ANALYSIS OF EXPLOSIVE ENERGY DISTRIBUTION AT PIT 7 WEST PT. MAKMUR MANDIRI UTAMA BINUNGAN SUARAN - BERAU, EAST KALIMANTAN PROVINCE

ANALISIS DISTRIBUSI ENERGI BAHAN PELEDAK DI PIT 7 WEST PT. BUKIT MAKMUR MANDIRI UTAMA BINUNGAN-SUARAN - BERAU, PROVINSI KALIMANTAN TIMUR

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ABSTRACT

Blasting geometry and blasting material filling are closely related to the rock mass characteristics and the geological conditions to obtain ideal fragmentation. Blastability Index analysis, including Description of Rock Mass, Combined Plane Spacing, Combined Plane Orientation, Specific Gravity Influence-y, and Hardness, are the alternative geometry experiment conducted to overcome the problem of rock fragmentation so that the speed of excavation equipment can increase according to the productivity of Komatsu PC2000 plan at PT. BUMA Jobsite BINSUA. Furthermore, the actual rock values obtained from blasting location and alternative geometry recommendations using R.L.Ash theory combined with Vertical Energy Distribution theory. In the C2 layer with a rock factor value of 5.95, the recommended load is 7.2 m, space is 8.3 m, and the VED explosive power is 48%. In layer D2 the rock factor value is 6.89 with a load of 7.5 m, space of 8.3 m, and 55% VED explosive charge. While in the DU layer, the rock factor value is 6.39 with a load of 7.3 m, 8.4 m space, and 51% VED filling of explosives. Prediction of blasting fragmentation analysis using Kuz-ram theory obtained fragmentation > 100 cm, namely 14.99% for the C2 layer, 14.84% for the D2 layer, and 14.82% for the DU layer.

Keywords: blastability index, fragmentation, blasting geometry, R.L.Ash, VED.

ABSTRAK

Geometri peledakan dan pengisian material peledakan erat kaitannya dengan karakteristik massa batuan dan kondisi geologi untuk mendapatkan fragmentasi yang ideal. Analisis Blastability Index *yang meliputi Deskripsi Massa Batuan, Jarak Bidang Gabungan, Orientasi Bidang Gabungan*, Specific Gravity Influency, *dan* Hardness, *adalah eksperimen geometri alternatif yang dilakukan dengan tujuan untuk mengatasi masalah fragmentasi batuan sehingga kecepatan peralatan galian dapat meningkat sesuai dengan produktivitas rencana Komatsu PC2000 di PT. BUMA Jobsite BINSUA. Selanjutnya nilai batuan aktual yang diperoleh dari lokasi peledakan dan rekomendasi geometri alternatif menggunakan teori R.L.Ash yang dipadukan dengan teori Distribusi Energi Vertikal. Pada lapisan C2 dengan nilai faktor batuan sebesar 5,95, beban yang direkomendasikan sebesar 7,2 m, ruang sebesar 8,3 m, dan daya ledak VED sebesar 48%. Pada lapisan D2 nilai faktor batuan sebesar 6,89 dengan beban 7,5 m, ruang 8,3 m, dan daya ledak VED 55%, sedangkan pada lapisan DU nilai faktor batuannya sebesar 6,39 dengan beban 7,3 m, ruang 8,4 m, dan pengisian bahan peledak 51% VED. Prediksi analisis fragmentasi peledakan menggunakan teori Kuz-ram diperoleh fragmentasi > 100 cm yaitu 14,99% untuk lapisan C2, 14,84% untuk lapisan D2, dan 14,82% untuk lapisan DU.*

Kata kunci: blastability index, *fragmentasi, geometri peledakan,* R.L.Ash, VED.

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INTRODUCTION

Open-pit mining is a surface mining technique and directly in contact with the air. In open-pit mining, the overburden removal carries out to get the coal at mining area of PT. Bukit Makmur Mandiri Utama Jobsite Binungan-Suaran. The overburden was a blasting method. The blasting method has been chosen because the rock hardness value is high. It cannot be directly dismantled by a free-digging method or a ripping and dozing method.

The blasting separates the material from the source rock in generating the fragmentation size that can facilitate further mining activities (Saptono *et al.*, 2016). The success of blasting is indicated from the production targets that were fulfilled, the efficiency of using explosives to obtain the volume of unloaded rock (powder factor), and rock fragmentation blasting from blasting process with little chunks (<15% with rock dimensions of 100 cm). In addition, successful explosion has a rock surface that is stable and flat (no cracks, overhangs, or fissures), generally safe (compatible with standard operating procedures), and has a minimum environmental impact (rock flying, ground shaking, air bursts, poisons and gases) (Bhandari, 1997; Naveen *et al.*, 2016; Hidayat, 2021).

The blasting process during overburden demolition at PT. Bukit Makmur Mandiri Utama Jobsite Binungan Suaran is still dissatisfactory. Compared to the successful blasting parameters such as fragmentation, digging time, powder factor, fly-rock, ground vibration, and air blast; the blasting process is different from the standard one. Based on the observation, three out of six parameters that do not suit the blasting success parameters include fragmentation, digging time, and powder factor.

The stripping removal (both overburden and inter-burden) has been carried out at one of the mines in PT. Bukit Makmur Mandiri Utama Jobsite Binungan Suaran, specifically in Pit 7 West. According to the report "The effect of insufficiency productivity from loading devices" issued in January - March, the hard material and the boulder fragmentation from blasting were ranked in the eighth position with 222 reports over the last three months as shown in Figure 1.

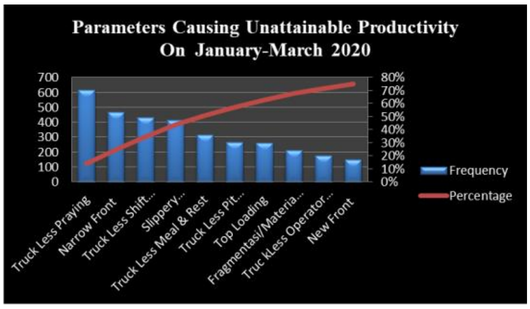

Figure 1. Pareto diagram of factors causing unattainable productivity

Based on the analysis results taken from the Pareto diagram towards the hard material as shown in Figure 2, three interburden layers have a top three percentage as D2, C2, and DU seams in Pit 7 West.

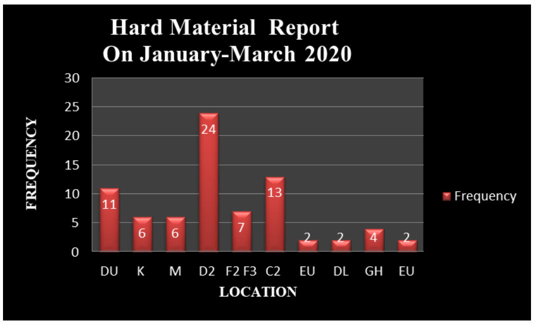

Figure 2. Location analysis of unattainable productivity

Based on the observation conducted by the writer at PT. Bukit Makmur Mandiri Utama Jobsite Binungan Suaran, several explosions produced fragmentation categorized as a boulder. The writer analyzed the blasting fragmentation using the software Split-desktop 2.0 and found that the fragmentation of 100 cm is 20 - 30%. Nevertheless, the company expected the fragmentation was 1/3 of the size of the loader used by Komatsu PC200, with the ideal fragmentation being 100 cm < 15% used by Koesnaryo (2001).

