SCHOOL OF MATERIALS AND MINERAL RESOURCES ENGINEERING

UNIVERSITI SAINS MALAYSIA

BLASTED ORE FRAGMENTATION

AND ITS INFLUENCE ON EXCAVATORS PRODUCTIVITY

By

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DECLARATION

I hereby declare that I have conducted, completed the research work and written the dissertation entitled "Blasted Ore Fragmentation and its influence on Excavators Productivity". I also declare 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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LIST OF ABBREVIATION

BCM	Bank Cubic Meter
P_{20}	Size of particle at 20% passing
P_{50}	Size of particle at 50% passing
P_{80}	Size of particle at 80% passing

Pemecahan Bijih yang telah Diletupkan dan Kesan Terhadap Sesebuah Mesin Penggali

ABSTRAK

Untuk mencapai sasaran komuniti global terhadap industri perlombongan dan pengkuarian, prestasi peletupan batu dan bijih adalah penting untuk meningkatkan pengeluaran. Salah satu ciri utama yang penting untuk meningkatkan pengeluaran bahan logam dan mineral ialah serpihan yang dihasilkan selepas letupan mesti ideal supaya mampu mengikut permintaan pembekal dan dapat disuap kepada mesin penghancuran, sekiranya diperlukan. Untuk menilai pemecahan bijih yang telah diletup, kaedah simulasi berangka digunakan dengan menganalisa imej. Perisian yang digunakan ialah Split-Desktop, sebuah perisian yang dicipta oleh Split Engineering dan digunakan untuk menentukan saiz dan pengedaran saiz serpihan yang dihasilkan. Oleh sebab pemisahan mempunyai kesan ke atas produktiviti sesebuah penggali, masa kitaran untuk penggalian diambil di lombong dan direkodkan secara manual. Disebabkan bijih yang akan disuap kepada penghancur adalah terhad kepada 400mm, saiz itu menjadi penanda aras bagi saiz serpihan yang dihasilkan. Berdasarkan dapatan kajian, serpihan yang dihasilkan pada 400 mm hanyalah 65% dan dianggap sebagai sederhana atasan, dan 65% daripada jumlah akan dihantar ke loji penghancuran untuk proses pengambilan bijih bernilai. Bagi produktiviti sesebuah penggali, ia menyebabkan 12.95 minit lebih lambat daripada yang dirancang pada awalnya.

Blasted Ore Fragmentation and its influence on Excavators Productivity

ABSTRACT

In order to achieve expectation global community from mining and quarrying industry, rock and ore blasting performance are crucial to improve the productions. One of the important key features to increase production of metals and minerals, the fragments produced after blasting must ideal so that it will follow according to the demands supplier and able to feed to crushing operation, if comminution needed. In order to assess the blasted ore fragmentation, numerical simulation method used by using image analysis. The software used is Split-Desktop, a software created by Split Engineering, used to determine fragments size and particle size distribution. Since fragmentation has effect on excavator's productivity, excavator's cycle time are taken on-site and recorded manually. Since ore will be feed to crusher on the site is limited to 400mm, that size become indicator for accepted fragments sizes .Based on the result obtained, the fragments produced at 400 mm are 65 % which considered above average, as only 65 % of total volume will send to crushing plant for recovery process. For excavators' productivity, it causes 12.95 minutes later than planned.

CHAPTER 1

INTRODUCTION

1.1.Overview

Blasting can be described as a field work to break the rock mass by using certain explosives that suit the condition and characteristics of rock itself so that it become smaller and easier to dig and transport. By creating certain amount of gas in high pressure and temperature as well as a shockwave, it will create a breakage inside rock mass. To get appropriate and good break mechanism, certain amount of charges and explosives need to rightly chosen as it is the key aspects of blasting.

This technique has been proved efficient regarding of cost and methods to handle while giving a lot of profits for production. Nowadays, mining industry need to control operating and capital cost so that maximum productivity and cost of revenue can be achieved. In order to maximize productivity, fragmentation of rock after blasting need to become effective as it may influence the loading and hauling process as well as contributes significant effect towards the overall economy of mining industries.

1.2. Background Research

The chosen site, Penjom Gold Mine, located at Kuala Lipis, Pahang contained gold ore deposits. As for their lithology, the mine geology is dominated by a sequence of rocks assigned Permian Padang Tengku Formation of the Raub Group. A series of competent, narrow tornalite sills intruded during the folding of the sedimentary units.The deposit formed includes tornalite, tuffaceous siltstone or shale, tuffaceous conglomerate, calcareous shale or limestone and carbonaceous shale. Penjom thrust, the dominant structure was controlled the distribution of mineralization of gold.

