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IMPACT ON MAHAMAYA SUGAR MILL DUE TO GROUND VIBRATION AND AIR OVERPRESSURE IN JAGANNATHPUR OPENCAST COAL MINE

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ABSTRACT

The Research paper aims to evaluate the ground vibrations and Air overpressure/ noise (AOP), caused by blasting in Jagannathpur Open-cast coal mine The blasting technique is mainly used for breaking the rock mass. It is also required to control blast-induced ground vibrations for the safety of nearby structures and habitats. The present study aims to examine the ground vibrations and Airoverpressure/noise produced by blasting, which are of serious concern to mine operators as well as the nearby inhabitants. Fifteen field-scale trial blasts were conducted and recorded to measure ground vibrations and Air overpressure produced by blasting in a Jagannathpur open cast coal mines of Bhatgaon Area. The regression analysis have performed of data obtained during experiment to predict the peak particle velocity (PPV) and Air overpressure (AOP) with distance between the blasting site and measuring station, charge per delay and scaled distance as the input parameters. The correlation coefficient (R^2) is found 0.7955, which implies a strong relation between input and output parameters. The range of dominate frequency recorded fall within 3-35Hz. Standard by Director General of Mines Safety (DGMS) Circular have used in study to analyse the damage potential to nearby structures. It has found that the PPV values are well within the threshold limit

Keywords: Blasting; Ground Vibration; Air overpressure PPV; Regression Analysis.

1. INTRODUCTION

On detonations of explosive charges in blastholes , apart from the effective utilization of the explosive energy in the fragmentation and displacement considerable part of the energy is wasted in the form of ground vibrations, air blast noise , fly rock , dust and noxious gases. This waste energy exposure creates lot of a problems the local inhabitants in the nearby area. Although blasting vibrations and air overpressure/noise are short term transient phenomena, the residents in the vicinity of operations feel that if vibrations and air overpressure/ noise then their dwelling may get damaged, uncontrolled blast lead to complaints and damage to buildings and structures in the vicinity of blasting operations[1].

As per the objectives mining operations between 500m distance from the Mahamaya sugar mill were to be studied in detail to assess its impact on the sugar mill. During preliminary site visit, that there were Jagannathpur Opencast coal mines which resort to use explosives for rock breakage. As a part of the study, to conduct the blasting experiments in order to evaluate the peak particle velocity (PPV) of blast-induced vibration and air overpressure (AOP)/noise. Apart from the preliminary site visit, 20 rounds of experimental blasting investigations were carried out by blasting experiments at blasting sites.

Blasting experiments using different blast design parameters were successfully experimented in mines.[2] This blasting study conducted in the mines front of Mahamaya sugar mill. Regulations on ground vibrations focus primarily on peak particle velocity (PPV) and Airoverpressure/ noise which has been studied by various researchers The United States Bureau of Mines (USBM) established the first PPV predictor equation modified predictors from other researchers and institutions. However the PPV predictor equation of USBM is still the most popular one.[4].

The key objectives of this study are as follow-

1. Blasting experiments to evaluate the attenuation characteristics of ground vibration and air- over pressure /noise in Jagannathpur Opencast coal mines.
2. Data analysis to evolve vibration and air overpressure attenuation characteristics.
3. Analysis of damage potential of vibrations and air overpressure in the various National and International Standards.

Site description –

The trial blasts were carried out in Jagannathpur open-cast coal mine in Bhatgaon area SECL. Block III & IV area is situated about 30 km of ambikapur, and its

Latitudes -23⁰21'22" & 23⁰23'05" N

Longitudes - 83⁰11'44" & 83⁰14'05" N

After initial site investigation, blasting experiments in the mines were started with usual blasting practices in the Jagannathpur Opencast coal mines. Initially experiments were conducted to generate database to evaluate attenuation characteristics of vibration in mines.

In all the experiments, it was tried to conduct blasting operations using the blast design parameter as per mine. In Jagannathpur Opencast coal mines, experiments were conducted using different combination of blast design parameters.

2. BACKGROUND

Prediction of Ground Vibration levels

In blasting, it is extremely difficult to take into account of all the above parameters in a single equation in predetermining the level of vibration which would be experienced at a given distance so that quantity of explosive would not cause damage to a given structure. As a result, empirical approaches are widely used for ground vibration prediction. The United States Bureau of Mines concluded that any linear dimension should scale with the square root of the charge weight. The corresponding relationship assumes the form-[1]

\ $V = K (D/W^{1/2})^{-\beta}$ Eq. …..…(1)

Where

V = Peak particle velocity in mm/s.

