CORRELATION OF BLAST DESIGN AND GROUND VIBRATION DURING BLASTING AT IMERYS (M) SDN BHD.

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UNIVERSITI SAINS MALAYSIA

2022

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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

September 2022

DECLARATION

I hereby declare that I have conducted, completed the research work and written the dissertation entitled 'Correlation of Blast Design and Ground Vibration During Blasting at Imerys (M) Sdn. Bhd.'. I also declare that it has not been previously submitted for the award of any degree and diploma or other similar title of this for any other examining body or University.

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Witness by

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Date: 19/08/2022

ACKNOWLEDGEMENT

Alhamdullilah, thanks to the almighty god because His blessings and strength, I can successfully finish my final year project thesis, although I have faced some obstacles while doing this research.

I would like to thank Assoc. Prof. Ir. Ts Dr. Mohd. Hazizan Bin Mohd. Hashim as my supervisor for this project, for his useful guidance, advices, and willingness to accept me under his supervision for this project. He styles of works the encourage all of his sub-unit to be independent eager me to become one of his sub-unit for this final year project in USM. Without his moral supports, patience, and encouragement, I may lose the hope to finish this project.

I also want to express my sincere gratitude to the staffs from Imerys M Sdn Bhd for helping me to do the research by guiding me during working on the site. To Mr. Alireza, Mr. Pugal and Mr. Choong high appreciation should be given to them for their cooperation and contribution.

Special thanks to my family, especially my parents, Mr. Saad and Mrs. Fazilah which never stops supporting me in order to finish this project. Last but not least, I would like to delicate this acknowledgement to whole staff of School of Materials and Mineral Resources Engineering, Universiti Sains Malaysia for giving me the chance to undergo this project.

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LIST OF ABREVATION

Sdn. Bhd.	Private limited company
M	Mineral
PPV	Peak particle Velocity
SD	Scaled Distance
R	Disntance to shot
Q	Maximum charge per delay
PF	Powder Factor
UCS	Uniaxial Compressive Strength

ABSTRAK

Hasil daripada aktiviti perlombongan dan pembinaan yang semakin meningkat di kawasan yang berhampiran dengan populasi manusia, getaran tanah telah berkembang menjadi masalah alam sekitar yang ketara kerana fakta bahawa ia berpotensi merengsakan orang ramai dan menyebabkan kerosakan pada struktur. Kajian telah dijalankan di Imerys (M) Sdn Bhd, Ipoh, Perak untuk mengkaji getaran tanah. Objektif penyelidikan ini adalah untuk membangunkan satu kaedah untuk menganalisis korelasi antara reka bentuk letupan dan getaran tanah iaitu untuk mewujudkan hubungan antara halaju zarah puncak (PPV) dan jarak berskala dengan menggunakan analisis regresi dan untuk menentukan hukum pemalar tapak yang boleh pakai dalam PPV dalam persamaan USBM untuk meramalkan getaran tanah oleh kuari. Pemantauan letupan, pengumpulan data dan analisis regresi telah dilakukan untuk mencapai objektif kajian ini. Analisis regresi dilakukan untuk menentukan pemalar tapak dan ramalan ke atas nilai regresi. Nilai R-square obained hampir mencapai 1.0, yang menunjukkan bahawa semua variasi dalam pembolehubah bersandar dijelaskan sepenuhnya oleh pembolehubah bebas. Nilai K dan B daripada tahap keyakinan 95 peratus digunakan untuk meramalkan nilai PPV dengan memasukkan 70 kilogram cas setiap kelewatan dan 300 meter jarak ke dalam persamaan; hasilnya ialah 3.74 milimeter sesaat. Daripada analisis regresi, jarak dan cas berat (jarak berskala) kedua-duanya mempunyai pengaruh yang besar terhadap keamatan getaran.

CORRELATION OF BLAST DESIGN AND VIBRATION DURING BLASTING AT IMERYS (M) SDN BHD

ABSTRACT

As a result of growing mining and construction activity in areas close to human populations, ground vibration has evolved into a significant environmental problem due to the fact that it has the potential to irritate people and cause damage to structures. Study was conducted at Imerys (M) Sdn Bhd, Ipoh, Perak to study the ground vibration. The objective of this research is to develop a method to analyse the correlation between blast design and ground vibration which are to establish the relationship between peak particle velocity (PPV) and the scaled distance by using regression analysis and to determine the site constant law that can adopt in PPV in USBM equation to predict ground vibration by quarry. Blast monitoring, data collection and regression analysis was performed to accomplish objective of this study. Regression analysis was performed to determine the site constant and the prediction on the regression value. The R-square value obained came close to reaching 1.0, which indicates that all variations in the dependent variable are totally explained by the independent variables. The value of K and B from a confidence level of 95 percent was used to predict the value of PPV by plugging in 70 kilogrammes of charge per delay and 300 metres of distance into the equation; the result is 3.74 millimetres per second. From the regression analysis, the distance and the weight charge (scaled distance) both have substantial influences on the intensity of vibration.

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The approach of quarry production areas to sensitive structures or residences typically leads to an increase of vibration and air blasts levels. The majority of quarry firms are forced to contend with the requirement of reducing the amount of ground vibration and noise in order to lessen or get rid of the likelihood of customer complaints or damages (Roy, 2005).

Because of its direct impacts on environment, ground vibration is a major and critical issue in quarry operations. If the blast design is not properly designed, may cause ground vibrations strong enough to affect mine or quarry plant and structures, as well as nearby structures outside the mining permission area (Hustrulid, 1999). Air blasts, on the other hand, are created as a result of blasting operations.

The parameters that have an impact on ground vibration can be divided into two categories which are uncontrollable and controllable parameter. Geological features and the position of existing structures are examples of parameters that cannot be controlled. On the other hand, parameters that can be controlled include burden, spacing, sub-drilling, stemming, delay duration, charge type, weight per delay, distance to shot and scaled distance.

