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5th ICEMINE 2022

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RESEARCH ARTICLE | SEPTEMBER 06 2024

Preface: The 5th International Conference on Earth Science, Mineral, and Energy (ICEMINE 2022)

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Preface: The 5th International Conference on Earth Science, Mineral, and Energy (ICEMINE 2022)

The 5th International Conference on Earth Science, Mineral, and Energy (ICEMINE) 2022 is an annual event held by Faculty of Mineral Technology, Universitas Pembangunan Nasional Veteran Yogyakarta, proudly present the theme of "Earth Resource Management as a Prime Mover to Achieve Economic Recovery Post Pandemic" where the discussion focused on the earth resources management to be able to improve the economic growth post pandemic situation. More than 60 presenters and speakers from universities and companies in Indonesia and also the contributor countries (South Korea, Japan, Brazil, and Canada) were involved in this conference.

Indonesia has abundant natural resources including renewable an non-renewable. The utilization of natural resources needs to be adjusted with the area development as well as control enhancement by implementing regulation. Energy sector activities should be done with the concept of environmental sustainability starting from exploration, until extraction. This concept could preserve energy resources for the future as well as improve the economic growth. Post Covid-19 pandemic, community lives have not fully recovered from the impact on all sectors of life in society, including the economic sector. Not only the environmental sustainability issue but also the exploration, exploitation, and extraction process have the challenges and opportunities to optimize the national economic growth and energy resilience.

The conference reached final result where the post pandemic could be seen as a challenge to enhance and improve our knowledge and technology in the earth resource management to keep the economic growing. Optimizing the existing methods, implementing a new technology, and collaboration were the important aspects to keep in mind post pandemic situation. The committee also thank the participants and all parties who made ICEMINE 2022 held successfully.

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Analysis of ground vibration due to blasting using variation of scaled distance method in limestone mine

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Analysis of Ground Vibration due to Blasting Using Variation of Scaled Distance Method in Limestone Mine

Antonio Gabriel Felito Obe[1], Yuga Maulana[1, a)], Pantjanita Novi Hartami[1], Edy Jamal Tuheteru[1], Mixsindo Korra Herdyanti[1], Reza Aryanto[1]

[1]*Mining Engineering Departemen, Faculty of Earth Technology and Energy, Universitas Trisakti, West Jakarta, Indonesia*

[a)] Corresponding author: yuga.maulana@trisakti.ac.id

Abstract. Currently, construction development is increasingly being carried out in Indonesia. In this case, PT. Indocement produces cement to meet these needs. Cement is produced from the earth's limestone (limestone). In an effort to meet their production needs, they carry out their own limestone mining. Blasting is chosen to dismantle the limestone mass. However, blasting also has a negative impact due to the release of large amounts of energy that can damage building structures or interfere with human comfort. Based on the AMDAL's location close to residential and office buildings, it is necessary to conduct research on the vibration and sound of the blasting. The data obtained is secondary data collected from 2017 to 2021. The method used is quantitative and comparative, namely processing using Scaled Distance theory to obtain future vibration predictions according to company standards to meet SNI 7571:2010, then compared with other Scaled Distance models. (Indian Standard, Langefors & Kiehlstrom, and Ambraseys-Hedron). The measurement results show that some exceed the set standard. The calculation results with predictions that are close to the actual value are the Scaled Distance model of the Ambraseys-Hedron equation with an average percent correction of 29,92% from the Ambraseys-Hedron equation, the constant (k) of 2811,9 & (m) -1,503 with a determination (R2) of 0,662. The prediction of the maximum explosive material that fits the PPV standard is done with several variations of the 50-meter interval that can be adjusted to mine progress in the future with the USBM model. Then the prediction results of explosives are used to determine the SPL prediction, which is for a distance of 500 meters at 80 dB for the PPV parameter of 2,5 mm/s according to company standards from the reference of SNI 7571:2010.

Keywords: Vibration, sound, explosives per delay, regression, scaled distance

INTRODUCTION

PT. Indocement is one of the largest and oldest cement companies in Indonesia, in an effort to increase the independence of their company, they have long been mining limestone as one of the important raw materials in making cement. In addition to lime stone, they also carry out claystone mining in different locations to support the main raw materials for the cement they produce (1). Limestone mining activities in Indocement are located in lulut village, citeureup district, West Java, which is still located in the same region as the factory. The quarry open-pit mining method is selected based on the characteristics of the rocks taken (2). In an effort to take the excavated material, it is necessary to carry out effective disassembly, then the blasting method is chosen. However, these blasting activities often cause uncontrolled vibrations to settlements when the planning is not done properly (3)(4). The purpose of this study is to predict how explosives are used in blasting production planning in PT. Indocement, from the vibrations measured using Blastmate III, a constant will be obtained that describes the correlation of the conditions in the field. From these predictions, it can be calculated that the need for explosives per delay recommendation to meet PPV 2.5 mm/s based on company standards can be calculated.

THEORETICAL FOUNDATIONS

Research Location

PT. Indocement Tunggal Prakarsa, Tbk (PT ITP) which is administratively located in Lulut, Leuwikaret, Bojong, Nambo and Klapanunggal Villages, Klapanunggal District, Bogor Regency. Geographically, the study area is located at coordinates 6o28'45" LS – 6o31'00" LS and 106056'45" BT – 106o58'30" BT. The AMDAL study stated that the block of blasting sites closest to the rubber leuwi village is about 800 meters and the mining division office is the closest, which is 500 meters away. The quarry D Citeureup pit mining area is adjacent to:

