Journal Techno, Vol. 9, No.1, 2023, pp. 027 - 038
ISSN. 2461-1484

DIGGING TIME DECREASION ON THE BLASTING OF OVERBURDEN EXPLOSION GEOMETRY OVERVIEW

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ABSTRACT

This study aimed to evaluate the geometric design the P80 or Passing 80% of rock fragments and the digging time of equipment for sandstone overburden blasting with rock density, 2.43 kg/m^3. As a basis for the results of observations on the current geometric design with a burden of 9 m, spacing of 9 m, and a depth of blast holes of 8 m, problems were found in the results of rock fragments that did not meet the criteria with the size of the rock fragments P80, 79.24 cm, the digging time of loading, 13.03 second and an average powder factor of 0.24 kg/m^3. To obtain more uniform rock fragments is to improve the blasting geometry, so the energy distribution can be even that rock fragments and better digging time can be obtained in sandstone. The blasting geometry design which is proposed to improve fragmentation, 8 m; burden, 9 m; spacing; 3.5 m stemming; and 8 m blast hole depth with a column filled explosives of 4 m and the number of perforated explosives is 163.2 Kg, with powder factor, 0.28 kg/m^3. The proposed blasting geometry produces suitable rock fragment. P80 is 39.93 cm and average digging time of 10.61 seconds.

Keywords: *Overburden, digging time, blasting.*

INTRODUCTION

PT. Saptaindra Sejati (PT. SIS) is one of the business units of PT. Adaro Energy Tbk provides mining services, particularly overburden removal and transportation, coal transportation, and mine reclamation activities to various companies in Indonesia, including PT. Berau Coal (PT. BC) Binungan site located in Berau District, East Kalimantan Province. Blasting is the basis for overburden stripping carried out by PT—the Binungan SIS site, where the operation uses an open pit mining system. The monthly coal acquisition target is 1 million tonnes, with 12.5 million tonnes of cubic meters per month of overburden stripping.

The blasting geometry at Pit D2 is burden, 9 m, and spacing, 9 m. The target powder factor set for a blast hole > 10 m is 0.25 kg/m^3, with the fragmentation result of the P80 being at a size of 50 cm and the target digging time for the loading equipment is 12 seconds. The problem in the field is that, in rock layers with a density of 2.12-2.43 g/cm^3, the 9 m burden geometry and 9 m spacing need to produce an appropriate target for blasting fragmentation targets. The digging time of the loader for the percent passing 80% (P80) > 50 cm, as determined by the company, is 12 seconds. Therefore, it is necessary to repair the fragmentation.

Research Purposes

The three objectives of this study are (a). Observation of fragmentation distribution resulting from blasting and digging time of loading equipment in Pit D2; (b). Improvement of blasting geometry according to rock conditions so that the targets of fragmentation and digging time of loading equipment are met, and; (c). Evaluation of distribution of rock fragmentation resulting from blasting after repairing fragmentation and digging time by applying blasting geometry according to rock conditions.

Calculation of rock fragmentation distribution using photography with Split-desktop software. The detonation method is non-electric (none), using emulsion explosives. The drilling pattern is staggered with a powder factor of 0.25 kg/m^3.

Research Methods

Several stages in this research are (a). Literary Studies; (b). Field observations include geological conditions, blasting geometry, blasting patterns, blasting processes, blasting results, and observation boundaries; (c). Data sampling includes secondary data and primary data. Secondary data includes rock mass characteristics, topographic and geological maps, climate and rainfall, and mine planning maps. The primary data are

- the actual blasting geometry,
- the weight of the explosives used,
- the size of the fragmentation resulting from the blasting, and
- the digging time of the loading equipment.

Stemming (T), which can be found as 0.7 of the burden length, is formulated in detail by Jimeno (1995) as,

$$T = 0{,}13176 \times De \times \left(\frac{ST_v}{SG_r}\right) \quad (1)$$

In this case, De is the diameter of the blast hole; STv is the relative bulk strength of the explosive (Kj/m), and SGr is the specific gravity of the rock that can be demolished.

