenuated waves are not reflected from a free face, then they may cause vibrations in the rock. However if a free face is available, the waves reflected from a free face cause further breakage in the rock mass under the influence of the dynamic tensile stress. Fig 3 is a pictorial representation of the various zones described above and explains the phenomenon of reflection of waves.

2.1.2 Wave forms of blast vibration

Ground vibration radiates outwards from the blast site and gradually reduces in magnitude, in the same manner as ripples behave when a stone is thrown into a pool of water, schematically shown below. The motion of the wave can be defined by taking measurements of a float on the surface of the water. With suitable instruments the displacement or amplitude, velocity, acceleration and wave length of the waves can be measured.

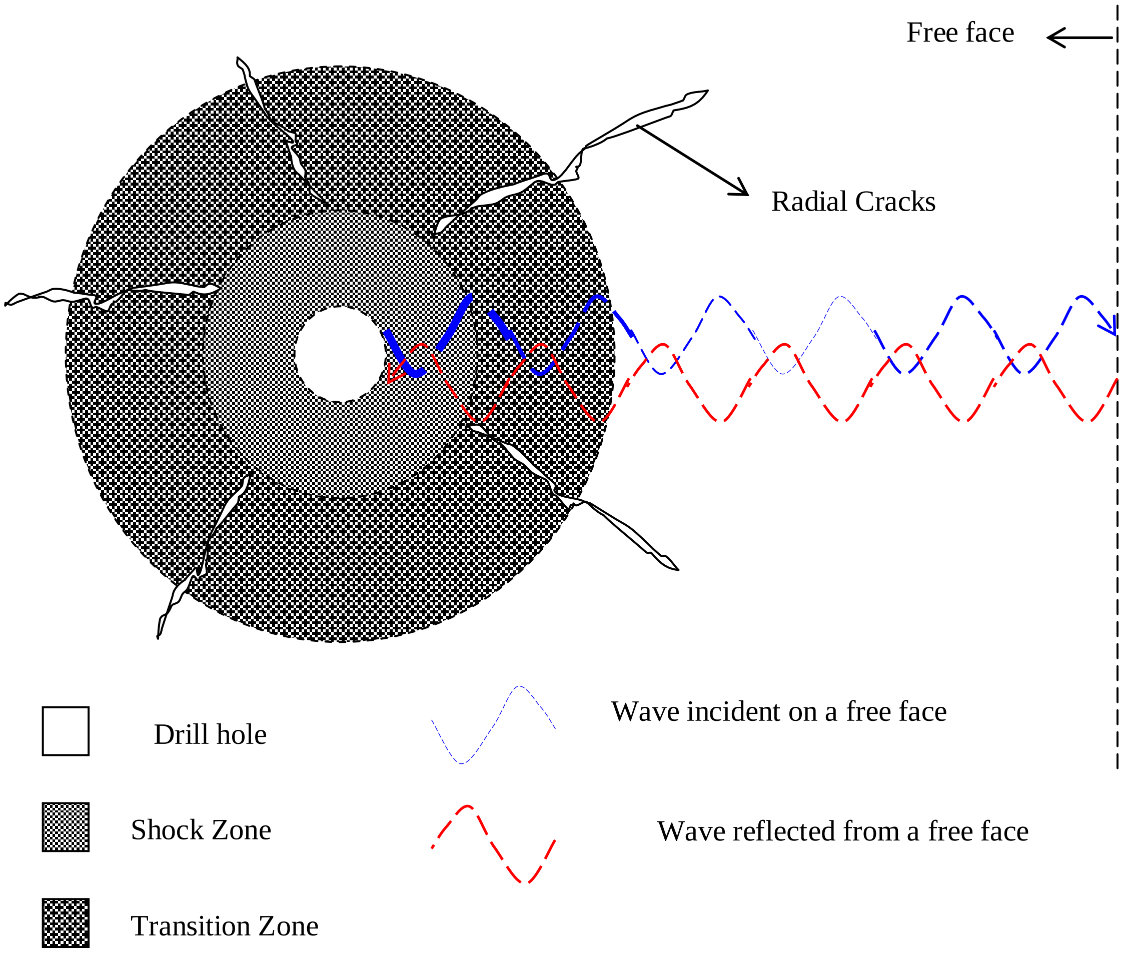

Fig 1: Pictorial representation of the various zones and the Phenomenon of reflection of waves

The ground vibration wave motion consists of different kinds of waves:

- Compression (or P) waves.
- Shear (or S or secondary) waves.
- Rayleigh (or R) waves.

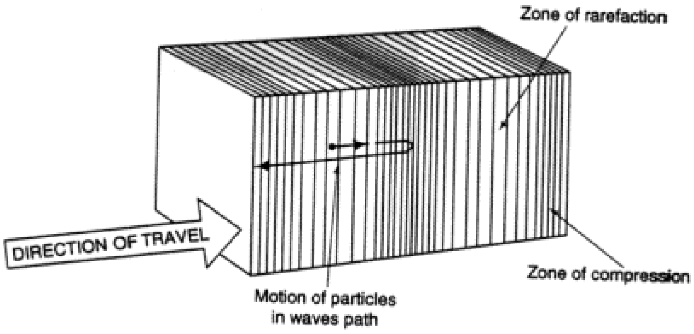

Fig 2: Illustration of the motion of the particles within ‘P’ wave

The Compression or ‘P’ wave is the fastest wave through the ground. The simplest illustration of the motion of the particles within the ‘P’ wave is to consider a long steel rod struck on the end. The particles of the rod move to and fro as the compressive pulse travels along the rod, i.e. the particles in the wave move in the same direction as the propagation of the wave. The ‘P’ wave moves radially from the blasthole in all directions at velocities characteristic of the material being travelled through (approximately 2200 m/s).

