A STUDY OF ENERGY IN ROCK BLASTING

A thesis submitted in partial fulfilment of the requirements for the degree of

Bachelor of Technology and Master of Technology
(Dual Degree)

in

Mining Engineering

By

ASHISH RAJPUT

Department of Mining Engineering
National Institute of Technology, Rourkela
May, 2016

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Ashish Rajput
711MN1088

Under the Supervision of
Prof. M.K. Mishra

Department of Mining Engineering
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National Institute of Technology

Rourkela

CERTIFICATE

This is certify that the thesis entitled **“A Study of Energy in Rock Blasting”** submitted by **Mr. Ashish Rajput** in partial fulfilment of the requirements for the award of Bachelor of Technology & Master of Technology Dual Degree in Mining Engineering at National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

Prof. M. K. Mishra
Associate Professor
Department of Mining Engineering

Date:

ACKNOWLEDGEMENT

In quest for this scholastic attempt, I feel independently blessed. First and preeminent, I express my genuine appreciation and obligation to Prof. M.K. Mishra, Professor of Department for permitting me to bear on the present theme **"A Study of Energy in Rock Blasting"** and later on for his motivating direction, productive feedback and important recommendations all through this anticipate work.

A gathering of this nature would not be conceivable without reference to and motivation from the works of others whose subtle elements are specified in reference area. I recognize my obligation to every one of them. My true on account of every one of my companions and research researchers in the Dept. who have quietly developed a wide range of aides for fulfilling this task.

At last, I modestly bow my head with most extreme appreciation before the God Almighty who constantly guided me the distance and without whom nothing could have been conceivable

Date:

Ashish Rajput
Department of Mining Engineering
National Institute of Technology
Rourkela – 769008

ABSTRACT

Creation impacts have been observed in quarry so as to evaluate the quantifiable structures of energy in which the energy conveyed by the unstable is changed in rock impacting. The seismic field from Minimate readings, the introductory speed of the impacted rock face acquired utilizing Gurney condition, and the section size disseminations from picture investigation of the muckpile material are utilized to decide the seismic wave energy, the Kinetic energy and the Fragmentation energy, individually, moved in the impacting procedure. The impacting information and the techniques for figuring of the energy terms from those are depicted in subtle element. The most extreme aggregate energy measured records for not more than 26% of the accessible dangerous energy in the event that this is appraised as the warmth of blast, however lower figures are normally acquired.

Sample of iron ore collected for laboratory experiment to find out the fragmentation energy with the help of “WipFarg Software (used for sieving of different rock sizes)”, drilling and blasting data, average size of fine and coarser particles, data for ppv to find out seismic energy, also Gurney equation for calculation of kinetic energy

The energy discharged by the explosive, borne in the detonation endless supply of the chemical reaction, is changed over into heat and work to the surroundings as indicated by the first principle of thermodynamics.

Some of these structures get to be obvious amid the impact, to be specific:

- the fracture work, that eventually shows up as new surface in the rock fragments;
- the work exchanged as shock wave into the rock, that proliferates as plastic and at last elastic waves, showing up as seismic wave or ground vibration; and
- the work to uproot the rock and shape the muckpile, that shows up as kinetic energy conferred to the rock.

Other energy exchange happens, in a less evident manner, as takes after:

- expansion work of the fractures, that is consumed as elastic and plastic miss happening of the rock in the surface of the fractures as they are infiltrated by the gasses;
- heat exchanged to the rock from the hot detonation items; and
- heat and work passed on as enthalpy of the gasses venting to the air through open fractures and stemming.

The energetic analysis provides a good insight of the explosive/rock interaction and a better understanding of the blasting process, encompassing a broad range of scientifically challenging subjects .For each energy component, first of all some experiments have been carried out in laboratory and some data collected from Iron Ore Mine to find out some results for different energy. Then with the help of some software and some equations from literature helped me to do my project work with efficiency.

Energies ratios with respect to the total explosive energy are: Fragmentation energy is 31.45%, seismic energy is 1.69%, kinetic energy 13.599%. Total explosive energy measured is equal to 2.434 GJ

Keywords: Fragmentation energy, Seismic energy, Kinetic energy, Rittinger's law, Explosive energy, Heat and work, Shock wave

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Chapter 1

Introduction

1.1 Background of the Problem

Explosives are the essential wellspring of energy. The work into which the energy is changed over changes rock into a dispersion of fragments and uproots them so they can be advantageously stacked and pulled for further comminution and handling. In spite of the fact that the energetic capability of explosives is not especially high (any fuel/oxygen blend utilized as a part of the force business conveys more energy per unit mass than do explosives), they are minimal sources, which can convey their energy in a self-governing structure at a quick rate. This outcomes in reaction items at high weight that can perform mechanical work in distorting and softening the material up their region. This is the thing that makes explosives valuable and by and large imperative for rock uncovering. This quick energy conveyance, as a lot of reaction items at high weight and high temperature, is indivisible of various changes other than the craved fracture and toss, for example, the seismic wave into the rock.

Any explosive information sheet or business leaflet cites some kind of energetic portrayal. Explosives energy is appraised in an assortment of ways, acquired either from computation or from exploratory tests. In any case, the inquiries of what measure of that explosive energy is exchanged to the rock and what part of it is changed over into effective work in the standard common use of rock blasting remains to a great extent vague. Despite the fact that the estimation of a portion of the impacts of the explosive in rock is standard (vibration, discontinuity and, to a minor degree, rock development), they are typically led for impact control reason and the outcomes are seldom thrown as far as their energy content. The purpose behind this might be that it is not the energy utilization in either wonder that matters, but instead the end impacts, i.e., level of fracture, toss and vibration levels. Information and estimations on energy segments in rock blasting are in this manner restricted to a couple of analysts. The fundamental hypothesis and exploratory foundation for the determination of a portion of the energy segments in rock blasting are portrayed first. These are then connected to generation impacts.

1.2 Balance of Blasting

The energy discharged by the explosive, borne in the detonation endless supply of the chemical reaction, is changed over into heat and work to the surroundings as indicated by the first principle of thermodynamics.

Some of these structures get to be obvious amid the impact, to be specific:

- the fracture work, that eventually shows up as new surface in the rock fragments;
- the work exchanged as shock wave into the rock, that spreads as plastic and at last elastic waves, showing up as seismic wave or ground vibration; and
- the work to uproot the rock and frame the muckpile, that shows up as kinetic energy bestowed to the rock.

This energy segment is to some degree self-assertive and depends on the end impacts of the blasting. Case in point, part of the fracture work is in its first stage personally associated with the shock wave stream in the region of the hole and, in the later stages, additionally to the rock development, which starts as the fractures burst open. Such a parcel is, be that as it may, helpful while the physical sizes related with every segment can be measured.

Other energy exchange happens, in a less obvious manner, as takes after:

- expansion work of the fractures, that is assimilated as elastic and plastic distortion of the rock in the surface of the fractures as they are entered by the gasses;
- heat exchanged to the rock from the hot detonation items; and
- heat and work passed on as enthalpy of the gasses venting to the climate through open fractures and stemming.

The energy balance of the impact can in this manner be communicated by :

$$\mathbf{E_E=E_F+E_S+E_K+E_{NM}} \qquad \text{...} \ (1)$$

Where,

- E_E is the explosive energy,
- E_F is the fragmentation energy,
- E_S is the seismic energy,
- E_K is the kinetic energy , and
- E_{NM} is the energy forms not measured.

The terms fragmentation, seismic and kinetic proficiency are utilized from this point forward for the proportions of the individual energies to the explosive energy.

1.3 Aim and Objective

The aim and objective of the project are:

- To know the rock mass properties of the strata
- Which helps us to find out the energy releases from rock
- To know the blasting condition
- To know the geology of the strata
- To know the blasting process

The aim of the project is to develop a correlation between parameters like explosive energy, measured energy and not measured energy. Also measured the parameters with precision. For that 1) should have taken the readings with precaution and with accuracy , 2) have to check the instrument used for measurement 3) have to use the right equation for energy calculation

1.4 Methodology

Various types of data collected from iron ore mine with accuracy and precision. I visited the iron ore mine for some data collection and for some data laboratory experiment has been carried out. Some of the data already known from published literature or information. Instantel Minimate Blastware also used for frequency and amplitude measurement at the time of blasting. WipFrag Software also used for rock sieving or size distribution of rock.

1.5 Layout of Thesis

The investigation carried out to achieve the aim and objectives are presented in 5 chapters. Chapter 1 includes introduction hat discusses the background of the problem, aim and objectives of the project and the methodology. Chapter 2 contains the literature review sourced from different journals and papers published. Chapter 3 includes the methodology of the work with data collected for same. Chapter 4 contains, results and analysis. In the end chapter 5 contains the conclusion of whole work with recommendation for future.

Chapter 2

Literature Review

The human civilisation, development of nation as well as the standard of living have direct relation with the exploitation and extraction of resources from earth. Mining of minerals is a major activity to address those issues. Mining of minerals invariably is related to loosening of earth materials. This section deals with the critical review of available pertinent literatures.

2.1 Mining Process

Drilling and Blasting is the controlled utilization of explosives and different strategies, for example, gas weight blasting pyrotechnics, to break rock for Drilling and Blasting is the controlled utilization of explosives and different strategies, for example, gas weight blasting fireworks, to break rock for excavation. It is polished frequently in mining, quarrying and structural building, for example, dam or street development. The consequence of rock blasting is regularly known as a rock cut.

Drilling and Blasting as of now uses a wide range of assortments of explosives with various arrangements and execution properties. Higher speed explosives are utilized for generally hard rock as a part of request to smash and break the rock, while low speed explosives are utilized as a part of delicate rocks to produce more gas weight and a more noteworthy hurling impact. For example, a mid-twentieth century blasting manual contrasted the impacts of dark powder with that of a wedge, and explosive to that of a hammer. The most generally utilized explosives as a part of mining today are ANFO based mixes because of lower expense than explosive.

Prior to the approach of passage drilling machines, drilling and blasting was the main practical method for uncovering long passages through hard rock, where burrowing is impractical. The choice whether to develop a passage utilizing a TBM or utilizing a drill and impact strategy incorporates various variables. Burrow length is a key issue that should be tended to in light of the fact that vast TBMs for a rock burrow have a high capital expense, but since they are normally speedier than a drill and impact burrow the cost per meter of passage is lower. This implies shorter passages have a tendency to be less temperate to develop with a TBM and are hence for the most part built by drill and impact. Overseeing ground conditions can likewise significantly affect the decision with various techniques suited to various dangers in the ground.. It is polished frequently in mining, quarrying and structural building, for example, dam or street development. The consequence of rock blasting is regularly known as a rock cut.

2.2Procedure of Blasting

As the name suggests, drilling and blasting works as follows:

- Various holes are bored into the rock, which are then loaded with explosives.

- Exploding the explosive causes the rock to crumple.
- Rubble is expelled and the new passage surface is fortified.
- Rehashing these progressions until wanted excavation is finished.

The positions and profundities of the holes (and the measure of explosive every hole gets) are controlled by a precisely developed example, which, together with the right planning of the individual blasts, will promise that the passage will have a roughly round cross-segment.

Some of these structures get to be obvious amid the impact, to be specific:

a) the fracture work, that eventually shows up as new surface in the rock fragments;
b) the work exchanged as shock wave into the rock, that engenders as plastic and eventually elastic waves, showing up as seismic wave or ground vibration; and
c) the work to uproot the rock and shape the muckpile, that shows up as kinetic energy bestowed to the rock.

So these above forms come under category of measured energy

2.2.1 Energy Balance

- This energy segment is to some degree discretionary and depends on the end impacts of the blasting.
- For case, part of the fracture work is in its first stage personally associated with the shock wave stream in the region of the hole and, in the later stages, additionally to the rock development, which starts as the fractures burst open.
- Such a segment is, nonetheless, advantageous in as much as the physical extents related with every part can be measured.

Other energy exchange happens, in a less clear manner, as takes after:

a) expansion work of the fractures, that is consumed as elastic and plastic distortion of the rock in the surface of the fractures as they are entered by the gasses;
b) heat exchanged to the rock from the hot detonation items; and
c) heat and work passed on as enthalpy of the gasses venting to the air through open fractures and stemming.

So these structures go under classification of non-measured energy

Amid operation, blasting mats might be utilized to contain the impact, smother tidy and commotion, for fly rock anticipation and some of the time to coordinate the impact.

2.3 BLASTING IN SURFACE MINES

Most rocks require blasting preceding excavation in surface mines. Generally four sorts of explosives are utilized as a part of surface mining: slurries, dry blends, emulsions and the half breed overwhelming ANFO. Choice of explosives relies on upon numerous elements, which essentially incorporates basic breadth, hydrostatic weight, temperature, least preliminary weight, thickness weight quality, mass quality, hole affectability, water resistance, stacking methodology, coupling or decoupled properties, timeframe of realistic usability, unwavering quality for mass operations and general drilling and blasting financial matters.

Blasting Practices in Mines, a paper by P. Sharma give a snappy diagram on impact outline and example in surface mines. Here are two pictures which I have taken from his paper:

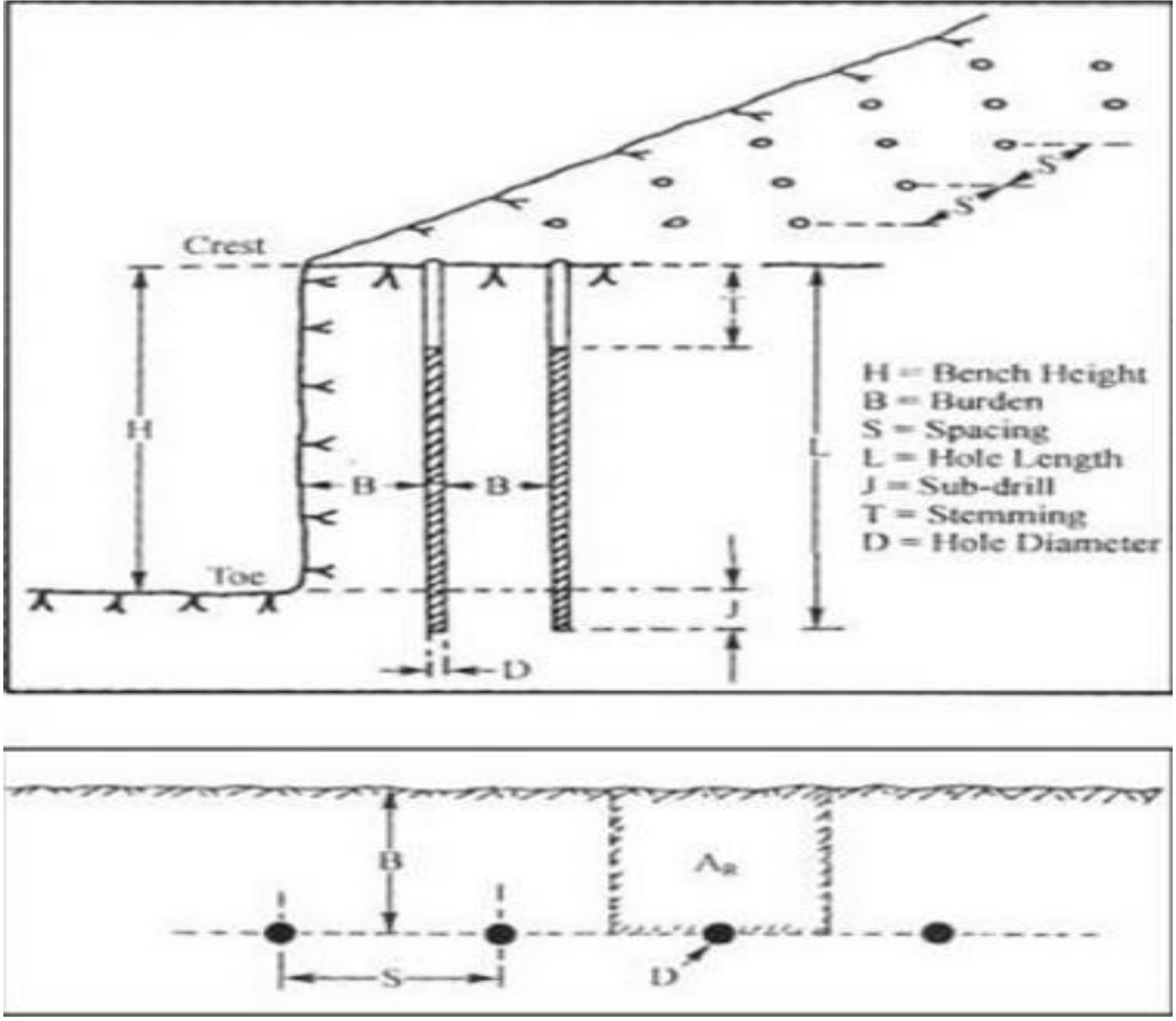


Figure 1: Bench Blast Pattern in Open Pit (after Phifer and Hem, March 2012)

