SCHOOL OF MATERIALS AND MINERAL RESOURCES ENGINEERING

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ANALYSIS OF ROCK FRAGMENTATION USING WIPFRAG AT LAFARGEHOLCIM RAWANG QUARRY, SELANGOR

By

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DECLARATION

I hereby declare that I have conducted, completed the research wok and written the dissertation entitled "Analysis of Rock Fragmentation using WipFrag at LafargeHolcim Rawang Quarry, Selangor". 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:

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In the name of Allah, the Most Gracious and the Most Merciful

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ABSTRAK

Penilaian pemecahan sesuatu longgokan batuan adalah unsur kritikal untuk mengendalikan sebarang operasi letupan. Pemecahan batuan dianggap sebagai perkara yang paling penting dalam kuari kerana kesan langsungnya terhadap kecekapan dan kos penggerudian dan peletupan, dan selepas memuat, mengangkut, dan akhirnya operasi pemecahan. Pemecahan batuan bergantung pada dua parameter pembolehubah; 1) ciri-ciri jisim batuan yang tidak boleh dikawal, dan 2) reka bentuk letupan yang boleh dikawal dan dioptimumkan. Kaedah menganalisis imej telah menjadi kaedah praktikal dan berguna untuk mengukur prestasi peletupan dalam memecahkan batu, menentukan kesahan model letupan dan memeriksa kecekapan penghancur dan pengisaran. Dalam kajian ini, perisian WipFrag digunakan dalam penilaian pemecahan batuan di kuari LafargeHolcim Rawang. Hasilnya dalam bentuk graf pengawalan saiz partikel dan penilaian dilakukan dengan menghubungkan struktur geologi, reka bentuk letupan, faktor serbuk dan kekuatan batu kapur. Ciri-ciri geologi di kawasan kajian turut direkodkan. Gambar-gambar untuk analisis imej diambil selepas waktu letupan. Dalam masa yang sama sampel batu dikumpulkan untuk ujian beban mata, PLT untuk menentukan kekuatan mampatan batuan yang diletupkan. Berdasarkan analisis yang dijalankan, ciri-ciri geologi memberi kesan terhadap secara keseluruhan prestasi peletupan berbanding reka bentuk peletupan.

ANALYSIS OF ROCK FRAGMENTATION USING WIPFRAG AT LAFARGEHOLCIM RAWANG QUARRY, SELANGOR

ABSTRACT

The assessment of fragmentation of muckpile are the critical element of managing any blasting operation. Rock fragmentation is considered the most important thing in quarrying because of its direct effects on the efficiency and cost of drilling and blasting, and after loading, hauling, and finally crushing operations. Rock fragmentation depends on two groups of variables; 1) rock mass properties which cannot be controlled, and 2) blast design that can be controlled and optimized. Image analysis systems have become practical and useful tools for measuring the performance of explosive in breaking rock, determining the validity of blast models and examining the efficiency of crushers and grinding. In this research, WipFrag software is used in the assessment of rock fragmentation from blasting at LafargeHolcim Rawang quarry. The results are in a form of size distribution graphs and evaluation are made by relating to the geological structures, blast design, powder factor and the strength of the limestone rocks. The geological features on research area was observed and described. Photographs for images analysis is taken after the blasting this is for the image analysis. Meanwhile rock samples are collected for point load test, PLT to determine the rock strength of the blasted rock. In this analyses, the geological features gives an effect on the performance of the blast even though the appropriate blast design is used.

CHAPTER 1

1.0 INTRODUCTION

1.1 Introduction

The primary role of blasting is to fracture the rock into fragments that can be efficiently excavated and handled by the downstream process. Factors affecting blasting performance in terms of fragmentation include oversized fragments, fines, ease of excavation, issues related to the transport of the muckpile and the detailed requirements of the mine's customer (Scott, 2009).

Objectives in blasting are to gain a good fragmentation, face stability and casting where the hauling and lorry transport are taking part in the process. A proper blast design will yield adequate fragmentation, which will lower downstream cost related to hauling, equipment maintenance and crushing (Sereshki, 2016).

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 unit operations is directly associate with the size distribution of muckpile (Siddiqui, 2009).

Rock fragmentation depends on this two variables; geological structure of rock which cannot be controlled and blast design parameters that can be controlled and optimized

(Singh, 2016). The geological conditions for any areas are different, so the blast design should be design compatible with the geological structures in the particular areas.