D = Distance of measuring point to Blast site in m.

W= Maximum explosive Charge weight per delay in kg.

K= site constant.

β= attenuation rate of ground vibration.

Prediction of air overpressure/ noise levels

For surface blast , the combined effects of charge weight and distance from the blast source observed Air overpressure/noise (AOP),The attenuation characteristic of Air overpressure/ noise corresponding relationship assumes the forms-[2]

$AOP = K(D/ W^{0.33})^{-\beta}$ Eq……(2)

Regulatory limits on blast-induced ground vibrations, Airoverpressure/ noise and frequencies

It has been established that the particle velocity of ground motion near structures is an effective criterion for the assessment of damage. According to USBM RI 8507, PPV provides the best description for ground vibrations. Over the last more than two decades, PPV and frequency have been together used for assessment of damage due to blasting. Accordingly, the USBM and DIN regulatory standards were developed (Table 2).

then PPV may be considered safe (USBM approach). [7].

According to the Indian standard as specified by the DGMS,

Table 1 shows the regulatory limits in terms of PPV and frequency of ground vibrations. Therefore, it is implicit that for a thorough study of blasting vibrations, measurement of frequency as well as PPV is essential.

Standards on Safe Limit of Air overpressure

Directorate General of Mine Safety (DGMS) India. Circular suggests 90 dB-A as the threshold for continuous occupational exposure of noise up to 8 hours duration. However, there is no guideline from DGMS or Indian Bureau of Mines (IBM) regarding permissible safe level of air overpressure (AOP) produced due to blasting. For large scale surface mining operations, air overpressure can be characterized by lower frequency.

[16] For large scale operation, a common overpressure limit of 134 dB-L is recommended by the United States Bureau of Mines (USBM) in RI 8507 (Siskind et al, 1980). USBM recommended values are presented in **Table 3.** As Table 3 is internationally accepted, the same has been adopted for evaluating the AOP threshold values in the present study.[21]

Standards of DGMS:

As per the present Indian standards, as mentioned in Directorate General of Mines Safety (DGMS) (Tech) (S&T) Circular No. 7 dated 29th August, 1997, depending on the type of structures and dominant excitation, the peak particle velocity (PPV) on the ground adjacent to the structure shall not exceed the values as given below in the Table 1.[15]

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Table-1: Regulatory limits of ground vibration according to Director General of Mine Safety (DGMS), India.

Type of Structures	Dominant Excitation Frequency, Hz		
	< 8 Hz	8 - 25 Hz	> 25 Hz
(A) Buildings/structures not belong to the owner			
Domestic houses /structures (Kuchha brick and cement)	5	10	15
Industrial buildings (RCC and framed structures)	10	20	25
Objects of historical importance and sensitive Structures	2	5	10
(B) Building belonging to owner with limited span of life			
Domestic houses /structures (Kuchha brick and cement)	10	15	25
Industrial buildings (RCC and framed structures)	15	25	50

Standards USBM & DIN

The various international standards United States Bureau of Mines (USBM) and German Standards (DIN) set regulatory limits of ground vibrations

Table 2. Regulatory limits of ground vibration USBM-RI8507, PPV (mm/s) and DIN criteria DIN-4150. PPV (mm/s).[16]

USBM-RI8507			DIN-4150			
PPV (mm/s)			PPV (mm/s)			
Structure	<40Hz	≥40 Hz	Structure	10Hz	10-50Hz	50-100Hz
Modern homes – dry Wall interiors	18.75	50	Industrial buildings	20	20-40	40-50
Older Homes	12.75	50	Residential building	5	5-15	15-20
			More sensitive buildings	3	3-8	8-10

Table 3: Typical Air overpressure criterion (Siskind et al, 1980)

Air Overpressure Limits dB(L)	Damage potential
180	Some structural Damage
171	General window breakages
140	Occasional Window breakage
134	US Bureau of mines recommendations for large scale surface mine blasting.