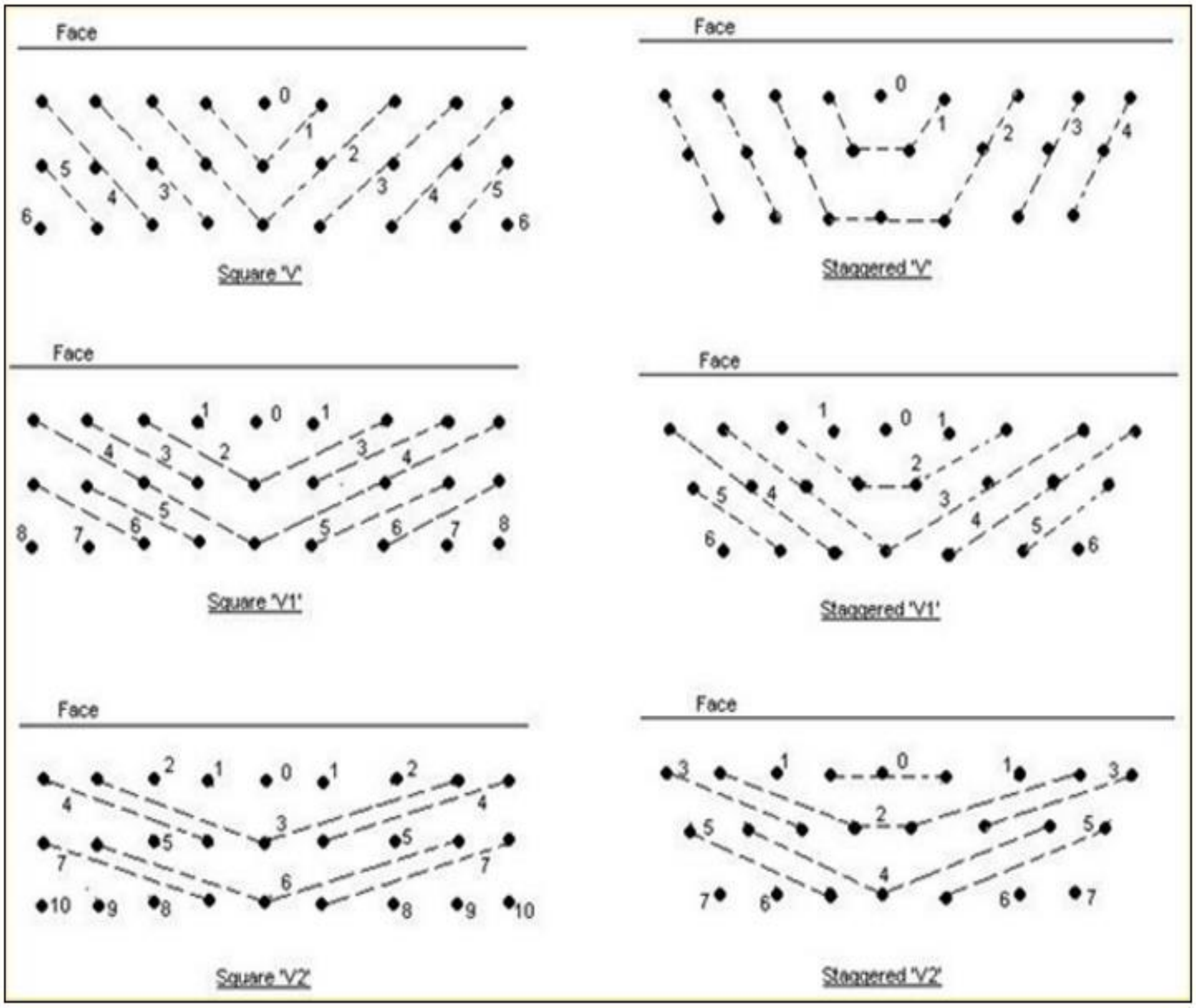


Figure 2: Blastholes Design and Initiation patterns for shots fired to an open face (after Phifer and Hem,March 2012)

2.4 Definitions The definition of a few terminology associated are given below.

Airblast - The airborne shock wave generated by an explosion.

ANFO – A blasting agent composed primarily of ammonium nitrate and fuel oil.

Authorized Blasting Assistant – An individual who has been authorized by the certified blaster in-charge to work on a blasting operation after such blaster-in-charge has confirmed that the individual is either a certified blaster, or otherwise meets the following qualifications:

(1) Is at least eighteen years old;

(2) Has been properly trained in the performance of the tasks to be assigned; and
(3) Has been made aware of and understands the blasting hazards and risks.

Backbreak – Rock broken beyond the limits of the last row of holes in a blast, synonymous with overbreak.

Base Charge – The main explosive charge in the base of a detonator or a heavy charge at the base of a column of presplit powder.

Battered Production Holes – The row of production holes closest to presplit line, drilled at the same angle as the presplit holes.

Bench – A horizontal ledge from which holes are drilled downward into the material to be blasted.

Binary Explosive – A blasting explosive formed by the mixing of two phosphoric materials, for example, ammonium nitrate and nitromethane.

Blast Pattern – The plan view of the drill holes as laid out for blasting.

Blast Plan – A written procedure that details the methods and manner by which a Project blaster will comply with pertinent laws, rules, regulations, and contract documents. The plan shall include all information, as detailed in Section 2A, necessary to evaluate the effectiveness and safety of the proposed blasting operations.

Blaster-in-Charge – The Project Blaster in charge of a specific blast. Responsibilities include delivery of explosives, storage, loading, and detonation of the blast. A project may have several Project Blasters, but only one blaster is in charge of each blast.

Blasting Agent – An explosive material, consisting of fuel and oxidizer that can't be detonated with only a No. 8 blasting cap.

Blast Area – An area near any blasting operation in which concussion, flying material or debris, or gases resulting from a detonation of explosives can reasonably be expected to cause injury or property damage.

Blasting Galvanometer – An electrical resistance instrument designed specifically for testing electrical continuity of electric detonators and circuits containing them. Other acceptable instruments for this purpose are Blasting Ohmmeters and Blaster's Multimeters.

Blasting Mat – A Mat of woven steel wire, scrap tires, or other suitable material to cover blastholes for the purpose of preventing flyrock.

Blasting Site – The specific place defined by the Blaster-in-Charge where explosives are used in blasting operations. A blast site is part of the blast area.

Blasting Superintendent – The Contractor may use a Blasting Superintendent to provide general oversight for drilling and blasting operations. However, the Blaster-in-Charge is responsible for each blast.

Blasting Vibrations – The energy from a blast that manifests itself in the form of vibrations which are transmitted through the earth away from the immediate blast area.

Booster – An explosive charge, usually of high detonation velocity and detonation pressure, designed to be used in the explosive initiation sequence between an initiator or primer and the main charge.

Bulk Strength – The strength per unit volume of an explosive calculated from its weight strength and density. Burden – The distance from the borehole to the nearest free face or the distance between boreholes measured perpendicular to the spacing.

Certified Blaster – An individual who has been issued a "Blaster Certificate of Competence" by the NYSDOL for using explosives.

Collar – The mouth or opening of a borehole.

Column Charge – A long, continuous, unbroken column of explosives in a blasthole.

Continuity Check (Circuit) – A determination that an initiation system is continuous and contains no breaks or improper connections that could cause stoppage or failure of an ignition system. For an electric initiation system, the check is performed both visually and by using a blasting galvanometer or other device. For a non-electric initiation system, the check can only be done visually.

Loading (Decking) – A method of loading blastholes in which the explosive charges, called decks or deck charges, in the same hole are separated by stemming or an air cushion. The separate decks may or may not be fired on the same delay.

Deflagration – An explosive reaction such as a rapid combustion that moves through an explosive material at a velocity less than the speed of sound in the material.

Delay Blasting – The practice of initiating individual explosive decks, boreholes, or rows of boreholes at predetermined time intervals using delay detonators, or other delaying methods, as compared to instantaneous blasting where all holes are fired essentially at the same time.

Delay Detonator – An electric or nonelectric detonator used to introduce a predetermined lapse of time between the application of a firing signal and the detonation of a charge.

Departmental Engineering Geologist – An Engineering Geologist of the Geotechnical Engineering Bureau authorized by the Director of the Geotechnical Engineering Bureau to perform the duties required under the NYS DOT Standard Specifications.

Emulsion – An explosive material containing substantial amounts of oxidizer dissolved in water droplets, surrounded by an immiscible fuel; or droplets of an immiscible fuel surrounded by water containing substantial amounts of oxidizer.

Explosion – A chemical reaction involving an extremely rapid expansion of gases usually associated with the liberation of heat.

Explosive – Any chemical compound, mixture, or device, the primary or common purpose of which is to function by explosion.

Explosives License – Own & Possess – A license issued by NYS Department of Labor for the purpose of purchasing, owning, possessing, or transporting explosives.

Explosive Loading Factor – The amount of explosive used per unit volume of rock. Also called Powder Factor.

Explosive Materials – These include explosives, blasting agents, and detonators. The term includes, but is not limited to, dynamite and other high explosives; slurries, emulsions, and water gels; black powder and pellet powder; initiating explosives; detonators (blasting caps); and detonating cord.

Extra (Ammonia) Dynamite – A dynamite in which part of the nitroglycerin is replaced by ammonium nitrate in sufficient quantity to result in the same weight strength.

Extraneous Electricity – Electrical energy, other than actual firing current or the test current from a blasting galvanometer, that is present at a blast site and that could enter an electric blasting circuit. It includes stray current, static electricity, RF (electromagnetic) waves, and time varying electric and magnetic fields.

Flyrock – Rocks propelled from the blast area by the force of an explosion. Fragmentation – The breaking of a solid mass into pieces by blasting.

Free Face – A rock surface exposed to air or water which provides room for expansion upon fragmentation. Sometimes called open face.

Fuel – A substance which may react with oxygen to produce combustion.

Fumes – The gaseous products of an explosion. For the purpose of determining the fume classification of explosive material, only poisonous or toxic gases are considered.

Gelatin Dynamite – A type of highly water resistant dynamite characterized by its gelatinous or plastic consistency.

Geology – A description of the types and arrangement of rock in an area; the description usually includes the bedding dip and strike, the type and extent of pre-existing breaks in the rock, and the hardness and massiveness of the rock, as these affect blast design.

Loading Limits – The maximum quantity of explosives allowed per delay period as specified by the Standard Specifications.

Loading Pole – A nonmetallic pole used to assist in placing and compacting explosives charges in boreholes.

Low Explosives – Explosives which are characterized by deflagration or low rate of reaction and the development of low pressure.

Magazine – Any building, structure, or container approved for the storage of explosives materials.

Mass Explosion – An explosion which affects almost the entire load or quantity of explosives virtually instantaneously.

Maximum Particle Velocity (Peak Particle Velocity) – The maximum velocity at which the ground surface moves as a wave passes under it. The customary practice is to apply vibration limits to the peak particle velocity of the largest single component on the seismograph.

Misfire – A blast or specific borehole that failed to detonate as planned. Also the explosive materials that failed to detonate as planned.

Muckpile – The pile of broken material resulting from a blast.

Nitroglycerin – An explosive chemical compound used as a sensitizer in dynamite.

Nonelectric Detonator – A detonator that does not require the use of electric energy to function.

Nonsparking Metal – A metal that will not produce a spark when struck with other tools, rock, or hard surface.

Overbreak – See backbreak. Overburden – Material of any nature laying on top of the rock that is to be blasted.

Oxidizer – A substance, such as nitrate, that readily yields oxygen or other oxidizing substances to promote the combustion of organic matter or other fuel. Particle

Velocity - The velocity at which the ground surface moves as a wave passes under it.

PETN – An abbreviation for the name of the high explosive pentaerythritol tetranitrate. Placards – signs placed on vehicles transporting hazardous materials (including explosive materials) indicating the nature of the cargo.

Plosophoric Materials – Two or more unmixed, commercially manufactured, prepackaged chemical materials which are not classified as explosives but which, when mixed or combined, form a blasting explosive.

Powder Factor – The amount of explosive used per unit volume of rock. Also called Explosive Loading Factor.

Preblast Survey – A documentation of the preexisting condition of structures near an area where blasting is to be conducted.

Premature Firing – The detonation of an explosive charge before the intended time.
Prilled Ammonium Nitrate – Ammonium nitrate in a pelleted or prilled form.

Primer – An explosive charge used to initiate other explosives or blasting agents. The primer is initiated by a detonator or detonating cord to which is attached a detonator.

Production Blasting – A blasting method whose sole purpose is to fragment the rock.

Propagation – The detonation of an explosive charge by an impulse received from an adjacent or nearby explosive charge.

Project Blaster(s) – A certified blaster who has been approved to blast on State ROW (see Blaster-in-Charge).

Relief – The effective distance from a blast hole to the nearest free face (synonymous with burden).

Round – A group of boreholes fired or intended to be fired in a continuous sequence.

Scaled Distance – A factor relating expected vibration levels from various weight charges of explosive materials at various distances.

Secondary Blasting – Blasting to reduce the size of boulders resulting from a primary blast.

Seismograph – An instrument which records ground vibrations generated by blasting operations. Particle velocity displacement is generally measured and recorded in three mutually perpendicular directions.

Sensitivity – A physical characteristic of an explosive material classifying its ability to be initiated upon receiving an external impulse such as impact, shock, flame, friction, or other influence which can cause detonation.

Shaped Charges – An explosive with a shaped cavity specifically designed to produce a high velocity cutting or piercing jet of product reaction; usually lined with metal to create a jet of molten liner material. They are generally used to cut steel members during superstructure demolition.

