ANALYSIS OF POWDER FACTOR IN LIMESTONE MINE – A CASE STUDY

चूना पत्थर खदान में पाउडर कारक का विश्लेषण– एक अध्ययन

By

HEMANT SUKHWAL

THESIS

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IN
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UDAIPUR- 313001 (RAJASTHAN)

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CERTIFICATE-II

This is to certify that this thesis entitled **"Analysis of powder factor in limestone mine- A case study"** submitted for the degree of **Master of Technology** in the subject of **Mine Planning,** embodies bonafide research work carried out by **Mr. Hemant Sukhwal** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of the thesis was also approved by the advisory committee on date 19th February 2019.

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ABSTRACT

In hard rock excavations, drilling and blasting is the cheapest method of rock breaking and it is widely used. Blasting efficiency depends on many parameters includes controllable and non controllable. The blasting efficiency assesses in the form of rock fragmentation, powder factor and blast induced environmental nuisances. Powder factor is an important parameter used in blast design process. It is ratio between amount of rock broken and total weight of explosive consumed (tonne/kg or m^3/kg). Higher powder factor produces oversize and lower powder factor resulted into fines. The favourable size for primary crusher feed will have positive effects on power factor and cost consumption. An optimum blast is associated with the most efficient utilization of explosive energy in the rock breaking process. This research work is carried out to aim analysis and improvisation of powder factor and rock fragmentation achieved by blasting at JK cement Maliakhera limestone mine, Nimbahera, Chittorgarh. All blasts were conducted on the same geology and blast parameter. The variable parameter is quantity of explosive by the use of decking provided between charge lengths through air deck (wooden spacer)/ solid decking by (drill cutting). To analyze rock fragmentation WG-FRAGALYST 3.0 software based on digital image analysis technique was used. Fragmentation characteristics such as fragment size K25, K50, K98 and uniformity index were calculated by introducing digital images to the software.

The variable parameter is quantity of explosive by the use of decking provided between charge lengths. Wooden spacer (Air deck) and drill cutting aggregates were used to provide deck between charge columns. Powder factor and rock fragmentation size distribution analysed for all baseline blasts and experimental blasts. In the analysis, powder factor was improved 7.61% in solid deckand14.34% in air deck blasting. The obtained mean fragment size K50 and top size K98 decreased for required maximum crusher feed size is 1.0 m. Though in oversize boulders reduced 19.67% and 37% respectively. Reduction in energy factor 8.77% in case of solid decking and 12.93% in case of air deck blasting. By decking total charge per hole reduced and results of rock fragmentation and powder factor were improved.

सार

हार्ड रॉक खुदाई में, ड्रिलिंग और ब्लास्टिंग रॉक ब्रेकिंग की सबसे सस्ती विधि है और इसका व्यापक रूप से उपयोग किया जाता है। ब्लास्टिंग दक्षता कई मापदंडों पर निर्भर करती है जिसमें नियंत्रणीय और गैर नियंत्रणीय शामिल हैं। ब्लास्टिंग दक्षता रॉक विखंडन, पाउडर फैक्टर और ब्लास्ट प्रेरित पर्यावरण उपद्रवों के रूप में मूल्यांकन करती है। पाउडर फैक्टर ब्लास्ट डिजाइन प्रक्रिया में प्रयुक्त एक महत्वपूर्ण पैरामीटर है। यह चट्टान की मात्रा और विस्फोटक खपत के कुल वजन (टन / किग्रा या एम 3 / किग्रा) के बीच का अनुपात है। उच्च पाउडर फैक्टर ओवरसाइज़ पैदा करता है और कम पाउडर फैक्टर के कारण जुर्माना लगता है। प्राथमिक कोल्हू फ़ीड के लिए अनुकूल आकार का बिजली के कारक और लागत की खपत पर सकारात्मक प्रभाव पड़ेगा। एक इष्टतम विस्फोट रॉक ब्रेकिंग प्रक्रिया में विस्फोटक ऊर्जा के सबसे कुशल उपयोग से जुड़ा हुआ है। यह शोध कार्य जेके सीमेंट मालीखेड़ा चूना पत्थर खदान, निम्बाहेड़ा, चित्तौड़गढ़ में विस्फोट से प्राप्त पाउडर फैक्टर और रॉक विखंडन के विश्लेषण और सुधार के उद्देश्य से किया गया है। सभी विस्फोट एक ही भूविज्ञान और ब्लास्ट पैरामीटर पर किए गए थे। चर पैरामीटर हवा डेक (लकड़ी के स्पेसर) / ठोस अलंकार (ड्रिल कटिंग) के माध्यम से चार्ज लंबाई के बीच प्रदान की गई अलंकार के उपयोग से विस्फोटक की मात्रा है। रॉक विखंडन का विश्लेषण करने के लिए डिजिटल इमेज विश्लेषण तकनीक पर आधारित WG-FRAGALYST 3.0 सॉफ्टवेयर का उपयोग किया गया था। विखंडन आकार जैसे K25, K50, K98 और एकरूपता सूचकांक की गणना सॉफ्टवेयर में डिजिटल छवियों को पेश करके की गई थी।

चर पैरामीटर चार्ज लंबाई के बीच प्रदान की गई अलंकार के उपयोग से विस्फोटक की मात्रा है। चार्ज कॉलम के बीच डेक प्रदान करने के लिए लकड़ी के स्पेसर (एयर डेक) और ड्रिल कटिंग समुच्चय का उपयोग किया गया था। पाउडर फैक्टर और रॉक विखंडन आकार वितरण सभी बेसलाइन विस्फोटों और प्रयोगात्मक विस्फोटों के लिए विश्लेषण किया गया। विश्लेषण में पाउडर फैक्टर में 7.61% सॉलिड डेक और 14.34% एयर डेक ब्लास्टिंग में सुधार किया गया। प्राप्त किए गए औसत टुकड़े का आकार K50 और शीर्ष आकार का K98 आवश्यक अधिकतम कोल्हू फ़ीड के आकार के लिए घटाकर 1.0 मीटर है। हालांकि ओवरसाइज़ में बोल्डर क्रमशः 19.67% और 37% कम हुए। ठोस अलंकार के मामले में ऊर्जा कारक 8.77% की कमी और एयर डेक ब्लास्टिंग के मामले में 12.93% है। छेद प्रति कुल चार्ज को कम करके और रॉक विखंडन और पाउडर फैक्टर के परिणामों में सुधार किया गया।

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LIST OF ABBREVIATIONS

Abbreviation	Description
mm	Millimeter
cm	Centimeter
m	Meter
Kg	Kilogram
MPa	Mega Pascal
m/s	Meter per second
PETN	Pentaerthritol tetra nitrate
TNT	Trinitrotoluene
DF	Detonating fuse
TLD	Trunk line delay
ANFO	Ammonium nitrate fuel oil
PPV	Peak particle velocity
PVS	Peak vector sum
Hz	Hertz
dB (L)	Decibel
Nonel	Non electric delay detonator
VOD	Velocity of detonation

CHAPTER 1

INTRODUCTION

CHAPTER 1

INTRODUCTION

1.1 General

In hard rock excavations, drilling and blasting is the cheapest method of rock breaking and it is widely used. Drilling and blasting operations is one of trends to increase efficiency of excavation. Inspite of the best efforts to introduce mechanization in the opencast mines, blasting continue to dominate the production. Drilling and blasting cost in any project can be as high as 25% of the total production cost (Adhikari *et.al.,* 1995). Therefore, to minimize the cost of production optimal fragmentation from properly designed (explosive-rock mass interaction) blasting pattern has to be achieved. To optimize a blasting operation, it is necessary to understand the characteristics of blasting parameters.

An optimum blast is also associated with the most efficient utilization of explosive energy in the rock-breaking process. During blasting with explosive, a huge amount of energy in terms of pressure and temperature liberates. Only a part of explosive energy is actually used for the fragmentation and displacement, the rest of the energy is wasted which creates a number of blast nuisances like ground vibration, air over pressure, flyrock, dust, fumes etc. These blasting nuisances cannot be completely eliminated but certainly minimize up to a permissible level to avoid damage to the surrounding and existing structures.

Blasting efficiency depends on controllable and noncontrollable parameters. Controllable parameters are mainly related to blast hole geometry and explosive characteristics includes hole diameter, hole depth, sub drill depth, hole inclination, stemming length, stemming type, blast pattern, burden to spacing ratio, bench height to burden ratio and direction of blast, initiating system, initiating sequence, no of free faces, explosive types, explosive energy, explosive density, velocity of detonation, charge geometry, loading method etc. While noncontrollable factors are geology of deposit, rock strength and properties, presence of water, joints and discontinuities in rock mass. After blasting the assessment of blast is important. These assessment parameters are fragmentation, blasting nuisances and powder factor. A correct fragmentation would optimize the cost and change the overall economics which is assessed in the form of powder factor.

Powder factor is the ratio between the amounts of rock broken and total weight of explosive consumed (tonne/kg or m^3/kg). It is taken tonne/kg in case of ore or coal and m^3/kg waste rock is broken. Reverse of powder factor known as specific charge kg/tonne or kg/m^3.It is an important parameter used to blast design when it is referring to a pattern explosive or is expressed as energetic consumption (Jimeno *et. al.*, 1995). Powder factor is economic index for assessment of blastability of rock. Higher powder factor causes oversize and lower powder factor results into crushed rock. Powder factor can serve a variety of purpose, such as an indicator of how hard the rock is, or the cost of the explosive needed, or even as a guide to planning a blast. Powder factor is a blasting parameter for any opencast mines is depends on various parameter such as geology of rock, blast design including hole diameter, spacing, burden and bench height, size requirement of rock fragmentation, impedance matching, explosive energy output and its utilization etc.

To achieve efficient blasting result, proper understanding between rockmass-explosive interaction and blast geometry is needed. Once the blast has been carried out, it is necessary to analyze the obtained results, as its interpretation will give hints for the successive modifications of the blast parameters for the next blast round.

In this case study, blast tests were carried out in limestone mines based on existing surface blast design parameters.

1.1.1 Importance of powder factor

Powder factor is a relationship between how much is rock broken and how much explosive is used to break it. Powder factor serves a variety of purpose these are

i) An indicator of rock hardness.
ii) Powder factor can be used to calculate cost of explosive needed.
iii) Powder factor is important parameter to blast design.

1.2 Objectives

Keeping all these aspects in mind, the present study has been undertaken with the following objectives of research study are;

i) To evaluate present powder factor and rock fragmentation in limestone mine.

ii) To evaluate explosive energy with combination of various explosives in blast.

iii) To monitor and record blasting nuisances like ground vibration, air over pressure and flyrock on existing and experimental blast.

iv) To find out suitable blast design for improving powder factor in experimental blast.

1.3 Methodology

The study involves collection of data and undertaking observations in the field, analysis through software available in computer laboratory in the department. The field study was conducted at the prestigious of M/s. J.K. cement Maliakhera limestone mines, Nimbahera, Chittorgarh, Rajasthan.

1.3.1 Field work

Field work includes pre-blast measurements, during blast measurement and post blast measurements as described below:

i) Pre-blast measurements

Pre-blast measurements includes blast geometry such as bench height, blast hole diameter, burden, spacing, charging length, Type and length of decking, stemming height, explosive type-quantity per hole etc.

ii) During blast measurements

During blast measurements includes blast induced ground vibration and air over pressure monitoring with seismograph, explosive velocity of detonation measurement by Handitrap-II, high speed videography for throw and flyrock measurement.

iii) Post blast measurements

Post blast measurements include to take photographs of the blasted rock for fragmentation analysis, back break and over break observations.

1.3.2 Laboratory work

Data collected from the field will be analyzed in the laboratory and mine computing lab is as followed:

i) Rock fragmentation analysis with the WG-Fragalyst 3.0, which is based on Kuz-Ram fragmentation model. The fragment size distribution curve is produced by rosin-rammler distribution equations.

ii) Pattern simulation software is used for analyzing blasting patterns in computer laboratory.

iii) Ground vibration analysis with blastware software in the computer laboratory, which were recorded on the field during blast with Minimate™.

iv) Determination of physico-mechanical properties of rock sample such as compressive strength, tensile strength and point load index in the rock mechanics laboratory.

v) Ultrasonic P-wave velocity measurement on collected sample in the rock mechanics laboratory.

1.4 Outline of thesis

This thesis has been organised into five chapters.

Chapter – 1: Introduction

This chapter gives a general introduction about the blasting, importance of powder factor, optimization of blast fragmentation, software used for analysis and objectives of this study.

Chapter – 2: Review of Literature

This chapter covers the available literature in the subject field and deals with various features of fragmentation, powder factor. The aspects covered in this chapter are mechanism of rock breakage by blasting, rock fragmentation, blast assessment parameters; mainly deals with the different research were carried out so far and sort out for deciding the main objectives of the research work.

Chapter – 3: Field Investigation and Laboratory Investigation

This chapter mainly contains two phases: field investigation and laboratory investigation. In field investigation the general, geological and mining details of the mines where the studies were actually conducted, data related to blasting are collected such as blast design parameters, types of explosives used, types of delay element, priming system and initiation system used and ground vibration, air over pressure monitoring for different blasts, photographic images taken for further fragmentation investigation, velocity of detonation measurement. In laboratory investigation, physico-mechanical properties of samples collected during the field work have been determined. Some analysis work is also carried out with the help of software available in mine computing lab i.e. WG-Fragalyst, Blastware, Pattern simulation software, Data Acquisition Suit etc.

Chapter – 4: Results and Discussions

In this section, the results based on field investigation and laboratory investigations are discussed in details and on the basis of it, it should be decided that this study properly meets the objectives or not.

Chapter – 5: Conclusions and Recommendations

In this chapter enumerated conclusions and suggestion for future work in this subject field.

CHAPTER 2

LITERATURE REVIEW

CHAPTER 2

REVIEW OF LITERATURE

This section briefly deals with the review of the research work carried out in relation to the objectives of the proposed study. An extensive review of research literature has been made on the lines of objectives contemplated to facilitate devising an appropriate methodology towards accomplishing the entire research topic.

2.1 Blast design and powder factor analysis

Hagan (1983) summarized controllable factors that affect blast results are blast design, type of explosive, initiation system, and initiation sequences. Uncontrollable factors that affect blasting are geology, proximity of nearby structures. Size distribution of rock pieces in blasted muckpile influences total cost of mining operation. To achieve good blast results it is necessary to understand the rockmass- explosive interaction and blast geometry.

Rustan (1983) narrated that the rock fragmentation depends on specific charge, blast design, and physical properties of homogeneous rock. In their experiment Critical burden-The angle of breakage is inversely proportional to burden for all materials except luossavaara magnetite. The angle is dependent on p-wave velocity of the material. They found a good linear correlation between critical burden and rock impedance. The critical burden is an important parameter to describe blastability of rock.

Verma (1993) advocated that performance rating of explosives has become a primary need because of the growing requirement and competition. In experiments, the usually accessed parameters are the strength though there is no such parameter still to compare the performance index of the explosives. At present, the only way out is to compare the lab results and the company or manufacturers claimed results about the explosive properties.

Jimeno *et al.* (1995) studied that the specific charge referring to a type of explosive or energetic consumption of a blasting is increased with increasing the diameter of the blasthole, rock strength, degree of fragmentation, displacement, swelling desired, poor charge distribution, improper stemming, inadequate spacing burden ratio, ineffective delay timing. Blast holes are parallel to the free face, equilateral triangular patterns, initiated with sequences in V- pattern are favourable to decreases specific charge.

Adhikari and Venkatesh (1995) suggested that drilling and blasting cost in any project up to 25% of the total production cost. So the blast design and its implementation must be given on high priority. Optimization of blast parameter would increase the profitability. Data collection and monitoring of each stage pre-blast, In-blast, post blast of blasting. They observed to achieve a certain degree of improvisation systematic and scientific approach is required.

Bozic (1998) studied on control of fragmentation by blasting. The degree of fragmentation affects the overall cost of mining. Characteristics of blasted rock such as rock fragmentation, volume and mass are important variables affecting the economics of a mining operation and are in effect the basis for evaluating the blast. The properties of fragmentation, such as size and shape are very important information for the optimization of production. Three factors control the fragment size distribution includes the rock structure, the quantity of explosive, charge distribution.

Kemeny *et al.* (1999) studied on rock fragmentation analysis in several opencast mines in Arizona. The primary crushers equipped with Split-online rock fragmentation analysis software. In this system, one camera installed at the truck dumps to monitor primary crusher feed and another one installed at the discharge belts monitor primary crusher product. He observed by online image analysis that the large decrease in F80 (Feed 80% coarser and 20% finer) Kcal/tonne with increasing explosive energy was noted. This fragmentation relationship will form the basis for a mine-specific fragmentation model.

