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IMPACT OF BLASTING WITH ELECTRONIC DETONATOR USING SEGMENTATION AND NON-SEGMENTATION METHODS

DAMPAK HASIL PELEDAKAN DENGAN DETONATOR ELEKTRONIK MENGGUNAKAN METODE SEGMENTASI DAN NON-SEGMENTASI

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ABSTRACT

Sebuku Tanjung Coal, a mining company, has a blasting location close to the building structures. This building is included in the Class 2 building on SNI 7571:2010 with a maximum peak vector sum (PVS) value of 3 mm/s or peak particle velocity (PPV) value of 3 - 7 mm/s at the frequency of 0-100 Hz. Several critical areas are located between 200 and 700 meters from the blasting location. The used initiation system is Hanwha Electronic Blasting System 2nd Generation (HEBS II), which uses HiMex 70 (emulsion) as an explosive type. In this paper, the tie-up design of blasting uses segment and non-segment methods to compare the results of blasting using the two methods. Based on 16 compared data points, the vibration results obtained using segment and non-segment had a value range of 2,767-15,102 mm/s. The average result of the digging time using the segment method is 10.9 seconds, while the non-segment method takes 10.3 seconds. The average size of fragmentation (D80) with the segment method is 49.1 cm, while the non-segment method is 45.4 cm.

Keywords: segment, non-segment, vibration, electronic detonator, blasting.

ABSTRAK

Sebuku Tanjung Coal adalah sebuah perusahaan pertambangan yang memiliki lokasi peledakan berdekatan dengan struktur bangunan. Struktur bangunan tersebut termasuk ke dalam bangunan Kelas 2 menurut SNI 7571:2010 dengan maksimal nilai peak vector sum *(PVS) sebesar 3 mm/s atau nilai* peak particle velocity *(PPV) sebesar 3-7 mm/s pada frekuensi 0-100 Hz. Beberapa area kritis berada pada jarak 200-700 m dari lokasi peledakan. Sistem inisiasi yang digunakan adalah* Hanwha Electronic Blasting System 2nd Generation *(HEBS II) dengan kombinasi HiMex 70 (*Emulsion*) sebagai jenis bahan peledaknya. Penelitian ini, menerapkan rangkaian peledakan metode segmen dan non-segmen untuk membandingkan hasil peledakan kedua metode tersebut. Berdasarkan 16 data yang dibandingkan, didapatkan hasil getaran menggunakan segmen dan non-segmen dengan kisaran 2.767-15.102 mm/s. Rata-rata hasil digging time menggunakan metode segmen sebesar 10,9 detik, sedangkan menggunakan metode non-segmen sebesar 10,3 detik. Rata-rata ukuran fragmentasi (D80) dengan metode segmen sebesar 49,1 cm, sedangkan dengan metode non-segmen sebesar 45,4 cm.*

Kata kunci: segmen, non-segmen, getaran, detonator elektronik, peledakan.

INTRODUCTION

Construction activities such as blasting, piling, compaction, excavations, and construction traffic can produce vibrations of sufficient strength to cause damage to neighboring buildings and structures. However, building damage assumed to originate from vibrations are seldom observed. This may indicate that today's limit values are unnecessarily strict

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(Norén-Cosgriff *et al.*, 2020). Ground vibrations are moving waves on the surface caused by the presence of energy source (seismic waves). These energy sources come from nature, such as earthquakes or the existence of human activities, including the blasting activities (Cheng *et al.*, 2019). Blasting vibrations that can cause damage to surrounding buildings and structures belong to subject surface waves (Rayleigh and Love Waves) from waste energy that does not work to fracture the rocks (Kumar, Choudhury and Bhargava, 2016). In blasting activities there are controllable parameters such as tie-up design, charge weight per delay, type of explosives, initiation type, etc. The parameters that cannot be controlled are geological conditions, rock characteristics, weather, etc. Nowadays, to manage controllable variables in ground vibration, blasting technology has been updated to reduce the environmental impact using electronic detonators with high accuracy of delay timing. When assessing the performance of blast timing, the current practice indicates that the performance should be evaluated according to the reliability of the individual detonator (Silva, Li and Gernand, 2018).

