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Importance of blast-design in reduction of blast-induced ground vibrations

The dissipated energy generated during blasting creates environmental problems in the form of ground vibration, air overpressure and flyrock. With increasing mining and construction activities in areas close to human settlements, ground vibration has become a critical environmental issue as it can cause human annoyance and structural damage. The magnitude of ground movement was measured in term of peak particle velocity (PPV) with the aid of seismograph. Site constant K, and site geological factor m were determined for both quarries by plotting the graph of the maximum PPV against scaled distance. The data collected for the blasting activities in each of the quarry sites have shown that the peak particle velocities (PPV) recorded varied directly with the charge weight per delay but inversely with scaled distance (SD). A comparative analysis between the results obtained for constant charge per delay and monitoring distance were carried out.

Keywords: *Blast-induced vibrations, scaled distance, peak particle velocity, seismograph*

1.0 Introduction

Blasting is the principal method of rock breakage in mining and construction projects throughout the world. This may probably be due to its distinct advantages like economy, efficiency, convenience and ability to break the hardest of rocks. However, only a portion of the total energy of the explosives used in blasting is consumed in breaking rocks while the rest is dissipated. The dissipated energy creates environmental problems in the form of ground vibration, air overpressure and flyrock. With increasing mining and construction activities in areas close to human settlements, ground vibration has become a critical environmental issue as it can cause human annoyance and structural damage [1].

During blasting, explosive charges produce a great amount of energy, some of which is transmitted in the form of stress waves beyond the area of the fragmented rock. The propagating stress waves travel in the rock and soil and produce ground vibrations that have the potential to cause damage to structures in the vicinity of the blast. Much of the damage that has occurred near blasting sites in the past has been to residential structures that have experienced cracks in walls and ceilings. However, there is the potential for more serious structural damage if the vibration levels are too high [2].

In the past forty years, many investigations have looked at the damage that ground vibrations from blasting may cause. The United States Bureau of Mines has done many of the studies, primarily concentrating on the damage to residential structures. On the basis of damage studies to residential type structures, the U.S. Bureau of Mines in 1962 recommended that the ground motion should not exceed a 50.0 mm/sec peak particle velocity at a point of concern [3].

One of the most controversial issues facing the mining, quarrying and construction industries is ground vibration resulting from blasting. There are quite a number of court cases against these companies and citizens close to the proximities of their operations react negatively often to nuisance caused by blast induced vibration [4]. Recently there has been an increase in infrastructure and mineral resources developments. As a result quarrying activities has also increased to supply the needed construction materials. Consequently, there is an increase in the effects of ground vibration on the environment [5].

2.0 Method and materials

The materials used for the execution of this research included a seismograph for measuring blast-induced vibration, explosives (ANFO – ammonium nitrate and fuel oil, Powergel, SME), blasting accessories such as detonating cord, safety fuse and cap for blasting and a computer programme for analysing a regression model developed by Pal and Brahama.

Using the blast seismograph, ground vibration components induced by blasting in two quarry sites were monitored to estimate site-specific attenuation factors for each of the quarries. The charge quantity per delay and the distance between the shot points in the quarries and the monitored stations were recorded carefully. The blasting models applied in these quarries were bench blasting. The

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blasting patterns and drilling patterns were observed and no changes were made in these patterns and the vibrations were measured on the ground surface with the aid of a seismograph.

In blasting operations at these sites, ANFO (blasting agent), gelatin dynamite (priming), and nonelectric detonators (firing) were used as explosives. In the prediction of ground vibration, although a lot of empirical relations have been established and used by different researchers in the past, the most reliable relations are those comprising the scaled distance and the particle velocity. The regression model by Pal and Brahama [6], developed from USBM predictor equation was used in this research. The scaled distance is a concept that utilizes the amount of explosive creating energy in seismic waves and the effect of distance. The scaled distance is derived by a combination of distance between blasting source and monitored points, and maximum charge per delay. The equation used for the scaled distance is given below:

Fig.1 PPV against scaled distance of Suras block

Fig.2 PPV against scaled distance of Dhulkhera block

$$SD = \frac{R}{W}$$

where, SD = scaled distance; R = distance between the blast site and the monitored station (m); and W = the maximum charge per delay (kg). The USBM predictor equation was used for the estimation of the peak particle velocity (PPV):

$$PPV = K(SD)^m$$

where, PPV = peak particle velocity; K = rock energy transfer coefficient; m = specific geological constant.

Pal and Brahma did an analysis of blast vibration data for a suitable mathematical model to predict the future course of action for conducting controlled blasting operation in a mine keeping in view the variation of dependent variables and its effect on the stability of structures that is based on USBM predictor equation. The fundamental predictor equation of ground vibration is represented in the following form:

$$V_m = k\left(\frac{D}{\sqrt{Q}}\right)^m$$

where, V_m = peak particle velocity in mm/sec., Q = the maximum charge/delay in kg. D = distance of the monitoring point from the blast site in meters, k, m = constants dependent upon the rock types, type of explosives and blast design parameters. $D/\sqrt{Q}$ = square root scaled distance or simple scaled distance.

3.0 Results

Tables 1 and 2 show the blast-induced ground vibration monitoring at Suras block and Dhulkhera block of Jindal Saw Ltd iron ore mines respectively. Figs.1 and 2 show the chart of PPV against scaled distance respectively.