The characteristics of the blast hole, the presence or absence of water, the charge per delay, the vibration frequency, the rock properties, and the propagation of surface waves and body waves in the ground all have an effect on the vibration level at a certain distance. Rocks that have been subjected to tensile and shear pressures will eventually develop fractures. As a result, research into blast-induced ground vibrations in rocks has become more important. It is possible to express the relation between PPV and scaled distance (SD) using the formula:

$$\text{PPV}=\text{PPV}=K(SD)^{-B}$$

$$\text{SD}=\text{R}/\sqrt{\text{Q}}$$

Where PPV is the peak particle velocity (mm/s), SD is the scaled distance (m/kg^0.5), K and B are the site constants, R is the distance to shot (m) and Q is the maximum charge per delay (kg). The ground vibration consists of three distinct waves which are:

- Compressional (or P) waves
- Shear (or S)
- Waves,Rayleigh (or R) waves.

The compressional wave, also known as the P wave, travels the fastest through the earth. Consider a long steel rod hit on the end as the simplest example of particle motion within the P wave. As the compressive pulse travels down the rod, the particles of the rod move to and from, i.e. the particles in the wave move in the same direction as the propagation of the wave. The shear wave, also known as the S wave, moves at a velocity that is roughly 50–60 percent that of the P wave.

To demonstrate how particles move within a wave, shake one end of a rope. This will show how the particles are moving. The wave moves in a path parallel to the rope, while the particles that make up the wave move in a direction that is perpendicular to the movement of the wave. Because they move through the rock in three dimensions, P and S waves are frequently referred to as body waves. This is because they go through the rock itself. The R wave, also known as the Rayleigh wave, is a surface wave that quickly attenuates with increasing depth and travels more slowly than the other two waves. The motion of the particles that make up the wave is described as elliptical, taking place on a vertical plane and moving in the same direction as the wave's propagation. At the surface, the motion is opposite to the direction in which the wave is travelling.

The focuses of this study are to concentrates on the relationship between the blast vibration and blast design, which is scaled distance. In addition, to understanding the measurement and control of the blast-induced ground vibration that caused by quarry activities.

1.2 Problem Statement

The employment of explosive energy is necessary in order to break rock. However, the utilisation of this energy is not effective in every single way. A portion of the energy is dissipated into the atmosphere, which results in the generation of flyrock and either airblast or air vibrations. Some of it also leaves the blast site in the form of ground vibration, which travels through the surface soil and the bedrock.

As a result of growing mining and construction activity in areas close to human populations, ground vibration has evolved into a significant environmental problem due to the fact that it has the potential to irritate people and cause damage to structures. Structures may include mining offices located on site, housing located off site, schools and churches located off site, transmission lines, and subsurface pipelines. There is a possibility that some of these buildings have historic or cultural elements that are very susceptible to even low levels of vibrations.

It stands to reason that the blast designs used in quarries in this region are different in comparison to those used in other countries. This is because the geological conditions and procedures at each site are entirely different . Due to the complexity of the situation, decision makers in the quarry business in Malaysia require a set of tools that can demonstrate in a straightforward manner the connection that exists between the blasting parameters and ground vibration. Why is it necessary to be aware of the connection? It can help in defining mitigation methods and predicting their qualitative impacts on ground vibration. The majority of the adjustable factors are connected to the various blast designs that are used in the operation, with the charge weight having the most significant impact.

1.3 Objectives

Based on the identified research gap, the objective of this research is to develop a method to analyse the correlation between blast design and ground vibration. The process of this research is divided into the following objectives to accomplish the aim of the research:

1. To establish the relationship between peak particle velocity (PPV) and the scaled distance by using regression analysis.
2. To determine the site constant law that can adopt in PPV in USBM equation to predict ground vibration by quarry.

1.4 Thesis Outline

This project contains five chapters. A brief explanation of each chapter is as follows:

The first chapter serves as an introduction. It includes the study's background, problem statement, objectives, and the thesis's structure.

The findings of previous researchers on the blast outcome are reviewed in Chapter 2. Previous research into lowering ground vibration by adjusting blasting parameters.

The method of the study, which includes collecting blast design data, regression analysis, vibration results, and a sample of rock after the blast, and a point load test, is discussed in Chapter 3.

The analyses and findings of the study in terms of blast design, ground vibration, and point load test are covered in Chapter 4.

Chapter 5 concludes the project by addressing the study's objectives, as well as limitations and suggestions for future research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The correlation of blast design and vibration during blasting has been discussed by many researchers and engineers from all around the world. This chapter presents the literature review about the influence of blasting parameter, properties of explosive, and vibration generation. The literature review was assembled from relevant journal articles, research, and books by a range of authors.

2.2 Explosives

An explosive is a liquid, solid or mixture that, when ignited properly, undergoes a quick transformation into gases at high temperature and pressure (Das Sharma, 2012). Proper initiation of industrial explosives quickly converts chemical reaction into high-temperature, high-pressure gas exertion. The fast growth of these gases inside the confines of rock causes extraordinarily high stresses. Via introducing a dynamic force on the rock mass, fragmentation is accomplished by blasting. The explosive loading of rock may be divided into two parts, shock wave and gas pressure shown in Figure 2.1.