- North Boundary : Gunung Putri District
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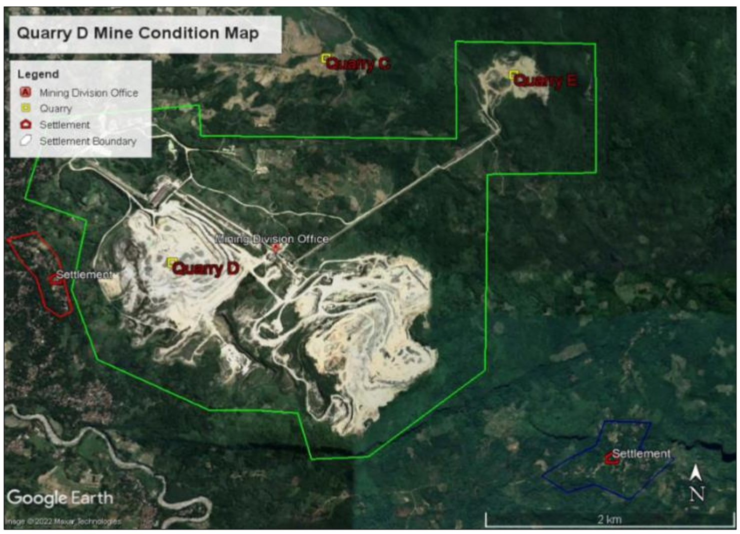

FIGURE 1. *Quarry Research Area Appearance Map (Google Earth,2022)*

Ground Vibration

Ground vibration is a movement that occurs as a result of a seismic wave propagation that has significant attentions (5). In any mine blasting activity can produce seismic waves. It takes a certain amount of energy to go beyond the elastic limit of the rock. If this happens, the rock will be cleared, according to the purpose of the blast itself is to reap the rock mass. The method that the most popular is scaled distance regression analysis (6). Biased blasting vibrations are predicted using the theory of the Scaled Distance equation.

1. Vibration calculation equation

$$PPV = k\ (SD)^{-m} \tag{1}$$

Information:
PPV = peak partikel velocity (mm/s)
k = distance affected constants, initiation patterns, and the number of explosives (site factor)
SD = square root scaled distance (m/kg^1/2)
m = constants influenced by the conditions and properties of rocks

Blasting

Blasting is an effort to eradicate compact rock masses by using explosive energy. Blasting is usually said to be safe if one of the impacts has met the established limit. The impact of vibration is set by the threshold in the Environmental Ministry no.49 of 1996 to regulate how the quality standards of vibration value against blasting open pit mines can be seen below (Table 1)

TABLE 1. *Standard Vibration Levels Due to Blasting Open Pit Mines Against Buildings* (7).

Clas s	Building Type	Peak Vektor Sum
1	Ancient buildings protected by law (Law No.6/1992) on cultural heritage	2
2	Buildings with brick foundations and cement mortar only. In this case, it includes buildings with wooden foundations and floors with cement mortar	3
3	Buildings with brick foundations and concrete slope cement mortar	5
4	Buildings with masonry foundations and cement mortar concrete slopes, columns and connective frames with beam rings	7 ± 20
5	Buildings with masonry foundation and cement mortar, concrete slope, columns fastened with steel frames.	12 ± 40

Based on SNI 7571:2010 the company has provisions against vibration and sound. For maximum standards PPV 2,5 mm/s and *SPL* 120 dB.

Scaled Distance Theory

Scaled Distance is used as a parameter for distance components with explosives in one delay time. This theory developed to state the relationship between the two variables. This theory is used as an analysis to find the price of a constant which will later be used as a prediction for the next detonation vibration(1,8). The equation is as follows:

(USBM) $$SD = \left(\frac{D}{W^{\frac{1}{2}}}\right) \quad (2)$$

(Indian Standart) $$SD = \left(\frac{W}{D^{\frac{2}{3}}}\right) \quad (3)$$

Langefors & Kiehlstrom $$SD = \left(\frac{W^{\frac{1}{2}}}{D^{\frac{1}{3}}}\right) \quad (4)$$

Ambraseys-Hedron $$SD = \left(\frac{D}{W^{\frac{1}{2}}}\right) \quad (5)$$

Information:
SD = Scaled Distance
D = Blasting distance to the measurement point (m)
W = Amount of explosives per *delay* (kg)

Correlation Theory

According to (Supardi 2013) that correlation is a term commonly used as a measuring parameter for the strength of a relationship in a variable to another variable. This correlation is a way to find out the presence or absence of relationships between the connected variables, for example the most common is the relationship between two variables.

RESEARCH METHODS

This study fully used indirect (secondary) data acquisition from the mining division office of PT. ITP. In this study also uses quantitative and comparative analysis methods, which in measuring the actual vibration obtained will be used quantifiable theory to analyze it. While a comparative analysis of how to compare the results of different models of the scaled distance equation.

