SCHOOL OF MATERIALS AND MINERAL RESOURCES ENGINEERING

UNIVERSITI SAINS MALAYSIA

ATTEMPT TO REDUCING THE GROUND VIBRATION LEVEL DUE TO BLASTING ACTIVITY BASED ON THE EVALUATION OF BLASTING GEOMETRY

By

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Dissertation submitted in partial fulfillment

of the requirements for the degree of Bachelor of Engineering with Honours

(Mineral Resources Engineering)

Universiti Sains Malaysia

JUNE 2018

DECLARATION

I hereby declare that I have conducted, completed the research work and written the dissertation entitled "Attempt to Reducing the Ground Vibration Level Due To Blasting Activity Based on the Evaluation of Blasting Geometry". I also declare that it has not been previously submitted for the award of any degree or diploma or other similar title of this for any other examining body or University.

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Date:

ACKNOWLEDGEMENTS

Firstly, I would like to express my gratitude to God for His blessings as the strength for me to complete my final year project successfully and submit this dissertation on time. This dissertation is also to fulfill the credit hour in which is the part of the criteria of the program of Degree in Mineral Resources Engineering that have been provide by Universiti Sains Malaysia.

In addition, I would also like to show my gratitude and much appreciation to my project supervisor Dr. Teuku Andika Rama Putra for his great guidance and management throughout the progress of my project. Besides that, not to forget I would like to thank all the staffs from the School of Materials and Mineral Resources Engineering for they have provide me with the information and also technical help needed for my project. My appreciation and gratitude is extended to all the staffs of Penjom Gold Mine which have contributed directly or indirectly towards the successfulness of this project.

Last but not least, I would like to thank my family, friends and my course mates who have supported and motivated me upon completing my final year project. May God bless you all.

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ABSTRAK

Hasil getaran permukaan akibat aktiviti perletupan di Penjom Gold Mine telah diklasifikasikan sebagai selamat dan terjamin berdasarkan tahap getaran standard mengikut Jabatan Mineral dan Geosains Malaysia dengan PPV sebenar 0.4 mm / s - 2.39 mm / s. Walau bagaimanapun, penduduk yang tinggal di sekitar kawasan dalam radius 1700 meter masih boleh merasakan getaran permukaan yang boleh merosakkan rumah mereka. Oleh itu, ia memerlukan reka bentuk geometri dan corak letupan yang dijangka mampu mengurangkan tahap getaran permukaan. Getaran permukaan diukur menggunakan “vibrometer” dan dinyatakan dalam halaju zarah puncak (PPV). Nilai PPV sebenar diperlukan untuk mencari nilai SD (skala jarak) dengan formula $\frac{d}{\sqrt{w}}$ untuk mengira perbezaan antara PPV sebenar dan teori. Pengiraan ini juga untuk mendapatkan pemalar k dan m yang kemudiannya digunakan untuk mengira reka bentuk geometri dan corak peletupan yang dicadangkan yang menghasilkan nilai PPV minimum jejari 1700 meter. Perbandingan nilai PPV pada geometri letupan sebenar dengan nilai PPV dalam reka bentuk geometri yang dicadangkan menunjukkan pengurangan getaran purata bumi sebanyak 5% daripada PPV sebenar. Dari 0.4 mm / s - 2.39 mm / s menjadi 0.018 mm / s - 0.558 mm / s.

ATTEMPT TO REDUCING THE GROUND VIBRATION LEVEL DUE TO BLASTING ACTIVITY BASED ON THE EVALUATION OF BLASTING GEOMETRY

ABSTRACT

Ground vibration result from blasting activity at Penjom Gold Mine has been classified as safe and secure based on the standard vibration level according to Departmen of Minerals and Geoscience of Malaysia with 0.4 mm/s – 2.39 mm/s actual PPV. However, the resident who live around the area within 1700 meters radius may still can feel the ground vibration that could damage their houses. Therefore, it required geometric design and blasting patterns which is expected to be able to reduce the level of ground vibration. The ground vibration is measured using vibrometer and expressed in peak particle velocity (PPV). The actual PPV value is required to find the SD (scaled distance) value with $\frac{d}{\sqrt{w}}$ formula in order to calculate the difference between actual and theoretical PPV. This calculation is also to obtain the k and m constants which later used to calculate the proposed geometric design and blasting pattern which results in a minimum PPV value of 1700 meters radius. The comparison of PPV values on actual blast geometry with PPV values in the proposed geometry design indicates an average ground vibration reduction of 5% of actual PPV. From 0.4 mm/s – 2.39 mm/s becomes 0.018 mm/s – 0.558 mm/s.

CHAPTER 1

INTRODUCTION

1.1.Significance of Project

Blasting is the main component for quarrying and mining sector as it functions as the part of rock fragmentation from the overburden or helps to breaks the deposited sedimentary rocks such as limestone and granite into desirable size before transport it to the processing plant. However, it is certain that blasting activity in the quarry or open pit mine may causing certain effect towards the environment especially for the nearby residential areas from the quarry or mine. The environmental effect of blasting that are most likely affecting the nearby residence exists in the form of toxic gases, fly rocks, noise, dust, air blast and the ground vibration. Among all the stated environmental effect of blasting, the most crucial one is the ground vibration and air blast which can cause damage to the nearby local residency such as houses, schools and clinics.