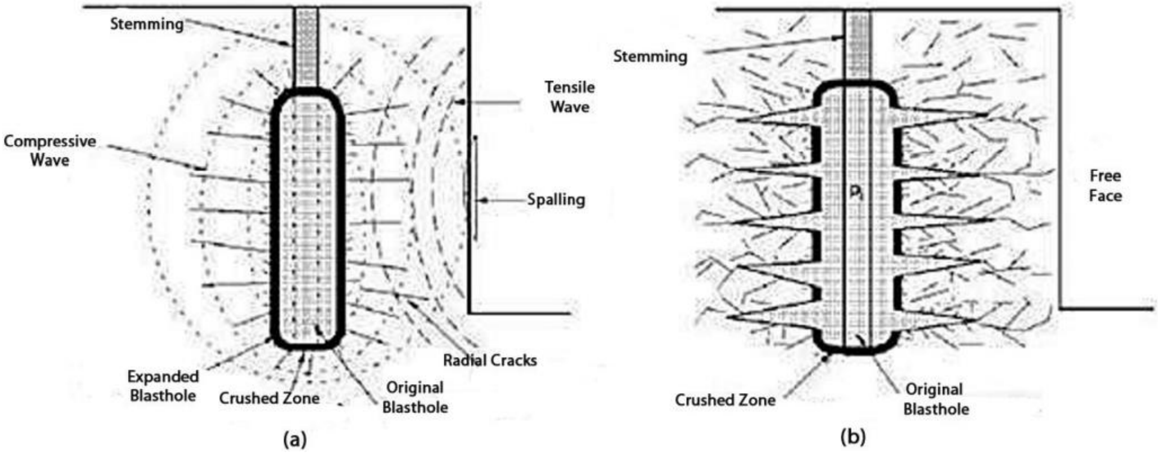

Figure 2.1: Two phases of explosive rock mass loading:
Shock wave propagation & b) gas pressure expansion.

2.2.1 Classification of explosives

Industrial explosives were be divided into two classes, low and high, based on their detonation requirements. A low explosive is an explosive that can be detonated without the need of a detonator. This type of explosive is often ignited by a flame, heat, or spark given by the spit of a safety fuse, a wick, or the head of an electric fuse. Low explosive examples are gunpowder and black powder. In the past, gunpowder was made and utilised as a military explosive and rock-blasting explosive. Charcoal, saltpetre, and sulphur constitute the components of gunpowder. Gunpowder is mostly utilised in safety fuse, propellant, and other pyrotechnic applications nowadays.

High explosives are a separate category with their own primary and secondary categories. Primary high explosives are utilised as the initiating charge in detonators. Due to their great sensitivity to stress, friction, and heat, they respond by rapidly igniting or exploding. Mercury fulminate, lead styphnate, and lead azide are examples of main high explosives. Furthermore, secondary high explosives are relatively resistant to stress, friction, and heat. They can be ignited when exposed to heat or flame in tiny concentrations, although explosions are possible. Their power is employed when they are put to detonators to increase their effectiveness. Secondary boosters include dynamite, emulsion, watergels, and cast boosters like pentolite. The velocity of detonation (VOD) ranges from 4,000 to 7,500 metres per second (m/s) according on composition, density, degree of confinement, and diameter.

2.2.2 Explosive ingredient

A blasting agent is an explosive that contains non-explosive elements that can only be detonated by a high explosive charge put within it, not a detonator. All explosives have ingredients like oxidizer, sensitizer, and fuel. Oxidizer is a chemical that supplies oxygen for a process. The most prevalent oxidant is ammonium nitrate. The reaction between fuel and oxygen produces heat. Fuel oil and aluminium powder are common heat-producing fuels.

When the sensitizer creates voids that operate as "hot spots" after detonation, the reaction will begin. Most sensitizers are air and gas in the form of extremely small bubbles, occasionally represented by glass micro balloons (GMBs).

2.2.3 Types of explosives

In the loosening of rock from benches, the mining industry employs a variety of explosives, including ammonium nitrate and fuel oil (ANFO), watergels, and emulsions (Kumar, 2013).

Emulsions, often known as "water in oil" combinations, were initially created in the early 1960s with the intention of enhancing the performance of water gels. They are hot solutions of oxidizer salts, which can be composed of calcium, ammonium, AN, CN or sodium, SN, and nitrates. These solutions are then blended with oil and an emulsifier. The oil phase is commonly made up of diesel fuel and/or mineral oil, both of which include sensitizers in the form of micro-balloons. Fine droplets of ammonium, sodium, or calcium nitrates are spread in a continuous phase of fuel oil to generate emulsions. The emulsifying component stabilises this emulsion against liquid separating. In most cases, the emulsion appeared in the form of a white and homogenous cream, as seen in Figure 2.2.

The creation of watergels was a reaction to the deficiencies of ANFO in wet environments. A gelatinizing chemical, often known as a thickening, modifies their consistency. Watergels are safer to manufacture, transport, and store, as well as less dangerous because of it size and packaging that shown in Figure 2.3. At low ambient temperatures and if the supersaturated AN solution crystallises, generating an imbalance of oxidizers and fuels in their two phases, water gels are less effective than slurry explosives (that is, in their solid and liquid forms).

ANFO is a mixture of inert chemicals that, when mixed in the correct proportions, generate an explosive material. The mixture's ideal ratio is 94.3 percent AN to 5.7 percent FO, resulting in an effective blasting agent. Because it is very affordable and safe to handle, ANFO is the most often used explosive in the blasting sector. Explosive-grade prills are created in a prill tower, where a hot, supersaturate AN liquid (4 percent water) is released from spray nozzles at a height of 100 to 200 feet against an updraft of warm aqueous.

