ANALYSIS OF BLAST VIBRATION IMPACT AT PARAMBAHAN COAL MINE, WEST SUMATERA USING SQUARE ROOT SCALED DISTANCE METHOD

AGUS NUGROHO, WIROTO WIMBO PRIHONO AND TATANG WAHYUDI
R & D Centre for Mineral and Coal Technology
Jalan Jenderal Sudirman 623 Bandung 40211
Ph. (022) 6030483-5, Fax. (022) 6003373, e-mail: agusn@tekmira.esdm.go.id

ABSTRACT

Blasting which was conducted at Parambahan produced a series of blast vibrations that might be harmful to human safety and surroundings. Therefore, the vibrations need to be evaluated whether it was over permitted the threshold for human safety or not. One of analysis methods for this purpose is square root scaled distance. The principle of the proposed method is to assess blast vibration impact on the environment for the cases when the blasting for opening mine had been performed previously. Analysis results shows that blast vibrations at Parambahan is below the allowed threshold of blast vibration for environment. Using measurement distance from blast source of 20 to 2,000 m, the lowest measured vibration is 0.18 mm/s and the highest one is 21.0 mm/s. Those mean that blast-generated vibrations at Parambahan are still safe for human and surrounding environment.

Key words : blasting, vibration, scaled distance.

1. INTRODUCTION

Blasting process is an energy balance as shown on the diagram below (Figure 1). Essentially, the chemical energy of the explosives must be dissipated as fragmentation, rock movement, vibration and air overpressure. It can be seen that a blast with poor fragmentation is likely to have a higher than expected environmental impact. The impact of blasting to the environment depends on blast design, geology and weather. The former relates to the operators control and the later is not under operators control but can be taken into account. Weather - the last one - is not under operators control and cannot easily be taken into account. Therefore effective blast design is the key to both efficient blasting and environmental impact control.

Human response to blast induced ground vibration and air-overpressure/noise is a major concern of current mining activity. This is because the fact that mines are fast transgressing the habitats and people are getting educated. Consequently the response of humans is changing and expectedly will increase in days to come with no viable and economic alternative to blasting-an essential component of mining. The response of humans can be purely physiological or psychological in nature or combination of both depending upon the situation and conditions of mining. However, it is not possible to blast without causing vibration and air overpressure. Most problems arising from blasting are related to the response of people to the operation. These complaints are often connected with the fear of structural damage despite the fact that vibration levels are usually way below those likely to cause even cosmetic damage.

PT Allied Indo Coal retains a coal concession at Parambahan (Figure 2). Such a concession is characterized by two normal faults, namely Bulurotan and Tamasu faults and includes soil, claystone, siltstone, sandstone, coaly clay and coal (seam B and C) lithologies. The company employed blasting method to open its coal concession area. PT Allied Indo Coal's blast site is located around 2 km from settlement or known as Bukit Bual village. Complaints had been addressed by the residents to the company regarding blast-

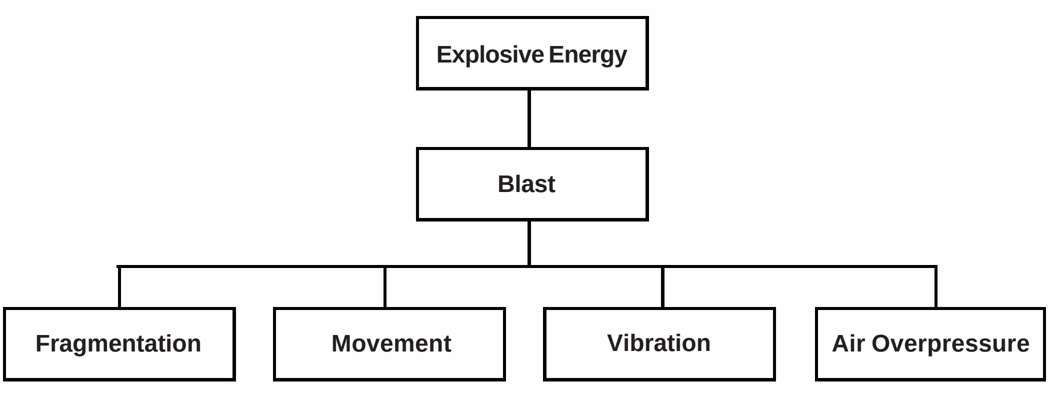

Figure 1. A diagram showing components of blast process (www.iie-nline.com/pdfs/IIE)