Jhanwar and Jethwa (2000) concluded that influence of air deck blasting on blast performance, blast economics. The air deck blasting technique is effective in soft rock formation and medium strength rocks. Air deck blasting resulted in to reducing fines, producing more uniform fragmentation and improving blast economics. They observed by air deck blasting fines, oversize boulders, explosive cost, throw, backbreak, ground vibration were reduced in homogeneous sandstones and shovel loading efficiency was improved.

Pal and Ghosh (2002) studied the optimization of blasting pattern implemented at Sonepur-Bazari opencast project for controlling blast induced nuisances ground vibration, flyrock, air overpressure with improved production and productivity. Their study revealed that by proper design of blast parameters the desired results in fragmentation, vibration were achieved whereas flyrock needed good supervision. They suggested use of shock tube initiation. This increased the cost but gave back in productivity reducing chances of misfire, flies rock and achieved proper fragmentation with reduced sub-grade drilling. They suggested a blast design for proper balance between environmental aspects and productivity criteria.

Cho *et al.* (2003) narrated that the evaluation of fines also important in analysis of rock fragmentation. Image analysis of rock fragmentation not accurately considered fine ratio. After corrected fines ratio the achieve size distribution of rock fragmentation approximately coincide with fragment size distribution obtained by sieving analysis.

Altindag and Guney (2005) studied that the degree of jointing, which is one of the most important parameters influencing seismic velocities in rock mass. It must be considered when design structures in rockmass. By experiment on four different types of rocks they observed that the seismic velocity of rock depends on joint thickness, no. of joints. P-wave velocity decreases with increases no. of joints in rockmass.

Siddiqui *et al.* (2009) narrated that the rock fragmentation analysis by digital image processing software is a quick and economic. Sieving is a direct and accurate method for fragmentation analysis. Sieving is time consuming and costly. Split system is digital image processing software developed to compute the size distribution of blasted rock fragment from digital images. In their study, size distributions were analyzed by using Split Desktop ® system. In the analysis, the mean fragment size obtained was 149.76 mm and top-size 1057.44 mm. 25% of the fragments are below 30 mm. A thorough appraisal of blasting operation is suggested to enhance the efficiency of all the post-blast operations such as loading, hauling, crushing and Grinding and also reduces the cost of secondary breaking. They observed 25% fragments are below 30 mm, which is product size of primary crusher; this percentage can be enhanced by optimizing the overall blasting operation. In blast geometry burden, spacing is main parameter that affects rock fragmentation.

Rai and Yang (2010) studied on blast design parameters includes spacing, burden, firing pattern. They indicated that the effective spacing, effective burden (firing burden) must be designed vis-à-vis firing pattern. Spacing to burden ratio can be increased up to 2.5, by changing firing pattern, increasing the effective spacing and reducing the effective burden values. Spacing, burden needs to be designed and implemented in accordance to the firing pattern. Depending on the rockmass condition, the inter row delay timing values can range from 6-15 ms/m of effective burden for desired result. The problems of stemming area can be resolved by stemming plug.

Ramulu and Sinha (2010) studied that the bottom hole air decking experiments in Plexiglas models proved that the explosive energy was effectively used in uniform fracturing and more breakage in comparison to the conventional charging. The bottom air decking resulted in 25-30 % improvement of fragmentation and better uniformity index in granite and basaltic rock formations, reduction in specific charge 15-20%. The peak particle velocity was reduced by 35% in comparison to the conventional charging. The laboratory and field experimental results prove that the bottom–hole air decking is an effective technique for improving the opencast blasting productivity as well as safety.

Strelec *et al.* (2011) narrated that predictions and analyses of blasted rock mass fragmentation is important to decrease the downstream operation includes loading, hauling, crushing. Optimization of blast design represents an effort to decreases oversize and reduces fine in the muck pile.

Choudhary and Kumar (2013) studied that the Schmidt hammer rebound number is increases as powder factor decreases. Increases in rebound means rock mass is compact which requires more chemical energy to break. Therefore, more explosive were charged in the holes to get the required blasting result in terms of improved fragmentation. They observed that the cycle times of the shovel were remains constant due to uniform rock fragmentation.

Choudhary (2013) advocated that the firing pattern affects the spacing to burden ratio. By changing the firing patterns the effective spacing to burden ratio increases in comparison to the drilled spacing to burden ratio. The increased spacing and reduced burden at the time of blasthole initiation, results in increased in-flight collisions of broken rock during its movement hence, improved the fragmentation.

Dhariwal (2013) studied that the effect of structural discontinuity on rock fragmentation. He observed good fragmentation in thinly bedded and naturally fractured rock formation because the rock had small natural size blocks. Whether hard, thickly bedded and widely spaced joints, the probability of coarse size fragmentation was high. Blast optimisation pattern would be a tool to control the environmental nuisances within safe limit and perform mining with greater safety with productivity.

Singh and Abdul (2013) observed by bench blasting that when increases spacing to burden ratio mean particle size and index of uniformity of the blasted muck decrease. Spacing to burden ratio in the range of 1.5 to 2 gives optimum results. An increment in mean particle size with the increase in the burden to hole diameter ratio because the hole diameter was kept constant. Mean particle size increases with the increase in the stemming length as % of the bench height, joint orientation factor plane, joint spacing. The value of bench stiffness between 2 to 3 gives optimum results in terms rock fragmentation.

Rommayawes *et al.* (2013) indicate that the average fragmentation size increases with increasing air deck length, maximum joint spacing. In addition, an unfavourable blasting direction also increases average fragmentation size. Using an air deck length of 20 % can result in an average passing size was 40-60cmhaving joint spacing between 90cm to 200cm. With the maximum joint spacing above 300cm, an average passing size more than 90cm. so an air deck length of between 20-30 % gives a high possibility that the average passing size will be less than 100cm.

Torbica and Lapcevic (2014) indicated that the density of radial cracks around the blast hole is proportionally depending on explosion pressure that generates the pressure wave, diameter of hole. Radial crack density is inversely proportional to tensile strength of rock and poisons ratio.

Chandar and Sastry (2015) studied on assess the influence of depth of excavation and scaled distance on the seismic energy wasted in the form of ground vibrations. The seismic energy dissipated into the rock mass is having good correlation with scaled distance and seismic energy. The seismic energy dissipated into the rock mass and the work done by the explosive energy are found to decrease with increase in scaled distance at a given depth of excavation.

Chi *et al.* (2015) summarised that the electronic delay detonator is better than the non electronic delay detonator. An electronic detonator has a number of advantages, higher precision and improved blasting result owing to a wide range of delays, reduction of air blast, ground vibrations and greater safety.

Kamel *et al.* (2015) studied that the weakness planes (joints) can, depending on their direction and other properties, attenuate the stress wave and the growing of radial cracks during blasting. Usually, they also decrease the strength of the rock and make a difficult for cracks to pass across them and, therefore, the crushed zone around the blasthole is reduced. Positioning the detonator at the centre of the vertical hole gave best results for different joints directions. Fair agreement has been obtained between the results of fragmentation from small scale blasting and the Kuz-Ram (Kuznetsov-Rammler) model.

For further model experiments, determination of the limestone material properties can, for a standard case ,be limited to measurement of longitudinal wave velocity, transversal wave velocity, density, compressive strength(uniaxial) and tensile strength (Brazilian test). These properties describe rocks for the purpose of ground preparation and give valuable information in bench blasting. For example, the tensile strength test is necessary in bench blasting because the main part of the material is broken in tension.

Nefis and Talhi (2016) indicated that the photo analysis technique is quick and accurate method. The image analysis technique compares favourably with conventional methods of measuring fragmentation, like sieving, which is simply more time consuming and not economically feasible for large sizes. Using the comprehensive photographic record, stored digitally, analysis can be carried out without disrupting production.

Solving of actual production problems need to conduct advanced applications and in that way Fragscan system leads to higher profits (optimisation of blasting parameters, selection of industrial equipment). Method of sampling and digitization based on the Fragscan system has been tested. Image analysis method has been concerned for correcting the apparent size distribution to give a true volumetric or weight distribution of the broken rock. It showed a performance for measuring of the fragmentation by blasting with explosives.

Singh *et al.* (2016) studied that mean fragment particle size increases with the increase in the burden to hole diameter ratio. This increase was mainly due to the increase in burden as the blast hole diameter was kept constant. Mean fragment size of the blasted muck decreases with the increase in the spacing to burden ratio. The optimum value of spacing to burden ratio ranged from 1.1 to 1.3 and resulted in excellent rock fragmentation. Uncontrollable parameters such as joints and fractures have significant influence on uniformity index (n). Mean fragment size of fragmented rock decreases with the decrease of stemming length to burden ratio. As anticipated, the increase in the charge/powder factor resulted in increase of rock fragmentation level, i.e. decrease in the mean fragment size of the rock. The mean fragments size decrease with increasing stiffness ratio.

Kulula *et al.* (2017) narrated that the Kuz-Ram model overestimated almost all of the fragment size distributions analyzed. This model underestimates the fine parts of rock fragmentation. The reliability of any fragmentation model to evaluate blast performance by analysis of blast parameters used prior to blasting depends on the accuracy of rock mass characterization and the ability to model and measure the amount of fines generated in blasting. They concluded that the density was found to have an inverse relationship with blast performance, the higher the density, the lower the blast performance. Volume of the blast was found to be directly proportional to the blast performance, such that when the volume of blast increases the blast performance increases.

Bahadori and Amnieh (2017) narrated that direction of detonation wave propagation affects the amount of ground vibration caused by blasting. They observed when the primer is at the bottom of the blast hole, the ground vibration is minimum than other because of the orientation of blasting cone wave is towards the upper part of the blast hole. When primer is in the centre of the explosives column creates waves with complex super positions since two cone wave fronts are formed on two sides of the blast hole and interface with destructive wave hemisphere but it is expected that the resulting ground vibration to be average of two above mentioned states.

Zhang (2017) observed that the kinetic energy carried by the rock fragments is an important component of the total input energy, and it increases with increasing loading rates. According to dynamic tests, it is estimated that in blasting, the kinetic energy can be up to 28% of the total input energy if burden speed is 20 m/s. Different types of experiments have shown that secondary breakage to flying fragments is possible. Therefore, the kinetic energy carried by a flying fragment can be utilized in its secondary breakage so as to increase the energy efficiency and improve fragmentation.

In open pit blasting, to utilize the kinetic energy and improve fragmentation, a part of muck pile from previous blast should be left in front of new bench face. In this case when next blast happens, the fragments from the first row will collide with the muck pile left from the previous blast.

The rockmass characteristics have a significant influence on blasting results. The important parameters that need to be addressed in a blast design are blasthole diameter, burden, spacing, hole depth, stemming, powder factor, initiation sequence, explosive type and delay timing, decking. Despite many years of fundamental work aimed at describing the role of rock mass properties in blasting these properties are not satisfactory included in blast design. There is a need for characterising the site by sample and measurable parameters and incorporate them in blast design. Suitable delay intervals result in an improved fragmentation, good displacement, reduced ground vibration and flyrock. To achieving efficient blasting result, proper understanding between rockmass- explosive interaction and blast geometry is needed.

Various approaches to blast design and the parameters that affect the blast result are reviewed to understand the present state of knowledge. So far, no substantial research works have been carried out in “Analysis of powder factor in limestone mines. Hence, a detailed study on this aspect has been carried in limestone mines.

CHAPTER 3

FIELD AND LABORATORY INVESTIGATIONS

CHAPTER 3

FIELD AND LABORATORY INVESTIGATIONS

This chapter involves four phases: The first one is the study area which involves the site location and geology of the mine, second one is the field investigation which involves the study of data in the field such as blast design parameters, types of explosive, types of priming system, types of delay element, types of initiation sequence and vod was recorded with handitrap II and ground vibration and air over pressure measured with Minimate™. In the third phase study was carried out for baseline blast pattern and experimental blast pattern. The fourth one is the laboratory investigation which involves the analysis work on samples collected in the field like measurement of p-wave velocity, compressive strength, tensile strength and point load index thereafter the analysis work by some software like Fragalyst, data acquisition suit, pattern analyzer, blastware, etc.

3.1 Study Area

The study area selected for the field experiments is J. K. Cement Maliakhera limestone mine Nimbahera, Chittorgarh, Rajasthan.

Fig.3.1: A view of Maliakhera limestone mine

3.1.1 Site location

Maliakhera limestone lease area is located at distance of about 5 kilometres from Gambhiri railway station in the western direction near village Maliakhera Tehsil Nimbahera Chittorgarh District of Rajasthan, India.

The mining lease area lies approximately between the latitudes 24°40'4.7" - 24°41'22.4" N, and longitudes 74°36'22.0" - 74°37'22.7"E. The lease area forms a part of the survey of India toposheet no 45L/10.The lease area covers portions of 5 villages namely Maliakhera, Bansa, Piplia Gadia, Phalwa and Bhatt Kotri. The location map of this mine is shown in Figure 3.2

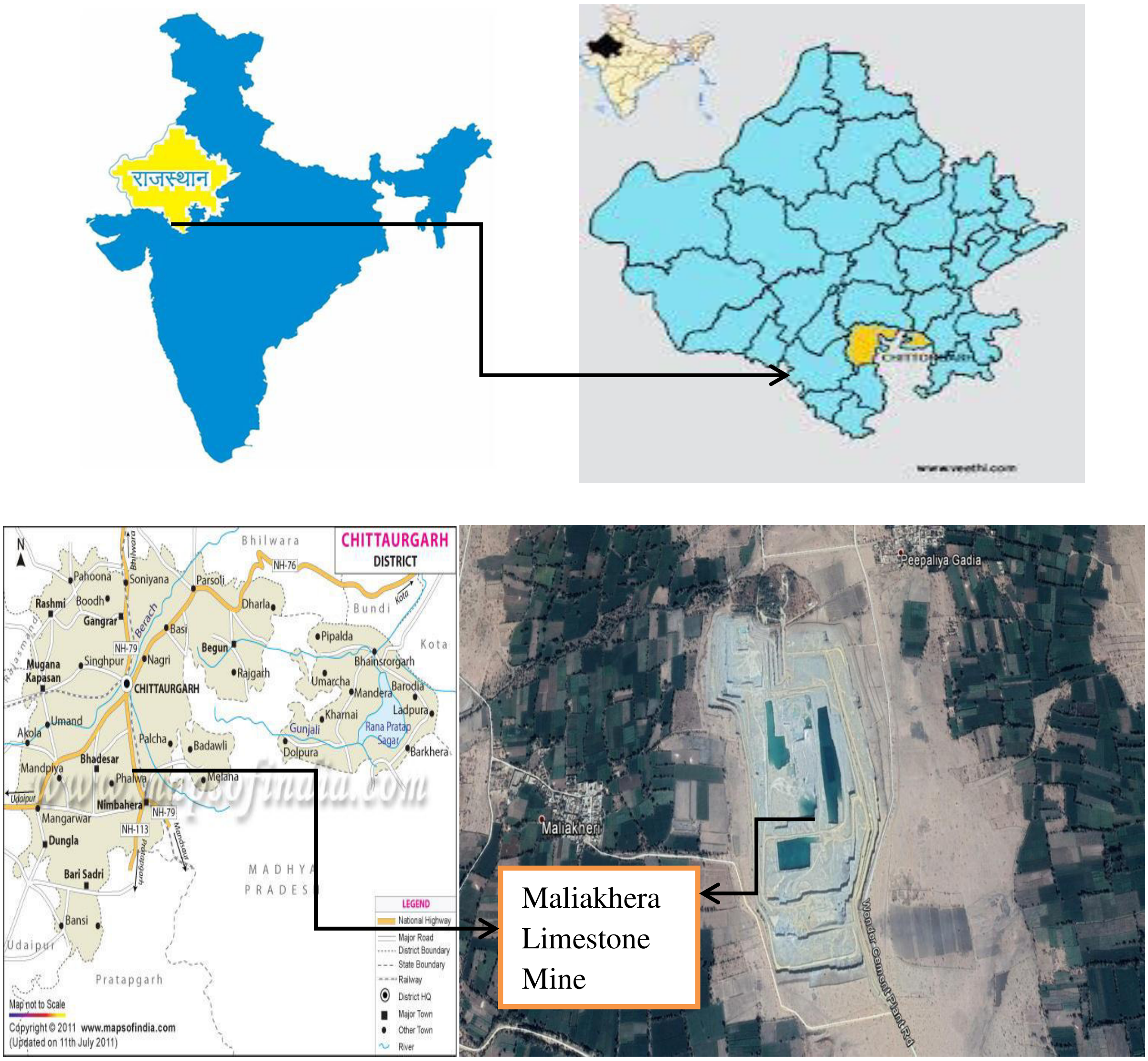

Fig. 3.2: Location map of JK cement Maliakhera limestone mine

3.1.2 Geology of study area

The rock formation of eastern Rajasthan and Mandasaur district of Madhya Pradesh were studies by Dr. A.M, Heron in 1936. He classified the limestone formations of this area under Nimbahera limestone belt which is equivalent to the Semri series of lower Vindhyan. Nimbahera limestone named after its typical place of occurrence can be continuously traced from near Jawad to Nimbahera and thereafter in patches in Chittorgarh, Binota, Khori and Sawa. The total thickness of the Nimbahera limestone is estimated to be 144 metres of which the bottom 9 metres is deep reddish purple in colour while the upper 135 metres is grey in colour, fine grained and is thinly bedded. The Nimbahera Limestone is conformable with the Suket shales occurring above it and the Nimbahera shales lying below.

