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Configuration of Blasting Initiation System in Mining to Reduce the Impact of Ground Vibration on the Settlement Environment

Raden Haris Handayana, Jerri Mapanta, Eri Barlian, Nasfryzal Carlo, Hamdi
Department of Magister of Environment Science, Universitas Negeri Padang, Padang, Indonesia

Jihan Lubis
Department of Technical Services & QC Hanwha Mining Services Indonesia, Indonesia

Abstract: *This research was conducted in one of the biggest limestone quarries in Indonesia (Cemindo Quarry) at Lebak, Bayah, Banten, Indonesia. Using signature hole analysis, the vibration was recorded from a series of single hole firing and resulted in delay variation which resulted in the desired vibration prediction value. From a total of 12 data blasts comparing the electronic detonator and non-electronic detonators, analysis data has been made using log scale comparation scale distance and Peak Particle Velocity from every data recording, the result showed that the electronic detonators curve line lies well below the non-electronic detonator curve. This result also indicates that, with distance getting closer to the nearest resident, electronic detonators are still capable of maintaining results below 3 mm/s with an equal quantity of explosives that is used on non-electric blasts. Compared to SHA prediction, every blast of electronic detonators has used the recommendation of SHA analysis which is Inter Hole 53ms and Inter Row 144ms, with predicted value PPV 1.87 mm/s based on nearest distance SHA monitoring 382 m, the actual value was achieved with PPV 1.97 mm/s on similar distance. It could be concluded that the electronic detonator could reduce vibration value by 21.5% compared to non-electric detonators applied in the blasting process in a limestone quarry, in Bayah, Indonesia.*

Keywords: *Electronic Detonator, Groundvibration, non-electric detonators, quarry.*

Introduction

Ground vibration is a wave that moves in the ground caused by the presence of an energy source resulting from blasting activities to dismantle rock which is one of the most important environmental problems in open pit mines (Agrawal & Mishra, 2020), especially in open pit mines which are very close to settlements. Therefore, accurate analysis of ground vibrations due to explosions is very important, to avoid complaints from the surrounding community due to damage to building structures (Andersen et al., 2007) the Limestone Quarry blast in Indonesia runs with many difficulties and challenges. Climate condition, geological structure, also social and environmental issue usually occurs when mining and blasting activity were close to the community area (Kahriman, 2004). This research was conducted in one of the biggest limestone quarries in Indonesia (*Cemindo Quarry*) at the leak, Bayah, Banten, Indonesia. Bayah Quarry represented a scenario where the use of electronic detonators could be developed to bring real benefit. With the required minimum total production of almost 40000 tons/day, a minimum blast volume must be exceeding the required total production. Production requirement is constrained by material production limitation due to mining progress that getting closer

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to residential areas. Using pyrotechnic detonators, the blast process was limited to a maximum of 25 holes with a segment delay applied. The noise and vibration issue which limited to a value of 4 mm/s in distances 400 to 500 m from the resident area. This limitation gives a direct effect on blast material production, and also fragmentation issues that have come from pyrotechnic detonators combined to delay segmentation. Electronic detonators were applied to the blasting process with challenges to minimize vibration value and also break the limit blast production and increase the uniformity of size fragmentation as crusher requirements with values below 80 cm in passing 95%.

Several studies have been carried out in analyzing the effects of blasting vibrations on settlements, such as those conducted by Simbolon et al (2015), the impact of andesite mining blasting activities on the residential environment, using explosive reduction based on regression analysis, level of vibration can be reduced according to standard. Other research such as that conducted by Lubis et al (2018) regarding the study of blasting vibrations with a fault tree analysis, is also based on the parameter of the explosive charge level against the distance to the settlement to limit the load level and several detonations. Past research in Indonesia still focuses on analyzing vibration with scale distance prediction, in this research the signature hole analysis was applied combined with electronic detonators for resulting delay customization to achieve low vibration values that affect residential areas. The purpose of this research is to find out how the blasting results from the use of electronic detonators are compared with non-electronic detonators on limestone quarry mining applications in Indonesia. Using electronic detonators, blast fragmentation was expected for resulting size fragmentation below 80 cm in 95% passing, reducing explosive consumption with extended pattern geometry and reducing blast vibration effect that still became a community issue from the nearest residence.