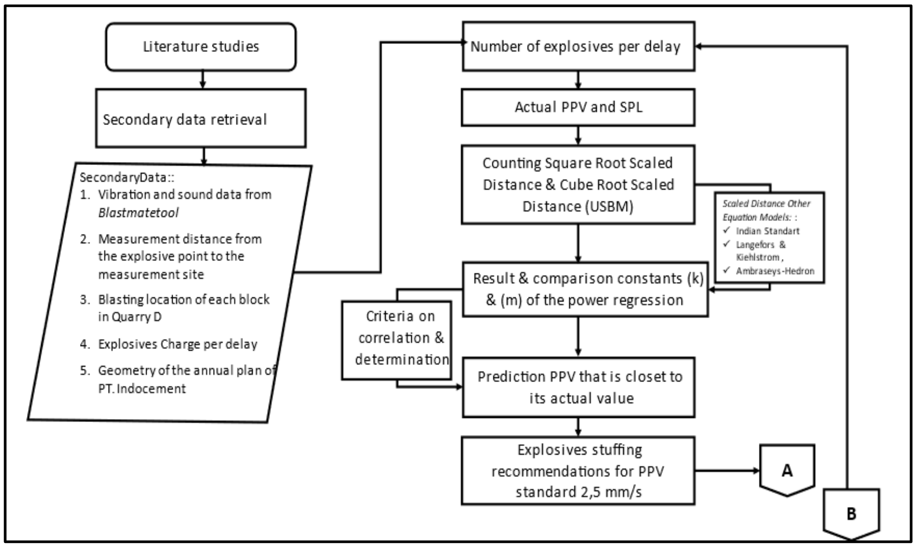

FIGURE 2. *Research Flow Chart*

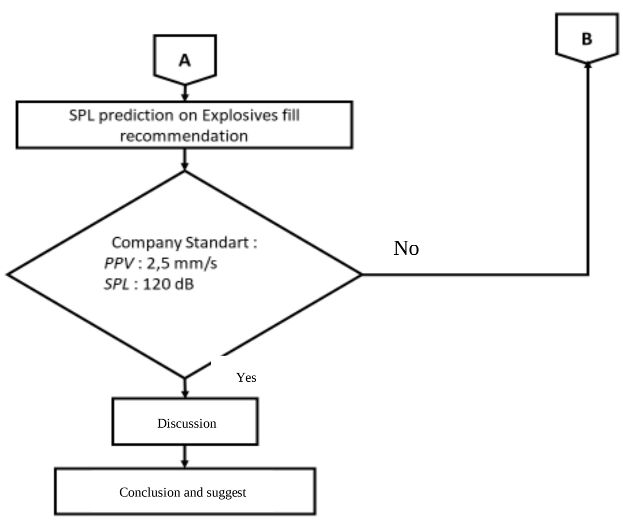

FIGURE 3. *Research Flow Chart (continued)*

RESULTS AND DISCUSSION

Actual Vibration Data

From the data collected from 2017 to 2021, several measurements passed the company's standard and SNI 7571: 2010.

TABLE 2. Vibration Measurement Criteria Above Standards

Date	Location	Explosives	Distance	PPV	Company Criteria	SNI 7571:2010 Criteria
		(kg/*delay*)	(m)	(mm/s)	(2.5 mm/s)	(3 mm/s)
1-sept-17	*Quarry D*	69,4	350	3,268	Not Safe	Not Safe
	Quarry D	69,4	350	3,262	Not Safe	Not Safe
2-sept-17	*Quarry D*	85,8	350	3,675	Not Safe	Not Safe
	Quarry D	94,6	350	3,953	Not Safe	Not Safe
	Quarry D	59,7	350	3,289	Not Safe	Not Safe
	Quarry D	72,4	500	2,533	Not Safe	**Safe**
20-sept-21	*Quarry D*	71,5	800	2,562	Not Safe	**Safe**

Explosives data per delay

Data obtained from PT. ITP is in the form of explosives for each segment in one blasting block, where each primer is filled with one detonator. The blasting pattern used hole by hole. Where it is calculated from the total explosives (kg) per segment divided by the number of holes per segment (Table 3).

Square Root Scaled Distance (SRSD)

Using equation (1) can be calculated square root scaled distance to determine the equation of prediction of future vibrations.

Relationship between PPV with SD

After obtaining the SRSD value, it is plotted with the actual ppv value and formed a graph from Microsoft Ecxel to obtain the power regression equation (Figure 4).

Relationship between PPV with SD various equation models

To better see which equation is more relevant to the state of blasting vibrations in PT mining. This ITP. Thus, counted other Scaled Distance models such as the Indian Standard, Langefors & Kiehlstrom, as well as the Ambraseys-Hedron. Then a regression graph is created to get the predictive equation of each Scaled Distance model.

TABLE 3. Explosives per delay

Date	Mining Block	*Tie Up*	Holes per Segment	Deto. Number	Explosives per segment (kg)	Explosive s per delay (kg)
01-Sep-17	QD-BLOK II	*Hole by hole*	5	5	347	69,4
02-Sep-17	QD-BLOK II	*Hole by hole*	5	5	429	85,8
03-Sep-17	QD BLOK III	*Hole by hole*	5	5	119	23,8
03-Apr-18	QD BLOK II	*Hole by hole*	5	5	161,5	32,3
06-Apr-18	QD BLOK II	*Hole by hole*	10	10	481	48,1
07-Apr-18	QD BLOK II	*Hole by hole*	5	5	227	45,4
02-Dec-19	QD-BLOK II	*Hole by hole*	6	6	353,4	58,9
03-Jan-20	QD BLOK II	*Hole by hole*	5	5	121,5	24,3
10-Jan-20	QD-BLOK II	*Hole by hole*	5	5	236,5	47,3
13-Jan-20	QD-BLOK II	*Hole by hole*	5	5	277,5	55,5
14-Jan-20	QD-BLOK II	*Hole by hole*	5	5	278	55,6
15-Jan-20	QD BLOK III	*Hole by hole*	5	5	219	43,8
06-Sep-21	QD-BLOK II	*Hole by hole*	5	5	154,5	30,9
07-Sep-21	QD BLOK II	*Hole by hole*	5	5	227	45,4
08-Sep-21	QD BLOK II	*Hole by hole*	5	5	353	70,6
14-Sep-21	QD BLOK II	*Hole by hole*	5	5	278	55,6
20-Sep-21	QD BLOK III	*Hole by hole*	5	5	357,5	71,5

