Monitoring of Ground Vibrations for Estimation of Safe charge at Marki Mangli Coal Mine No. 1 District Yavatmal. (Maharashtra)

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Abstract— Blasting is very important process for mining operation and a lot of explosive is used for this purpose. Blasting activities in the mines certainly affects the equilibrium of surroundings. 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. It becomes more important than even before to study more critically environmental impacts of blasting on surroundings consisting of various structures of importance and forest of national interest located in an around the mine site. Environmental Impact Assessment emphasizes monitoring of blast seismic vibrations. In this paper the authors have made effort to highlight the requirement of monitoring of blast induced ground vibrations for estimating safe maximum charge per delay under controlled blasting and limiting the peak particle velocity values under the existing compliance.

Blast induced ground vibration was monitored with one seismograph. In all blast ground vibrations were monitored at different monitoring stations in the direction of nearby surface structures and village.

The results determined from the study indicates that the peak particle velocity due to blasting were within the limits. The safe charge per delay for the blasting operation was determined from the study.

Keywords—Blast, Environmental impact, Ground vibrations, Maximum charge per delay, Peak particle velocity.

I. Introduction

Marki Mangali-I Coal Mine at Pardi, Po-Marki,Tah. Jhari-Jamni, Dist-Yeotmal has been Vested to Topworth Urja & Metals Ltd, as per Vesting order No-104/32/2015/NA Dated–30thSeptember,2015, from Ministry of Coal, Govt of India, New Delhi.

TABLE I
BRIEF PARTICULARS
OF PROJECT

Sr. No	**Name of the Mine**	**Marki Mangli I, Coal Mine Italic**
1	Name of the Owner	Topworth Urja & Metals Ltd. 126-128, 1st Floor, Shriram Tower, Kingsway, Sadar, Near NIT Office, Nagpur-440 001,Maharashtra.
2	Name of the Nominated Owner	Shri. Manish Kumar(Director) TopworthUrja& Metals Ltd., 126-128, 1st Floor, Shriram Tower, Kingsway, Sadar, Near NIT Office, Nagpur-440 001,Maharashtra.
3	Name of the Agent	Amitabh Singh (B.Tech-Mining) 126-128, 1st Floor, Shriram Tower, Kingsway, Sadar, Near NIT Office, Nagpur-440 001,Maharashtra. Telefax: 0712 - 2527120 – 21 – 22
4	Name of the Manager	Arun B.Vaidya (BE, FCC) MarkiMangli-I Coal Mine, Village: Pardi, Post: Marki, Tehsil: JhariJamni, District: Yavatmal-445 305, Maharashtra.

II. LOCATION OF THE MINE

- Village Covered under ML area —Pardi, Pandharkawda, Marki(Bk.), Marki (Kh.) & Ganeshpur.
- Address of Mine-VillageTaluka -JhariJamni, Dist-Yavatmal. MS
- Nearest Police Station-Mukutban(9km)
- Nearest Railway Station-Dhanora (15km)
- Nearest State Highway-Wani to Adilabad (7km)
- Nearest National Highway-N.H-7 (Bori-30km)
- Nearest Airport- Morava-Chandrapur (75km) & Nagpur- 170km
- GEOGRAPHICAL LOCATION-
Latitude - 19o 50'27.63''N to 19o51'55.39" N
Longitude - 78o45'45.53''E to 78o48'34.25" E
- TOPOSHEET NO-56 I/3 as per GSI

Indian Map showing Mine Location

TABLE II
MINE PARTICULARS

Sr. No	Particulars	Status
1	TYPE OF MINING	OPENCAST METHOD (Shovel-Dumper combination with conventional benching method).
2	Mine Lease area	682.78 Ha
3	Geological block area	6400 Ha
4	Net workable reserve	24.26 MT
5	Total extractable coal reserve	10.49 MT
6	Life of mine	30 yrs
7	Mine capacity	0.3 MTPA
8	Present pit life	9 Yrs
9	Exploration done	By DGM,MECL,BSIL
10	Present Surface area	53.57716 Ha including Mine Infrastructure, Roads etc.
11	Effective seam thickness	2.5m to 4.5m
12	Average annual rainfall	1250-1350 mm
13	Over all stripping ratio	1 : 6.75
14	Depth of working	18m -48m
15	End use of coal	Sponge Iron Plan & Captive Power plant of TUML situated at Mouza – Ukkarwahi, Village – Heti, Tahsil – Umred, Dist. Nagpur.
16	Mining operation started on	23.03.2017
17	Coal production started on	19.04.2017
18	Power supply	11kv rural feeders of MSEB sub-station located at Patan

III Ground Vibration Phenomenon:

Use of explosive energy during blasting results in effects like rock shattering and displacement, ground vibration & air vibration. In general, both air and ground vibration increases with increasing charge (explosives) mass and reduces with increasing distance. When an explosive charge detonates in the blast hole, intense dynamic waves are set around the blast hole due to sudden acceleration of the rock mass. The energy liberated by the explosives is transmitted to the rock mass as strain energy. The transmission of the energy takes place in form of the waves. Whenever blast vibrations occurs, it vibrates the ground/soil particles with certain velocity and imparts to it certain amount of acceleration. Ground vibrations are therefore quantified as displacements that vary with time, acceleration and / or particular ground location.