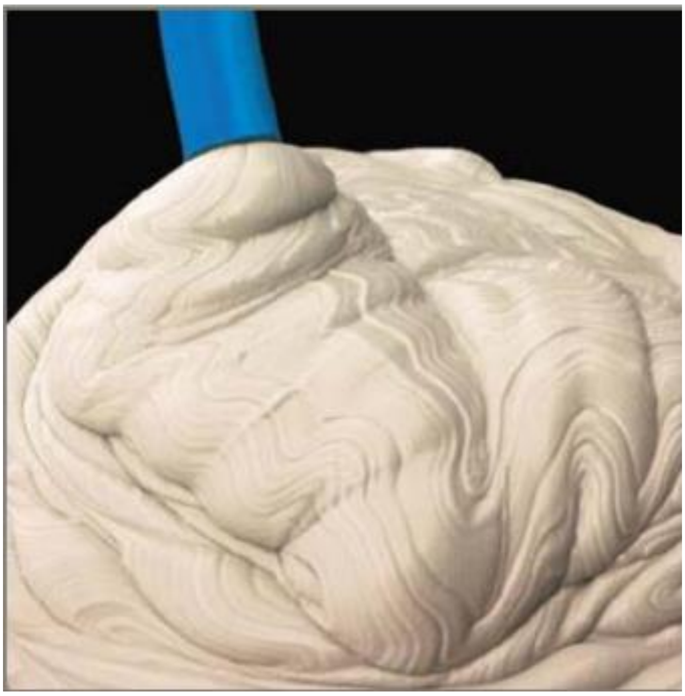

Figure 2.2 : Emulsion

Figure 2.3: Water gel

Figure 2.4: ANFO granules.

2.2.4 Properties of explosives

The primary factors influencing the performance and choosing of an explosive are velocity of detonation, water resistance, effective energy, density, physical characteristic, detonation pressure and fume characteristic. (Das Sharma, 2012)

The detonation wave's velocity of detonation (VOD) is the pace at which it travels down an explosive column. The bigger the VOD, the greater the explosive's force or "breaking" impact. High VOD explosives are more suited for hard rock, whereas low VOD explosives are better suited for softer rock. In general, lower VOD explosives release gas over a longer period of time, resulting in more 'heave.' In commercial explosives, the VOD range is 2500-7500 m/s.

Frequently, blasting occurs in wet conditions, or even underwater for certain needs. In such situations, the water resistance of an explosive is a crucial factor to consider. ANFO has no resistance to water, whereas emulsions and slurries have good resistance to water. It is possible to classify the water resistance of an explosive by evaluating its capacity to explode after exposure to water for specific time periods (Atlas 1987).

Some explosive energy is always lost (vented to the environment, lost as heat, etc.), hence it is more practical to characterise explosive power as the amount of energy a user may anticipate having available to perform meaningful work (ICI 1997).

The density of an explosive is its mass per unit volume and is measured in grammes per cubic centimetre (g/cm3). If the density of an explosive is more than 1.00g/cm3of water density, it will sink in water (assuming that the blast hole water does not include considerable concentrations of suspended particles or salts). If the density is less than 1.00g/cm3, however, the explosive floats (Orica Quarry Service, 2008).

The physical properties of an explosive can be crucial for its operation and loading into blastholes. ANFO is a granular substance that is loose and fluid. It can be easily poured into a blast hole from bags or blown in with compressed air from a huge container. Bulk emulsions have a gel-like consistency and may be poured into blastholes from huge containers; other emulsions can be packaged in plastic sausage-shaped cartridges that are simple to load by hand.

When an explosive detonates, the detonation pressure is the pressure within the reaction zone. It is a crucial indicator of the potential of an explosive to create effective fragmentation. Primer features that are desirable include a high detonation pressure (Atlas 1987).

The majority of the gases created by the ignition of an explosive are non-toxic carbon dioxide, nitrogen, and steam. However, minor quantities of hazardous gases, mostly carbon monoxide and oxides of nitrogen, are also created. Slurry explosives and AN-based explosives are preferred for blasting. During detonation, factors such as insufficient charge diameter, poor priming, inappropriate delay timing, and water degradation can affect the chemistry of an explosive.

2.3 Drilling

Blasting operations begin with drilling, which is the most important step. Drilling is a costly endeavour that needs significant initial investments as well as ongoing maintenance. During the process of drilling a hole, a cylinder-shaped hole is formed, which is then positioned in such a way as to retain and confine an explosive charge. The ore and rock are shattered as a result of the explosion caused by the charge. The primary goal of blasting is to maximise the explosive strength in order to produce desired effects such as splitting and smooth blasting, or to achieve good fragmentation, whichever comes first. Drilling that is not done properly might result in an increase in operational expenses because to the increased difficulty of excavation, transport, and crushing. Additionally, it may result in difficulties with flying rocks, vibrations, airblast, and blasting.

One of the drilling methods is rotary, while the other is percussive. Drilling may be done in both directions. Rotary drilling is typically reserved for making huge holes that are at least 6 inches in diameter. There are two different kinds of rotary drilling, and they are called rotary cutting and rotary crushing. Shear forces are what generate the hole while using rotary cutting. The energy required for breaking rock is given by rotational torque in the drill rod, and the drill bit is outfitted with a cutter insert made of hard metal alloys. Rocks having a low tensile strength, such as salt, silt, and soft limestone, are ideal candidates for this technique. The other method is called rotational crushing, and it involves breaking up the rock using a high point load and a toothed drill bit that is forced downwards with a lot of power. Compressed air is used to clear away the cuttings while the bit, which is of the tricone roller type and has tungsten carbide buttons attached to it, is concurrently turned. Rotary drill rigs are notable for their size and weight. The weight of the rig and the spin generated by the motor combine to provide downward push.

The rock is broken apart by hammering strikes during the percussion drilling process, with the energy being transmitted from the hammer to the drill bit at the bottom of the hole. Inside of the hammer mechanism is where the energy is created, and it does so by either pneumatic or hydraulic pressure. As more pressure is applied, the resulting force, when applied, propels the piston in the forward direction. The top hammer drill might be a pneumatic drill, which requires an air compressor, or it could be a hydraulic drill, which requires hydraulic fluid. The most typical configuration for a pneumatic drill rig is one that is mounted on tracks, and it must be accompanied by a separate air compressor unit.