Table3.1: The sequence of the rocks in the region

Formation	**Age**
Alluvium	Recent
Laterite	Sub Recent to Pleistocene
Deccan Trap	Upper Cretaceous
Kaimur Sandstone	Upper Vindhyan
Suket Shale	Lower Vindhyan
Nimbahera Grey Limestone	
Nimbahera Purple Limestone	
Nimbahera Purple Shale	
Khori-malan Conglomeratic Sandstone & Boulder Bed	

Table3.2: The Stratigraphic sequence of rocks in the area

Era	**Super Group**	**Group**	**Formation**	**Litho Unit**
PROTEROZOIC	VINDHYAN	Kaimur	Kaimur Sandstone (Chittor Fort)	Sandstone
		Khorip	Suket Shale	Shale
			Nimbahera Limestone	Limestone
			Bari Shale	Shale
			Jiran Sandstone	Sandstone

Limestone deposits exposed in this area are a part of the Nimbahera limestone belt belonging to Semri series of lower Vindhyan age. The limestone is trending almost N-S direction with dip of the beds varied from 5° to 20°. Most of the area is soil covered, Small outcrops are intermittently exposed. The thickness of the soil cover varied from 0 to 2.0 m. Topography of mines was on plane surface. The mines had different beds of limestone in a sequence of dark grey limestone, medium grey limestone, light grey limestone (low grade), pink limestone. The limestone deposit in Maliakhera mine is of moderate thickness having closely spaced joints which may not create problem in fragmentation in blasting operations except the zone of embedded boulders particularly on the top bench.

3.2 Field investigations

The main purpose of the bench blasting is to facilitate fracturing and moving of intact rock mass so that it can be loaded, hauled and further processed in an easy and efficient way. There are several parameters that influence the performance of a bench blast. Among the most significant ones are the rock mass properties and geometrical features of the blast design. Secondary parameters include explosive and detonator type, initiation pattern and timing etc. A brief overview of blasting parameters and charging sequences used at JK cement Maliakhera limestone mine can be seen in following Figure 3.3

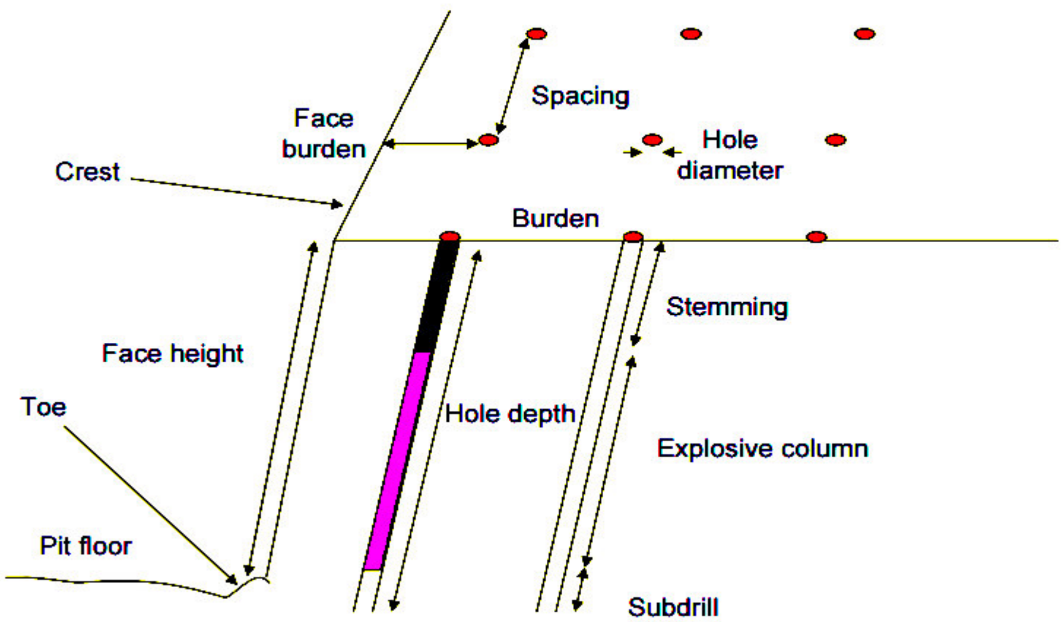

Fig. 3.3: Blast design parameters

3.2.1 Method of mining and blast geometry

The Maliakhera mines of JK cement works is fully mechanized and being worked by with deep hole drilling and blasting and subsystem adopting shovel- dumper combination for loading &hauling. The drilling is carried out in rectangular pattern using 115 mm diameter DTH drill machines with a burden 3 to 3.5m and spacing 4.5 to 5.5m. ANFO was used as column charge and Kelvex-600E, Kelvex- PE (83mm dia.) as booster charge and priming respectively. The number of holes varied between 8 and 16. The holes are drilled at angle 80-85. The sub grade drilling of 0.3 m was being followed at few locations where dip of foliation was against the free face. The blasts were initiated by shock tube system with DTH of 250ms,450 ms and trunk line delay(TLD) consisting of 17 ms,42 ms,65 ms were commonly used in blasting. Stemming column kept between 2.1m to 2.4 m. Drill cuttings were used as stemming material.

1) Blast hole depth and diameter

Drilling of blast hole diameter 115 mm is carried out with the help of DTH. Drill length is kept varied from 7.30m to 9.50 m.

- ✓ Blast Hole Depth – Varied from 7.30 m to 9.50 m (24 ft. to 31 ft.)
- ✓ Hole Diameter – 115 mm

2) Burden and spacing

- ✓ The burden and spacing are kept around the 3.00 m to 3.5 m &4.5-5.5 m (9.84to11.5 ft. & 14.76-18ft.) respectively.

3) Charging length and stemming length

- ✓ Charging length is kept 5.2 m to 6.0m.
- ✓ Stemming length is kept 2.1m to 2.5 m**.**

4) Subgrade drilling

- ✓ Subgrade drilling 0.3-0.4m followed by direction of strata.

3.2.2 Type of explosive used in blasting

The regular blasting practice in the mine was to use ANFO in conjunction with cartridge emulsion /slurry explosive.

ANFO: A common blasting agent used in open pit mines today is a combination of ammonium nitrate (AN) and diesel oil/fuel oil (FO). The combination is called ANFO. Although neither of these components are explosive in themselves, under the proper conditions the mixture can be made to detonate (the explosion front will be propagate along a column of explosive). Under other conditions, the mixture will simply deflagrate (burn) at a very rapid rate. ANFO used for column charge. It has density of 0.8 g/cc with velocity of detonation (VOD) 3200 m/sec, the relative weight strength is 100 and the explosive energy is 3.8 MJ/kg.

Fig.3.4: Ammonium nitrate fuel oil (ANFO)

Cartridge emulsion explosive: Cartridge emulsion explosive used for priming ANFO in blast holes. Kelvex-600E, Kelvex PE is brand name of emulsion explosive manufactured by Keltech energies ltd. Kelvex-600E is booster explosive. It can be used alone or in combination with booster sensitive water gel or emulsion explosives. It is meant to be used in medium hard to hard strata along with column charges for economical blasting.

Table3.3: Explosive properties

Explosive	**VOD (m/s)**	**Density (g/cc)**
KELVEX-600E	4000±200	1.16-1.21
KELVEX-500	4000-4300	1.14-1.19
KELVEX- PE	4750-5500	1.20-1.25
ANFO	3200	0.8

Fig.3.5: Cartridge emulsion explosive

3.2.3 Types of priming system, delay element and initiation system used in blasting

(1) **Types of priming system:**

(i) Detonating fuse – A detonation fuse needs itself to initiate by a detonator. Detonating fuse are advantages in blasting of long holes with long column of explosive charges. Where contact of detonation fuse with the explosive over the whole length of column desirable for proper detonation of the whole column of explosive. It has velocity of detonation almost 6500 m/s. It is a high – speed fuse which explodes, rather than burns, and is suitable for detonating high explosives. It is used for trunk line connection of the hole on the surface. The detonating fuse is then connected with Amardet (DTH).

(ii) Amardet (DTH) - It is the most suitable element for primer. It is also called down the hole delay (DTH) because by DTH delay timing can be provided in the bottom of the hole. In Maliakhera limestone mine, mainly 09 m DTH of 250 ms and 450 ms delay were used.

(2) Type of delay element

With detonating fuse (DF), the hole to hole delay of 17 ms, 42 ms and 65 ms are used as a delay element for hole to hole connection.

3.2.4 Types of decking used in blasting

In Maliakhera mines deck charging practices followed in charging with geology of strata. Solid decking by drill cutting and Air deck by wooden spacer .Generally deck length is kept 0.6 m (2 feet) Maliakhera mines.

Solid Deck (Drill cutting) solid decking is done by drill cuttings which are easily available near collar of hole.

Air deck (Wooden spacer)

Fig.3.6: Wooden spacer (60cm length)

Wooden spacer (Figure 3.6) having length of 2 feet (0.60m) was used in Maliakhera limestone mines to providing air decking. In this technique an explosive column is combined with an air chamber (wooden spacer) in blast holes. This technique helps in controlling the breakage process through effective distribution of explosive energy and thereby enhancing the breaking power on the rock.

3.2.5 Blast induced ground vibration and air over pressure measurement

Ground vibrations and noise levels are always been topic to discuss with blasting. In this research work of analysis of powder factor, ground vibrations and air over pressure were measured in various blasts carried out.

Ground vibration and air over pressure were measured with the help of seismograph instrument called Minimate^{TM}, which shown in Figure 3.7.

Fig. 3.7: Seismographs (Minimate^{TM})

It contains mainly two units: the first one is the geophone which is used to measure the ground vibrations (mm/s) and another one is the microphone which is used to measure the air over pressure (dB).The sensor measures transverse, vertical and longitudinal ground vibrations in terms of particle velocity. The ground vibration and air over pressure results of different blasts are discussed in chapter 4.

Flyrock induced by blasting were evaluated on the site. Videography of the blast was used to assume the maximum flyrock distances and then it has been measured with tape.

3.2.6 Explosive velocity of detonation (VOD) measurement

The rate at which the detonation wave travels through an explosive column is called the velocity of detonation. It is the most important property for selection of explosives. Velocity of detonation is specified by explosive manufacturers in their product literature. Usually these VOD values are based on the measurement in laboratories. However, the laboratory values do not match with the VOD measured in the hole. Evaluation of a blast design is carried out with the assumption that the explosives have performed as per the specifications, which may not be true in all cases. A reduction in the VOD will produce a reduction in the detonation pressure as well as in the availability of the shock energy of the explosive. It is important that the explosive detonates at its optimum rate and induces sufficient detonation pressure leading to good fragmentation. The VOD of an explosive can, therefore, be used as one of the indicators of its performance.

Here, to measure velocity of detonation (VOD) of emulsion explosive called ‘Kelvex 600’ and ANFO ‘Handitrap II’ VOD recorder instrument was used which is shown in Figure 3.9.

(a) (b) (c)

Fig. 3.8: (a) ‘HanditrapII’ VOD Recorder (b) Probecable-HT (c) Probecable-HT in hole

For measuring in hole explosive velocity of detonation Probecable – HT of 30 m in length is used. It is lowered at the bottom by wrapping on rock as shown in Figure 3.10 (b). Then, the Probecable-HT is connected with co-axial cable of 99 m at one end and the other end is to be connected to VOD recorder with BNC adapter. Before starting the measurement whole circuit is tested for any short circuit and low resistance problem. The instrument is remained switched on after blasting and then it is directly connected to computer to retrieve recorded data with computer software which is provided with the instrument.

On the blasting site velocity of detonation (VOD) was recorded for two blasts. The results will be shown in the chapter 4.

3.2.7 Blast videography

Visual identification of the flyrock and throw of the blast can be analyzed by Videography. We have recorded many videos of the blasts from safe distance to elaborate the blasting. Blast hole initiation sequence and blast direction was recorded in the videos. Many aspects have been understood after analyzing these videos, which helped to improve better blasting sense.

3.3 Experimental work carried out for Powder Factor Analysis of Baseline blasts & Experimental blasts.

In this section of field investigation, many blasts were analyzed. On the basis of many blasts carried out and geological data acquired from mines it is found that limestone deposits described in data is of two types thin and thick bedded. The average bed thickness of thick bedded limestone is 25cm to 1m.

3.3.1 Study of baseline blasts design

In this section, 16 blasts were conducted to analysis blast fragmentation with dominant blasting pattern. The holes are drilled in rectangular pattern. The blast hole has 7.3 m - 9.5 m of depth. In each blast hole booster explosive is placed for priming hole. Booster are Kelvex-600E, Kelvex PE' from Keltech energies ltd., which has 83 mm diameter and 2.78kg, 1 kg of charge. To give delay time at the bottom of the hole Amardet (DTH) of 250 ms, 450 ms are used. The hole is charged with combination of ANFO and emulsion explosive called Kelvex-PE, Kelvex-600E and Kelvex-500 from Keltech energies ltd. The hole is charged with explosive up to 5.2 m to 6.0m.It is filled with drill cuttings as stemming in order to minimize the risk of flyrock and improve breakage by prolonging the action of gas masses generated during the detonation of explosive material. Table 3.4 shows the blast hole parameters of all 16 blasts which were carried out to evaluate existing blasting fragmentation and powder factor.

As derived in the Table 3.4 in the existing blasting pattern burden and spacing are 3.5m and 5m respectively. Here spacing to burden ratio is 1.42. All the blasts carried out, have same geometrical parameters and different charge.

Table 3.4: Baseline blast parameters

Baseline blast																
Blast No.	**B-1**	**B-2**	**B-3**	**B-4**	**B-5**	**B-6**	**B-7**	**B-8**	**B-9**	**B-10**	**B-11**	**B-12**	**B-13**	**B-14**	**B-15**	**B-16**
No. of rows	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	1
No. of holes	14	14	16	10	10	16	10	10	14	10	14	10	10	10	16	12
Burden (m)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Spacing (m)	5	5	5	5	5	5	5.25	5	5	5	5	5.5	5	5	5	5
Hole length (m)	7.62	7.92	7.62	8.22	7.92	9.44	7.62	7.62	7.92	7.92	7.92	7.92	8.22	7.92	8.22	8.53
Subgrade Drill (m)	0.31	0.3	0.31	0	0	0	0	0.31	0	0.3	0.3	0.3	0.3	0	0.3	0.31
Bench height (m)	7.31	7.62	7.31	8.22	7.62	9.44	7.62	7.31	7.92	7.62	7.62	7.62	7.92	7.92	7.92	8.22
Stemming (m)	2.44	2.13	2.13	2.44	2.13	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44
Charge length (m)	5.18	5.79	5.49	5.78	5.79	7	5.18	5.18	5.48	5.48	5.48	5.48	5.78	5.48	5.78	6.09
Explosive per hole(kg)	34.92	34.92	35.28	36.05	32.8	40.43	32.5	32.5	32.67	32.5	33.21	35	37.5	35	30.62	35.83
Loading density(kg/m)	6.741	6.031	6.426	6.237	5.664	5.775	6.274	6.274	5.961	5.93	6.06	6.386	6.487	6.386	5.297	5.883
Total Explosive(kg)	489	489	494	360.5	328	647	325	325	457.44	325	465	350	377	350	490	430
Booster %	7.97	7.97	8.9	9.86	8.53	7.26	7.69	7.69	8.3	7.69	8.6	7.14	7.16	7.14	8.16	6.97
Rock broken (m^3)	1790.95	1866.9	2046.8	1438.5	1333.5	2643.2	1400.175	1279.25	1940.4	1333.5	1866.9	1466.85	1386	1386	2217.6	1726.2
Powder factor(m^3/kg)	3.662	3.817	4.143	3.99	4.065	4.085	4.308	3.936	4.241	4.103	4.014	4.191	3.676	3.96	4.525	4.014
PF (tonne/kg)	9.15	9.54	10.35	9.975	10.16	10.21	10.77	9.84	10.6	10.25	10.03	10.47	9.19	9.9	11.31	10.03

3.3.2 Study of Experimental blasts design

After evaluating and analyzing 16 blasts of baseline blast powder factor and fragmentation, there is need of more precise fragments for production. In order to optimize fragmentation and powder factor air deck spacer was altered. Here spacing to burden ratio is 1.42. Spacing and burden are important parameters and have immediate impacts on rock fragmentation in blast design. Excessive burden creates resistance to penetrate the explosion gases into the fracture and displace rock, and will also produce excessive vibration level. Small burden allows the gases to escape and push the blasted rock uncontrollably with high speed. Small spacing causes excessive crushing between the holes and superficial crater breakage. Excessive spacing results in inadequate fracturing between the blast holes which creates irregular faces with toe problems. Here, by reducing spacing adequate crushing of the holes will occur and the fragment size will be considerably reduced due to sufficient spacing between holes.