An optimum blast is also associated with the most efficient utilization of blasting energy in the rock-breaking process, reducing blasting cost through less explosive consumption and less wastage of explosive energy in blasting, less throw of materials, and reduction of blast vibration resulting in greater degrees of safety and stability to the nearby structures (Rout, 2007).

A systematic approach to the optimization of any system is basic to engineering. The definition and quantification of the objectives of a blasting operation need to be understood and clear for both mine and its customers towards optimizing the process. The blast design process involves using data describing the rock mass and explosive properties and feedback from the previous performance. Therefore, performance must be routinely measured and compared with the defined target performance (Scott, 2009).

The optimum rock fragmentation is obtained when it contains a maximum percentage of fragments in the desired range of size. The desired size usually means the size that is demanded and can be effectively utilized by the customers for further operations devoid of any processing (Vengkatesh, 2010).

The word “fragmentation” is very loosely used and can mean anything from “the limits of breaking” to “the percentage passing, above or below, a certain size”. Fragmentation: the economically significant size range of a definable volume of broken rock. This definition is useful for discussing blasting objectives (Cunningham, 1996).

The breakage mechanisms occurring in rock fragmentation by explosives loaded in drill holes depend on the number of free faces, the burden, the hole placement and rock geometry, the physical properties and loading density of the explosive, the quality of stemming, the rock properties and other factors (Clark, 1987).

1.2 Significant of the Project

(Vengkatesh, 2010) cited from Hilton et al., (2006) postulated that the sieving and screening is a direct and accurate method of evaluation of size distribution of particles or fragmentation. The question is can this method be used for the muckpile fragmentation analysis? Yes, but feasible in case of small-scale blasts. For blasting production, this is too costly, time-consuming and inconvenient. The analysis of the rock fragmentation performance can help to improve the blast design in order to achieve the objectives.

Optical methods are the only viable way to monitor fragmentation of most operations in mining where involves the handling of very large volumes of rock. There are three distinct points at which fragmentation information is required;

- Blast muckpiles;
- Truckloads at, or in, the crusher; and
- On conveyor belts laboratory tables.

By knowing the fragmentation handled by the primary earth mover, ie in the blast muckpile, it is a major part of an evaluation for one is attempting to study the effect of blast parameters on mine economics. The evaluation of images from a blast muckpile is particularly difficult owing to its size, depth and internal variation (Cunningham, 1996).

1.3 Objectives

The objectives of the project are:

- To analyze the fragmentation of the blasted rock using WipFrag image analysis system;
- To study the performance of rock fragmentation; and
- To identify the cumulative passing rock data on research area by using Wipfrag software.

Primarily, the objective of this project is to understand the mechanism of WipFrag software in industries, practically to ease the process of understanding the particles size distribution. This software can help in improving the blast activities and downstream process.

1.4 Field Investigation

The test site is located at LafargeHolcim Quarry, Rawang, Selangor. This quarry produces limestone aggregates that will be processed next to the cement plant. The number of blast per week is up to 4 times per week. In Selangor, the maximum holes per blast are only 50 holes per blast. Therefore, it is necessary for this quarry to perform more than 1 times blasting to achieve a designated volume of blasted rock and production per month required. The location of the Quarry is at (3°24′11.93"N, 101°24'57.39"E) as shown in Figure 1.1.