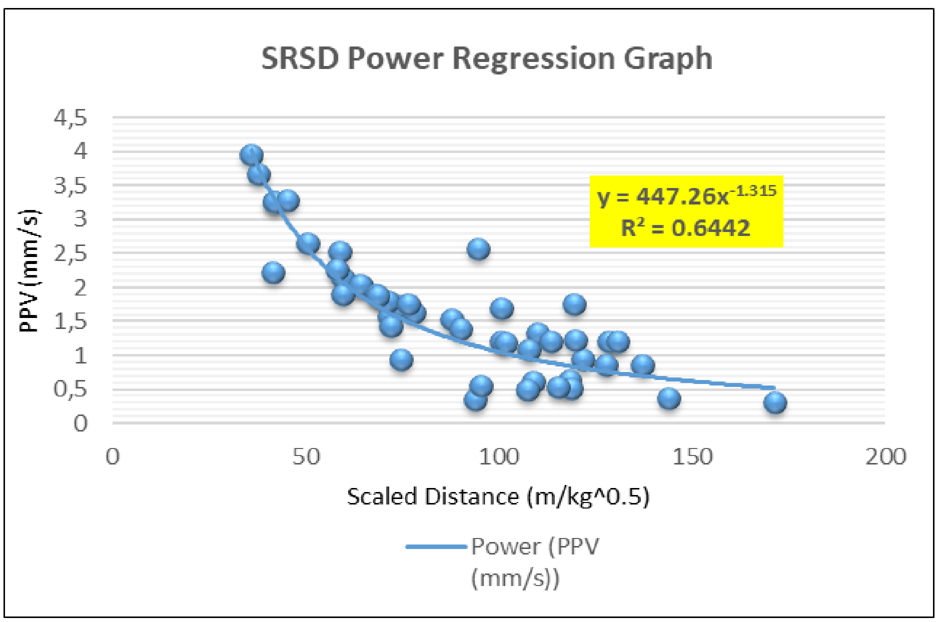

FIGURE 4. Graph of SRSD Power Regression

The graph of the power regression relationship at (Figure 4) states a price of the constants k and m which are vibration and sound factors at the study site. The prediction equation is as follows: (USBM)

$$PPV = k\,(SD)^{-m} \tag{6}$$

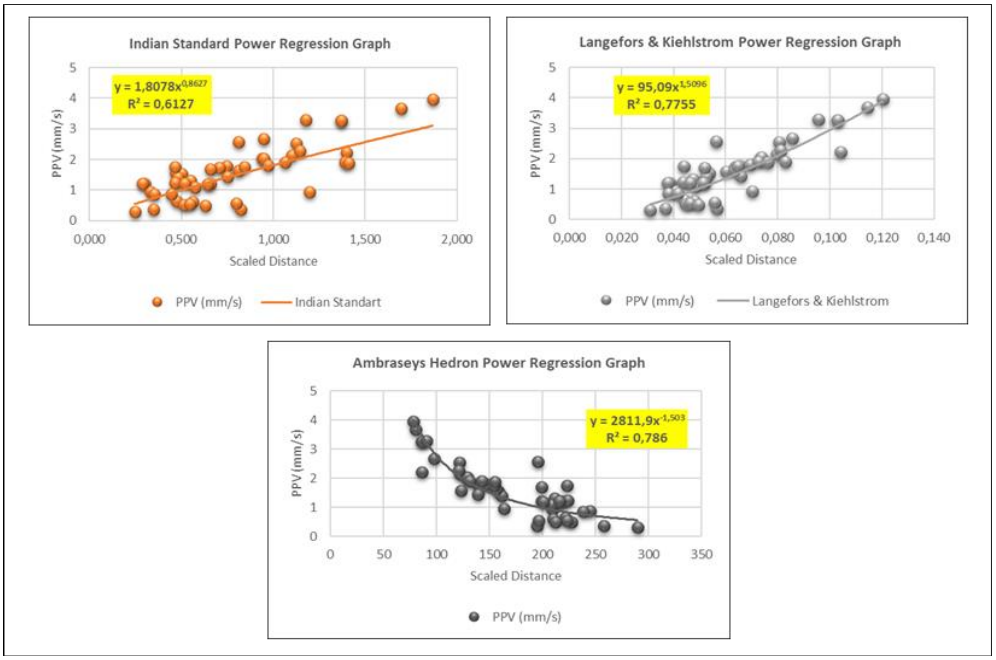

FIGURE 5. Graph relationship between ppv with scaled distance for various equation

When looking at Figure 5, it is obtained from the same method using the power regression method, by plotting between the actual ppv and the results of the Scaled Distance calculation for various equation models to get the power regression equation.

Power Regression Equation :
PPV = 447,26 (SD)^-0,863 (Indian Standart)
PPV = 2811,9 (SD)^-,503 (Ambraseys-Hedron)
PPV = 95,09 (SD)^-1,510 (Langefors & Kiehlstrom)

Comparasion of actual ppv with ppv prediction from various Scaled Distance models

Based on Figures 4 and 5, a comparative calculation is made between the actual PPV and the predicted PPV on all scaled distance models to show which equation is closest to the actual value.