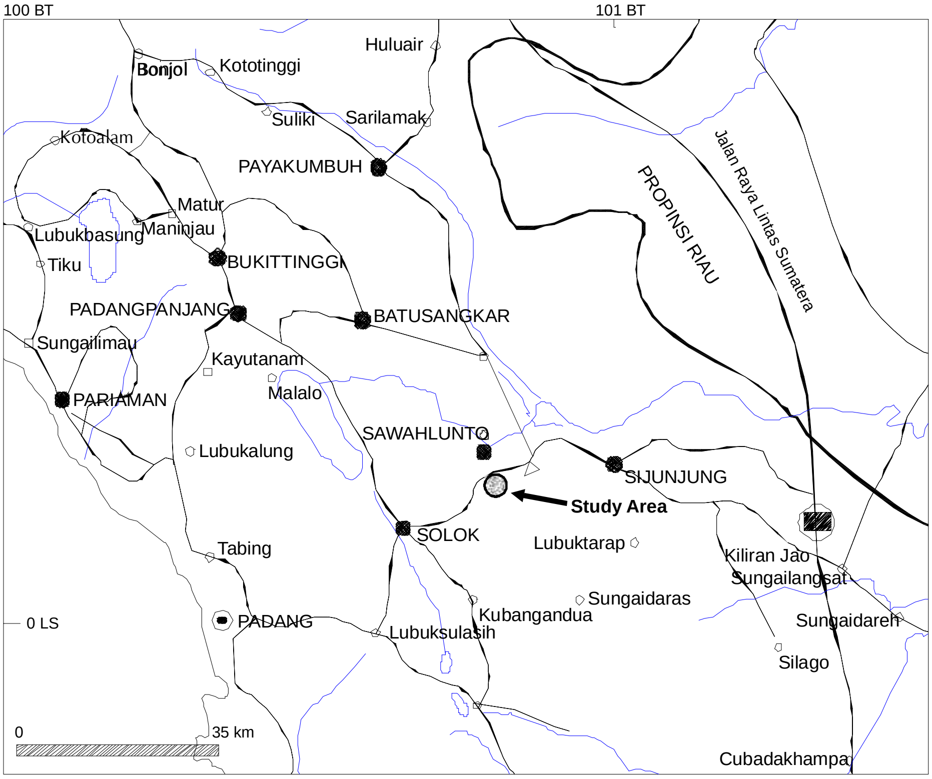

Figure 2. Study area at which blasting activity was conducted

generated vibrations. They said that the generated vibrations were felt through their area. The fact that blast-generated vibrations may cause unexpected impact needs to be evaluated.Referring to such complaints, the company asked a team from Research and Development Center for Mineral and Coal Technology (RDCMCT) to conduct a research on such a phenomenon. This paper discusses vibration analysis at Parambahan area in terms of evaluating blasting effect to human and surroundings.

2. METHOD OF STUDY

The occurring vibrations were monitored and measured by blastMate III. Using a blastware program (software), data from blastMate II measurement results were processed. The results were then analyzed using square root scaled distance (SRSD) method. Referring to the United States Bureau of Mines, such a method is expressed by:

$$SRSD = \frac{R}{\sqrt{W}}$$

where:

R : measurement distance from blast source (m)
W : loading capacity of explosive per delay (kg)

Calculation results were tabulated and compared to a series of standard reference as stated in Table 1.