Ground vibration is the vibration caused by the blasting. This vibration is at a certain level if it has exceeded the threshold causing damage to the surrounding environment. The resulting ground vibration is strongly influenced by the maximum explosive charge per delay and the distance from the blasting point to the measuring location. To know how big the impact that occurs due to the vibration of the land to the building, it must measurement of vibration and noise. Measurement results are compared with raw blast vibration and noise levels. When the value exceeds standard vibration level the blasting design should be changed to ensure vibration for the environment. The standard reference of the vibration level to analyze the magnitude of the vibration the ground is

USBM (United State Bureau of Mines), Australian Standard and Department of Environment Malaysia. In this study, refers to the standard blasting operation which is set by the Department of Minerals and Geoscience Malaysia.

1.2.Problem Statement

Even though it has been over a decades since blasting has been employed in mining and quarrying sector in Malaysia, this method is still considered as a new method in Malaysia. For group of people consists of mining and quarry engineers, blasters and the project supervisors that are responsible to manage any risks that could be arise from blasting activity it has become a rising challenge as many quarry and mines are located to populated areas nowadays. Besides that, the environmental concern also may include how the blasting activity may affects the animals that are living nearby the quarry and mines. In general, blasting is very costly and also a major concern of social and environmental issues if it is conducted without proper training and controls. These group of people that responsible to in charge of blasting, regardless of what is their blasting activity scale should never underestimate the importance of preparing suitable blasting controls and also the public relations program as the effect of blasting could be serious.

Blasting activity in quarry and mines normally results in ground and airborne vibration. The following effects such as loud noise and vibration which is known as air blast that could cause any objects to vibrate and thus producing noise. In mining sector in Malaysia where most of the local mines are located in remote areas, it is unlikely for any structural properties nearby to occur a damage. On top of that, noise levels resulting from the blasting activity in mines are not probable to cause any hearing damage to anyone that is at the outside of the mine. The blasting activity only has enough capacity to makes people who are not aware of the blasting to be startled. It is very uncommon for the blasting activity to cause any properties or structural damage as it is composed of a wave of air particles that are compressed. In Malaysia, at the boundary of the quarry it has been set that air blast levels below 110 decibels is considered as the safety standard.

Blasting can results in distress and unpleasantness as the noise induce by the blast could make individuals startles or in which the air blast and ground vibration also causes disturbance and vibration of windows and any other items that could be broken due to excessive vibration. However, the degree of distress cause by the air blast and vibrations may be affected by factors such as time of blasting and the weather of that area on that day.

Ground vibration induced by blasting activity has destructive effect on nearby structures like roads, dams, natural slopes, railroads and also buildings or houses. This is among the very concerning environmental issue in Malaysia in the present day. The magnitude of vibration did play a very important role in all type of adverse effects towards the environment. In short, ground vibration is identical to a seismic event in that it will cause the ground to be shaking. It also has the tendency to cause catastrophe to any nearby structures if it reach a very high readings of vibrations. In Malaysia, the accepted vibration at the boundary of a quarry or mines is set to be limited under 5 mm/s which is a standard set for Malaysian blasting standard. Hence, it is very crucial to control and measure the magnitude of possible vibration as accurate as possible. Various researchers had carried out numerous of investigations to overcome its negative impact and due to the safety reasons lots of legal measures have been proposed to prevent the negative effect of blast vibration.

The importance of this project is due to that the reality is that no research has been made in the crisis of prediction of air blast and ground vibration in the quarry and mines in Malaysia. Every quarry and mines are tend to be different from another quarry and mines in terms of their existing rock geology and the blast wave propagation. Therefore, this is the reason that recently the existing local and also the international prediction for ground vibration failed to be applied throughout all the quarry and mines in Malaysia. Other than that, there has no any air blast and ground vibration prediction models for quarry and mines in Malaysia.

1.3.Objectives

- To determine the influences of blast design variables on vibration and air blast.
- To obtain a new blast geometry that is expected to reduce the levels of vibration and air blast induced by blasting.
- To compare the relationship between the predicted value of ground vibration and air blast with the actual value from the site.

1.4. Study Area

The largest gold mine in Malaysia is the Penjom Gold Mine which has been commisioned since year of 1996. This gold mine is situated in Kuala Lipis, Pahang. At the current moment, this gold mine belongs to PT J Resources. Before the year of 1990, which is during the 19th and 20th centuries mining activity was here and there to exploits the oxide ore, alluvial deposits and also going deeper such as underground mining. In the year of 1990, after the Pahang state government reviewed the economic potential of gold which then led to the vast exploration takes place in which bringing back Penjom to the world map as the larger scale producer of gold in mining activity that takes place in Peninsular Malaysia by applying the latest technology in mining sector.

THESIS OUTLINE

This thesis had been organized into five main chapters:

- Chapter 1: Introduction, this chapter introduces briefly the coverage of the thesis, including the overview of the research background, problem statement, objectives and scope of this research work.
- Chapter 2: Literature Review, covers in detail the existing literature on ground vibration induced by blasting activity, blasting parameters as well as the standard to be followed according to certain country.
- Chapter 3: Research Methodology, presents the overall flow of this study, information about the location and all the collecting data methods.
- Chapter 4: Results and Discussion, presents and discusses results from the data and result tabulated. Explain the importance of findings and acknowledge any mistake or limitation in the research.
- Chapter 5: Conclusions and Recommendations, summarizes the finding of the research and makes recommendations based on it.