2.4 Blasting

2.4.1 Rock breakage

The process of rock fragmentation is exceedingly complicated, and there are still many unknowns. However, there is consensus on a few of the mechanisms, and they provide the basis for accurately predicting blast results. The rock fracture process for a single hole in competent rock has seven steps: detonation, shock wave propagation gas crack expansion, blast hole expansion, radial cracking, shock wave reflection, and burden relief/movement.

2.4.1(a) Detonation

The solid explosives are swiftly transformed to hot high-pressure gases as the detonation front advances through the explosive's column. The pressure in the blast hole rises to about 5000 MPa, well exceeding the compressive strength of the rock mass, which can range between 20 and 350 MPa. As the pressure rises, a powerful compression wave forms and pushes out into the rock mass. Depending on the seismic velocity of the rock mass, this wave travels between 2500 and 7000 metres per second. Figure 2.5 shows the detonation of an unconfined 25 mm plug the detonation front and expanding shockwave (Shotfirer Course Manual, 2021).

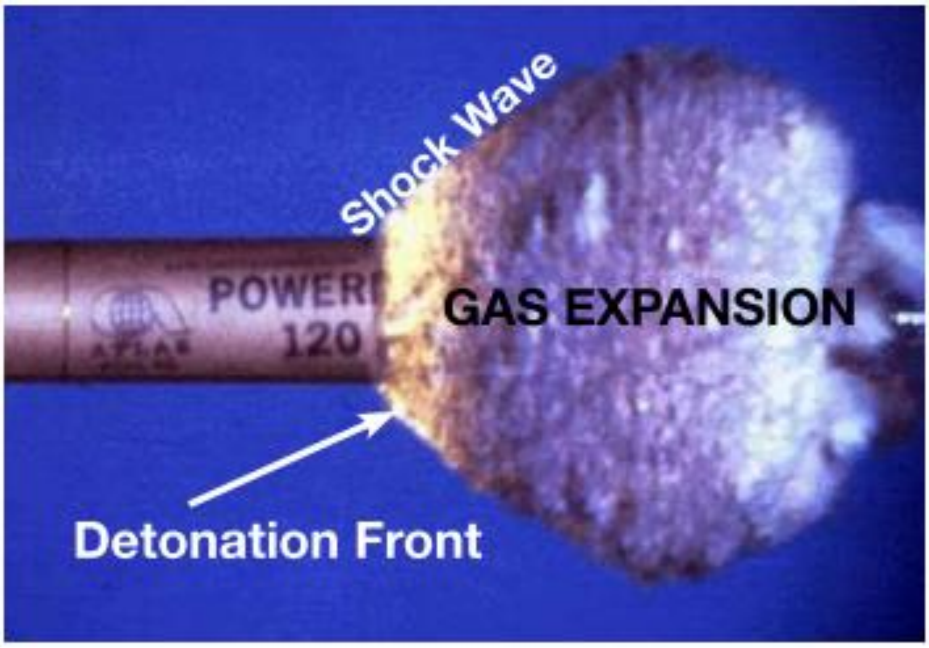

Figure 2.5: The expandation of shockwave.

2.4.1(b) Blasthole expansion

During the explosion, the pressure in the blast hole is far higher than the rock's compressive strength. The rock reacts by expanding the blast hole diameter to one to four drill diameters, depending on the type of explosive detonation pressure and the structural qualities of the rock. All the tension around the hole is compressive for the first few microseconds, and no cracks emerge. Figure 2.6 shows the shock wave moving through the rock mass at seismic velocity, which is generally between 4000-5400 metres per second depending on type of explosives.

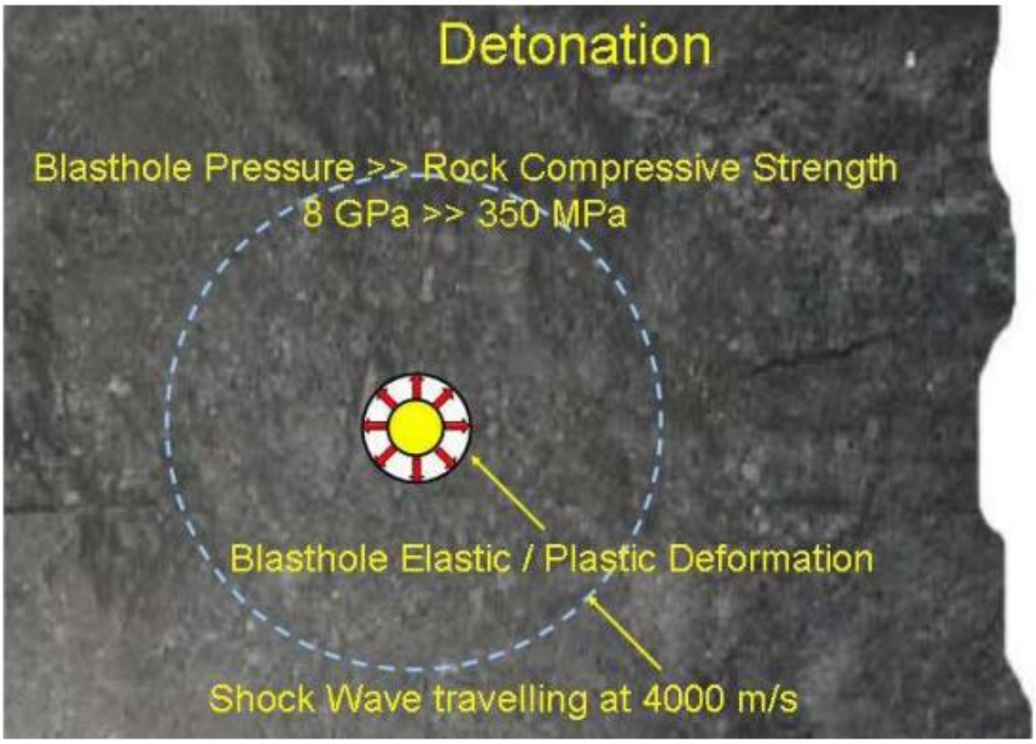

Figure 2.6: The shock wave movement through the rock mass rapidly at seismic velocity.