One of the latest electronic technologies introduced is Hanwha Electronic Blasting System 2nd Generation (HEBS II), an electronic detonator that uses an Android-based application and makes the handling and operation process easier. The HEBS II chip has an accuracy or precision up to 0.02% for blasting between the holes with a maximum delay of 50,000 ms. Delay combination can be adjusted based on the delay time device of the system contained in the electronic detonator. The HEBS II research used segment and non-segment coupling methods at the blasting location.

This research was carried out at Pit T3 at Sebuku Tanjung Coal Mining in Indonesia. From the two methods, comparisons will be made, including: 1) the value of ground vibration for evaluating the impact of blasting; 2) the average value of blasting fragmentation; and 3) the performance of the digger, which produces the value of digging time as an evaluation of productivity performance. Previous research by Kekre, Patankar dan Galiyal, 2013; Silva-Castro dan Li, 2018; Silva, Li dan Gernand, 2018; did not focus on conducting a research on the value of ground vibration close to the building structure in coal overburden blasting and the used methods were different.

The use of applications using segmentation and non-segmentation methods for overburden coal blasting design tie-up is one of the improvements in the comparison of the two methods. This paper is the result of a study to see blasting performance close to the building structures and optimize the blasting results such as ground vibration value, coefficient of determination based on multiple linear regression, fragmentation, size uniformity, and digger performance.

METHODOLOGY

This study took place at the Hillcon Jayasakti site, Sebuku Tanjung Coal, and was carried out from January to April 2022. The data collection process was based on quantitative data using primary data. The blasting activity at this location uses an electronic detonator as the initiation system combined with emulsion as bulk explosives. Making improvements to the design of blasting tie-ups and delay timing using segmentation and non-segmentation methods. The processing data is based on the scale distance analysis and the multiple linear regression. Furthermore, the results of the analysis of data processing can be applied to the next blasting activity so as to optimize blasting performance. The results of the evaluation of the blasting performance obtained were ground vibration values, coefficient of determination, fragmentation size, size uniformity, and digger performance of the Komatsu PC-2000 excavator.

Segmentation and Non-Segmentation Test

The use of the segment approach is predicated upon employing an electronic detonator, which can be configured to the desired delay duration. In contrast to non-electric detonators, the delay is inherently incorporated into the detonator as a standard feature. Hence, acquiring research data pertaining to segments and non-segments is appropriate for the utilized detonator. The notion of linear superposition is employed to explain the phenomenon wherein many waves propagate simultaneously in a given medium that results in the displacement of particles inside such a medium. The resulting deviation is determined by calculating the algebraic sum of the positive and negative deviations for each wave. The phenomenon being referred to is often known as the superposition principle. Linear superposition is a fundamental notion in the wave theory, whereby several waves with varying phases travel simultaneously in a shared medium and time, possessing identical amplitudes and wavelengths. As a consequence of this principle, the resulting deviation is nullified (Pradatama, Pradasara and Nurdiansyah, 2019).

When designing blasting tie-ups using the segmentation approach, the blasting tie-up location is split into the multiple segments as needed by adding a long delay in the designated segment area (Figure 1).

In the context of blast tie-up design, the utilization of the non-segmentation approach is exemplified in Figure 2. This method involves the execution of the blasting operation whereby a single blasting hole shot is conducted without any intervals between the blasting holes.