CHAPTER 2

LITERATURE REVIEW

This research was made as an attempt to investigate and study the effect of different blasting parameters on the ground vibration. Explosive activity cannot be separated from rock mass destruction. The energy produced by the explosives will be transmitted into the mass rocks so that the rocks are distant. At the time of the explosion, not all energy used to produce rock fragmentation. But some energy is passed into the rock mass in the so-called waveform as a seismic wave. The greater the energy transmitted into rock mass, the smaller the size of the fragmentation rocks that will be produced by the blasting process. In fact, in addition to providing destructive effects in rocks, the energy generated from a blasting operation also raises effects are less favorable one of them in the form of ground vibration.

2.1.Blasting

According Koesnaryo (2001), the main purpose of blasting is to dismantling the quarry material from the parent rock. A blasting operation shall be deemed successful in mining activities if:

i. The production target is met which is expressed in tonnage per day or tonnage per month.
ii. The use of efficient explosives, expressed in the amount of rocks successfully dismantled per kilogram of explosives which known as the powder factor.

iii. The fragmentation of the rock is evenly distributed with a bit of blocky size rock is produced.

iv. Obtained a stable rock wall and flat which means there is no overbreak, overhang and cracks.

v. Environmental impact of blasting such as flyrock, vibration, air blast, toxic gas and dust is minimal.

vi. Secure.

2.1.1 Factors Affecting Blasting Activities

Generally speaking in the blasting activity there are two factors that can affect blasting results, among which there are factors that can be controlled by human beings and factors that cannot be controlled by humans.

Factor which can be controlled by humans as follows:

a) The direction and slope angle of the blast hole.

b) Drilling pattern.

c) Diameter of the blast hole.

d) Blasting geometry.

e) Firing pattern.

f) Delay intervals.

g) The properties of explosives.

h) Explosives charging.

While the factors that cannot be controlled by humans, include:

a) The characteristics of the rock mass.

b) Groundwater effect.

c) The weather conditions.

2.1.1.1 Controlled Parameters

a) The direction and slope angle of the blast hole.

The direction of the drilling is divided into two, they are the direction of the vertical drill and inclined drilling as in Figure 2.1. Mining companies using drill tools the type of turn-pound will apply the inclined drilling system, but on an open pit mining company that has a large area of mining operation tend to use a vertical drilling system. To determine which types of drilling should be employed in any quarry or mines, note the advantages and disadvantages of each of this direction drilling.

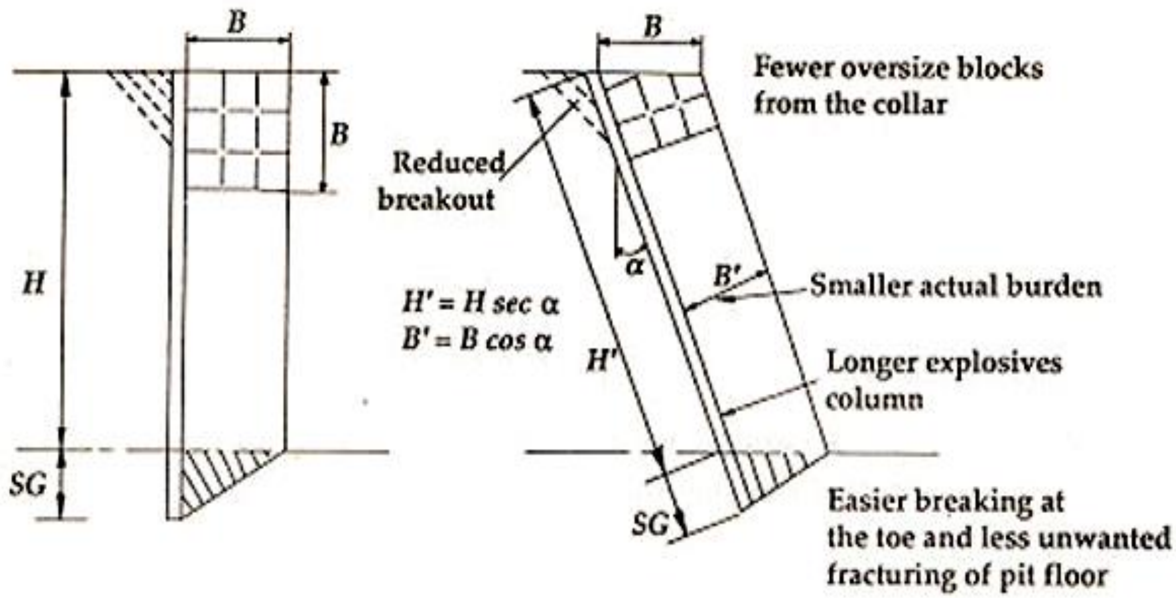

Figure 2-1 - Vertical blasthole and inclined blasthole.