2.4.1(c) Radial cracking

Tangential stresses can induce radial cracking to develop at up to 2 blasthole diameters due to compressive stress relaxation with blasthole expansion. Many fractures develop and propagate at about a quarter of the seismic velocity. Figure 2.7 shows he development of the radial cracks.

Figure 2.7: Development of radial crack.

2.4.1(d) Shockwave propagation

The compression wave hits the free face at this moment. The radial fractures continue to expand and induce shearing and crushing in the vicinity of the blasthole. This is when most of the blast-generated fines are formed. In a powerful enormous rock mass, these shockwaves will travel long distances without losing or consuming all of their kinetic energy.

2.4.1(e) Shock wave reflection

The compression wave is reflected as a tension wave from the free face. Because the tensile strength of rock is only approximately 8% of the compressive strength, this wave has the potential to push the rock apart. The reflected tension wave can produce spalling of the rock face if the powder factor is very high (far higher than for conventional blasting). The most common cause of a change in the look of a rock face shown Figure 2.8 is the mobilisation of dust on the face.

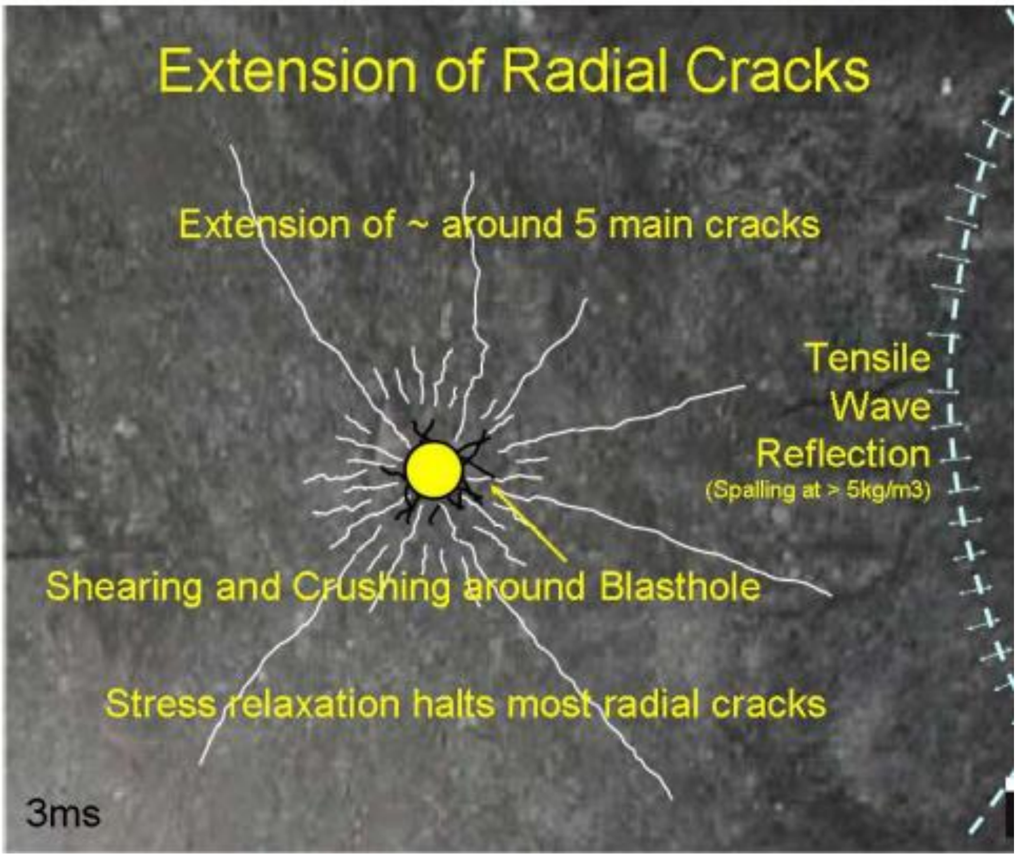

Figure 2.8: Extension of radial cracks.

2.4.1(f) Gas driven crack extension

The remaining gas pressure in the blast hole causes the radial cracks (and any other pre-existing joints and fractures) to widen and expand. These expanding fractures interact with the returning tensile wave from the free face to drive the fragmentation process between the hole and the free face shown in Figure 2.9. As soon as the fracture reaches the free face, the fractured rock may move. The residual gas pressure accelerates the rock similarly to an engine piston shown in Figure 2.10.

