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MODIFICATION OF BLASTING GEOMETRY TO INCREASE BLASTING EFFECTIVENESS IN QUARRY

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ABSTRACT
It is thought that a technique for carrying out blasting operations for rock extraction must be both effective and secure. It is intended that the blasting will be both safe and able to meet the needs of the stockpile material because the blasting area is adjacent to residential areas. This study intends to determine the cost and duration of the rock excavation work by blasting at the Trenggalek Tugu Dam Construction Project, as well as the effectiveness brought about by the implementation of modified blasting geometry. The inquiry was supported by descriptive and comparative methodologies. For this study, both quantitative and qualitative data were required. Quantitative data was gathered using working drawings, tool specifications, and material specifications; qualitative data was gathered using work procedures, specifications, and islands for related jobs. Quantitative information is obtained through the analysis of papers written by consultants and service providers. To acquire qualitative power, interviews with subject-matter experts and literature research were conducted. Because the work can be done more rapidly than with the prior geometry and because doing so has a lower cost analysis, the results reveal that using the modified geometry is more cost-effective than using the prior blasting geometry. Utilizing a combination of blasting geometry using the CJ Konya method and ICI-Explosive, there was a 9.3% acceleration in task execution and a 1.133% cost efficiency of the contract value (Trial & Error).

Keywords: Blasting, Construction; Cost-effective; Geometry

1. INTRODUCTION
Trenggalek is one of 29 regencies in the East Java Province, which lies near the easternmost point of the island of Java. It is situated around latitudes 7o63' to 8o34' south and longitudes 111o24' to 112o11' east. With a total area of 126,140 acres and elevations ranging from zero to nearly 700 meters above sea level, Trenggalek Regency is divided into lowland and mountainous terrain. Three regencies, namely Tulungagung, Ponorogo, and Pacitan regencies, border the city of Trenggalek (Pemerintah Kabupaten Trenggalek, 2021).

The Keser river, one of the rivers that contributed to the flood tragedy in Trenggalek Regency, is located in the Tugu subdistrict. In order to prevent water shortages or drought during the dry season and flooding during the rainy season, the area must have a water storage facility. During the wet season, the Keser River has the potential to produce catastrophic flooding. The Keser River has been causing floods in Trenggalek Regency

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for numerous decades, splitting residential areas and economic hubs with its meandering characteristics. This flooding has resulted in the destruction and inundation of thirty to hundreds of hectares downstream of the river (Sudaryanto, 2016). The government is attempting to solve these issues by constructing the Tugu Dam. Together with consultant PT Mettana, PT Wijaya Karya carried out the development process.

Water management is required to solve the issues of flooding and landslides. The building of the Tugu Dam in Nglinggis, Tugu, and Trenggalek is one of the initiatives done. The Keser River, a tributary of the Ngrowo River and a component of the Brantas watershed is planned to have a dam built on it. There are many potentials in the area close to the dam. Agricultural land with irrigation systems in the forms of simple irrigation, technical irrigation, and semi-technical irrigation with an area of 312, 354, and 260 ha, respectively, is one of the possibilities. In addition to being used for agriculture, the areas of dry land, community forests, and state forests total 2089, 408, and 2526 ha, respectively. In addition to irrigation requirements, there is also the potential to use the Tugu Dam as a source of raw water for the nearly 50,000 population of 15 villages in the Tugu District. This dam is categorized as a source of raw water and irrigation water and is projected to have a total water capacity of 9.3 hm3 (Source: Balai Besar Brantas River Basin, Directorate General of Water Resources).

The Tugu dam project, which is being managed by PT Wijaya Karya (Persero) Tbk, is now under development. Rock extraction by blasting is one of several operations that have been completed. Blasting excavation is done to obtain rip rap (Zone 6) and embankment rock for backfill (Zone 5). There is a problem with the project, though. The problem is that the settlement is only 120 m from the rock excavation operations being done by blasting. This is highly risky because blasting produces loud noises, shivers,s, and flying rock, among other impacts. The side effects are hazardous and can interfere with blasting operations. If blasting work is interfered with, it will interfere with the job of heaping stones (Zone 5) and rip rap (Zone 6). The rip rap embankment work must be completed by mid-July 2019 due to time considerations. Therefore, a method for doing rock excavation operations using blasting that is both efficient and secure is required. Because the blasting area is close to residential areas, it is planned that the blasting is both safe and able to meet the needs of the stockpile material.