For its mineralization, it is related to quartz-ankerite-dolomite-sulphide veins. The favorable place for mineralization were the contact between tornalite and sedimentary rocks, particularly in intensely faulted or tightly folded area, resulting competency contrast and chemical activity of carbon thus serving as main factors in focusing gold mineralization and introduced during compression event. The color of agglomerate or conglomerate can depend on oxidation and reduction process during deposition.

For blasting process, one of the guidelines that influence the effectiveness of blasting is the uniformity of blasting rock fragmentations. In order to obtain the uniform fragmentation thus suitability of loading equipment, the parameters that influenced it are burden and spacing dimensions, stemming, length of column, depth of blast hole, thickness of burden, powder factor, geometry of blasting and characteristics of rock mass.

Figure 1.2-1 Big boulders produced and less fine ores obtained from blasting

For load and haul process, it is a crucial element in mine cycle as it will determine the profitability of mining company, based on how much productivity per day or month. This process involved machineries such as excavators as loaders and dump trucks as haulers. In order to obtain excellent production, several parameters regarding to load and haul cycle time need to record concisely. For loading, detailed parameters are digging time, swinging time, loading time and return time (where the bucket needs to spot other digging place). While for hauling are time for dump truck to arrive at loading point, maneuver and spotting time, loading time (includes number of bucket passes), time for load travel, time when it arrives at waste dump/ run-of-mine pad (ROMpad), interval between reversing the dump truck and dumping (operator skill for reversing is important so that lesser time obtain for truck cycle time thus increasing production) and lastly empty travel to loading site.

Based on this background study, the analysis towards blasted ore fragmentation and study of its influence on excavators' productivity has been chosen as final year project. With this research, it hopes that the solution to increase the excavator productivity can be achieve related to ore fragmentation.

1.3. Problem Statement

During loading and hauling process, the mining company has its own target for productivity, either per hour or day so that mining activities will run smoothly. However, this productivity target sometimes deviates from initial estimation of productivity. One of the factors that may contribute to this problem is the blasted ore fragmentation. Therefore, distribution of fragmentations as results from blasting at researched site need to examine and at the same time, its effects to the productivity of an excavator also need to assess. Other factors that may contribute the deviation from estimated productivity target also need to be identified by observation or the reports from machine operators or maintenance team. The blasted fragments are behavior also needs to check.

1.4. Objectives

In order to complete this project successfully, the objectives need to be achieved. The purpose of this research includes:

a. Study and analyze the distribution of fragmentations as a result from blasting at researched site.
b. Study the relationship between distribution of blasted ore fragmentation and productivity of an excavator.
c. Study and identify the other factor that may contribute the deviation from estimated productivity target.
d. Investigate the behavior of fragments produced.

1.5. Thesis Outline

Every thesis build has its own blueprints. For this thesis, there are several chapters to include this research. The outlines consist of:

Chapter 1 Introduction: consists of overview of this title project **Blasted Ore Fragmentation and its influence on Excavators Productivity**, background research, objectives for this study and limitations. This chapter also includes information site chosen.

Chapter 2 Literature Review: covers the previous study done by several researches regarding this project. Various journals, conference papers and other reading sources were studied so that this project can be further understand.

Chapter 3 Methodology: covers on procedures to finish this project successfully. Every detail needs to reveal and mention so that it can be embellish for future use. For this writing, the scope involves blasting, factors affecting to blasting performance, ore and rock fragmentation, ore fragmentation analysis by Split-Desktop and other methods, excavators productivity, factors affecting excavators productivity and excavator and loading performance assessment.

Chapter 4 Results and Discussion: covers the results got from data collection at site. It will present particle size distribution and excavators productivity regarding fragments produced at blasted site. This chapter also discusses the relationship between this distribution and excavator productivity and why it behaves in such manner.

Chapter 5 Conclusion and Future Use: covers the conclusion about this research and to improve results in future use.

1.6. Limitations

This thesis has broad scope to begin with. So several constraints need to be taken which are:

a. The focused parameter for this research are fragments produced and loading time for excavator, not for overall production for mining activity which includes movement of dump trucks or other haulers
b. Discussion about economic is proscribed.