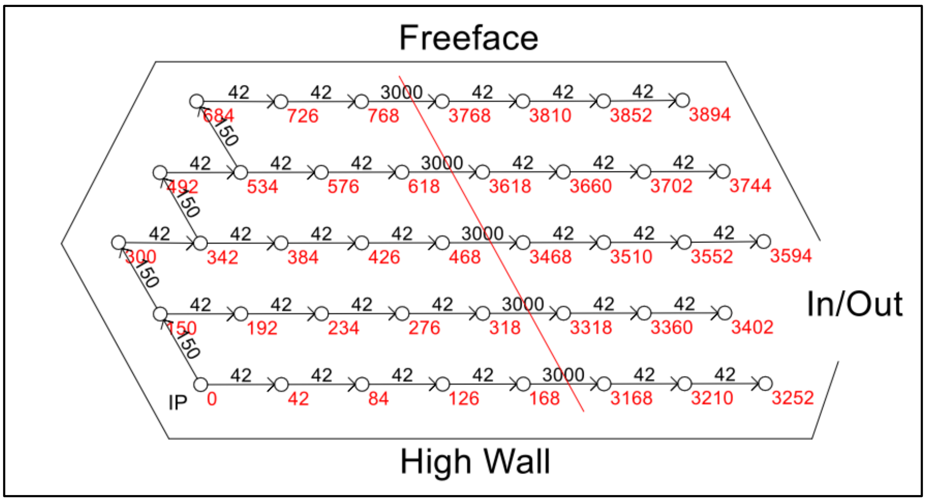

Figure 1. Tie-up design for segmentation methods

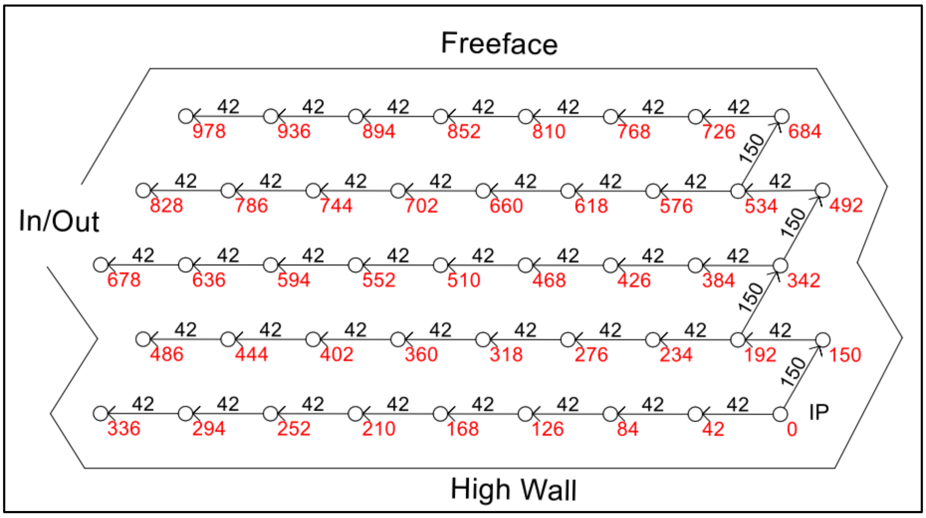

Figure 2. Tie-up design for non-segmentation methods

Scale Distance and Peak Particle Velocity

Scaled distance is a parameter for the distance dimension. It is expressed as a ratio between the distance and charge of the explosive affects the results of vibrations and explosive energy on the surface. The value of scale distance is used to predict the PPV by considering the site constant value. Its formula was popularized by Duval and Fogelson (1962) (Lawal *et al.*, 2021).

$$SD = \frac{D}{\sqrt{W}} \quad (1)$$

Where:

SD = Scale Distance ($m/kg^{1/2}$)

D = Distance from the center of the blasting site to the measuring unit (m)

W = Charge weight per delay (kg)

The Site Constant (K,b) is the constant value of the blasting site that is affected by geological conditions, geological structures, water, and measurement/mounting location. K represents the initial energy transferred from the explosive to the surrounding rocks. B is a slope factor that induces the attenuation rate of the PPV caused by the geometric spreading and the influence of rock characteristics. K and b values are obtained using Scale Distance regression analysis. (Faramarzi, Ebrahimi Farsangi and Mansouri, 2014).

$$PPV = K \times SD^{b} \quad (2)$$

Where:

PPV = Peak Particle Velocity (mm/s)