The passage of viscoelastic waves forces the ground particles to vibrate in an elliptical manner in three dimensions. Therefore to define the ground motion three mutually perpendicular components of vibration parameters in longitudinal, transverse and vertical directions are measured. Resultant of all vibration vector components can be calculated from the readings of three mutually perpendicular transducers. However for industrial purpose only peak values are required.

The propagation of ground vibration is a complex phenomenon since rock mass is not homogeneous, inelastic and anisotropic. Many researches in the world over have co-related the propagation of ground vibration with different parameters to predict the vibration levels. The most widely accepted measurement of ground vibrations considered to cause potential damage to structures is the peak particle velocity, defined as the speed at which a particle of earth vibrates as the waves pass through a particular section.

Physical facilities surrounding the blast site will respond to the ground vibration intensities varying depending on physical variables such as distance, explosive charge weight per delay, the frequency of the vibration, shot geometry and confinement. Other geological variables may cause significant differences as the site shifts geographically but at any on one particular site, particularly for one specific blast the three primary variables are

i. Distance from blasting to physical facilities of interest.

ii. Explosive charge per delay

iii. Frequency of vibration

Thus parameters influencing propagation and intensity of ground vibrations are categorized into two groups

i. Non Controllable parameters: This includes
   a. The local geology
   b. Rock characteristics and
   c. Distance of the physical structure from the blast site.

ii. Controllable parameters: This includes,
   a. Charge weight (kgs)
   b. Delay interval (ms)
   c. Type of explosives
   d. Direction of blast progression
   e. Burden (m)
   f. Spacing (m)
   g. Specific Charge
   h. Coupling
   i. Confinement
   j. Spatial distribution of charges.

IV FIELD INVESTIGATIONS:

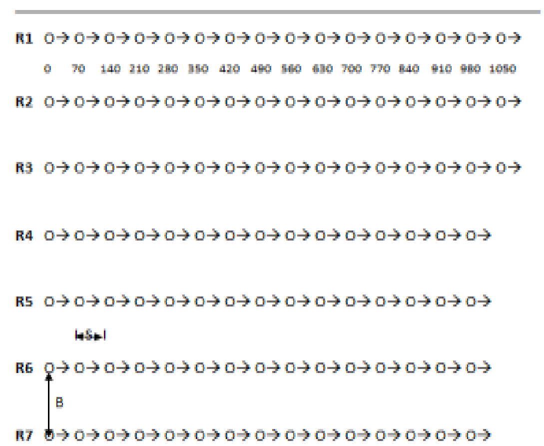
Faculties of Department of Mining Engineering, RCERT, Chandrapur visited the mine site to evolve safe blasting strategy at Marki – Mangli -I Mine and conducted 25 Nos of test blast from dated 15-05-2019 to 27-05-2019. During the study ground vibrations were monitored by means of MiniMate Blaster. A total of 25 vibrations events were recorded and collected data related to the geo-mining conditions and ground vibrations as well as air over – pressure. This Paper summarises these blasting events and the results along with recommendations for safe and productive blasting pattern.

V DESCRIPTION OF TRIALS

A total of 25 readings were taken from 25rounds of blasting on given parameters which were conducted in both coal and overburden benches during trial period. The observation stations were fixed at 300m distances from the source of blast. The depth of hole varied from 3m to 5.5m depending upon the bench height with burden of 4.0m and spacing of 5.0 m. The holes were drilled with drills having drill bit dia. of 100/150 mm for overburden as well as coal benches.During the trial period Solar Prime Slurry explosives were used. The holes were connected in series by Nonel system of intiation with 70 ms delay interval hole to hole (25ms+45ms) and 350ms delay for down the hole. To arrest the ground vibrations trenching is carried out prior to blast.