The results of size distribution are given in the next chapter. Table 3.5 shows the blasting parameters of the improved fragmentation.

Table3.5: Experimental blast parameters

Experimental blast	Solid decking									Air deck provided by wooden spacer						
Blast No.	**E-1**	**E-2**	**E-3**	**E-4**	**E-5**	**E-6**	**E-7**	**E-8**	**E-9**	**E-10**	**E-11**	**E-12**	**E-13**	**E-14**	**E-15**	**E-16**
No. of rows	2	2	1	2	3	2	2	2	2	3	2	2	3	2	2	2
No. of holes	14	14	10	13	12	15	15	14	11	13	16	8	9	12	14	12
Burden (m)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Spacing (m)	5	5	5	5	4.5	5	5	5	5	5	5	5	5	5	5	5
Hole length (m)	7.92	7.62	7.92	8.53	8.53	7.92	8.53	7.31	8.23	8.53	7.62	7.92	8.53	7.62	8.83	7.01
Subgrade Drill (m)	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0
Bench height (m)	7.92	7.62	7.92	8.23	8.53	7.92	8.53	7.31	8.23	8.53	7.62	7.92	8.53	7.62	8.83	7.01
Stemming (m)	2.44	2.44	2.44	2.74	3.05	2.44	3.05	2.44	3.05	2.44	2.44	2.44	2.44	3.04	2.44	2.44
Charge length (m)	5.48	5.18	5.48	5.79	5.48	5.48	5.48	4.87	5.18	6.09	5.18	5.48	6.09	4.58	6.39	4.57
Deck length (m)	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
Explosive per hole(kg)	32.73	28.37	32.27	32.25	34.72	34.9	37.73	30.85	27.54	33.46	31.94	27.5	30.33	27.5	34.52	27.5
Loading density(kg/m)	5.972	5.476	5.888	5.569	6.335	6.368	6.885	6.334	5.316	5.494	6.166	5.018	4.98	6.004	5.402	6.017
Total Explosive(kg)	458.34	397.22	352.78	458.34	416.66	513.9	452.78	432	303	435	511.12	220	273	330	483.34	330
Booster%	23.63	24.47	22.04	23.63	21.99	22.16	22.69	7.4	9.24	8.04	21.74	9.09	8.42	9.09	22.41	9.09
Rock broken (m^3)	1940.4	1866.9	1386	1872.3	1612.1	2079	2239.1	1790.9	1584.2	1940.5	2133.6	1108.8	1343.4	1600.2	2163.3	1472.1
Powder factor(m^3/kg)	4.233	4.699	3.928	4.084	3.869	4.045	4.945	4.145	5.228	4.46	4.174	5.04	4.92	4.849	4.475	4.46
PF (tonne/kg)	10.58	11.74	9.82	10.21	9.67	10.11	12.36	10.36	13.07	11.15	10.43	12.6	12.3	12.12	11.18	11.15

3.3.3 Image acquisition for fragmentation analysis

Fig.3.9: Scale for calibration purpose

After blasting photographs (Figure 3.9) of blasted muckpile were captured for fragmentation analysis. All the photographs were taken from the approximately same distances. 15-20 photographs were captured and photographs with good lighting condition were selected for fragmentation analysis.

3.4 Laboratory Investigation

In this section, different software and instrument were discussed which has been used in the laboratory such as Fraglyst for fragmentation analysis of photographs collected from the field, Blastware for analyzing the vibration data collected in the field work, Data acquisition suit for analysis VOD Recorder data, Pattern simulation software for analyzing the different firing pattern, Universal testing machine for measuring the compressive strength and tensile strength of samples collected during field work, Ultrasonic p- wave monitor for measuring p-wave velocity of samples collected during field work and Point load index tester for measuring point load index of samples collected during field work.

3.4.1 Fragmentation analysis with WG-Fragalyst 3.0 software

To analyze blasted rock fragments computer based software called ‘WG-Fragalyst 3.0’ is used. The software will accept a digitized image of a pile of fragments and perform a computerized analysis of the image for obtaining vital size and shape related information of visible fragments. Fragment analysis is the task of calculating the diameter, volume, weight, spherocity and shape-factor of the various fragments present in the image of a particular muck of the current blast. To generate the above parameters, the system will perform various image-processing operations on the given image. Along with the standard image-processing functions the package will provide an intelligent editor to edit and fine tune the boundaries detected for the various fragments.

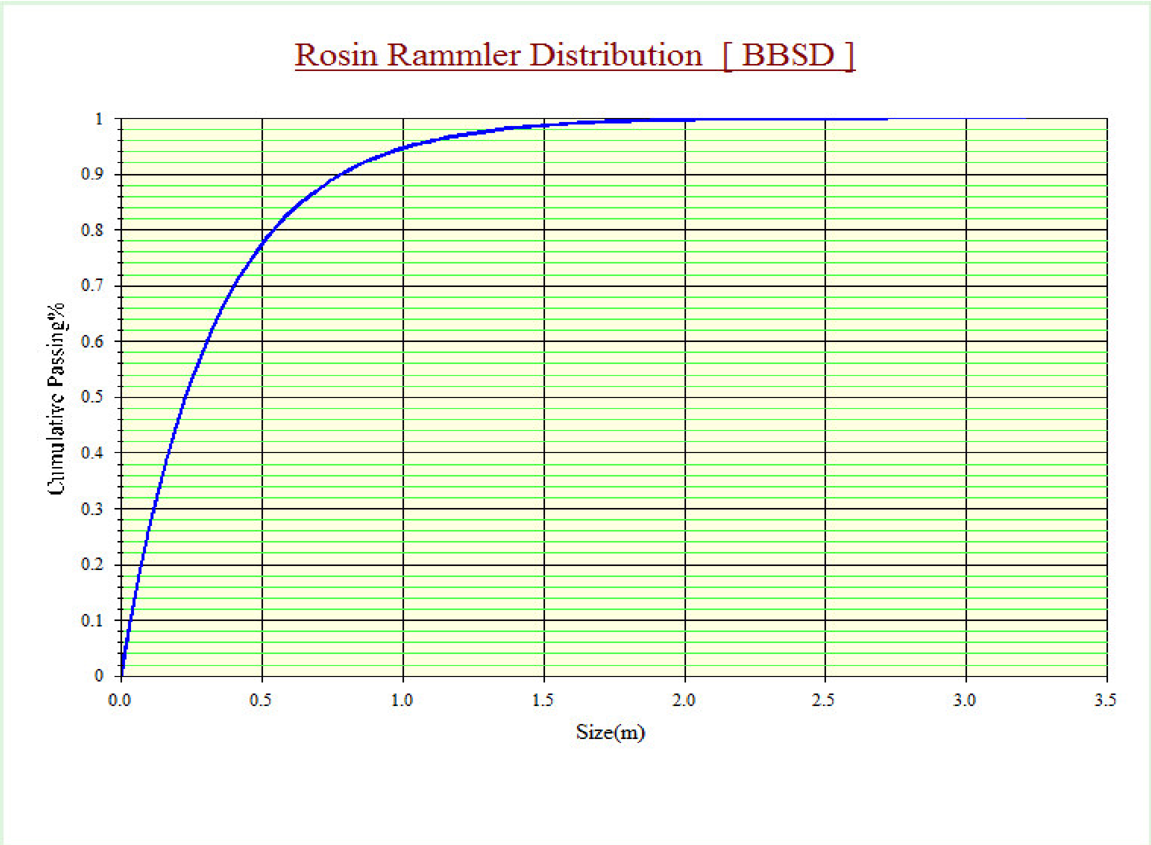

Fig.3.10: Size distribution diagram for blasted rock

The system will produce graphical results in the form of various distributions like the Rosin-Rammler curve and the Normal Distributions (Figure 3.10).

Here, many photographs were captured of blasted muck pile and they are analyzed by this software.

3.4.2Analysis of vibration data and noise level by Blastware software

This software is the analytical arm of seismograph ‘Blastware’ which was used during the field work for measuring the vibration data and noise level of different blast. At first, vibration and noise level readings were taken with the help of seismograph and then vibration results were retrieved through the Blastware software.

3.4.3Velocity of detonation (VOD) data analysis with data acquisition suit software

During blasts velocity of detonation (VOD) was recorded on instrument called ‘Handitrap II’. Subsequently recorded data was retrieved in the software and was analyzed with software to measure actual VOD in the hole explosive detonation. This software has facility to quantify different VODs by the charge length in any intervals. Whole charge length VOD can be measured in two different modes like two point method and linear regression method. The analyzed data will be shown in next chapter.

3.4.4Analysis of firing pattern by Pattern simulation software

Pattern simulation software used to evaluate various firing patterns and comparative study of different firing patterns can be done by this software. As we are using rectangular pattern of drilling and hole to hole delay firing pattern is used. Primary geometrical data are the only input for this software. Software has module to view blast hole explosion sequence in different time windows. Wave reinforcement diagrams have been generated which will be discussed in the next chapter.

3.4.5Measurement of p-wave velocity by p – wave monitor

The measurement procedure of Ultrasonic P-wave velocity of the limestone sample is shown below in Figure 3.11. The lower velocity of P-waves indicates the structural damage to the rock after blasting. The results will be shown in next chapter.

Fig. 3.11: P-wave monitor

3.4.6Measurement of compressive strength by universal testing machine

Figure 3.12 shows the universal testing machine for measuring the compressive strength. Sample collected from face is tested by this machine.

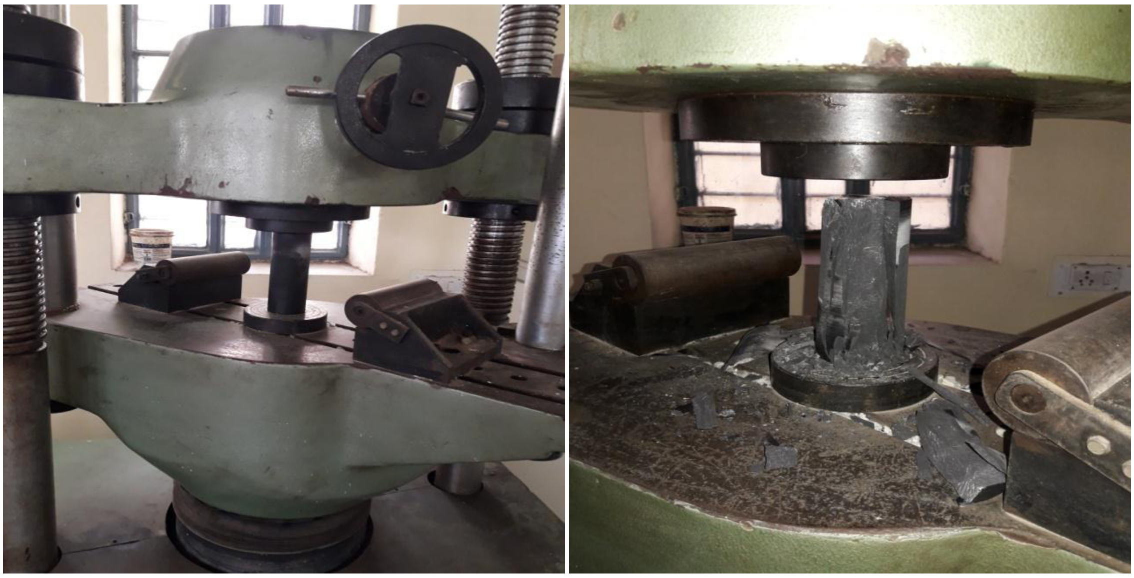

Fig.3.12: Universal testing machine

3.4.7Measurement of tensile strength by Brazilian test

Figure 3.13 shows the Brazilian test for measuring the tensile strength. Collected rock samples are tested on this machine to evaluate tensile property of the rock.

Fig. 3.13: Brazilian test

3.4.8 Measurement of point load index by point load index tester

In this measurement, samples were collected and the point load index was measured. The point load index was tested by the point load index tester as shown in Figure 3.14 and the result of measurement of point load index is given in the next chapter.

Fig. 3.14: Point load index tester

CHAPTER 4
RESULTS AND DISCUSSIONS

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RESULTS AND DISCUSSIONS

This chapter deals with the results analyzed from field investigation at JK cement Maliakhera limestone mine and laboratory work in computer laboratory and rock mechanics laboratory. Muckpile photographs captured were investigated by WG-FRAGALYST 3.0 software. Pattern simulation software was used to evaluate firing pattern. Ground vibration and noise level were recorded by Minimate^{TM} (BLASTWARE software) at the time of blasts. Velocity of detonation is also measured with 'HANDITRAP II' VOD Recorder. Mechanical properties of rock samples were tested in the laboratory are described in this chapter. This chapter mainly consists of five parts. In first part, the results of the existing blast fragmentation have been discussed. In second part, the results of experimental blasts have been discussed. In third part, the comparative discussion has been carried out for above both situations. In fourth part, results of ground vibration and noise level and VOD measurement were discussed. Also results of analysis of firing pattern by Pattern simulation were discussed. In fifth part rock mechanics laboratory test results were discussed.

4.1 Analysed Fragmentation of Baseline Blast and Experimental Blasts

To evaluate existing blasting 16 blasts observed at Maliakhera limestone mine and bench height, burden, spacing, hole length, explosive consumption and blast hole data collected during the blasts. After each blast, photographs were captured putting scale and then analyzed with WG-FRAGALYST 3.0.

To appraise each blast, 15 digital photos of blasted muckpile were taken and then selected on the basis of good light conditions. For each image, fragment size distribution curve was acquired with fragment size values of K25 to K98. During analysis these values were averaged per blast in order to produce what is considered to be an approximate representation of the size distribution of the material fragments within that particular blast.

Blasted block size distribution curve has been produced by the software on the basis of Rosin-Rammler distribution. The curve derives the size (mm) to cumulative passing % of the blasted fragments. Blasted size chart will also be produced by the software. The size K25 means 25 % fragments are finer and rests are coarser fragments. Uniformity index has also been acquired by this analysis. Uniformity index 0.50 is bad and 2 means very good. The primary crusher installed at JK cement accepts feed size as large as 1 m. Hence, optimum size of fragments should be in this criterion.

4.1.1 Analysis of mean fragment size K50, K25, K98

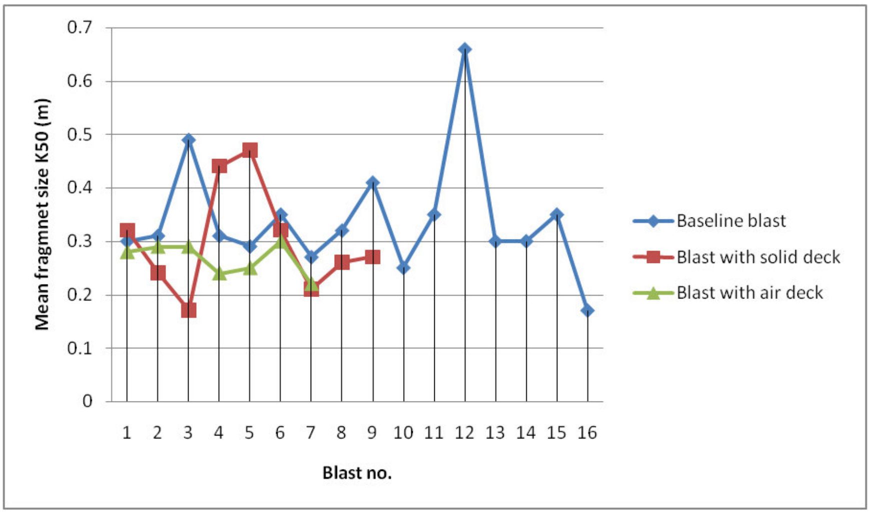

Fig.4.1: Analysis of mean fragment size (K50)

Figure 4.1 shows comparative fragment size distribution of blasted muckpile without deck, with solid deck and with air deck. Rock fragmentation size K50 is overall lowest in case of air decking. Decreasing K50 means the mean size of fragmentation decreases and it is desired.