Research Questions:

1. How much are the budget and time required for rock excavation work with blasting on the Trenggalek Tugu Dam Construction Project?
2. How much is the efficiency resulting from the application of blasting geometry modification for rock excavation work by blasting at the Trenggalek Tugu Dam Construction Project?

2. LITERATURE REVIEW

To asses the blasting geometry in relation to rock fragmentation and costs, Dian Abimanyu, Tommy Trides, and Sakhdillah (2018) conducted research using observations at PT Teguh Sinarabadi in West Kutai, East Kalimantan. The fragmented rock that is spread as a result of blasting is what matters since it directly contributes to the blasting outcomes that have an impact on the subsequent stage. According to the current norm, blasting is considered successful if the percentage of boulders is less than 15%. The explosive geometry, which is simple to control, is one of many factors that influence the fragmentation to reach this value. Both direct methods, like image analysis, and the Kuz-

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ram mathematical modeling are used to determine the degree of fragmentation of the blasting results. It is also necessary to assess the budget plan that was spent in order to determine whether the blasting action is efficient. The estimated boulder fragmentation rate determined by Kuz-ram modeling is based on the results of eight blasts, with the least values being 14.09%, 14.35%, 14.94%, 15.27%, 16.35%, 16.56%, 16.90%, and 19.72%. With the help of the picture analysis tool Splitdekstop 2.0, it was possible to calculate the boulder fragmentation rate, which came out to be 15.80, 15.90, 16.60, 16.92, 17.35, 17.56, 19.58, and 20.77%. Each blasting activity's total cost was estimated, and it came to 0.256, 0.281, 309, 0.284, 0.322, 0.300, 0.282, and 0.274 $/BCM. The following step is to suggest a new blasting geometry based on Anderson (1952), Ash (1963), Konya (1972), and Austin Powder equations. Based on the results of the cost estimation, it is predicted that the study of blasting costs based on the new proposed geometry will employ the correlation between the overall cost of blasting and the powder factor (PF).

PT Bukit Asam (Persero), Tbk, Tanjung Enim, a coal mining business whose operational area is in Tanjung Enim, South Sumatra, undertook a study on the examination of ground vibration level reduction in the implementation of B2C inter burden blasting at the Air Laya coal mine (Maryura, Toha, and Sudarmono, 2013). Open pit mining is the method used. At the Air Laya Tambang B2C inter burden pit, PT Bukit Asam and PT Pamapersada Nusantara worked together to demolish rocks using blasting techniques. The result of this effort is the appearance of ground vibrations, which, if they are greater than the safe value (5 mm/s) within a 500-meter radius, will break the office building and harm the bench nearby. The measurements of 28 vibrations were made with the Blasmate III equipment using an actual blasting geometry of six meters of burden, seven meters of spacing, and an average depth of 7.8 meters. There are three stages in the measurement stage. The first measurement is done before making any modifications. The second measurement is made once the explosive content is reduced to 70 kg/hole. The final stage comes after adjusting the delay using a pre-split and echelon cut pattern so that the final average vibration in a radius of 500 m is 3.4 mm/s. The precision of the fieldwork and other criteria, such as measuring distance, an explosive charge per delay with an optimal load of 70 kg per hole, and accurate delay setting utilizing the echelon cut pattern, are all crucial to the success of the blasting operation. Additionally, the bench can be shielded from the effects of vibration by employing the pre-splitting approach. Blasmate III measurements must be made and assessed on a regular basis. Consequently, the firm's goal is to achieve a vibration of 5 mm/s in a radius of 500 m.