Shock Tube – A small diameter plastic tube used for initiating detonators. It contains only a limited amount of reactive material so that the energy that is transmitted through the tube by means of a detonation wave is guided through and confined within the walls of the tube.

Short Delay Blasting – The practice of detonating blastholes in successive intervals where the time distance between any two successive detonations is measured in milliseconds.

Slurry – An explosive material containing substantial portion of a liquid, oxidizers, and fuel, plus a thickener.

Stemming – Inert material placed in a borehole on top of or between separate charges. Used for the purpose of confining explosive gases or to physically separate charges of explosive material in the same borehole.

Subdrilling – The practice of drilling boreholes below floor level or working elevation to insure breakage of rock to working elevation.

Sympathetic Detonation – The detonation of an explosive material as the result of receiving an impulse from another detonation through air, earth, or water. Synonymous with sympathetic propagation.

Tamping – The action of compacting the explosive charge or the stemming in a blasthole. Sometimes refers to the stemming material itself.

Warning Signal – An audible signal which is used for warning personnel in the vicinity of the blast area of the impending explosion.

Water Gel – An explosive material containing substantial portions of water, oxidizers, and fuel, plus a cross-linking agent.

Water Resistance – The ability of an explosive to withstand the desensitizing effect of water penetration.

Weight Strength – The energy of an explosive material per unit of weight.

2.5 Fly Rock

- Rock blasting is the process which consists of several operations such as drilling of blast holes, Charging of the blasting holes, connecting the holes by suitable blasting pattern and detonated by safety fuse or exploder.
- When explosives are detonated, some energy is released.
- Out of the energy, some is useful energy and rest is waste energy.

The useful energy capable of doing work and it can be calculated.

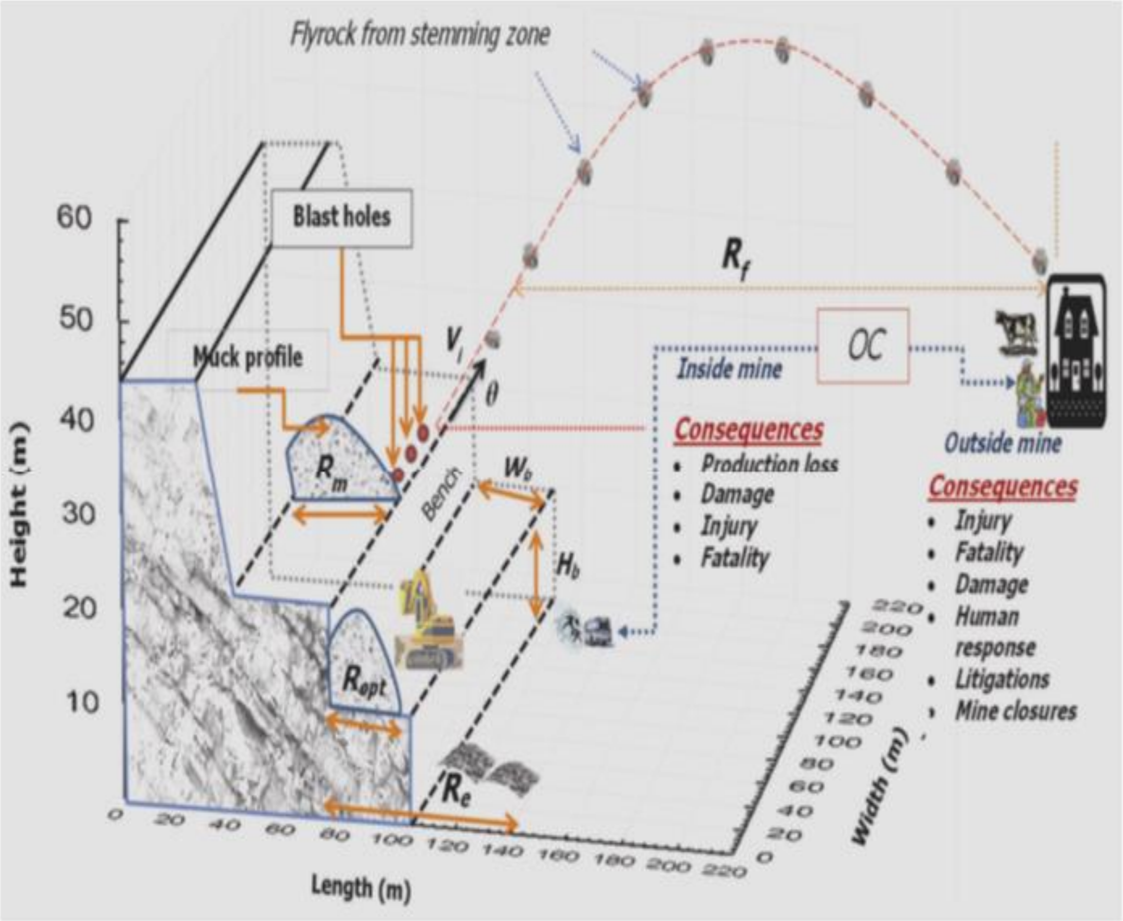


Figure 3: Description of throw, excessive throw and flyrock (after Raina, 2015)

Three common approaches which have been used to describe the work done in breaking down the material from one particle size to another using mechanical means.

- ✓ Rittinger (1967) suggested that energy was functions of area.
- ✓ Kick (1885) concluded that energy was functions of volume.
- ✓ Bond (1952) suggested that energy was function of both volume and area.

- ✓ Oka (1969) showed that all the three of these laws can be described by following formula

$$\mathbf{W = K_i (P^{-6/B} - F^{-6/B})} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where,
W = total energy (work) required for size reduction from feed size (F) to product size (P)
F = feed diameter
P = Product diameter
K_i = constant which is law dependent
B = infinite (kick's law)
B = 6 (Rittingers law),
B = 12 (Bond's law)

Fragmentation of rocks, the most fancied target of blasting, is connected with removals of the refuse that are termed as toss, unreasonable toss and flyrock separation (Figure). Flyrock is a rock piece moved from an impact face under the effect of explosive gasses that voyages past expected separations. Toss is the removal of divided rock amid blasting that spreads to an appropriate separation inside the seat width.
Appropriate toss is key for assistance of successful stacking of the refuse. Exorbitant toss is the undesired dislodging of the broken rock mass past the seat width or products of seat stature Excess toss influences the stacking proficiency of excavators and decreases efficiency of a mine

2.5.1 Semi-empirical Trajectory Physics-based Models

- The initial velocity (V) of flyrock is the center of such models. Thus such models are the most looked for after.
- One of the models by St. George and Gibson, and addressed by Little and Blair1 and later altered by Stojadinović et is given in taking after condition

$$V_0 = \frac{3p_e C_d^2 \Delta t}{32\emptyset p_r} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where,
p_e is the density of the explosive, (g/cm3),
C_d is the velocity of detonation , (m/s),
t is the length of impulse time,
p_r the density of rock (g/cm3) and Q is the diameter of the particle.

Seismic waves produced due to detonation that causes ground vibration. Vibration is shacking of ground caused by elastic wave emanating from a blast and consists of numerable Individual particle. These particles are either body wave or surface wave. Body wave when reflected and refracted from the surface, became surface waves. Ground motion consists of combination of these waves. These waves affect structure building on the surface. There are three factors which causes ground such as ground vibration amplitude, ground vibration duration, ground vibration frequency. Ground vibration is estimated for a specific location using the following equation such as:

$$\mathbf{PPV = \beta\ (SD)^{\alpha}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Where,
PPV = Peak Particle Velocity , (mm/s)
SD = Scaled Distance , (m/kg$^{1/2}$) and
α and β are site-specific constants based on the geology of the terrain

2.6 Explosive Energy

- The explosion energy Qv for an explosive is the energy released in a constant volume explosion.
- Reference is made to the chemical equilibrium of the decomposition products at the constant before and after the explosion.
- Water is in its gaseous phase.
- Assuming we are going to use ideal gas law p Δ v= ΔnRT

$$Q_{\mathrm{V}} = -\left[\sum_{i=1}^{k} n_i\left(\Delta H_f^{\circ}\right)_{\mathrm{i}} - \sum_{j=1}^{t} n_{\mathrm{j}}\left(\Delta H_f^{\circ}\right)_{\mathrm{j}} - \Delta nRT\right]$$

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Where,
n_i = no. of moles of the i th species of detonation products,
n_j = no. of moles of the j th explosive igredient,
ΔH_f = standard enthalpy of formation at 298.15K
T = temperature(298.15K)
R = gas constant(8.3143 J/mole)

2.7 Detonation Energy

- The detonation energy Qv is the heat of reaction where reference is made to the chemical equilibrium of the decomposition products.
- Water is in its gaseous phase

$$Q_{\text{d}}=-\left[\sum_{i=1}^{k} n_i\left(\Delta H_f^{\circ}\right)_{\text{i}}-\sum_{j=1}^{t} n_{\text{j}}\left(\Delta H_f^{\circ}\right)_{\text{j}}\right] \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

Where,

- n_i =no. of moles of the ith species of detonation products,
- n_j no. of moles of the jth explosive ingredient,
- $\Delta(H_d)$=used for the heat of detonation and is determined in a bomb calorimeter

2.8 Fragmentation Energy

A particular measure of energy is required to make another fracture surface]; let this energy, per unit surface, be G_F.
The fragmentation energy can accordingly be figured by

$$\mathbf{E_F = A_F G_F} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

Where,
A_F: New surface area generated.

G_F: The specific fracture energy. It can be ascertained from test fragmentation tests under a controlled energy contribution by method for mechanical comminution, prompting the Rittinger coefficient (a devastating effectiveness, the surface territory made per unit energy include), or got from material properties of the rock—the fracture durability and the elastic modulus. The first technique includes a large number of fractures in the rock, while the fracture sturdiness is gotten from tests in which one and only fracture is framed. For the estimation of the fragmentation effectiveness by blasting, where an extraordinary measure of fines is created, the backwards of the Rittinger coefficient is utilized here as the particular fracture energy. The devastating proficiency idea or more Eq accept that such productivity is steady for all section sizes.

Rittinger's law: The energy consumed in the size reduction of solids is proportional to the new surface area, produced.

So**, energy ∝ new surface area produced**

Or, energy = k* new surface area = k [final – initial surface area]

2.9 Seismic Energy

The energy exchanged to the rock as seismic wave is computed as the fundamental of the energy stream past a control surface at a given separation from the impact. The energy flux (the force or rate of work, per unit region) is the scalar result of the anxiety at the surface and the molecule speed.

A seismic source is a gadget that produces controlled seismic energy used to perform both reflection and refraction seismic studies. A seismic source can be straightforward, for example, explosive, or it can utilize more advanced innovation, for example, a particular compressed air firearm. Seismic sources can give single heartbeats or persistent scopes of energy, creating seismic waves, which go through a medium such as water or layers of rocks. A portion of the waves then reflect and refract and are recorded by beneficiaries, for example, geophones or hydrophones.

Seismic sources might be utilized to examine shallow subsoil structure, for designing site portrayal, or to ponder more profound structures, either in the quest for petroleum and mineral stores, or to outline flaws or for other exploratory examinations. The returning signs from the sources are recognized by seismic sensors (geophones or hydrophones) in known areas in respect to the position of the source. The recorded signs are then subjected to pro handling and elucidation to yield understandable data about the subsurface.

2.10 Kinetic Energy

The kinetic energy is figured from estimations of initial speed of the rock face at various statures along the highwall. Rapid film and radar estimations demonstrated that the face speed dispersions for some impacts were moderately slender, and the rocks behind the face for the most part move as one with the face (this conduct is average of equipped fragile rocks .Assuming that parallel varieties of speed are of second request to the vertical varieties, i.e., that the speed of the whole rock mass is steady in a level area of the weight, the kinetic energy E_K of the rock uprooted by a blasthole is figured.

Where a variable rock thickness has been considered, r(y), to represent lithology varieties along the tallness, accepting an on a level plane layered rock (this is utilized for El Alto, where, overburden and rock are separated), the seat stature, the dividing amongst holes and the mean, horizontal load, acquired from the face profile.

Energy happens in numerous structures, including chemical energy, warm energy, electromagnetic radiation, gravitational energy, electric energy, elastic energy, atomic energy, and rest energy. These can be sorted in two principle classes: potential energy and kinetic energy. Kinetic energy is the development energy of an object.

So, the kinetic energy (E_K) of the rock produced by a blasthole is :

$$E_K = \frac{1}{2} V_0^2 S B_h (\, p_1 h_1 + \ p_2 h_2)$$

…………………………………..…..(8)

$E_K = kinetic\ energy$
$v_0 = \ \ Average\ initial\ velocity\ , m/s$
$S = \ \ Spacing, m$
$B_h = Burden, m$

2.11 Ballistic Trajectories

For flyrock at an initial velocity V_0 and an initial angle θ, the horizontal range L is given by:

$$L = \frac{V_0^2 sin 2\theta}{g}$$

…………………………………..…..(9)

where g is acceleration of gravity . Maximum fly rock range Lm is obtained when θ = 45°,
or

$$L_m = \frac{V_0^2}{g}$$

…………………………………..…..(10)

If the flyrock originates at an elevation of h above ground level, then maximum range L' for return m of the projectile to ground level is given by:

$$L'_m = \frac{L_m}{2}\left(\sqrt{1 + \frac{4h}{L_m}} + 1\right)$$

…………………………………..…..(11)

Other equations which will be useful in the interpretation of some of the data are:

$$t_m = \frac{v_0 sin^2\theta}{g}$$

…………………………………..…..(12)

where t_m is the time for the projectile to reach its maximum elevation h , and

$$h_m = \frac{v_0^2 sin^2\theta}{2g}$$

…………………………………..…..(13)

Some theories to find out the initial velocity of rock after blasting

2.12 Initial Flyrock Velocities from Vertical Faces

The Gurney recipe effectively predicts initial speeds of metal plates and metal fragments pushed by explosives. Thus, it is coherent to endeavour to adjust the Gurney way to deal with the determination of initial speeds of rocks impelled by explosives, or all the more particularly, to flyrock speeds got in seat blasting.

The general type of the Gurney condition is

$$v_{0=}\sqrt{2E}f(c/m)$$

…………………………………..…..(14)

where $\sqrt{2E}$, the Gurney constant, is characteristic of explosive used;

c and m separately are the masses (all out, or per unit length, or per unit region) of explosive and material that is pushed; the type of the capacity *f* relies on upon the geometry of the framework . It will be demonstrated later that initial flyrock velocity corresponds much better with c/m than with more recognizable terms, for example, powder elements.