The advantages of the inclined drilling system are:

- Fragmentation result from the blasting is better and uniform.
- The surface of the wall and floor level produced are relatively flat.
- Reduce the problem known as back break.
- Minimizes the danger of landslide at the bench, so it is secure for workers and any transportation such as dump truck and excavators.
- The working space produce has larger area.
- The lower powder factor needed, when the shock wave is reflected to destroying rocks on the floor level are more efficient.
- High wheel loader productivity due to pile of blasting (muckpile) lower and uniform.

- Subdrilling is shorter, so the use of blasting energy is more efficient and the resulting vibration is smaller.

The disadvantages of the inclined drilling system are:

- Difficulty in placement of the same angle between the blastholes and more precision is required in drill holes
- The length of the explosive hole and the time required for drilling is longer.
- Having difficulty in charging of the explosives.
- In drilling the inner part of the blasthole, the established deviation angle will increase.

According to Koesnaryo (2001), the advantages of vertical drilling blasthole are:

- Drilling can be done more easily and more accurately.
- Shorter length of blasthole in case of the same bench level compare to inclined drilling.
- The likelihood for the occurrence of flying rock (fly rock) is less.

The disadvantages of vertical drilling of blasthole are such as follows:

- The possibility of occurrence a large remnant toe on the floor.
- It has the possibility of back-break and thus will likely produce larger ground vibrations.
- Produce block size rocks on the stemming area.
- Destruction along the blast hole is uneven.

b) Drilling pattern.

The drilling pattern is a drilling pattern for placing systematic explosive holes. According to Koesnaryo (2001). In general there are 2 kinds of drilling pattern as in Figure 2.2, namely:

i. Parallel pattern

ii. Staggered pattern

The parallel drilling pattern is the drilling pattern by hole placement at sequential explosion and parallel to the burden. While the staggered pattern is a drilling pattern that the placement of the hole is alternate to each blasthole. At the field, parallel drilling patterns are easier to be made but the fragmentation of the rocks as the blasting results are less uniform. Meanwhile, as for the staggered drill pattern, the resulting fragmentation level is more uniform and better than with parallel drilling patterns even though it is more difficult to be done at the field. This is due to the drilling pattern of staggered pattern the energy produced is more optimally distributed in the rocks as in Figure 2.3.

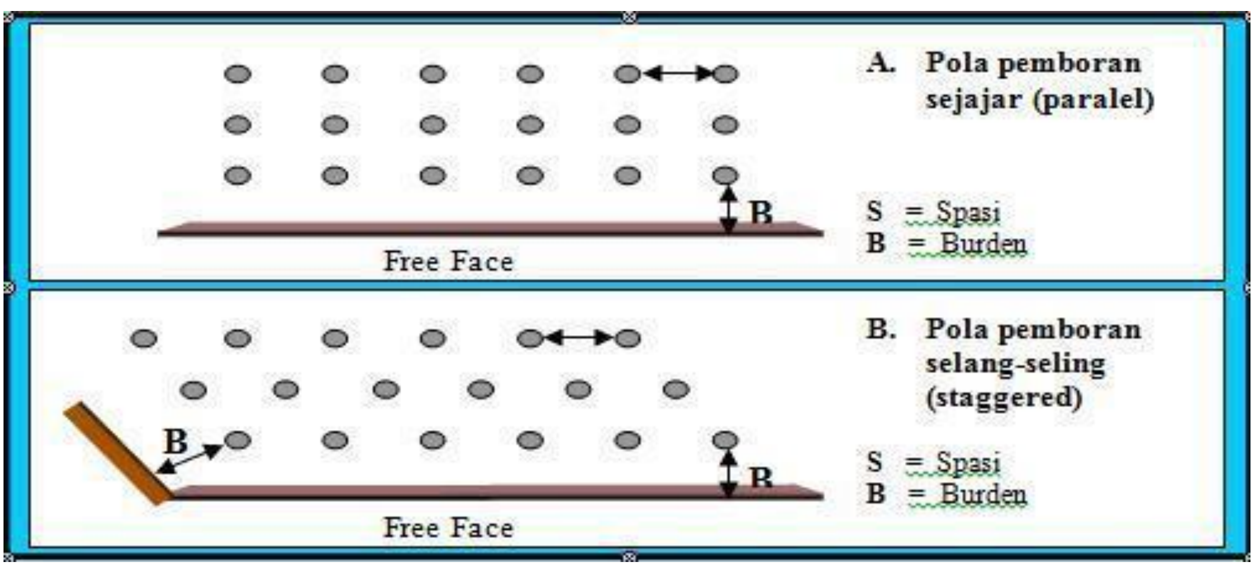

Figure 2-2 - Parallel and Staggered drilling pattern

Source : Wibisono, 2017.