CHAPTER 2

LITERATURE REVIEW

Global aggressiveness is leading the mining trade towards maximizing productivity by controlling capital and operative prices. Rock fragmentation features a central influence over production and prices. The target of blasting in an exceedingly mine is to come up with a muck pile which will be efficiently loaded and transported. The potency of the loading instrumentation features an important impact on the economy and productivity of mining operations. The productivity and potency of a loading machine is laid low with many factors including: muck pile characteristics; loading geometry and practice; operative conditions; and loading style. To obtain further knowledge regarding this thesis, several readings have to be done.

2.1.Blasting

On the past, people imagines overthrown the fragments of rock, a bunch of tremors and clamors that caused by air blast and giant clouds of smoke formed. Blasting is an activity not only a field work to break the rock mass by using certain explosives that suit the condition and characteristics of rock itself so that it become smaller, but it is also involving a touch of knowledge of arts, science and technology itself. Now, there are more and more techniques and tools involved in global scale, that available for the blasting engineer, drilling engineer and even shot-firer have to aid in honing process and skills, so that this blasting become improved, mainly in fragmentation and less aftermath produced such as ground and air vibration, airblast and fly rock.

Now, since science and technology have improved over time, blasting has become more science-driven activity as miners and engineers are able to implement the improvement of rock piles and fragmentation produced and variety of explosives and detonators (Hollingsworth, 2010). Onwards to future, the innovations regarding blasting are more steer towards maximizing profits, at the same time maximizing safety.

2.2. Factors Affecting to Blasting Performance

One of the significant need in blast specification is to record the blasting work correctly and faithfully. The blast design must be clearly recorded. Burden, spacing, depth, blasting location, explosive used and the protection methods to control fly rock must be recorded and shown on the plan (Sahari, 2010). Videos or photographs of blasting work must be taken. To check compliance, monitoring programs to supervise bad aftermath such as vibration and airblast by recorded and implemented correctly to protect the owner from possible critics from communities and as supporting documents in discussion with the authorities during their inspection and also in case of lawsuit happens.

The parameters for blasting are important to get ideal results. In order to achieve that, the engineer or shot-firer need to implement their knowledge and experience to make sure blasting is ‘according to the plan’. To make it succeed, there is huge challenge. The major variable that will affect the results of blasting are:

- Spacing: It is the distance between blast holes in a row in adjacent manner.
- Bench height: Gap between crest and toe. The distance obtain may affect the machine for excavation purposes selection.
- Burden: The gap between free face and blast hole. This is a vital information in parameter designed to determine the wanted outcome, as it is a signal of the activity that the hole has to do with misplaced rock and fragmentation as well as the load that need to be placed inside the blast hole.
- Diameter of blast hole: The diameter of drilled hole. This variable has ‘deeply in relationship’ with other variable which are spacing and burden. Shot-firer and engineer must include this set and apply the rule of thumb between these 3 variables:
    - Spacing = 1 to 1.5B B=Burdens’ distance
    - Diameter = $<1/70^{th}$ of BH BH=Bench Height
    - Burden = 25 to 35D D=Blast hole diameter

As seen on rule of thumb applied here, shot-firer and engineers are able to do a blast design with chosen variables to modify the expected results by changing these variables input. The range is wide to function in and remain within to what are considered to be typical practices.

- Initiation system: The method that need to initiate the explosives to make it detonate. In this industry, most commonly initiation systems are capped non-electronic or famously known as NONEL, detonating cord, electric, capped fuse and electronic. Mostly, NONEL are dominant in markets and usability.

Each system has their own advantages and disadvantages. The key features that need to pay attention are cost, safety, accuracy, easiness for usage, and availability.

- Explosives: The chemical compound or mixture that has high destructive force when initiate by detonators or other material with same purposes, intended for blasting. In mining and quarrying, commonly used explosives are Ammonium Nitrate Fuel Oil A.K.A ANFO, Bulk Emulsion, Cartridge Explosives, slurries and bulk blended product. The suitability of explosive to be chosen depends on geological condition and capability to obtain from suppliers. When it comes to choose correct substance to put inside blast hole, the compromise needs to make. Each explosive have their own pro and cons and several key features need to pay attentions, such as water resistance, cost and energy produced.
- Blasting Pattern: There is restricted selection for pattern which includes square, staggered and rectangular. For this variable, it is crucial to decide best pattern so that big boulders created can be avoid by dealing geological characteristics and condition as well as energy distribution produced.