The rock breakout delivered by the detonation of one borehole of an ordinary seat impact, with explosive section length , stemming lengths, and weight to-the free face b. Shot conditions are thought to be such that breakout happens just at the "vertical" free face in the area of length . We admire the circumstance by considering that the homogeneous rock encompassing the borehole goes about as an "inflexible divider 11 in all headings with the exception of that of breakout to the free face. This breakout per borehole has the state of a crystal. Likewise indicated is the aggregate volume of the rock broken (parallelopiped) that is ordinarily utilized as a part of registering powder components. It was accepted that the breakout edge is 90°, therefore the breakout width at the free face is 2b . On the off chance that this edge is an as opposed to 90°, the breakout width at the free face is 2btan(α/2).. At that point, per unit length of stacked borehole:

$$c/m = \frac{w/l}{p_m b^2 \tan(\alpha/2)}$$
……………………………..…..(15)

Where,
w/l = the explosive weight per unit length of borehole, and

p_m = the density of the rock

α = close to 90°

For fly rock from the vertical face (see figure) and for the geometry of the system considered,

$$v_{0=}\sqrt{2E'}\sqrt{c/m}$$
……………………………..…..(16)

where $\sqrt{2E'}$ is less than $\sqrt{2E}$ (not much difference) because direction of the detonation is tangential to rock and not head-on

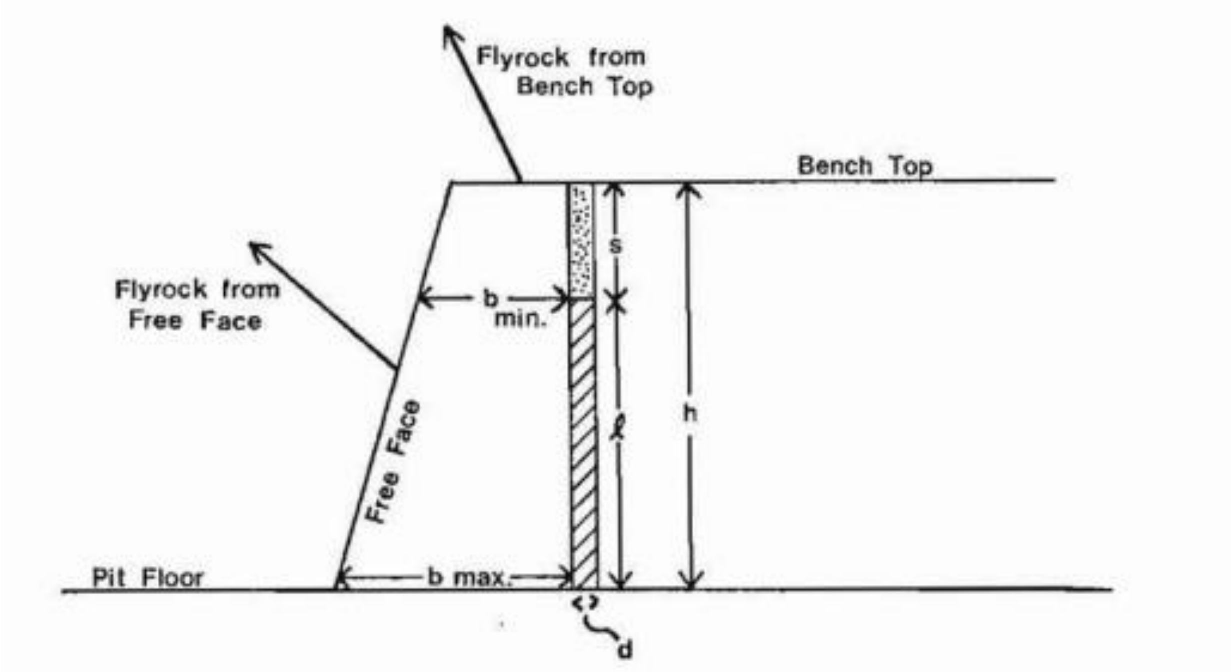


Figure 4: Plan view of a bench blast (after Roth, 1979)

$\sqrt{2E'} = D/3$ here D is detonation velocity of the explosive.

However, for ANFO, which is the explosive used in most of the surface mine blasts,

$$\sqrt{2E'} = 0.44D$$

……………………………..…..(17)

In this cases we will use

for most of the other shots.

$$v_{0=}\frac{D}{3}\sqrt{c/m}$$

For ANFO shots

$$v_{0=}0.44\sqrt{c/m}$$

……………………………..…..(18)

the above refers to the shots in single borehole.

2.13 WipFrag Software:

Speedy and precise estimations of size dissemination are vital to overseeing divided rock and different materials. WipFrag is a robotized picture based granulometry framework that utilizations computerized picture investigation of rock photos and video tape pictures to decide grain size dispersions.

WipFrag pictures can be digitized from altered camcorders in the field, or utilizing wandering camcorders. Photographic pictures can be digitized from slides, prints or negatives, utilizing a desktop duplicate stand. Computerized pictures in an assortment of configurations, conveyed on circle or over electronic systems, can be utilized. WipFrag utilizes intense picture investigation systems to separate the individual part limits. Edge location is advanced by setting Edge Detection Variables (EDV). Manual altering can be utilized to enhance the constancy of edge recognition. WipFrag has the offices for zoom-blend investigation, where the consolidated examination of pictures taken at various sizes of perception can be utilized to defeat the size confinements natural with a solitary picture. On the other hand, an exact adjustment mode is accessible.

Impact models, equations, expected results, we as a whole realize that this way to deal with anticipating impact results is futile without the device to evaluate what truly matters; fragmentation .this fragmentation examination advancements establish somewhere down in the explosives business, it comprehends the strides required to enhance impact fragmentation, and the limitless number of variables which influence the outcomes.

WipWare innovation engages us with the instruments we have to gather verifiable information, build up a measurable gauge and track unpretentious changes all through the advancement procedure so we can settle on choices in view of reality, rather than hypothesis.

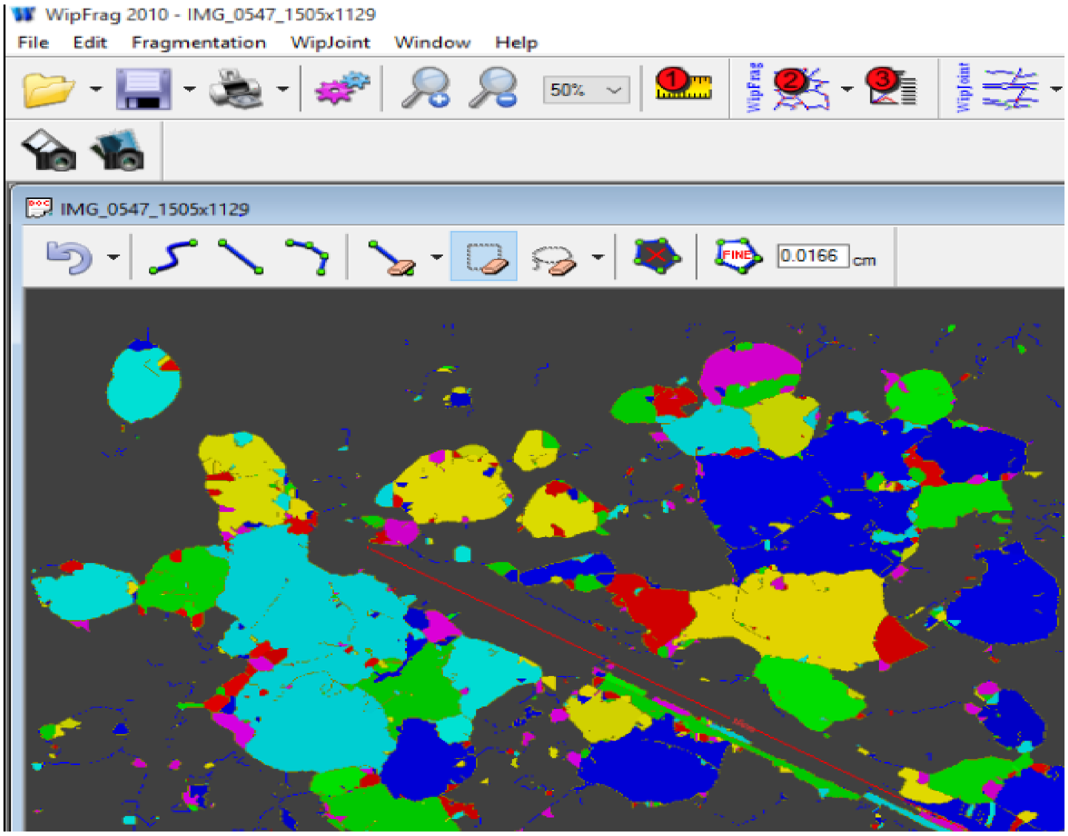


Figure 5: WipFrag Software

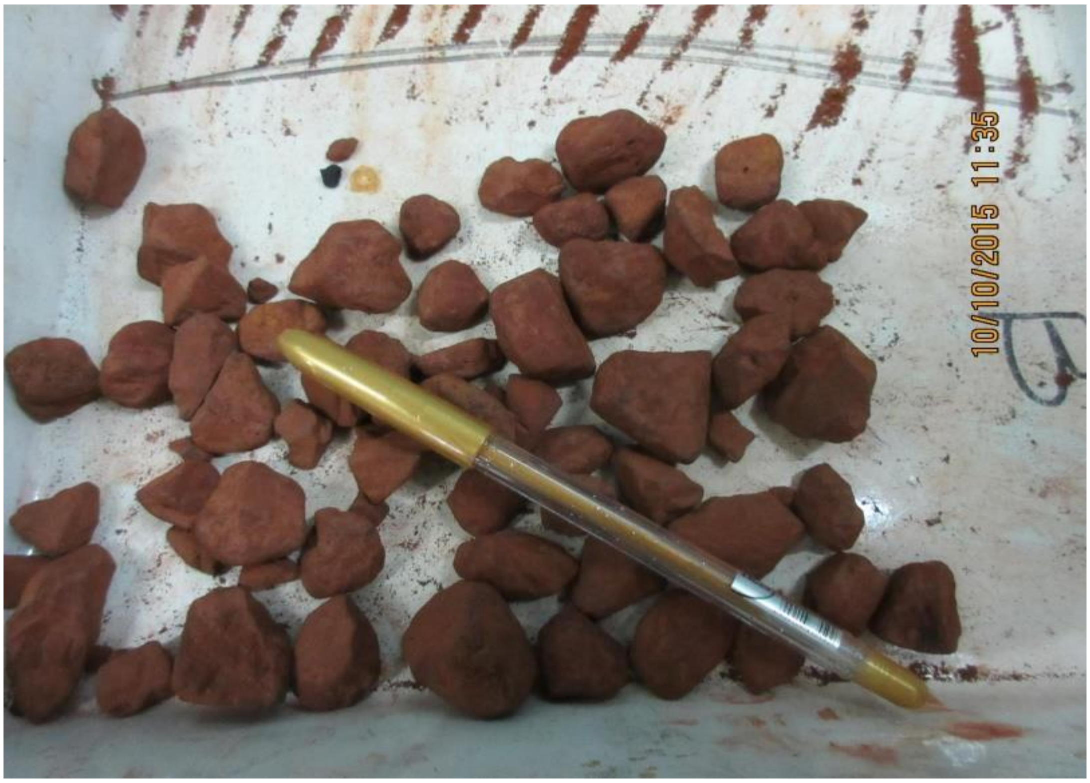
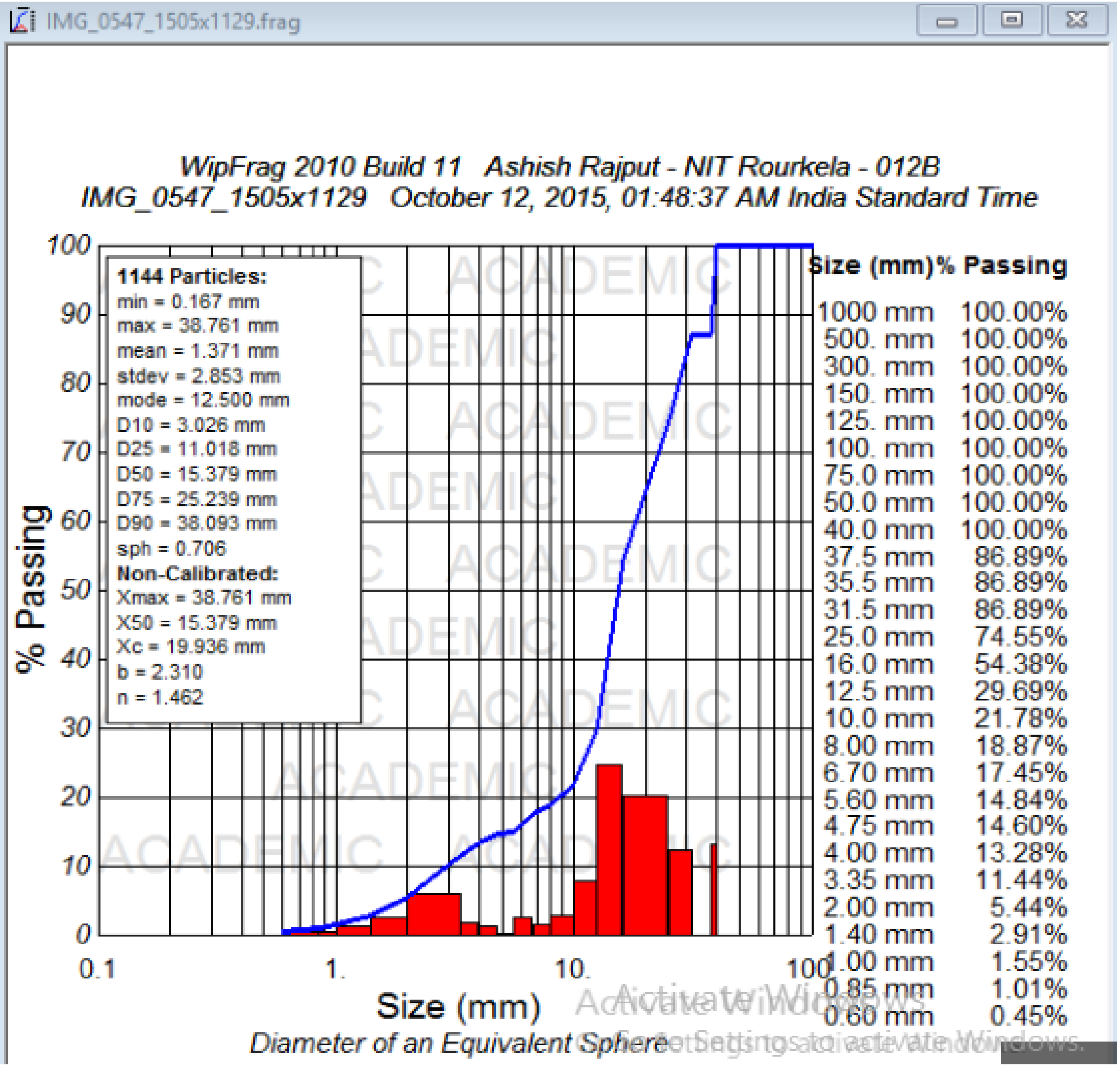