K, b = Site Constant

Multiple Linier Regression

Multiple Linear Regression is a visual model of linear regression involving more than one independent variable or predictor.

$$Y = \alpha + \beta 1\ X2 + \beta 2\ X2 + \beta n\ Xn + e \quad (3)$$

Where:

Y = Variable response

X = Variable predictor

α = Constant

β = Coefficient estimate

Fragmentation Size and Digging Time

One of the success rates of the blasting process is the percentage of fragmentation distribution and uniformity of fragmentation size (Sanchidrian, 2022). The analysis process of fragmentation results is processed using the *WipFrag software version 3.3.14* (WipWare, 2018). Processing digging time uses the *Cycle Pro software version 1.0.1*. Value of this digging time is an evaluation of the digger tool performance for optimizing the value of productivity and cycle time. The digger uses a Komatsu PC-2000 excavator and the hauler uses a Komatsu HD-785.

RESULTS AND DISCUSSION

PPV Limit for Structure Building

The laws pertaining to ground vibration threshold values for building structures in Indonesia are established according to SNI 7571:2010. These values are quantified in terms of peak particle velocity, with the units of measurement expressed in millimeters per second (Badan Standardisasi Nasional, 2010). The displacement value, measured in millimeters, characterizes the motion of particles on the surface and the maximum amplitude of vibration resulting from a singular blasting event. The Sebuku Tanjung Coal Mine is situated close to some areas of interest, as observed in the field. The area of concern is classified as a class 2 building according to the Indonesian National Standard (SNI) 7571:2010. A maximum peak velocity (PVS) value of 3 mm/s and a maximum peak particle velocity (PPV) value of 7 mm/s are the highest vibration levels that are allowed. The data presented in Tables 1 and 2 represents visually the information.

Segmentation and Non-Segmentation

Blast induced ground vibration in and around the mines has become a serious environmental issue. From the perspective of the mining industry, it is a critical issue that needs to be properly addressed. With restrictions being imposed by the local councils, the vibration monitoring has become an essential part of the mine operation (Jayasinghe *et al.*, 2019). The process of measuring ground vibration in the field using the Micromate from Instantel Company can be seen in Tables 3 and 4 (Instantel, 2014).

Table 1. Indonesian standard for ground vibration (PVS)

Class	Building Type	Peak Vector Sum (mm/s)
1	Ancient buildings protected by cultural heritage laws (Law No. 6 of 1992)	2
2	Buildings with foundations, masonry, and cement mortar only, including wooden foundation buildings and the floors are given cement mortar	3
3	Buildings with foundations, masonry, and cement mortar are fastened with concrete slopes	5
4	Buildings with foundations, masonry, and mortar cement slope concrete, columns, and frames fastened with ring balk	7-20
5	Buildings with foundation, masonry and cement mortar, concrete slopes, columns and fastened with steel frames	12-40

Source: Badan Standardisasi Nasional (2010)

Table 2. Indonesian standard for ground vibration (PPV)

Class	Frequency	Peak Particle Velocity (mm/s)
1	0 – 5	2
	5 – 20	3
	20 – 100	5
2	0 – 5	3
	5 – 20	5
	20 – 100	7
3	0 – 5	5
	5 – 20	7
	20 – 100	12
4	0 – 5	7
	5 – 20	12
	20 – 100	20
5	0 – 5	12
	5 – 20	24
	20 – 100	40

Source: Badan Standardisasi Nasional (2010)

Scale Distance and Multiple Linier Regression

Based on 8 comparisons between segment and non-segment data, it is obtained a graph of the scale distance effect on the PPV value. The equations obtained from the graphs are related to the predictions of the contents of the segment and non-segment methods. Based on the graph above, the coefficient of determination of segment is 81.3% and that of non-segment is 89.5%. The two-coefficient values state that the effect of the scale distance value on the PPV value is large. The parameters of the distance and the total explosive charge are directly proportional. The value of the coefficient of determination means that the variable x (scale distance) has a strong influence on the variable y (PPV) and, that the variable x has the ability to provide all the information needed to predict the variable y. Meanwhile, the values of 10.5% and 18.7% are the remainder that are influenced by other variables as seen in Figure 3 and 4.