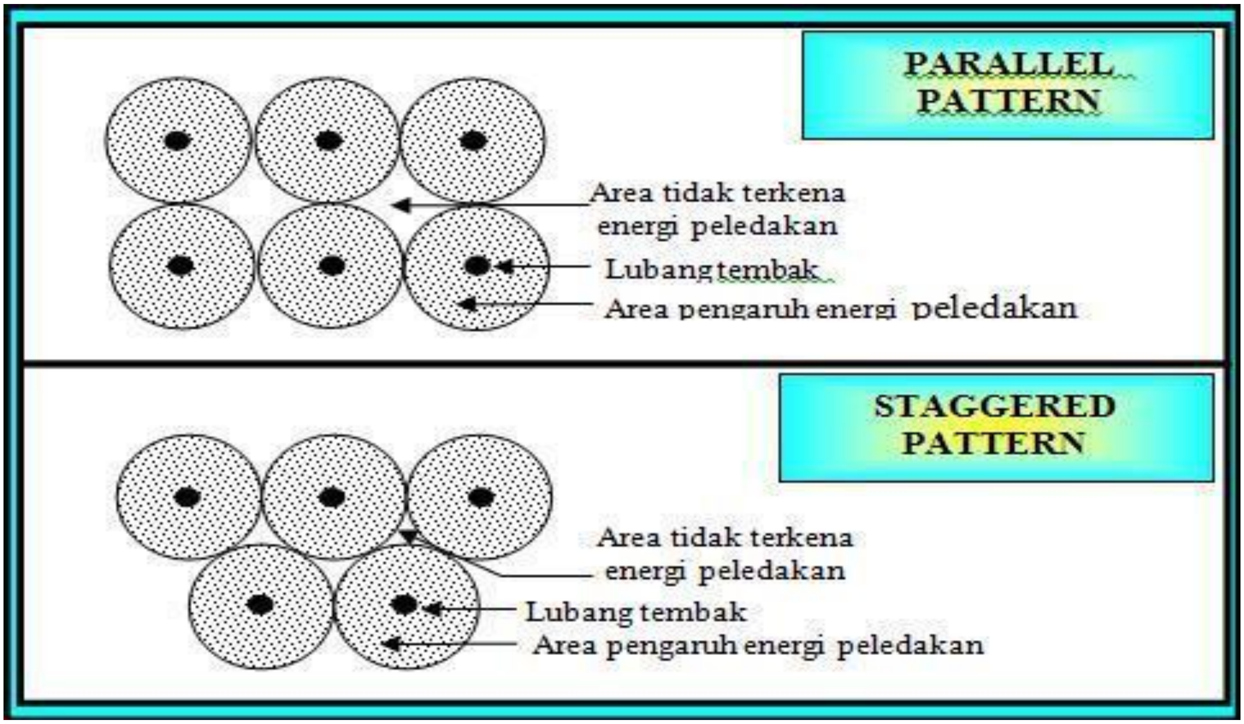

Figure 2-3 - Effect of Blasting Energy on Drilling Patterns

Source : Koesnaryo, 2001

c) Diameter of the blasthole.

The blasthole diameter affects the determination of the distance of the burden and number of explosives to be used in each blasthole. Factors that are affecting the determination of blasthole diameter are such as:

i. Volume of rock mass to be blast.
ii. Height of the bench level.
iii. The desired level of fragmentation.
iv. Available drill machines (related to drilling costs).
v. Capacity of loading equipments to handle the blasted rocks.

The blasthole diameter affects the length of the stemming. Large diameter of blasthole should have long stemming. Whereas if a small diameter blasthole then the used stemming becomes shorter for avoiding ground vibrations and flying rocks (flyrock). If stemming too long then the explosive energy is not capable of destroying the rocks on the area at around the stemming. The blasthole diameter is also limited by the height of the bench, with a minimum diameter for certain blast. If the limit of this minimum diameter is not achieved then there will be an excessive deviation that are destructive, which will cause ground vibration.

d) Blasting geometry.

Blasting geometry is very influential in controlling the blasting results because if it is a very good blasting geometry it would produce better rock fragmentation which corresponds to the size of the crusher in the absence of blocky size of rocks, the condition of the bench which is more stable, as well as the safety for workers and the mechanical equiments and transportation are more secure. In blasting operations there are seven basic standards of geometry blasting that is: burden, spacing, stemming, subdrilling, depth of blasthole, charge length and the bench height as in Figure 2.4. Method that can be apply on how to determine the blasting geometry is by the method proposed RL. Ash (1967), as follows:

i. Burden(B)

Burden is the shortest perpendicular distance between a blasthole filled with explosive charge with free face or in which direction the rock is blasting will be thrown. A good burden is the distance at which the explosive energy can be pressing the rock to the maximum so that the rock breaks can be in accordance with fragmentation of the planned rock by keeping as small as possible the occurrence of flying rocks, lumps and rock cracks at the end of the bench as in Figure 2.5.