Figure 6: Sample for Analysis



WipFrag 2010 Build 11 Ashish Rajput - NIT Rourkela - 012B
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```
1144 Particles:
min = 0.167 mm
max = 38.761 mm
mean = 1.371 mm
stdev = 2.853 mm
mode = 12.500 mm
D10 = 3.026 mm
D25 = 11.018 mm
D50 = 15.379 mm
D75 = 25.239 mm
D90 = 38.093 mm
sph = 0.706
Non-Calibrated:
Xmax = 38.761 mm
X50 = 15.379 mm
Xc = 19.936 mm
b = 2.310
n = 1.462
```

Size (mm)	% Passing
1000 mm	100.00%
500. mm	100.00%
300. mm	100.00%
150. mm	100.00%
125. mm	100.00%
100. mm	100.00%
75.0 mm	100.00%
50.0 mm	100.00%
40.0 mm	100.00%
37.5 mm	86.89%
35.5 mm	86.89%
31.5 mm	86.89%
25.0 mm	74.55%
16.0 mm	54.38%
12.5 mm	29.69%
10.0 mm	21.78%
8.00 mm	18.87%
6.70 mm	17.45%
5.60 mm	14.84%
4.75 mm	14.60%
4.00 mm	13.28%
3.35 mm	11.44%
2.00 mm	5.44%
1.40 mm	2.91%
1.00 mm	1.55%
0.85 mm	1.01%
0.60 mm	0.45%

Figure 7: Equivalent Diameter of Particle Size

Fragmentation investigation has been demonstrated valuable in the mining, ranger service and total commercial ventures by cutting energy costs, enhancing effectiveness and minimizing gear upkeep costs.

WipFrag now incorporates WipJoint, beforehand a stand-alone programming arrangement, to portray and record jointing designs on in-situ rock surfaces. This straightforward and simple to utilize programming instrument permits clients to survey the comminution component, which is the mean piece size taking into account jointing before the impact isolated by the mean square size measured after the impact. This component can be utilized to anticipate fragmentation in light of jointing information for future shots and impact models can be "tweaked" and acclimated to deliver more precise results.

How It Works?

Load picture tests containing a scale reference into either WipFrag or WipJoint. Restrictive edge location is utilized to render a polygon system around every molecule to in a split second produce material particulars, for example, size conveyance, consistency, shape and different measurements.

Benefits include:

Non-Contact
Non-Disruptive
Detect Irregularities
Establish Quality Control
Characterize Geology
High Accuracy
Instant Results
Improve Safety
Improve Fragmentation
Objective Quantification
Increase Throughput
Reduce Maintenance
Reduce Re-Handling
Reduce Dilution
Reduce Waste

Chapter 3

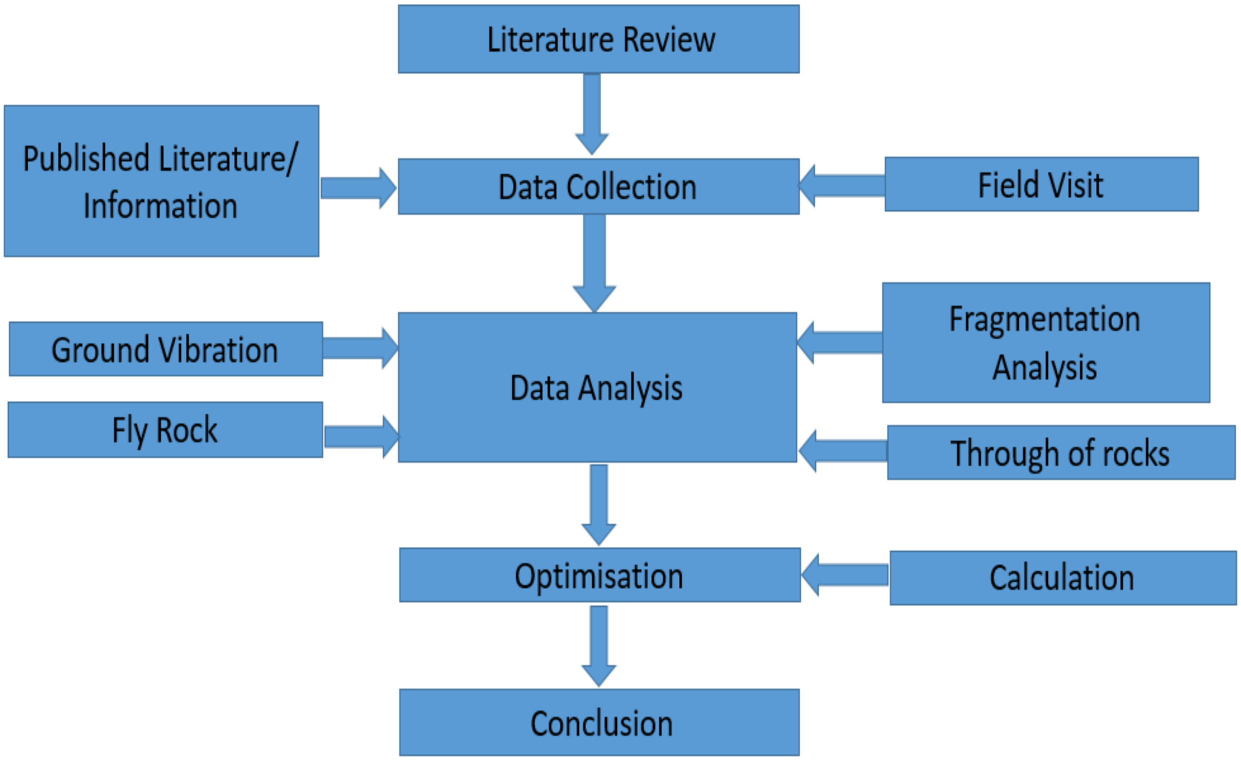
Methodology and Data Collection

The aim and objectives are proposed to be achieved through well determined steps

The methodology involves the following:

- Critical review of literature to understand blasting , fragmentation, shock wave ,through of rock and its effect.
- Visit of mines to observe the actual phenomena and collection of the data.
- Field experimentation tor measuring ground vibration and through of rock .
- Laboratory Experiment of blasted rock and collection of data.
- Fragmentation analysis using “ Wipfrag Software”.

The work plan has been divided as per flowchart given below:



Various types of data collected from iron ore mine with accuracy and precision. I visited the iron ore mine for some data collection and for some data laboratory experiment has been carried out. Some of the data already known from published literature or information. Instantel Minimate Blastware also used for frequency and amplitude measurement at the time of blasting. WipFrag Software also used for rock sieving or size distribution of rock.

Chapter 4

Result and Discussion

4.1 Explosive Energy

In this project , two types of explosives are used as

1. Aquadyne – Base charge
   Density = 1.2 g/cc
   Specific Energy =3.809 MJ/Kg

2. Emergel – Prime Charge
   Density = 1.12-1.22 g/cc
   Specific Energy = 3.34 MJ/kg

As seen in the table that total charge used for blasting side in this process
= 708.9 kg

But the ratio in which base and prime charges used is **20 : 80**

That means base charge is 20 % of total charge

And prime charge is 80% of total explosive used

Table 1: Drilling and Blasting Data

Toal Depth of hole (m)	**Burden (m)**	**Spacing (m)**	**Total charge (kg)**	**Stemming (m)**	**Volume (m^3)**	**No of holes**	**Specific charge (Kg/m^3)**	**Tonne**	**Specific Charge Kg/Tonne**
169	3	3.5	708.9	0.62-1.71	1774.5	24	0.395	7098	0.099

Total no. of holes = 24
Total charge = 708.9 kg
Therefore, charge per hole = $\frac{708.9}{24}$ = 29.53 kg
Base charge = 0.2 × 29.53
= 5.9 kg

Prime charge = 0.8 × 29.53

= 23.63 kg

Each catridge has weight = 2.78 kg
So, 3 catridges of base charge and 8 catridges of prime charge uses for each blast hole
or

Amount of Aquadyne used for whole blasting =0.2*708.9=141.28 kg

Amount of Energel used for whole blasting =0.8*708.9=567.12 kg

Because $\frac{Aquadyne}{Emergel} = \frac{20}{80}$

Each cartridge has weight 2.78 kg

So total energy of explosive is equal to E_E

$$E_E = A_E \times SE_E$$

Where,
E_E= Explosive Energy
A_E= Amount of Explosive
SE_E=Specific Energy of Explosive

$$E_E = \text{Amount of Aquadyne} * \text{Specific energy of Aquadyne} + \text{Amount of Energel} * \text{Specific energy of Energel}$$

$$E_E = A_a SE_a + A_e SE_e$$

$A_a =$ Amount of Aquadyne
= 141.78 kg

SE_a= Specific energy of Aquadyne
= 3.809 MJ/kg

A_e= Amount of Energel
= 567.12 kg

SE_e= Specific energy of Energel
= 3.34 MJ/kg

$$E_E = 141.78 * 3.809 + 567.12 * 3.34$$

$$E_E = 2434.2\ MJ$$

E_E=2434.2 MJ
or 2.43 GJ

4.1.1 Result:

The explosive energy that should be transferred to the rock after rock blasting is 2.434 GJ

4.2 Fragmentation energy

A specific amount of energy is required to create a new fracture surface let this energy, per unit surface, be GF.

The fragmentation energy can thus be calculated by

$$\mathbf{E_F = A_F G_F}$$

where ,
A_F: new surface area generated due to blasting

G_F:The specific fracture energy.

4.2.1 Calculation for Specific Energy (G_F)

Specific Energy can be calculated by “Rittinger’s Coefficient($K_{R)}$”

Rittinger’s Coefficient = K_R

, energy = k * new surface area = k [final – initial surface area]

=k (final no. of Particles*Surface Area of Each Final Particles -
Initial no. of Partciles* Surface Area of Each Initial Particles)

$$\frac{P}{m} = k(\frac{1}{d_f} - \frac{1}{d_i})$$

……………………………………………… **(19)**

Where,
P = Power,Watts(W)
M = Feed Rate,kg/s
K = Rittinger's Coefficient
d_f = Avg. Size of Final Particle
d_i = Avg. Size of Initial Particle

So basic formula used for calculation of G_F

$$\frac{energy/time}{feed\ rate} = k(\text{final surface area} - \text{ initial surface area})$$

……………………………………………… **(20)**

$$\frac{power}{feed\ rate} = k(\text{final surface area} - \text{ initial surface area})$$

$$\frac{energy/time}{feed\ rate} = k(A_f - A_i)$$

$$\frac{power}{feed\ rate} = k(A_f - A_i)$$

……………………………………………… **(21)**

Here,
Power,P= 9.9 MND
Feed rate= materials supplied to the mill per unit time
A_f= final surface area
A_i= initial surface area