3. RESEARCH METHODOLOGY

The research methodology adopted here includes the conduct of real-time trial blasting and measurement of PPV and frequency. In the present study, a total of 15 nos. trial-blasting In Jagannathpur Opencast coal mines, altogether 15 rounds of blasting experiments were conducted and blast induced ground vibration recorded using two (2) numbers of tri-axial seismographs. the blasting locations included OB (sandstone), OB (shale), and Coal. In this exercise, near-field vibration monitoring was done. Sensors were placed within the mines and near domestic structures toward the Mahamaya sugar mill direction in all the cases.

The seismic energy dissipated in elastic waves is revealed by ground vibration caused by blasting. This study aids in understanding the impact on the near structures and habitats. As a result, the ground vibration monitoring points were set up at the point of interest. The tri-axial geophones (ISEE compliance sensor) were installed, and measured peak particle velocity (PPV), Air overpressure/ noise (AOP) and frequency, ranges were 0.7411 to 15.56 mm/s, 82.5 to 135.0 Db(L) and 3.2 to 34.5 Hz, respectively.

All the sensors were placed near structures and multiple distances (100 to 430 m) and directions. The square root scaled distance ranged between 10.95 to 64.12 m/kg^0.5. and cube root scaled distance ranged 0.33 to 4.12 m/kg^0.33 between The geophones were placed in three directions (behind bench face, the opposite and same direction of detonation sequence) and along & across the rock bed strike to analyze ground vibration attenuation behavior .Blast data details in Table 4.

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Table.4 Data used for Ground vibration and Air overpressure (AOP).

Sr. No.	Independent Variable		Dependent Variable	Calculated Scaled Distances	Calculated Scaled Distances	Data Measurement	Dominant Frequency
	D	MCD	PPV	SD	SD	AOP	DF
Units →	m	kg	mm/s	m/kg^0.5	m/kg^0.33	dB(L)	Hz
1	330	90.2	3.074	34.75	1.22	111.2	23.00
2	360	80.2	2.646	40.20	1.50	109.5	6.00
3	170	110.2	10.04	16.19	0.51	135.0	12.75
4	210	60.1	8.251	27.09	0.50	133.6	9.25
5	350	90.2	2.872	36.85	1.16	114.0	34.50
6	380	80.2	2.198	42.43	1.29	95.5	22.50
7	180	110.2	10.09	17.15	1.58	114.2	13.75
8	140	120.2	15.56	12.77	0.54	104.5	9.25
9	190	90.2	7.542	20.01	0.33	102.8	15.50
10	200	150.3	8.629	16.31	0.39	97.5	7.25
11	160	90.2	10.02	16.85	0.70	111.5	13.00
12	220	150.3	8.569	17.94	0.44	94.0	10.75
13	290	90.2	4.26	30.53	0.59	97.0	5.25
14	210	18.3	2.426	49.09	0.49	101.2	21.25
15	190	16.3	2.409	47.06	1.07	108.2	17.25
16	140	30.2	5.385	25.48	0.36	114.0	5.30
17	410	110	2.652	39.09	3.83	90.2	7.30
18	390	37	0.952	64.12	3.89	93.5	4.60
19	290	37	5.465	47.68	1.55	104.2	6.20
20	320	55	4.533	43.15	4.12	91.0	18.00
21	350	36	0.7411	58.33	1.24	89.5	12.50
22	310	130	2.547	27.19	3.51	84.5	5.30
23	420	100	2.662	42.00	0.69	82.5	3.20
24	350	30	1.536	63.90	2.61	98.4	25.20
25	320	40	2.472	50.60	1.94	112	15.50
26	290	37.5	5.042	47.36	3.24	111.8	6.89
27	310	90	4.7	32.68	0.79	104.9	12.2
28	330	120	3.634	30.12	3.67	114	16.30

D= Distance, MCD= Maximum Safe Charge per delay. PPV= Peak Particle Velocity, SD= Scaled Distance. AOP=Air overpressure. DF= Dominant Frequency.

Figure 1. Blast vibration monitoring locations .Entrance gate of Mahamaya sugar mill.

4. RESULTS AND DISCUSSIONS

Determination of Predictor equation using the USMB method.

The measured ground vibration dataset, including Peak particle velocity (PPV), and Scaled distance (SD) for the blasts were statistically analysed to determine the site constants (K & β) of the USBM predictor equation for the mine. The predictor equation develop using the statistical analysis in given equation (3).

$PPV= 458.92x\ (SD)^{-1.361}$ $(R^2=0.7955)$ Eq…………..(3)

The site constants K and β were determine by regression analysis and their value s were 458.92 and -1.361 respectively .