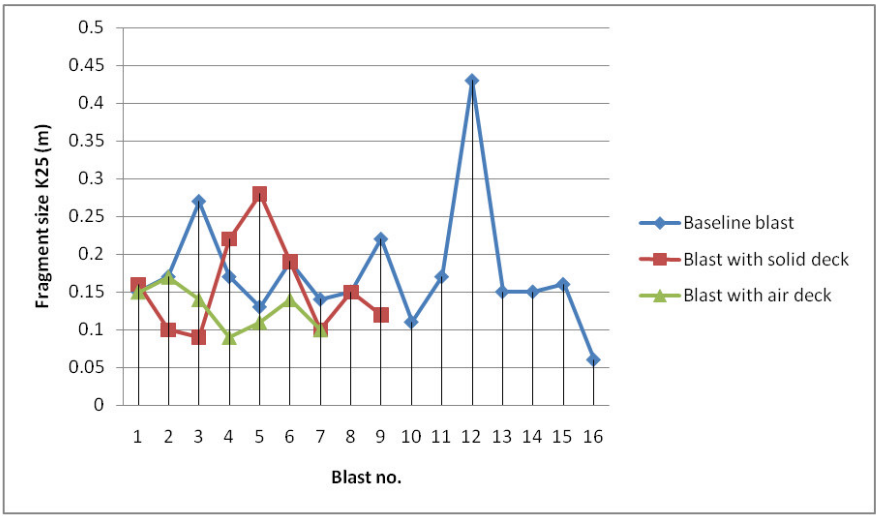

Fig.4.2: Analysis of fragment size (K25)

The results of fragmentation (K25) analysis are graphically shown in Figure 4.2. It is observed that the size (K25) decrease with air deck blasting. In case of solid deck the fragment size (K25) is between in air deck and without deck.

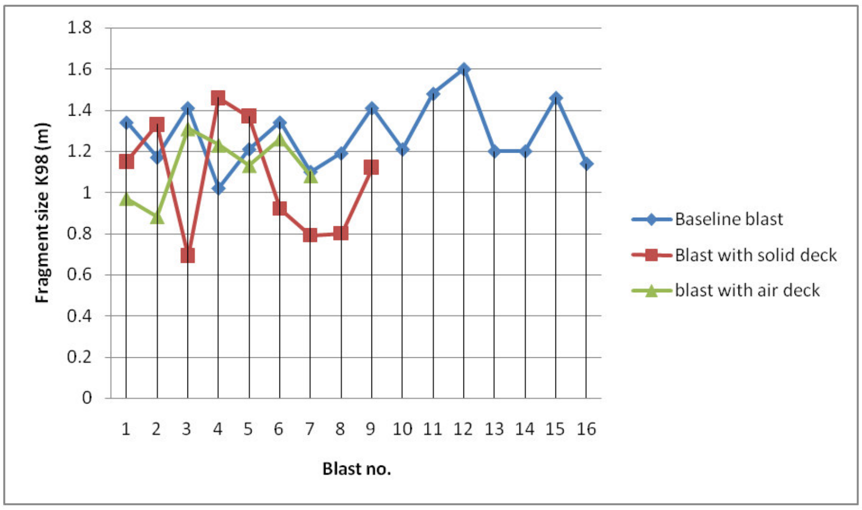

Fig.4.3: Analysis of fragment size (K98)

4.1.2 Analysis of oversize fragments

Size of rock fragments more than the primary crusher feed size is known as oversize. Oversize needs secondary breaking. The aim of any industry is produce minimum oversize so that need of secondary breaking is least. Figure 4.4 shows that the oversize fragment produces in blasting without deck, with solid deck and with Air deck.

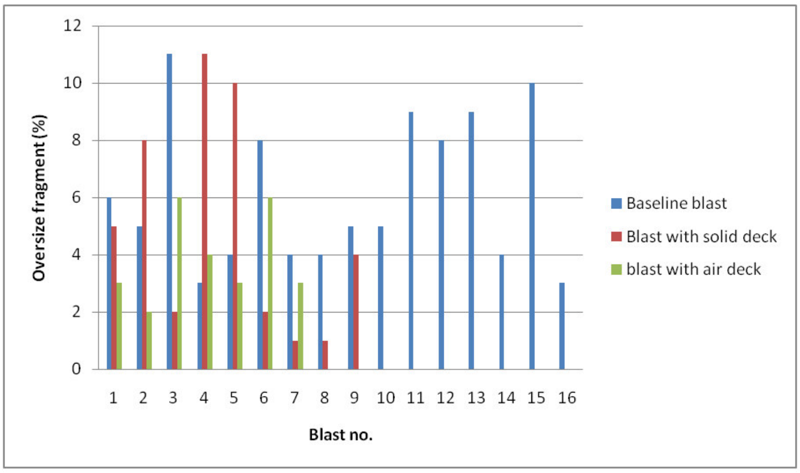

Fig.4.4: Analysis of oversize fragments (%)

It is evident from the fragmentation analysis that the oversize fragment generations are more in the case of without deck blasting as compare to solid deck blasting and air deck blasting. It was also observed that the oversize fragment (%) is least in case of air deck blasting.

4.2 Analysis of Powder Factor

Powder factor is the ratio between the amounts of rock broken and total weight of explosive consumed (tonne/kg or m^3/kg). Higher powder factor causes oversize and lower powder factor results into crushed rock. Figure 4.5 shows comparative powder factor (tonne/kg) of each blast with different charging practices includes without deck, solid deck and air deck blasting.

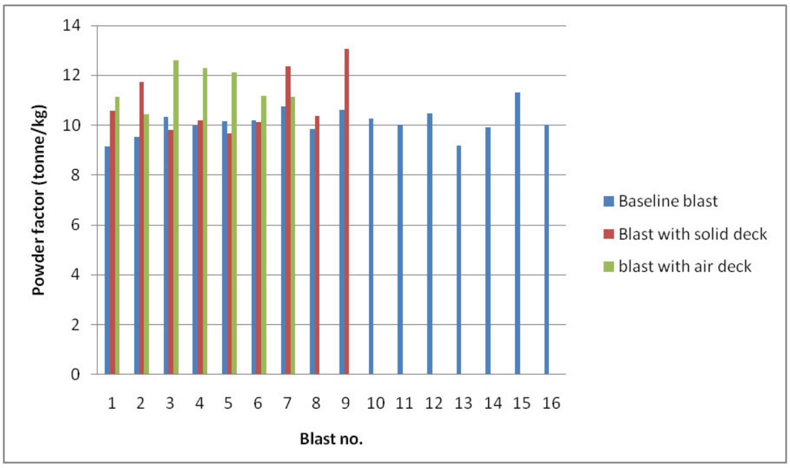

Fig.4.5: Analysis of powder factor (tonne/kg)

Figure 4.6 shows average powder factor without deck, with solid deck and deck provided with wooden spacers (Air deck). Powder factor is lower in solid deck blasting comparative to air deck blasting because in solid deck the column required more booster charge.

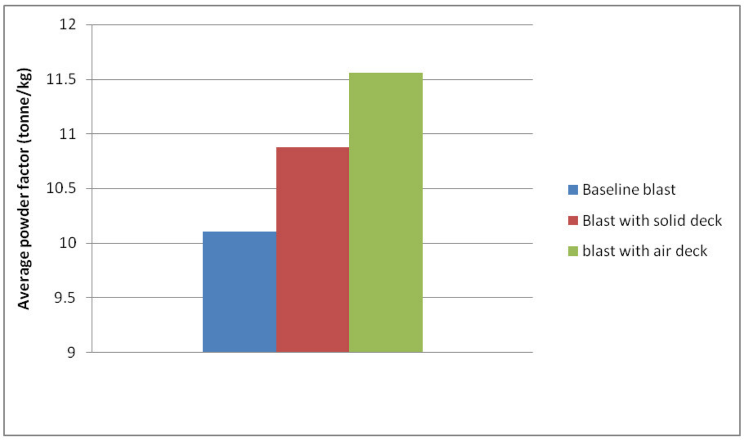

Fig.4.6: Analysis of average powder factor (tonne/kg)

4.3 Analysis of Energy Factor

Energy factor is the amount of the explosion energy required to break a unit weight or volume of material being blasted and expressed as MJ/t or MJ/m^3. This term is same as the powder factor, but explosives used other than ANFO has to be quantifying with energy factor. This factor fluctuates due to changes in type of explosives. It is representative of average explosive energy used per volume of rock. Following Table 4.1 shows the energy factor MJ/m^3 of each baseline and experimental blasts.

Table 4.1: Analysis of energy factor (MJ/m^3)

Baseline blast																
Blast No.	**B-1**	**B-2**	**B-3**	**B-4**	**B-5**	**B-6**	**B-7**	**B-8**	**B-9**	**B-10**	**B-11**	**B-12**	**B-13**	**B-14**	**B-15**	**B-16**
Energy factor (MJ/m^3)	0.99	0.95	0.87	0.91	0.91	0.91	0.86	0.95	0.87	0.91	0.91	0.87	1.02	0.93	0.82	0.93
Experimental blast																
Blast No.	**E-1**	**E-2**	**E-3**	**E-4**	**E-5**	**E-6**	**E-7**	**E-8**	**E-9**	**E-10**	**E-11**	**E-12**	**E-13**	**E-14**	**E-15**	**E-16**
Energy factor (MJ/m^3)	0.82	0.76	0.9	0.88	0.92	0.89	0.73	0.9	0.69	0.83	0.86	0.74	0.76	0.77	0.77	0.83

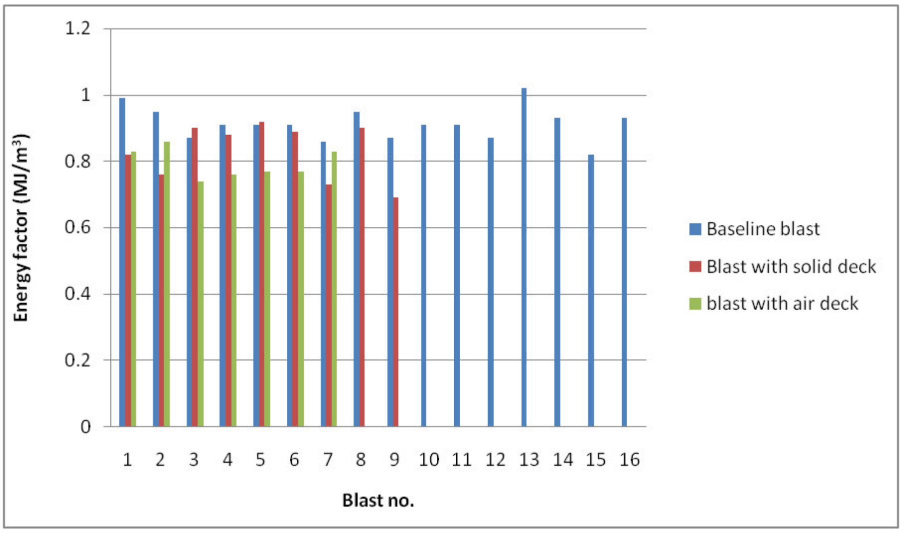

Fig.4.7: Analysis of energy factor (MJ/m^3)

The amount of energy consumed per volume of rock in the baseline blast is 0.82 MJ/m^3 to 1.02 MJ/m^3 and in experimental blast 0.69 MJ/m^3 to 0.92 MJ/m^3 Hence this reduction in energy factor means improving utilisation of explosive energy.

4.4 Analysis of Cost

In rock excavation, cost plays important role. Increase in costing in blasting operation has adverse effect in the mining operation. In this research work, blasting cost of the blasts performed has been evaluated. Here drilling cost consider constant for every blast.

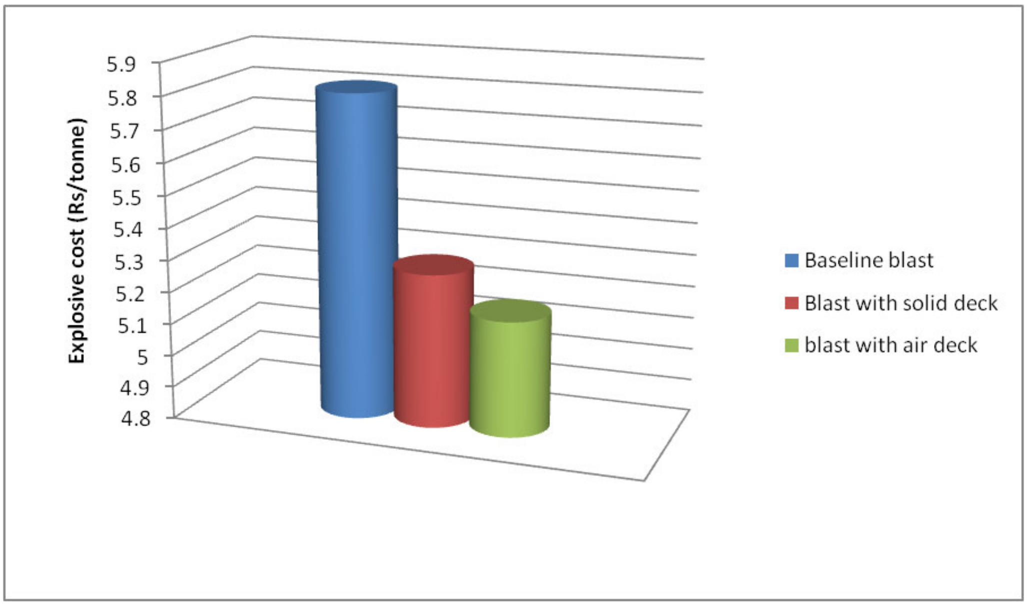

Fig.4.8: Analysis of cost (Rs/tonne) per tonne

As shown in Figure 4.8, cost of explosive (Rs/tonne) of rock broken used in blasting is lowest in case of air deck blasting followed by solid deck. By decking the total quantity of explosive used in a hole is reduced and improved charge distribution, hence the cost of explosive in case of air deck is lower than other.

4.5 Results of Ground Vibration and Noise Level and Flyrock

Ground vibration is measured by seismograph called Minimate^{TM} for 29 blasts conducted for this research work. Due to uncertain face condition and to maintain safe distance from the blast each recording distance has been changed in every blast. All the reading has been taken from the back side of the blast. Table 4.2 gives the result of ground vibration for every blast. The reports acquired from the blastware have been attached in appendix no. 33 to 60.

Table 4.2: Results of ground vibration and noise level

Baseline blast						Experimental blast			
Blast No.	PVS (mm/s)	Noise Level (dB(L))	Distance (m)			Blast No.	PVS (mm/s)	Noise Level (dB(L))	Distance (m)
B-1	3.33	115.6	250			E-1	1.13	100.0	400
B-2	2.76	112.0	300			E-2	1.38	114.0	300
B-3	2.13	109.5	250			E-3	1.76	124.1	350
B-4	1.03	100.0	350			E-4	1.41	118.1	250
B-5	2.97	112.0	250			E-5	2.49	109.5	300
B-6	3.25	122.9	250			E-6	2.17	121.6	250
B-7	3.59	106.0	250			E-7	1.14	123.5	200
B-8	4.06	109.5	225			E-8	1.76	123.5	300
B-9	2.67	106.0	350			E-10	2.27	109.5	350
B-10	1.79	109.5	350			E-11	3.32	115.6	250
B-11	3.38	120.0	250			E-13	5.49	109.5	250
B-12	2.22	112.0	300			E-15	4.6	115.6	250
B-13	4.16	106.0	250						
B-14	3.29	121.6	300						
B-15	1.52	114.0	400						
B-16	1.25	100.0	400						

Table 4.2 shows peak vector sum (PVS) of every blast is below the prescribed limit designated by DGMS. Though, in this research work all the blasts are under the permissible limit in the sense of ground vibration and noise level.

Excessive flyrock is rock that is projected beyond the normal blast-affected area. It is generated when there is too much explosive energy for the amount of burden, when stemming is insufficient, or when the explosive energy is rapidly vented through a plane of weakness. The flyrock may take place from the bench face or bench top. Here, during this study the flyrock observed is between 32 m to 108 m from the blast face and it seems that flyrock are under control.

4.5.1 Analysis of blast vibration data

The ground vibration data including peak particle velocity (PPV), distance of monitoring, explosive charge per delay for various blasts were analyzed for understanding the effect of ground vibration induced by blast at Maliakhera limestone mine.