Blasting geometry is based on the employed drill equipment (Antono, 2003; Vutukuri and R.D. Lama, 1992)). Referring to such a fact, the shot holes at Parambahan were made using three types drilling equipments, namely CRD, DHD and DM-45. CRD shot hole had a spacing and burden of 4 m respectively whilst DHD one retained spacing and burden of 6 m respectively. Spacing and burden of DM-45 shot hole were 7 and 8 m respectively. Shot hole depth drilled by either CRD or DHD was between 5 to 7 m whereas the depth of the shot hole made by DM-45 was 9 m. Stemming for shot holes made by the three-drill equipment was 2 m. All shot holes either drilled by CRD, DHD or DM-45 were loaded by ANFO that consisted of 94% ammonium nitrate and 6% diesel fuel as their explosive. CRD, DHD and DM-45 shot holes were filled by Superdyne with VOD of 5,300 m/s and density of 1.22 g/cc as their primary explosive. The quantity of loaded primary explosive for each CRD shot hole was 0.5 kg while each hole drilled by DHD and DM-45 was loaded by 1 kg primary explosive respectively. The average explosives (primary and ANFO explosives) within each CRD shot hole were 17.68 kg; the DHD contained 51 kg and the DM-45 kept 101 kg explosives. All shot holes drilled by the three-drilling equipment employed non electric detonator retaining delay number of 25 and 42 ms with in-hole delay of 500 ms.

Table 1. A reference for determining the damage due to blast-generated vibration

Standard Reference from	Observed Materials	PPV (ips)	Damaging Level
USBM	Buildings/Housings	< 2.0 2.0 – 4.0 4.0 – 7.0 > 7.0	Na Damage Plaster Cracking Minor Damage Major Damage to Structure
Langefors, Kihlstorm dan Westerberg (1957)	Buildings/Housings	2.8 4.3 6.3 9.1	No Noticeable Damage Fine Cracks & Falling Plaster Cracking of Plaster and Masonry Wall Serious Cracking
Edwards dan Northwood 1959		< 2.0 2.0 – 4.0 > 4.0	Safe, No Damage Caution Damage
Nicholl, Johnson dan Duval (1971)		< 2.0	Safe, No Damage

3. RESULTS AND DISCUSSION

The energy balance above (Figure 1) shows that good, efficient blast design optimizes fragmentation and movement whilst keeping environmental impact to a minimum. Factors to be considered here include safety; blast geometry including, free-faces, burden, spacing, etc.; initiation pattern and angled holes. Referring to the four factors, blasting at Parambahan (Figure 2) started by making a series of shot holes to be loaded by explosives. Retaining inclination of 0 to 5^{o}, the depth of the hole was made between 6 to 9 m. All drilling holes performed a zigzag pattern.

As usual, the blast produces seismic waves. The shock compresses the material thus increasing the temperature to the point of ignition. The ignited material burns behind the shock and releases energy that supports the shock propagation (Dowding, 1985; Marmer, 2003). Shock propagation creeps through the earth with particular velocity and this velocity determines the quantity of blast-generated vibration. Figure 3 shows the blast process which is conducted to fragment the rocks in a mine. In relation to blast activity, explosive detonation at Parambahan took 5 days. During the five days, blast execution by PT Allied Indo Coal lasted for 12 times. To monitor vibrations, two blastMate IIIs were placed at 20 to 2,000 m from the blast source. Such equipments recorded peak particle velocity (PPV) that consists of transversal, longitudinal and vertical waves.

Figure 3. Blast process in a mine produces fragmented rocks and a series of blast-generated vibrations (www.terradinamica.com/program.htm).

Processing PPV data by blastware resulted peak vector sum (PVS) data (Table 2). PVS calculation results of the blast area varied from 0.18 to 21.0 mm/s.

The control of vibration and air overpressure centers on the quantity of explosives fired on any single delay, usually known as the maximum instantaneous charge weight. Based on this fact, data from Table 2 were analyzed using SRSD and tabulated in Table 3. The purpose is to get information regarding secure particular distances between blast and vibration measurement sites by referring to the maximum loading capacity per delay. The tabulated data were then inputted into blastware program to be processed. The result is an SRSD graphic that illustrated the scaled distance versus the PVS as shown in Figure 4. Such a graphic serves as a reference for a mine company to determine employed maximum explosive quantity by referring to a relatively safe distance as stated in Table 4. For example, if the allowed vibration at the tailgate is 10 mm/s and the secure distance is 100 m, the permitted loading capacity refers to 8.56 kg. Such a figure will yield blast-generated vibration less than 10 mm/s. The table also shows that the longer the distance the bigger the loading capacity.

