SCHOOL OF MATERIALS AND MINERAL RESOURCES ENGINEERING

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ANALYSIS OF ROCK FRAGMENTATION BY USING POWERSIEVE SOFTWARE

By

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DECLARATION

I hereby declare that I have conducted and completed the research work and written the dissertation entitled '**Analysis of Fragmentation of Rocks using PowerSieve Software'**. I also declared that it has not been previously submitted for the award for any degree or diploma or other similar title of this for any other examining body or University.

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ABSTRAK

Keupayaan operasi letupan boleh diklasifikasikan berdasarkan sebab dan tujuan dalam pelbagai cara. Ia bergantung sama ada letupan dilakukan berdasarkan zon galian atau zon steril dalam operasi perlombongan. Dalam zon yang ‘mineralised’, peringkat utama proses penumbukan umum adalah letupan dan tujuannya adalah untuk menghasilkan saiz serpihan tertentu yang sesuai bagi menggantikan pengendalian bijih dan pemprosesan mineral (Hudson, 1993).Sedemikian, cara ini adalah berdasarkan penilaian saiz serpihan berbangkit dari letupan (J.Aler, J.Mouza Du, M.Arnould, 1996).

Terdapat pelbagai faktor yang mempengaruhi pemecahan batu granit .Faktor-faktor tersebut boleh dibahagikan kepada faktor dikawal dan tidak terkawal. Faktor-faktor yang boleh dikawal seperti beban, jarak, ketinggian bangku, faktor serbuk, sub-penggerudian, berpunca, urutan pemulaan letupan dan diameter lubang. Faktor yang tidak terkawal lebih focus kepada struktur geologi batu (Orica, Safe and Efficient Blasting in Quarries, 2008) .Dalam kajian ini faktor utama adalah lebih kepada faktor-faktor dikawal. Ujian titik beban yang dilakukan kepada sampel batuan untuk memastikan bahawa kekuatan dan struktur geologi adalah tetap di kawasan itu dipilih untuk diletupkan. Faktor yang paling kerap digunakan untuk menyatakan keupayaan pemecahan letupan adalah 'faktor serbuk' (Rizza, 2017) , tetapi dalam kajian ini ,telah dikaji letupan untuk faktor-faktor lain seperti kekuatan pukal relatif dan jenis letupan.

Kajian ini dijalankan di Batu Tiga Quarry (BTQ), Masai, Johor. Terdapat tiga peringkat dalam kajian ini adalah pemerhatian tapak, analisis data dan sampel ujian. Pemerhatian laman mengiktiraf apakah nilai faktor serbuk sesuai untuk digunakan

keadaan dan struktur geografi di kawasan kajian diperhatikan. Dalam analisis data, imej timbunan pasir ditangkap, imej-imej itu kemudian dipindahkan ke dalam perisian PowerSieve. Perisian PowerSieve menganalisis dan menilai gambar-gambar yang diambil dan mendapatkan pengedaran pemecahan, peratusan terkumpul lulus dan peratusan kawasan perlindungan . Ujian sampel juga melibatkan titik ujian beban pada sampel batu dikutip di kawasan letupan untuk menentukan kekuatan batu.

Analisis menunjukkan bahawa letupan yang mengunakan detonasi elektronik menghasilkan pemecahan yang lebih baik berbanding dengan letupan yang mengunakan detonasi bukan elektrik. Pada masa yang sama, bahan letupan dengan kekuatan pukal relatif tinggi mempunyai pemecahan yang lebih baik. Faktor biasa yang digunakan untuk analisis pemecahan adalah factor serbuk. Dalam kajian ini, dua letupan dimasukkan sebagai perkara yang standard untuk menunjukkan kesan perbezaan factor serbuk pada pemecahan letupan. Ujian beban titik diambil untuk menunjukkan kesan faktor yang tidak terkawal pada pemecahan letupan yang adalah kekuatan batu.

ANALYSIS OF ROCK FRAGMENTATION BY USING POWERSIEVE SOFTWARE

ABSTRACT

The ability of blasting operations can be esteemed relying upon the reason on the purpose in various ways. It depends whether blasting is done in mineralized or the sterile zone in mining operations. In mineralized zone, the primary stage of the general comminution process is blasting and its purpose is to produce a specific fragment size appropriate for succeeding ore handling and mineral processing (Hudson, 1993) .Usually, these means are based on evaluation fragment size consequential from blast (J.Aler, J.Mouza Du, M.Arnould, 1996).

There are various factors that affect the fragmentation of granite rocks. These can be divided into controlled and uncontrolled factors. The controllable factors such as burden, spacing, bench height, powder factor, sub-drilling, stemming, sequence of blast initiation and diameter of holes. The uncontrollable concern more towards geological structure of rocks. (Orica, Safe and Efficient Blasting in Quarries, 2008). In this research the main concern is more towards controlled factors. Point load test carry out on rock samples to make sure that the strength and geological structure is constant in the area selected to be blasted for purpose of this research. The most common factor used to state a fragmentation of blasting is 'powder factor' (Rizza, 2017) .However, in this research, blasting performance is analysed with other factors such as relative bulk strength and type of detonation.