Listine, Nurhakim, Dwiatmoko, and Excelsior T.P3 (2015) did a technical research in PT Putera Bara Mitra, Mantewe, Mentawakan Mulya Village, Tanah Bumpu Province, South Kalimantan. Contractor PT Putera Bara Mitra used drilling and blasting procedures to achieve goal yields and speed up the loading, unloading, and transportation processes at the iron ore mine owned by CV Bina Usaha in order to identify the blast geometry and PF for iron ore offloading. Each blast's density necessitates the selection of a crush size that is compatible with both the specified PF value and the width of the crusher aperture. The Rossin-Rammler equation, which establishes the percentage of material retained in a sieve of a particular size, and the average size of rock fragments are both included in the Kuznetsov model. In addition, it is anticipated that using the Splitdesktop application will enable image analysis of the fragments left over from blasting, producing a graph showing the proportion of material that has fled as well as the typical size of the fragments left over. The blasting geometry is 3 m by 3 m in size, with a theoretically calculated percentage of gravel (50 cm) of an average of 45.36% and a real percentage of 36.6%, with various PF. Boulder percentage is 13.09–14.92 percent using the recommended blasting geometry, ladder height 5.5 m, blast hole depth 6 m, load 2.2–2.4 m, spacing 2.5–2.63 m, and PF 0.80–0.85 kg/m^3 (if the boulder percentage is less than 15%, the fragment is good).

Rudi Hartono, Risanto Panjaitan, Aris Herdiansyah (2018) conducted research on the study of blasting rules at PT Pro Intertech Indonesia, in Sorong, West Papua. Exploitation methods like blasting have the effect of speeding up the mining process, which in turn boosts output. Because conventional methods cannot be used to extract mineral reserves, this process is required. Blasting techniques appropriate for the soil and rock conditions at the site must be employed to achieve the best results when blasting rocks. An appropriate blasting technique must be employed at the site in order to produce the best blasting results. The goal of this study is to assess the explosion's geometry and choose the best blasting technique to maximize the explosion's yield. In this study, data were gathered utilizing a variety of techniques, including observation, interviews, and literature review. The "Modern Technique of Rock Blasting," which is used to examine blasting performance in accordance with the geometry of the blasting process, is the methodology utilized for data analysis. The blasting geometry currently being used at the site by PT Pro Intertech Indonesia for mining operations is as follows: load (B) 1.5 m, spacing (S) 3.5 m, tamping (T) 2.5 m, and deep drilling (U) 2.5 m. The blast hole's depth is 15 meters, its slope is 150 degrees, and its ladder height is 12.07 meters. Geometry yields blasting results of 10335.24 tons, which are inconsistent with the stated aims. After analysis utilizing contemporary rock blasting techniques, the following theoretical facts were discovered: Loading (B) = 2.621 meters, Space (S) = 3.276 meters, Packing (T) = 2,621 meters, Deep Drilling (U) = 0,91 meters, Blast Hole Depth = 13,629 meters, Slope = 150 meters, Ladder Height = 12,285 meters. The geometric design can lower the use of explosives from 1,805.25 kg to 1,589.75 kg while increasing the blasting capacity to 10,519,338 tons.

3. RESEARCH METHOD

Descriptive and comparative approaches were used to support the investigation. A descriptive method is a technique that accurately and truthfully portrays a phenomenon. A comparative method is one that involves contrasting two circumstances or things. Alternative blasting techniques are described and contrasted using these two techniques. As a result, researchers can identify and choose a viable approach to solving current issues.

Data was needed for this research, including quantitative and qualitative data. Working drawings, tool specifications, and material specifications were used to collect quantitative data, whilst work techniques, specifications, and islands for related tasks were used to collect qualitative data. The analysis of papers produced by consultants and service providers yields quantitative data. Interviews with subject-matter specialists and literature reviews were used to gather qualitative power.

4. RESULT AND DISCUSSION

4.1 The Cost And Time Requires For Rock Excavation Work With Blasting On The Trenggalek Tugu Dam Construction Project

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The cost per unit vary since there are differences in the manpower and explosive requirements for each shape. The powder factor, which measures the relationship between explosives and the productivity of the subsequent blasting, demonstrates this. For each blasting geometry, the results of the calculation of the unit price analysis are displayed in the following table:

Table 1 Details of Blasting Costs With The Initial Method Prior Unit Price Analysis