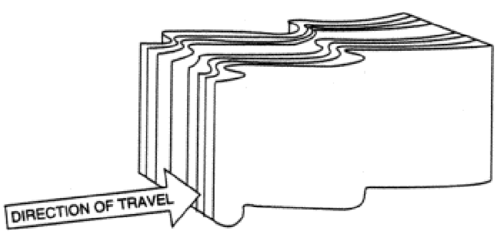

Fig 3: Illustration of the motion of the particles within S – Wave

The Shear or ‘S’ wave travels at approximately 1200 m/s (50% to 60% of the velocity of the ‘P’ wave). The motion of the particles within the wave can be illustrated by shaking a rope at one end. The wave travels along the rope, but the particles within the wave move at right angles to the direction of motion of the wave. The ‘P’ waves and ‘S’ waves are sometimes referred to as “body waves” because they travel through the body of the rock in three dimensions.

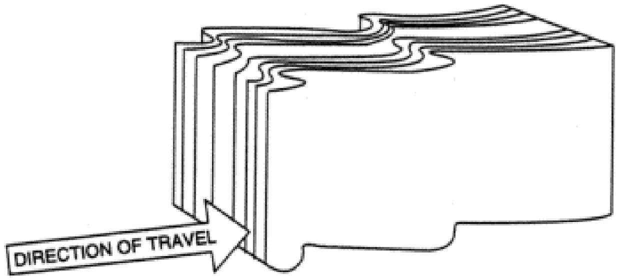

Fig 4: Illustration of the motion of the particles within R – wave

The Rayleigh or ‘R’ wave is a surface wave, which fades rapidly with depth and propagates more slowly (750 m/s) than the other two waves. The particles within the wave move elliptically in a vertical plane in the same direction as the direction of propagation. At the surface the motion is retrograde to the movement of the wave, similar to waves on the ocean.

In general terms, ground vibration increases with increased charge (explosive) mass and reduces with distance. The relationships between charge mass, distance and vibration can be determined from analysis and then used in predictive formula to limit and control the ground vibration.

2.1.3 Parameters influencing propagation and intensity of ground vibrations

The parameters, which exhibit control on the amplitude, frequency and duration of the ground vibration, are divided in two groups as follows:

a. Non-controllable Parameters
b. Controllable Parameters

The non-controllable parameters are those, over which the Blasting Engineer does not have any control. The local geology, rock characteristics and distances of the structures from blast site is non-controllable parameters. However, the control on the ground vibrations can be established with the help of controllable parameters. The same have been reproduced below:

1. Charge Weight
2. Delay Interval
3. Type of Explosive
4. Direction of blast progression
5. Burden, spacing and specific charge
6. Coupling
7. Confinement
8. Spatial distribution of charges

2.1.4 Reduction of ground vibrations

To protect a structure, it is necessary to minimize the ground vibrations from the blast. The acceptable techniques for reduction and control of vibrations are:

a. *Reduce the charge per delay: This is the most important measure for the purpose. Charge per delay can be controlled by:*

   i. Reducing the hole depth.
   ii. Using small diameter holes
   iii. Delayed initiation of deck charges in the blast holes
   iv. Using more numbers of delay detonators series
   v. Using sequential blasting machine

b. *Reduce explosive confinement by:*

   i. Reducing excessive burden and spacing
   ii. Removing buffers in front of the holes
   iii. Reducing stemming but not to the degree of increasing air-blast and fly rock
   iv. Reducing sub-grade drilling
   v. Allowing at least one free face
   vi. Using decoupled charges
   vii. Drilling holes parallel to the bench face
   viii. Accuracy in drilling

c. *Limit the explosive confinement to bedrock if the overburden can be excavated by other means.*

d. *Square patterns produce more vibrations*

e. *Limit frequency of blasting*

f. *Time the blasts with high ambient noise levels*

g. *Use controlled blasting techniques*

h. *Use a low VOD and low density explosive*

2.2 Air Overpressure

Pressure waves emanated in the atmosphere by the detonating charge is called air-overpressure/noise. The intensity of noise depends upon the quantity of the charge and its confinement. . The frequency of the pressure waves in the range of to 20 Hz. To 20 kHz are in the audible range.

The air overpressure is calculated in dB (A) or Pa.

The dB (A) is calculated by the following formula

$$dB = 20\log\left(P/P_o \right) \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Where P is measured pressure and P_o is the reference pressure of 0.00002 Pa.

A low level of air-over pressure plays an important role in causing distress because of rattling windows. At present we don't have any standards regarding levels of air-over pressure. However, type of the damage that occurs by air-overpressure (as established by different researchers) is reproduced in Table 6.

The principle sources of air-over pressure are:

a. Detonation of unconfined charges.

b. Too short stemming or improper stemming material

c. Venting of high velocity gases through poorly designed blasts.

When air overpressure is within the range of hearing it is called 'sound'. When its frequency is below the range of hearing, it is generally referred to as 'concussion' or 'airblast'. Air vibration from blasting is measured with an air vibration meter, which meets the requirements of Australian Standard 2187.2-2006 and is expressed in terms of decibels (linear) or dBL.

The techniques to control air-over pressure are:

a. Use of NONEL in place of D-cord in the blasts near the residential area.

b. Reduction in the size of the blast.

c. Avoiding top initiation.

d. Avoiding excessive delays between the rows.

e. Avoiding blasting in early morning, late afternoon and evening when temperature inversions are likely to occur.

f. Avoiding blasting when the wind is blowing towards residential area as the sound waves travel in the direction of the wind.

CHAPTER - 3

PREDICTION OF GROUND VIBRATION

A number of investigators have studied ground vibrations from blasting and have developed theoretical analysis to explain the experimental data. The energy released is considered to be proportional to the square root of charge.