The practical part of the research was carried out at Batu Tiga Quarry (BTQ) Masai, Johor. This research is divided into three stages, (1) site observation, (2) data analysis and (3) sample testing. Site observation recognizes what is the value of powder factor

perfect to be utilized the condition and geographical structure on research area was observed. In data analysis, the images of muck piles were captured, the images are then transferred into the PowerSieve software. PowerSieve software used to perform analyses and evaluates the pictures taken and get the fragmentation distribution, cumulative passing percentage and cover area percentage. The sample testing involves point load test on rock samples collected from blast area to determine the strength of the rocks.

The analysis shows that electronic detonation produces a better fragmentation compared to non-electric detonation. In the meantime, explosive with high relative bulk strength have better fragmentation. The usual factor which is used for fragmentation analysis is Powder Factor. In this research, two blast were included as a standardized matter to show the effects of Powder Factor on blast fragmentation. The point load test is taken to show the effect of uncontrollable factor on the blast fragmentation that is the strength of rocks.

CHAPTER 1

1.0 Introduction

In numerous ways, the ability of blasting operations can be esteemed relying upon the reason on the purpose. It depends whether blasting is done in mineralized or the sterile zone in mining operations. In mineralized zone, the primary stage of the general comminution process is blasting and its purpose is to produce a specific fragment size appropriate for succeeding ore handling and mineral processing (Hudson, 1993) .Usually, these means are based on evaluation fragment size consequential from blast (J.Aler, J.Mouza Du, M.Arnould, 1996).

Fragmentation is the primary aim of rock blasting but it is extremely difficult to evaluate the degree of fragmentation. The degree of rock fragmentation plays a major role in order to reduce and control the total production cost including loading, hauling and crushing costs. The energy efficiency of comminution processes and thousands of kilowatt-hours energy per year can also be saved. The pioneer step of the size reduction in mining is blasting and it is followed by crushing and grinding unit operations. The efficiency of these units operations is directly associated to the size distribution of muck pile (F.I.Siddiqui, S.M.Ali Shah ,M.Y.Behan, 2009).A dependable evaluation of fragmentation is a critical mining problem (S.Esen, H.A.Bilgin, 2001). The work load of primary crusher is reduced by production of finer fragmentation, thus increasing the crusher efficiency and reducing the crushing cost. The crushing rate per hour will also increase (F.I.Siddiqui, S.M.Ali Shah ,M.Y.Behan, 2009).

The accurate method of evaluation of size distribution of particles or fragmentation is sieving or screening. However this technique is expensive and tedious for production blasting (J. Sudhakar, G. R. Adhikari, and R. N. Gupta, 2006). The oftenly utilized strategy to analyse the fragmented is a basic visual estimation of fragments on the surface of the waste heap. This is too intuitive for a complete blast assessment program. Therefore, indirect methods, such as photographic methods have been in use in blasting research (S.A.Rholl, S.G.Grannes , M.S.Stagg, 1987). Digital images processing and analysis systems are becoming increasingly famous in fragmentation measurement because of their advantages on photographic with the advances in technology.

Issues and problems were faced when trying measure fragmentation using photographic images. The individual rock fragments in image must be either delineated by hand or image processing techniques. What causes delineation nearly impossible using standard edge-detection routines are issues with non-uniform shadow, lighting, noise and high range in fragment sizes. Other issue is appropriately obtaining the 3D information from 2D images. Assumptions need to be made for the fragment sizes in 3D.Futhermore, rock fragments will overlay and alterations have to be made. Lastly assumptions regarding the relationship between the size distribution on the surface of a pile and overall size in 3D volume has to be made. (M Kemeny,Ashutosh Devgan,M Hagaman,Xiagqiang Wu, 1993).

Digital images processing and analysis systems are becoming increasingly famous in fragmentation measurement because of their advantages on photographic with the advance in technology Many research work has been carried out throughout the world to develop image analysis system. Several countries/organisations have developed their own image analysis systems. These includes IPACS , TUCIPS , FRAGSCAN , CIAS, GoldSize, WipFrag SPLIT ,PowerSieve and Fragalyst . Few field tests have been done so far to check the validness of the outcome, though these systems are guaranteed applicable for rock fragmentation analysis. (J. Sudhakar, G. R. Adhikari, and R. N. Gupta, 2006).

There are many softwares that can be used to analyse fragmentation. PowerSieve is a software that is used to analyse fragmentation after blasting. These is a major content of this study . Photographs of the fragmentation face is the input material. Then, for automatic analysis and determination of the distribution, the users pre-process these images. With already assessed and analysed blast or blast segments the outcomes is utilized as relative. (Orica, Orica Fragmentation Assessment, 2017). In this research I will be using PowerSieve software to analyse and evaluate the fragmentation of granite rocks.

There are various factors that affect the fragmentation of granite rocks.These can be divided into controlled and uncontrolled factors. The controllable factors such as burden, spacing, bench height, powder factor, sub-drilling, stemming, sequence of blast initiation and diameter of holes. The uncontrollable concern more too geological structure of rocks. (Orica, Safe and Efficient Blasting in Quarries, 2008)(*Safe and Efficient Blasting in Quarries*, 2008) .This research mainly concerns more to controlled factors. Point load test has been done to rock samples to make sure that the strength and geological structure is constant in the area chosen to be blasted for the research. The most common factor used to state a fragmentation of blasting is ‘powder factor’ (Rizza, 2017) ,but in this research studies have analysed blasting for other factors such as relative bulk strength and type of detonation.