Table 3. Segmentation measurement result

No	Date	Location	Total Holes	MiC (kg)	Distance (m)	PPV (mm/s)	PVS (mm/s)	Scale Distance
1	7/12/21	RT4 Karetan	115	65	566	3.247	3.351	70.2
2	22/12/21	RT4 Karetan	36	102	510	4.233	4.272	50.5
3	15/3/22	RT3 Bu Misna	65	115	300	11.113	11.891	28.0
4	18/3/22	RT4 Karetan	59	112	485	5.596	5.692	45.8
5	26/3/22	RT3 Bu Misna	40	108	421	10.570	10.653	40.5
6	28/3/22	RT4 Karetan	90	118	456	6.045	6.469	42.0
7	5/4/22	RT3 Bu Misna	57	115	263	12.934	12.685	24.5
8	8/4/22	RT3 Bu Misna	40	104	260	14.231	15.879	25.5

Table 4. Non-segmentation measurement result

No	Date	Location	Total Holes	MiC (kg)	Distance (m)	PPV (mm/s)	PVS (mm/s)	Scale Distance
1	5/12/2021	RT4 Karetan	69	63	584	2.767	3.277	73.6
2	11/12/2021	RT4 Karetan	38	105	496	3.334	4.058	48.4
3	5/2/2022	RT3 Bu Misna	65	116	320	12.753	14.470	29.7
4	4/2/2022	RT4 Karetan	54	110	460	4.327	6.195	43.9
5	10/2/2022	RT3 Bu Misna	22	105	420	9.821	11.880	41.0
6	4/2/2022	RT4 Karetan	54	117	460	4.327	6.195	42.5
7	19/2/2022	RT3 Bu Misna	59	112	278	14.093	14.124	26.3
8	8/2/2022	RT3 Bu Misna	44	108	265	15.102	16.015	25.5