There is also a blasted hard material on the second layer that cannot be loaded by the loader Komatsu PC2000. The solid material showed up due to the explosives energy that is not maximal in blowing up the rocks, so the unexposed part produces hard material. It can also reduce the diggability of loading equipment, even leaving residual material that affects the production target.

The parameter that determines the excavation rate and excavator productivity results from rock fragmentation after blasting, where the company sets the productivity at 718 Bcm/hour. As a result, the expected digging time to reach productivity is 12 seconds, but the actual digging time to extract the blasted material is 14.81 seconds making the excavator productivity is unattainable. The ideal fragmentation also depends on the maximum distribution of the explosive energy while rocking. The larger the size of rock fragmentation from the explosion will make it more difficult for the digging tool to dig up the rock, reducing the productivity of the digging tools. Meanwhile, the smaller the blasted size of rock fragmentation, the easier it will be for the excavator to dig up the rock. However, obtaining a fragmentation that matches the bucket size for the digging and loading equipment takes many costs. Obtaining the distribution of explosive rock size fragmentation based on the excavator bucket size must consider the suitability of the blasting geometry and rock conditions. That is because the coal seam in Pit 7 West is a multi-seam, and there are about 18 active seams with a slightly upright angle of the seam (51 degrees). Hence, the inter-burden layer has rock mass characteristics and different geological conditions, that depends on the conditions and affect the sedimentation process.

In determining the blasting geometry, it has to start from the load, distance, length of the fill column, stemming, surface height, sub-drilling, the depth of the blowhole, and the powder factor. It must consider the rock mass characteristics and the geological conditions that exist in each layer. Nonetheless, there has been no study on the actual conditions regarding the rock factor at each layer.

According to the condition above, the writer thought it was necessary to investigate the rock mass characteristics and the geological conditions to determine blasting geometry. Consequently, the writer conducted the research entitled *Blasting Geometry Technical Studies based on Blastability Index Analysis to Achieve Ideal Fragmentation Targets and Diggability of Komatsu PC2000 on Hard Material D2, C2, and DU Seam at PIT 7 West PT. Bukit Makmur Mandiri Utama Jobsite Binungan-Suaran, Berau Regency, East Kalimantan Province.* The results of this study are expected to provide the success information of blasting carried out by PT. Jobsite Bukit Makmur Mandiri Utama Binungan-Suaran, in case it will make the company can determine which the suitable blasting geometry can be used.

LITERATURE REVIEW

Research Sites

The research location is at PT Bukit Makmur Mandiri Utama Jobsite Binungan-Suaran, located in Labana Makarti Village, Teluk Bayur, Sambaliung District, Berau Regency, East Kalimantan Province which coordinates at 02º 00 '50.53 "NL to 02º 02' 00.67" NL and 117º 19 '58.27 "East Longitude to 117º 25' 59.36" East Longitude. This job-site located about 51 km from the city of Tanjung Redep, Berau, or approximately is 691 km from Balikpapan city, Suaran based on searches using the Google Earth Pro Software as can be seen in Figure 3 below. The data were collected at Pit 7 West on the inter-burden seam layers C2, D2, and DU as shown in Figure 4 below.

Research Data

The research data was taken from the rock mass description parameter (blastability index) including: 1) The description of the rock mass, which was taken by measuring the fracture space in the blasting area and obtained the rock quality design in percent; 2) The image of the joint mass seen in the fracture/fracture space obtained in the blasting area; 3) The orientation of the Joint Plane is seen from the rock layers that occur in the blasting area; 4) The effect of specific gravity is taken from the density of the rock being blasted and; 5) The hardness which can be measured by the hardness of the blasted rock (Lilly, 1987).

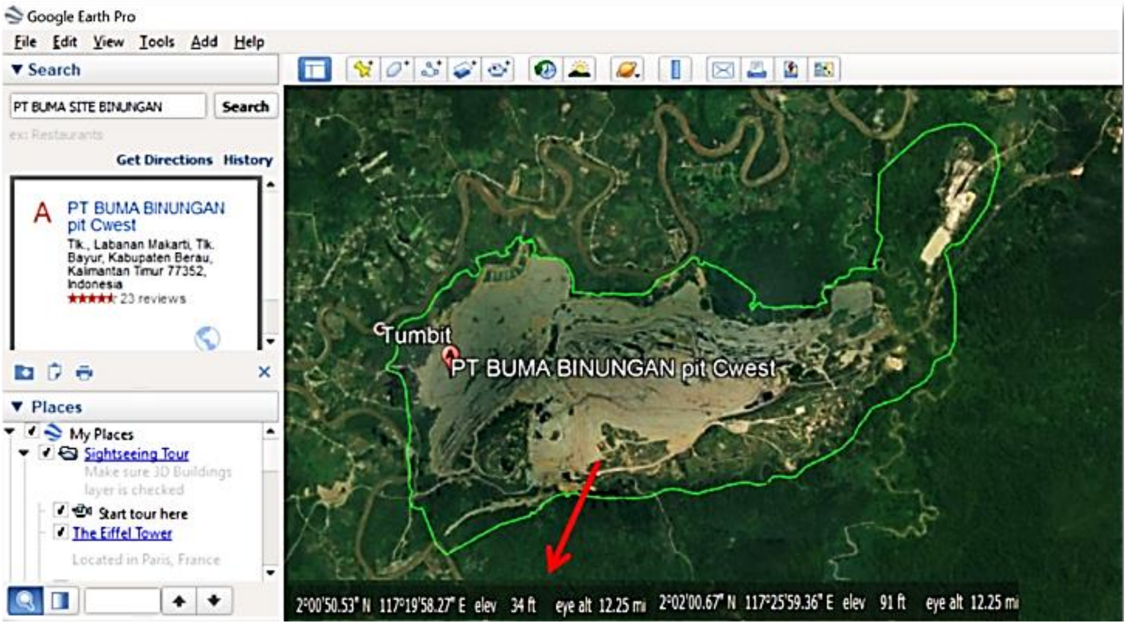

Figure 3. Map of PT. Bukit Makmur Mandiri Main Jobsite Binungan-Suaran, Berau, East Kalimantan