Figure No: 1 Marki Mangli – I Coal Mine Blast Design

Location: West side OB IV[th] Bench



Legends:

i.	______	Free Face
ii.	O	Blast Hole
iii.	→	Delay Interval
iv.	S	Spacing
v.	B	Burden
vi.	R1 to R7	Firing Point / Round
vii.	Connection	Series
viii.	Drilling Pattern	Staggered / Zig- zag
ix.	Delay	Bottom 350 ms
		Surface 25+45 ms = 70 ms (Hole to Hole)

Much care was taken in respect of stemming material and length of top stemming column. For stemming purpose moist sand with clay and drill cuttings at the hole of benches was used. the stemming material was stemmed hard into the shot hole to prevent blown out shots and efficient utilization of explosives energy for rock breakage. Further entire row was covered with scrap conveyor belt to avoid the fly rocks.

Before connection of shot holes all loose stone / coal pieces were removed from the blast site manually. Pre blast survey of nearby villages was conducted. The village namely Pandharkawda is located 500m away from the place of firing of shot hole. During the survey no cracks were observed on the walls of surface village structures. All the houses in the village were constructed of brick masonry work on brick or stone foundations. Not a single building with a concrete frame structure or a concrete foundation were observed in the village. When inhabitants or village people were interacted regarding the blast induced vibrations, no complaint were reported. No misfire or blown out shots were observed during trial period. Detail of each trial blast, blast geometry, explosive charges and its distribution, sequence of delay are shown and summarized data enclosed in annexure from I to III.

VI INSTRUMENTATION

The vibration produced due to blasting were measured by Instantel make DS-077 vibration monitor manufactured by M/s Instantel of Canada it is a microprocessor based unit with geophone and sound level sensor. It can record peak particle velocity in all the three mutually perpendicular directions and gives vector sum of particle velocity and also records frequency , displacement and acceleration.

Instantel make DS – 077 Vibration Monitor Specifications

Serial No B E 18969

Geophone No BG 18099

Vibration measuring stations were located inbetween pit boundary and village at a distance of 300m from blast site.

VII METHODOLOGY:

Blast induced ground vibration was monitored with one seismograph mentioned above. In all blast ground vibrations were monitored at different monitoring stations in the direction of nearby surface structures and village. Effect of fly rocks was minimized by covering blast holes with scrap belt conveyor pieces. Blasting rounds were conducted at different locations mentioned in Annexure-I. Cartridged slurry emulsion explosive was used in the blast round. Bottom hole initiation was used in all the blast using shock tubes and non-electric delay detonators. The stemming material used was approximately 5 to 8 mm size drill cuttings for large diameter to improve the blast performance and to reduce the side effects like ground vibrations, air over pressure and fly rocks.

VIII BLAST DESIGN PARAMETERS:

The drilling and blasting parameters practiced during trial blasts at Marki – Mangli Mine No 1 are given in the following sections

A. Drilling Parameters.

a. Hole Diameter: 100 mm

b. Average Depth of Hole: 5.5m for Overburden & 3.0m for Coal.

c. Average Burden: 4m for OB & Coal

d. Spacing: 5m for Coal & Coal.

e. Angle of Hole: Vertical

f. Hole Drilling Pattern: Staggered / Zigzag

B. Blasting Parameters

a. Type of Explosives: Class II Emulsion 83mm

b. Detonator: Detonator NONEL with 350ms DTH & 70ms (25ms + 45ms) TLD Hole to hole delay

c. Charge per Hole: 11.27 Kg For OB & 5.56 Kg For Coal

d. Maximum Charge per delay: 11.27 Kg For OB & 5.56 Kg For Coal

e. Powder Factor: 9.73 m^3 per kg

f. Stemming:Drill cuttings

Initiation Systems: Bottom hole initiation with shock tube. Care should be taken to avoid damage to NONEL tube while charging.

IX BLAST RESULTS

Blast induced ground vibrations and air over pressure were monitored by a seismograph (MinimateInstantel, Canada) at various monitoring stations at a distance of 300m from the blast site. The vibration produced due to blasting were measured by Instantel make DS-077 vibration monitor manufactured by M/s Instantel of Canada it is a microprocessor based unit with geophone and sound level sensor. It can record peak particle velocity in all the three mutually perpendicular directions and gives vector sum of particle velocity and also records frequency, displacement and acceleration.

The details of the vibrations and fly rocks are tabulated and complied in Annexure—I.

Following observations were recorded during and after the blast:

I. Fragmentation was observed to be good and presumably no secondary blasting required.

II. Blasted rocks were heaped near the face with least scattering.

III. No fly rocks were observed.

IV. No blown out shots were observed.

V. In some round few misfires were observed.

VI. Excavabilityof muck pile was found to be good.

VII. No new cracks in the buildings of nearby village were observed.

VIII. No complaints regarding blast induced vibrations were received.

X REGRESSION ANALYSIS:

Based on the monitoring data of 25 blasts events of Marki – Mangli Mine No 1, a regression analysis has been carried out for square-root scaled distance and graph of the regression line of Marki – Mangli Mine No 1 is given in Annexure-III.