Bukit Bual residents had filed a complaint regarding the blat-generated vibrations that were felt through their settlement. However; based on PVS measurement at Bukit Bual, it was recorded that the PVS at that village was around 0.18 to 0.31 mm/s. The figure is small enough and serves as safe category for human and housings as stated in Table 1. This means that residents' objection does not have any reasons.

Table 2. Results of blast-generated vibration measurement at Parambahan

Date	Blast site	D (m)	LC/Dly (kg)	AB Meas.		Results of										Expl.
				BM III dB (L)	SLM dB (A)	Transversal meas.			Vertikal meas			Longitudinal meas			PVS	
						mm/s	Hz	g	mm/s	Hz	g	mm/s	Hz	g	mm/s	
8 March 05	Tailgate Air shaft	20 BP1)	1,5	-	-	5,33	114	0,37	6,48	68	0,40	4.32	34	0,13	7,22	BM TG
	East Central (BP2)	100	35	140	-	14,2	19,3	0,16	5,06	16	0,10	16,3	14	0,17	18,8	shelter
	East Central (BP2)	300	35	124	77	0.78	12	0,01	0,89	15	0,01	1,6	11	0,01	1.73	Eq. Park
	West Central (BP3)	270	101	101	-	3,52	37	0,09	5,91	39	0,14	5,19	30	0,14	7.17	TG-AS
	West Central (BP4)-(1st hole MF)	270	101	95	-	1,95	47	0,06	2,17	43	0,07	2,25	26	0,07	3.11	TG-AS
9 March 05	Tail Gate (BP5)	140	1,5	91,5	-	0,32	>100	0,03	0,81	>100	0,10	0,41	>100	0,04	0.84	Aux. Shaft
	West Central (BP6)	350	51	<88	-	0,62	85	0,03	1,14	18	0,10	0,08	>100	0,01	1,14	Aux. Shaft
	West Central (BP6)	270	51	118	-	4,67	37	0,01	7,03	32	0,13	4,11	34	0,11	7.7	TG-AS
	West Central (rock falling-BP6)	270	51	101	-	0,70	>100	0,06	0,46	>100	0,04	0,53	>100	0,05	0.85	TG-AS
10 March 05	West Central (7th holes)-BP7	270	51	101	-	2,71	51	0,10	2,95	30	0,06	2,6	39	0,08	3,64	TG-AS
	West Central (10th holes MF-BP8)	270	51	104,9	-	5,22	43	0,17	5,45	37	0,12	8,3	39	0,21	8,83	TG-AS
	West Central (10th holes MF-BP8)	350	51	94	-	1,27	12	0,02	0,59	16	0,01	1,08	9,7	0,01	1.33	Aux. Shaft
	East Central (BP9)	2000	101	119,4	-	0,11	6,3	0,01	0,13	5,7	0,004	0,16	5,2	0,01	0.18	SD.Bkt. Bual
11 March 05	West Central (BP10)	300	51	119,1	96	1,52	11	0,023	1,73	18	0,0199	1,85	12	0,0125	2,37	Emp. TSM
	West Central (BP10)	270	51	117		1,37	11	0,013	0,762	18	0,0133	0.714	14	0,0094	1.38	Aux. Shaft
	East Central (BP11)	300	37	138,2	103	1,00	10	0,009	0,651	12	0,0099	1,29	11	0,0194	1.31	Eq. Park
	East Central (BP11)	80	37	-	-	9,52	15	0,113	10,5	20	0,195	18,0	17	0,207	21	Bunker blst
13 March 05	Middle Central (BP12)	2000	101	104,2	-	0,254	3,7	0,007	0,159	12	0,007	0,238	4,7	0,007	0,31	SD. Bukit Bual
	Middle Central (BP12)	780	101	120,1	-	1,22	12	0,012	1,06	8,1	0,018	1,14	6,0	0,013	1.74	Air Shaft