1.1 Problem Statement

A good fragmentation is hard to be obtained due to many factors that can be controlled and can’t be controlled. The degree of rock fragmentation plays a major role in order to reduce and control the total production cost including loading, hauling and crushing costs. The energy efficiency of comminution processes and thousands of kilowatt-hours energy per year can also be saved. A proficient programming is needed to analyse and evaluate fragmentation of rocks. There are many software which analyses and evaluates rock fragmentation. A system that gives accurate results should be used in order to analyse the blast fragmentation. Only if the fragmentation is analysed efficiently, the total production cost can be controlled and reduced. Image analysing softwares should also be compared to find the highly efficient software which can be used for an accurate fragmentation analysis of rocks.

There are many factors that affect the fragmentation of granite rocks. There are controlled and uncontrolled factors. The controllable factors such as burden, spacing, bench height, powder factor, sub-drilling, stemming, sequence of blast initiation and diameter of holes. The uncontrollable factor concern more too geological structure of rocks. The geologic structure and conditions are beyond control, whereas other factors or parameters which can be controlled plays a very important part on improving the fragmentation. There are many oversize and ultrafine rocks after blasting due to these factors. The selection and setting of parameters should be done to optimize the fragmentation.

1.2 Objectives

I. To analyse the fragmentation of granite rocks by using PowerSieve software

II. To study the parameter that effects the fragmentation of granite rocks, that is type of detonation and relative bulk strength of explosive.

Fragmentation is the main concern of blasting. There are many ways to evaluate and analyse the fragmentation of blast. Digital image processing and analysis systems are commonly used to analyse and evaluate the fragmentation of rocks. PowerSieve is used to analyse and evaluate the fragmentation of granite rocks in BTQ Masai Quarry.

There are many parameter which affects the blast performance and fragmentation. There are factors that can be controlled and there are factors which cannot be controlled. The uncontrollable concern more too geological structure of rocks. The geologic structure and conditions are beyond control. Controllable factors are burden, spacing, bench height, powder factor, sub-drilling, stemming, sequence of blast initiation and diameter of holes. Compared to other studies, this research focuses more on the effect of parameters such as type of detonation and relative bulk strength of explosive on blast fragmentation. Electronic delay detonators gives a good blast performance and fragmentation compared to Non electric detonators and explosive with high relative bulk strength produces better fragmentation

1.3 Significance of Research

The significance of this research is to evaluate and analyse the fragmentation of granite rocks by utilizing PowerSieve software for different detonating system and relative bulk strength. The degree of rock fragmentation plays a major role in order to reduce and control the total production cost including loading, hauling and crushing costs. The energy efficiency of comminution processes and thousands of kilowatt-hours energy per year can also be saved. Therefore it is essential to improve the fragmentation of a blasting. The most common factor used to state a fragmentation of blasting is 'powder factor' (Rizza, 2017), but in this research studies have analysed blasting for other factors such as relative bulk strength and type of detonation.

1.4 Scope of Research

There are several stages of site observation and experimental activities in this research. Site observations were carried out in the mid region of BTQ Quarry. Despites geological structure being an uncontrolled parameter, blasts were done not far from each other, to make sure that the geological structure and strength are constant for each blast. The data collection was conducted within 2 weeks in the quarry and the information obtained was recorded. These included the blast design, fragmentation distribution data and the controllable parameters considered in the blast design. There are many parameters affect the blasting process and quality fragmentation of rocks, but in this research the main parameters that will be analyse is type of detonation relative bulk strength of explosive. The Orica's PowerSieve software is used to analyse the quality fragmentation of rock.

CHAPTER 2

2.0 Literature Review

2.1 Introduction

Drilling and blasting is done to prepare materials to be excavated and transported, it will then be delivered to crushing plant. This is the main function of blasting. The blasted rocks should have the size within a range where it can be transported and can enter the crusher for communition.Drilling and blasting is an essential part in this process and the results, such as fragmentation, muck-pile shape and looseness, dilution, damage and rock softening affect the efficiency of downstream processes. (C.J.Konya, E.J.Walter, 1990).

There are various factors that affect the fragmentation of granite rocks. These can be divided into controlled and uncontrolled factors. The controllable factors such as burden, spacing, bench height, powder factor, sub-drilling, stemming, sequence of blast initiation and diameter of holes. The uncontrollable concern more too geological structure of rocks (Orica, Safe and Efficient Blasting in Quarries, 2008). It must be comprehended that rock blast and crack spread happens fundamentally behind the stress wave so as to use detonators in a way that takes into consideration the optimizing the fragmentation of those effects (Ruth, 2015). Type of detonation plays a very important part in optimizing the blast performance and blast fragmentation.

Strength of explosive can be defined as capability of explosive to do a functional work. It alludes to the measure of amount of energy stored in an explosive (Pradhan, 2007). Strength can be expressed as absolute weight strength, absolute bulk strength, relative weight strength and relative bulk strength (Fidler, 2017). Research is done to see the effect of relative weight strength/relative bulk strength on the blast performance and fragmentation.

2.2 Fragmentation measurement techniques

Streamlining of blasting requires a level of trade-off between the competing aims of maximum fragmentation, least weakening and least expenses for drilling and explosives. Likewise, mining organizations and quarry operations need to look at and reduce production expenses to stay competitive. In any case, no single element, for example, cost of explosives, can be legitimately assessed without estimations of fragmentation and rock quality. Consequently the need to oversee production costs requires the need to measure the post-blast fragmentation. (M.Venkatesh, 2010).