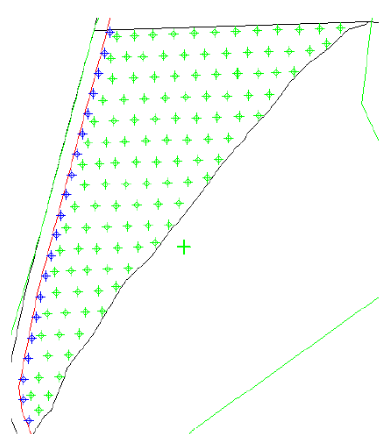

Figure 2.2-1 – Staggered-pattern. This pattern obtained from Tenaga Kimia Sdn. Bhd.

- Time of firing: Optimum timing is crucial not only effect on negative impact such as airblast, also for community. The best time depends on environment and community ease, which when the people are busy going out, favorable wind condition, minimal cloud and afternoon as at this time, temperature inversion is likely to persist and airblast may be avoided. Mostly, these weather condition able to get from nearest airport. Based on previous research, inefficient timing accuracy contributes fatal flaw has been stated by S Winzer *et al* (1977):

  > **'Accurate timing must be considered imperative in producing consistent blasting results and in reducing noise, vibration, fly-rock, back break and poor fragmentation. In the overwhelming majority of cases that we have studied in detail (37 production shots), poor performance can be directly related to timing problems, which tend to overwhelm other blasting parameters.'**

- Stemming: a process where to fill the void part inside blast hole. Type of material and stemming length are the factors for this process. The aim is to hold the energy produced by explosives inside the hole. The compromises came by the cost making, fragments produces and availability of material chosen regarding the confinement of the explosives gas.

However, there is sometime blasting become difficult because of the constraint present. These constraints are challenges to shot-firer and engineers and it's their role to challenge this overwhelming task to make changes when facing certain constraints. When nature give resources to recover with the package consist of hard-to-handle rock properties and geological feature, they must deal with it. At one point, the alternative ideas popped up from mind to a certain extent such as instance dewatering the holes, but these instances are finite. These are the list of examples of constraints that shot-firer and engineer must face:

- Geological condition: Mainly related to rock type and discontinuity present. The wanted rock or ore has specific characteristic and wanted by the supplier. So it may be hard to blast, abrasive when loading, crushing or hauling and difficult to drill. This also applies to discontinuity and fracture present at site such as joints, foliation and faults. For this case it hard to modify it and just deal with it.
- Budget: Since it is mostly limited by owner, so it needs to consider as constraint. Mine is to make profits, so the cost for blasting need to lower than it should so that profit is obtain and the activity able to continue for a period of time. Thus, blasting is done with a condition where the cost needed kept below certain level.
- Water: It is vital to know the origin of water and how to endure it. By using 5W and 1H, investigation about water can be done such as how it flows to here? Where wills the water that has been pumped runoff to, if it can be pumped? The water itself might come from ground or rain. If it cannot be preventing, someone need to manage it by removal and sealing by gas bag by example.
- Environment: The after effect related to environment caused by blasting includes noise and vibration. The contaminants produced such as dust also need to precautious. Every mine has their threshold limit such as vibration

limit that has been set by state or national law, and offer serious limitations on mine operation. This limit is difficult to change, making it blasting frequency and shot-size may become limited thus affect blast outcomes adversely. To overcome dust problem, wind direction must be known so that it will blow away to desired direction.

- Location: Location for blasting operation will causing outcome become unfavorable. If blasting become a daily routine and at community development area, it will constraint in drill and blast activity as it may interrupt people nearby. The location also inflicted not only to housing area but infrastructure inside mine or quarries as well.
- Final product demands: The market demands to produce end-products will be cause that the engineer and shot-fire to cooperate with. For example, can they produce more products with current amount of input capability? The balance between demands for product and capability form an important part of the balancing act that shot-firer has to manage. If demands drop, it might challenge for many company, especially for engineer and shot-firer.
- Personnel: The questionnaire includes their skill, available workers and working quality. It is vital to choose right worker and operator so that blasting result will be satisfied. As shot-firer and engineer, their duty is to maximize the contribution of employed worker.
- Equipment: The designated blast must be delivered by capable fleet. For example, if hole's diameter has been set as 4 inch, shot-firer and engineer must know the machine present that can bore a hole for desired diameter.

- Bench and Pit Geometry: The size and shape of bench inside mine will constrict the capability of drill and blast, especially at the edge. So when planning at that particular place, drill and blast planning must aim at keeping shots as straight and symmetrical as possible.
- Explosive selection and availability: Site condition, as well as physical location and lead times often become constraint when to load and initiate blasting. Harsh condition will trouble for transportation to send wanted explosives and no preferred explosives to use. To overcome this problem, it is suggest that know the available explosive before drilling process. When holes have been drilled, it is hard to adjust the hole, especially when it has to be drilled again.