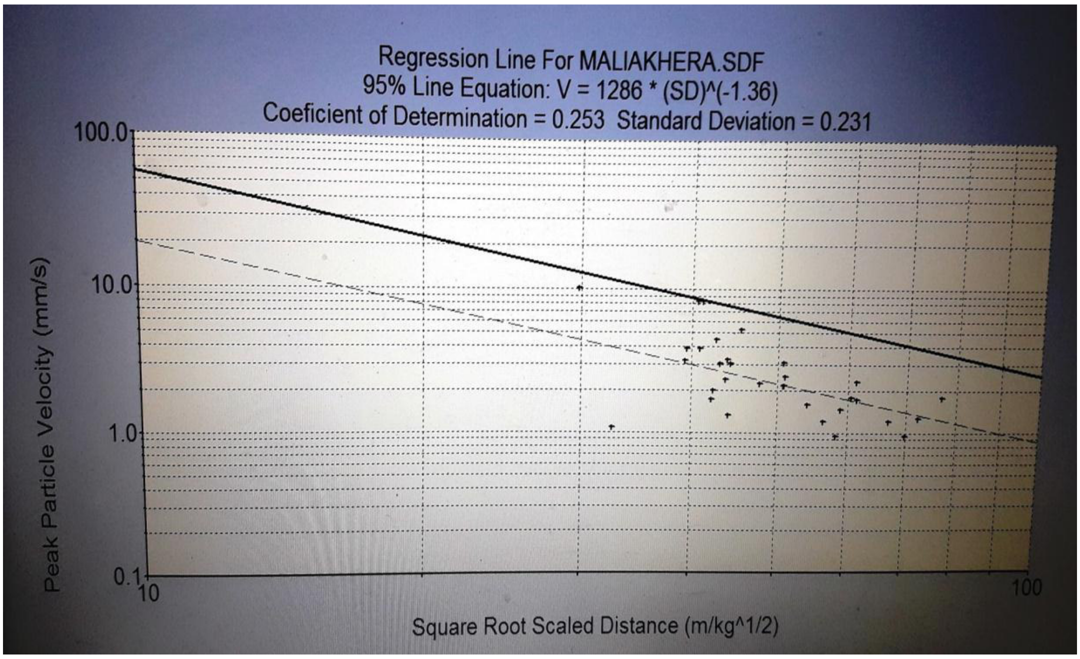

Fig. 4.9: Peak particle velocity versus scaled distance

The prediction of particle velocity requires that the average and upper bound values be well known. The 50% average line is the line about which the recorded data is gathered. The 95% prediction limit line is a line generated from the standard error and data distribution curve as shown in the Figure 4.9.

The following predictor equation in terms of scaled distance and PPV is found to represent the data, and proposed for utilization of safe charge per delay to keep vibration level within safe limit for Maliakhera limestone mines.

$$V = 1286* (\text{Scaled Distance})^{-0.1.36}$$

The ground vibration generated is related to the amount of charge per delay used in the blast holes. It has a critical value at which it gives the optimum output, amount more than that value will generate more ground vibration. This vibration generated can cause damage to the structures nearby. From the monitoring of ground vibration from a number of blasts the safe amount of charge per delay was determined. The safe charge per delay recommended to keep the vibration level below 10 mm/sec at various distances from the blast site is given in below Table 4.3.

Table 4.3: Safe charge per delay at various distances for 10 mm/s vibration level

Distance (m)	Safe charge per delay (kg)
100	7.72
150	17.4
200	30.9
250	48.2
300	69.4
350	94.5
400	123.0
450	156.0
500	193.0

4.5.2 Analysis of Flyrock

(i) Flyrock is caused by mismatch of the distribution of explosive energy, type of confinement of the explosive charge, and mechanical strength of rock. We conducted Blast videography of many blast to access the range of flyrock. For measuring distance red flags was kept horizontally known distances. Flyrock measurement by blast videography and visual measurement the maximum flyrock lies in the range of 60 m to 140 m.

4.6 Analyzed firing pattern with Pattern simulation software

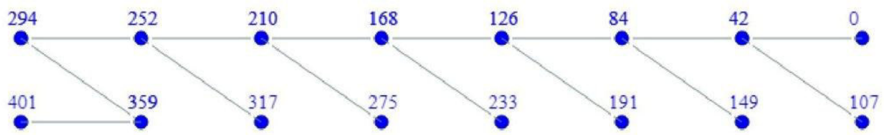

Fig.4.10: Diagonal pattern (cumulative delay)

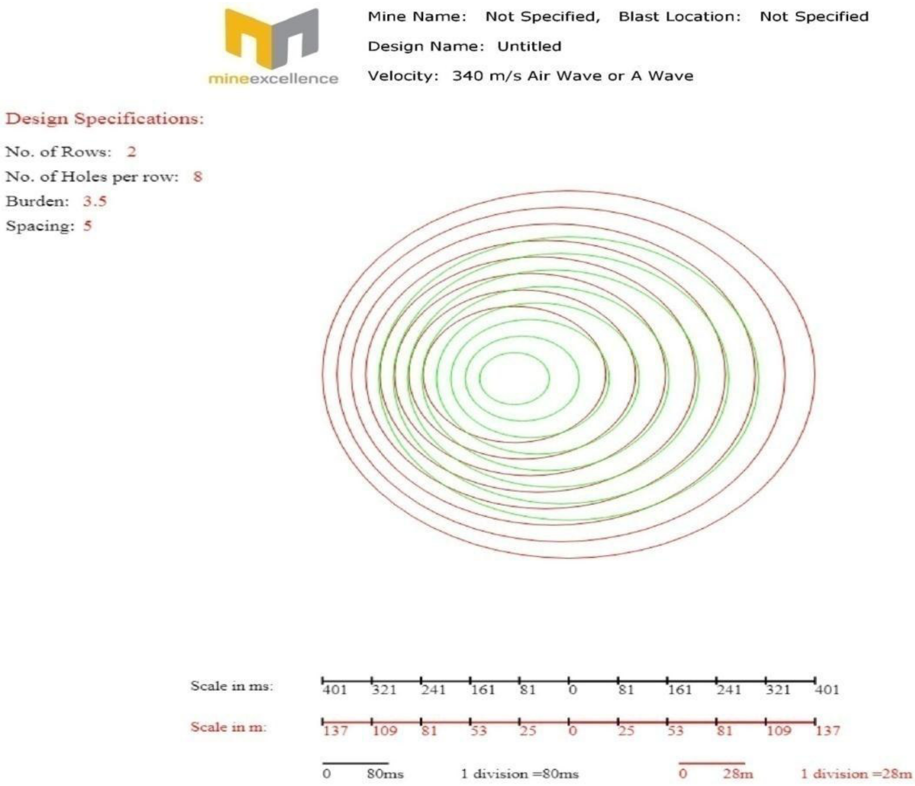

Fig.4.11: Wave reinforcement diagram of air wave

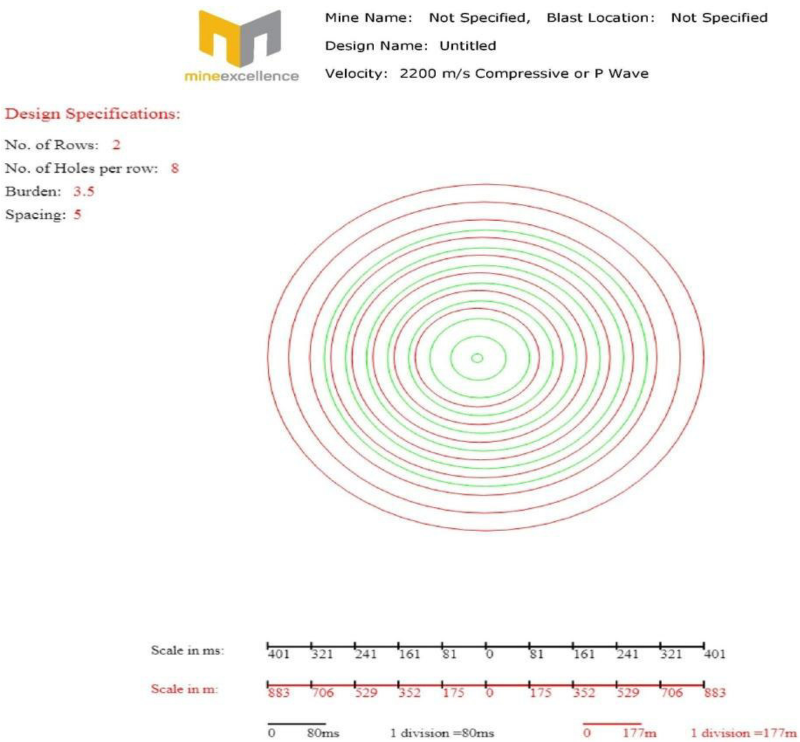

Fig.4.12: Wave reinforcement diagram of compressive wave

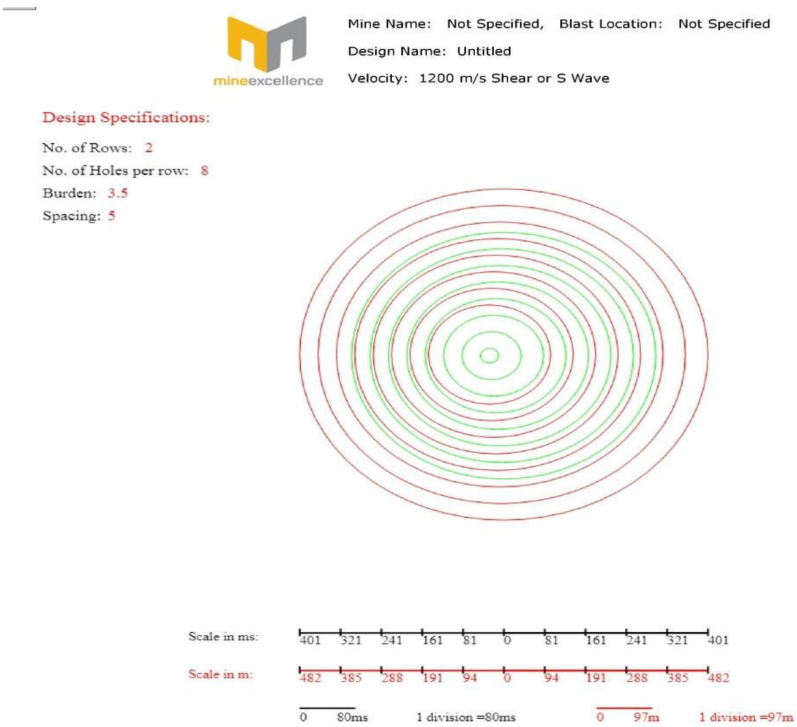

Fig.4.13: Wave reinforcement diagram of shear wave

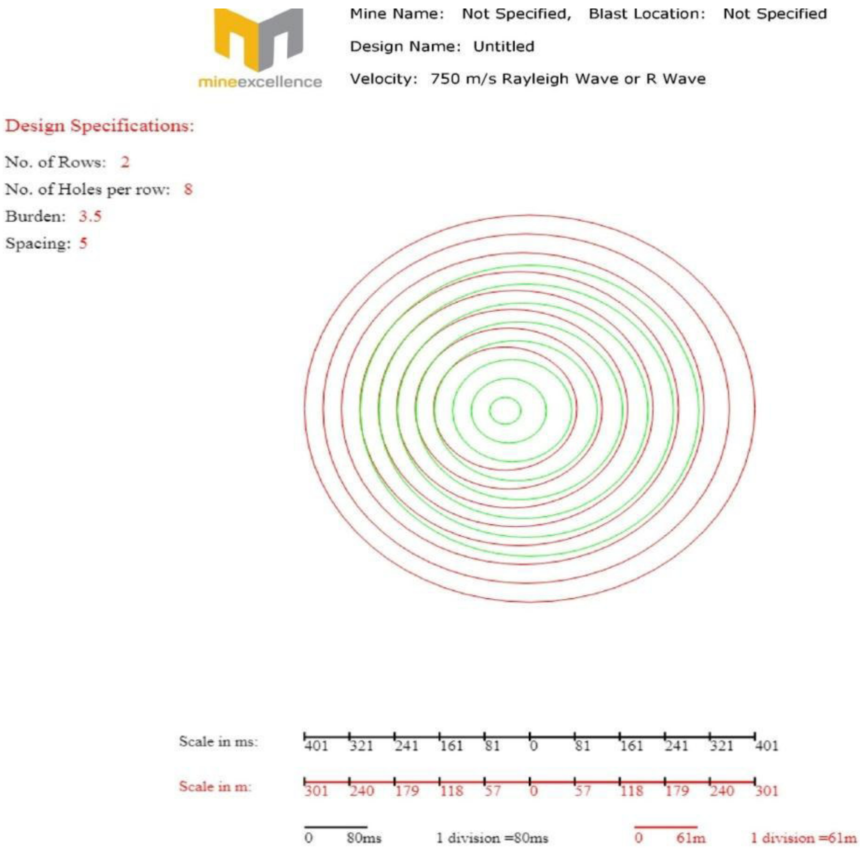

Fig.4.14: Wave reinforcement diagram of Rayleigh wave

The reinforcement diagrams (Figure 4.11 to 4.14) shows that the air wave, compressive wave, shear wave and rayleigh wave, all waves are divided with respect to row of hole. Green colour and red colour of diagram indicates the first row and second row of holes of firing pattern respectively. Overlapping of waves indicates that each hole has not fired separately. It is because all the holes of the rows were blasted at the same time. Though waves generated is intersecting each other. These waves are major cause of induced ground vibration.

4.7 Results of Velocity of Detonation Recorded by VOD Recorder

Velocity of the explosive column has been recorded two times during the blasts. For the measurement of velocity of detonation 'Handitrap II' instrument was used with its accessories. The parameter and results of VOD have been given in the Table 4.4.

Table 4.4: VOD measurement parameters

Parameters	VOD blast-1		Parameters	VOD blast-2
Hole diameter	115 mm		Hole diameter	115 mm
Hole depth	8.2 m		Hole depth	6.70 m
Charge length	5.2 m		Charge length	3.70
Angle of hole	inclined		Angle of hole	inclined
Stemming	3.0 m		Stemming	3.0 m
Wrapped on rock	4.3		Wrapped on rock	5.0 m
Probecable-HT placed	8.2 m		Probecable-HT placed	6.70 m
Primer placed	8.2 m		Primer placed	4.4 m
VOD (m/s)	4020		VOD (m/s)	4224.0 m/s

Probecable-HT is wrapped on the rock up to 4.3 m in VODblast-1 and 5m in VOD blast-2. This rock is placed at the bottom of the hole and the primer is placed above in VOD blast-1 and this rock is placed 2.3 m below primer in VOD blast-2 to record proper VOD of the blasts.

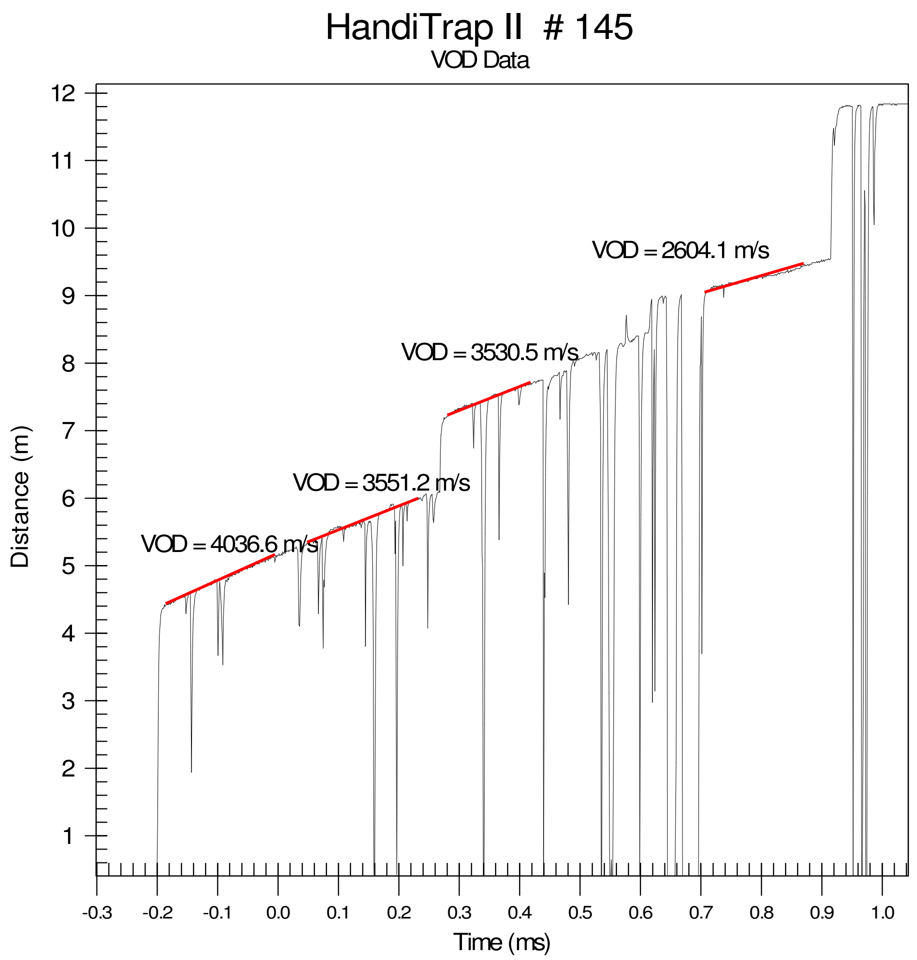

Fig.4.15: VOD blast-1 graph

In VOD blast-1 VOD recorded at bottom of hole is 4020 m/s. It found to be low because hole bottom is not properly cleaned and consist some drill cutting, hole is full of fracture/ cracks which resulted drop in VOD. Above Figure 4.15 shows at the initiation of booster at 4.3m to 5.3m VOD was 4020.4 m/s. Then at the length 5.5 m to 8 m, it decreased to 3550 m/s. At the end from 8.5 m to 9.5 m near stemming VOD is decrease up to 2600 m/s.VOD recorded near stemming were low because contamination of stemming material with explosive.