Powder factor is the value of the ratio between explosives (kg) to blasting material (m3) or,

$$PF = \frac{pc \times de \times n}{v} \quad (2)$$

Which *pc* is the length of charge per blast hole (in meters), de is the loading density (kg/m), n is the number of blast holes, and the volume of rock blasted (m3) is denoted as v.

We are processing data using a computer and statistical analysis. The data processing of rock fragment distribution utilizes Split-desktop software. Observing the actual blasting geometry is analyzed to find out the causes of mismatched fragmentation targets.

GENERAL REVIEW

PT. BC has a Coal Mining Concession Contract Agreement (PKP2B) with a concession area of 118,400 Ha. It located in Berau Regency, East Kalimantan Province, in five sub-districts: Gunung Tabur, Segah, Teluk Bayur, Tanjung Redeb, and Sambaliung. The geographic position is at coordinates 117°7'48" - 117°38'18" East Longitude and 1°52'24" - 2°25'6" South Latitude.

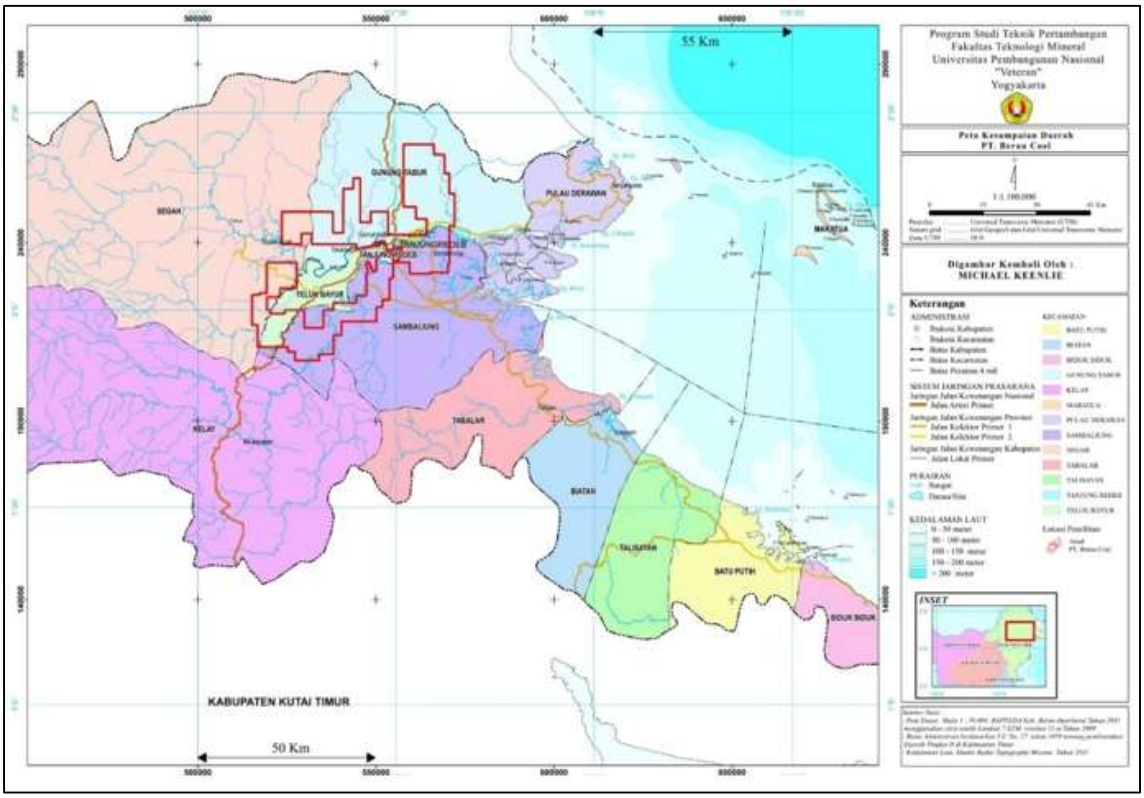

Figure 1. Map of Location and Coverage of Research Areas

RESEARCH RESULT

Rock Mass Characteristics

The characteristics of the rock mass can be seen from the physical properties and mechanical properties of the layers, where the condition of each type of rock varies. The physical properties of overburden pit D2 are rock density, where the layer types consist of mudstone, siltstone, and sandstone. Of the three layers, the most dominant is sandstone. Therefore, the value of the uniaxial compressive strength of the rock layers, as shown in Table 1, row two, column three, is 14.04 MPa.

Drilling uses a staggered pattern in which the blast holes are 200 mm in diameter and 6.5 to 8 m deep. Blasting geometry includes burden, spacing, stemming, sub-drilling, powder charge, and blast-hole depth. The blasting design is adjusted to field conditions, especially the characteristics of the rock mass and the type of explosives used. This blasting aims to obtain good rock fragmentation so that the loading and unloading equipment can dig and load according to the expected production target.