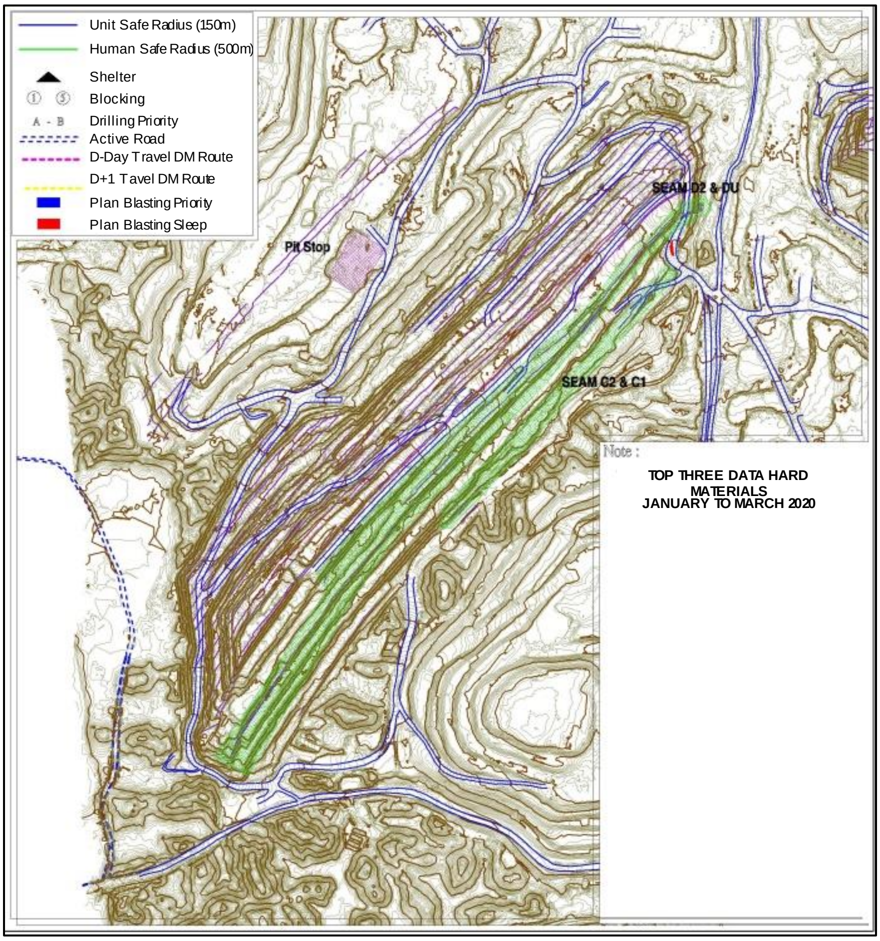

Figure 4. Research locations of the interburden seams C2, D2, and Du

The activity in blasting covers burdens, distance, depth of blast holes, loading density, powder factor, steeming, time delay, hole diameter, blasting patterns, initialization patterns, fragmentation images. The excavator cycle time data was the data taken by the researcher in this study (primary data). The purpose of collecting image fragmentation data is to be analyzed by split desktop software (the percentage of material that passes through a 100 cm filter) as the Komatsu PC2000 Loader size. The analysis example can be seen in Figure 5 and Figure 6.

Figure 5. Before delineation

Prediction of Kuz-Ram Fragmentation

Estimation based on the Kuz-Ram method regarding the size distribution of blasting fragmentation requires several data inputs, including rock factors, blasting geometry, and the number of explosives. This model uses the first equation (1) to find the mean particle size (Xm).

$$Xm=A \times \left\{\frac{V_o}{Q}\right\}^{0.8} \times Q^{0.1667} \times \left\{\frac{E}{115}\right\}^{-0.63} \quad \text{........ (1)}$$

The equation consists of rock factor data (A), the volume of uncovered rock (m3) (Vo), weight of explosives (Q), and RWS of explosives (ANFO = 100). The next step is to look for the size characteristics (Xc) using the second formula (2) then determine the rock uniformity index using the third formula (3), then perform calculations to find the percentage of rock size using the Rossin Ramler equation in the fourth formula

$$Xc= \frac{x_m}{0.693^{1/n}} \quad \text{... (2)}$$

$$n= \left[2.2-\left(\frac{14B}{d}\right)\right] \times \left[1-\left(\frac{W}{B}\right)\right] \times \left[1-\left(\frac{1+\frac{S}{B}}{2}\right) \times \left(\frac{PC}{H}\right)\right] \quad \text{...................................... (3)}$$

$$R=e^{-\left(\frac{x}{X_c}\right)^n} \quad \text{... (4)}$$

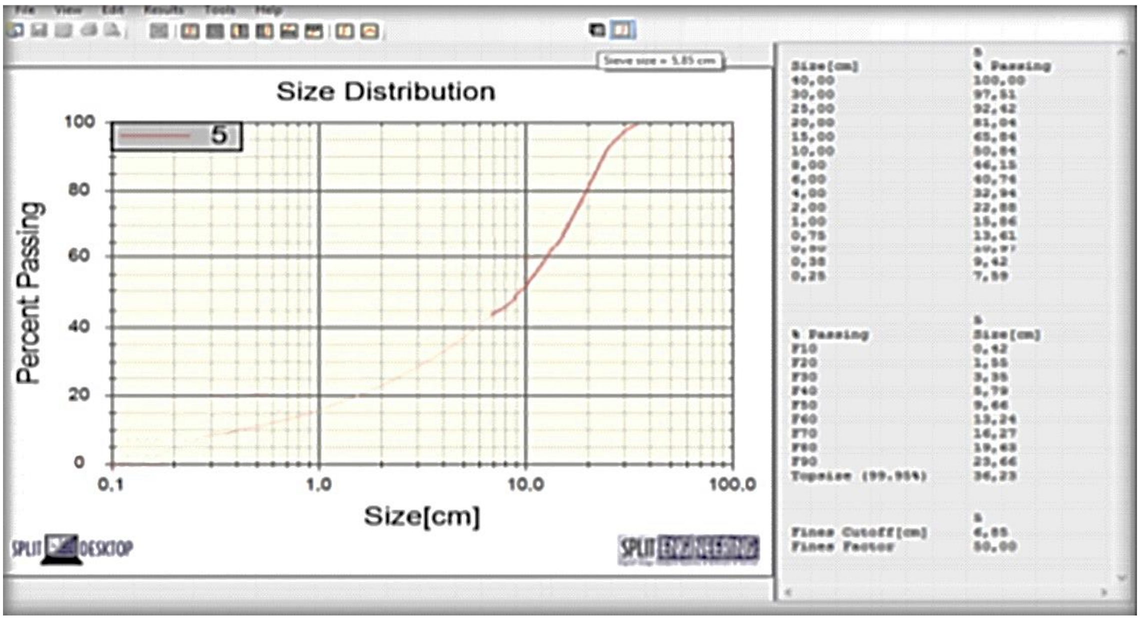

Figure 6. Output of fragmentation analysis results with split desktop software

Blastability Index Analysis

Lilly (1987) Blastability Index (BI). The index is an empirical method of linking geological characteristics with the effectiveness of rockbreaking with bulk explosives. The second objective was to use rock mass classification to inform perimeter blast design with the BI as an indicator of potential rock response. Unlike mechanical and numerical approaches, rock mass classification features the use of empirical relationships between the rock mass and the design applications. The third objective was to develop an empirical control index linking rock mass characteristics and wall control design input factors to various design outputs. Control of the western highwall (WHW) of the Cut H pit has proven to be challenging in that the designed catchment berms and wall competence have been perpetually unachievable, from the pit crest to the current mining levels. This has exposed the mining operation to safety hazards such as the local wallrock failure from the damaged crests, the frozen toes, and the rolling rockfalls from the higher mining levels. The standoff distances from the concerned highwall have increased, which has reduced the available manoeuvring area on the pit floor. The factor of extraction that is safely achievable has also reduced as mining cannot fully advance to the planned pit limit. The study seeks to investigate the application of rock mass classification and the BI as a means to improve wall control (Segaetsho and Zvarivadza, 2019).

The effect of the stated parameters can be summarized as follows: BI value has determined from the sum of the weights of the five parameters, namely rock mass description (RMD), joint plane spacing (JPS), joint plan orientation (JPO), specific gravity influence (SGI) and hardness (H).