K=Specific Energy
Or G_F=k

$$\frac{power}{feed\ rate} = G_F(\text{final surface area} - \text{ initial surface area})$$

4.2.2 Laboratory Experiment

Power Calculation:
P=9.9 MND Watt
M=total mass (rod + feed material),kg
N=frequency, Hz
D= diameter of the Mill, m

Rod Mill Reading :

Feed =.896 kg
RPM=35
Frequency, N=35/60=0.5833 Hz
Total no of rods used=7
Weight of each rod=1.33 kg
Therefore, total weight of rods=9.31 kg

Diameter of the Mill,D=38 cm
Total time for crushing = 12 minutes = 720 second
Therefore, M=weight of rods and weight of feed material
= 9,31+0.896=10.206 kg
N = 0.5833 Hz
D = .38 m
Therefore,

Power , P =9.9×10.2×.5833×.38
P = 22.4 W

4.2.2.1 Average Final size of the material after crushing:

Average size of fine size particles after crushing

Table 2: Average size of fine size particles after crushing

BSS Mesh no.	Nominal Aperature µm	Average size,d µm	Feed Remains f,kg	f/d Ratio of order 10^{-5}
25	600	-	-	-
36	425	512.5	.020	3.90
52	300	362.5	.024	6.62
60	250	275.0	.025	9.09
72	212	231.0	.030	12.98
100	150	181.0	.055	30.30
300	53	101.5	.090	88.67
Pan	0	28.5	0	0
			$W_1=\sum f=0.244$	$\sum f/d = 151.56 \times 10^{-5}$

Figure 8: Fine Material after crushing (Sample)

Average Size = $\frac{\sum F}{\sum F/D} = \frac{0.244}{151.56\times10^{-5}}$ µm

S_1 = 160.99 µm = 0.161 m

Average size of coarser size particles after crushing
Total mass = 0.649 kg=W_2

Using “WipFrag Software”,the average size of coarser material
S_2 = 16.958 mm

Figure 9: Coarser particles after crushing

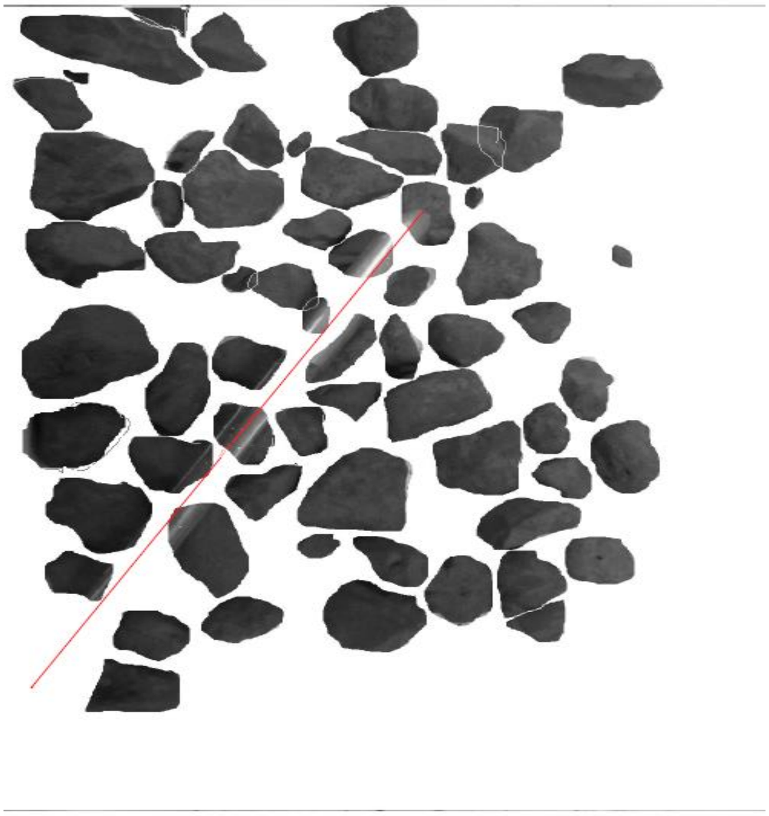


Figure 10: Coarser particles Net Generated by WipFra

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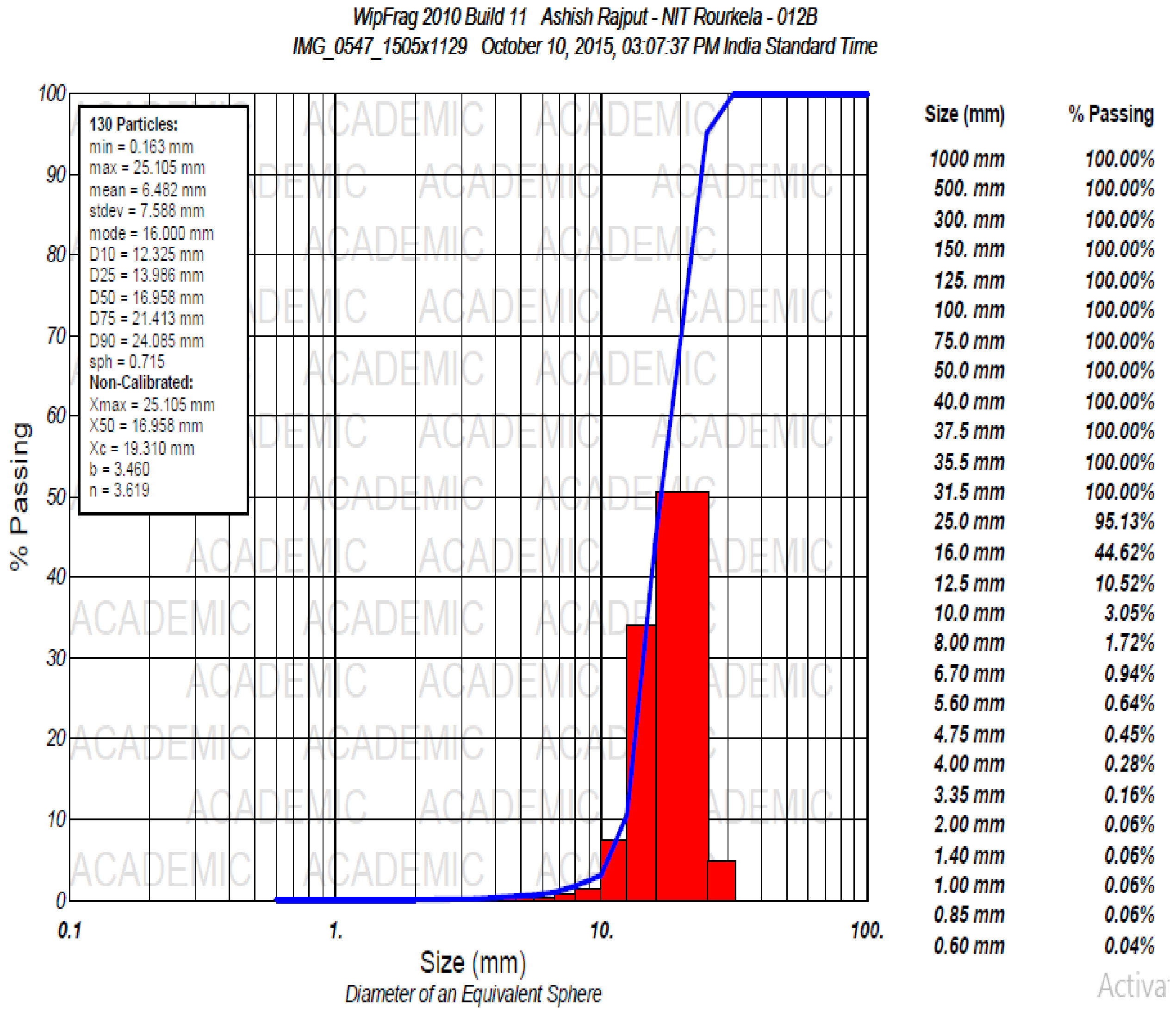


130 Particles:
min = 0.163 mm
max = 25.105 mm
mean = 6.482 mm
stdev = 7.588 mm
mode = 16.000 mm
D10 = 12.325 mm
D25 = 13.986 mm
D50 = 16.958 mm
D75 = 21.413 mm
D90 = 24.085 mm
sph = 0.715
Non-Calibrated:
Xmax = 25.105 mm
X50 = 16.958 mm
Xc = 19.310 mm
b = 3.460
n = 3.619

Size (mm)	% Passing
1000 mm	100.00%
500. mm	100.00%
300. mm	100.00%
150. mm	100.00%
125. mm	100.00%
100. mm	100.00%
75.0 mm	100.00%
50.0 mm	100.00%
40.0 mm	100.00%
37.5 mm	100.00%
35.5 mm	100.00%
31.5 mm	100.00%
25.0 mm	95.13%
16.0 mm	44.62%
12.5 mm	10.52%
10.0 mm	3.05%
8.00 mm	1.72%
6.70 mm	0.94%
5.60 mm	0.64%
4.75 mm	0.45%
4.00 mm	0.28%
3.35 mm	0.16%
2.00 mm	0.06%
1.40 mm	0.06%
1.00 mm	0.06%
0.85 mm	0.06%
0.60 mm	0.04%

Figure 11: Sieving of coarser particles by WipFarg

Average size of Sample = $\frac{W_1+W_2}{\frac{W_1}{S_1}+\frac{W_2}{S_2}}$

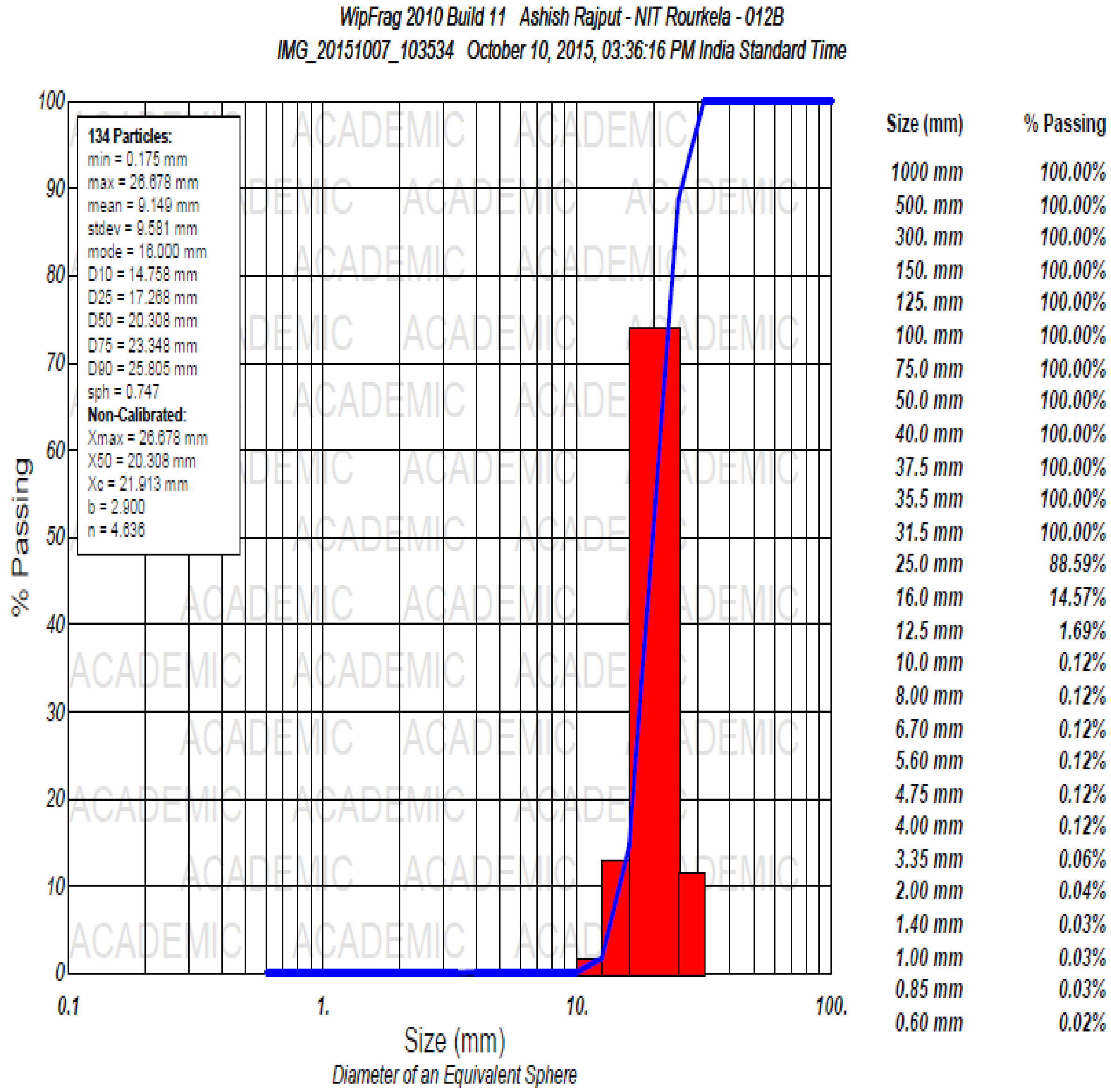
$$d_f = \frac{.244+.649}{\frac{,244}{.161}+\frac{.649}{,16.958}} = 0.576 \text{ mm}$$

Average Final size of the initial material(Sample) :

Using “WipFrag Software”,the average size of sample

Figure 12: Sample of Iron Ore

Figure 13: Generated Net of Simple by WipFrag



WipFrag 2010 Build 11 Ashish Rajput - NIT Rourkela - 012B
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134 Particles:
min = 0.175 mm
max = 26.678 mm
mean = 9.149 mm
stdev = 9.581 mm
mode = 16.000 mm
D10 = 14.758 mm
D25 = 17.268 mm
D50 = 20.308 mm
D75 = 23.348 mm
D90 = 25.805 mm
sph = 0.747
Non-Calibrated:
Xmax = 26.678 mm
X50 = 20.308 mm
Xc = 21.913 mm
b = 2.900
n = 4.636

Size (mm)	% Passing
1000 mm	100.00%
500. mm	100.00%
300. mm	100.00%
150. mm	100.00%
125. mm	100.00%
100. mm	100.00%
75.0 mm	100.00%
50.0 mm	100.00%
40.0 mm	100.00%
37.5 mm	100.00%
35.5 mm	100.00%
31.5 mm	100.00%
25.0 mm	88.59%
16.0 mm	14.57%
12.5 mm	1.69%
10.0 mm	0.12%
8.00 mm	0.12%
6.70 mm	0.12%
5.60 mm	0.12%
4.75 mm	0.12%
4.00 mm	0.12%
3.35 mm	0.06%
2.00 mm	0.04%
1.40 mm	0.03%
1.00 mm	0.03%
0.85 mm	0.03%
0.60 mm	0.02%

Figure 14: Sieving of Sample by WipFrag

D_i = 20.308 mm

From Equation

$$\frac{power}{feed\ rate} = G_F(\text{final surface area} - \text{ initial surface area})$$

$$G_F((\text{final no. of Particles} * \text{Surface Area of Each Final Particles} - \text{Initial no. of Partciles} * \text{ Surface Area of Each Initial Particles })= \frac{power}{feed\ rate}$$

……………………………….(22)

$$G_F\left[\left(\frac{\frac{m_1}{p_1}}{\frac{4}{3}\pi r_1^3} \times 4\pi r_1^2 + \frac{\frac{m_2}{p_2}}{\frac{4}{3}\pi r_2^3} \times 4\pi r_2^2\right) - \left(\frac{\frac{m_i}{p_1}}{\frac{4}{3}\pi r_i^3} \times 4\pi r_i^2\right)\right] = \frac{22.4}{\frac{1}{720}}$$

$$\frac{3G_F}{p}\left[\frac{m_1}{r_1} + \frac{m_1}{r_1} - \frac{m_i}{r_i}\right] = 16218 \text{ Ws}$$

$$= 16.128 \text{ KJ}$$

$$G_F = \frac{16.128 \text{ p}}{3\left[\frac{m_1}{r_1} + \frac{m_1}{r_1} - \frac{m_i}{r_i}\right]}$$

……………………………….(23)

Where,

m_1=0.244 kg m_2=0.652 kg m_i=0.889 kg

r_1=.08 mm r_1=8.479 mm r_i=10.154 mm

By putting the value of m_1 ,m_2, m_i, r_1, r_1, $r_1$and p in equation
Density of iron ore , p = 4 g/cc =4000 kg/m^3

$$G_F = \frac{16.128 \times 4000}{3\left[\frac{.244}{.08} + \frac{.652}{8.479} - \frac{.889}{10.154}\right]\frac{1}{10^{-3}}}$$

$$=7.168 \frac{KJ}{m^2}$$

4.2.3 Total Surface Area (SA) Created During Blasting:

4.2.3.1 WipFrag Software:

- Quick and precise estimations of size appropriation are vital to overseeing divided rock and different materials.
- WipFrag is a mechanized picture based granulometry framework that utilizations advanced picture investigation of rock photos and video tape pictures to decide grain size conveyances.
- Blast models, recipes, expected results, we as a whole realize that this way to deal with foreseeing impact results is pointless without the device to evaluate what truly matters; fragmentation .
- This fragmentation examination advancements establish somewhere down in the explosives business, it comprehends the strides required to enhance impact fragmentation, and the unbounded number of variables which influence the outcomes.

4.2.3.1.1 MODES OF ANALYSIS

- There are three techniques for investigation that can be utilized when utilizing WipFrag, contingent upon the relative exactness required, and the time and assets accessible. Since WipFrag utilizes geometric likelihood hypothesis to unfurl a 3-D conveyance (Maerz, 1996), there are here and there littler particles "missing" in individual pictures.

- These little fragments are not obvious either in light of the fact that they are too little to be in any way determined or are taken cover behind bigger particles (washed around downpour or dust control watering). Since the extent of these "missing fines" is profoundly variable and hard to anticipate, one of the accompanying arrangements is utilized.

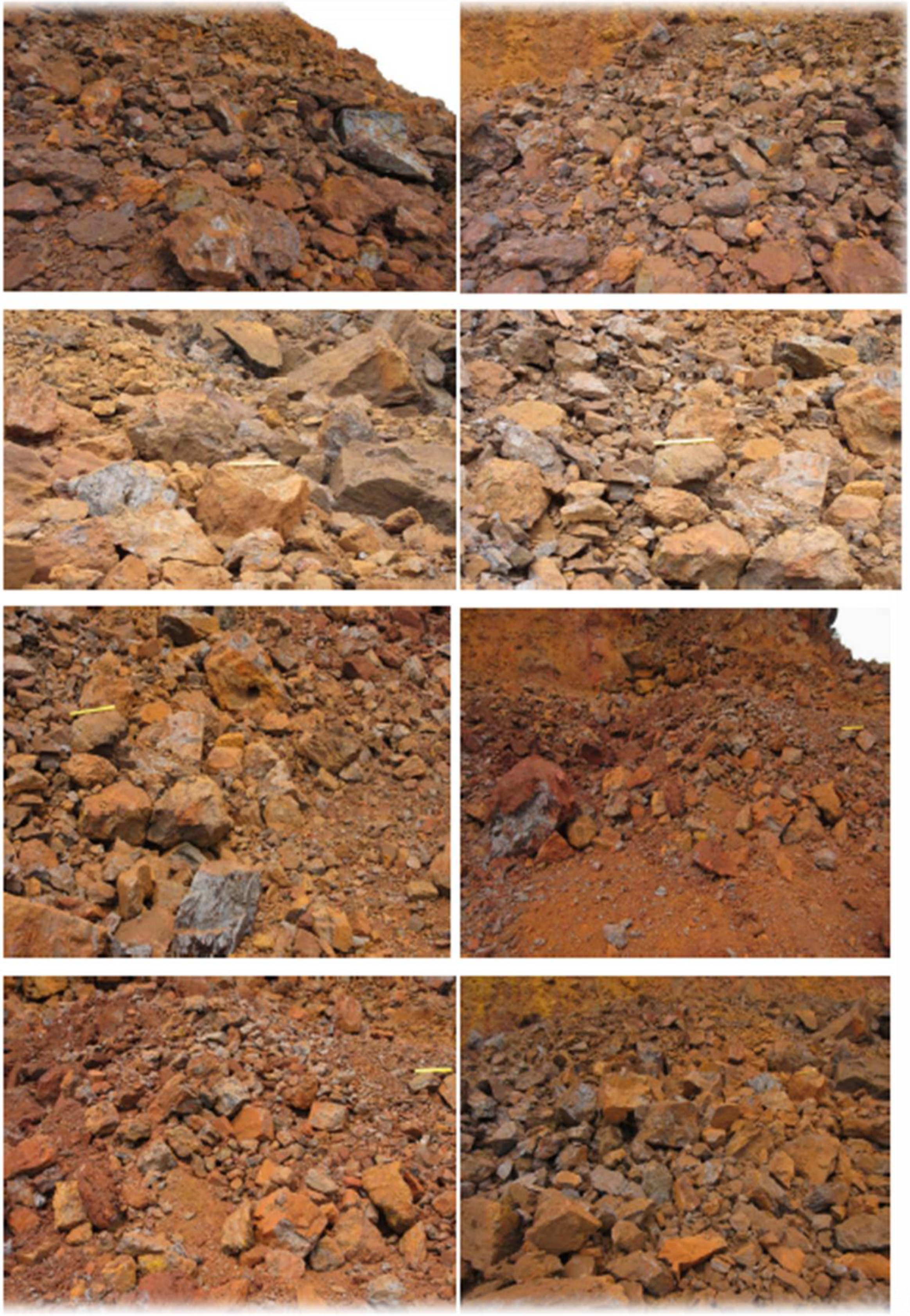
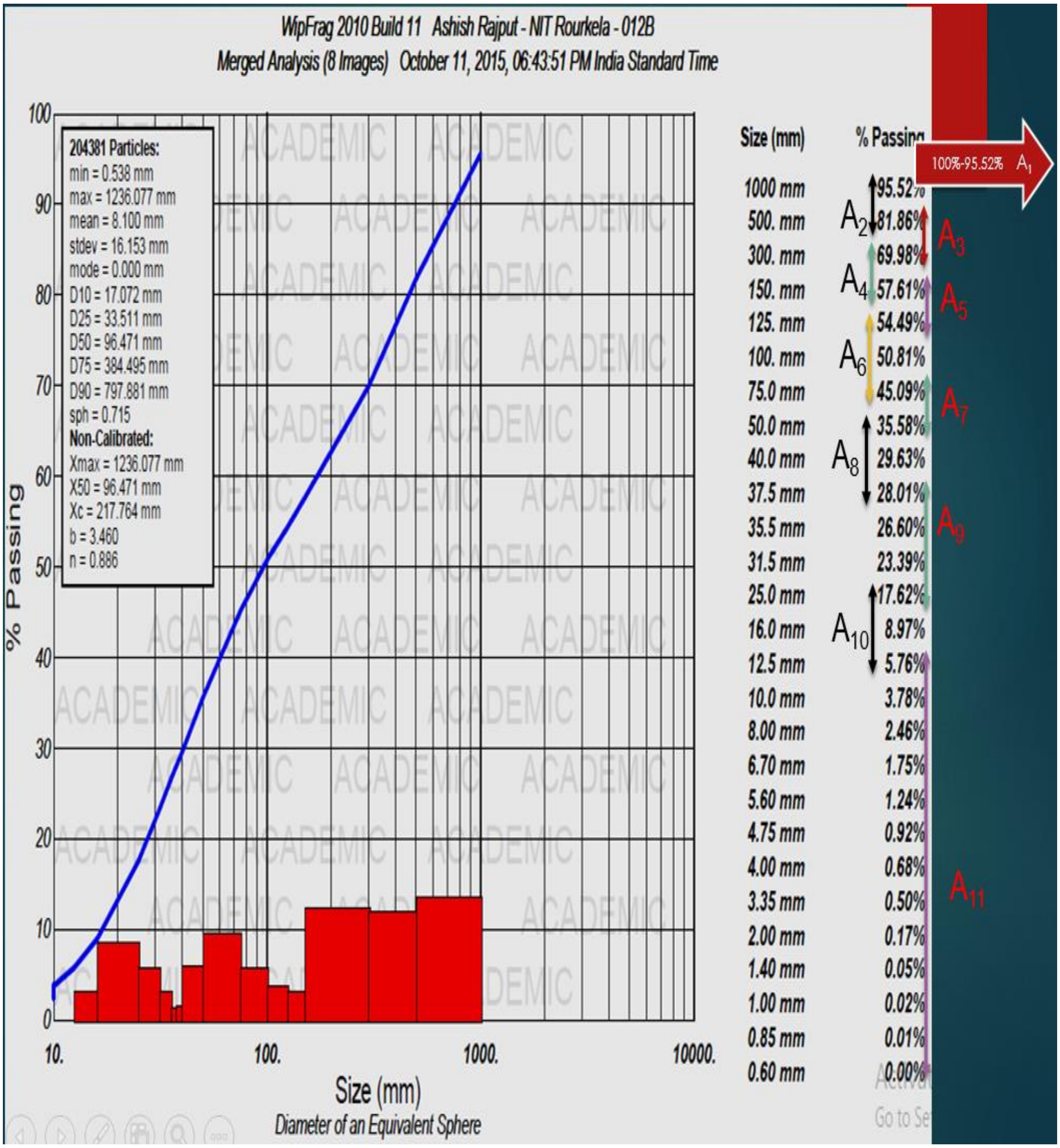


Figure 15: Images of blasted rock


WipFrag 2010 Build 11 Ashish Rajput - NIT Rourkela - 012B

Merged Analysis (8 Images) October 11, 2015, 06:43:51 PM India Standard Time

204381 Particles:
min = 0.538 mm
max = 1236.077 mm
mean = 8.100 mm
stdev = 16.153 mm
mode = 0.000 mm
D10 = 17.072 mm
D25 = 33.511 mm