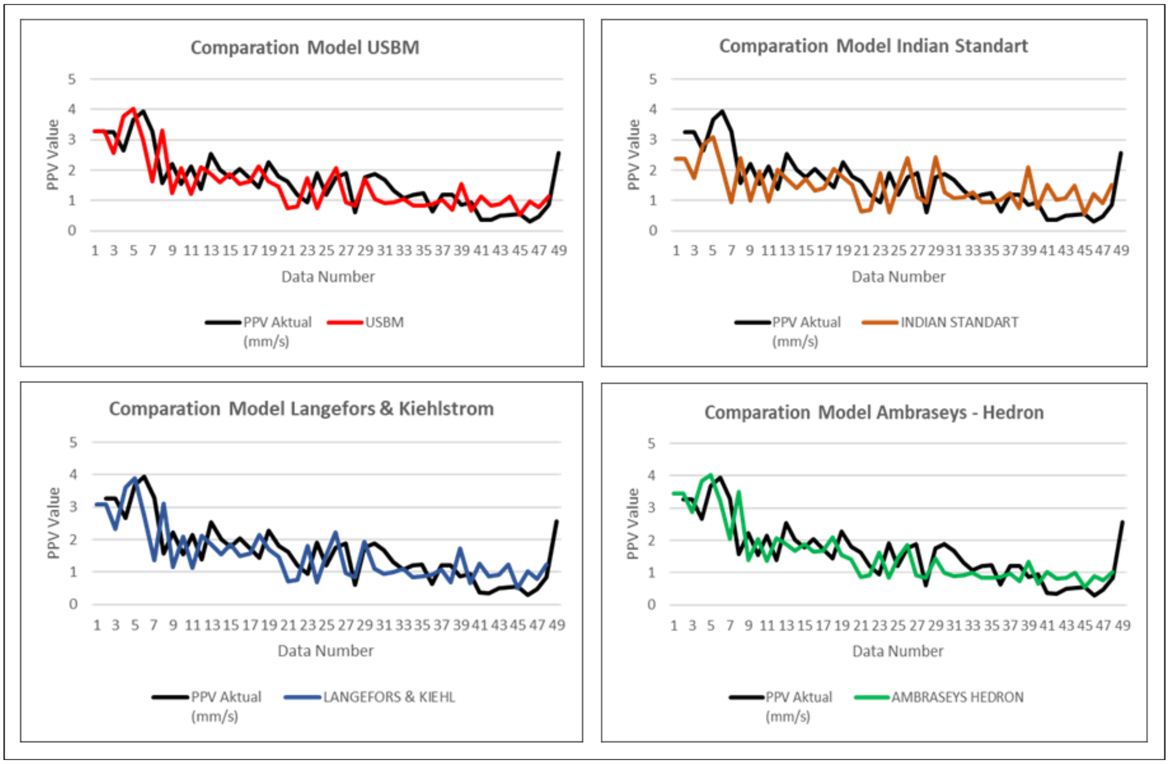

FIGURE 6. Deviation between Actual PPV and Prediction

Then from the graph, a percent correction calculation is carried out for each of these comparisons, to see which equation is closest to the value of its actual ppv (Table 4).

TABLE 4. Percent Correction between Actual PPV and Prediction

No.	Scaled Distance Models	Average Deviation (%)
1	USBM	30,948
2	Indian Standart	43,57
3	Ambraseys-Hedron	**29,92**
4	Langefors & Kiehlstrom	33,51

On the graph it can be stated that the smallest average percentage of each model of the *Scaled Distance* equation in predicting vibrations, then it can be concluded that the model of the Ambraseys-Hedron equation is the equation that is closest to the actual value of *ppv* at the state of blasting vibrations in PT. Indocement Tunggal Prakarsa.

Correlation and Determination

In analyzing vibration resistance using power regression methods, of course, it involves two important variables in an effort to predict future vibrations, before that it will be done how the criteria for the relationship between ppv and scaled distance (involving distance and explosives) in influencing pvv levels in Quarry D. This the criteria for correlation and its determination are made (Table 5).

In this correlation and determination analysis guideline, a simple study will be carried out on how factors affecting the level of vibration and sound occur from the actual PPV data in the field (9). A comparison was made between this study and previous researchers (1)

TABLE 5. Correlation Comparison and Determination

Researcher's Name	Data Type	Research Location	Correlation Coefficient (R)	Guidelines For Assessment	Coefficient Determination (R^2)	Degrees Relationships (%)
Didik Sudarmanto (1)	Limestone Vibrations	PT. Semen Indonesia Tuban, West Java	-0,842	**Very Powerful**	0,709	70,9%
	Grainstone Vibrations		-0,580	**Medium**	0,359	35,9%
Antonio Gabriel Felito Obe	Vibration Model Ambraseys-Hedron	PT.ITP Citeureup, West Java	-0,8136	**Very Powerful**	0,662	66,2%

Showing the correlation coefficient states a very strong guideline on limestone measurements with a relationship of 70.9% stating that the distance and amount of explosives affect 70.9% of ppv levels at the PT research site. Semen Indonesia, then in this study used the Ambraseys-Hedron model stated that the correlation coefficient was very strong according to the guidelines, while the relationship drajat was 66.2% in the condition of PT blasting vibrations. Indocement Tunggal Prakarsa.

Maximum Explosives Prediction

To calculate the maximum allowable explosives used the company's standard vibration reference with a PPV of 2.5 mm/s and for this calculation a model of the Ambraseys-Hedron SD equation was used, while for the sound standard used followed from the standard that the company had set, namely 120 dBL. To produce vibrations that are in accordance with these standards, a calculation is made in the prediction (10). With a variation in the distance of 50 meters from a distance of 50 meters to 1400 meters, the maximum explosive prediction results are as follows (Figure 7). The reference distance for offices and settlements in the boundary with a blue line to indicate what the maximum explosive needs are. The PPV standard of 2.5 mm/s was chosen to meet the reference of SNI 7571:2010 which states that settlements around the site are in the ppv class of 3 mm/s.