Earlier studies on wave propagation showed that the amplitude of particle displacement can be given by

$$A = K\frac{Q^{0.5}}{D} \qquad \text{.........................} (2)$$

Where K is site constant; D is the distance and Q is the charge per delay.

Assuming the cylindrical explosive geometry for long cylindrical charges, Researchers working on blast-induced ground vibrations concluded that any linear dimension should be scaled with the square root of the charge weight. Blasts should be scaled to the equivalent distance, which is the actual distance divided by the square root of the charge. The corresponding relation known as USBM predictor equation takes up following form:

$$A = K\left(\frac{D}{Q^{0.5}}\right)^{\beta} \qquad \text{..............................} (3)$$

Where, K and β are site-specific constants, which depend on local geology and ground characteristics and other terms have their usual meanings. The USBM predictor equation is used in India for calculating maximum safe charge per delay for different distances according the standards fixed by DGMS. The value of K and β are determined by regression analysis of the data generated by trial blasts in terms of *A, D and Q*.

3.1 Peak Particle Velocity (PPV)

Ground vibration can be measured by the concept of peak particle velocity.

Peak Particle Velocity – is defined as the highest speed at which an individual earth particle moves or vibrates as the waves pass a particular site.

There are many predictive equations to compute explosive weight per delay to attain a specific level of peak particle velocity.

Some of the predictors are –

3.1.1 USBM predictor

Assuming cylindrical explosive geometry for long cylindrical charges, Duvall and Petkof (1959), Duvall and Fogelson (1962), Duvall et al (1963),Sinkin et al (1980), Daemen (1983), of United State Bureau of Mines (USBM) concluded that any linear dimension should be scaled with the square root of the explosive charge weight based on dimensional analysis. The equation proposed by USBM is

$$v = K[R/\sqrt{Q_{max}}]^{-B} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; (4)$$

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

3.1.2 Langefors and Kihlstrom predictor (1963)

Langefors et al (1958) and Langefors and Kihlstrom (1963) proposed the following relationships for various charging levels ($Q/D^{3/2}$) to estimate peak particle velocity. The equation is

$$v = K\,[\sqrt{(Q_{max}/R^{2/3})}]^{B} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

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

3.1.3 Ambraseys-Hendron predictor (1968)

The USBM investigator suggested that any linear dimension should be scaled to the cube root of the explosive charge weight for spherical geometry. An inverse power law was suggested to relate amplitude of seismic waves and scaled distance to obtain the following relationship.

$$v = K[R/(Q_{max})^{1/3}]^{-B} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

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

3.1.4 Indian standard predictor (1973)

Indian standard (1973) suggested that the blast should be scaled to the equivalent distance or the scaled distance, defined as the explosive charge weight divided by cube root of square of real distance. The proposed equation is

$$v = K\,[(Q_{max}/R^{2/3})]^{B} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

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

3.1.5 General predictor (1964)

Number of researchers proposes this general empirical equation for vibration prediction (Davies et al 1964; Attewell, 1964; Birch and Chaffer, 1983; etc.). They considered particular charge symmetry.

$$v = KR^{-B}\,(Q_{max})^{A} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

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, A, B = site constants which can be determined by multiple regression analysis.

3.1.6 Ghosh – Daemon predictor (1983)

Ghosh – Daemon predictor (1983) proposed that various inelastic effects cause energy losses during wave propagation in various medium. This inelastic effect leads to a decrease in amplitude in addition to those due to geometrical spreading. They modified the propagation relations of USBM in terms of adding inelastic attenuation factor (α).

GHDN1 $v = K[R/\sqrt{Q_{max}}]^{-B}e^{-\alpha R}$ …………………………… (9)

GHDN2 $v = K[R/(Q_{max})^{1/3}]^{-B}e^{-\alpha R}$ ……………………………(10)

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 and α = site constants which can be determined by multiple regression analysis.

3.1.7 CMRI predictor (1993)

Pal Roy (1993) proposed a new predictor equation based on the data collected from different Indian geo-mining conditions. This equation is only valid in the zone of disturbance, i.e. when $Q_{max}>0$ and $v>0$.

$v = n+K[R/\sqrt{Q_{max}}]^{-1}$ …………………………… (11)

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),

n = site constants which is influenced by rock properties and geometrical discontinuities,

K = site constants which related to design parameters.

CHAPTER - 4

BLAST VIBRATION STUDY AT

OPEN CAST COAL MINE – A CASE STUDY

4.1 General Description of the Mine

4.1.1 Location

Jindal Power Open Cast Coal Mine is captive mine of Jindal's 1000 MW (4 x 250 MW) thermal power plant. The block is located between Longitudes - 83°29'40" to 83°32'32" (E) and Latitude - 22°09'15" to 22°05'44" (N) falling in the topo sheet no. 64 N/12 (Survey of India). Administratively, the block is under Gharghoda Tahsil of Raigarh District, Chhattisgarh.

4.1.2 Communication

The block is well connected by Road. It is about 60 km from Raigarh town, which is district head quarter and nearest railway station on Mumbai - Howra Main Line.

4.2 General Geology of the Block

4.2.1 Geology

In the sub-block IV/2 & IV/3 only lower groups of Gondwana seams have been deposited. Strata are gently dipping by 2 to 5 southwesterly. The general strike of the seams in NW-SE, which is almost uniform throughout the block. Two normal faults of small magnitude have been deciphered based on the level difference of the floor of the seams, though the presence of some minor faults of less than 5 m. throw cannot be overruled.

4.2.2 **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.

4.3 Experimentation

A number of blasts were monitored to study various blast parameters related to blasting of Overburden and Coal benches and to understand the effect of blast on the surrounding structures. Peak particle velocity and frequency of ground vibrations due to blast at different distances from the blast site were measured with suitable instruments in the field (vibroblast, geophone).