Rock mass description (RMD)

RMD is a spatial parameter used to determine the quality of the rock mass by considering the rock structure and its muck pile. The RMD is categorized into three classes, namely brittle (powderylfriable), block structure (blocky), and very dense (total massive).

Joint plane spacing (JPS)

JPS is the perpendicular distance between two consecutive weak planes, in which the rocks will have a thick layer if the distance between the weak planes is getting farther away. In contrast, the sedimentary rocks will have a small distance. Based on the RQD value, the distance between the weak fields can be determined by calculating the field frequency value per meter using the Prist & Hudson equation (Lilly, 1987).

Joint plane orientation (JPO)

In a blasting operation, the orientation of the main weak area to the rock mass can result in the following:

1) Horizontal (discontinuity orientation parallel to the free area), producing controlled slope stability and throw direction;
2) Dip Out of Face (orientation of the area to the pit), causing unstable slopes and producing an excessive back break;
3) Normal to face strike (discontinuity angular orientation to the free area) will produce the yellow surface and excessive damage;
4) Dip into Face (the orientation of the discontinuity area to the rock mass), causing toe not to crush and interfere with the rock potential.

Specific Gravity Influence (SGI)

SGI is a property of rocks in terms of specific gravity and priority. Rocks with low bulk density are generally more deformable and require less blast energy to fracture. Porosity indicates the number of pores in a rock, while the large rock porosity indicates a large spacing between rock grains. The increased porosity inhibits the propagation of shock waves within the bedrock, inhibits the formation of new cracks, and produces larger rocks.

The mechanical properties of rocks are related to their strength, such as uniaxial compressive strength and rock hardness. The uniaxial rock compressive strength measures the rock's ability to withstand loads or forces acting in the uniaxial direction. The amount of pressure required to cause damage to the rock can be expressed in terms of hardness. For instance, in the blasting process, rocks with high hardness and high uniaxial compressive strength will tend to be more difficult to destroy and vice versa, so an explosive with greater power is required to break it down.

All of these factors are used as rock mass weighting data for blasting to obtain rock factor values from the explosion index (BI). The relationship between the five parameters is used like the following equation:

BI= 0.5 (RMD + JPS + JPO + SGI + H) …. (5)
Source: Hustrulid (1999)

Digger Load Productivity

The calculation of cycle time in this study uses the 16th equation (16) sourced from Eugine P. Fleider (1972) in Ananda and Anaperta, 2019).

Ctm = Tex + Tswl + Tdu + Tswe .... (6)

Ctm : excavator cycle time (seconds);
Tex : time excavating or digging (seconds);
Tswl : swing loaded time (seconds);
Tdu : dumping time (seconds);
Tswe : time to swing empty (seconds).

Then, the calculation of digging rate and productivity is finished with equation numbers (7) and (8).

Digging Rate = Bucket Capacity (Bcm) x 3600/Cm .... (7)

Productivity = Digging Rate x PA x UA ..... (8)
Source: Rocman Hadi (1992) in Putri (2018)

Design of Blasting Geometry Proposal

The proposed blasting geometry design uses blastability index analysis, namely blasting geometry design with geomechanical parameters (Hidayattullah and Heriyadi, 2019), and R.L. Ash combines VED. The theory of R.L Ash (1967) made a guideline for calculating the level blasting geometry by considering correction factors for the position of rock layers, the state of the geological structure, as well as corrections to the number of blast holes detonated (Putri, 2018).

From the previous research, making the proposed geometry design is also necessary to analyze the contents of the explosives that take into account the rock factor and the fragmentation of the blasting product (Zhang *et al.*, 2020). So that in the recommendation of the blasting geometry, the author uses the theory of R.L Ash (1967) combined with the VED theory (Vertical Energy Distribution).

Vertical Energy Distribution (VED) is the energy generated from the blasting process that can be distributed vertically in the rock mass. The VED value is obtained by the formula:

$$VED= \frac{Pc}{H} \times 100\% \ .... (9)$$
Source: (Drill and Blast)

If the rock mass is to be blasted hard from top to bottom, it is better if the VED value is more than 80% to produce evenly distributed fragmentation values. The VED reference that can be used based on the Stiffness Ratio value can be seen in Figure 7.

METHOD

Research Design

Research design/research type

Sugiyono, (2014) says, "Research is a scientific way based on scientific characteristics to obtain data with a specific purpose or use." This is applied research, which is conducted about the practical realities, application, and development of science produced by basic research. The main purpose of applied research is to find solutions that can be directly applied to solve the problems.

Research time

Collecting the data on April 1 - June 30, 2020 with the details of April 1 - April 14, 2020 is the field observations, April 15 - May 30, 2020 for collecting the data (primary-secondary data), and June 1 - June 15, 2020 for field data processing.

Research sites

The research was conducted at PT Bukit Makmur Mandiri Utama Jobsite Binungan-Suaran, in Labana Makarti Village, Teluk Bayur, Sambaliung District, Berau Regency, East Kalimantan Province, with the coordinates 02º 00 '50.53 "NL to 02º 02' 00.67" NL and 117º 19 '58.27 "East Longitude to 117º 25' 59.36" East Longitude. Data was especially collected at Pit 7 West in the inter-burden seam layers C2, D2, and Du.

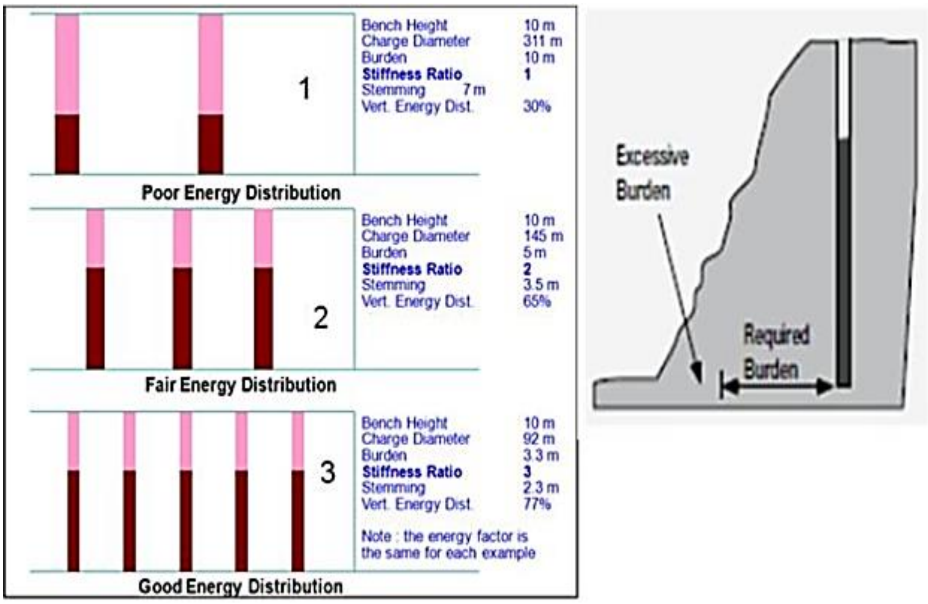

Figure 7. Relationship between stiffness ratio and VED

Types and Sources of Research Data

The data needed in this study are grouped into two types, namely primary data and secondary data. On one side, the primary data in this study were taken from observations and laboratory tests, such as actual slope geometry, rock samples for testing the physical and mechanical properties of rocks, and measurement of slope discontinuity conditions in the field. On the other side, the secondary data comes from company research reports, company brochures, related agency data, and also from literature (lithology, topographic maps, geological maps, and rainfall data).