The velue of 0.7955 (R^2) indicates that 79.55%nof PPV variability is explained by regression analysis. Figure 4 shows the the relationship between PPV and SD on a log- log scale.

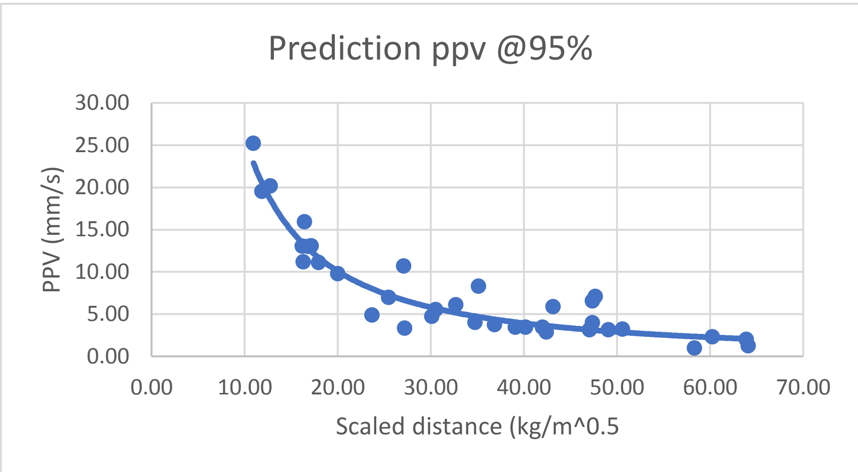


Figure 2. PPV vs SD for prediction ppv @ 95%

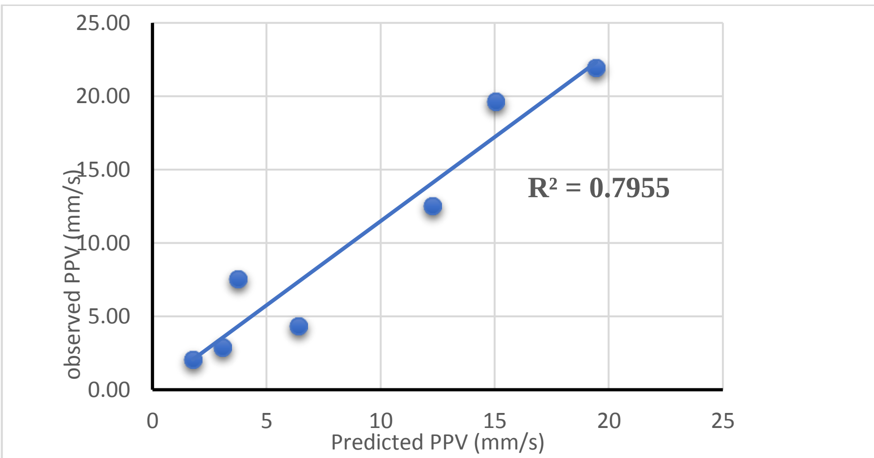


Figure 3. Comparison between observed and predicted PPV using MCD (USBM Equation

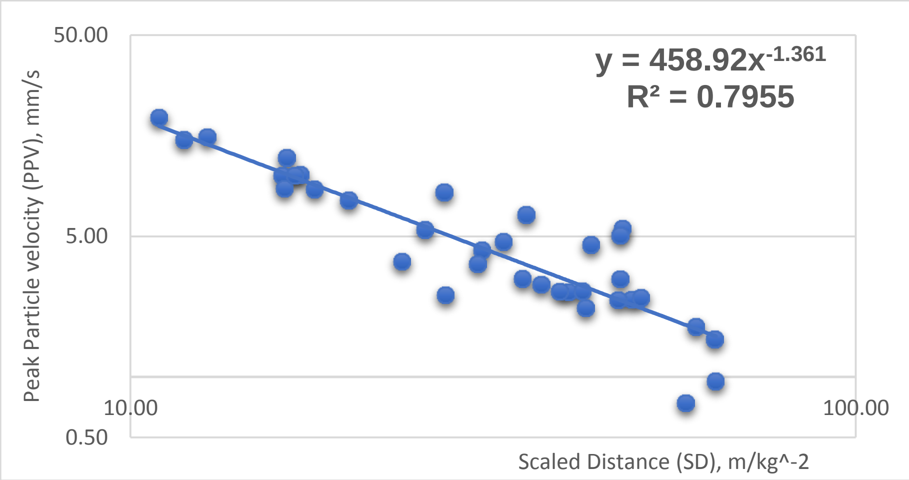


Figure 4- Empirical relationship between PPV and scaled distance for charge per delay