These listed constraints are invincible barriers. The result got is a give and take situation to what was planned envisaged or initially. To adapt changes always a challenge, especially for worker, but when they become comfortable with improved technique and technology, several effects will improved as well such as powder factors reduced with increased drill pattern, fewer back break, air-blast and vibration minimalized, quarry's life for reserve increased, and most importantly, fragmentations improved while at the same time, secondary blasting will be fewer and crusher productivity, loading cycle times will improved as well.

Other than assessing fragmentations, blasting performance also can be evaluated by the non-existence of back break and toe problems.

- Toe problem: Caused by ineffective blasting practices. The effect of this problem also includes the need to do a secondary blasting and it makes more employees involved, more work to be done, and ultimately, production cost will increase. The loading phase also will slowing down due to the existence of boulders in unevenly-sized. The difficulty to obtain targeted level quarry floor also affected from toe's existence. In order to prevent it, blast holes need to drill vertically or according to designated pattern and specifications and bottom the blast holes obtained at equal reduced bench level. Also, it is recommended to use more explosives for the primer since it requires approximately 3 times more blasting energy to crush the toe or use water-resistant explosives at wet holes, if needed.

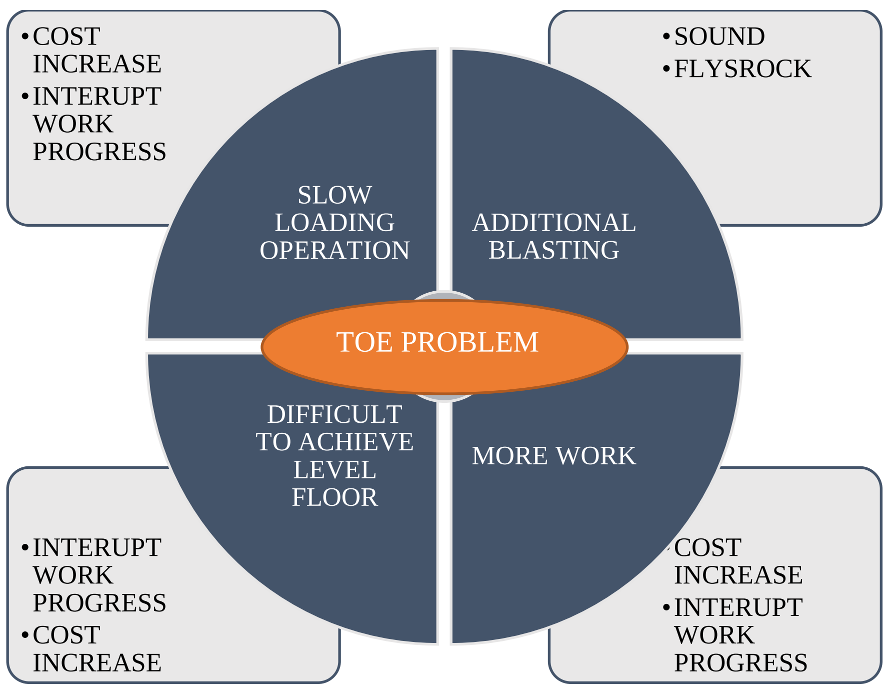

Figure 2.2-2 – Adverse outcomes due to occurences of toe problems (Mohd. Lip, Mustafa, & Goh, 2015)

- Back break: Another major problem that caused by in effective blasting practices. The effect when this incident occurs includes the difficulties to drill the blast hole for next blasting activity, increasing the probability to produce more oversize and at the same time, the production efficiency will decrease. The formation of cavities also increases and will overcharging and cost increased. The air-blast and noise levels probability to occur also increase as well as higher probability for fly rocks to happen. Shot firing efficiency also decrease via wastage in explosive energy produced. In order to minimize the back break formation, decrease the bench height in blast design to 15 m, if possible. The usage of bulk emulsion also recommended since it has higher Velocity of Detonation (VOD) compared to ANFO. Other than that, the problem also can be effective minimized by reducing the spacing and burden when planning the blast design, use higher explosives for primer and the blast holes drilled vertically or according to blast design and pattern,