Measurement of fragmentation on a bigger scale is a to a great degree entangled errand. Since it needs a significant measure of time to discover physically the grain estimate circulation in a muck pile. Inquire about has been done worldwide with various techniques and devices for estimation of fragmentation. These techniques are sieving or screening, oversize boulder count method, explosive consumption in secondary blasting method , shovel loading rate method , bridging delays at the crusher method , visual analysis method , photographic or manual analysis method , conventional and high speed photogrammetric method and high speed photography or image analysis method (M.Venkatesh, 2010).

2.2.1 Sieving or screening (M.Venkatesh, 2010)

Sieving or screening is an immediate and precise strategy for assessment of size distribution of particles or fragmentation. Nonetheless, this technique is expensive, tedious and inconvenient for production blasting, this strategy is practical if there should be an occurrence of small scale blasts. In this technique the fragmentations are screened through sieves of various mesh numbers for various section sizes. At that point the screened out sections are assembled by their size and the quantity of fragments in each size range is numbered to predict the way of the blast.

2.2.2 Oversize stone number technique (M.Venkatesh, 2010)

In Oversize boulder count technique, manual counting of the oversize boulder in muck pile which can't be taken care of by the shovel is finished. This straightforwardly gives an over-size list regarding the aggregate in-situ rock mass blaster. It is an extremely prominent technique for deciding the post blast fragmentation.

2.2.3 Explosive utilization in auxiliary impacting strategy (M.Venkatesh, 2010)

In Explosive utilization in secondary blasting technique, a record with respect to the utilization of explosives in secondary blasting by either pop shooting or plaster shooting is resolved. This file is then utilized for contrasting the level of fragmentation of a gathering of blasts.

2.2.4 Shovel loading rate technique (M.Venkatesh, 2010)

This technique makes assumption that the speedier the mucking the better the fragmentation. In this strategy the loading rate of shovel for a specific muck pile is considered. This system might be utilized all the more precisely for a similar record of the way of fragment of a gathering of blasts.

2.2.5 Bridging delays at the crusher technique (M.Venkatesh, 2010)

In the Bridging delays at the crusher technique, the delay in bridging at the crusher for the most part because of oversize boulders is watched. This characteristics in deciding the quantity of oversize rocks in the muck pile. This technique is normally ideal in a small production site instead of in vast scale blasting circumstances.

2.2.6 Visual analysis method (N.H Maerz , T.C Palangio , J.A Franklin, 1996)

Is an abstract evaluation method. Through this method the post blast muck is observed right after the blasting and intuitive assessment is made. This method is not reliable as the shallow view of the muck cannot teach anything about the hidden portion.

2.2.7 Photographic or manual analysis method (M.Venkatesh, 2010)

Tracing the fragments on the photographs of muck pile is carried out manually in photographic method to decide the number of fragments using a graph paper.015m x 0.10m size photographs of the muck pile are printed for this. A transparent paper is then placed on top of each photograph and fixed with pins. The fragments are then traced on the transparent paper. Larger fragments are traced first because of their effect on the results. Small as possible fragments are then tried to be detected and traced. The scale situated in the middle of muck pile is used to convert the measured distance on photograph to actual distance. A Photostatted of the delineated paper is then placed on a graph paper. A scale factor is determined by jotting down reference scale on graph paper. The area covered by the fragments is measured by counting the number of small blocks on the graph paper covered by that piece, for every fragments. Then, the area is multiplied with scale factor. The third dimension is calculated using the equivalent circle of area method, for converting the area into volume. The parameters are calculated as follows

Equivalent diameter $=\sqrt{(4\text{xArea}/\pi)}$,m

Spherical volume = Area x Equivalent diameter, m^3

Weight of the fragment =Spherical volume x density of the rock, kg

It takes about one to two hours to manually analysis a photograph

2.2.8 Conventional and high speed photogrammetric method (M.Venkatesh, 2010)

More dependable and accurate technique compared to photographic method. Three dimensional measurement is given and this helps in the calculation of fragmentation volume

2.2.9 High speed photography or image analysis method (N.H Maerz , T.C Palangio , J.A Franklin, 1996)

Currently Digital images analysis system with advanced technology are becoming highly common in fragmentation evaluation. This is because of their benefits compared with photographic methods. Some of the image analysis stems are

- IPACS
- TUCIPS
- FRAGSCAN
- Fragalyst
- WipFrag
- PowerSieve

2.2.9.1PowerSieve (Orica, Orica Fragmentation Assessment, 2017)

PowerSieve is a software that is used to analyse fragmentation after blasting. These is a major content of this study. Photographs of the fragmentation face is the input material. Then, for automatic analysis and determination of the distribution, the users pre-process these images. With previously evaluated and analysed blast or blast sections the results is used as comparative

2.2.9.2 WipFrag (N.H Maerz , T.C Palangio , J.A Franklin, 1996)

Granulometry system is used in the analysis of digital image to predict the grain size distribution of muck pile. Automatically generated net against the rock image can also be compared using WipFrag .Evaluation of fragment boundaries is done using Edge Detection Variables(EDV).Using manual editing, inaccuracies can be corrected.

2.3 Explosive

Explosive is defined as a solid or fluid substance or a blend of substances which on importance of a fitting jolt is changed in a brief span interim into other more steady substances, to a great extent or absolutely vaporous with the improvement of warmth and high pressure. There are many sort of current modern explosives are available to meet the shifted necessities of the mining, quarrying and development ventures. It is fundamental to think about each kind of explosive with a specific end goal to pick and utilize the hazardous proficiently and securely (Bhandari, 1997).