No	**Details**	**Unit**	**Quantity// Coefficient**	**Cost per Unit (IDR)**	**Total (IDR)**
1	2	3	4	5	6 = (4×5)
I	**Wage / Employee**				
	Master Blasting	person/day	0.0014	85,000.00	119.93
	Worker	person/day	0.0198	72,500.00	1,432.10
	Craftsman	person/day	0.0071	80,000.00	564.37
Sub Total I				**2,116.40**	
II	**Materials**				
	Dynamite	kg	0.0042	125,000.00	529.10
	ANFO Powder	Kg	0.3457	48,400.00	16,732.57
	Detonator	Bh	0.0212	68,000.00	1,439.15
	Stemming Gravel	Kg	0.4341	194.44	84.41
	Cable	M	0.0526	7,500.00	394.18
	Cross bit, 65 mm	Bh	0.0050	756,000.00	3,780.00
Sub Total II				**22,959.41**	
III	**Equipment**				
	Drill, Pneumatic Crawler	Hour	0.0169	114,673.00	1,941.55
	Compressor 4000-6500 L/M	Hour	0.0169	217,791.00	3,687.47
Sub Total III				**5,629.02**	
Sub Total (I+II+III)				**30,704.84**	
VAT 10%				**3,070.48**	
Total				**33,775.32**	

Table 2 Details of Blasting Cost Using The CJ Konya Method Cost Analysis of CJ Konya Unit

No	Details	Unit	Quantity// Coefficient	Cost per Unit (IDR)	Total (IDR)
1	2	3	4	5	6 = (4×5)
I	**Wage / Employee**				
	Master Blasting	person/day	0.0014	85,000.00	119.93
	Worker	person/day	0.0198	72,500.00	1,432.10
	Craftsman	person/day	0.0071	80,000.00	564.37
Sub Total I					**2,116.40**
II	**Materials**				
	Dynamite	kg	0.0042	125,000.00	529.10
	ANFO Powder	Kg	0.2305	48,400.00	11,155.05
	Detonator	Bh	0.0212	68,000.00	1,439.15
	Stemming Gravel	Kg	0.6077	194.44	118.17
	Cable	M	0.0673	7,500.00	503.97
	Cross bit, 65 mm	Bh	0.0050	756,000.00	3,780.00
Sub Total II					**17,525.44**
III	**Equipment**				
	Drill, Pneumatic Crawler	Hour	0.0159	114,673.00	1,820.21
	Compressor 4000-6500 L/M	Hour	0.0159	217,791.00	3,457.00
Sub Total III					**5,277.21**
Sub Total (I+II+III)					**24,919.05**
VAT 10%					**2,491.91**
Total					**27,410.96**

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Table 3 Details of Blasting Costs With The ICI-Explosive (Trial ang Error) Method
Cost Analysis od ICI-Explosive Unit (Trial and Error

No	Details	Unit	Quantity// Coefficient	Cost per Unit (IDR)	Total (IDR)
1	2	3	4	5	6 = (4×5)
I	**Wage / Employee**				
	Master Blasting	person/day	0.0012	85,000.00	104.94
	Worker	person/day	0.0173	72,500.00	1,253.09
	Craftsman	person/day	0.0062	80,000.00	493.83
Sub Total I					**1,851.85**
II	**Materials**				
	Dynamite	kg	0.0037	125,000.00	462.96
	ANFO Powder	Kg	0.3025	48,400.00	14,641.00
	Detonator	Bh	0.0185	68,000.00	1,259.26
	Stemming Gravel	Kg	0.0522	194.44	10.14
	Cable	M	0.0522	7,500.00	391.20
	Cross bit, 65 mm	Bh	0.0050	756,000.00	3,780.00
Sub Total II					**20,544.57**
III	**Equipment**				
	Drill, Pneumatic Crawler	Hour	0.0139	114,673.00	1,592.68
	Compressor 4000-6500 L/M	Hour	0.0139	217,791.00	3,024.88
Sub Total III					**4,617.56**
Sub Total (I+II+III)					**27,013.98**
VAT 10%					**2,701.40**
Total					**29,715.37**

The Price Analysis Of Indirect Costs
The Trenggalek Tugu Dam Development Project (MYC) Phase 2's needs and issues that occur from excavation work with blasting are used to calculate the indirect costs of that work. Here, the costs associated with each blasting geometry on a daily basis are examined:

Table 4 Details Of Indirect Cost Actual Method

No	Details	Unit	Quantity// Coefficient	Cost per Unit (IDR)	Total (IDR)
1	2	3	4	5	6 = (4×5)
I	**Food**				
	Master Blasting	person/day	4.000,00	15.000,00	60,000.00
	Worker	person/day	25.000,00	15.000,00	375,000.00
	Operator	person/day	21.000,00	15.000,00	315,000.00
Sub Total I				**750,000.00**	
II	**Workers' Accommodation**				
	Workers' Transportation	person/day	50.000,00	5.000,00	250,000.00
	Workers' Residence	person/day	50.000,00	15.000,00	750,000.00
Sub Total II				**1,000,000.00**	
III	**Residents Evacuation**				
	Compensation of Family Heads	Hour	1.000,00	1,600,000.00	1,600,000.00
Sub Total III					**1,000,000.00**
Sub Total (I+III)					**2,750,000.00**

Table 5 Details Of Indirect Cost CJ Konya Method

No	Details	Unit	Quantity// Coefficient	Cost per Unit (IDR)	Total (IDR)
1	2	3	4	5	6 = (4×5)
I	**Food**				
	Master Blasting	person/day	3.7500	15,000.00	56,250.00
	Worker	person/day	24.0625	15,000.00	360,937.50
	Operator	person/day	19.7500	15,000.00	296,250.00
Sub Total I				**713,437.50**	
II	**Workers' Accommodation**				

	Workers' Transportation	person/day	47.5625	5,000.00	237,812.50
	Workers' Residence	person/day	47.5625	15,000.00	713,437.50
Sub Total II				**951,250.0**	
Sub Total (I+II)				**1,664,687.50**	

Table 6 Details Of Indirect Costs ICI-Explosive (Trial & Error) Method

No	Details	Unit	Quantity// Coefficient	Cost per Unit (IDR)	Total (IDR)
1	2	3	4	5	6 = (4×5)
I	**Food**				
	Master Blasting	person/day	3.8100	15,000.00	57,150.00
	Worker	person/day	25.2400	15,000.00	378,600.00
	Operator	person/day	20.0500	15,000.00	300,750.00
Sub Total I				**736,500.00**	
II	**Workers' Accommodation**				
	Workers' Transportation	person/day	49.1000	5,000.00	245,500.00
	Workers' Residence	person/day	49.1000	15,000.00	736,500.00
Sub Total II				**982,000.00**	
Sub Total (I+II)				**1,718,500.00**	

Working Time

The productivity of each blasting geometry is determined by the outcomes of geometric planning in sub-chapter 5.3. Because the quantity of explosives in each geometry affects the output of blasted stone, it varies. This is evident from the DF, which measures the number of explosives used in relation to the blast's production. The productivity of the material being blasted determines how quickly the excavation work is finished. A blast management plan was divided into two stages as part of the Tugu Trenggalek Dam Construction Project (MYC) Phase 2 construction,. The execution time of excavation by blasting can be computed from this plan by dividing the volume of the intended rock to be extracted by the productivity of the planned blasting geometry. The estimate of the amount of time necessary to meet the production goal in accordance with the blasting plan is as follows:

1. Prior Method

a. Productivity per day: 3685,50 m^3
b. Time needed for production target

$$\frac{V\ total\ plan}{V\ daily\ productivity} = \frac{1.800.000\ m^3}{3.685,5\ m^3} = 635\ days$$

2. Combination Method (Cj Konya and ICI-Explosive)
   a. Productivity per day : 3685.50 m^3 (CJ Konya)
   : 4212 m^3 (ICI-Explosive)

   b. Time needed for production target

$$\frac{V\ total\ \ plan\ of\ location\ near\ settlements}{V\ daily\ productivity} = \frac{500.000\ m^3}{3.685,5\ m^3} = 176\ days$$

   c. Time needed for production target

$$\frac{V\ total\ plan\ of\ locaton\ near\ settlement}{V\ daily\ productivity} = \frac{1.300.000\ m^3}{4.212\ m^3} = 401\ days$$

   So, time needed for combination method is 176+401=578 days

Working Costs

1. *Direct Costs*

   Direct costs are outlaid for labor, supplies, and equipment used in the production of goods and services. The time needed to finish the work is determined for the rock excavation work by blasting at the Trenggalek Tugu Dam Construction Project (MYC) Phase 2 as computed in accordance with the blasting planner. Therefore, using the time acquired and the unit price analysis that has been computed, it is possible to determine the direct cost of blasting work for each blasting scheme. A direct cost analysis for each blasting geometry is as follows:

   1) Prior Method

      Direct Cost: Total of Day × Analyst Cost per Job × volume

$$= 176 \times 33.775,32 \times 1.800.000\ = IDR\ 60.795.575.174$$

   2) Combination Method (CJ Konya and ICI-Explosive)

      Direct Cost: Total of Day × Analyst Cost per Job × volume

$$= (176 \times 27.410.96 \times 500.000) + \ (401 \times 29.715,37 \times 1.300.000)$$
$$= IDR\ 52.335.462.744$$

2. *Indirect Costs*

   Expenses that come from sources other than the production of the work are referred to as indirect costs. Housing expenses for employees, meal stipends, and transportation expenses are examples of indirect costs. In addition, issues and delays at the workplace can result in direct costs. Residents are compensated for indirect costs associated with blasting activity, such as fly rock, ground vibration, and misfire, and the work is also halted owing to social, equipment, and resource issues. The time needed to finish the rock excavation work by blasting is calculated in section 5.4.2 in accordance with the blasting plan in section 5.2 for the Trenggalek Tugu Dam Construction Project (MYC) Phase 2. Therefore, using the time acquired and the unit cost analysis that has been computed in sub-chapter 5.4.1, it is possible to determine the direct cost of blasting work for each blasting scheme. A direct cost analysis for each blasting geometry is as follows:

1) Prior Method
   Indirect Cost: Total of Days × Daily Indirect Cost
   $= 176 \times 2.750.000{,}00 \ = Rp\ 1.746.031.746$

2) Combination Method (CJ Konya and ICI-Explosive)
   Indirect Cost: Total of Days × Daily Indirect Cost
   $= (176\ x 1.664.687{,}50) + (401\ x 1.718.500) \ = Rp\ 983.117.284$

The efficiency of the blasting geometry modification implementation for rock excavation work by blasting at the trenggalek tugu dam construction

4.2 Analysis Recapitulation Od Costs, Time, And Risk

A general cost, time, and risk analysis based on the findings of the discussion on the Case Study of Modifying Blasting Geometry to Increase the Effectiveness of Blasting in Quarry at the Trenggalek Tugu Dam Project (MYC) Phase 2 is shown in Table 7.

Table 7 Analysis Of Costs, Time, and Risks

		Costs	
No	**Details**	**Actual**	**Combination**
1	Direct Cost	IDR 60.795.575.174	IDR 52.335.462.744
2	Indirect Cost	IDR 1.746.031.746	IDR 983.117.284
3	Risk Reserve Cost	IDR 474.586.384	IDR 245.542.923
4	**Total of Cost**	**IDR 63.016.193.304**	**IDR 53.564.122.951**
		Time	
1	Total of Day	635 Days	578 Days
		Quality and SHE	
1	Fragmentation	Good (appropriate Specifications)	Good (appropriate Specifications)
2	Air Blast	Hard	Moderate
3	*Fly Rock*	Lots	A little

4	*Ground Vibration*	8,45 mm/s	5,34 mm/s

Numerous findings, including direct costs, indirect costs, and risk reserve costs between using the prior method and the geometric combination method, were found based on the examination of rock excavation operations with blasting at the Tugu Dam Development Project, Trenggalek Regency. The prior blasting geometry method needed IDR. 63.016.193.304, and IDR. 53.564.122.951 is required for use of the geometric combination method. The work execution times for the geometric combination method and prior geometry method are 578 days and 635 days, respectively.
The blasting geometry employed in this study can be used as a guide for rock excavation work when using ANFO explosives and electric detonators in a quarry with rock compressive strengths between 350 and 700 kg/cm2 and fewer than 500 meters between the quarry and communities.

5. CONCLUSIONS

The usage of the modified geometry is found to be more cost-effective than the implication of the prior blasting geometry because the work can be completed more quickly than with the prior geometry and because the cost analysis of doing so is less expensive. The implementation cost for performing rock extraction by blasting with a changed geometry is IDR. 52,335,462,744. The execution period required to complete the rock excavation operation using the CJ Konya method and the ICI-Explosive (Trial & Error) method is 578 days.
Based on the analysis, there was a 9.3% acceleration in job execution and a 1.133% cost efficiency of the contract value employing a combination of blasting geometry using the CJ Konya method and ICI-Explosive (Trial & Error). Due to a decrease in the quantity of ground vibration, quality and SHE also improved. In accordance with the product quality goal of the Tugu Dam Construction in Trenggalek Regency (MYC) Phase II, the product excavated by blasting also creates good fragmentation.
The following are suggested that other blasting geometries require further study. Explosives and other accessory research are required so that blasting excavations can be done in a variety of ways. All projects involving blasting operations require the adoption of rules for the management of non-mining commercial explosives

6. REFERENCES

Nurdianaa, A., and Setiabudi, B., (2018), *Aplikasi manajemen risiko pada proyek jalan tol Semarang-Solo Ruas Bawen-Solo*. Semarang

Darmawi, H., (2008), Manajemen Risiko, Bumi Aksara, Jakarta.