Prediction of Air ovrpressure/ noise-

Similar to vibration analysis, observed Air overpressure (AOP) values were analyzed using cube root scaled distance .(Equation 4). The attenuation characteristics of AOP in Jagannathpur open cast coal mine.

$$AOP = 162.82\left(\frac{D}{\sqrt[3]{Q_{max}}}\right)^{-0.066} \quad \text{Eq. .... (4).}$$

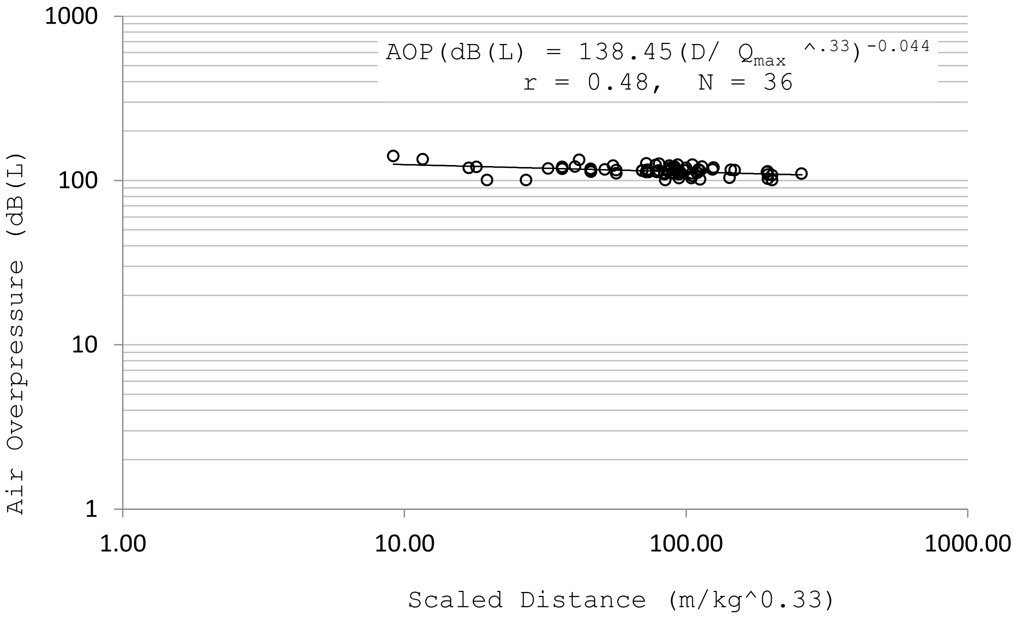
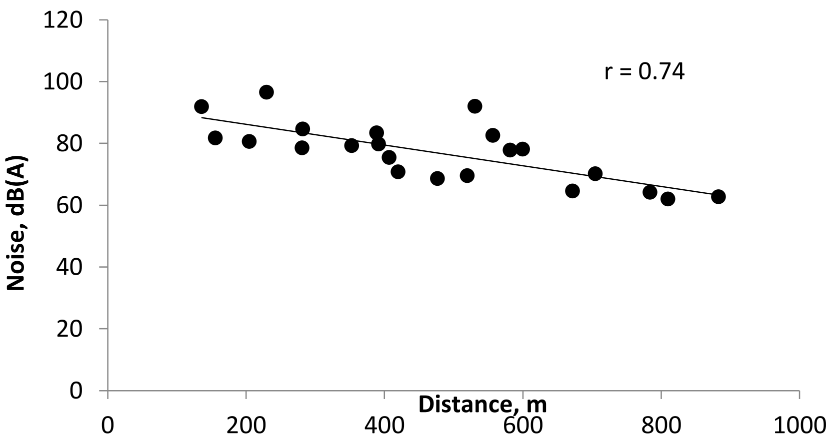


Figure 5: Attenuation characteristics of AOP in Jagannathpur open cast mine (Hole diameter= 160 mm)