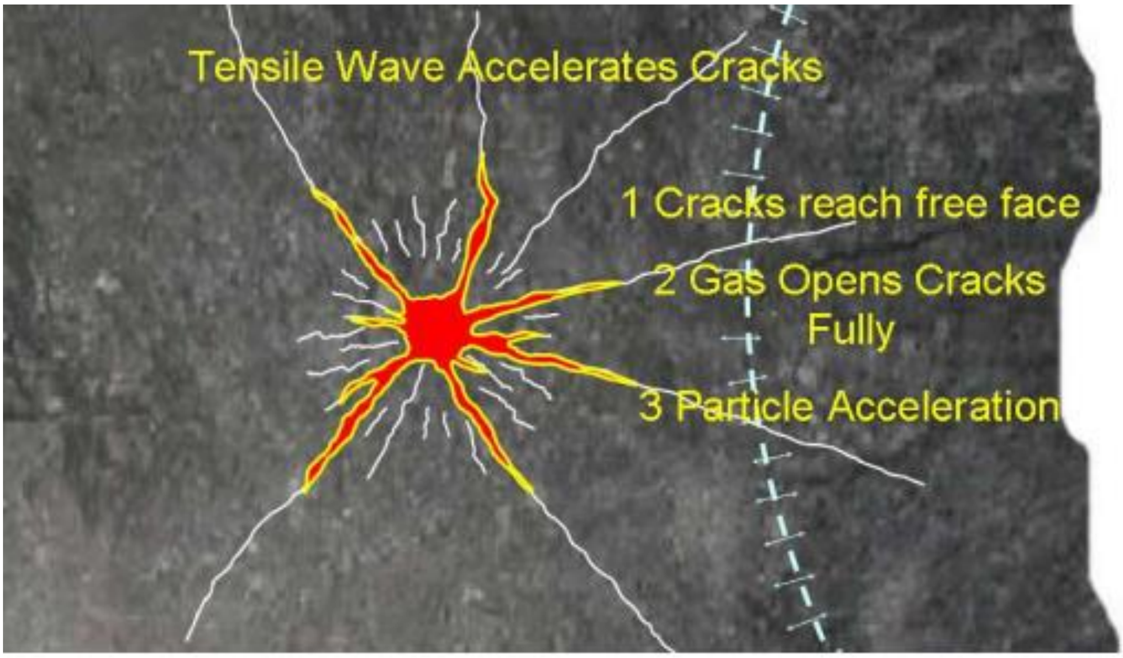

Figure 2.9: Interaction between crack and tensile wave.

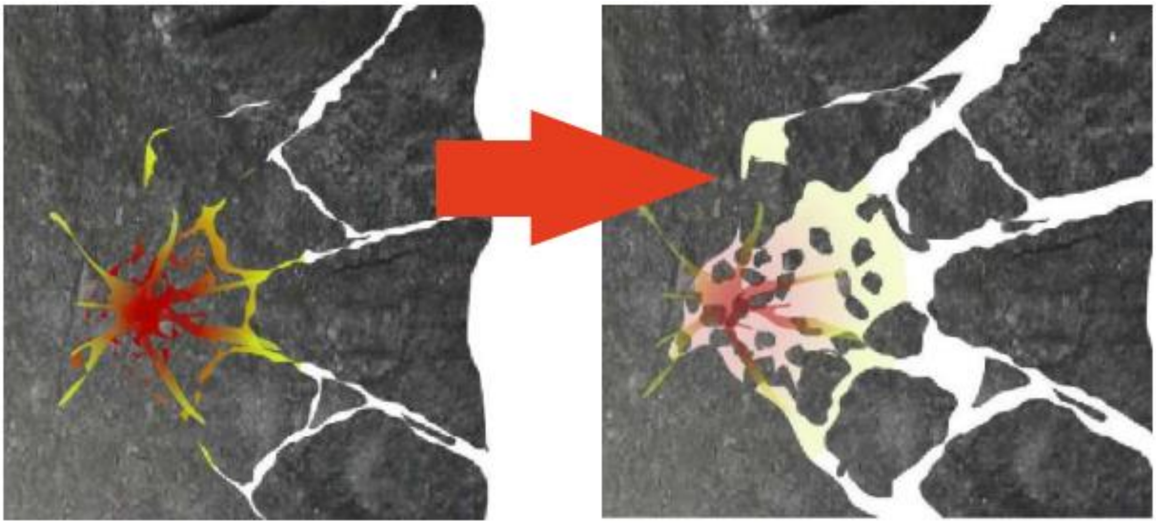

Figure 2.10: Rock acceleration by gas pressure.

2.4.1(g) Burden relief/ movement

As the fractures reach the free surfaces, the burden detaches and rock movement occurs. As explosive gases escape into the environment, the pressure rapidly lowers. As the rock is blasted out, the majority of the fragmentation process is accomplished, although there is extra grinding and collision-induced fragmentation.

The previous theory assumes a solid rock mass devoid of faults and joints. The reason of failure is substantially more difficult where joints are present, which is usual. As the compression wave reflects off joints, fracture propagation is altered and gas reaches both blast-induced and preexisting joints. Where the rock mass is widely fractured, the explosion may create relatively little cracking, and the principal effect of the explosion is the gas forcing the rock into the void

2.4.2 Blast design

2.4.2(a) Burden

The best load size for any specific blast may be determined by calculating the diameter of the hole, the relative density of the rock, and the explosive that will be used. Inadequate weight might result in excessive airblast and flyrock. An high load, on the other hand, might result in toe problems, improper fragmentation, and excessive ground vibrations. Field testing must be conducted to establish the maximum practical load for a given set of blasting conditions (Engineering Geology Manual, 2001).

Field testing and experience will yield the optimal load to be utilised. Lower ratios of weight to charge diameter should be applied as a first estimate.

The assumption of 25 times the diameter is an appropriate starting point for the load when employing ANFO (0.85 g/cu. cm) in rock with a density of 2.7 g/cu. cm (granite). When blasting with a denser emulsion or bulk (1.2 g/cm3), it is possible to increase the weight to 30 to 35 times the diameter.

Thus, the load when ANFO is utilised in 3-inch holes would be around 6.5 feet. Industry standards for 3-inch hole blasting in granite are 6 it (ANFO) and 7-8 ft (Bulk), 3.5 inch hole is 8 ft (ANFO) and 10-12 ft (bulk) and 4 inch hole is 12 ft (ANFO) and 14 ft (bulk) (bulk).

2.4.2(b) Spacing

Because of the narrow spacing, problems like as cratering and crushing between the holes, blouders, and toe troubles might occur. An inadequate amount of fragmentation will occur if the holes are too far spaced apart. When determining the appropriate beginning point for measuring the distance between holes that will be simultaneously blasted, it is reasonable to make the assumption that the distance will be between 1.6 and 2.0 times the burden. When firing in a box cut or "V" pattern consecutively down the row, the distance between each shot should be between one and one and a half times the weight of the target (GMDC, 2018).