Abimanyu, D., Trides, T., Sakhdillah., (2018), *Evaluasi geometri peledakan terhadap fragmentasi batuan dan biaya peledakan PT Teguh Sinarabadi, Kabupaten Kutai Barat Provinsi Kalimantan Timur.* UPN Veteran Jogjakarta

Listine, D., Nurhakim., Dwiatmoko, M. U., Excelsior T.P3 (2015), *Studi teknis penentuan geometri peledakan dan powder factor (pf) pada pembongkaran bijih besi di PT Putera Bara Mitra, Desa Mentawakan Mulya Kec. Mantewe, Kab. Tanah Bumbu, Kalimantan Selatan.* UPN Veteran Jogjakarta

Sudarmono, D., (2013), *Kajian Pengurangan Tingkat Getaran Tanah. Skripsi.* Universitas Sriwijaya

Hartono, Rudi, (2018), *Studi Metode Peledakan. Tesis.* UPN Veteran Jogjakarta

Koesnaryo, S., (2001), Rancangan Peledakan Batuan, Jurusan Teknik Pertambangan, Fakultas Teknologi Mineral, Universitas Pembangunan Nasional "Veteran" Yogyakarta

Konya J. Calvin dan Edwaed J. Walter., (1990), Surface Blast Dessign, Prentce Hall, Inc New Jersey

Nurgaheni, Dewi. S., dan Utomo. C., (2011), Analisa Frekuensi Kejadian Risiko pada Pelaksanaan Pemasangan Samungan Pipa Air PDAM Surabaya, ITS, Surabaya.

Pemerintah Republik Indonesia, (2016), Peraturan Menteri Pertahanan Republik Indonesia No 5 Tahun 2016 tentang Pembinaan dan Pengembangan Industri Bahan Peledak. Jakarta: Kementrian Pertahanan Republik Indonesia

Pemerintah Republik Indonesia, (2017), Peraturan Kepala Kepolisian Republik Indonesia No 17 Tahun 2018 Tentang Perizinan, Pengamanan, Pengawasan dan Pengendalian Bahan Peledak Komersial. Jakarta: Kepolisian Republik Indosesia.

Ramli, (2011), *Manajemen Risiko dalam Perspektif K3 OHS Risk Management, 2nd edition,* Dian Rakyat, Jakarta.

Maryura. R., Toha. M. T., Sudarmono. D., (2013), *Kajian pengurangan tingkat getaran tanah (ground vibration level) pada operasi peledakan interburden B2-C tambang batu bara Air Laya PT Bukit Asam (Persero), Tbk Tanjung Enim. PT Bukit Asam (Persero), Tbk.* UPN Veteran Jogjakarta

Hartono. R., Panjaitan, Herdiansyah, (2018), *Studi metode peledakan pada PT Pro Intertech Indonesia Kotamadya Sorong Provinsi Papua Barat.* UPN Veteran Jogjakarta

Sakhdillah, (2018), Evaluasi Geometri Peledakan terhadap Fragmentasi Batuan dan Biaya Peledakan. *Skripsi.* Kalimantan

Sonhaji, (2011), Manajemen Risiko dalam Proyek Jalan Tol, Diskusi Panel Manajemen Risiko Jalan Tol di Teknik Sipil Undip 2 Mei 2011.

Syafrudin, (2015), *Aplikasi Manajemen Risiko Pada Pembangunan Sistem Penyediaan Air Minum (SPAM). Jurnal Media Komunikasi Teknik Sipil.* Universitas Diponegoro

Wijaya Karya, (2019), *Prosedur Sistem Manajemen Risiko. No. Dok: WIKA-SMR-PM-01.01*. Jakarta