A chemical explosive is a compound or blend which is capable of experiencing exceedingly fast disintegration, in this manner discharging huge measures of heat and gas. An explosive makes vitality by discharging hot gasses which require a space many time the unique volume of the explosive and after that apply great pressure on the surrounding (Hemphill, 1981).

An explosion can divided into four phases:

i. Gas release;

ii. Intense heat;

iii. Extreme pressure; and

iv. Explosion.

These are the important elements that plays an important part in rock breakage. There is release of gas, when an explosive is detonated, where temperature and pressure of the gas increases (Hemphill, 1981).

Function of explosives is just to create a blast and quickly break down synthetically, along these lines delivering hot gas which can do mechanical work on the close-by material. Explosive additionally have enough compound stability to not disintegrate spontaneously under any of the stimuli for example, as impact, friction or limited heating that may occur in often quite rough normal handling and storage to be useful in convenient application. In all explosives, the immediacy of the substance response relies on upon the quality of the shock wave spreading the explosion reaction (Per-Anders Persson, Roger Holmberg, Jaimin Lee, 1994) .

Explosive properties:

i. Effective energy;

ii. Velocity detonation;

iii. Density;

iv. Detonation pressure;

v. Sensitivity;

vi. Water resistance;

vii. Physical characteristics;

viii. Fume characteristics; and

ix. Storage life

2.3.1 Explosive Characteristic

Function of explosive is to break or part the stone to the littler size that is legitimate for further processing which involves crushing and screening plant to the required size appropriate for industrial uses. The variety of explosives utilized is as critical as the way it is being connected when explosives are utilized in blasting operations. Each type of explosives has its own properties to suite the application it is being used for, so choosing an explosive which has the appropriate characteristics to the application it will be used is a very important part of blasting. (Bhandari, 1997).

The explosives can be classified into three types:

i. Low explosives (deflagrating);

ii. Primary high explosives; and

iii. Secondary high explosives.

The most primitive to be produced are low explosives. These prompt to a blast which is truly a fast appearance of ignition in which the particles blaze at their surfaces and expose increasingly of the mass until all has been devoured such as the deflagration and the response for this situation moves slower than the speed of sound. Normal cases of this sort are the blasting powder or gun powder, rocket charges, pyrotechnics and fuels in ammo (Bhandari, 1997). The velocity of detonation(VOD) for low explosives is less than 2000 m/s.

High explosives relying upon their composition, the VOD around 1500-8000 m/s and create extensive volumes of gasses at significant heat at to a greatly high pressures.High explosives themselves might be progress subdivided into primary and secondary explosives. Primary explosives are described by their sensitivity to boosts like weak mechanical shock and fire or spark, the use of which will take explosive mixes from conditions of deflagration to explosion effectively. The cases of these explosives are Mercury Fulminate, Tetrazzini, Lead Aside, Lead Styphnate and another blend. These primary explosives are utilized as initiating charges in detonators. Secondary explosives is initiated by a shock wave which regularly created by the explosion of essential explosives. The cases of these explosives are TNT, RDX, PETN, HMX and different blends of these and industrial explosives like nitro glycerine, slurries, bulk emulsion, ammonium nitrate fuel oil (ANFO) and other powder explosives (Bhandari, 1997).

2.3.2 Types of Explosives

Explosives have been the essential strategy for breaking and relaxing rock since the creation of black powder and to a great extent through commitment to look into and improvement in safety and quality, have developed into today's extensive variety of safe and financially savvy products. When appropriately initiated, commercial explosives are rapidly transformed into gasses at high temperature and pressure. At the point when the explosive is detonated, it releases a litre of explosive that extends to around 1000 litres of gas in milliseconds. At the point when restricted by rocks, expanding explosion gasses result in enormously high strains in the stone. The vitality unconfined amid detonation acts similarly taking all things together headings yet as one would expect, tends to escape through any low resistance path. In this way, the blast hole ought to be charged and stemmed so that the gasses are limited for adequate time to give ideal breakage, displacement and detachment of the impacted rock. (Orica, Safe and Efficient Blasting in Quarries, 2008).

Explosive ingredients:

These are the essential ingredients in explosives

i. Oxidiser;

ii. Fuel; and

iii. Sensitizer.

An oxidiser is a chemical that provides oxygen to undergo reaction process. Ammonium nitrate is by far the mainly common oxidiser. Then, fuel reacts with oxygen to provide heat. The common fuels are fuel oil and aluminium powder. A sensitizer provides voids that proceed as 'hot spots' and at which reactions start during detonation. Sensitizers are commonly air or gas in the form of very small bubbles, sometimes encapsulated in glass micro-balloons (GMBs) (Orica, Safe and Efficient Blasting in Quarries, 2008).

Many sorts of modern high explosives are accessible to meet the differed need of the mining, quarrying and development enterprises. A full scope of items must be given to affirm that appropriate compositions are accessible for an explosive applications. Compositions can vary in the amount of oxidizing and flammable ingredients and also sensitizer. The rate and make up of every ingredient is reliant on the required demonstration and wellbeing attributes (Sahari, 2015).