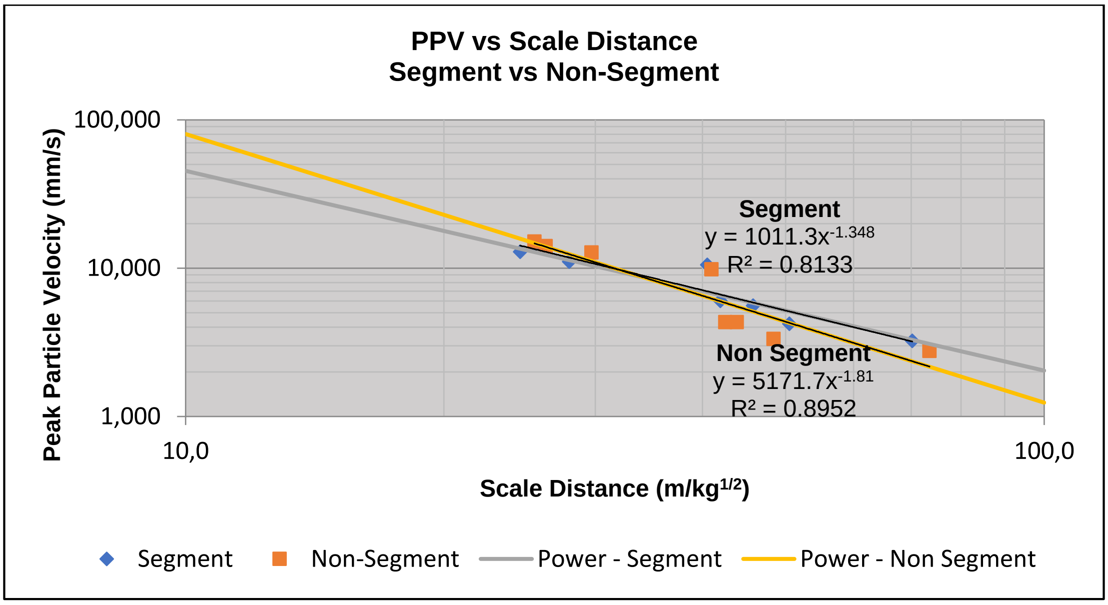

Figure 3. PPV vs scale distance

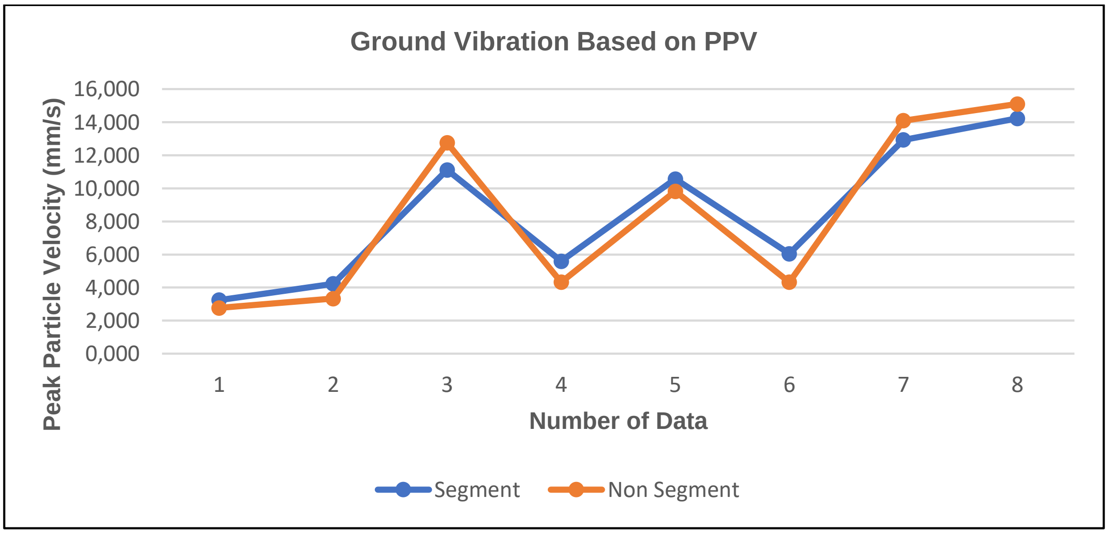

Figure 4. Segment vs non-segment at PPV limit 7 mm/s

Fragmentation Size and Digging Time

Based on collection of 16 data points, it can be observed that the mean fragmentation size (D80) in the first layer is 45.4 cm for non-segmented samples and 49.1 cm for segmented samples. The outcome successfully met the objective of being less than 60 cm. The fragmentation size (D80) of the segment has a higher value compared to that of the non-segment. This phenomenon occurs due to the extended duration between the segments, leading to suboptimal contact among the blast holes. The level of regularity in fragmentation size is 1.36 for segments and 1.51 for non-segments. The non-segment fragmentation size uniformity value exceeds that of the segment indicates that the utilization of the non-segment approach for achieving fragmentation uniformity is preferable. This phenomenon is observable in Figure 5.

Duration of excavation activities was analyzed using the Cycle Pro software, specifically version 1.0.1. The assessment of the temporal investment in excavation serves as a means to appraise the efficacy of the digging apparatus in enhancing efficiency and reducing the duration of each operational cycle. A Komatsu PC-2000 excavator serves as the excavation tool, and a Komatsu HD-785 transporter facilitates the transportation of materials. Based on the collected and analyzed data, it has been determined that the mean duration for excavation by the Komatsu PC-2000 is 10.3 seconds for non-segments in the initial layer, while for segments in the initial layer, the average time is 10.9 seconds. It exists as a discrepancy of 0.6 seconds between the two calculated averages. The data conforms the specified requirement of 12 seconds. The data arfe visually represented in Figure 6.