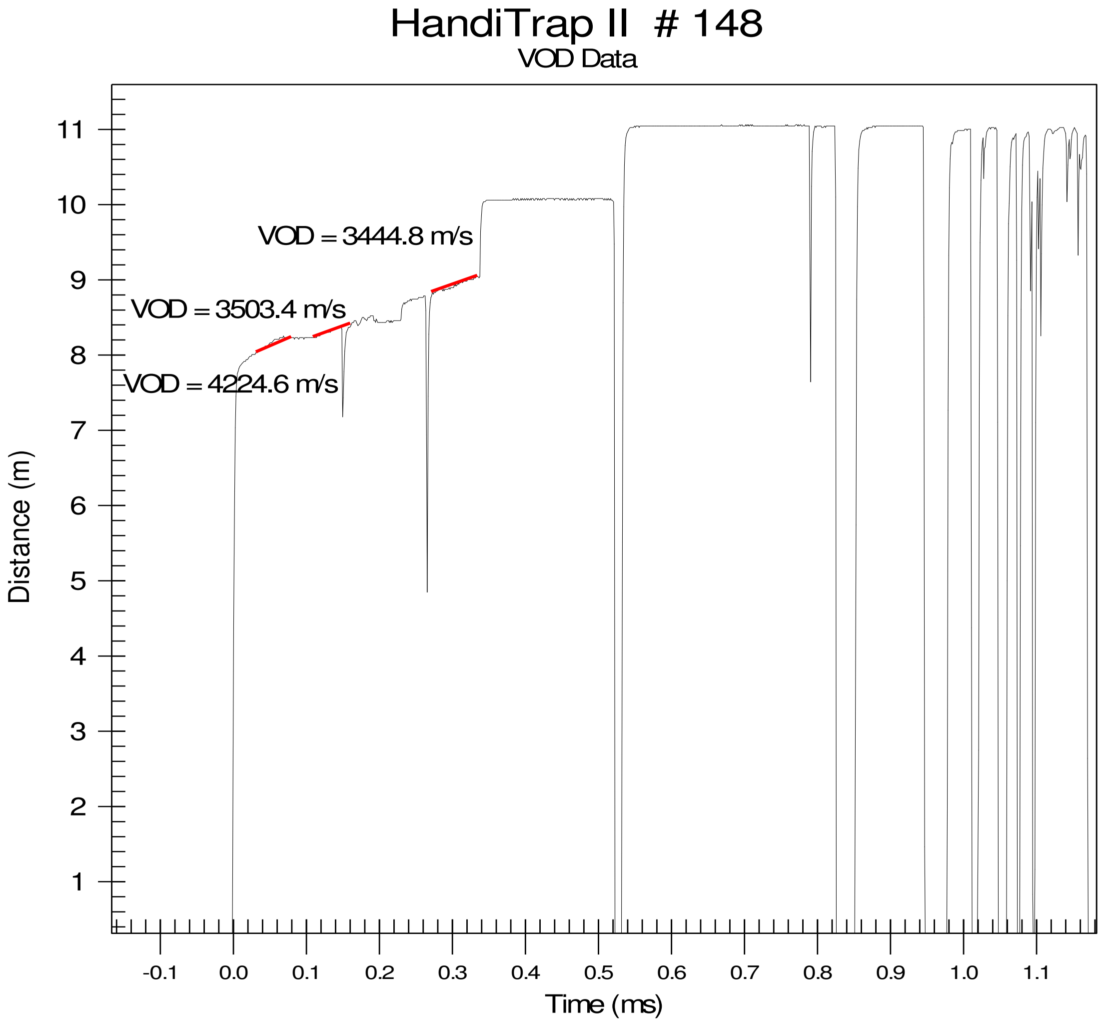

Fig.4.16: VOD blast-2 graph

In the VOD blast-2 explosive VOD was 4100 m/s near primer at 7.3 m to 8 m. It is found very well because the primer (Kelvex-600, 0.60 m) is placed middle of the blast hole. Figure 4.16 shows recorded VOD of explosives.. At the cable length from 7.3m to 8m VOD is 4224 m/s and at cable length of 8 m to 8.7m VOD got 3444.8 m/s. VOD is comparatively high near stemming area due to presence of booster charge.

Though, by examining both VOD blasts conclusion has drawn that at starting point VOD seems to be low in VOD blast-1. It is due to primer location. At the middle of the explosive column (ANFO with Kelvex booster) the VOD is 3500 m/s in both blasts. However in these tests explosive vod were evaluated and got fine results as per expectations.

The explosive used emulsion called 'Kelvex-600E' by the manufacture Keltech energies ltd. According to the description of manufacture, the claimed VOD of Kelvex-600E is 3800 to

4200m/s. As per results of VOD blast-1 and VOD blast-2 the VOD of emulsion tested on the field and claimed by the manufacture are same.

4.8 Results of Laboratory Investigation on Samples Collected From the Mine

Laboratory investigations were done on various samples collected from the mine. Various mechanical properties were tested in the laboratory work such as P-wave velocity measurement, compressive strength measurement, tensile strength measurement and point load index measurement.

4.8.1 Result of p-wave velocity

P-wave velocity measurement has been carried out in rock mechanics laboratory on the core sample of 54 mm. Results of testing are given in below Table 4.5.

Table 4.5: Result of p –wave velocity

Length of Sample (cm)	Time (µs)	P-Wave velocity (m/s)
14.1	22.5	6266
14.2	22.7	6255
23.0	37.2	6182

4.8.2 Result of compressive strength

The compressive strength measurement was carried out on samples collected from blasting site and results of laboratory testing are given in below Table 4.6.

Table 4.6: Results of compressive strength

L/D ratio of Sample	Compressive strength (Mpa)
2.6	76.62
2.6	75.25

4.8.3 Result of tensile strength

The tensile strength measurement was carried out on samples collected in the laboratory and results are given in Table 4.7.

Table 4.7: Results of tensile strength

L/D ratio of Sample	Tensile strength (Mpa)
0.5	5.69
0.5	5.14

4.8.4 Result of point load index

The point load index measurement was carried out on sample collected and results are given in Table 4.8.

Table 4.8: Result of point load index

L/D ratio of Sample	Point load index (Mpa)
1.85	2.51

4.9 Suitable Blast Design for Improving Powder Factor

By analysing fragment size distribution in blasted rock mass, powder factor, energy factor and cost of explosives it was observed that the higher powder factor and good rock fragmentation were achieved in case of air deck blasting practices followed by solid decking and continuous charging method. Charging of hole with air deck / solid deck length 0.60 m placed above 2/3rd from hole bottom gives optimum results. Table no gives various parameters to achieve optimum powder factor. Table 4.9 shows blast design parameters and figure 4.17 shows deck charging.

Table 4.9: Suitable blast design parameters

Hole diameter	115 mm
Burden (m)	3.5 m
Spacing (m)	5 m
Hole length (m)	8.4 m
Subgrade Drill (m)	0.3 m, Depending on blast direction
Bench height (m)	8.40 m
Stemming (m)	2.44 m
Air deck length	0.6 m
Explosive type	ANFO+ Emulsion/Slurry
Delay	DTH 250ms, 450 ms and TLD 17 ms,42 ms
Firing pattern	Diagonal

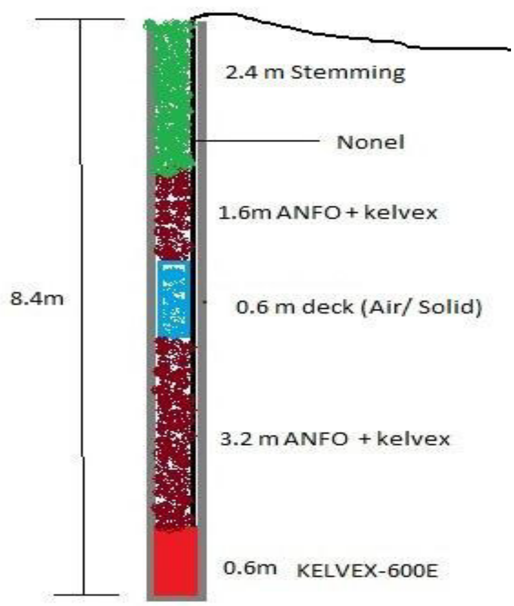

Fig.4.17: Deck Charing

CHAPTER 5

CONCLUSIONS AND RECOMMEDATIONS

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Rock fragmentation is always considered as the chief constraints in the blasting operation. Poor fragmentation has adverse effects on the downstream operation and cost of mining operation. In this research existing blasting pattern was evaluated and results were analyzed with image analysis software. Then experimental blasts were performed and the analyzed results were compared with existing blasts. Powder factor, mean fragment size and oversized fragments percentages were compared. Cost per tonne and energy factor of the blasts were also compared and following conclusions have been drawn from this research work.

5.1 Conclusions

(ii) Powder factor improved significantly in experimental blasts. It increased by 7.61% in solid deck blasting & 14.34% in case of air decking respectively compared to as continuous column charge blasting method.

(iii) Improvement in size distribution of blasted rock was observed. Mean fragment size K50 decreased in experimental blasts. Reduction in oversize 19.67% and 37% in solid deck and air deck respectively. Secondary breaking has been reduced and ensures the normal efficiency of the shovel loading compared to baseline blasting.

(iv) Cost of explosive reduced by 9.12% in solid deck and 11.18% in air deck blasting.

(v) Reduction in energy factor 8.77% in solid deck blasting and 12.93% air deck blasting.

(vi) Ground vibrations and noise level recorded during the blasts were under the permissible limit as prescribed by Directorate General of Mines Safety (DGMS), regulatory body of Government of India.

(vii) Flyrock measurement by blast videography and visual measurement the maximum flyrock lies in the range of 60 m to 140 m.

5.2 Recommendations

There are few areas that deserve attention for future work:

(i) To have better understanding of rock fragmentation and the factors influence it, we also need to know the size distribution of rock blocks before blasting for this purpose Investigation of geological and structural aspects such as effect of joints on the blast fragmentation may be carried out.

(ii) VOD monitoring can be carried to confirm whether detonation, deflagration or failure have taken place and to investigate the effective length of decking.

(iii) It is recommended to distribute the charge column in the hole according to hard/ soft bands.

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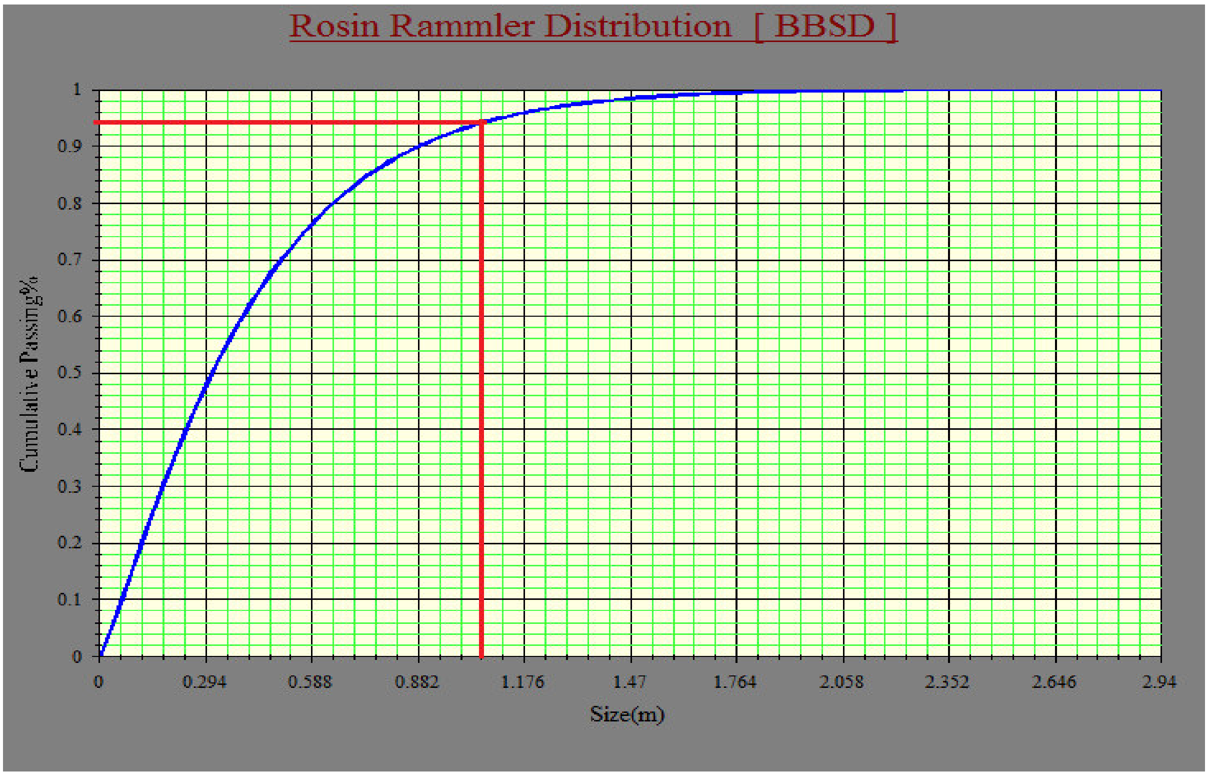
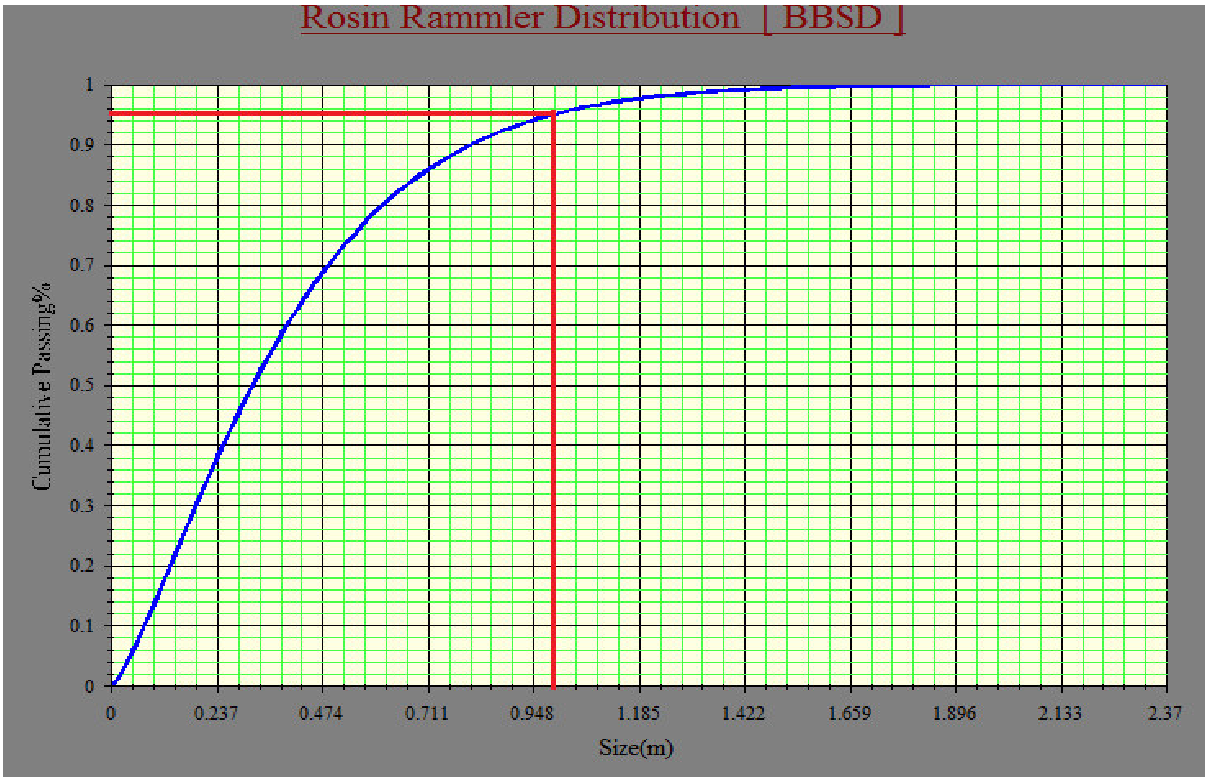
APPENDICES