Table 1. Parameter Properties of Pit D2 PT. BC.

Lithology	Physical Density r^2 (gr/cm^3)	USC (Unconfined Compressive Strength)		
		σ_c (MPa)	E (MPa)	υ
Sandy Mudstone	2,29	11,89	1757,5	0,3
Sandstone	2,43	14,04	2492,2	0,2
Mudstone	2,16	12,74	1655,2	0,3
Muddy Sandstone	2,12	8,15	1453,5	0,3

The design of each blasting geometry is burden (B), 9 m; space (S), 9 m; stemming (T), 3.5 m; sub drilling (J), 0.5 m; powder charge (PC), 4 m; blast hole depth (H), 8 m, and; ladder height (L), 7.5 m. The explosives used are Emulsion brand Trojan 4070 with a density of 1.15 g/cc, detonation energy, 2.8 MJ/kg, Relative Weight Strength (RWS), 0.75, and detonation speed of 4817 m/s. The blasting method uses non-electric (none) streaks between holes. The detonator uses an in-hole delay of 500 ms and a surface delay varying between 25 ms, 67 ms, and 109 ms. The initiation point uses an electronic delay detonator connected to the surface delay: echelon pattern blasting, Box Cut, and V-Cut. The target powder factor set is <0.25 kg/m3. A column two of Table 2, five powder factor values meet the target, namely, blasting 0403-D with values (0.2 kg/m^3; 0903-D (0.24 kg/m^3); 1903-F (0.24 kg) /m^3); 2103-F (0.19 kg/m3); and 2203-F (0.23 kg/m^3).

Table 2 Powder Factor and Fragment Size Distribution with 80% Passing

Detonation code	*Powder Factor* (kg/m^3)	Depth (m)	Rock fragmentation, P80 (cm)
2802-F	0,26	6,50	68,03
0103-F	0,26	6,50	72,34
0403-D	0,20	8,00	85,06
0803-F	0,26	6,70	94,61
0903-D	0,24	6,50	124,90
1003-E	0,26	7,00	78,58
1903-F	0,24	8,00	56,96
2003-D	0,27	8,00	70,73
2103-F	0,19	6,50	74,59
2203-F	0,23	6,50	66,65
Average		7,02	79,25

The value of rock fragments, based on Table 2, also appears to vary with an average of 79.25 cm, which is 124.9 cm, and the smallest is 56.96 cm. Rock fragments, as well as column four, none of which meet the requirements of less than 50 cm.