The data obtained by monitoring were interpreted using "BLASTWARE" software and the plots were obtained and studied.

From the monitoring of the blasts provided the blast vibration is to be determined by determining the peak particle velocities associated with different blasts.

4.3.1 Damage criteria:

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 1 and 2 is followed for the present investigations to estimate safe charge per delay to limit the ground vibrations within safe limit of 5 mm/sec as the frequency was within the limits of 8 to 25 for the present observations (considering the structures as sensitive and not belonging to the village –Kosumpali).

Table 1: Damage criteria vis-à-vis 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 vis-à-vis 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

4.4 OBSERVATIONS

A number of Blasts were monitored by the team of Blasting Experts and assisted by Blasting In charge of Jindal Power Open cast Coal Mine. Details of a typical blast are presented in Table 4. Details of other 12 blasts are given in Appendix-1.

Table 4: Details of a Blast Vibration Study Report of Jindal Power Open Cast Coal Mines

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
	<u>Post Blast Observations</u>	
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				

The blast result was assessed in terms of ground vibrations, its frequency, air over Pressure produced. The vibrograph was installed at a predetermined distances in the range of 100 to 350 m from blast site to the monitoring station to monitor the ground vibrations generated from blast. The Peak particle velocity (PPV) was measured for about 13 blasts with respect to the distance from the blast site to the monitoring station including the Charge per delay for various blasts is presented in Table 5.

Details of observations including the wave pattern in a typical blast is presented in Figures 5 & 6 with the damage criteria of OSMRE/USBM indicating that the ground vibrations vis-à-vis frequency content of vibration is within the safe limit for the structures corresponding to the distance of about 150 m from the blast site.

Table 5: Peak Particle Velocity (PPV) observed for various blasts at Jindal Power Open Cast Coal Mine

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

CHAPTER - 5

ANALYSIS OF BLAST VIBRATION DATA

5.1 PPV Predictor Equation for the mine

The ground vibration data including Peak particle velocity (PPV), the distance from the blast site to the monitoring station; the explosive Charge per delay for various blasts was analyzed for understanding the effect of ground vibrations induced by blasting at Jindal Power Open Cast Coal Mine.

The following predictor equation in terms of the scaled distance (x) and PPV (Peak particle velocity) is found to represent the data, and proposed for utilization in estimation of safe explosive charge per delay to keep the vibration level within the safe limits.

$$\textbf{PPV} = \textbf{290.12} \, (\textbf{Scaled distance})^{-1.296} \qquad \ldots\ldots\ldots \, (12)$$

Accordingly, the safe charge per delay recommended to keep the vibration level below 5 mm /sec is presented in Table 6 for the geomining conditions of Jindal Power Opencast Coal Mine - Tamnar.

The air overpressure recorded the monitoring of blasts at Jindal Power Opencast coal mine was in the range of 114 to 127.6 dB(L), which is within the safe limits as shown in the Table - 3.