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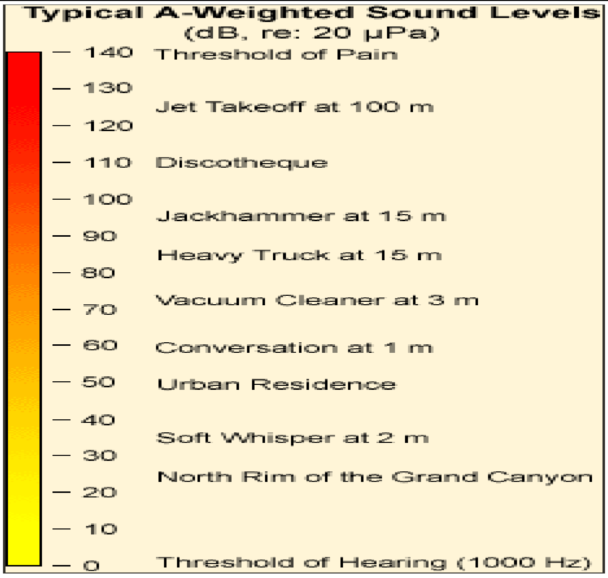

Figure 6 (A) Decay pattern of noise induced by blasting in mines0 (B) ISO Standards of Noise.

It is clear from the above Figure 6 that the blast induced noise becomes less than 80 dB at a distance of 500 m from the blasting locations.

5. ANALYSIS OF FREQUENCY

The observed field data of dominant frequency are presented in table 1. Further to analyze these frequency data, the four bins created of 1 to 4 Hz , 4 to 15 Hz, 15 to 40 Hz and > 40 Hz. The pie chart for the frequency of the studied blasts data is shown in **Figure 7**

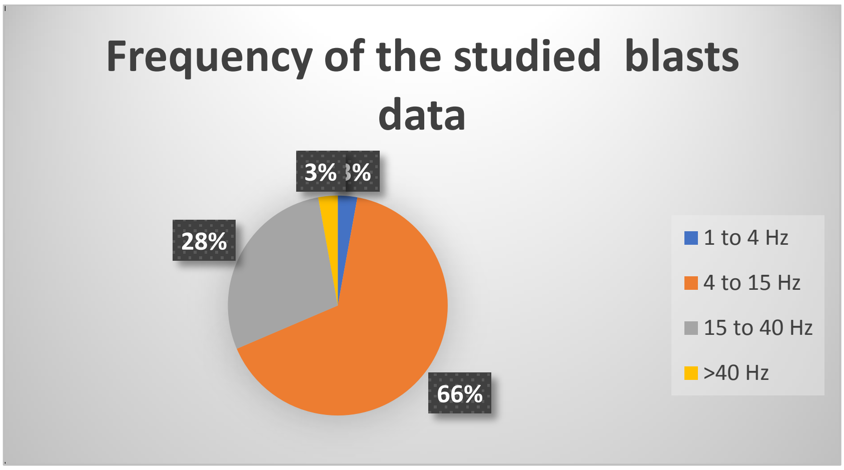

Figure 7. Pie chart for the frequency of the studied blasts data

6. CONCLUSIONS

The Boundary of Jagannathpur Open-cast coal mine, Bhatgaon area is in proximity of industrial and housing structures. Therefore, prediction of blast-induced ground vibration. The closest structure to the mine boundary is Mahamaya Sugar Mill, 500 m away. As per the DGMS Circular, the recommended safe limit for such structures is 5mm/s corresponding to dominant frequency <8Hz.

An experimental field study was carried out at Jagannathpur Open-cast coal mine to evaluate the ground vibration prediction model and Air overpressure/noise . During this study, 15 nos. blast rounds were conducted with varying blast design parameters. Simultaneously, blast-induced ground vibration was monitored at different locations. The monitoring location includes Mahamaya sugar mill. Altogether 28 vibrations data were recorded during this study. The observed vibration data were analysed as per USBM prediction equation model for further prediction of Ground vibration, PPV (mm/s). The determination coefficient (R^2) of the developed model is 0.7955, which implies a strong relation between input and output parameters. The developed site-specific prediction model at 95 % confidence interval is given as $PPV = 458.92(D/\sqrt{Q_{max}})^{-1.361}$ and Air overpressure/ noise as $(AOP)= 162.82(D/Q0^{.33})^{-0.066}$. Based on the established damage criteria of USBM,DIN 4150 and DGMS, The measured value of ground vibration (PPV), and frequency at the field were bellow the threshold limits. So as a result show The Mahamaya sugar mill no damage to the irrespective of the source of ground vibration and air overpressure/ noise (AOP).

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