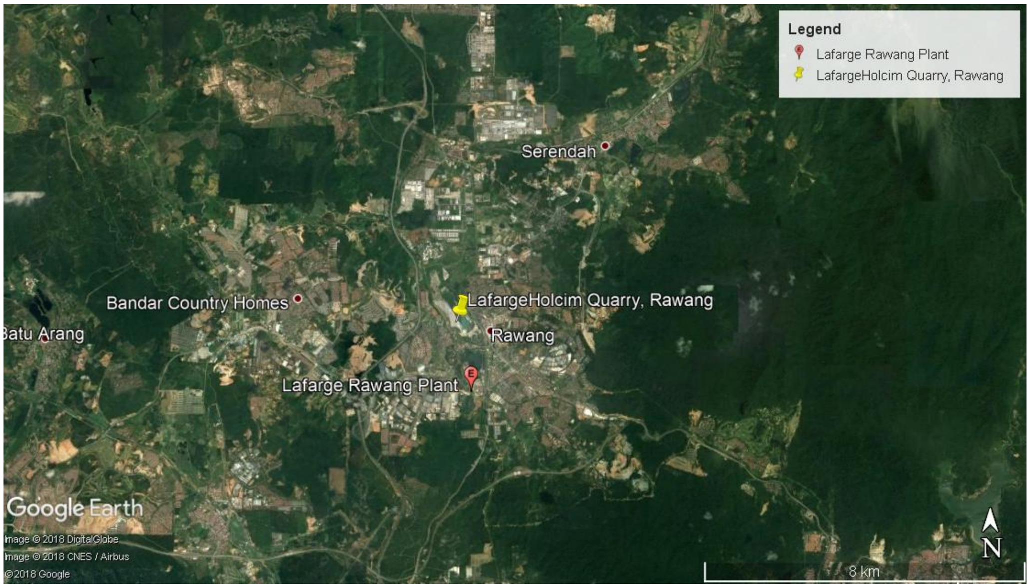

Figure 1.1: The location of LafargeHolcim Quarry, Rawang.

1.5 Geology of Rawang

The bedrock of most of the alluvial mines at Serendah and Rawang is limestone. At Rawang, the limestone is cut by aplite-veins. In one case the vein was displaced 150 feet horizontally by a fault, and the fault-fissure, which had been the primary cause of a solution channel in the limestone, had on one side a quartz-vein with little cassiterite. There were other quartz-veins, all stated by the staff of the Rawang Tin-sluicing syndicate to contain a little cassiterite (Scrivenor, 1927).

1.6 Dissertation outlines

There are several stages of site observation, image analysis and test activities in this research. Site observations were carried out before, during and after the blasting time. The geological structure strengthen the factor of the strength and the structure may not be the same since the location of each blast is far from each other. The data collection was conducted within a week in the quarry and the information obtained was recorded. These included the blast design, photographs, blast monitoring, aggregates sample and the observation relating to uncontrollable parameters. There are many parameters affecting the blast and quality of fragmentation of rocks. In this research, WipFrag image analysis software is used to analyze the quality fragmentation of blasted rock.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Introduction

Image analysis systems have become practical and useful tools for measuring the performance of explosives in breaking rock, determining the validity of blast models and studies the efficiency of crushers. The WipFrag fragmentation analysis system has been in many uses for many years such as in explosive, mining, and materials handling industries for the purpose of evaluating the efficiency of the comminution process, whether by blasting, crushing, grinding or by materials handling processes (Palangio, 1999).

The assessment of fragmentation in blasting, crushing and grinding stages is an important issue in mining/quarrying control and optimization. Fragmentation characteristics influence the productivity, the crusher throughput and energy consumption, the plant efficiency, and the price of the product in the case of industrial minerals and aggregates (Sanchidrian, 2013).

Fragments size distributions are a statistical representation of the population of the fragment, or particle sizes. The size distribution is typically expressed as a cumulative probability in a form of a cumulative distribution function, giving the probability that a fragment is smaller than a given size. Such probability may be estimated form histograms of a number of particles or from histograms of mass fractions in the common industrial sieving way (Sanchidrian, 2013).

2.2 Mechanism of Rock Fragmentation

Rock is a complex engineering material because of its highly variable in its composition, structure, and history. Its static properties are best treated in terms of statistical distributions rather than absolute values. Its dynamic properties are even less well defined and the roles of various mechanisms of breakage less well understood. A broad understanding of this mechanism can help to interpret how blast designs should be modified to improve the fragmentation performance of blasts (Scott, 2009).

The fragmented rock that forms the muck pile has three sources;-

I. Fragments formed by the new fractures created by the detonating explosive charge;
II. The in situ blocks that have simply been liberated from the rock mass without further breakage; and
III. Fragments formed by extending the in situ fractures in combination with the new fractures.

There are a number of relevant rock breakage mechanisms that may take place during blasting. These can be divided in terms of the short duration, dynamic loading of the blast hole by the shock energy from the explosive, and the subsequent gas pressure phase of explosive loading. The proportion of energy slit between the shock and gas phases will depend on the explosive and the rock properties and the degree of confinement (Scott, 2009). Figure 2.1, shown the illustration showing the formation of crushing zone, fracture zone, and fragment formation zone.