D ; distance
LC/Dly : loading capacity/delay
AB meas.: air blast measurement
BM III : blastMate III
SLM : sound level meter

Table 3. Data scaled distance between blasting point in central and measurement around underground

Serial No	Date/Time	Tran. Peak (mm/s)	Vert. Peak (mm/s)	Long. Peak (mm/s)	Mic Peak (dB)	Back Ground (dB)	Ldng.cap. (Kg)	D. (m)	Description (m)
BA5372	08/03/05 12:18:24	0.778	0.889	1.60	124	0.0	35.3	300	Parambahan
BA5372	08/03/05 18:16:24	3.52	5.91	5.19	101	0.0	101	270	Parambahan
BA5372	08/03/05 18:42:17	1.95	2.17	2.25	95.9	0.0	101	270	Parambahan
BA8917	09/03/05 18:11:10	0.635	1.14	0.0794	81.9	0.0	51.5	350	Parambahan
BA5372	09/03/05 18:12:13	4.67	7.03	4.11	118	0.0	51.5	270	Parambahan
BA8917	10/03/05 12:37:57	2.71	2.95	2.60	101	0.0	51.5	270	Parambahan
BA8917	10/03/05 13:03:56	5.22	5.45	8.30	105	0.0	51.5	270	Parambahan
BA5372	10/03/05 13:04:59	1.27	0.587	1.08	94.0	0.0	51.5	350	Parambahan
BA8917	11/03/05 11:57:50	1.52	1.73	1.86	119	0.0	51.5	300	Parambahan
BA5372	11/03/05 11:58:51	1.37	0.762	0.714	117	0.0	51.5	270	Parambahan
BA5372	13/03/05 13:39:05	1.22	1.06	1.14	120	0.0	101	780	Parambahan

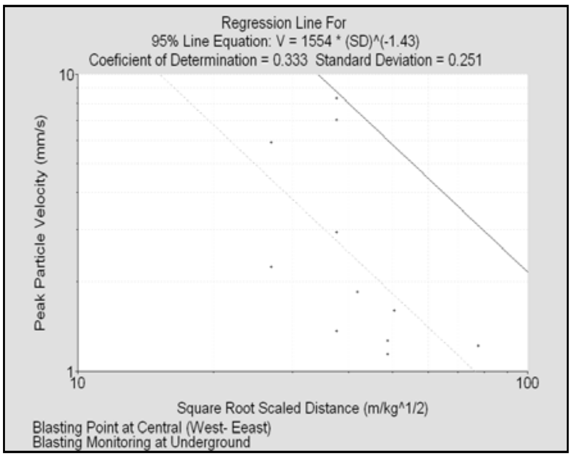

Figure 4. A square root scaled distance (SRSD) graphic that can be used to determine the permitted quantity of explosive loading capacity to get a relative safe distance

Table 4. Maximum weight of explosive per delay based on PVS 10 mm/s in maximum

Distance from Blast Source (m)	Permitted Explosive quantity (kg)
100	8.56
150	19.3
200	34.2
250	53.5
300	77.0
350	105
400	137
450	173
500	214
550	259
600	308
650	362
700	419
750	481
800	548

4. CONCLUSIONS AND SUGGESTIONS

Evaluation on blast-generated vibrations at Parambahan shows that such vibrations are still under the permitted vibration standard. The vibrations are safe for human and surrounding environment. It was recorded that the lowest PVS was 0.18 mm/s and the highest one was 21.0 mm/s at a distance of 20 m to 2,000 m from the blast source.

Parambahan lithologies are not the massive ones (mostly sediment rocks). This means that the rocks are bad media to propagate the blast-generated seismic waves. As a result, the occurring vibrations are relatively small and will be minimized by the long distance between the blast source and measurement site. In addition, techniques for controlling vibration also includes delay detonator initiation systems, reducing hole diameters and splitting the explosive charge column into discrete charges fired on separate delays.

Square root scale distance method can be applied as a reference to determine a secure distance limits by referring to explosive loading capacity in terms of gaining a particular vibration level.

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