2.4.2(c) Bench height

Bench height is determined by several factors, including geology and quarry plan, kind of mineralization and quarry overburden, and rock hardness (very hard rock requires the length more than twice the burden). The second factor is vibration limitations and face stability. The ideal bench height for quarries is less than 15 metres, which often results in holes that are straight. The explosion should create adequate fragmentation with a clean face and little back break, a ten-meter-high bench may be advantageous (GMDC, 2018).

2.4.2(d) Blast hole diameter

First and foremost in any blast design is the size of the blast hole. The burden is determined by the diameter of the blast hole, the type of explosive employed, and the type of rock to be blasted (distance from the blast hole to the nearest free face). The burden determines all other blast dimensions. This discussion presupposes that the blaster has discretion over the borehole size. Numerous activities restrict borehole size dependent on the availability of drilling equipment. Practical blasthole sizes for surface construction excavations range from 3 (75 mm) to around 6 (380 mm) (38 cm). Large blasthole diameters often result in inexpensive drilling and blasting expenses, as large holes are less expensive to drill per unit volume and less sensitive, less expensive blasting chemicals may be utilised in larger diameter holes. Larger-diameter blastholes also allow for greater loads and distances, and they can produce coarser fragmentation. (Engineering Geology Manual, 2001)

2.4.2(e) Subdrill

Subdrilling refers to the process of drilling a certain distance below the floor level or the real needed blast depth in order to ensure that the whole face of the rock may be removed without exceeding the set excavation limit.

To obtain a smooth pit floor, subdrilling may be necessary. In general, the subdrill section of a borehole is backfilled with drill cuttings or other stemming material. In subdrill, explosives are not loaded. High peak particle velocity ground vibrations will result from excessive confinement (Engineering Geology Manual, 2001).

2.4.2(f) Stemming

In strong, massive rock stemming length may be kept short to ensure good breakage at the collar, but not induce excessive airblast or flyrock. Small pocket charges may be used if required. In weak rock, stemming lengths can be increased to take advantage of the weaker material in the collar area breaking.

It should also be recognised that the stemming length should be longer than the burden to promote forward movement rather than upward movement. If upward movement I required the stemming length may be less than the burden but should generally not be less than 0.8 burden to contain flyrock, airblast and cratering of blastholes (energy is released too easily and does not work on rock between blastholes). To prevent flyrock and airblast, relatively lengthy stemming columns should be employed for any front-row blasthole that has an inadequate load alongside the top of the charge. This is done in order to ensure that the blasthole remains intact. These kinds of circumstances are typical in situations in which vertical blastholes are drilled beside walls that have a steep or shallow slope. There is also the possibility of using pocket charges in these front-row blast apertures. When drilling back-row blastholes, a longer stemming column may be utilised to cut down on over break.

2.4.2(g) Blast pattern

There are three blast patterns in bench blasting described as below. The most commonly used is staggered pattern, followed by rectangular and the least is square pattern. Square pattern is where burden is equal to spacing shown in the Figure 2.11. This pattern is seldom used.

Rectangular pattern is quite common for well-developed benches with less geological problems such as bedding planes or fracture zones shown in Figure 2.12.

The spacing is more than burden. It is easy to do blast hole layout and easy to do blast sequence timings.

Staggered pattern is commonly used in quarry industry shown in the Figure 2.13. The position of holes in each row are offset such that holes in one row are positioned in the middle of the spacings of the holes in the preceding row. The spacing is larger than burden. For staggered pattern it is recommended that the number of holes from second row onwards should be less than the front row. This is to prevent damage to sides of the face; poor back break and higher vibration due to confinement.

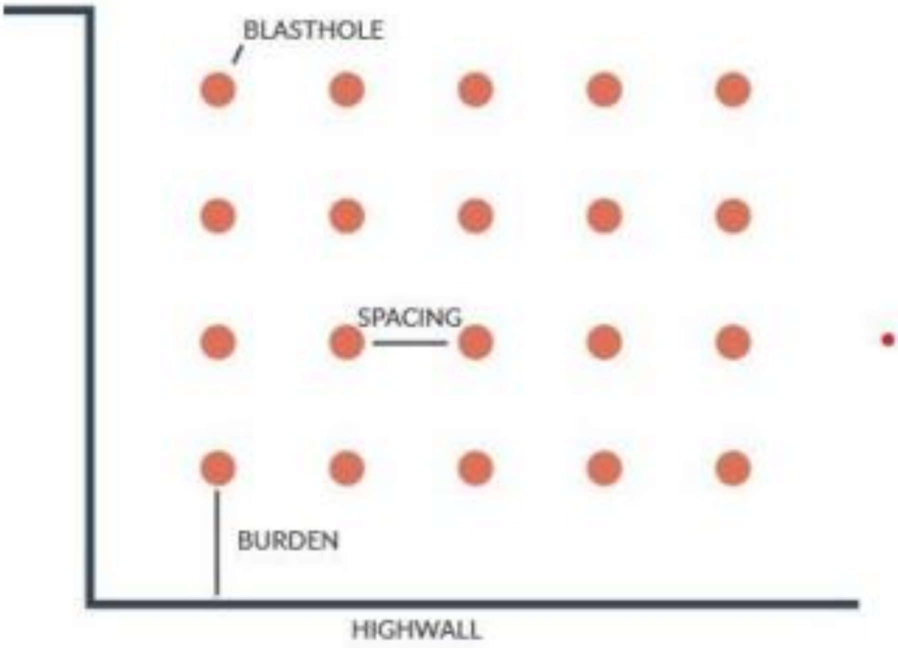

Figure 2.11: Square pattern.