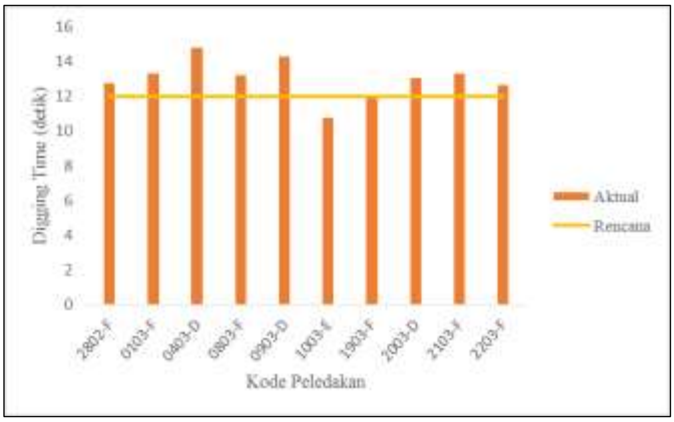

Figure 2. Digging time histogram of Load Truck

Digging Time of Blasted Rocks

The purpose of blasting is to remove rock that diggers cannot dismantle. After being scattered, the blasted material is excavated and loaded into a dump truck for transport. The diggers used in this case vary, namely the Backhoe Komatsu PC 2000 and the Backhoe Komatsu PC 1250. All these tools have a target digging time that must be met, as shown in Figure 2, namely 12 seconds.

Table 3. Digging Time and Relative Error for Excavator

Detonation code	*Digging Time* (second)	Relative error (%)
2802-F	12,74	6,17
0103-F	13,35	11,25
0403-D	14,83	23,58
0803-F	13,20	26,67
0903-D	14,28	19,00
1003-E	10,78	10,17
1903-F	12,06	0,50
2003-D	13,06	8,83
2103-F	13,35	11,25
2203-F	12,68	5,67
Average	13,03	10,28

Note: The size of the burden and the spacing for each blasting is 9 m. Depth of each blasting as column three Table 2.

The success rate of applying the blasting geometry design is based on the relative error of the experiment with the digging time error tolerance, 12 ± 1 second, or the maximum relative error value of 8.33%. Based on Table 3, out of 10 trials, there were six trials that had a relative error of > 8.83%, so the success rate of applying the 9 × 9 pattern based on digging time was 40%.

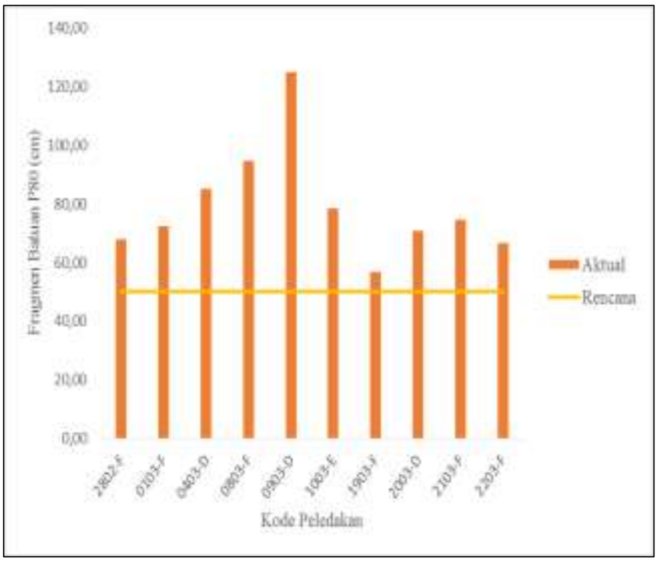

Figure 3. Histogram of P80 Percent Rock Fragment Distribution

Proposed Blasting Geometry

Efforts to improve rock fragments to maximize the distribution of blasting energy are carried out by making a blasting geometry design, namely reducing the burden and spacing values. Four trials were carried out to determine the success rate of rock fragment repair in overburdened Pit D2. The actual blasting geometry data in the field are as follows: Burden = 8 m, spacing = 9 m, stemming = 3.5 m, sub drilling = 0.5 m, powder charge = 4 m, depth of blast holes (H) = 8 m, and ladder height = 7.5 m.

DISCUSSION

Evaluation of Blasting Geometry

The current blasting geometry is the geometry with a burden and a spacing of 9 m × 9 m. In this condition, it was found that the size of the P80 rock fragments was > 50 cm, so the digging time of the digging tool was > 12 seconds.