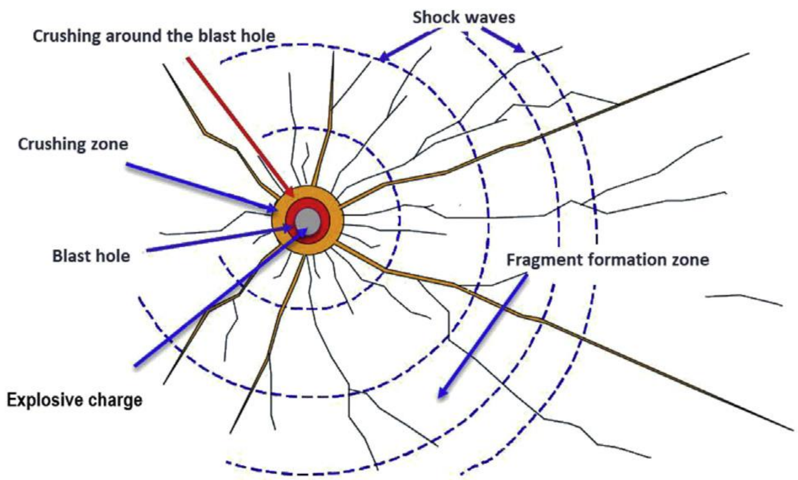

Figure 2.1: Schematic illustration showing the formation of crushing zone, fracture zone, and fragment formation zone.

2.3 Fragmentation Problems

Three level of fragmentation problem are those where is routinely little control over the fragmentation being achieved from blasting. This always causes cost increases in further size reduction and processing operations. Second is where the size distribution does not conform with that required to optimize the overall economics of the mining operation. It is a matter of optimization rather than of problem-solving and requires a high standard of operation practices if it is to yield the potential benefits. Lastly, the most common fragmentation problem is where the size distribution is an inconsistent fragmentation problem indicated by a sudden increase in the amount of boulder-sized or fine material produced by a blast (Scott, 2009).

2.3.1 Sources of Fragmentation Problems

The source of inconsistent fragmentation probably involves;-

- Poor and inconsistent explosive performance;

- Poor blast design in the first place;
- Damaged rock contributing to poor fragmentation;
- A change in rock mass conditions; and
- Poor implementation of the blast design in the field.

2.3.2 Observation and Fragmentation Problems

The blasting engineer must, therefore, rely on simple observations and any data which can provide valuable information on the mechanism of breakage and explosive performance. These observations include;-

- Some interpretation of the location of boulder, free face region, within blast volume or near rear of the blast;
- The burden and spacing of jointing relative to the blast dimensions;
- The extent of cracking behind the last row of the blast and therefore the degree of damage influence in the new free face;
- The area that joint and bedding planes form the free faces of particles found I the muckpile;
- The digability of different regions of the blast; and
- Any feedback on size distribution and the crusher performance.

The distribution of fragmentation throughout the blasted volume can provide important clues on the performance of the blast. The extent that joints, bedding planes, and foliation form the free faces of particles forming the muckpile can be important. Where if the majority of faces are formed by natural features, rather than fresh breakage surfaces, this would indicate that liberation rather than breakage is the significant factor influencing the resulting fragmentation. It is essential to complete the feed-back loop by relating any change in blasting result to changes in the blast design. As it indicates the direction for the future improvement (Scott, 2009).

2.4 Assessment of Fragmentation through Image Processing

Although physical counting of fragments can correlate very closely to the actual size distribution in the muck pile it is very inconvenient, time consuming and exhausting. All in all these researchers have been working over a period of time to involve methods to assess fragmentation. Image processing techniques proved to be suitable and effective (Venkatesh, 2013).

Another technique using image processing programs that have been developed and have made rapid and accurate blast fragmentation distribution assessment possible, are IPACS, TUCIPS, FRAGSCAN, CIAS, SPLIT, Fragalyst, PowerSieve, GoldSize, WipFrag, FragScan and GoldSize. WipFrag, Split Desktop, FragScan, and GoldSize are software packages based on 2D image processing for performing size distribution analysis of the blasted rock blocks (Sereshki, 2016).

The Scaled fragmentation photographs can be manually digitized from the original photograph or by using a light pen on the computer screen. The outline of all visible rocks above a certain minimum resolution is traced by the digitizer mouse or pen (Scott, 2009).

However, some errors are also associated with the digital image analysis. It is extremely hard to obtain accurate estimates of rock fragmentation after blasting (Siddiqui, 2009).

The main reasons for error in using image analysis programs are;-

- Sampling errors; image analysis can only process what can be seen with eye (2-D image). Image analysis programs cannot take account the internal rock, any overlapping rock;

- Missing fines; very fine particles can be underestimated, especially from a muck pile after blasting; and
- Poor Delineation of Fragments; Automatic netting produced larger mean fragment size in some cases due to the failure of the software to recognize boundaries between groups of fine particles, which were counted as a single fragment. In other cases, automatic netting produced lower mean fragment size as some large fragments were broken into many smaller fragments because of the rough surface and shadow. This two called fusion and disintegration. Disintegration plays a crucial role in results because it affects large fragments and large volume (Maerz N. H., 1996) (Siddiqui, 2009).