D50 = 96.471 mm
D75 = 384.495 mm
D90 = 797.881 mm
sph = 0.715
Non-Calibrated:
Xmax = 1236.077 mm
X50 = 96.471 mm
Xc = 217.764 mm
b = 3.460
n = 0.886

Size (mm)	% Passing
1000 mm	95.52%
500. mm	81.86%
300. mm	69.98%
150. mm	57.61%
125. mm	54.49%
100. mm	50.81%
75.0 mm	45.09%
50.0 mm	35.58%
40.0 mm	29.63%
37.5 mm	28.01%
35.5 mm	26.60%
31.5 mm	23.39%
25.0 mm	17.62%
16.0 mm	8.97%
12.5 mm	5.76%
10.0 mm	3.78%
8.00 mm	2.46%
6.70 mm	1.75%
5.60 mm	1.24%
4.75 mm	0.92%
4.00 mm	0.68%
3.35 mm	0.50%
2.00 mm	0.17%
1.40 mm	0.05%
1.00 mm	0.02%
0.85 mm	0.01%
0.60 mm	0.00%

Figure 16: Sieving of blasted rock using “WipFrag”

Average size of blasting material = 96.471 mm

So ,total surface area created = $\sum_{i=1}^{n} A_i$ = SA

Here,

A_i = percentage of particle × Total particles × Avg surface area of particle
= particles total in a particular range × surface area

Therefore,

A_i= total no of particles in a particular range (N_{p^i})
×resultant surface area of a particle

$$A_i = N_{p^i} \times 4\pi r_{avg_i}^2$$

Or

$$A_i = N_{p^i} \times \pi d_{avg_i}^2$$

…………………………………(24)

$$\sum A_i = A_1 + A_2 + A_3 + A_4 + A_5 + A_6 + A_7 + A_8 + A_9 + A_{10} + A_{11}$$

…………………………………(25)

Results concluded from WipFrag Software after sieving:

Table 3: Respective surface area in the range (see fig)

Area	Range (particles %)
A_1	100-95.42
A_2	95.42-81.86
A_3	81.86-69.98
A_4	69.98-57.61
A_5	57.61-54.49
A_6	54.49-45 .09
A_7	45 .09-35.58
A_8	35.58-28.01
A_9	28.01-17.62
A_{10}	17.62-5.76
A_{11}	5.76-0

- A_1(100-95.42)

Maximum size=1236.077 mm
Minimum size=1000 mm

Average diameter of spherical rock, d_1 =1118.03 mm

Total no of particles , N = 20438
Total percentage in above range, N_1 =4.48%
No. of particles in this range, N_{p^1}= .048*N
= 9810

Therefore,

$$A_1 = N_{p^1} \times \pi d_1^2$$

$$A_1 = 9810 \times \pi\ 1.18^2$$

A_1=38521 m^2

- A_2(95.42-81.86)

Maximum size=1000 mm
Minimum size=500 mm

Average diameter of spherical rock, d_2 = 750 mm
Total no of particles , N = 20438
Total percentage in above range, N_2 = 13.66%
No. of particles in this range, N_{p^2}= .1366*204831
= 27918.44

Therefore,

$$A_2 = N_{p^2} \times \pi d_2^2$$

A_2 = 49335 m^2

- A_3(81.86-69.98)

Maximum size=500 mm
Minimum size=300 mm

Average diameter of spherical rock= 400 mm
Total no of particles , N = 20438
Total percentage in above range, N_3 =11.68 %

No. of particles in this range, N_{p^3}= 23924

Therefore,

$$A_3 = N_{p^3} \times \pi d_3^2$$

A_3 = 12025.5 m^2

- A_4(69.98-57.61)

Maximum size=300 mm
Minimum size=150 mm

Average diameter of spherical rock= 225 mm
Total no of particles , N = 20438
Total percentage in above range, N_4 =12.37 %
No. of particles in this range, N_{p^4}= 25338

Therefore,

$$A_4 = N_{p^4} \times \pi d_4^2$$

A_4= 4029.77 m^2

- A_5(57.61-54.49

Maximum size=150 mm
Minimum size= 125 mm

Average diameter of spherical rock= 137.5 mm
Total no of particles , N = 20438
Total percentage in above range, N_5 =3.12%
No. of particles in this range, N_{p^5}= 6390

Therefore,

$$A_5 = N_{p^5} \times \pi d_5^2$$

A_5= 379.58 m^2

- A_6(54.49-45 .09)

Maximum size=125 mm
Minimum size=75 mm

Average diameter of spherical rock= 100 mm
Total no of particles , N = 20438
Total percentage in above range, N_6 =9.4%
No. of particles in this range, N_{p^6}=19254

Therefore,

$$A_6 = N_{p^6} \times \pi d_6^2$$

A_6=6048.86 m^2

- A_7(45 .09-35.58)

Maximum size=75 mm
Minimum size=50 mm

Average diameter of spherical rock= 62.5 mm
Total no of particles , N = 20438
Total percentage in above range, N_7 =9.51%
No. of particles in this range, N_{p^7}= 19437
Therefore,

$$A_7 = N_{p^7} \times \pi d_7^2$$

A_7= 238.52 m^2

- A_8(35.58-28.01)

Maximum size= 50 mm
Minimum size= 37.5 mm

Average diameter of spherical rock= 43.75 mm
Total no of particles , N = 20438
Total percentage in above range, N_8 =17.57%
No. of particles in this range, N_{p^8}=15471
Therefore,

$$A_8 = N_{p^8} \times \pi d_8^2$$

A_8=93 m^2

- A_9(28.01-17.62)

Maximum size=37.5 mm
Minimum size=25 mm

Average diameter of spherical rock= 31.25 mm
Total no of particles , N = 20438
Total percentage in above range, N_9 =10.39%
No. of particles in this range, N_{p^9}= 21235
Therefore,

$$A_9 = N_{p^9} \times \pi d_9^2$$

$$A_9 = 65.14 \text{ m}^2$$

- A_{10}(17.62-5.76)

Maximum size=25 m
Minimum size=12.5 mm

Average diameter of spherical rock= 18.75 mm
Total no of particles , N = 20438
Total percentage in above range, N_{10} = 11.86%
No. of particles in this range, $N_{p^{10}}$= 24239.6
Therefore,

$$A_{10} = N_{p^{10}} \times \pi d_{10}^2$$

$$A_{10} = 26.77 \text{ m}^2$$

- A_{11}(5.76-0)

Maximum size=12.5 mm
Minimum size= 0

Average diameter of spherical rock=6.25 mm
Total no of particles , N = 20438
Total percentage in above range, N_{11} = 5.76%
No. of particles in this range, $N_{p^{11}}$= 11773
Therefore,

$$A_{11} = N_{p^{11}} \times \pi d_{11}^2$$

$$A_{11} = 1.44 \text{ m}^2$$

Total surface area created during blasting, A_T =

$$\sum A_i = A_1 + A_2 + A_3 + A_4 + A_5 + A_6 + A_7 + A_8 + A_9 + A_{10} + A_{11}$$

$$\sum A_T = \sum A_i = 38521 + 49335.2 + 12025.5 + 4029.77 + 379.88 + 6048.86 + 238.52 + 93 + 65.14 + 26.77 + 1.44 \ \ m^2$$

$$A_T = 110765.08\, m^2$$

$$A_T = 1.10765 \times 10^5 \quad m^2$$

4.2.4 Result:

Fragmentation Energy, E_F

$$\mathbf{E_F = A_T G_F}$$

$$E_F = 7.168 \times 1.10765 \times 10^5 \ kj$$

$$E_F = 7.96 \times 10^5 \ kj$$

Total fragmentation energy measured in this process is equal to 795.65 GJ

4.3 Seismic energy

The energy transferred to the rock in the form of seismic wave is calculated as the integral of the energy flow past a control surface at a given distance from the blast. The energy flux (the power or rate of work, per unit area) is the scalar product of the stress at the surface and the particle velocity.

Table 4: PPV for Energy Calculation

Radial Dist (m)	*Max. Charge/delay (kg)*	*Scaled distance ($m/\sqrt{kg}$)*	*Cub root of scaled distance ($m/\sqrt[3]{kg}$)*	*PPV (mm/s)*	*Air pressure levels (dB)*	*Frequency (Hz)*
70	25.02	13.994	23.958	7.94	142.0	10.0
310	25.02	61.975	106.104	3.76	108.8	3.50
270	25.02	53.978	92.413	3.89	110.6	2.25

Energy absorbed by the seismic effect of the explosion ,calculated by the following relation

$$\boldsymbol{E_S = 4\pi^3 R^2 \times p_r \times C_L \times a^2 \times f^2 \times t_v \times 10^{-6}\ MJ}$$

E_S=seismic energy , MJ

R= distance between the explosion point and reading point, m
=70 m

pr = rock density , kg/m3
=4.2 g/cc = 4200 kg/m3

C_L=Longitudinal wave velocity , m/s

$$C_L = \sqrt{\frac{\frac{4}{3}\mu + k}{p_r}}$$

…………………………………(26)

Where,

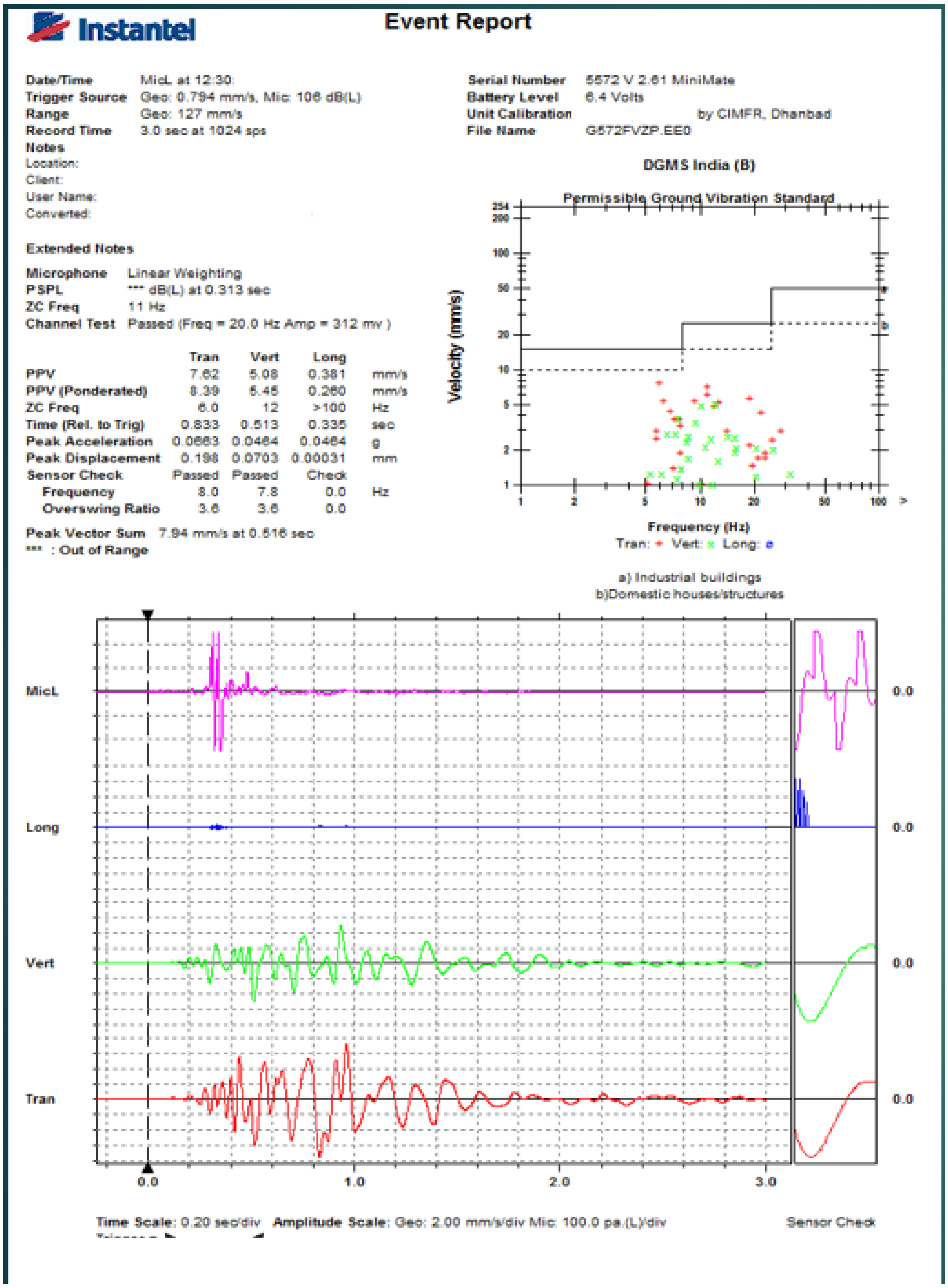
μ=shear modulus
k=bulk modulus
p_r= density of rock

for iron ore

μ =39-64 GPa
k=95-105 GPa
p_r =4200 kg / m3

Therefore,

$$C_L = \sqrt{\frac{\frac{4}{3}47 + 100}{4200} \times 10^9} = 6223\, m/s$$



Event Report

Date/Time MicL at 12:30:
Trigger Source Geo: 0.794 mm/s, Mic: 106 dB(L)
Range Geo: 127 mm/s
Record Time 3.0 sec at 1024 sps
Notes
Location:
Client:
User Name:
Converted:

Serial Number 5572 V 2.61 MiniMate
Battery Level 6.4 Volts
Unit Calibration by CIMFR, Dhanbad
File Name G572FVZP.EE0

Extended Notes

Microphone Linear Weighting
PSPL *** dB(L) at 0.313 sec
ZC Freq 11 Hz
Channel Test Passed (Freq = 20.0 Hz Amp = 312 mv)

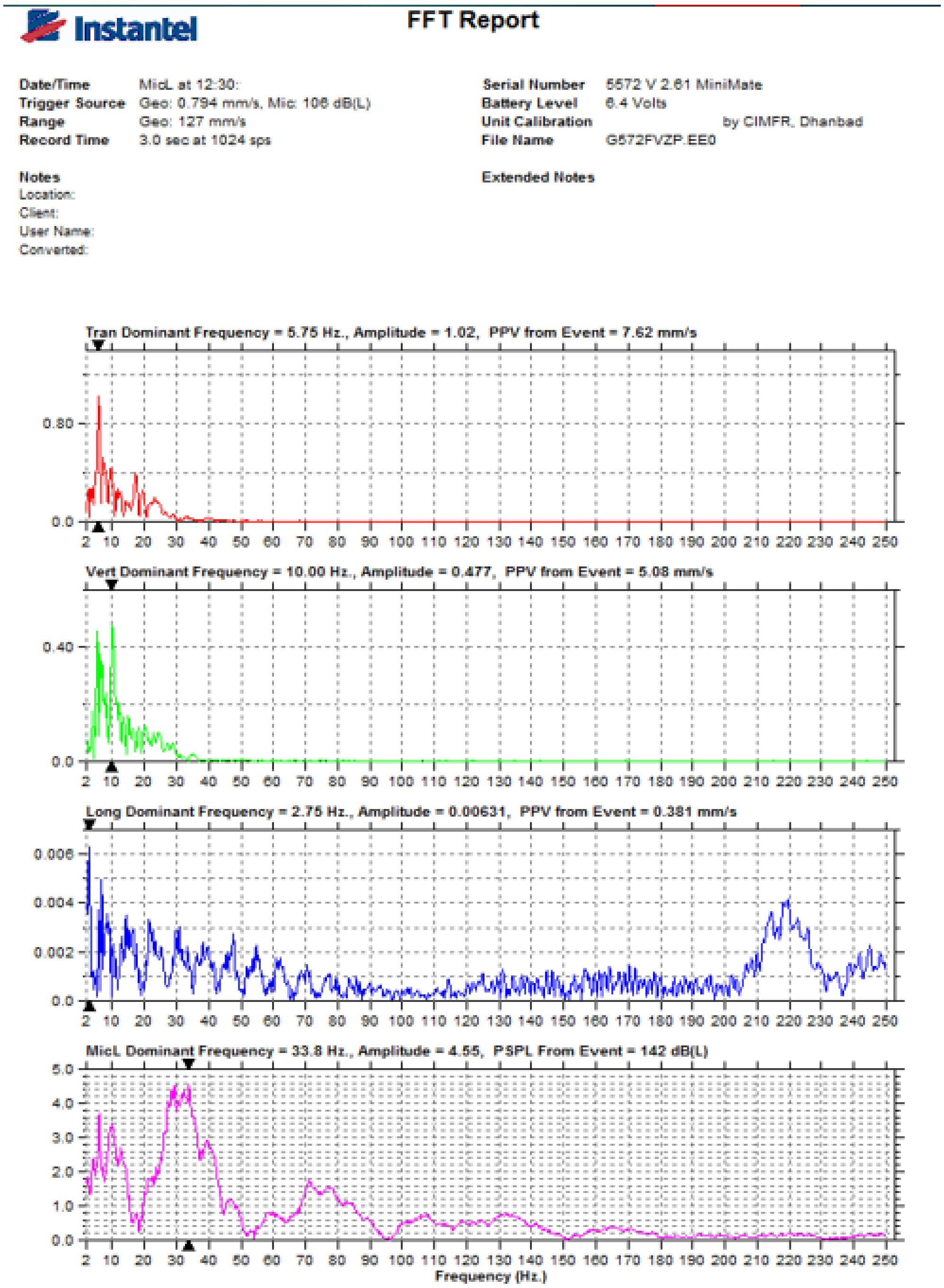
	Tran	Vert	Long	
PPV	7.62	5.08	0.381	mm/s
PPV (Ponderated)	8.39	5.45	0.260	mm/s
ZC Freq	6.0	12	>100	Hz
Time (Rel. to Trig)	0.833	0.513	0.335	sec
Peak Acceleration	0.0663	0.0464	0.0464	g
Peak Displacement	0.198	0.0703	0.00031	mm
Sensor Check	Passed	Passed	Check	
Frequency	8.0	7.8	0.0	Hz
Overswing Ratio	3.6	3.6	0.0	

Peak Vector Sum 7.94 mm/s at 0.516 sec
*** : Out of Range

Time Scale: 0.20 sec/div Amplitude Scale: Geo: 2.00 mm/s/div Mic: 100.0 pa.(L)/div

Sensor Check

Figure 17: Sensor check for Instantel instrument



Instantel FFT Report

Date/Time	MicL at 12:30:	**Serial Number**	5572 V 2.61 MiniMate
Trigger Source	Geo: 0.794 mm/s, Mic: 106 dB(L)	**Battery Level**	6.4 Volts
Range	Geo: 127 mm/s	**Unit Calibration**	by CIMFR, Dhanbad
Record Time	3.0 sec at 1024 sps	**File Name**	G572FVZP.EE0

Notes
Location:
Client:
User Name:
Converted:

Extended Notes

Tran Dominant Frequency = 5.75 Hz., Amplitude = 1.02, PPV from Event = 7.62 mm/s

Vert Dominant Frequency = 10.00 Hz., Amplitude = 0.477, PPV from Event = 5.08 mm/s

Long Dominant Frequency = 2.75 Hz., Amplitude = 0.00631, PPV from Event = 0.381 mm/s

MicL Dominant Frequency = 33.8 Hz., Amplitude = 4.55, PSPL From Event = 142 dB(L)

Figure 18: Easy-to-use Frequency (FFT) Analysis and reporting

4.3.1 Frequency Dominant

a =vibration amplitude, m
= 0.0703 mm

f = vibration frequency , s^{-1}
= 10 Hz

t_v = vibration time , s
= 0.2 sec/division

But there are 9 divisions

So, t_v= 9×0.2 = 1.8 sec

$$E_S = 4\pi^3 R^2 \times p^r \times a^2 \times f^2 \times t_v \times 10^{-6}\ MJ$$

$$E_S = 4\pi^3 70^2 \times 4200 \times 6223 \times (0.0703 \times 10^{-3})^2 \times 10^2 \times 1.8 \times 10^{-6}\ MJ$$

$$E_S = 14.14\ MJ$$

Seismic energy calculated for given case is 14.14 MJ. Which is 0.7% of the total explosive energy

4.3.2 Amplitude Dominant

R= distance between the explosion point and reading point, m
=70 m

p_r = rock density , kg/m3
=4.2 g/cc = 4200 kg/m3

C_L=Longitudinal wave velocity , m/s
= $6223\ m/s$

a=vibration amplitude, m
= 0.198 mm

f= vibration frequency , s-1
= 5.75 Hz
t_v = vibration time , s
= 0.2 sec/division

But there are 10 divisions

So, tv= 10×0.2 = 2 sec

$$E_S = 4\pi 3R2\times p\mathrm{r}\times a2\times f2\times t\mathrm{v}\times 10\text{-}6\quad MJ$$

$E_S = 4\pi 3702\times 4200 \times 6223 \times (0.198 \times 10^{-3})2\times 5.752\times 2 \times 10\text{-}6 \quad MJ$

$$E_S = 41.18\, MJ$$

4.3.3 Result

Seismic energy calculated for given case is 41.18 MJ. Which is 1.69% of the total explosive energy

4.4 Kinetic energy:

So,the kinetic energy (E_K) of the rock displaced by a blasthole in this case is :

$$E_K = \frac{1}{2} V_0^2 S B_h p H$$

$E_K = kinetic\ energy$
$v_0 = \quad Average\ initial\ velocity\ , m/s$
$S = \quad Spacing\ , m$
$B_h = Burden\ , m$
$p = density\ , kg/m^3$
$H \ = height\ , m$

Here,

$$v_{0=} \frac{D}{3} \sqrt{c/m} \quad \text{(Gurney equation)}$$

D = Detonation velocity of explosive
and

$$c/m = \frac{w/l}{p_m b^2 \tan(\alpha/2)}$$

Where,

w/l = is the explosive weight per unit length of borehole and

p_m = is the density of the rock

α = is indeed close to 90°

Table 5: Drilling and blasting data

Position of blasting patch at near RL	Toal Depth of hole (m)	Burden (m)	Spacing (m)	Total charge (kg)	Stemming (m)	Volume (m^3)	No of holes	Specific charge (Kg/m^3)	Tonne	Specific Charge Kg/Tonne
N 810 W	169	3	3.5	708.9	0.62-1.71	1774.5	24	0.395	7098	0.099

D = 4200 m/s
w/l = 4.195 kg/m
p_r=p_m=4000 kg/m3
B_h=3 m
α = 900
S= 3.5 m
H=7.041
N = no of boreholes
= 24
Therefore,

$$c/m = \frac{4.195}{4000 \times 3^2 \tan(90/2)}$$

$$c/m = \frac{4.195}{36000}$$

And

$$v_{0=}\frac{D}{3}\sqrt{c/m}$$

$$v_{0=}\frac{4200}{3}\sqrt{\frac{4.195}{3600}}$$

$v_{0=}$47.31 m/s

So, kinetic energy (E_k) is equal to

$$E_K = \frac{1}{2} V_0^2 S B_h p H$$

$$E_K = \frac{1}{2} 47.31^2 \times 3.5 \times 3 \times 4000 \times 7.041$$

$$E_K = 330.99\ MJ$$

$$E_K = 331\ MJ$$

4.4.1 Result

13.59% of total explosive energy is used for the rock displacement work

Chapter 5

Conclusion and Recommendation

The energetic examination gives a decent knowledge of the explosive/rock cooperation and a superior comprehension of the blasting procedure, enveloping an expansive scope of logically difficult subjects .For every energy segment, first of all some trials have been completed in research center and a few information gathered from Iron Ore Mine to discover some outcomes for various energy. WipFrag/Minimate programming and conditions like Gurney condition from writing helped me to do my venture work with proficiency.

The rock blasting prompts various effects on the earth. Opencast mining close to the neighborhoods has gotten to be unavoidable and in this manner ecological effects are required to be relieved. Ground vibrations and fly rock are the vital ecological effects as they may harm the properties and fly rock may bring about fatalities. The study examined in this paper demonstrates that these impacts can be minimized. A legitimate impact outline guarantees viable use of the energy of the explosives and is in this manner the response to the issue of alleviation of the natural effects.

1. Specific energy for rock, calculated by Rittinger's law with the help of experiment in laboratory is equal to 7.168 kJ/m^2.
2. New surface area generated due to rock blasting, calculated from sieving method by WipFrag Software, is equal to 1.11×10^5 m^2.
3. Explosives Aquadyne and Emergel were used in this process of rock blasting in the ratio 20:80.
4. Gurney equation used for measurement of average initial velocity of rock.
5. Fragmentation energy is 31.45%, seismic energy is 1.69%, kinetic energy 13.599% of total explosive energy. Total explosive energy measured is equal to 2.434 GJ

Recommendation

It is understood that without rock blasting mining processes are impossible. So, rock blasting played an important role for mining. A lot of researches have been carried out for the same but no one can determine the exact values of fragmentation/fracture energy, seismic energy, kinetic energy, explosive energy and heat energy. This project can be extended by proper instruments like high speed camera which helps our project to determine the true value of kinetic energy. Heat energies lost in process and energy loss due to loose confinement of explosive in blast hole may be taken up in future.

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