Distribution of Rock Fragments based on Split-desktop Software

Table 4 shows the P80 rock fragments and digging time using split-desktop blasting geometry software with burden and spacing, 9 m × 9 m.

The digging time of the equipment was varied; the average was 10.61 seconds, with the most significant value being 11.31 seconds and the smallest being 10.12 seconds. One of the factors causing the target not to match is the condition of the material to be detonated. Based on observations, there is white stone material (sandstone) which has a rock density of 2.43 gr/cm^3.

Table 4. Distribution of P80 cm Rock Fragments and Digging Time

Detonation code	Depth (m)	Rock fragmentation, P80 (cm)	*Digging Time* (second)
0204-E	8,00	35,97	10,12
0304-F	6,50	44,78	11,31
0504-D	8,10	34,92	10,20
0804-E	5,70	44,04	10,81
Average	7,08	39,93	10,61

Note: The length of burden and spacing are 8 m and 9 m, respectively.

Distribution of Explosion Energy Using Jksimblast Software

The application of blasting geometry for sandstone with a rock density of 2.43 gr/cm^3 needs to be revised. This situation can occur because P80 rock fragments are still found, and the digging time of the excavator loads above the set target, which is less than 12 seconds. The failure to achieve the target fragment < 50 cm and the digging time of the digging equipment < 12 seconds was due to the uneven distribution of blasting energy. One of the reasons is that the distance between burdens and spaces is too large (Figure 4).

Improvement of Rock Fragment Distribution

Several discussions related to improving the distribution of rock fragments and digging time to match the expected target include:

Blasting Geometry

As to determine the blasting geometry to improve the quality of blasting results as Konya and Walter (1990) that, the burden and spacing used are 9 m and 9 m, respectively, derived from a trial with consideration of the analysis of the coverage area of blasting energy. Based on the calculation of the value of the S/B ratio is 1 with the percentage of the area affected by the blasting energy, 78.5%. In this case, there is still a boulder area with a radius of 22.5% of the blasting energy spread.

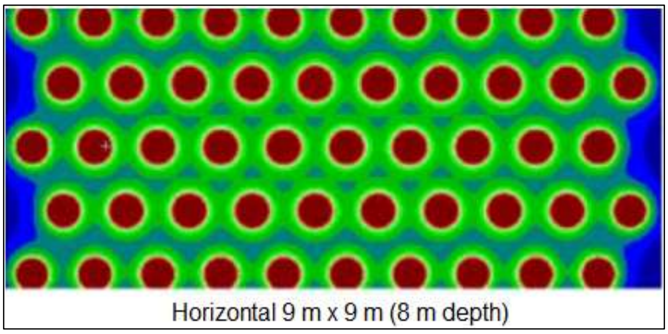

Figure 4. Simulation of the Explosion Energy Distribution with a Geometry of 9 m × 9 m × 8 m.

The theoretical ratio of the blasting geometry is 6.2 m, with a spacing of 7.05 m. The S/B ratio value of the blasting geometry is 0.897, where the percentage of area affected by blasting energy is 89.261%.

Table 5. Comparison of Actual Blasting Designs

Parameter	Actual	Konya and Walter (1990) base	Proposal
Diameter	0,2	0,2	0,2
Burden	9	6,2	8
Spacing	9	7,05	9
Stemming	4	4,06	3,5
level height	7,5	13	7,5
Sub-drilling	0,5	1,7	0,5
fill column	3,5	4	4
Blast-hole depth	8	14,8	8
Powder Factor	0,25	0,63	0,28
Delay time	109	61,6	109

By looking at the 10.76% difference in energy coverage percentage values, the actual blasting geometry is not that far apart. Burdens and spaces with sizes 8m and 9m can be applied in the field. In addition, applying geometry based on the Konya and Walter (1990) approach could be more effective because the burden distances and spacing are too short, causing the number of blast holes to increase and the use of explosives to increase. Improving the blasting geometry by reducing the bud by 1 m without changing the value of stemming, sub-drilling, and delay time is necessary.