There are other potential sources of errors but studies have shown that they are all negligible when compared to the errors listed above. These include such very different sources such as a photographic perspective error that can be reduced by the WipFrag rotation correction. Second is operator bias where different operators (photographers) can produce slightly different results using different EDV settings, and by the degree of secondary manual editing.

2.4.1 Digital Image Analysis Technique (DIAT)

Digital Image Analysis Technique (DIAT) is a method in vogue for more than 25 years now and one of the recognized methods for determination of fragmentation distributions resulting from blasting. A good number of attempts by the research community have resulted in an evolution of different software systems.

DIAT can be classified into two groups, static and dynamics systems. Static systems are which images of muckpile are collected and analyzed after collecting post blast images. Dynamic systems are also called online systems and are generally fixed over conveyors belts and capture and analyze crusher/plant feed fragment sizes at defined intervals (Raina, 2013).

WipFrag is one of the earliest systems that has been a proliferation of optically based measurement systems to measure size distributions. WipFrag is originally developed at the University Of Waterloo (Maerz N. H., Aggregate sizing and shape determination using digital image processing, 1998). The important published literature on the development of WipFrag is summarized in Table 2.1.

Table 2.1: Important published literature on WipFrag (Raina, 2013).

Year	Author	Description with respect to **WipFrag**
1995	Franklin et al.	**WipFrag**, quality control of underground blasting operations, key features of the granulometry, statistical choices.
1995	Palangio	**WipFrag** (Franklin, geotechnical Ltd., ETI Explosives, INCO and the University of Waterloo)
1996	Maerz et al.	**WipFrag**- granulometry system
1999	Barkley & Carter	**WipFrag** use, precision and measurements in DIAT (reproducibility, sample size, optical resolution and problem of 'lost fines')
2002	Hendricks	Design and application of AQUILA's drill systems, Fragmentation **WipFrag** use
2003	Latham et al.	FragScan, Powersieve, Split and **WipFrag** blind comparison, strengths and weaknesses of DIAT

2.5 WipFrag

WipFrag is an image analysis system for sizing materials such as blasted or crushed rock. It was developed by Wipware, Inc, Canada. It accepts images from a variety of sources such as camcorders, fixed cameras, photographs, or digital files. It uses automatic algorithms to identify individual blocks, and create an outline 'net'. WipFrag measures the 2-D net and reconstructs a 3-D distribution using principles of geometric probability. The system allows various types of output according to individual requirements, including cumulative size distribution graphs and percentage passing at different sieve sizes (Maerz N. H., 1996).

WipFrag is an image analysis software that analyzes using the information of brightness based on 2D image processing. In general, the area and boundary information of an object in the image can be analyzed automatically with this software. It is possible to determine the size, shape, and area of the fragments in a muckpile with the aid of menu-driven software.

2.5.1 Block Identification

The identification of block edges is done in two-stage process. Firstly, the operators detect the faint shadows between adjacent block. This stage uses several conventional image processing techniques, including the use of opening and gradient operators. This process works best on clean images with lightly texture rock surface. Secondly, a number of construction techniques to additionally delineate blocks that are only outlined during the first stage. These include knowledge-based and arbitrary reconstruction techniques to complete net.

2.5.2 Edge Detection Variables (EDV)

For each of the image processing stages, edge detection variables (EDV) parameters are accessible to the user. The user has the choice of adjusting individual variables or selecting one of nine preset combinations of EDV in order to optimize the edge detection process. The nine preset combination are arranged in sequence to produce more or less edges, depending on the properties of the image. Therefore, by selecting less edges will reduce the number of false edges in given image, while selecting more edges will reduce the number of missing edges in that image.

2.5.3 Manual Editing

Manual editing is to improve the fidelity of the net. The editing tools, to draw line and polines, erase lines or to erase areas, are used to improve the edges net by quickly remove false edges and draw missing edges to complete the net. Usually, delineation of fragments in each photograph was done manually after auto netting, generated by the image analysis systems to minimize possible errors caused by the software.