2.3. Ore and Rock Fragmentation

Drilling followed by fragmentation of rock or blasting is an undisputable combination of knowledge derived from arts and sciences (Ting Yew & Minto, 2015).The principle objective of rock fragmentation at quarry sites is the effective and controlled utilization of explosive energy to break the rock mass to the required market specifications with minimum negative impacts to the environment (Ho Cho & Kaneko, Rock Fragmentation Control in Blasting, 2004).By using accurate and efficient blasting methods and explosives, it will improve rock and ore fragmentation, making it to reduce the costs for optimizing the load and haul process, less secondary breakage required and increase crusher throughputs when handling the oversized rocks or boulders (Ting Yew & Kang

Ngen, Digital Detonators - Effective Improved Rock Fragmentation, 2010). Based on the vast experience, to employ effective usage of explosive energy inside blasthole, the analysis about blasted rock performance need to accurate as possible. If the assessment is successful, better fragmentation will obtained with minimal cause towards environment. The variables that potentially affect the fragmentation include:

- Blast geometry: require understanding on applicable free faces present and accurate position to fill charges, by doing borehole logging to identify borehole locations and rock structure present deep inside the Earth. Information obtained will assist to design blast effectively to obtain desired fragmentation. To obtain optimum fragmentation with minimal usage of explosives, maximum number of free faces of rock must parallel to and optimum distance from hole is needed. The considered inconstant includes blast-hole collar, explosives charge distribution, bench height , blast pattern, hole diameter, angle of drilling and burden and spacing. This data can be obtained by using laser profile equipment to get rock's surface assessment. As results from successful blast geometry design, critically deviated blasthole can be identified and blast design assurance improved for suitable fragmentation.
- Explosives: The supplier provide detailed performance characteristics of the products for best blasting performance based on case study and experience on-site under diverse and challenging operations at quarry and mines.
- Rock Mass: Most significant factor that influences the blasting performance. The characteristics and composition of rock mass can be identified by laboratory test and observation from drilled core samples. Rock properties'

principles that can influences of favorable fragmentation include its strength, structure and variability. For structure, it also includes strike, dip and dip direction; as well as several discontinuities such as shear, foliation, faults and bedding plane. For the hard rock especially in quarry, it is efficient to use high fragmentation energy explosives.

- Velocity of Detonation (VOD): can be defined as shockwave's velocity when travelling via the detonated explosives. It is one of the most important feature and the data must be recorded for comparison either the value got at blasted site same as data for explosives' manufacturers prepared.
- Energy losses: Causes economically lost as the gas release improperly and inappropriate mitigation.

2.4. Ore Fragmentation Analysis by Split-Desktop Method

The SPLIT is an image analysis package developed by the University of Arizona to work out size distribution of rock fragments produced, especially after blasting. It is operated with 8-bit gray scale pictures of rock fragments. There are 2 types of SPLIT programs; one would be an automatic analysis and continuous program that is handled on conveyors (mostly) and the other one is a manual program that uses the saved pictures. However, constant formula and algorithm is employed for each programs. A photographic camera is employed to capture the image of the blasted face, which will be analyzed in SPLIT.

Based on I Brunton *et al* (2003), if digging time can be improved by 20%, load and haul productivity and cost can be improved by 3%. For their current studies, it was conducted in Wallaby Pit, Granny Smith Mine, located at Southern Australia. Blast fragmentation was analyzed by using Split Engineering Software which is Spilt Desktop and excavator's cycle time was manually conducted.

As for blast fragmentation assessment conducted by I Brunton *et al* (2003), the photo was captured at the back of loader truck's tray, rather than in-situ itself just like in Figure 2.4-1. This photo then analyzed by using Split Desktop, software that process grey scale image and calculates the distribution of particle size of ore/rock fragments. The calculated size fragments' data will be present as cumulative particle size distribution (Particle Size vs. Percent Passing) just like in Figure 2.4-2.