Data Collection

Data collection technique in the preparation of this study is collecting and combining various supporting data for the development of this research. Data were collected by making direct observations that fit with the existing literature.

Data Analysis

1) Rock geomechanical parameter data is processed based on blastability index analysis and weighting according to actual field conditions and on data from rock mechanics laboratory tests.
2) The blasting geometry data is processed into Microsoft Excel and then the actual deviation from the area is calculated.
3) Data from blasting fragmentation are processed in two ways, namely theoretical and actual. The former were processed using the Kuz-Ram theory, and the later was processed using a split desktop program.
4) Digging and cycle time data are processed to obtain digging rate values.
5) The statistical analysis used is a simple linear analysis to obtain an equation that describes the relationship between rock factors based on blastability index analysis with blasting geometry against fragmentation and diggability targets. The resulting equation can be searched for the ideal conditions that describe the optimization of the blasting geometry based on the bistability index analysis of the objectives to be achieved.

RESULT AND DISCUSSION

Location of Collecting The Data

The research was conducted on the west side of Pit 7 West, including a low-wall area. Focused on the low wall area of the inter-burden seam layers C2, D2, and Du which had strike/dip values N 228° E / 51°. The low wall area of Pit 7 West and the research locations for the inter burden layers seam C2, D2, and Du can be seen in Figure 8.

Figure 8. Picture of Pit 7 West PT.BUMA Site Binungan-Suaran

Testing of Physical and Mechanical Properties of Rocks in Seams C2, D2, and Du at PT. Bukit Makmur Mandiri Utama Jobsite Binungan, Suaran

Physical and mechanical properties testing was carried out at the mining laboratory of PT. Berau Coal owns PT. Bukit Makmur Mandiri Utama Jobsite Binungan - Suaran. The sample testing was carried out as follows:

Physical property test

1. Inter burden seam C2
   From the laboratory test results on the physical properties of rock inter burden seam C2, obtained data is shown in Table 1.

Table 1. Average value of physical properties from rock layer C2

No.	Parameter	Sandstone
1	Natural Density gr/cm³	2.32
2	Saturated Density gr/cm³	2.18
3	Dry Density gr/cm³	2.39
4	Apparent Density	2.39

2. Inter burden seam D2
   Based on the laboratory tests on the physical properties of rock inter burden seam D2, the result obtained is shown in Table 2.

Table 2. Average value of physical properties from rock layer D2

No.	Parameter	Mudstone
1	Natural Density gr/cm³	2.10
2	Saturated Density gr/cm³	2.04
3	Dry Density gr/cm³	2.15
4	Apparent Density	2.15

3. Inter burden seam Du
   According to the laboratory tests on the physical properties of rock interburden seam Du, the result is indicated in Table 3.

Table 3. Average value of physical properties from seam Du

No.	Parameter	Interlaminated Sandstone and Mudstone
1	Natural Density gr/cm³	2.22
2	Saturated Density gr/cm³	2.17
3	Dry Density gr/cm³	2.29
4	Apparent Density	2.29

Mechanical properties test

The value of rock compressive strength is carried out based on the Unconfined Compressive Strength Test (UCS) on the rock samples. The UCS test was carried out on C2, D2, and Du interburden seam rock samples where these rocks were the constituent material of the research location. The tests were conducted with samples from the drilling conducted by PT. Berau Coal which is regular in shape with varying dimensions depending on the conditions of the sample rock. Based on the tests carried out, the results are shown in Table 4.

Table 4. Values of testing result from rock mechanical properties

Rock Location	Dimensions		Sc(Mpa)
	D (mm)	H (mm)	
Interburden seam C2	62	62,2	4.86
Interburden seam D2	62.1	62.3	8.03
Interburden seam Du	61.8	62.2	3.99

Parameter of Blastability Index at Blasting Site

Rock mass description (RMD)

Rock mass description of the parameters used to show the rock mass quality by observing the rock structure using RQD (Rock Quality Design). The RQD value of the research location was calculated based on (Priest and Hudson, 1976):

1. RQD Interburden seam C2
   The average RQD for interburden seam C2 is 99.29%. With the RQD, the rock quality is classified as Hard and Intact.

Table 5. RQD value of rocks seam C2

No.	Measurement block	RQD %
1	20	98,7
2	21	99,61
3	22	99,50
4	23	99,33
5	24	99,33
Average		99,29

2. RQD Interburden seam D2
   The average RQD for interburden seam D2 is 99.46%. With the RQD, the rock quality is classified as Hard and Intact.

Table 6. RQD value of rocks seam D2

No.	Measurement block	RQD %
1	14	99.26
2	15	99.54
3	16	99.78
4	17	99.46
5	18	99.46
6	19	99.26
Average		99.46

3. RQD Inter-burden seam Du
   The average RQD for interburden seam Du is 99.63%. With the RQD, the rock quality is classified as Hard and Intact.

Table 7. RQD value of rock seam Du

No.	Measurement block	RQD %
1	24	99.53
2	25	99.59
3	26	99.69
4	27	99.74
Average		99.63

Joint plane spacing (JPS)

JPS is the perpendicular distance between two consecutive weak areas.

1. RQD Inter burden seam C2
   From the measurement of the fracture spacing on the Interburden Seam C2, it was found that the average fracture spacing was 0.87 m so it was classified as an intermediate fracture distance (0.1 - 1 m) with a weight of 20.

Table 8. Value of stump spacing on inter burden seam C2

JPS Value of Interburden seam C2		
No.	Measurement block	Average of the Fracture Spacing (meter)
1	20	0.79
2	21	0.83
3	22	1.07
4	23	0.83
5	24	0.83
Average		0.87

2. RQD Inter burden seam D2
   From the measurement of the fracture spacing on Interburden Seam D2, it is found that the average fracture spacing is 0.99 m so that it is classified as an intermediate fracture distance (0.1 - 1 m) with a weight of 20.

Table 9. Value of stump spacing on interburden seam D2

JPS Value of Interburden seam D2		
No.	Measurement block	Average of the Fracture Spacing (meter)
1	14	0.78
2	15	1.06
3	16	1.5
4	17	0.93
5	18	0.93
6	19	0.78
Average		0.99

3. RQD Inter burden seam Du
   Based on the measurement of muscle distance on Interburden Seam Du, the mean fracture distance was 0.87 m and was classified as wide (> 1 m) with a weight of 30.

Table 10. Value of stump spacing in interburden seam Du

JPS Value of Interburden seam Du		
No.	Measurement block	Average of the Fracture Spacing (meter)
1	24	1
2	25	1.1
3	26	1.25
4	27	1.36
Average		1.17

Joint plane orientation (JPO)

In blasting operations, the weak area orientation to the rock mass is very important because it will affect the determination of the blasting direction to get the desired fermentation result. The analysis of the general direction of the stock is conducted using the software. The analyzed weak fields include:

1. Weak fields in C2 Inter burden seam
   In the inter burden seam C2, the weak area orientation in the rock mass is Dip Out of Face (area orientation towards the pit). Hence, this weak field orientation potentially slopes instability and unidirectional dip structures. For instance, potential backbreaking, damaged walls, and floor fragmentation problems. The weight of the geomechanical parameters is 20 shown in Figure 9.
2. Weak field on Inter burden seam D2
   In the inter burden seam D2, the weak field orientation in the rock mass is Dip Into Face (discontinuity area orientation towards the rock mass), so that the toe is not destroyed which causes the second layer of hard material and the potential of the rock will hang in the free-face direction. The weight of the geomechanical parameters is 40 shown in Figure 10 above.
3. Weak fields on Inter burden seam Du
   In the inter burden seam Du, the weak area orientation in the rock mass is Dip Out of Face (area orientation toward the pit), so this weak field orientation has the potential which causes slope instability and unidirectional dip structures. For example, potential back-break, damaged walls, and floor fragmentation problems. The weight of the geomechanical parameters is 20 shown in Figure 11.