2.6 Image Acquisition Methods (WipWare Technical Services, 2017)

Image acquisition of blasted rock for size distribution analysis is said to be the most critical phase of the analysis. The important issues in image acquisition are the location of the image, the angle from the surface of the muckpile, and the scale of the images. In order to obtain good images that are capable of being analyzed and representative of the entire rock assemblage, images sampling strategies must be carefully considered (Siddiqui, 2009).

There are many different ways to capture photographs. All strategies should aim to control as many variables as possible. Such variables; photographer must be trained and use the same equipment in the same way (same camera, lens, zoom, lighting, scale, perspective, exposure etc …) to achieve the best results (WipWare Technical Services, 2017). Image acquisition method such as;-

2.6.1 Simple Random method

The simple random method involves the use of an eligible randomizer to generate the sampling parameters. This method is very good as long as it eliminates human bias.

2.6.2 Systematic method

Systematic method involves a strict time interval sampling regardless of circumstance. With reasonable frequency, this method is typically superior to all other sampling methods as it is by definition systematic.

2.6.3 Stratified method

If there are multiple versions of the material in similar volume then stratified sampling may be suitable. The stratified method involves taking an equal number of random samples from each version of the material. This method is good if all versions of the material have similar volumetric proportions relative to the whole, otherwise, it is a poor selection as it may over-represent the smaller population and underrepresent the larger.

2.6.4 Probability Proportional to Size Method

If there are multiple versions of the material in dissimilar volume then probability proportional to size sampling may be suitable. Probability proportional to size involves taking proportion corrected number of random images from each version of the material. This method is good if the volumetric proportions can be accurately estimated; otherwise over/underestimation may occur.

2.6.5 Cluster Method

Cluster method involves collecting multiple samples at specific time intervals. This method can be good if it is executed properly but has a significant probability of missing important material variation.

2.6.6 Quota Method

Quota method is considered the non-probability method which involves the collection of a predetermined number of images from select versions of the material. This method is generally not recommended for the purpose of material images because it is non-random and has a significant probability of missing important material variation.

2.7 Particle Size Distribution Formula

Dozens of models are used to describe most of particle size distribution that is the best fit. However, WipFrag currently supports two methods which are Rossin Rammler and the Swebrec methods. Two parameters that used by Rossin Rammler as a performance indicator, KPI; X_c, known as the characteristic size of the distribution and more specifically D63.2, and secondly, n, the value is that measure of uniformity (WipWare Technical Services, 2017). The uniformity curves with unified soil classification system as shown in Figure 2.2.

Analyzes every fragment in the muckpile is fortunately not necessary because it is widely accepted that the mass percent of fragments smaller than any given size varies linearly with fragment size when plotted in the Rosin-Rammler domain. By measuring only a sufficient number of particles to confidently define the slope and intercept of the Rosin-Rammler line (Scott, 2009). A typical formula for Rosin-Rammler is shown in Equation 2.1.

$$Y = 1 - e^{-(\frac{X}{X_c})^n} \quad \text{………………………………….. (Equation 2.1)}$$

Where;-

Y= Cumulative fraction by weight undersize in relation to size x

X_c= Size Modulus which defines a characteristic size of the distribution

n= Distribution Modulus which defines the spread of the distribution.