Types of explosives:

i. Water gel/Slurry;

   Slurry explosives were first urbanized as a result of attempts to waterproof, strengthen and sensitise ammonium nitrate. Slurries are composed of ammonium nitrate and other nitrate both inorganic and organic, in solution and suspension with the accumulation of fine aluminium powder and other light metals, held in gelatinous state with the aid of organic gums. The advantages of such compositions over existing high explosives were rapidly realized

ii. Nitro-glycerine;

For commercial explosives Nitro-glycerine is the primary sensitizer. It is made by the blend of glycerine and glycol with a blend of acids, amid which the temperature ought to be painstakingly controlled a fragile operation (Sahari, 2015).The compositions in nitro-glycerine explosive are carbonaceous materials, for example, sawdust and nitrocellulose (guncotton). It is granular and has a high exploding velocity around 17000 ft/s or 5200 m/s. These days, it is seldom utilized in view of its affectability yet it is appropriate for ditching and mud topping (Hemphill, 1981)

iii. Gelatine;

Gelatine dynamites have a base of water resistant "gel" make by dissolving nitro-cotton on nitro-glycerine. The nitro-cotton gel is insoluble in water and ready to bind together other ingredients and making them water resistant and framing a firm, plastic-like substance having a confined exploding velocity of 13000 ft. /s or 4000 m/s (Hemphill, 1981)

The advantages of these explosives are:

i. High bulk strength;

ii. An excellent water resistance;

iii. Propagate extremely between cartridges and failures are most unlikely even under adverse conditions;

and

iv. Available in large range of cartridge diameters.

iv. Semi-gelatine;

The consistency of these explosives is semi-gelatinous which part away between gelatine and a powder. The properties of these explosives likewise lie between those of gelatines and powders. The density enough to counteract floating in wet boreholes and some imperviousness to water penetration. The benefits of these explosives is it can be adapted to meet particular necessities yet these days semi-gelatines are once in a while utilized but in small diameter cartridges (Sahari, 2015)

v. Nitro-glycerine powder;

These explosives are generally straightforward in design. It produced using ammonium nitrate and a flammable material with nitro-glycerine as a sensitizer. The nitro glycerine substance might be as low as 6% yet its all the more ordinarily 8-10% to ensure sufficient affectability and affectability

The advantages of these explosives are:

i. Relatively cheap;

ii. The compositions are reliably sensitive, even in small diameter cartridges; and

iii. It has low bulk strength relative to gelatines and can be used where economy of explosive is required (Sahari, 2015)

vi. Ammonium nitrate/fuel oil mixtures; and

Ammonium nitrate is the cheapest source of oxygen available for commercial explosive. It is a very important component in the explosive industry and used to form fixed explosive when used with solid fuels and sensitizers. When absorbent grade ammonium nitrate is mixed with fuel oil in the correct proportions, a very proficient 15 explosive is produced. The high blasting efficiency achieved by bulk loading can enhance its performance characteristics. When aluminium is adding to the mixture it will gives higher temperature reactions which rise up the strength (Sahari, 2015)

Table 2.1: Confined Detonation Velocity and Borehole Loading Density of ANFO (Hemphill, 1981)

Borehole diameter(inch)	Confined VOD (ft/s)	Loading density, lb/ft of borehole
1.5	7000-9000	0.6-0.7
2	8500-9900	1.1-1.3
3	10000-10800	2.5-3.0
4	11000-11800	4.4-5.3
5	11500-12500	6.9-8.2
6	12000-12800	9.9-11.7
8	12500-13300	17.6-20.8
9	12800-13500	22.0-26.8

vii. Bulk emulsion.

Bulk emulsion can be formulated to suit the client's need and conveyed specifically into the boreholes by a bulk explosives truck. The explosives ingredients which are put away in separate compartments on the truck are blended mechanically on the truck on the site and pump specifically into the boreholes. Bulk emulsion has a good water resistance and the gaps don't require water flushing. Actually it will supplant water in the boreholes in light of the fact that it has a higher bulk density contrasted with water. Bulk emulsion has significantly more prominent bulk strength and the burden spacing can extend around 30% (Sahari, 2015)Average density of a sensitized emulsion runs around 1.20 g/cc. The velocity of detonation increments with borehole diameter. Bulk emulsion explosives are well oxygen-balanced, so it creates at least toxic vapour and far less smoke. Critical diameter across of emulsion explosives again relies on droplet size and sensitizer utilized. Bulk emulsion are vastly improved water resistant than water gel slurry of ANFO, in view of the intimate blend amongst oxidizer and fuel, emulsion explosives have higher vitality than water gel slurries or ANFO and it matches with vitality level of Nitro-glycerine based explosives. (Sahari, 2015)

2.4 Initiating System

Initiating systems are utilized to safely initiate charges of explosives at prearranged times via conveying a firing signal starting with one place then onto the next, utilizing chemical or electrical energy. Modern initiating systems incorporate different explosive and inert components that are incompletely or completely expended in the explosion. Little amounts of signal tubing and wire regularly remain in the muck pile. (Orica, Safe and Efficient Blasting in Quarries, 2008)

Non-electric initiating systems apply reactive chemicals to store and transfer energy by controlled burning, detonation and shock waves. Electric and electronic initiation system apply electrical energy that is transmitted by a circuit of insulated conductors. With electronic blasting system delay timing is done digitally in circuits controlled by a capacitor on a circuit board located inside the detonators (Orica, Safe and Efficient Blasting in Quarries, 2008).