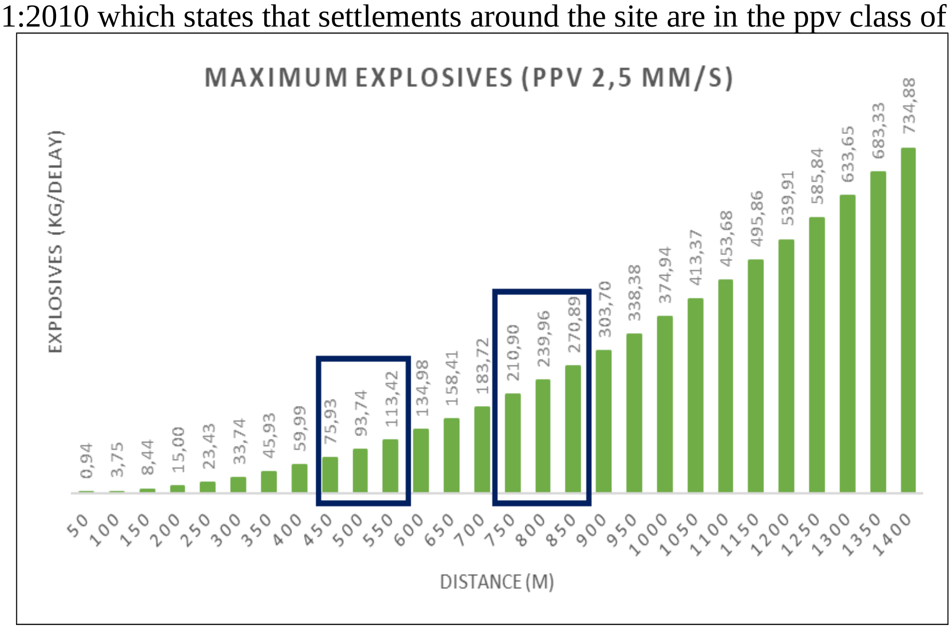

FIGURE 7. Graph of Maximum Explosives

CONCLUSION

Based on vibration data collected from 2017 to 2021, it is stated that it is in accordance with the SNI 7571:2010 standard and company standards according to residential and office buildings. The constant results obtained from the power regression graph state that the Square Root Scaled Distance with a value of k is 447.26 and m is -1.315 and for Cube Root Scaled Distance the value of k is 8757.1 and m is -0.999. Because there is an office distance of about 500 meters, a maximum explosive charge of 101.62 kg/delay can be used per delay to meet the 2.5 mm/s ppv standard (according to company standards). From the results of the calculation and comparison of the PPV prediction with the actual, it states that the Ambraseys-Hedron equation model produces the smallest percentage of correction (difference).

ACKNOWLEDGMENTS

Expressing our deepest gratitude to PT. Indocement Tunggal Prakarsa with the permission given to carry out the final project in this blast vibration research, and also to all relevant parties who helped.

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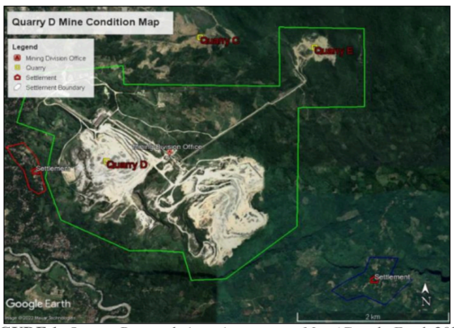

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m = constants influenced by the conditions and properties of rocks

Blasting

Blasting is an effort to eradicate compact rock masses by using explosive energy. Blasting is usually said to be safe if one of the impacts has met the established limit. The impact of vibration is set by the threshold in the Environmental Ministry no.49 of 1996 to regulate how the quality standards of vibration value against blasting open pit mines can be seen below (Table 1)

TABLE 1. *Standard Vibration Levels Due to Blasting Open Pit Mines Against Buildings* (7).

Class	Building Type	Peak Vektor Sum
1	Ancient buildings protected by law (Law No.6/1992) on cultural heritage	2
2	Buildings with brick foundations and cement mortar only. In this case, it includes buildings with wooden foundations and floors with cement mortar	3
3	Buildings with brick foundations and concrete slope cement mortar	5
4	Buildings with masonry foundations and cement mortar concrete slopes, columns and connective frames with beam rings	7 ± 20
5	Buildings with masonry foundation and cement mortar, concrete slope , columns fastened with steel frames.	12 ± 40

Based on SNI 7571:2010 the company has provisions against vibration and sound. For maximum standards PPV 2,5 mm/s and *SPL* 120 dB.

Scaled Distance Theory

Scaled Distance is used as a parameter for distance components with explosives in one delay time. This theory developed to state the relationship between the two variables. This theory is used as an analysis to find the price of a constant which will later be used as a prediction for the next detonation vibration(1,8). The equation is as follows:

(USBM)
$$SD = \left(\frac{D}{W^{\frac{1}{2}}}\right) \quad (2)$$

(Indian Standart)
$$SD = \left(\frac{W}{D^{\frac{2}{3}}}\right) \quad (3)$$

Langefors & Kiehlstrom
$$SD = \left(\frac{W^{\frac{1}{2}}}{D^{\frac{1}{3}}}\right) \quad (4)$$

Ambraseys-Hedron
$$SD = \left(\frac{D}{W^{\frac{1}{2}}}\right) \quad (5)$$

Information:
SD = Scaled Distance
D = Blasting distance to the measurement point (m)
W = Amount of explosives per *delay* (kg)

Correlation Theory

According to (Supardi 2013) that correlation is a term commonly used as a measuring parameter for the strength of a relationship in a variable to another variable. This correlation is a way to find out the presence or absence of relationships between the connected variables, for example the most common is the relationship between two variables.

RESEARCH METHODS

This study fully used indirect (secondary) data acquisition from the mining division office of PT. ITP. In this study also uses quantitative and comparative analysis methods, which in measuring the actual vibration obtained will be used quantifiable theory to analyze it. While a comparative analysis of how to compare the results of different models of the scaled distance equation.

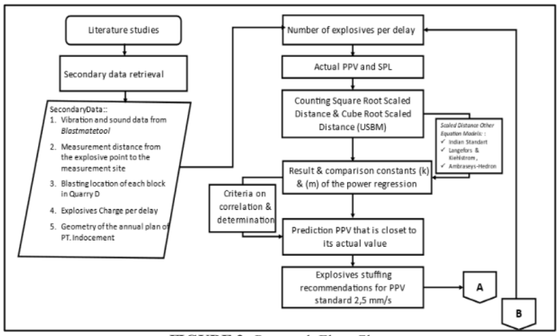

FIGURE 2. *Research Flow Chart*

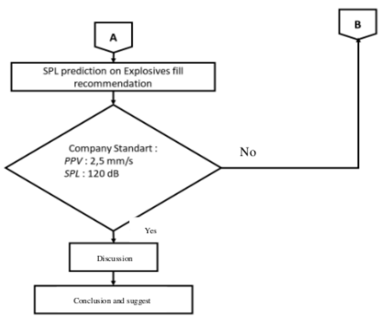

FIGURE 3. *Research Flow Chart (continued)*

RESULTS AND DISCUSSION

Actual Vibration Data

From the data collected from 2017 to 2021, several measurements passed the company's standard and SNI 7571: 2010.