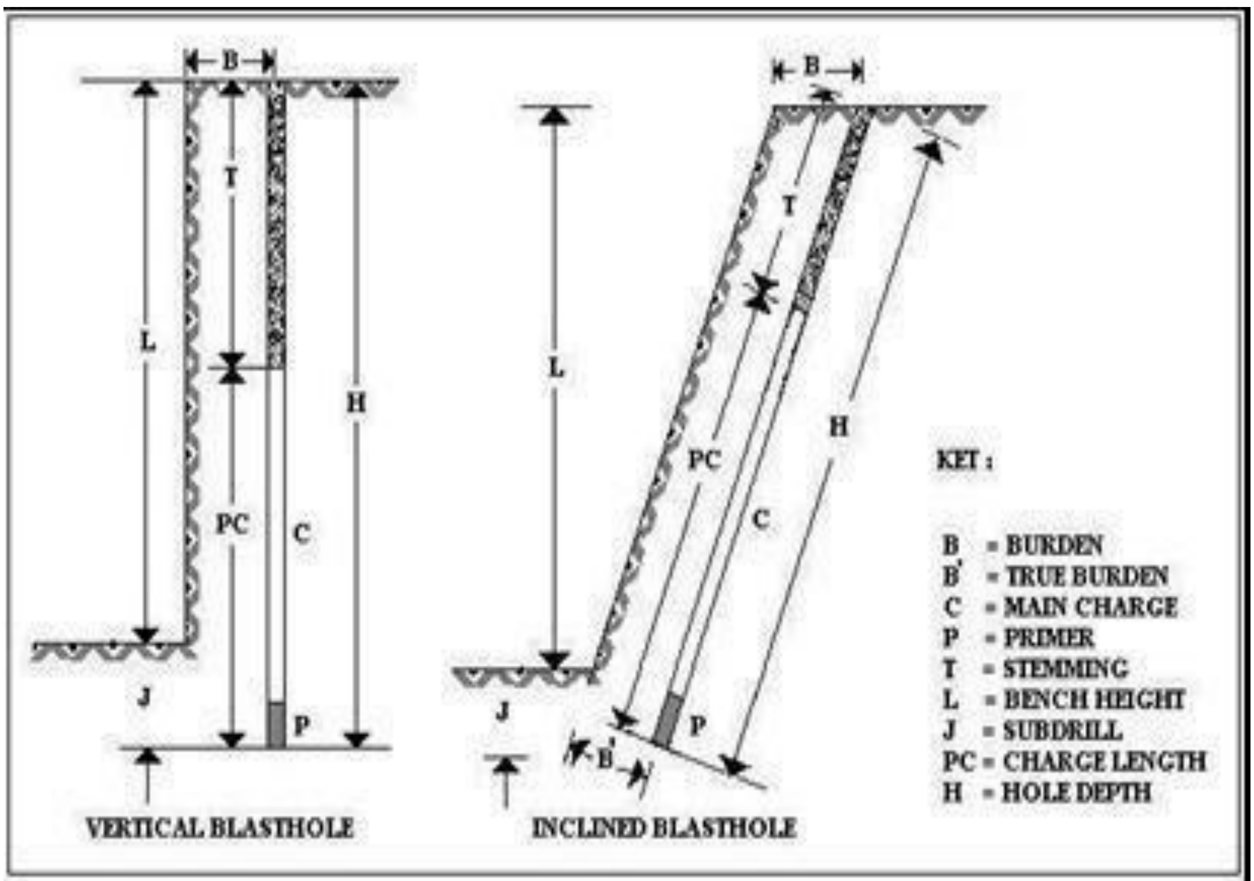

Figure 2-4 - Blasting Geometry(R.L. Ash, 1697)

ii. Spacing(S)

Spacing is the closest distance between two adjacent blastholes in a row. If the spacing distance is too small, then it will cause the rocks it breaks to be smoother, but when the spacing is greater than the provision it will causing lots of bumps and bulges between the 2 explosive holes after blown up.

$$S = Ks \times B \quad \text{(Equation 2.1)}$$

Where;

Ks = *spacing ratio* (1,00 – 2,00)

S= *spacing(m)*

B = *burden* (m)

The assumptions of 1.6B to 2.0B is a good starting point for determining the spacing of a blast to be initiated simultaneously in holes in the same row. For "V" pattern and box cut, spacing usually set between 1.0B – 1.5B. In Malaysia, the normal practice is 1.2 B.

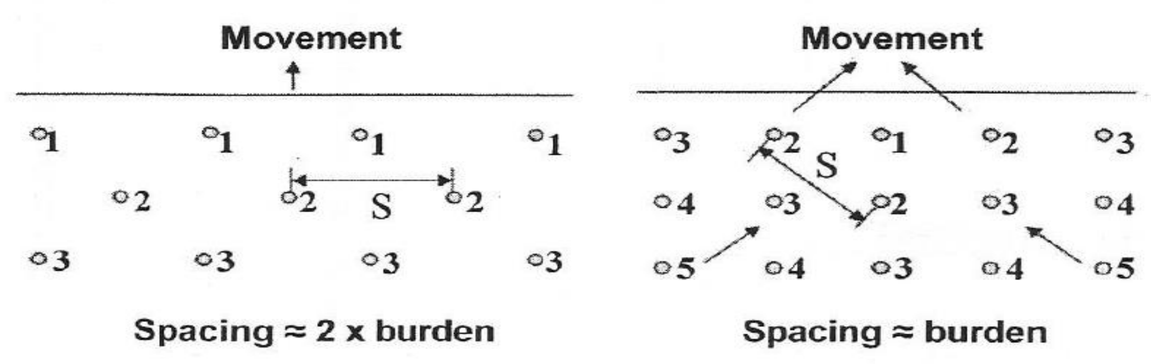

Figure 2-5 - Spacing versus burden

iii. Stemming(T)

Stemming is the cover material in the blasthole located at on explosive stuffing inside column. The function of stemming is that to balance the pressure in the blasthole and enclose the explosive gases so it can suppress the rock with maximum energy. The stemming that is long enough will result in the formation of a lump when the energy from the explosive unable to destroy the rock around the stemming. While stemming that is too short can lead to the emergence of rocks flying (flying rock) and the breaking of rocks will be small fragmentation.