The regression analysis for 95% line equation depicts the following empirical formula

Vmax = 34.21 * (SD)-0.59

Vmax = Peak Particle Velocity (mm / s)

SD = (D / √Q)

D = Distance of Seismograph from blast site (m)

Q = Maximum charge per delay (Kg)

For maximum peak particle velocity of 5, 10 & 15 mm / s distance wise safe charge values at any specified interval may be determined from the weight Vs distance graph as shown in Figure No based on square-root scaling for the above velocity lines. Maximum charge weight per delay in Kgs for peak particle velocity of 5.00, 10.00, and 15.00 mm / s at interval of 50m distance for Marki – Mangli Mine No 1 is determined from the above empirical formula and the same is given in Annexure--II

XI CONCLUSIONS & RECOMMENDATIONS

The peak particle velocity has so far been considered as the best criterion for evaluating blast vibration in terms of potentials in course damage. The extensive studies on the problem have established that the frequency of the waves is also equally important factor to consider the effect of damage

As recommended by D.G.M.S. vide Circular No. DGMS

(Tech)/(S&T) Circular No.7 of 1997, dated 29 August , 1997 , Threshold value of ground vibration depending on the type of structures and the dominant excitation frequency , the peak particle velocity in terms of mm/sec. on the ground adjacent to the structures shall not exceed the values given below in the Table.

Type of structure	Dominant excitation Frequency, Hz		
	<8 Hz	8-25 Hz	>25 Hz
(A) Buildings/structures not belong to the owner			
(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

Results:

i. Results are already been given in Annexure-I. It is observed that minimum peak particle velocity and maximum peak particle velocity are 0.618 mm / s and 2.196 mm / s respectively. Maximum peak particle velocity recorded is well below the threshold limit recommended by DGMS and followed in Indian mining scenario. This is reason no complaints have been made by inhabitants and no cracks in the buildings were observed. Probably the area between village and blast site consists of loose rocks having lower value of site constant K in the predictor equation (attenuating characteristic of the strata)

Recommendations: In order to assess and control hazards related to blasting are as under,

i. Peak particle velocity for known maximum charge per delay and scaled distance can be estimated from the predictor equations.

ii. Maximum charge per delay for corresponding distances should not exceed the values as suggested in Annexure-II.

iii. The predictor equation will be applicable only for Marki – Mangli Mine No 1 depending upon site constant.

iv. A free face should always be maintained and all loose stones and coal pieces from blast site should be cleared off before blasting.

v. To further reduce the vibrations a trench filled with loose rock debris can be introduced in between blast site and villages.

vi. Similarly fly rocks can be arrested if required by putting strong top stemming and covering surface of the blast with wire mesh or discarded conveyor belts loaded with sand bags.

vii. Since strata are not very strong or variation in strength characteristic of the strata was not visually observed, hence deck blasting is not required.

viii. No toe was reported. Therefore no sub-grade drilling required.

ix. Blast may be arranged in such a way that closer blasts are not taken continuously.

x. When mine workings approach towards the village or any permanent structure not belonging to the principal owner in the range of 150m to 100m, use of electronic detonator with logger is recommended.

xi. Blast should be carried out between 12:00 to 3:00 PM when temperature inversions are not likely and background noises should be high.

xii. No blasting should be carried when strong surface winds are blowing towards the important surface structures or village.

xiii. Existing design should be followed and the execution of the blast must be supervised by a competent person.

All records of drilling and blasting should be maintained.

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iv. Shri Narendra Pawde, Blasting Officer, MM-1