TABLE 2. Vibration Measurement Criteria Above Standards

Date	Location	Explosives	Distance	PPV	Company Criteria	SNI 7571:2010 Criteria
		(kg/*delay*)	(m)	(mm/s)	(2.5 mm/s)	(3 mm/s)
1-sept-17	*Quarry D*	69,4	350	3,268	Not Safe	Not Safe
	Quarry D	69,4	350	3,262	Not Safe	Not Safe
2-sept-17	*Quarry D*	85,8	350	3,675	Not Safe	Not Safe
	Quarry D	94,6	350	3,953	Not Safe	Not Safe
	Quarry D	59,7	350	3,289	Not Safe	Not Safe
	Quarry D	72,4	500	2,533	Not Safe	**Safe**
20-sept-21	*Quarry D*	71,5	800	2,562	Not Safe	**Safe**

Explosives data per delay

Data obtained from PT. ITP is in the form of explosives for each segment in one blasting block, where each primer is filled with one detonator. The blasting pattern used hole by hole. Where it is calculated from the total explosives (kg) per segment divided by the number of holes per segment (Table 3).

Square Root Scaled Distance (SRSD)

Using equation (1) can be calculated square root scaled distance to determine the equation of prediction of future vibrations.

Relationship between PPV with SD

After obtaining the SRSD value, it is plotted with the actual ppv value and formed a graph from Microsoft Ecxel to obtain the power regression equation (Figure 4).

Relationship between PPV with SD various equation models

To better see which equation is more relevant to the state of blasting vibrations in PT mining. This ITP. Thus, counted other Scaled Distance models such as the Indian Standard, Langefors & Kiehlstrom, as well as the Ambraseys-Hedron. Then a regression graph is created to get the predictive equation of each Scaled Distance model.

TABLE 3. Explosives per delay

Date	Mining Block	*Tie Up*	Holes per Segment	Deto. Number	Explosives per segment (kg)	Explosives per delay (kg)
01-Sep-17	QD-BLOK II	*Hole by hole*	5	5	347	69,4
02-Sep-17	QD-BLOK II	*Hole by hole*	5	5	429	85,8
03-Sep-17	QD BLOK III	*Hole by hole*	5	5	119	23,8
03-Apr-18	QD BLOK II	*Hole by hole*	5	5	161,5	32,3
06-Apr-18	QD BLOK II	*Hole by hole*	10	10	481	48,1
07-Apr-18	QD BLOK II	*Hole by hole*	5	5	227	45,4
02-Dec-19	QD-BLOK II	*Hole by hole*	6	6	353,4	58,9
03-Jan-20	QD BLOK II	*Hole by hole*	5	5	121,5	24,3
10-Jan-20	QD-BLOK II	*Hole by hole*	5	5	236,5	47,3
13-Jan-20	QD-BLOK II	*Hole by hole*	5	5	277,5	55,5
14-Jan-20	QD-BLOK II	*Hole by hole*	5	5	278	55,6
15-Jan-20	QD BLOK III	*Hole by hole*	5	5	219	43,8
06-Sep-21	QD-BLOK II	*Hole by hole*	5	5	154,5	30,9
07-Sep-21	QD BLOK II	*Hole by hole*	5	5	227	45,4
08-Sep-21	QD BLOK II	*Hole by hole*	5	5	353	70,6
14-Sep-21	QD BLOK II	*Hole by hole*	5	5	278	55,6
20-Sep-21	QD BLOK III	*Hole by hole*	5	5	357,5	71,5

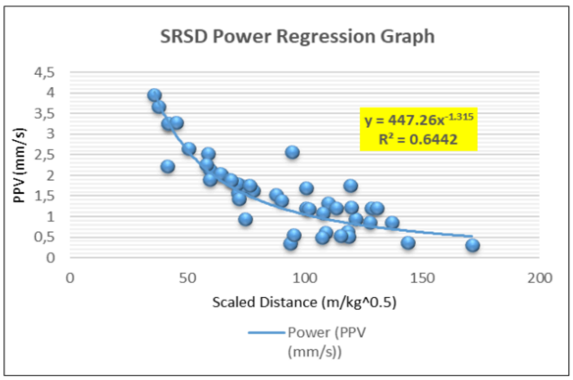

FIGURE 4. Graph of SRSD Power Regression

The graph of the power regression relationship at (Figure 4) states a price of the constants k and m which are vibration and sound factors at the study site. The prediction equation is as follows: (USBM)

$$PPV = k\ (SD)^{-m} \qquad (6)$$

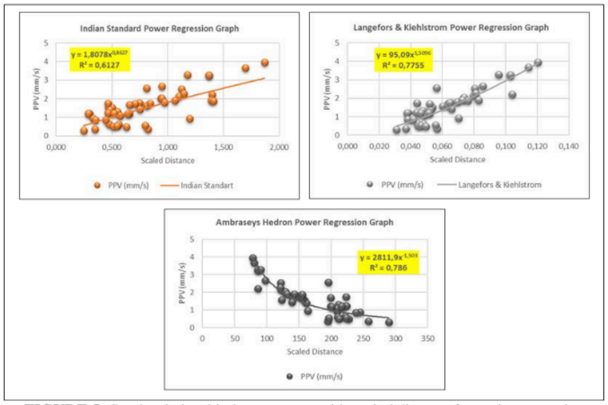

FIGURE 5. Graph relationship between ppv with scaled distance for various equation

When looking at Figure 5, it is obtained from the same method using the power regression method, by plotting between the actual ppv and the results of the Scaled Distance calculation for various equation models to get the power regression equation.

Power Regression Equation :
PPV = 447,26 (SD)^-0,863 (Indian Standart)
PPV = 2811,9 (SD)^-,503 (Ambraseys-Hedron)
PPV = 95,09 (SD)^-1,510 (Langefors & Kiehlstrom)

Comparasion of actual ppv with ppv prediction from various Scaled Distance models

Based on Figures 4 and 5, a comparative calculation is made between the actual PPV and the predicted PPV on all scaled distance models to show which equation is closest to the actual value.