Non-electric initiating systems based on signal tube are the most regular systems used for blasting in quarries. Mostly, quarries now use non-electric detonators inside blast holes, with remote initiation of blasts by a non-electric or electric firing system. Some quarries in particularly sensitive environments are using electronic blasting systems to provide better control of blast emissions. Many combinations of initiating systems are offered, so before any initiating explosives system is selected the relevant product Technical Data Sheet should be consulted for detailed information and recommendations (Orica, Safe and Efficient Blasting in Quarries, 2008).A wide range of initiating systems is available to cater for different operating conditions. The most suitable system for a particular quarry depends on many factors, which is:

i. Explosives type and charging method;

ii. Blast holes length, inclination and diameter;

iii. Decking requirements and stemming material;

iv. Rock properties and blast holes temperature;

v. Required fragmentation, displacement and looseness;

vi. Ground vibration and air blast restrictions;

vii. The time blast holes are left charged before firing;

viii. Groundwater conditions and hydrostatic pressure;

ix. The size of blasts and number of delays required; and

x. Electrical hazards from equipment, stray ground currents, static charges, radio frequency energy and electrical storms

2.4.1 Detonators

Detonators are designed to initiate explosive charges safely and cost-effectively, also to maintain blast performance by controlling firing sequences. Detonators have relatively sensitive explosives that are initiated by a signal from an external energy source. Delay detonators also incorporate components that initiate a controlled time delay to optimise the firing sequence of blast holes. All detonators have sensitive components that can be initiated if sufficient impact, heat, friction or electrical energy is applied (Orica, Safe and Efficient Blasting in Quarries, 2008).

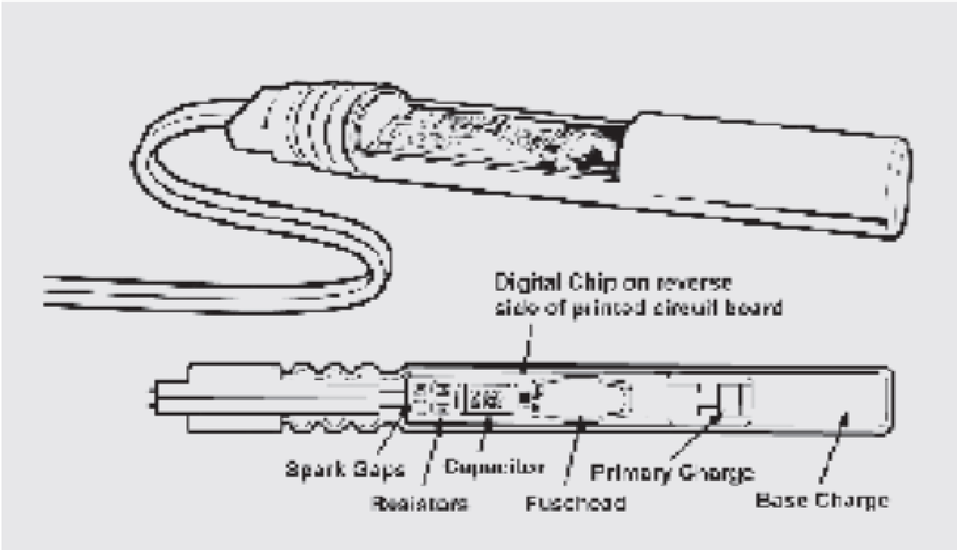

Figure 2.1: Electronic detonator (Orica, Safe and Efficient Blasting in Quarries, 2008)

The electronic detonator is the latest addition to the world of initiating explosives devices as shown at Figure 2.1. There are a number of electronic blasting systems existing to the quarrying industry, all with different modes of operation. Most electronic detonators have a microchip to control the very precise timing and an internal energy storage capacitor to supply the required power to run the electronic timer and then fire the fuse head

2.5 Blast geometry and rock breakage

By a chemical response in a gaseous medium as a space a self-sustained shock wave formed. This space of minor thickness is limited by two infinite planes on one side of the wave is not respond to explosive and on the other the detonated gases. Ahead of the shock wave there are three different zones which is the undisturbed medium ahead of the shock wave, a quick pressure rise zone which chemical reaction is generated by the shock and a stable state wave where pressure and temperature are maintained. (Orica, Safe and Efficient Blasting in Quarries, 2008)

Taking after explosion, high-pressure gasses compress and pulverize the stone immediately encompassing the explosives. This outcomes ascend in the measure of the size of blast hole and will vary according to the features of the rock. The blast holes expansion is calculated by guaranteeing that there is pressure balance at the borehole wall and that the shock deflection surroundings are coordinated in the explosive and the rock. There are two sorts of energy that is free by the explosive which is the shock energy and the gas energy as shown in the Figure 2.2.