Figure 2.4-1 – Image at truck's tray

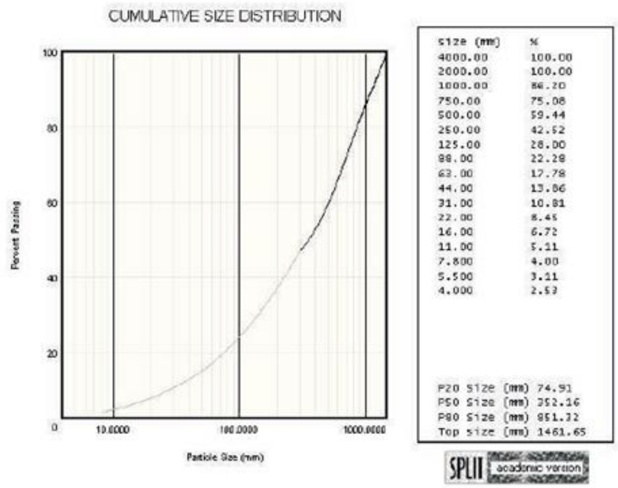

Figure 2.4-2 Split Desktop Analysis and Particle Size Distribution

2.5. Ore Fragmentation Analysis by other method

To assess blasted rock or ore fragmentation, other than Split-Desktop software other software also can be used such as Kuzram and Wipfrag. Achieving better fragmentation can make humongous cost savings; automated particle size analysis systems give a continuous stream of data to permit operators to make informed process decisions according to quantifiable fragmentation results (Roy, Paswan, Sarim, Kumar, Jha, & Singh, 2016). Compared to Split-Desktop, Kuz–Ram model is possibly the most widely used approach to estimate fragmentation from blasting, and renewed interest in the field of blast control has brought increased focus on the model (Cunningham, 2005). While for Wipfrag, it is an image analysis software system that emphasize the assess the digital image of blasted rock with granulometry structure to forecast the size distribution. Usually, the picture from camcorder at the site is used. A scaling object is needed to measure the size fragment. The pile's photo is then captured or recorded and this picture is then transferred into the Wipfrag software. The blasted rock image is reworked into a particle map or network. Network areas are then generated into weights and volumes. The data obtain will present as cumulative distribution graph. The speed of fragment edge detection and its fidelity enable automated remote watching at a rate of 1 image per three to 5 seconds (Venkatesh, 2010). Additional fragments are resolved over a larger size range.