Stemming

Especially when there is a confined condition where high explosives affect stemming, confined conditions cause stemming ejection, which affects the energy loss of detonation, which in turn causes flyrock and airblast during detonation. An effort to avoid this is calculated against the blasting energy's relative confinement level.

Scale depth of Burial (Livingston, 1956) is a method for determining the relative confinement value of blasting energy, that is, the ratio between absolute depth and explosives. The stemming of an 8 m blast hole is 4 m. The Scale depth of Burial (Sd) calculation yields a value of 1.15 m/Kg, which means it is still in the controlled energy category. Suitable values for Sd range from 0.92-1.4 m/kg (Chiapetta, 2004).

In order to maximize the stemming height in order to obtain an appropriate target distribution of rock fragments, the results of the Scale Depth of Burial calculation are substituted with the middle value in the Sd range, which is still included in the controlled energy, namely, between 0.92 to 1.4 m/kg.

Powder Factor

Changes to spacing, burden, and stemming will increase the powder factor. The size of the powder factor used will affect the rock fragmentation produced in blasting activities. The greater the powder factor, the smaller the rock fragmentation. Conversely, the smaller the powder factor, the greater the rock fragmentation. The powder factor in the current blasting geometry is 0.25 kg/m3, while the proposed powder factor is 0.30 kg/m^3.

Subdrilling

The sub-drilling applied in the field is 0.5 m, while according to Konya and Walter (1990), the sub-drilling length is 1.5 m. Subdrilling that is too small will result in uneven floors or undulation. In comparison, the sub-drilling value that is too large can potentially reduce the gain of blasting activity. The sub-drilling length of 0.5 m produces a flat-level floor and does not interfere with the conveyance activities.

Effect of Delay Time on Rock Fragment Distribution

Delay time in blasting aims to control blasting energy during blasting so that blasting energy can provide optimal results in rock breaking. Simultaneous detonation results in high detonation energy, so ground vibration is also high, resulting in high airblast and fly rock. In order to prevent the simultaneous detonation of each blast hole, it is necessary to arrange the initiation of successive detonations. In successive blasting, the direction of detonation can be controlled in a particular direction, and each blast hole also plays an influential role in controlling the movement of the muck pile. The successive detonation pattern through the delay time setting will allow a new free face to form. It can happen due to rock mass displacement in the blast hole that exploded previously. Thus, the detonation load borne by the subsequent blast hole becomes smaller. Simultaneous blasting energy is expected to produce an appropriate distribution of rock fragments.

Ignition detonation uses a novel detonator system with an in-hole delay of 500 ms; the surface delay on the control line is 67 ms, and on the echelon is 109 ms. Based on calculations by Konya and Walter (1990), the delay time constant is 3.69 m/feet. This value causes the blasting results to have a high muck pile average, and there are airblasts and back breaks on the blasted slopes. Using a short delay causes no free fields to form, so the distribution of rock fragments becomes unfavorable. Applying a delay time of 109 ms in the field is appropriate to obtain the distribution of rock fragments according to the criteria. Distribution of Proposed Blasting Energy Using JKsimblast Software

The results of the distribution of rock fragments at 80% passing (P80) and the digging time of the digger for the application of blasting geometry with burden and spacing, 9 m × 9 m on sandstone which has a density of 2.43 gr/cm^3 still does not match the 80% passing target < 50 cm and the digging time of the digging tool is <12 seconds. This is because the detonation energy is not evenly distributed.

Improvements to the trial blasting geometry as a proposal are 8 m × 9 m, where for sandstone rock types with a rock density of 2.43 gr/cm3, the blasting energy distribution is analyzed using the Jk-Simblast software. It can be seen in Figure 5 that the blasting energy for the blasting geometry on the burden and spacing of 8 m × 9 m is distributed more evenly than the blasting energy for the geometry of the blasting with the burden and spacing of 9 m × 9 m.