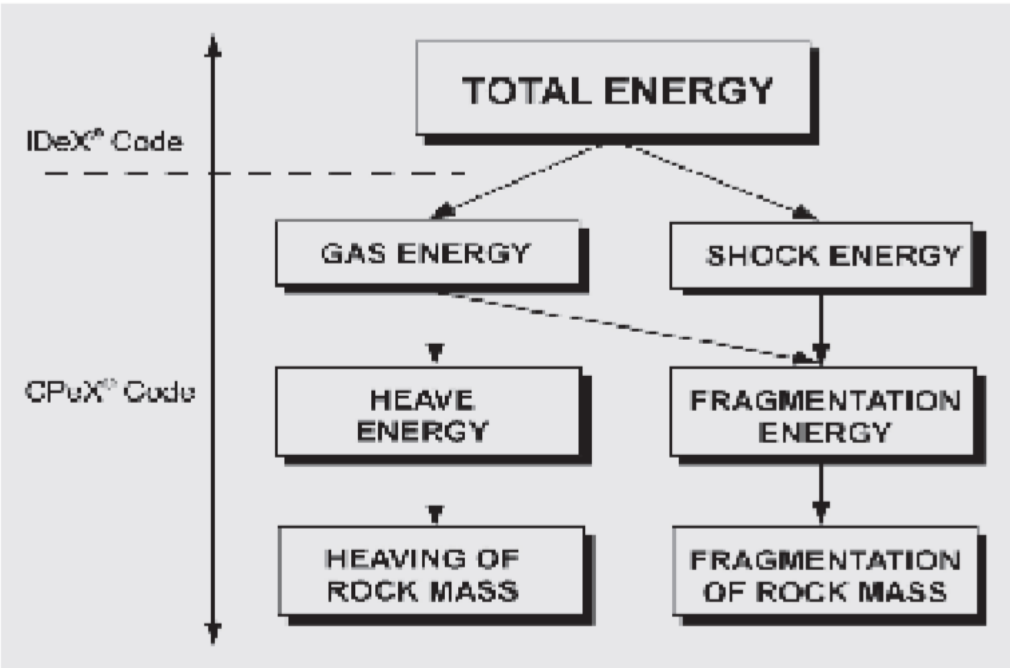

Figure 2.2: Explosive energy rating (Orica, Safe and Efficient Blasting in Quarries, 2008)

The capacity of the explosive to do work is the energy of an explosive. An explosive with more prominent explosive will have the capacity to do work on a greater quantity of rock. Energy created by a explosive can be computed utilizing thermodynamic codes and measured utilizing a miscellany of techniques. Explosive accomplishment has usually been determined from a perfect detonation calculation essentially in terms of the total energy discharged by the explosive composition without reference to the rate at which that energy is discharged and without worry of the impacts of the confinement. The non-ideal detonation at equilibrium state is shown as Figure 2.3 (Orica, Safe and Efficient Blasting in Quarries, 2008)

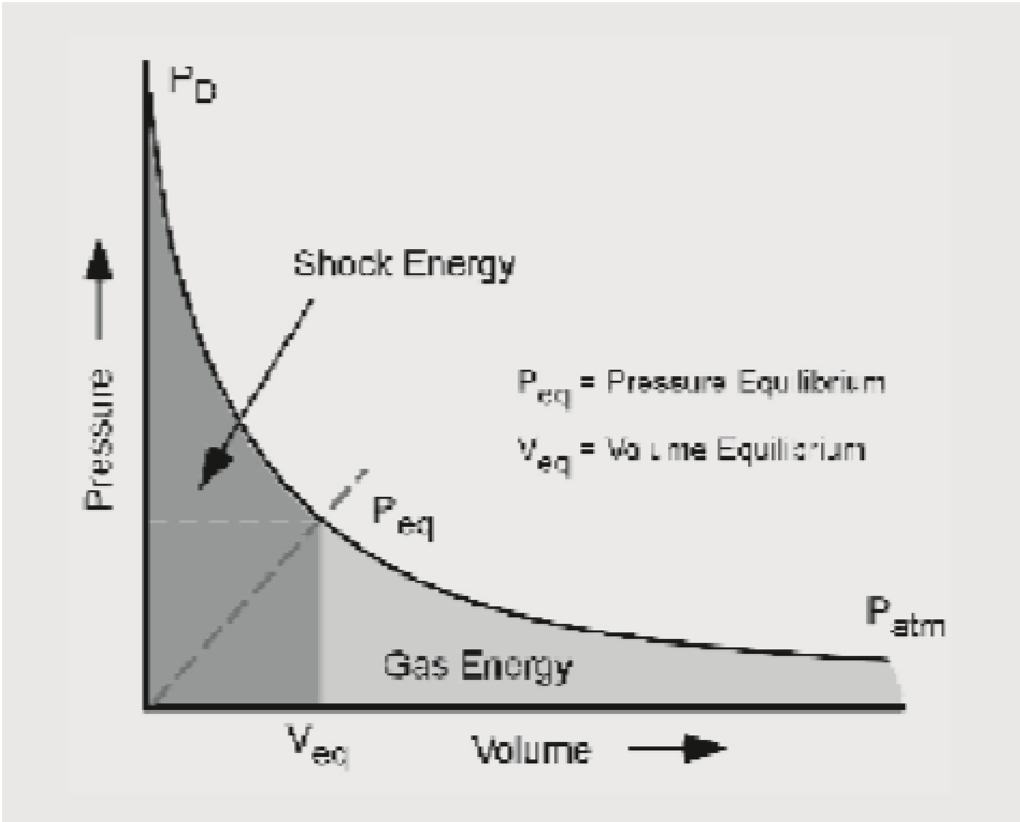

Figure 2.3:Non-ideal detonation at equilibrium state (Orica, Safe and Efficient Blasting in Quarries, 2008)

As the gas expands the pressure in the blast hole reduces until a provisional state of equilibrium is reached when the blast holes pressure equal the strength of the surrounding material. The shock energy that is delivered to the rock is related to the degree and the rate of the borehole extension to this state of equilibrium and includes the effects due to sub-optimal initiation. The only energy delivered thus far is termed "shock energy" which is principally responsible for conditioning the rock and initiating mechanisms that create fractures. The "gas energy" or "heave energy" is delivered