Methods

Signature hole analysis is a modeling technique used to help control vibrations due to explosions (Yuan et al., 2017). This process involves controlling the frequency content by adjusting the delay time in explosions containing multiple blast payloads. This technique incorporates a defined detonation time for each hole and locates the waves generated by each hole to predict the closest values of the peak particle velocity and ground vibration frequency due to the explosion (Agrawal & Mishra, 2020). In this study, an analysis of the signature hole was carried out in the explosion area at a distance of about 409 m from the residential area. Four holes were placed in the blast area and detonated after the production of the explosion. Each blast hole is filled using standard explosives and is delayed at 5000 ms intervals per hole. The figure and table below show the location of the blast hole marking holes for vibration monitoring and the resulting vibration values.

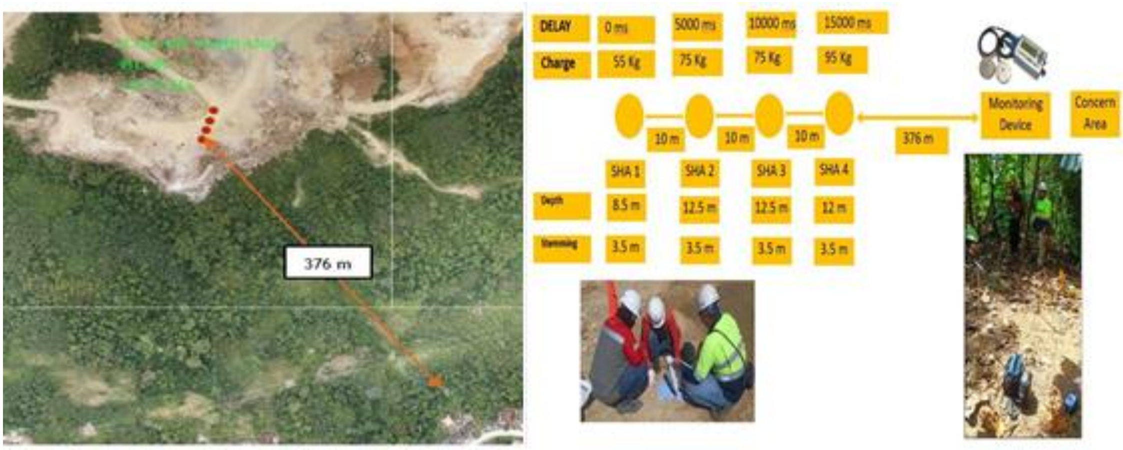

Figure 1. Signature hole installation and point monitoring

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The three SAH hole vibration values were successfully monitored by the vibration device, with the PPV value increasing as the distance to the monitoring device increased. The last signature hole was not recorded due to the possibility of a cavity under the blast hole. Table 1 shows the results of the signature hole blast vibration monitoring.

Table 1. Signature Hole Explosion Results

Hole SHA	Weight of Charge (kg)	Distance (m)	Delay (ms)	PPVresult (mm/s)
SHA1	55	409	0	1.974
SHA2	75	388	5000	2.063
SHA3	75	382	10000	2.270
SHA4	95	376	15000	-

The signature holes are placed in the direction closest to the community area. The concept of signature hole analysis is to record the vibration signal from a series of single-hole firings (Himanshu et al., 2022). The vibration signal from a series of single-hole shots is consistent in shape, and although there are variations in hole design and explosion type, the amplitude of the vibrations varies (Agrawal & Mishra, 2019). Other factors that affect the instantaneous load weight, free face, and load as factors that affect the amplitude of the vibration (Balmes & Wright, 2021). Vibration values were monitored using a micro-mate device from Instantel and analyzed using a blastwave advance module for signature hole analysis. The signature hole analysis resulted in four delay time options where the predicted PVS value was below 1.5 mm/s.

Table 2. Signature Hole Analysis Result

No	Inter Holes (ms)	Inter Row (ms)	PPV Predict (mm/s)
1	53	144	1.41
2	21	71	1.45
3	61	147	1.46
4	56	139	1.46

Vibration results using a non-electric detonator

Existing vibration measurement data using a non-electronic detonator initiation system shows the average vibration level produced is in the range of 3.57 mm/s. In some instances, vibration levels even exceeded 5 mm/s and there were measurements reaching a peak of 6.3 mm/s (Fig2). With a vibration level that exceeds SNI 7571:2010 (Indonesian National Standard) (Julianti et al., 2021) the threshold for class 2 buildings with the maximum acceptable peak particle is 3 mm/s (Table 3).