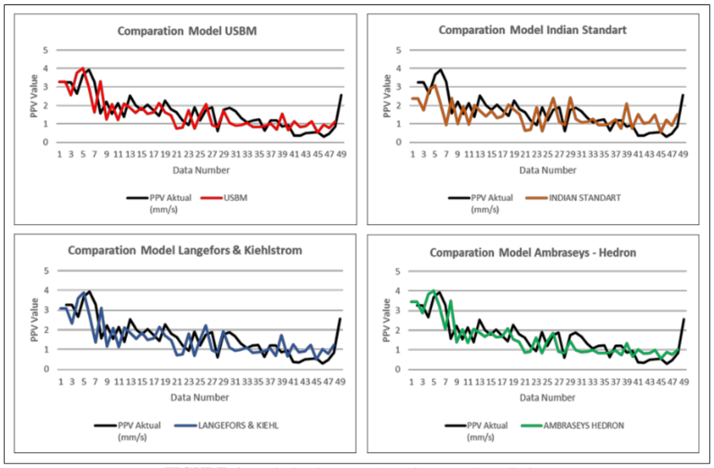

FIGURE 6. Deviation between Actual PPV and Prediction

Then from the graph, a percent correction calculation is carried out for each of these comparisons, to see which equation is closest to the value of its actual ppv (Table 4).

TABLE 4. Percent Correction between Actual PPV and Prediction

No.	Scaled Distance Models	Average Deviation (%)
1	USBM	30,948
2	Indian Standart	43,57
3	Ambraseys-Hedron	**29,92**
4	Langefors & Kiehlstrom	33,51

On the graph it can be stated that the smallest average percentage of each model of the *Scaled Distance* equation in predicting vibrations, then it can be concluded that the model of the Ambraseys-Hedron equation is the equation that is closest to the actual value of *ppv* at the state of blasting vibrations in PT. Indocement Tunggal Prakarsa.

Correlation and Determination

In analyzing vibration resistance using power regression methods, of course, it involves two important variables in an effort to predict future vibrations, before that it will be done how the criteria for the relationship between ppv and scaled distance (involving distance and explosives) in influencing pvv levels in Quarry D. This the criteria for correlation and its determination are made (Table 5).

In this correlation and determination analysis guideline, a simple study will be carried out on how factors affecting the level of vibration and sound occur from the actual PPV data in the field (9). A comparison was made between this study and previous researchers (1)

TABLE 5. Correlation Comparison and Determination

Researcher's Name	Data Type	Research Location	Correlation Coefficient (R)	Guidelines For Assessment	Coefficient Determination (R^2)	Degrees Relationships (%)
Didik Sudarmanto (1)	Limestone Vibrations	PT. Semen Indonesia Tuban, West Java	-0,842	**Very Powerful**	0,709	70,9%
	Grainstone Vibrations		-0,580	**Medium**	0,359	35,9%
Antonio Gabriel Felito Obe	Vibration Model Ambraseys-Hedron	PT.ITP Citeureup, West Java	-0,8136	**Very Powerful**	0,662	66,2%

Showing the correlation coefficient states a very strong guideline on limestone measurements with a relationship of 70.9% stating that the distance and amount of explosives affect 70.9% of ppv levels at the PT research site. Semen Indonesia, then in this study used the Ambraseys-Hedron model stated that the correlation coefficient was very strong according to the guidelines, while the relationship drajat was 66.2% in the condition of PT blasting vibrations. Indocement Tunggal Prakarsa.

Maximum Explosives Prediction

To calculate the maximum allowable explosives used the company's standard vibration reference with a PPV of 2.5 mm/s and for this calculation a model of the Ambraseys-Hedron SD equation was used, while for the sound standard used followed from the standard that the company had set, namely 120 dBL. To produce vibrations that are in accordance with these standards, a calculation is made in the prediction (10). With a variation in the distance of 50 meters from a distance of 50 meters to 1400 meters, the maximum explosive prediction results are as follows (Figure 7). The reference distance for offices and settlements in the boundary with a blue line to indicate what the maximum explosive needs are. The PPV standard of 2.5 mm/s was chosen to meet the reference of SNI 7571:2010 which states that settlements around the site are in the ppv class of 3 mm/s.

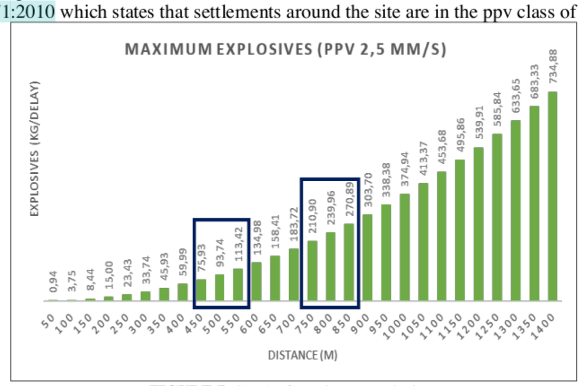

FIGURE 7. Graph of Maximum Explosives

CONCLUSION

Based on vibration data collected from 2017 to 2021, it is stated that it is in accordance with the SNI 7571:2010 standard and company standards according to residential and office buildings. The constant results obtained from the power regression graph state that the Square Root Scaled Distance with a value of k is 447.26 and m is -1.315 and for Cube Root Scaled Distance the value of k is 8757.1 and m is -0.999. Because there is an office distance of about 500 meters, a maximum explosive charge of 101.62 kg/delay can be used per delay to meet the 2.5 mm/s ppv standard (according to company standards). From the results of the calculation and comparison of the PPV prediction with the actual, it states that the Ambraseys-Hedron equation model produces the smallest percentage of correction (difference).

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