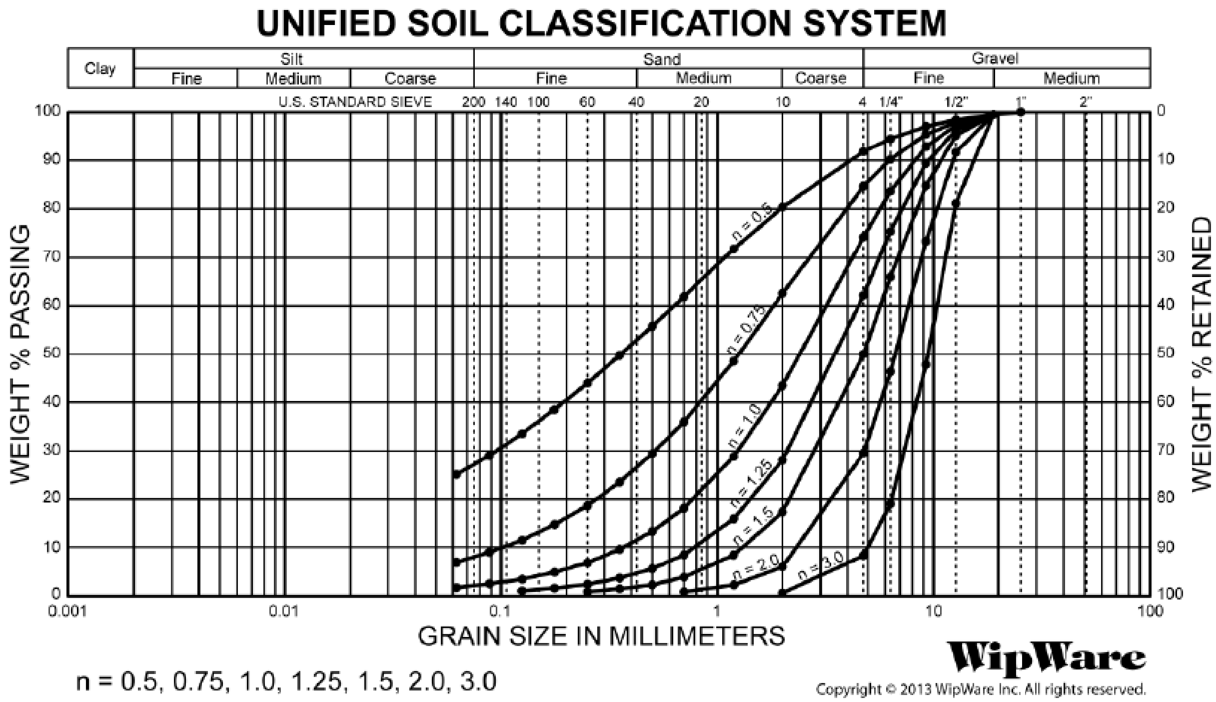

Figure 2.2: Uniformity curves with unified soil classification system.

Fragmentation characteristics such as mean fragment size, X_{avr} uniformity index, n and characteristic size, $X_c$were calculated by using digital images in an image analysis system (Engin, 2010). These two parameters yield by Rossin Rammler are used to derive the median (50% passing) size for the Equation 2.2.

$$x_{50}= x_c\,(\log_e 2)^{1/n} \quad \text{………………………….. (Equation 2.2)}$$

The slopes of a Rosin Rammler curve and the Swebrec function were similar near x_{50}, equating the two slopesx_{50} gives,

$$b = 2n\log_e(2)\log_e\frac{x_m}{x_{50}} \quad \text{……………………… (Equation 2.3)}$$

Where;-

x_m= the minimum of the in situ block size

The other two parameters for the Swebrec function are the maximum size, which it has been found that the maximum size has a significant influence on the quality of the data, and the second parameter is the undulation parameter. The undulating parameter is determined from the previous Equation 2.3. The equation assumes equality of the slopes of the cumulative distribution functions of the Rossin Rammler and the Swebrec function at the median (Spathis, 2013).

Rock fragmentation has been described for many years, almost exclusively, by means of the Rosin Rammler distribution; in the last seven years, the Swebrec function has gained a relatively high profile as it has been shown to represent the fragmented rock sizes with advantage to the Rosin Rammler both in fines and in the coarse ends (Sanchidrian, 2013).

2.8 Explosives

Explosive is an essential element in the development of any country in the world. Explosive is used to break rock or fragment rock to the smaller size that is suitable for further processing for the use in building highways, house and numerous other uses which better for our life, and can also be used for the destructive purpose of defending our country against unwanted elements. In general, explosive can be divided into a commercial and military explosive. However, the military can also be used for commercial application and vice-versa. This note will however, discuss the use of an explosive in the commercial sector which special emphasis on quarrying sector (Sahari, 2016).

Explosive is defined as a solid or fluid substance or a blend of substances which on the importance of a fitting joint 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 sorts 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, 1980)

An explosion can divide into four phases;-

I. Gas release;
II. Intense heat;
III. Extreme pressure; and
IV. Explosion.

These are the important element that plays an important part in rock breakage. There is the release of gas, when an explosive is detonated, where temperature and pressure of the gas increases (Hemphill, 1980).

A function of explosives is 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 a useful inconvenient 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, 1993).

2.8.1 Explosive Characteristic

In order to optimize a blasting operation, it is necessary to understand the characteristics of each component of the blasting process. The blasting task is to convert the in situ rock mass into a muckpile of an appropriate fragment size distribution to suit the available excavation equipment (Scott, 2009). Each type of explosive has its own set of characteristics which suite it to some particular applications but not to others, so it is essential to select an explosive which has characteristics appropriate to the conditions under which it will be used (Sahari, 2016).