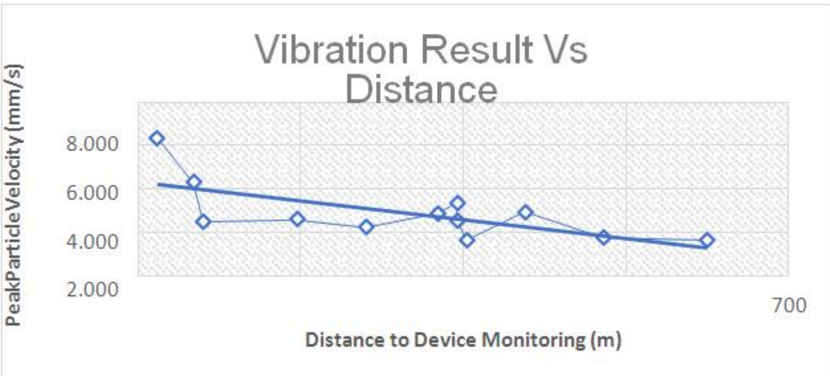

Figure 2. Vibration Results In Non-Electric Detonators

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Table 3. Indonesian National Standard for ground vibration (SNI 7571:2010)

Class	Building Type	Peak Vector Sum(mm/s)
1	Ancient buildings protected by cultural heritage law (Law No. 6/1992)	2
2	Buildings with foundations, masonry and cement mortar only, including buildings with wooden foundations and cement mortar floors	3
3	Buildings with foundations, masonry and cement mortar tied to concrete slopes	5
4	Buildings with foundation, masonry, and concrete slopes with mortar, columns, and frames bound together with balk rings	7-20
5	Buildings with foundations, masonry and cement mortar, concrete slopes, columns and bonded with steel frames	12-40

The vibration results using this non-electric detonator are predictable, the detonator delay interval in the shock tube initiation system, for surface and bottom hole initiation, varies between 17 ms and 500 ms with a scattering percentage variation of 3.5% to 5.5% (i.e., scattering of 17.5 milliseconds at a delay of 500 milliseconds) (Grobler, 2003). In comparison, the scattering of the electronic detonator varies by about 0.01% for each programmed delay period, which can be up to 20 seconds. This benefit is one of the main advantages of electronic detonators to produce better explosion performance compared to non-electric detonators (Fousson et al., 2016).

Compare vibration results using non-electric detonators and electronic detonators

Side by side explosions were carried out in one blast area to see a comparison between non-electronic and electronic detonators. Uses delays similar to non-EL applications 67 ms for between channels and 25 ms for ports. Side-by-side blasts are carried out in one blast area to see the comparison between non-electronic and electronic detonators. Uses a delay similar to non-el applications 67ms for between lines and 25ms for holes.

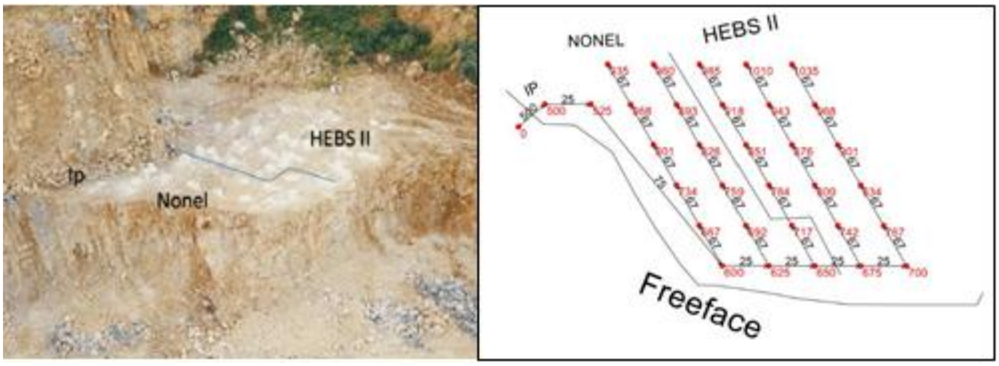

Figure 3. Side by side explosion with the application of non-electronic detonators and delayers and HEBSII

Vibration monitoring was also carried out, recordings were analyzed using THOR software, to divide the explosion time between explosions initiated by non-electric and electronic detonators. Using the same delay as the non-electronic detonator delay, the electronic detonator effectively reduces the vibration value to 21.5%, detailed in Fig. 4 below.