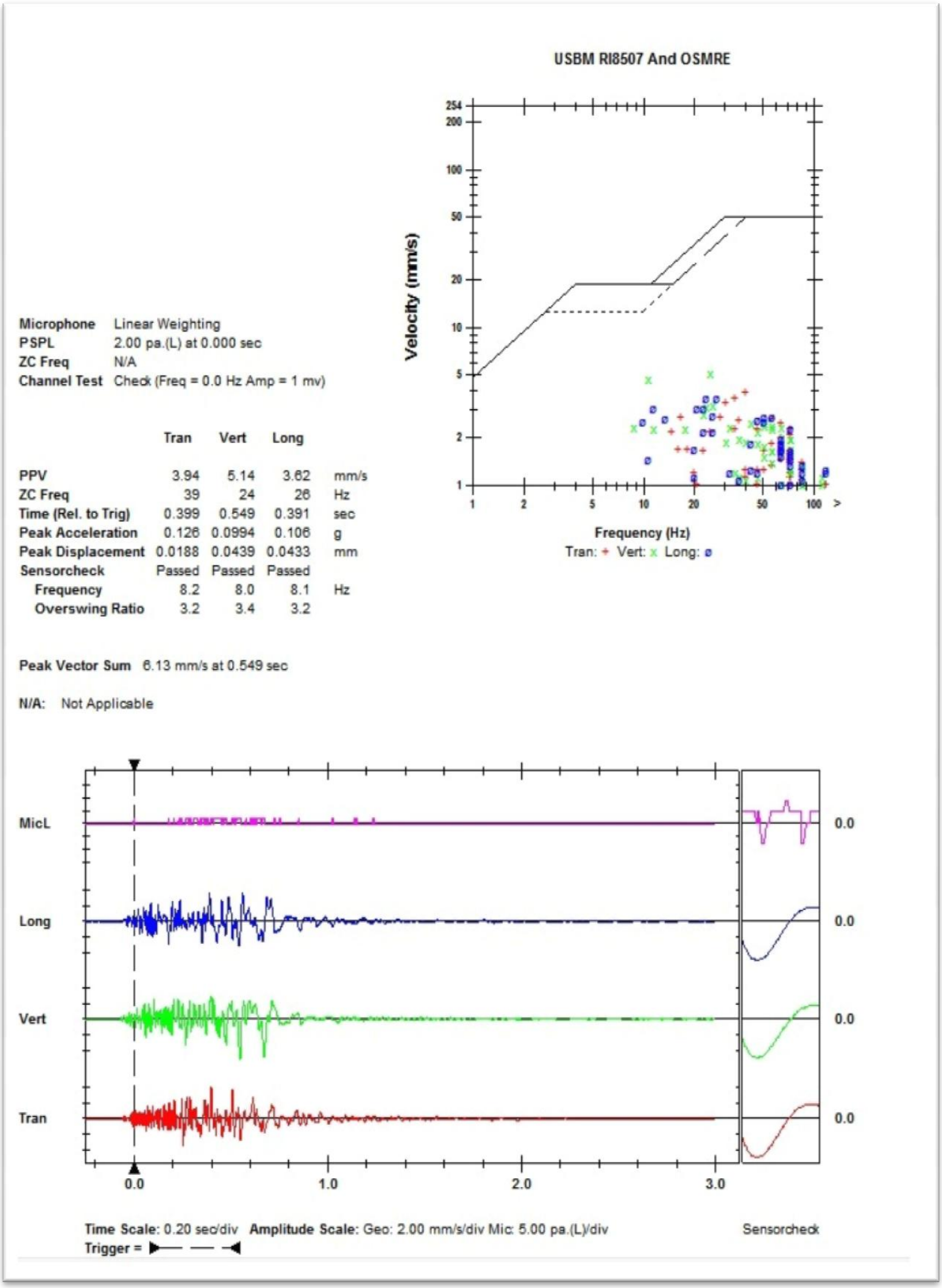

Fig 5: A typical blast vibration data related to the blast at Jindal Power Open Cast Coal Mine

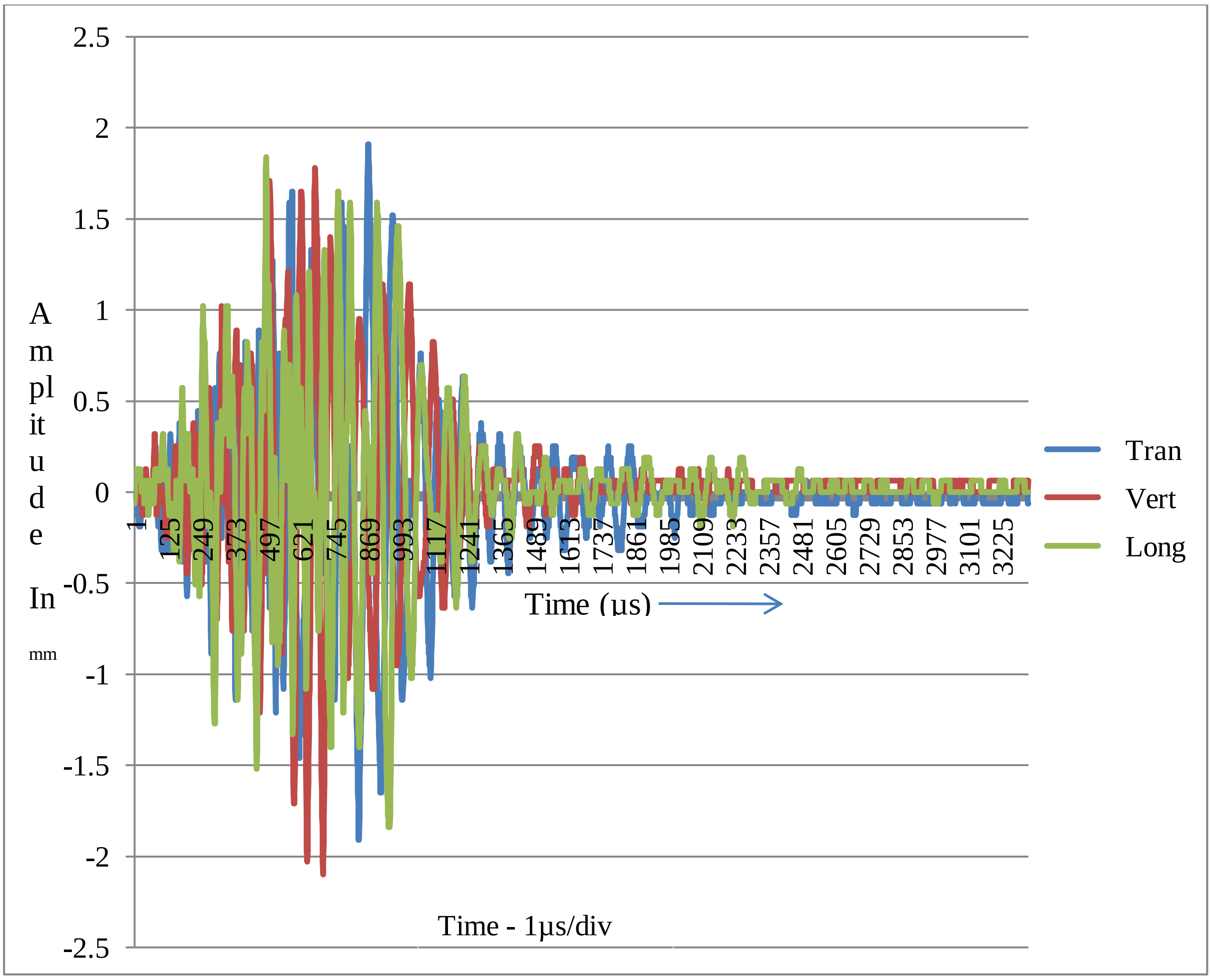

Fig 6: Graphical Representation of the Blast Generated Waves Using Microsoft Office Excel

Amplitude vs. time data in ASCII form was converted to excel chart, and the plot for a typical blast indicated a maximum of 2.1 mm in vertical direction (Fig 6). The sensor recorded the blast vibrating data for about 3 ms. Longitudinal wave has a maximum of 2.1 mm amplitude in vertical direction, while the transverse wave showed a maximum of 2.1 mm amplitude.