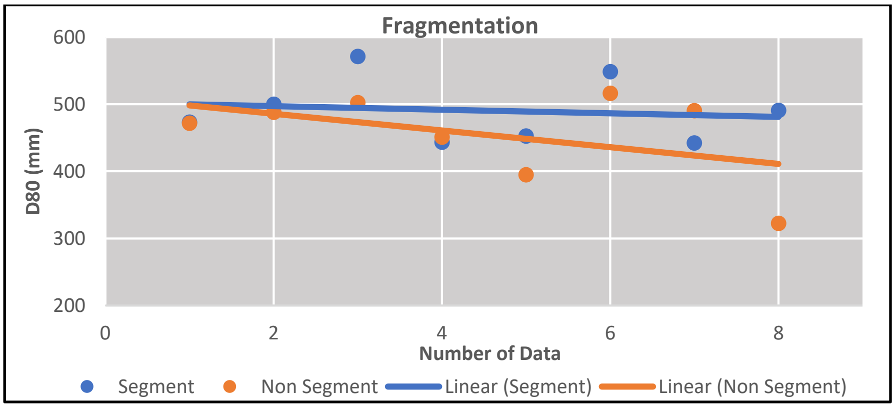

Figure 5. Surface fragmentation segment and non-segment

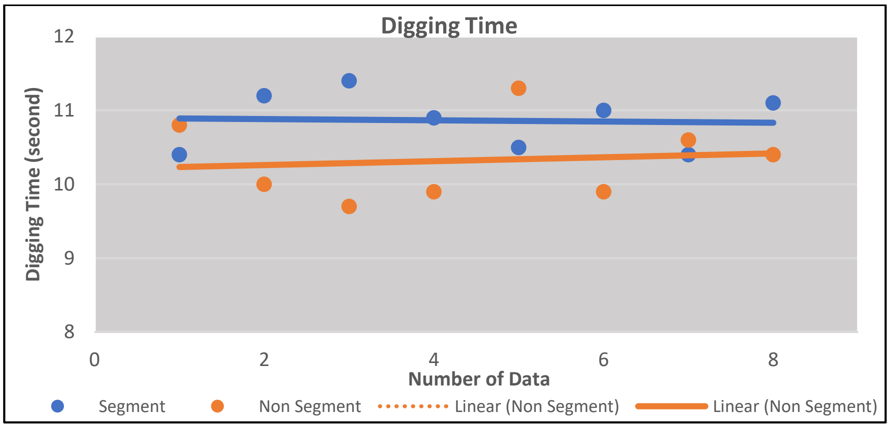

Figure 6. Digging time segment and non-segment

CONCLUSION

Based on the results obtained from this research, the following conclusions were obtained:

1. Peak Particle Velocity (PPV) results from 16 blasts using non-segment and segment reached 50% below 7 mm/s with a range of 2,767 – 15,102 mm/s. The use of segments produces vibration data five times higher than non-segments from the eight blast data compared. These data show that the use of electronic detonators with segments can reduce vibrations by 18.8%. This is directly proportional to previous research conducted by (Handayana *et al.*, 2022). By using pyrotechnic detonators, the explosion process is limited to a maximum of 25 holes with segment delays and the use of electronic detonators effectively reduces the vibration value up to 21.5% which is applied to the limestone mines.
2. The coefficient of determination obtained from the segment method was 81.3% and the non-segment was 89.5%. These two coefficients of determination values indicate that the vibration prediction value has a strong relationship.
3. The average excavation time of the Komatsu PC-2000 is 10.3 seconds for the non-segments in the first layer and 10.9 seconds for the segments in the first layer.
4. The average size of fragmentation (D80) is 45.4 cm in the first layer for non-segments and 49.1 cm in the first layer for segments.

With the information from comparing blasting techniques that use segmented and non-segmented approaches, it was found that using non-segmented approaches is better for reducing the effects of blasting activities on both the environment and the work site, with the goal of improving blasting operations. Using non-segments can potentially reduce the effects of ground vibration, fragmentation, and digging time

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