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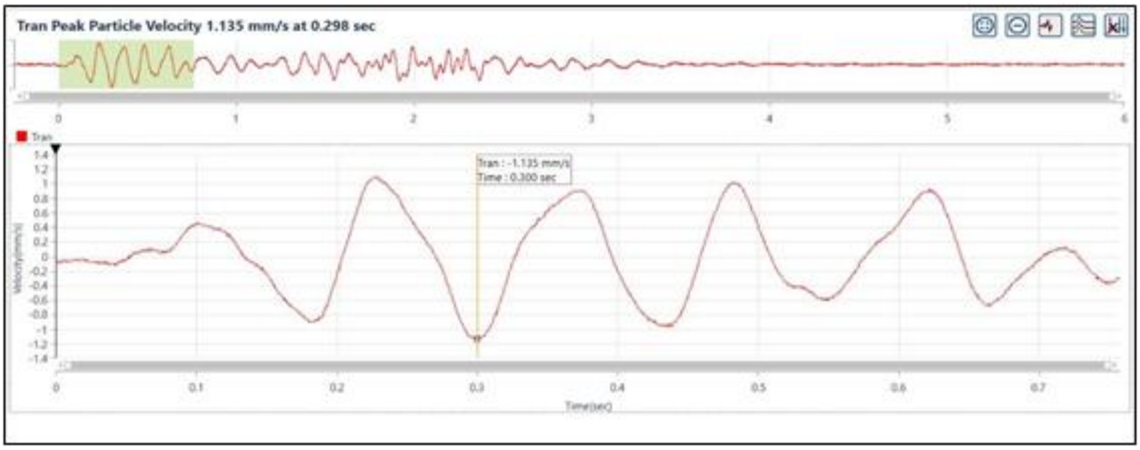

Figure 4. Non-electric detonator wave analysis, peak vibration value 1.135mm/s.

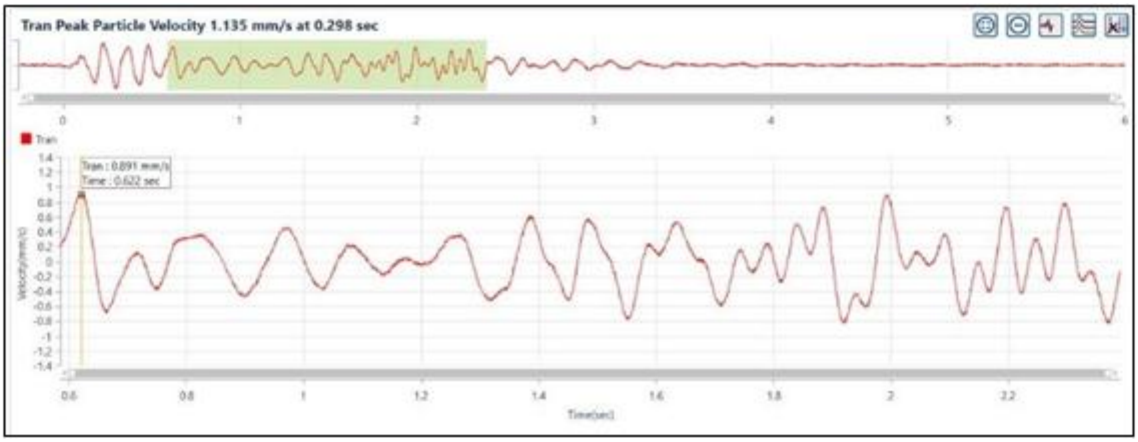

Figure 5. Electronic Detonator wave analysis, peak vibration value 0.891mm/s

Side-by-side detonation illustrates that electronic detonators improve blast performance either in terms of fragmentation or vibration value. Reduce by a percentage of 21.5% the value of the round vibration. Using this data, the analysis moves to another stage using the SHA analysis delay recommendations applied to near-residential explosions. From a total of 12 explosion data compared between electronic detonators and non-electric detonators, data analysis has been carried out using a distance log scale comparison scale and Peak Particle Velocity from each data recording, the results show that the electronic detonator curve line is far below the non-detonator curve. electricity. This result also shows that with a closer distance to the nearest resident, the electronic detonator is still able to maintain PPV results below 3 mm/s with the same amount of explosive used in non-electric explosions (Table 4). Where Fig 6 shows that the results of electronic vibration data at R are 78% higher than non-electric data with an R-value of 52%. These results indicate that electronic detonators provide a more precise prediction of peak particle PPV than non-electric detonators with a percentage value of 26%.