The main characteristics of the explosives are as follows;-

Strength

Strength refers to the energy content of the explosive and it is a measure of its ability to perform useful work. The most common methods of expressing strength are grade strength, relative weight strength (RWS) and relative bulk strength (RBS). All strength figures are calculated from the deflections obtained by the detonation of standard weight explosive charges in a freely suspended ballistic mortar.

Density

The availability of explosives due to densities to be varied to meet particular field conditions. Density is expressed in term of g/cc or a specific gravity, which is a ratio of the explosive to that of water. The higher the density, the more the explosive. Three types of densities; package density, bulk density, and loading density.

Velocity of detonation (VOD)

This is the speed at which the detonation wave passes through a column of explosive and is normally expressed in m/s. and usually measured in 37mm cartridge fired unconfined with a no. 6 strength detonator as initiator. Since the test criteria are not always the same, the test conditions should always be checked before the values are accepted. As a general rule, the higher the VOD, the greater is the shattering effect.

Sensitivity

Sensitivity is a measure of the ease of initiation of an explosive. A general rule, sensitivity decreases as the density increases. Sensitivity usually expressed in term of response to a particular initiator. This is usually a standard reference detonator but, in addition, a particular explosive is often said to be ‘cord sensitive’.

Sensitiveness

Sensitiveness in an explosive is a measure of its ability to maintain the detonation wave throughout a column consisting of a number of cartridges. Both sensitivity and sensitiveness are not universally agreed. In the British Ministry of Defense, the HSE and some international organizations, the definitions are applied in the opposite way, that is, sensitiveness applying to initiation and sensitivity to the propagation of initiation.

Water resistance

Water resistance cannot be defined in numerical terms. It is rated qualitatively from excellent to poor or non-existent. When water is encountered in blasting operations an explosive with at least a fair water resistance should be selected, provided charges can be detonated soon after loading.

While if the length of exposure is likely to be appreciable, it is advisable to select an explosive with good water resistance. The gelatinous or slurry types of explosives have the best water resistance and the low-density powder types have the least. The effect of water on an explosive with poor resistance is to impair the performance and to increase the production of toxic gases.

Fume characteristics

The relative quantity of noxious fumes in the gaseous products of an explosive may impose a serious limitation on its use especially underground, where miners often work in the ventilation circuits downstream of the blast site. Mining explosives generally have excellent fume characteristics, slurries and some other non-nitroglycerine explosive in particular, is exceptionally good. However, some explosives developed for special purposes should not be used underground or in confined spaces such as shaft and tunneling.

Gas volume

This is the total quantity of gases liberated on detonation of an explosive. It is expressed in term of litre/kg and a high value indicates that an explosive produces a good heaving effect.

Stability

Stability is to maintain their high and consistent quality, explosives are generally and rigorously tested under extreme conditions for chemical stability in storage and also safety in use. The above characteristics have traditionally been considered to be the most relevant.

Nowadays other characteristics are considered as important as follows;-

- Detonation pressure;
- Temperature;

- Shelf life; and
- Critical diameter.

2.8.2 Type of Explosives

The variety of explosives are utilized in blasting operations. Each type of 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;
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 have been devoured such as the deflagration and the response for this situation moves slower than the speed sound. Normal cases of this sort are the blasting powder or gunpowder, rocket charges, pyrotechnics and fuels in ammonium. The velocity of the detonation (VOD) for low explosives is less than 2000 m/s.

High explosive relying upon their composition, the VOD is around 1500-8000 m/s and create extensive volumes of gasses at significant heat at to greatly high pressure. 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 and are utilized initiating charges in detonators. Secondary explosives are initiated by a shock wave which regularly created by the explosion of essential explosives (Bhandari, 1997).

Many types of modern high explosives are accessible to meet the varied requirement of the mining, quarrying and development industries. A full scope of items must be given to affirm that appropriate compositions are accessible for explosive applications. Compositions can vary in the amount of oxidizing and flammable ingredients and also sensitizer. The percentage and make up of each ingredient is dependent on the required performance and safety characteristics (Sahari, 2016).

Types of explosives;-

- Watergel/ slurry explosives;
- Emulsion explosives;
- Nitroglycerine (based explosives);
- Gelatine explosives;
- Semi-gelatine explosives;
- Nitroglycerine powder explosives
- Cast boosters;
- Ammonium nitrate/ fuel oil mixtures; and
- Bulk explosive.

Detonators are designed to initiate explosive charges safely and cost-effective, and 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 optimize the firing sequence of blast