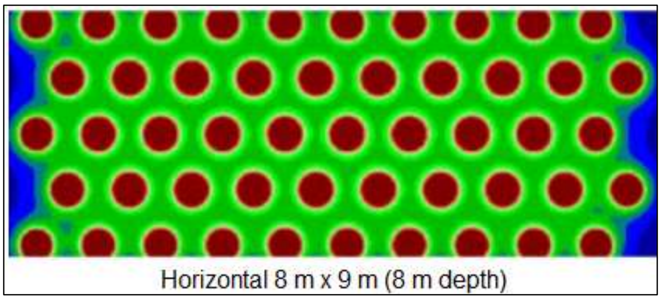

Figure 5. Simulation of the Explosion Energy Distribution with a Geometry of 8m × 9m × 8m

Distribution of Rock Fragments After Improved Blasting Geometry

Applying the proposed blasting geometry with a burden of 8 m and a spacing of 9 m for sandstone rock types with a rock density of 2.43 gr/cm^3 obtained the results of the rock fragment distribution of 80% passing and digging time, as shown in Table 4.

As the basis of the trial results in the field using the proposed blasting geometry with burden and spacing of 8 m × 9 m, there is an average reduction in the size of 3.93 cm and an average digging time of 10.61 seconds. An indication of the success of P80 rock fragments is the occurrence of 80% passing rock fragments < 50 cm and digging time < 12 seconds.

Correlation of Rock Fragments to Loading Tool Digging Time

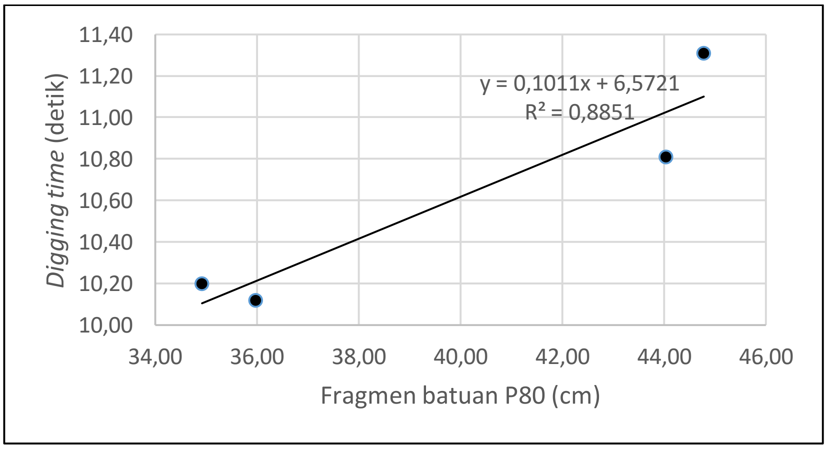

Figure 6. Graph of Digging Time Relationship to P80 Rock Fragments

Figure 6 shows the distribution of the relationship between the P80 rock fragments and the digging time (seconds) graph, which mathematically, the linear regression approach produces the equation, $y = 0.1011\ x + 6.5721$, and the coefficient of determination, 0.8851. This value indicates that the success rate is 80.51%, while the remaining 11.49% is the failure rate which other factors may influence for unknown reasons.

CONCLUSION

Some conclusions that can be drawn are that the application of a blasting geometry of 9m × 9m × 8m results in a distribution of rock fragments that do not meet the criteria with a passing size of 80% (P80) with an average of 79.24 cm and an average digging time of 13.03 sec. The blasting geometry design for repairing sandstone rock fragments with a rock density of 2.43 gr/cm^3 is 8 m burden, 9 m spacing, 3.5 m stemming, and 8 m blast hole depth with an average powder factor of 0.28 kg/m^3. Applying the proposed blasting geometry design with a geometry of 8 m × 9 m × 8 m produces an average distribution of rock fragments for passing 80 of 44.24 cm and an average digging time of 11.15 seconds.

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