v. Shri Manoj Thakur, Blasting Overman, MM-1

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ANNEXURE I

Blast No	Date	Blast Location	Hole Dia (mm)	Maximum Charge per Delay (Kg)	Distance of Monitoring (m)	PPV (mm/s)	No of Holes
1.	15-05-19	Westside OB III Bench	100	11.2	300	1.421	20
2.	15-05-19	Westside OB III Bench	100	11.2	300	1.907	20
3.	15-05-19	Westside OB III Bench	100	11.2	300	1.154	20
4.	15-05-19	Westside OB III Bench	100	11.2	300	**2.196**	20
5	15-05-19	Westside OB III Bench	100	11.2	300	1.734	21
6	15-05-19	Westside OB III Bench	100	11.2	300	1.791	21
7	19-05-19	SW side Coal Bench R1	100	9.5	300	NA	36
8	19-05-19	SW side Coal Bench R2	100	9.5	300	1.260	36
9	19-05-19	West OB IV Bench	100	9.5	300	1.468	25
10	19-05-19	West OB IV Bench	100	9.5	300	2.103	25
11	19-05-19	West OB IV Bench	100	9.5	300	0.900	25
12	19-05-19	West OB IV Bench	100	9.5	300	0.900	25
13	23-05-19	West OB IV Bench	100	11.11	300	1.999	16
14	23-05-19	West OB IV Bench	100	11.11	300	1.306	16
15	23-05-19	West OB IV Bench	100	11.11	300	1.014	16
16	23-05-19	West OB IV Bench	100	11.11	300	1.618	15
17	23-05-19	West OB IV Bench	100	11.11	300	0.942	15
18	23-05-19	West OB IV Bench	100	11.11	300	**0.618**	15
19	23-05-19	West OB IV Bench	100	11.11	300	1.114	15
20	27-05-19	Westside Coal Bench	100	14.75	300	1.260	16
21	27-05-19	Westside Coal Bench	100	14.75	300	1.364	16
22	27-05-19	Westside Coal Bench	100	14.75	300	NA	16
23	27-05-19	Westside Coal Bench	100	14.75	300	1.306	16
24	27-05-19	West OB IV Bench	100	14.75	300	1.149	20
25	27-05-19	West OB IV Bench	100	14.75	300	1.398	20

ANNEXURE II

Distance(m)	Safe Explosive Charge (kg) for 5mm/s	Safe Explosive Charge (Kg) for 10mm/s	Safe Explosive Charge (Kg) for 15mm/s
50	3.688170233	38.65908953	152.816815
100	14.75268093	154.6363581	611.2672599
150	33.1935321	347.9318057	1375.351335
200	59.01072373	618.5454324	2445.06904
250	92.20425582	966.4772382	3820.420374
300	132.7741284	1391.727223	5501.405339
350	180.7203414	1894.295387	7488.023934
400	236.0428949	2474.18173	9780.276158
450	298.7417889	3131.386252	12378.16201
500	368.8170233	3865.908953	15281.6815

ANNEXURE III

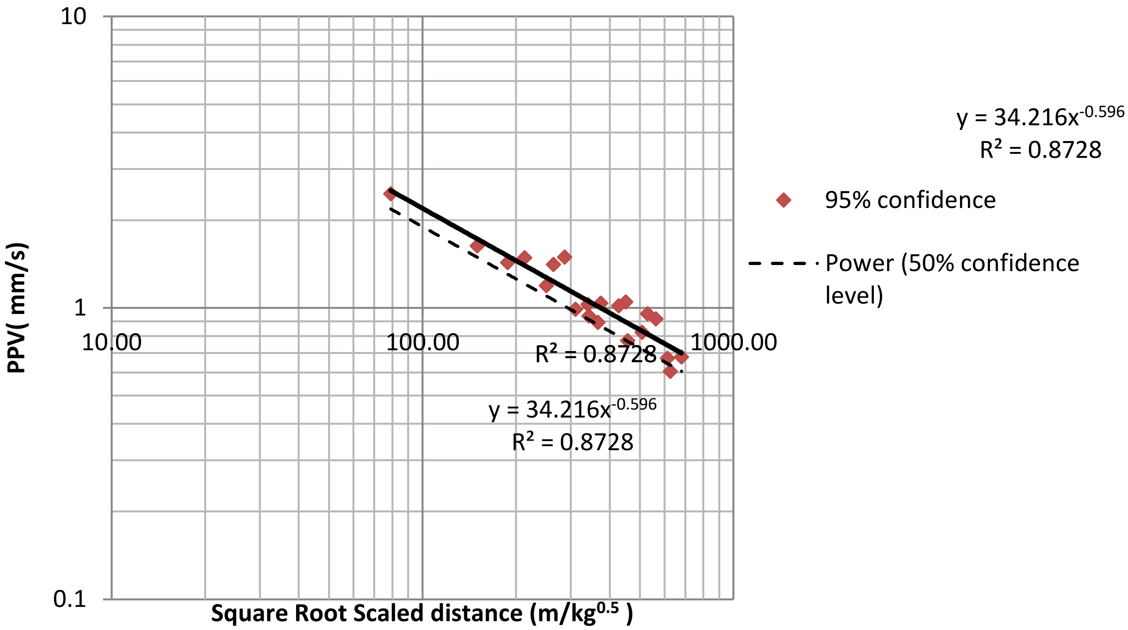

Fig. PPV vs. Scaled distance at 50% and 95% confidence levels