Specific gravity influence (SGI)

Specific gravity influence is a rock characteristic related to density and porosity. The following is the calculation result of the specific gravity influence of each inter burden seam C2 8, D2 2.5, and Du 5.

Hardness

The mechanical properties of rocks related to their strength are uniaxial compressive strength and rock hardness. In this study, rock hardness used the results of the rock mechanical properties test, with the hardness obtained such as inter burden seam C2 value 1.31, inter burden seam D2 value 1.99, and inter burden seam Du value 1.04.

Blastability Indeks

The balancing weight of the Blastability index at the blasting location is determined from the weighted sum of the five geomechanical parameters in Table 11.

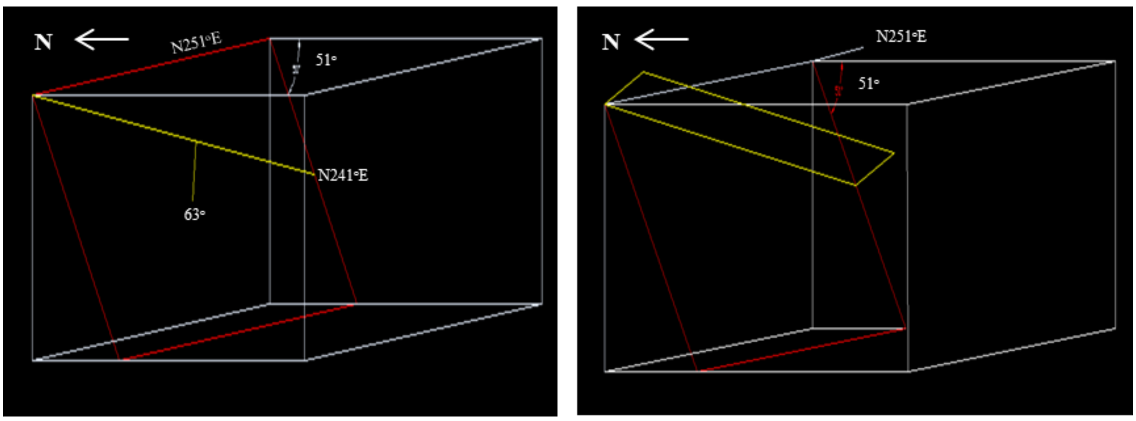

Figure 9. Sketch of solids against the position of the inter burden seam C2 slope

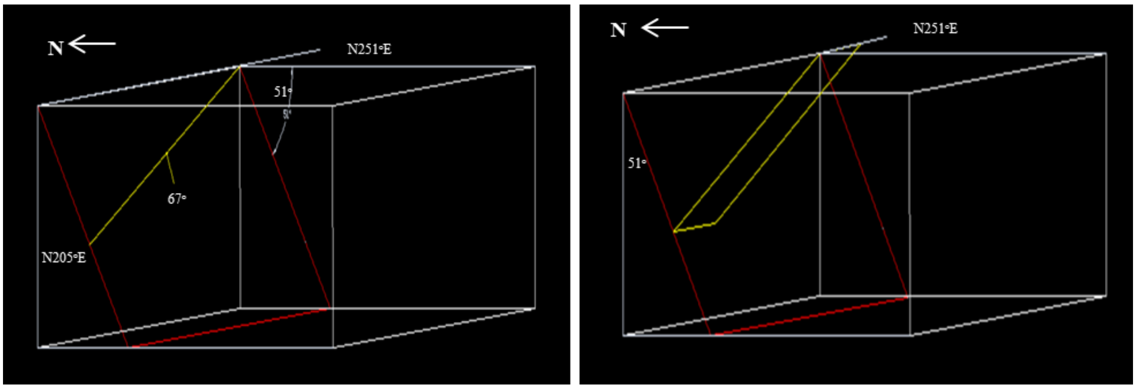

Figure 10. Solid sketch of the position from the inter burden seam D2 slope

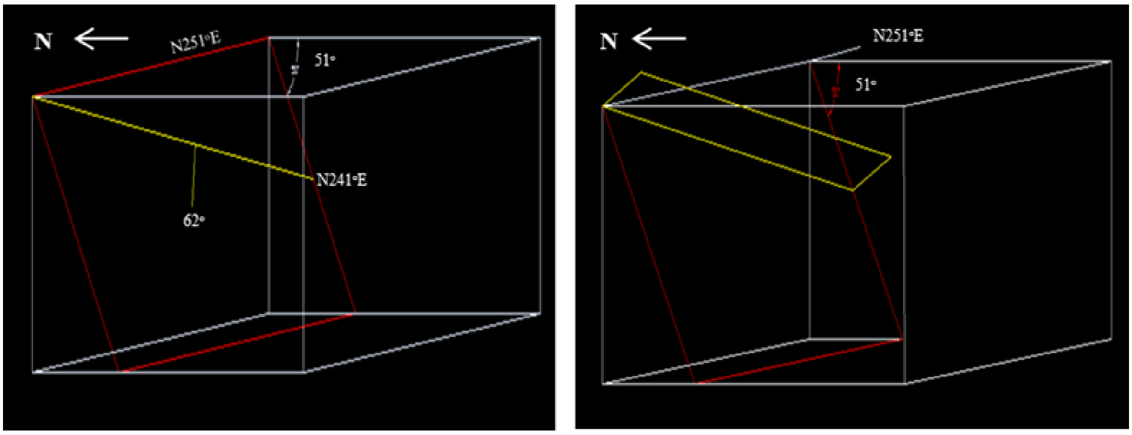

Figure 11. Sketch of solids against the position of the inter burden seam Du slope

At the blasting location, the blastability index used the formula BI = 0.5 x (RMD + JPS + JPO + SGI + H), obtained the BI Value on Interburden seam C2=49.65, Interburden seam D2=57.24, and Interburden seam Du=53.27. Then connect the rock factor with the explosion-ability of a rock A = 0.12 * BI, so obtained the rock factors on Interburden seam C2=5.95, Interburden seam D2=6.86, and Interburden seam Du=6.39.