For determination of the height of stemming used the formula:

$T = Kt \times B$ ……………………………………………………………………..(Equation 2.2)

Where;

T = *stemming* (m)

Kt = *stemming ratio* (0.75-1.00)

B = *burden* (m)

iv. Subdrilling(J)

Subdrilling is part of the length of the blasthole located lower than the floor level. Subdrilling is required to allow the explosive to blast and breaks the rocks as a whole and uncovered just at the floor level of the bench, so bulges on the floor level can be avoided. The formula used is:

J = Kj x B……………………………………………………………………...(Equation 2.3)

Where;

J = *subdrilling* (m)

Kj = *subdrilling ratio* (0.2-0.3)

B = *burden* (m)

v. Hole depth(H)

The depth of the blasthole is the total height between the bench levels with subdrilling height. The depth of the explosive hole is usually adjusted with production levels (loading capacity) and geotechnical considerations.

The formula used is:

H = Kh x B……………………………………………………………………….(Equation 2.4)

Where;

Kh = *hole depth ratio* (1.5-4.0)

H = *hole depth* (m)

B = *burden* (m)

vi. Charge length(PC)

The charge length is the length of the blasthole column filled with explosives. The length of this column is the depth of the blasthole minus with the stemming length that is used.

PC = H – T…………………………………………………………………….(Equation 2.5)

Where;

PC = *charge length* (m)

H = *hole depth* (m)

T = *stemming* (m)

vii. Bench height(L)

Specifically the maximum level of bench height is determined by the drill equipment and loader available. High levels of bench height may affect the outcome of the explosions such as rock fragmentation, air blasts, flyrocks and vibrations of the soil. Based on the comparison of the height of the bench with the distance of the burden applied stiffness ratio, it will be known the result of blasting that can seen in Table 2.1.

Table 2-1 - *Potential Problem as Related to Stiffness Ratio* (L/B) (After C. J. Konya, 1990)

Stiffness Ratio	***Fragmentation***	***Airblasts***	***Flyrock***	***Ground Vibration***	***Comment***
1	*Poor*	*Severe*	*severe*	*severe*	*Severe backbreak, toe problems, do not shoot, redesign*

2	*Fair*	*Fair*	*fair*	*fair*	*Redesign if posibble*
3	*Good*	*Good*	*good*	*good*	*Good control and fragmentation*
4	*Excellent*	*Excellent*	*excellent*	*excellen t*	*No increased benefit by increasing stiffness ratio above 4*

Determination of the bench height by using the stiffness ratio is calculated using the formula as follows:

L = 5 x De……………………………………………………………………..(Equation 2.6)

Where;

L = *minimum height of the bench* (ft)

De = *blasthole diameter* (inch)

e) Firing pattern

The firing pattern is the time sequence of blasting between holes explode in a row with an explosion hole on the next or inter line explosion hole with each other. As in Figure 2.6 blasting pattern determined by the timing of the blasting and the direction of material collapse expected. Based on the direction of collapsed rocks the blasting pattern is classified as follows:

i. *Box Cut* is a blasting pattern that the direction of the rocks rupture forward and form a box.
ii. *Corner Cut* is a detonation pattern that the direction of the rock rupture to one the angle of the free face.
iii. *V Cut* is the firing pattern that the direction of the rocks rupture forward and form the letter V.

Based on the timing of the blasting, the blasting pattern is classified as follows:

i. The simultaneous detonation pattern is a blasting pattern that occurs on a continuous basis simultaneously for all the blastholes.

ii. The pattern of successive explosive is a pattern that implements blasting with time delay between rows of one with other rows.