The graph also showed that after approx. 2µs of time lapse the wave forms have almost constant amplitude on both cycles which is going on decreasing with increase in time. The maximum amplitude for transverse wave was recorded at about 870 µs which is 1.9mm, for vertical wave it is 2.1mm at 746 µs and for longitudinal wave 1.8mm at almost 900 µs of time. At the time of blasting the waves show low amplitude & high frequency, and then amplitude increases gradually with increase of time with decrease in frequency and after some time both amplitude and frequency decrease at constant rate.

From the graph it is clear that the wave loses its effectiveness with an increase in time since the blasting operation. The distance covered by the vibration waves within the peak values should be determined to determine the effectiveness of vibration to the structures present near the blast site.

5.2 Safe charge for protection of structures

The amount of ground vibration generated is related to the amount of charge per delay used in the blast holes. It has a critical value at which it gives the optimum output, amount more than that value will generate more ground vibration. This vibration generated can cause damage to the structures present nearby. From the monitoring of ground vibration from a number of blasts the safe amount of charge per delay is determined.

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 Jindal Power Open Cast Coal Mine

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

CHAPTER - 6

CONCLUSION

Analysis of the blast vibration data the Peak Particle Velocities (PPVs) for various blasts was recorded. It was found that the PPV for different blasts vary with and related to that of the charge per delay associated with the blast. In most of the blasts the PPV remained within the limits as shown in table 1 & 2. This is because the different amounts of charge per delay associated with each blast. Hence a specific amount of charge per delay should be determined for a blast hole to keep the PPV and air overpressure generated by the blast within the limits determined by the DGMS. Table 6 shows recommended amount of safe charge per delay to keep the vibration level below the limits i.e. 5 mm/sec.

The vibration levels were found to be less than 5 mm/sec which is within the limits, when the recommended amount of charge per delay was used for blasting. The air overpressure values recorded were in between 114 to 127.6 dB (L), which is within the safe limits.

REFERENCES

1. ISRM. 1992, Suggested method for blast vibration monitoring. Int J Rock Mech Min Sci Geomech Abstr; 29(2):145–6.
2. http://www.vulcanhammer.net/svinkin/prediction.php
3. http://terrock.com.au/vibration/blasting.html
4. Khandelwal Manoj, Singh T N, 2007, PhD thesis, Evaluation and prediction of blast induced ground vibration and frequency for surface mine- a neural network approach, pp- 1-30
5. Langefors U, Kihlstrom B, Westerberg H., 1958, Ground vibrations in blasting. Water Power, 400p
6. Singh B, PalRoy P., 1993, Parameters influencing mine & ground excavation opereatio, Blasting in ground excavation & mines, pp- 1-7.
7. Singh B, PalRoy P., 1993, Generation, propagation & prediction of ground vibration from opencast blasting, Blasting in ground excavation & mines, pp- 21-35.
8. Singh P K, 2006, Standardisation of blast vibration damage threshold for the safety of residential structures in mining areas
9. Wiss JF, Linehan PW. 1978, Control of vibration and air noise from surface coal mines—III. Report no. OFR 103 (3)—79, Bureau of Mines, US, p. 623.

APPENDIX - 1

Table 1(a): Blast Vibration study report of Jindal Power Open cast Coal Mines- Blast no 1

1	Blast number	**1**
2	Location	VIII Seam OB
3	Strata	Medium hard Sand Stone
4	No of Holes	93
5	Depth of Holes	4.00 to 4.50mtr.
6	Burden x Spacing	4.0 x 6.00mtr
7	Diameter of Holes	159 mm
	Explosives Used	
8	Powergel B- 1 (SME) in Kgs	1985.0
9	Primex (100gm pellets) in Kgs	9.30
10	Total Explosives in Kgs	1994.30
11	Accessories Used	Exel (250/25MS, 42MS,65MS)
12	Electric Detonators	01
13	Maximum charge/ Delay (Kgs)	50
14	Volume Blasted (Cu. Mtr)	10044. 0
15	Powder Factor (Cu.Mtr/Kgs)	5.0
	Post Blast Observations	
16	Blast fragmentation	Good
17	Fly Rocks	Within 15 Mtr.
18	Throw	Normal
19	Muck File	Good

Distance (Mtr.)	**100**	**200**	**300**	**400**	**500**
PPV (mm/Sec)		3.75			
Frequency (Hz)		47			
Noise dB(L)		-			

Table 1(b): Blast Vibration study report of Jindal Power Open cast Coal Mines- Blast no 2