Table 11. Blastability index at the research location

Geomechanical Parameters	Interburden Seam C2		Interburden Seam D2		Interburden Seam Du	
	Ket.	Weighting	Ket.	Weighting	Ket.	Weighting
RMD	Totally Massive	50	Totally Massive	50	Totally Massive	50
JPS	Intermediate	20	Intermediate	20	Wide	30
JPO	Dip Out of face	20	Dip Into face	40	Dip Out of face	20
SGI	-	8	-	2.5	-	5.5
Hardness	UCS	1.31	UCS	1.99	UCS	1.04
Sum	99.31		114.49		106.54	
BI 0.5x(RMD+JPS+JPO+SGI+H)	49.65		57.245		53.27	
A 0.12 x BI	5.95		6.86		6.39	

Analysis of the Relationship of Explosives Stuffing with Kuz-Ram Fragmentation Prediction and Blasting Geometry Recommendations

Changes to blasting material filling are required to improve blasting product fragmentation based on blastability index analysis. The analysis of the relationship between the explosives contents and the fragmentation of blasting products has been studied previously entitled "Evaluation of Explosive Content using Analysis of Fragment Size Distribution in Overburden Blasting at Open Coal Mining". This study analyzes blasting fragmentation using the Kuz-Ram method and regression analysis with data on blasting geometry, explosive stuffing, and the rock structure, in general, to obtain predictions of ideal fragmentation distribution according to company targets.

Geometry Design and Fragmentation Prediction in Interburden Seam C2

Interburden seam C2 has a blastability index value of 49.65, and an average fragmentation size of > 100 cm is 23.73%. As a result, an attempt is made to improve which simulation of the explosives contents can be simulated to the target boulder percentage. For the explosives filling with a target of <15% boulder material and an average blasting rate of 7 m - 8 m, the value of stiffness ratio is 1 with a VED of 30 - 64%. In brief, the geometry recommendations and the explosives contents proposed for simulations to obtain the ideal fragmentation of the company's target can be seen in the table below.

Based on Table 12 above, one of the four blasting geometry recommendations in the table is chosen to test or apply it in the field, where the writer proposes a third recommendation with a VED of 48% because the fragmentation percentage of the blasting size is less than 14.91% as shown in Figure 12.

Geometry Design and Fragmentation Prediction in Interburden Seam D2

Interburden seam D2 has a blastability index of 57.24 and an average fragmentation size of > 100 cm is 25.07%. Therefore, an attempt is made to improve which simulation of the explosives contents can be simulated to achieve the target boulder percentage. For the explosives filling with a target of <15% boulder material and an average blasting rate of 7 m - 8 m, the value of stiffness ratio is 1 with a VED of 30 - 64%. In short, the geometry recommendations and the explosives contents proposed for simulations to obtain the ideal fragmentation from the company's target can be seen in Table 13.

Based on Table 13 above, one of the seven blasting geometry recommendations in the table is chosen to test or apply it in the field, where the writer proposes a seven recommendation with a VED of 55% because the fragmentation percentage of the blasting size is 14.48% as shown in Figure 13.

Table 12. Blasting geometry recommendation for interburden seam C2

Interburden seam C2						
No	Parameter	Blasting Geometry Recommendation with a VED				Unit
		30%	47%	48%	64%	
1	Blasting Geometry					
	a. Burden (B)	7.2	7.2	7.2	7.2	meter
	b. Spacing (S)	8.3	8.3	8.3	8.3	meter
	c. Stemming (T)	6.10	4.74	4.66	4.62	meter
	d. Powder Column (PC)	1.90	3.26	3.34	4.62	meter
	e. Loading Density (de)	36.11	36.11	36.11	36.11	kg/m
	f. Mass of Explosive (Q)	68.61	117.72	120.61	166.83	kg/hole
	g. Powder Factor (PF)	0.14	0.24	0.25	0.35	kg/m^3
2	Blasting Fragmentation Result based on the Kuz-Ram formula					
	a. Mean Particle size (Xm)	50.55	37.64	37.14	30.95	Centimeter
	b. Uniformity index (n)	0.64	1	1.02	1.36	
	c. Particle Size Characteristics (Xc)	88.90	54.34	53.21	40.54	Centimeter
	d. Mass Fraction Retained on screen opening (R100)	34.03	15.90	14.91	3.29	%

Table 13. Blasting geometry recommendations for the interburden seam D2

No	Parameter	Interburden seam D2							Unit
		Blasting Geometry Recommendation with a VED							
		30%	47%	48%	49%	50%	55%	64%	
1	Blasting Geometry								
	a. Burden (B)	7.5	7.5	7.5	7.5	7.5	7.5	7.5	meter
	b. Spacing (S)	8.6	8.6	8.6	8.6	8.6	8.6	8.6	meter
	c. Stemming (T)	6.10	4.74	4.66	4.58	4.50	4.10	3.38	meter
	d. Powder Column (PC)	1.90	3.26	3.34	3.42	3.50	3.90	4.62	meter
	e. Loading Density (de)	36.11	36.11	36.11	36.11	36.11	36.11	36.11	kg/m
	f. Mass of Explosive (Q)	68.61	117.72	120.61	123.50	126.39	140.83	166.83	kg/hole
	g. Powder Factor (PF)	0.13	0.23	0.23	0.24	0.25	0.27	0.32	kg/m^3
2	Blasting Fragmentation Result based on the Kuz-Ram formula								
	a. Mean Particle size (Xm)	60.51	45.54	44.94	44.36	43.79	41.23	37.46	Centimeter
	b. Uniformity index (n)	0.63	0.99	1.01	1.03	1.05	1.16	1.35	
	c. Particle Size Characteristics (Xc)	108.17	65.98	64.61	63.30	62.05	56.60	49.18	Centimeter
	d. Mass Fraction Retained on screen opening (R100)	38.61	22.12	21.13	20.14	19.16	14.48	7.24	%

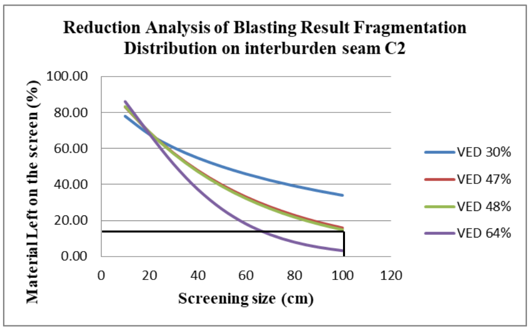

Figure 12. Reduction analysis of blasting result fragmentation distribution on interburden seam C2

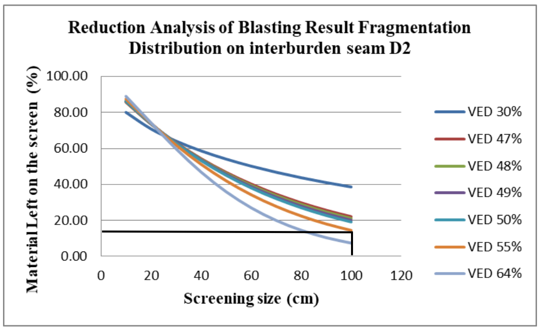

Figure 13. Reduction analysis of blasting result fragmentation distribution on interburden seam D2

Geometry Design and Fragmentation Prediction in Interburden Seam Du

Interburden seam Du has a blastability index of 53.18, and an average fragmentation size of > 100 cm is 19.84%. Thus, an attempt is made to improve which simulation of the explosives contents can be simulated to the target boulder percentage. For the explosives filling with a target of <15% boulder material and an average blasting rate of 7 - 8 m, the value of stiffness ratio is 1 with a VED of 30 - 64%. Overall, the geometry recommendations and the explosives contents proposed for simulations to obtain the ideal fragmentation from the company's target are shown in Table 14.