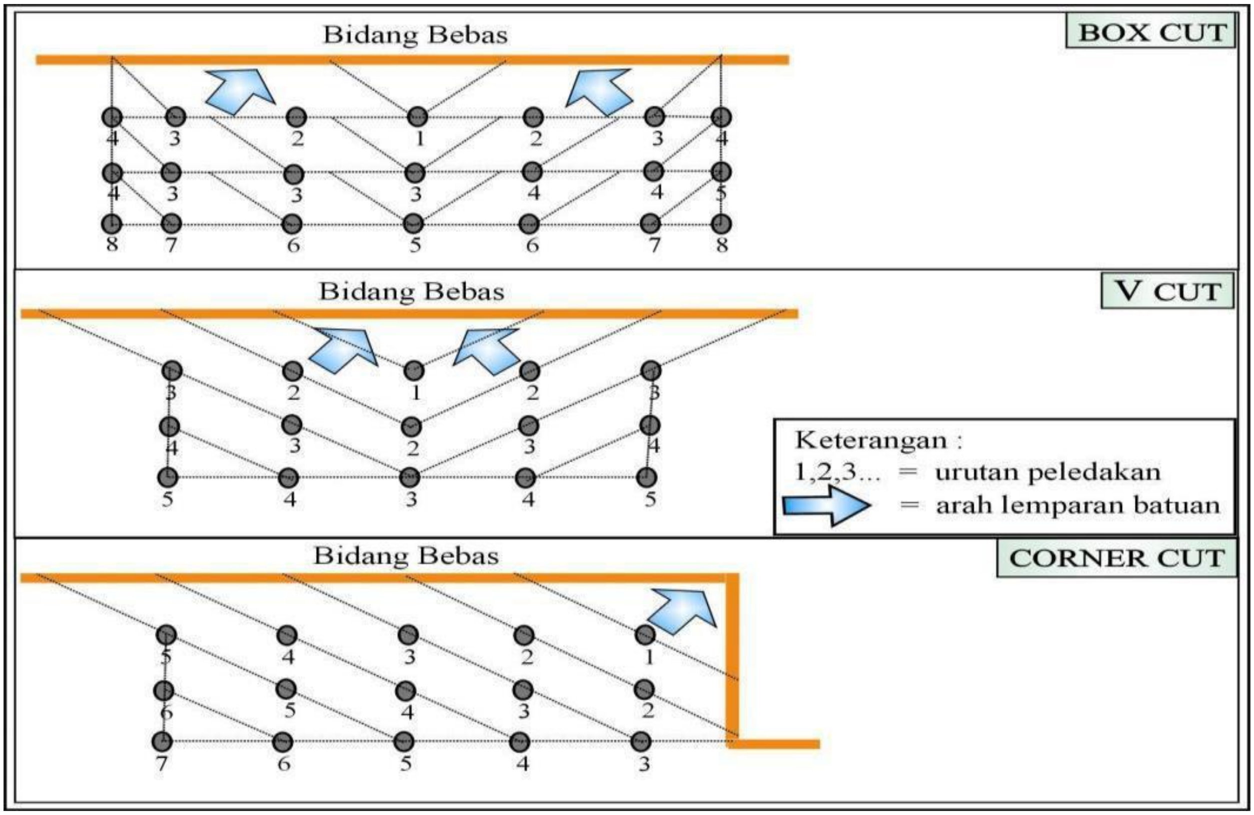

Figure 2-6 - Firing pattern based on the direction of rocks rupture.

Source : Koesnaryo, 2001

f) Delay intervals.

Delay time is the delay of blasting time for blasting between the front line and the line behind it using delay detonator. The advantages of blasting with time delay are:

- The fragmentation of the blasted rocks will be more uniform and good.
- Reduce the incidence of flyrocks and also the ground vibrations.
- Provide a new free face for the next blasting.

- Directions of where the rupture of the rocks will happen can be identified.
- Reduce the airblast.
- Reduce the muckpile as a result from the breakage of the rocks.

The purpose of blasting with delay intervals is to reduce the number the charge explodes at the same time and gives the grace time on material close to the free face to explode in a perfect manner as well as to provide a new free space for the next blasthole rows to shoot next. If the delay between rows is too short then the load that is loaded in the front row will block the shift from the next line so the possibility of the material on the second row will burst vertically form stack. As a result the pile of blasting material (muckpile) becomes very high and less stable and will be difficult for loading activities. But if the delay intervals is too long then the product will be dismantled thrown far ahead and most likely will causing flyrocks. This matter happen because there is no rock wall that serves as a throwing holder rock behind it.

g) The properties of explosives.

An explosive is an assembly consisting of shaped materials solid or liquid or mixtures of both, which, when exposed to such an action heat, impact, friction and so on will react with high speed, forming a gas and causing a heat effect as well as a very high pressure. The properties of explosives affecting blasting results are strength, speed of detonation, sensitivity, weight of content, pressure of detonation, resistance to water and toxic gas properties.

h) Explosives charging.

The amount of explosive use greatly affects the blasting results, especially with the level of fragmentation generated. Charging explosives into the blasthole is done by the blasting crew. For a dry blasthole, the explosives is directed directly into the blasthole, then charging the amount of explosives to the blasthole is set in accordance with predetermined amount. As for the wet blasthole, it will used plastic liner for wrapping the bulk emulsion cartridge as well as inhole detonator. When the plastic is filled with explosives with the specified amount then the top end of the plastic liner will be tied then pressed using a stick order the plastic stuffing can reach the base of the blasthole. After the bulk emulsion reaches the base of the blasthole then hole filled with stemming.

Factors that affecting the amount of explosives to be charged into the blasthole includes:

i. Loading density

The loading density is the number of explosive stuffed in the charge length(PC) of the blasthole. To calculate the loading density used the formula as follows:

$de = 0{,}508\ De^2\ (SG)$ ……………………………………………………...……(Equation 2.7)

Where;

de = *loading density* (kg/m)

De = *diameter of the blasthole* (inch)

SG = *specific gravity of the explosives used*

So that the number of explosives used in one shot hole can be searched using the following formula:

E = de x PC…………………………………………………………………...……..(Equation 2.8)

Where;

E= *number of explosives per blasthole*(kg)

de = *loading density from the explosives* (kg/m)

PC = *charge length* (m)

ii. Powder factor (PF)

Powder factor or specific charge is the ratio between the amount explosives used against the volume of rock being blasted.

PF= E / W…………………………………………………………………………..(Equation 2.9)

Where;

PF = *powder factor* (kg/ton)

W = *weight of the rocks to be blasted* (ton)

E = *weight of the explosives used* (kg)