4.0 Discussion

The vibration intensities were monitored in terms of the peak particle velocity in all the monitoring stations. The magnitude of vibrations recorded varied from a range of 2.548 to 8.702 mm/s for the Suras block and 2.192 to 7.067 mm/s for the Dhulkhera block within a monitoring distance of 130 to 200 m from the blast site. These were dependent on the amount of explosive detonated per delay and the distance from the blast site to the monitoring stations. The data collected for the eight blasting activities in each of the quarry sites have shown that the peak particle velocities (PPV) recorded varied directly with the charge weight per delay (Q) but varied inversely with scaled distance (SD) and shot to monitored distance (D) as shown in Figs.1 and 2.

TABLE 1: BLAST INDUCED GROUND VIBRATION MONITORING AT SURAS BLOCK

Blast no.	Blast parameters	Max charge per delay (kg)	Distance (m)	Vibration monitoring				Air over pressure (dB)	Fly rock (m)
				Tran peak (mm/s)	Vert peak (mm/s)	Long peak (mm/s)	PVS (mm/s)		
1.	Dia = 115 mm Depth = 8 m B and S = 2.5 and 3 m Stemming = 4.5 m Holes = 66	37.97	150	6.985	3.080	5.509	7.224	101.0	100
2.	Dia = 115 mm Depth = 10 m B and S = 3 and 3.5 m Stemming = 5 m Holes = 39	46.76	170	6.255	3.492	7.017	8.702	100.0	50
3.	Dia = 115 mm Depth = 8 m B and S = 2.5 and 3 m Stemming = 4 m Holes = 28	42.95	150	1.603	0.571	7.255	7.371	< 50	80
4.	Dia = 115 mm Depth = 6 m B and S = 3 and 3 m Stemming = 3.5 m Holes = 84	26.05	160	2.651	4.445	4.207	5.815	95.92	50
5.	Dia = 115 mm Depth = 8 m B and S = 2.5 and 3 m Stemming= 3.5 m Holes= 23	43.57	150	4.588	1.572	2.461	5.279	< 50	80
6.	Dia = 115 mm Depth = 8 m B and S = 2 and 2.5 m Stemming = 5 m Holes = 88	34.19	160	1.270	4.540	0.778	4.618	< 50	100
7.	Dia = 115 mm Depth = 9 m B and S = 2.5 and 3 m Stemming = 5 m Holes = 72	41.76	130	4.048	2.762	3.000	4.414	93.98	100
8.	Dia = 115 mm Depth = 8 m B and S = 3 and 3.5 m Stemming = 4.5 m Holes = 64	39.16	200	2.222	0.952	2.270	2.548	102.8	50

The safe charge per delay for both the blasting quarries at 500m distance is 247 kg and 135 kg respectively for the safe blasting without any damage to the structure.

5.0 Conclusion

A well planned quarry design is necessary to reduce the effects of blast induced vibrations. From the above we can see how blast design can reduce the negative effects of blast vibrations if we have the knowledge of site specific constant factors can be obtained using regression analysis. The computation revealed that the maximum of 247 kg and 135 kg charge weight per delay for Suras and Dhulkhera block respectively can be fired in a blast with respect to the safety of the structures. The aim is to prevent the excessive flying of rocks and draw-down of underground water in the proximity or is located outside the radius of 500 m from the centre of the blast site.

Generally, it can be concluded that blasting operation at Jindal Saw Ltd. iron ore mine is within the prescribed standards of DGMS and the generally it is believed that mining operation cannot be carried out without accompanying ground vibration, flyrock, air overpressure, dust and fumes.

Recommendation

It is highly recommended that in preparation for blasting, a good blast design must be done with respect to the site specific constants that act as the level of natural restriction

TABLE 2: BLAST INDUCED GROUND VIBRATION MONITORING AT DHULKHERA BLOCK

Blast no.	Blast parameters	Max charge per delay (kg)	Distance (m)	Vibration monitoring				Air over pressure (dB)	Fly rock (m)
				Tran peak (mm/s)	Vert peak (mm/s)	Long peak (mm/s)	PVS (mm/s)		
1.	Dia = 115 mm Depth = 10 m B and S = 3 and 3.5 m Stemming = 4.5 m Holes = 27	55.65	160	4.096	2.270	6.652	7.067	101.9	50
2.	Dia = 115 mm Depth = 8 m B and S = 3 and 3.5 m Stemming = 4.5 m Holes = 37	35.23	150	4.635	5.397	6.255	7.002	97.50	70
3.	Dia = 115 mm Depth = 9 m B and S = 2.5 and 3 m Stemming = 5 m Holes = 60	50.10	200	2.905	3.572	5.270	5.923	98.84	100
4.	Dia = 115 mm Depth = 6-8 m B and S = 2.5 and 3 m Stemming = 4-5 m Holes = 185	80	200	1.619	0.794	1.365	1.913	118.5	38
5.	Dia = 115 mm Depth = 8 m B and S = 3 and 3.5 m Stemming= 4 m Holes= 43	49.41	150	3.619	2.318	3.096	4.417	93.98	80
6.	Dia = 115 mm Depth = 9 m B and S = 3 and 3.5 m Stemming = 4.5 m Holes = 191	42.08	170	3.238	2.254	2.143	3.579	95.92	40
7.	Dia = 115 mm Depth = 10 m B and S = 3 and 3.5 m S = 3.5 m Stemming = 5 m Holes = 39	51.38	150	1.206	0.825	2.127	2.192	95.92	50
8.	Dia = 115 mm Depth = 8-10 m B and S = 2.5 and 3 m Stemming = 5-6 m Holes = 100	83.40	150	4.667	3.429	7.699	7.717	101.0	40

of rock in-situ. With this, damage done to structures in close proximity of quarries, prevention of excessive flying rocks and draw-down of underground water by induced vibrations can be avoided if blast designs are well done.

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