Table 4. Electronic and Electric detonators blast vibration data

Blast	Distance (m)	PPV (m/s)	Blast	Distance (m)	PPV (m/s)
Nonel 1	506	6.350	EDD 1	365	2.270
Nonel 2	517	4.300	EDD 2	375	2.063
Nonel 3	520	2.510	EDD 3	380	1.974
Nonel 4	549	2.580	EDD 4	382	2.169
Nonel 5	570	2.230	EDD 5	400	1.781
Nonel 6	592	2.880	EDD 6	404	1.280

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Nonel 7	598	3.380	EDD 7	407	1.271
Nonel 8	598	2.570	EDD 8	425	1.370
Nonel 9	601	1.660	EDD 9	457	1.530
Nonel 10	619	2.950	EDD 10	461	1.140
Nonel 11	643	1.770	EDD 11	496	1.200
Nonel 12	675	1.650	EDD 12	506	1.080

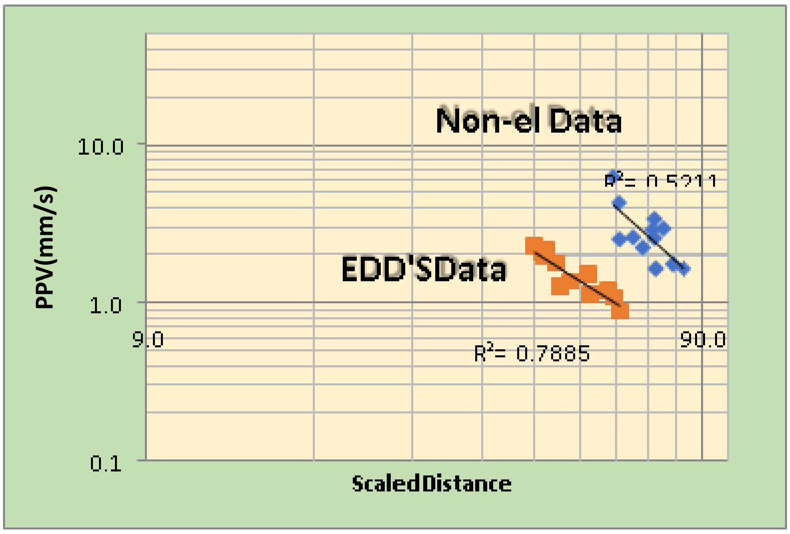

Figure 6. Log Plot (PV versus Scale distance) comparing the results of electronic and non-electrical vibrations.

Compare to SHA prediction, every blast of electronic detonators has used the recommendation of SHA analysis which is Inter Hole 53ms and Inter Row144ms, with predicted value PPV 1.87 mm/s based on nearest distance SHA monitoring 382 m, the actual value was achieved with PPV 1.97 mm/s on similar distance.

Table 5.Signature Hole PPV prediction and actual measurement

No	Inter Holes (ms)	InterRow (ms)	PPV Predict (mm/s)	Actual PPV (mm/s)	Distance (m)	SHA Predict Deviation (%)
1	53	144	1.87	1.97	380	5%

This result showed that using signature hole analysis the delay precision was the accurate result in the predicted value with a deviation of 5%. However, the signature analysis value is only applicable for corner cut or echelon tie-up systems and it's only applicable to the current geological area. Another factor, could also affect the result of vibration value such as initiation point placement and also the position of blast wave propagation to the concerned area, this factor must be included in future research.

Conclusion

The results of the study on the application of electronic detonators in limestone quarries concluded that electronic detonators are effective in reducing ground vibration values below 3 mm/s in areas close to residents. By using the same delay on the electric detonator, the electronic detonator has reduced the vibration value to 21.5%, this value indicates that the electronic detonator is proven to give higher accuracy delay timing compare to non-electric detonators. Using Signature Hole analysis, the predicted PPV was close to the actual measurement. Electronic detonators effectively increase the prediction value by 26 %. So, it's could be concluded that, compared to nonelectronic detonators, HEBS II is capable to maintain PPV below standard at a distance nearer to the resident area.

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