Based on Table 14 above, one of the seven blasting geometry recommendations in the table is chosen to test or apply it in the field, where the writer proposes a seven recommendation with a VED of 51% because the fragmentation percentage of the blasting size is 14.82% as shown in Figure 14.

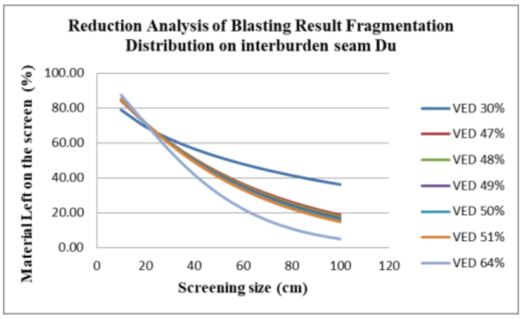

Figure 14. Reduction analysis of blasting result fragmentation distribution on interburden seam D2.

Results of Application of the Explosion Geometry Recommendations of RL.Ash and VED in the Field

The final result of the proposed blasting geometry application by RL.Ash and VED can be seen in Table 15.

As shown in Table 15, the blasting result of boulder size is much better than that of the actual percentage of fragmentation obtained by the company, where there has been a reduction in the fragmentation of the boulder size. Moreover, the diggability of the digging equipment is also much better, where the bucket fill factor of the digging equipment has increased so that the productivity of the digging tool has also been increased. Besides, the digging time has decreased so the cycle time of the digging tool decreases, and the productivity of the digging tool can be increased.

CONCLUSIONS AND SUGGESTIONS

Conclusions

1) Rock mass characteristics in the blasting area obtained the RQD for each interburden layer, that is interburden seam C2 = 99.29%, interburden seam D2 = 99.46%, and interburdet seam Du = 99.63%. The laboratory test consisted of physical and mechanical properties testing, in which the physical properties obtained the original content weight such as interburden seam C2 = 2.32 gr/cm^3, interburden seam D2 = 2.10 gr/cm^3, and interburdet seam Du = 2.22 gr/cm^3. The saturated weight of C2 interburden seam = 2.39 gr/cm^3, D2 interburden seam = 2.15 gr/cm^3, and Du seam interburden = 2.29 gr/cm^3. Next, the dry content weight of C2 interburden seam = 2.18 gr/cm^3, D2 interburden mechanical testing was seam

Table 14. Blasting geometry recommendations for the interburden seam Du.

Interburden seam Du										
No		Parameter	Blasting Geometry Recommendation with a VED							Unit
			30%	47%	48%	49%	50%	51%	64%	
1		Blasting Geometry								
	a.	Burden (B)	7.3	7.3	7.3	7.3	7,3	7.3	7.3	meter
	b.	Spacing (S)	8.4	8.4	8.4	8.4	8.4	8.4	8.4	meter
	c.	Stemming (T)	6.10	4.74	4.66	4.58	4.50	4.42	3.38	meter
	d.	Powder Column (PC)	1.90	3.26	3.34	3.42	3.50	3.58	4.62	meter
	e.	Loading Density (de)	36.11	36.11	36.11	36.11	36.11	36.11	36.11	kg/m
	f.	Mass of Explosive (Q)	68.61	117.72	120.61	123.50	126.39	129.27	166.83	kg/hole
	g.	Powder Factor (PF)	0.14	0.24	0.24	0.25	0.26	0.26	0.34	kg/m^3
2		Blasting Fragmentation Result based on the Kuz-Ram formula								
	a.	Mean Particle size (Xm)	54.72	41.19	40.64	40.11	39.60	39.11	33.87	Centimeter
	b.	Uniformity index (n)	0.64	0.99	1.02	1.04	1.06	1.08	1.35	
	c.	Particle Size Characteristics (Xc)	97.49	59.54	58.31	57.13	56.00	54.93	44.41	Centimeter
	d.	Mass Fraction Retained on screen opening (R100)	36.20	18.73	17.73	16.74	15.77	14.82	4.96	%

Table 15. The excavator that digs up the blasting material is the Komatsu PC2000 excavator

No	Determining Parameters	Actual Conditions			Application Results	
		Seam C2	Seam D2	Seam Du	Seam C2	Seam D2
1	Fragmentation Result of Blasting > 100cm	23.73%	25.07%	19.84%	6.23%	10.67%
2	Digging Time of loading tool	14.28 second	15.28 second	14.88 second	12.03 second	12.69 second
3	Bucket Fill Factor	0.6	0.6	0.6	0.7	0.7
4	Digging Rate of Digger fit	615.95 bcm/Hour	598.7 bcm/Hour	614.55 bcm/Hour	832.14 bcm/Hour	831.22 bcm/Hour

= 2.04 gr/cm^3, and Du seam interburden = 2.17 gr/cm^3. Otherwise, the carried out by UCS test which was obtained the compressive strength of the interburden seam rock C2 = 4.86 Mpa, D2 seam interburden = 8.03 Mpa, and Du seam interburden = 3.53 Mpa.

2) The weighting of the blastability index is used with the formula BI = 0.5 x (RMD + JPS + JPO + SGI + H), so the BI results are obtained on the inter-burden seam C2=49.05 with a rock factor value of 5.95, inter-burden seam D2=57.24 with the rock factor value is 6.86, and the Du inter-burden seam is 53.27 with the rock factor value 6.39.
3) The Joint Plane Orientation parameter is the most dominant of the five blastability index parameters, where the average weak area in the D2 inter-burden seam is Dip into Face (orientation of the discontinuity plane towards rock mass). Based on the blastability theory, this weak field index can cause the toe not to be crushed which will potentially transform into a hard material and boulder fragmentation. Whereas the Inter-burden seam Du occupies the second position and the most dominant blastability index parameter is Joint Plane Spacing, where the weak area in this layer is less than the other layers, so the rocks in the Du seam inter-burden layer are more compact than the C2 and D2 layers. The C2 inter-burden seam has a boulder fragmentation value of 23.73% from the blastability index analysis, which the most dominant parameter is Specific gravity influence. Based on the blastability index theory, to overcome the problem it requires an analysis of the repair of the explosive column so the writer conducted a study on the recommendation of blasting geometry based on the RL.Ash theory. This theory considers the rock factor value, and for the column, the writer uses the VED method, which can pay attention to the distribution of blasting energy.
4) The blasting geometry recommendation uses the RL.Ash theory because it considers the rock factor value. Based on the VED Theory of the blastability index, the Charging Sheet obtained the blasting geometry design for each layer and the filling recommendation. The result showed the C2 layer is recommended for a burden of 7.2 m, a space of 8.3 m, and a VED coating of 48%; the D2 layer uses a burden of 7.5 m, spacing 8.6 m, and filling of 55% VED plastic; last for Du layer recommended burden of 7.3 m, spacing 8.4 m and for VED material filling is 51%. Overall, the Prediction analysis of blasting fragmentation using Kuz-ram theory showed the C2 layer obtained fragmentation> 100 cm of 14.99%, the D2 layer is 14.84%, and the Du layer is 14.82%.

Suggestions

1) The parameters or the test reference can geological conditions in blasting. However, other parameters exist, like blasting delay.
2) It must be careful and include the test results in the prediction when entering the prediction of explosion result parameters using the Kuzram method.
3) be observed from the writer's research in carrying out the physical and mechanical properties test.
4) Many parameters influence the blasting fragmentation, but the writer focuses on the

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