<table>
<tr><td colspan="2">1</td><td colspan="2">Blast no</td><td colspan="2">2</td></tr>
<tr><td colspan="2">2</td><td colspan="2">Location</td><td colspan="2">VIII Seam OB</td></tr>
<tr><td colspan="2">3</td><td colspan="2">Strata</td><td colspan="2">Medium hard Sand Stone</td></tr>
<tr><td colspan="2">4</td><td colspan="2">No of Holes</td><td colspan="2">96</td></tr>
<tr><td colspan="2">5</td><td colspan="2">Depth of Holes (Mtr)</td><td colspan="2">2.10 to 2.50</td></tr>
<tr><td colspan="2">6</td><td colspan="2">Burden x Spacing (Mtr)</td><td colspan="2">3.0 x4.5</td></tr>
<tr><td colspan="2">7</td><td colspan="2">Diameter of Holes (Mtr)</td><td colspan="2">159 mm</td></tr>
<tr><td colspan="2"></td><td colspan="2">Explosives Used</td><td colspan="2"></td></tr>
<tr><td colspan="2">8</td><td colspan="2">Powergel B- 1 (SME) in Kgs</td><td colspan="2">708</td></tr>
<tr><td colspan="2">9</td><td colspan="2">Primex (100gm pellets) in Kgs</td><td colspan="2">9.60</td></tr>
<tr><td colspan="2">10</td><td colspan="2">Total Explosives in Kgs</td><td colspan="2">717.60</td></tr>
<tr><td colspan="2">11</td><td colspan="2">Accessories Used</td><td colspan="2">Detonating Fuse</td></tr>
<tr><td colspan="2">12</td><td colspan="2"></td><td colspan="2">Electric Detonator</td></tr>
<tr><td colspan="2">13</td><td colspan="2">Maximum charge/ Delay (Kgs)</td><td colspan="2">50</td></tr>
<tr><td colspan="2">14</td><td colspan="2">Volume Blasted (Cu. Mtr)</td><td colspan="2">3240.0</td></tr>
<tr><td colspan="2">15</td><td colspan="2">Powder Factor (Cu.Mtr/Kgs)</td><td colspan="2">4.50</td></tr>
<tr><td colspan="2"></td><td colspan="2"><u>Post Blast Observations</u></td><td colspan="2"></td></tr>
<tr><td colspan="2">16</td><td colspan="2">Blast fragmentation</td><td colspan="2">Good</td></tr>
<tr><td colspan="2">17</td><td colspan="2">Fly Rocks</td><td colspan="2">Within 25 Mtr.</td></tr>
<tr><td colspan="2">18</td><td colspan="2">Throw</td><td colspan="2">Normal</td></tr>
<tr><td colspan="2">19</td><td colspan="2">Muck File</td><td colspan="2">Good</td></tr>
<tr><td>Distance (Mtr.)</td><td>100</td><td>200</td><td>300</td><td>400</td><td>500</td></tr>
<tr><td>PPV (mm/Sec)</td><td></td><td>4.75</td><td></td><td></td><td></td></tr>
<tr><td>Frequency (Hz)</td><td></td><td>47</td><td></td><td></td><td></td></tr>
<tr><td>Noise dB(L)</td><td></td><td>-</td><td></td><td></td><td></td></tr>
</table>

Table 1(a): Blast Vibration study report of Jindal Power Open cast Coal Mines- Blast no 3

1		Blast no		**3**	
2		Location		VIII Seam OB	
3		Strata		Medium hard Sand Stone	
4		No of Holes		21	
5		Depth of Holes (Mtr)		4.0 to 4.80	
6		Burden x Spacing (Mtr)		4.0 x 6.0	
7		Diameter of Holes (Mtr)		159 mm	
		Explosives Used			
8		Powergel B- 1 (SME) in Kgs		550	
9		Primex (100gm pellets) in Kgs		2.10	
10		Total Explosives in Kgs		552.10	
11		**Accessories Used**		Detonating Fuse	
12				Electric Detonator	
				Cord Relay (25 MS)	
13		Maximum charge/ Delay (Kgs)		83	
14		Volume Blasted (Cu. Mtr)		2073.0	
15		Powder Factor (Cu.Mtr/Kgs)		3.80	
		Post Blast Observations			
16		Blast fragmentation		Good	
17		Fly Rocks		Within 25 Mtr.	
18		Throw		Normal	
Distance (Mtr.)	**100**	**200**	**300**	**400**	**500**
PPV (mm/Sec)		4.06			
Frequency (Hz)		28			
Noise dB(L)		-			

Table 1(d): Blast Vibration study report of Jindal Power Open cast Coal Mines- Blast no 4

1		Blast no		4	
2		Location		VIII Seam OB	
3		Strata		Medium hard Sand Stone	
4		No of Holes		47	
5		Depth of Holes (Mtr)		4.5 to 6.0	
6		Burden x Spacing (Mtr)		4.0 x 6.0	
7		Diameter of Holes (Mtr)		159 mm	
		Explosives Used			
8		Powergel B- 1 (SME) in Kgs		1500	
9		Primex (100gm pellets) in Kgs		4.70	
10		Total Explosives in Kgs		1504.70	
11		**Accessories Used**		Exel (250/25MS, 42MS,65MS)	
12				Electric Detonator	
13		Maximum charge/ Delay (Kgs)		70	
14		Volume Blasted (Cu. Mtr)		6158.0	
15		Powder Factor (Cu.Mtr/Kgs)		4.10	
		Post Blast Observations			
16		Blast fragmentation		Good	
17		Fly Rocks		Within 20Mtr.	
18		Throw		Normal	
19		Muck File		Good	
Distance (Mtr.)	**100**	**200**	**300**	**400**	**500**
PPV (mm/Sec)		3.75	2.35		
Frequency (Hz)		23	18		
Noise dB(L)		-	114		

Table 1(e): Blast Vibration study report of Jindal Power Open cast Coal Mines- Blast no 5

1	Blast no	5
2	Location	VIII Seam OB
3	Strata	Medium hard Sand Stone
4	No of Holes	48
5	Depth of Holes (Mtr)	2.4 to 3.1
6	Burden x Spacing (Mtr)	3.0 X 4.0
7	Diameter of Holes (Mtr)	159 mm
	Explosives Used	
8	Powergel B- 1 (SME) in Kgs	360
9	Primex (100gm pellets) in Kgs	4.80
10	Total Explosives in Kgs	364.80
11	**Accessories Used**	Detonating Fuse
12		Electric Detonator Cord Relay (25MS)
13	Maximum charge/ Delay (Kgs)	70
14	Volume Blasted (Cu. Mtr)	1486.0
15	Powder Factor (Cu.Mtr/Kgs)	4.10
	Post Blast Observations	
16	Blast fragmentation	Good
17	Fly Rocks	Within 25Mtr.
18	Throw	Normal
19	Muck File	Good

Distance (Mtr.)	**100**	**200**	**300**	**400**	**500**
PPV (mm/Sec)		2.35			
Frequency (Hz)		17			
Noise dB(L)					