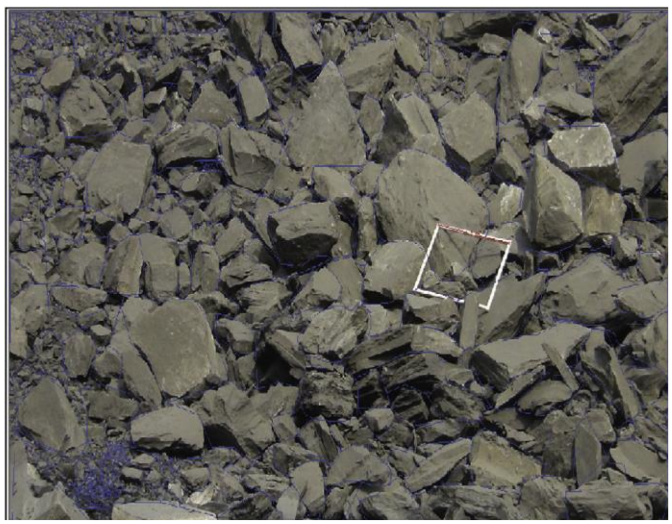

Figure 2.5-1 – Image of fragments on site

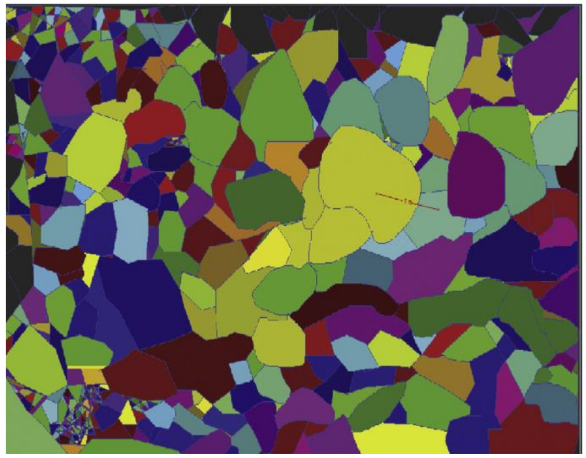

Figure 2.5-2 – Image formed as particle map or network

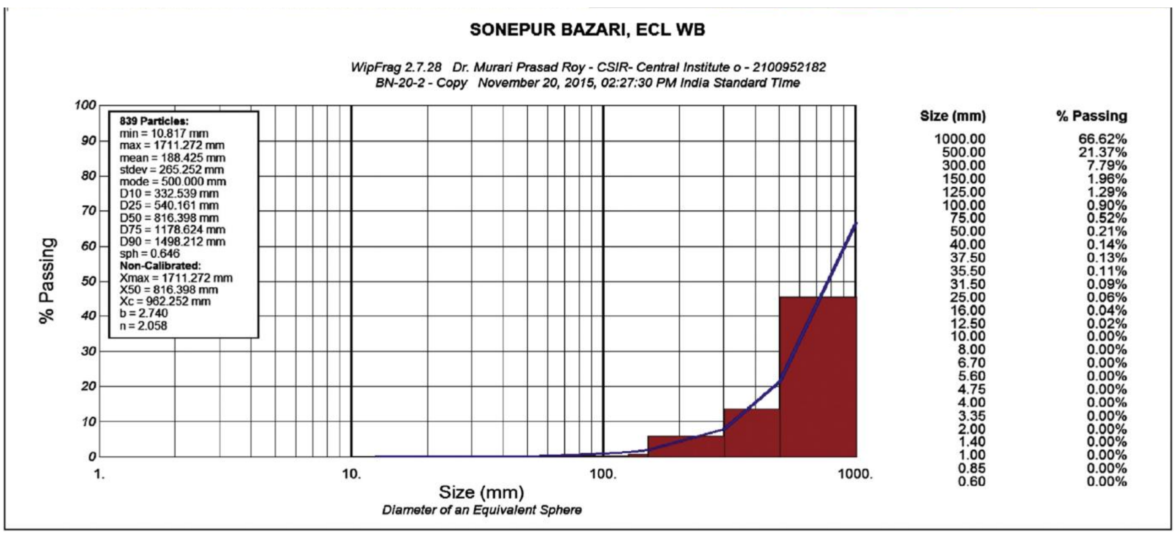

Figure 2.5-3 - Cumulative size distribution. This is an analysis of overburden bench of Sonepur Bazari project conducted by P.K Singh *et al* (2016)

2.6. Excavators Productivity

In production of metal and mineral, excavation or loading is involving the stripping of Earth material from surface. Rock excavation can be categorized as unconsolidated or loose rock excavation and consolidated or solid rock excavation. Consolidated rock, which consists in solid and hard rock, may require blasting so it is easier to remove. While unconsolidated rock, is a ‘disassemble’ of rock mass and can be remove without blasting as it easy to lift up. After blasting that causing rock chips formed, loading and hauling activity will take place. Loading can be described as an activity to lift up, scoop and dig the material above the ground by using some bucket or scoop attached to machines such as dragline, excavators and mechanical shovel. While, haulage is an activity where it carries this material from mine or quarry to point where it need to dump as waste or run-of-mine pad, where it needs to treat for further beneficiation.

Generally, in mining, the ultimate goal is to extract little amount of material at the same time gain maximum profit by recovering the metal that has been demanded. So, the higher the grade of an ore, the higher the profit can get. To minimalize the capital cost while reap the most value metal and mineral, mine planning must be cultivated so that the ore body can be recovered in expected manner. Nevertheless size of mine, the plan includes infrastructure, pit development, equipment, and mining rate and ratios. Mining rate and ratios can be defined as the reduce of ore reserve towards economic limit at demands.

Increased production at a minimum cost is the ultimate desire of any mining company (Olaleye & Adagbonyin, 2011). To obtain maximum production with a minimum cost is the most ambitious of any quarry and mine company. Loading, hauling as well as excavating are different aspects of any operation in productivity of mine and quarry and these parameter has been supervised in-detail so that maximum profits and optimum productivity can be achieved. According to Adedoyin (1991), it is harsh to see that production especially involving loading and hauling to be cultivated at uneconomic stage at the cost of more revenue need to use.

2.7. Factors Affecting Excavators Productivity

Since various variables contribute to a successful rock fragmentation scheme, any change carried out will affect the total cost and quarry productivity (Sannasy, Labuson, Goh, & Md. Din, 2015). The rock's nature contributes an important role to evaluate the excavation assessment (Mohamad, Komoo, Kassim, & Md Noor, 2010). The variables that affecting excavators productivity includes:

- Muck pile characteristics and displacement: The characteristics and shapes of muck pile produces contribute the productivity as it can affect cost of operations. The displacement produced can be measured by using surveying. The variables related to displacement include swell factor and horizontal displacement. One of the characteristics also that able to affect the excating operations also is the fragmentation. The parameter relates for fragmentation assessment also includes percentage of fines and oversize, fragmentation distribution curve, uniformity index and mean particles size produced.
- Digging activity: The variables include bucket fill factors, unplanned time loss during when the operator need to handle large boulders and unscheduled maintenance of machineries.
- Heterogeneous strength of rock: Because of the rock genesis, shale behaves differently correlated to sandstone when it comes to weathering process, as