Table 1(f): Blast Vibration study report of Jindal Power Open cast Coal Mines- Blast no 6

1	Blast no	6
2	Location	VIII Seam OB
3	Strata	Medium hard Sand Stone
4	No of Holes	75
5	Depth of Holes (Mtr)	3.0 to 4.5
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	1260
9	Primex (100gm pellets) in Kgs	7.5
10	Total Explosives in Kgs	1267.50
11	**Accessories Used**	Detonating Fuse
12		Electric Detonator Cord Relay (25MS)
13	Maximum charge/ Delay (Kgs)	52
14	Volume Blasted (Cu. Mtr)	5550.0
15	Powder Factor (Cu.Mtr/Kgs)	4.40
	Post Blast Observations	
16	Blast fragmentation	Good
17	Fly Rocks	Within 20Mtr.
18	Throw	Normal
19	Muck File	Good

Distance (Mtr.)	**100**	**200**	**300**	**400**	**500**
PPV (mm/Sec)		3.05			
Frequency (Hz)		17			
Noise dB(L)					

Table 1(g): Blast Vibration study report of Jindal Power Open cast Coal Mines- Blast no 7

1	Blast no	7
2	Location	VIII Seam OB
3	Strata	Medium hard Sand Stone
4	No of Holes	50
5	Depth of Holes (Mtr)	3.0 to 4.2
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	938
9	Primex (100gm pellets) in Kgs	5.0
10	Total Explosives in Kgs	943
11	**Accessories Used**	Exel (250/25MS, 42MS,65MS)
12		Electric Detonator
13	Maximum charge/ Delay (Kgs)	102
14	Volume Blasted (Cu. Mtr)	3990
15	Powder Factor (Cu.Mtr/Kgs)	4.25
	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)	9.14				
Frequency (Hz)	39				
Noise dB(L)	116.9				

Table 1(h): Blast Vibration study report of Jindal Power Open cast Coal Mines- Blast no 8

1	Blast no	8
2	Location	IX Seam Coal
3	Strata	Coal
4	No of Holes	95
5	Depth of Holes (Mtr)	4.0 to 4.7
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	2251
9	Primex (100gm pellets) in Kgs	9.5
10	Total Explosives in Kgs	2260.5
11	**Accessories Used**	Exel (250/25MS, 42MS,65MS)
12		Electric Detonator
13	Maximum charge/ Delay (Kgs)	25
14	Volume Blasted (Cu. Mtr)	8740
15	Powder Factor (Cu.Mtr/Kgs)	3.90
	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)	2.1				
Frequency (Hz)	26				
Noise dB(L)	122.3				

Table 1(i): Blast Vibration study report of Jindal Power Open cast Coal Mines- Blast no 9

1		Blast no		9	
2		Location		VII Seam OB	
3		Strata		Medium Hard sand Stone	
		No of Holes		68	
5		Depth of Holes (Mtr)		3.9 to 4.2	
6		Burden x Spacing (Mtr)		4.0 x 6.0	
7		Diameter of Holes (Mtr)		159 mm	
		Explosives Used			
8		Powergel B- 1 (SME) in Kgs		1670	
9		Primex (100gm pellets) in Kgs		6.8	
10		Total Explosives in Kgs		1676.8	
11		**Accessories Used**		Exel (250/25MS, 42MS,65MS)	
12				Electric Detonator	
13		Maximum charge/ Delay (Kgs)		30	
14		Volume Blasted (Cu. Mtr)		8740	
15		Powder Factor (Cu.Mtr/Kgs)		3.90	
		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)	4.95				
Frequency (Hz)	13				
Noise dB(L)	127.6				

Table 1(j): Blast Vibration study report of Jindal Power Open cast Coal Mines- Blast no 10

1		Blast no.		10	
2		Location		VIII Seam Coal	
3		Strata		Coal	
		No of Holes		9	
5		Depth of Holes (Mtr)		4.0 to 4.6	
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		199	
9		Primex (100gm pellets) in Kgs		0.9	
10		Total Explosives in Kgs		199.9	
11		**Accessories Used**		Exel (250/25MS, 42MS,65MS)	
12				Electric Detonator	
13		Maximum charge/ Delay (Kgs)		30	
14		Volume Blasted (Cu. Mtr)		756	
15		Powder Factor (Cu.Mtr/Kgs)		3.8	
		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)		5.97			
Frequency (Hz)		34			
Noise dB(L)					

Table 1(k): Blast Vibration study report of Jindal Power Open cast Coal Mines- Blast no 11

1	Blast no	11
2	Location	VIII Seam Coal
3	Strata	Coal
	No of Holes	49
5	Depth of Holes (Mtr)	1.2 to 2.0
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	200
9	Primex (100gm pellets) in Kgs	4.9
10	Total Explosives in Kgs	204.9
11	**Accessories Used**	Detonating Fuse
12		Electric Detonator Cord Relay (25 MS)
13	Maximum charge/ Delay (Kgs)	25
14	Volume Blasted (Cu. Mtr)	1180
15	Powder Factor (Cu.Mtr/Kgs)	5.80
	Post Blast Observations	
16	Blast fragmentation	Good
17	Fly Rocks	Within 30Mtr.
18	Throw	Normal
19	Muck File	Good

Distance (Mtr.)	**150**	**200**	**300**	**400**	**500**
PPV (mm/Sec)		1.65			
Frequency (Hz)		30			
Noise dB(L)					

Table 1(l): Blast Vibration study report of Jindal Power Open cast Coal Mines- Blast no 12

1	Blast no	12
2	Location	VII Seam Coal (pit I)
3	Strata	Coal
	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)	35
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)	7.87				
Frequency (Hz)	17				
Noise dB(L)	127.6				