APPENDICES-A

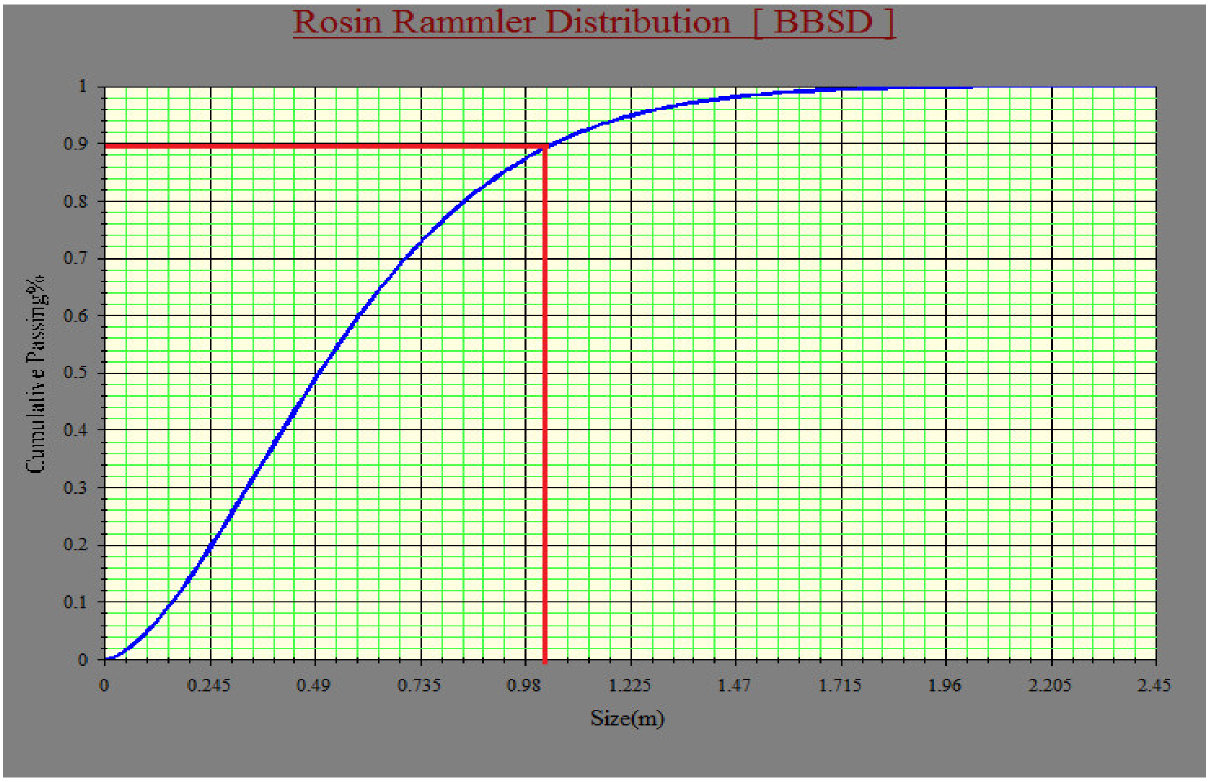
Appendix-1- Size distribution diagram for blast no. B-1



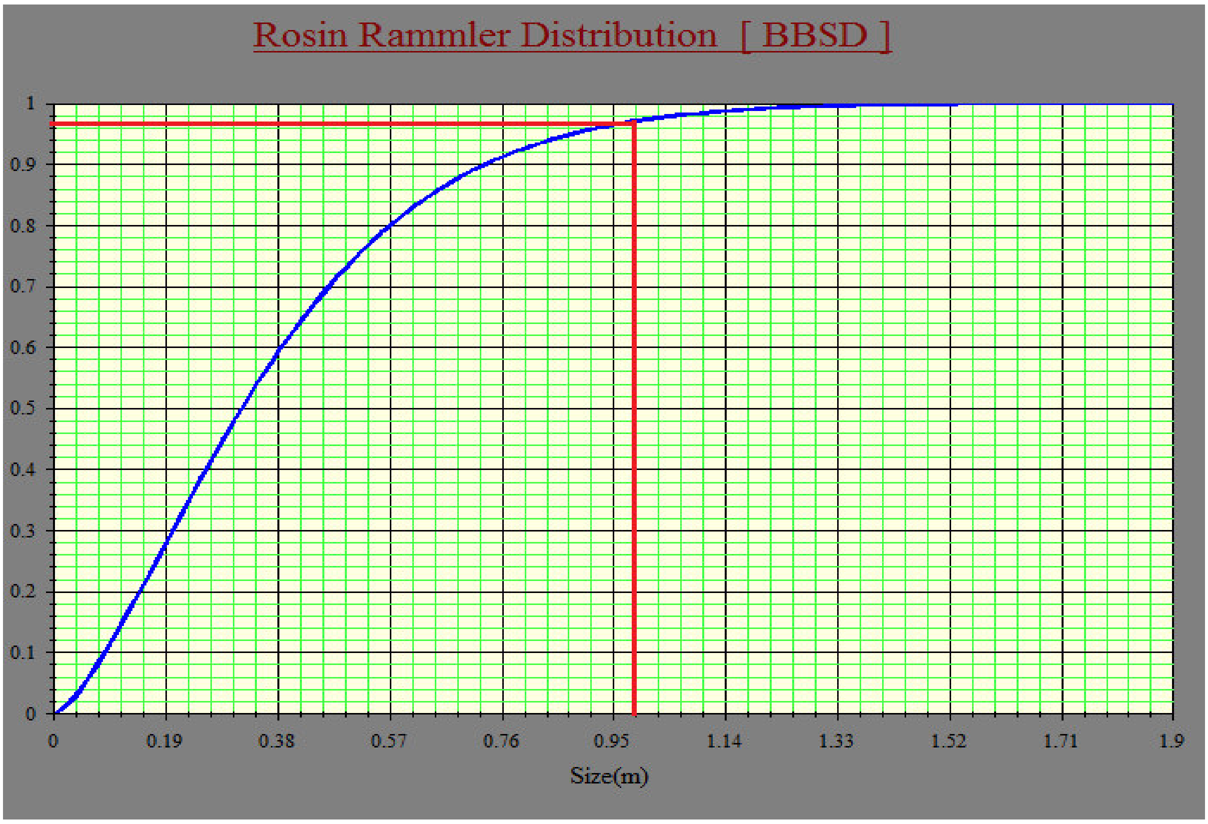
Appendix-2- Size distribution diagram for blast no. B-2



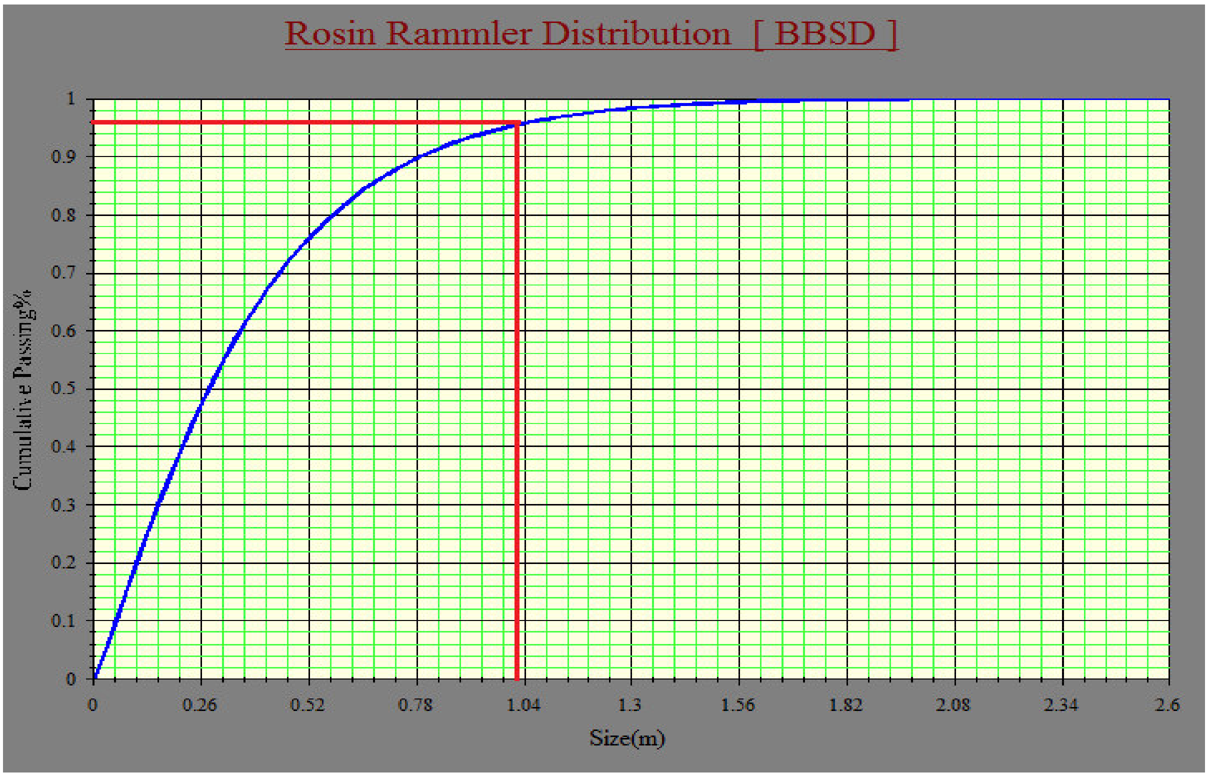
Appendix-3- Size distribution diagram for blast no. B-3



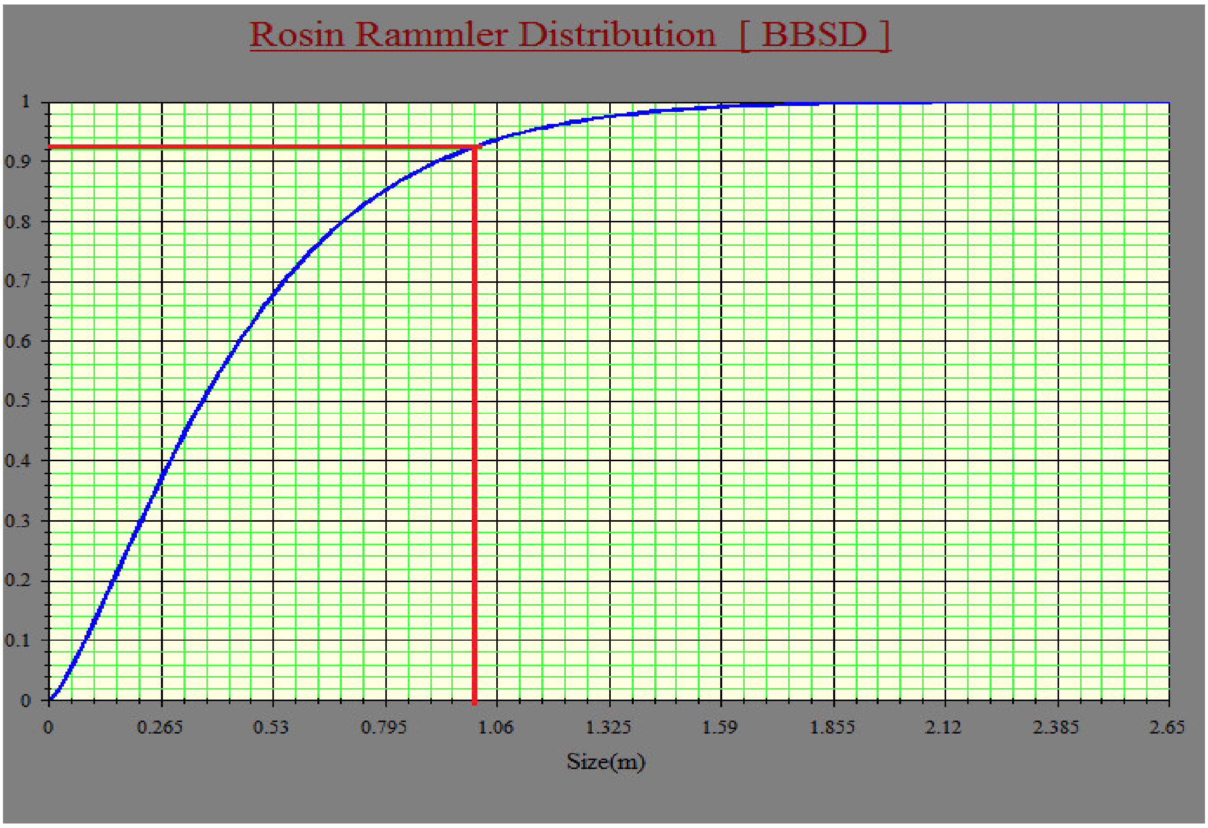
Appendix-4- Size distribution diagram for blast no. B-4



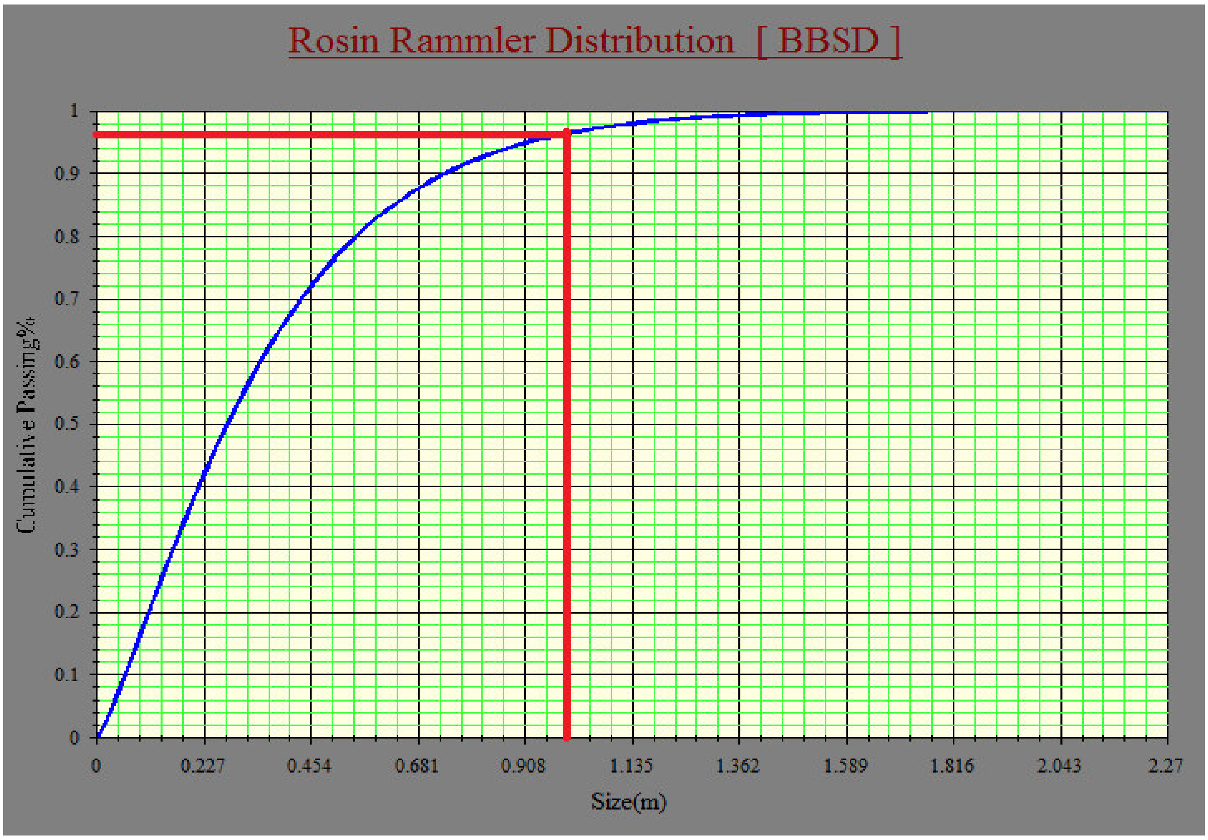
Appendix-5- Size distribution diagram for blast no. B-5



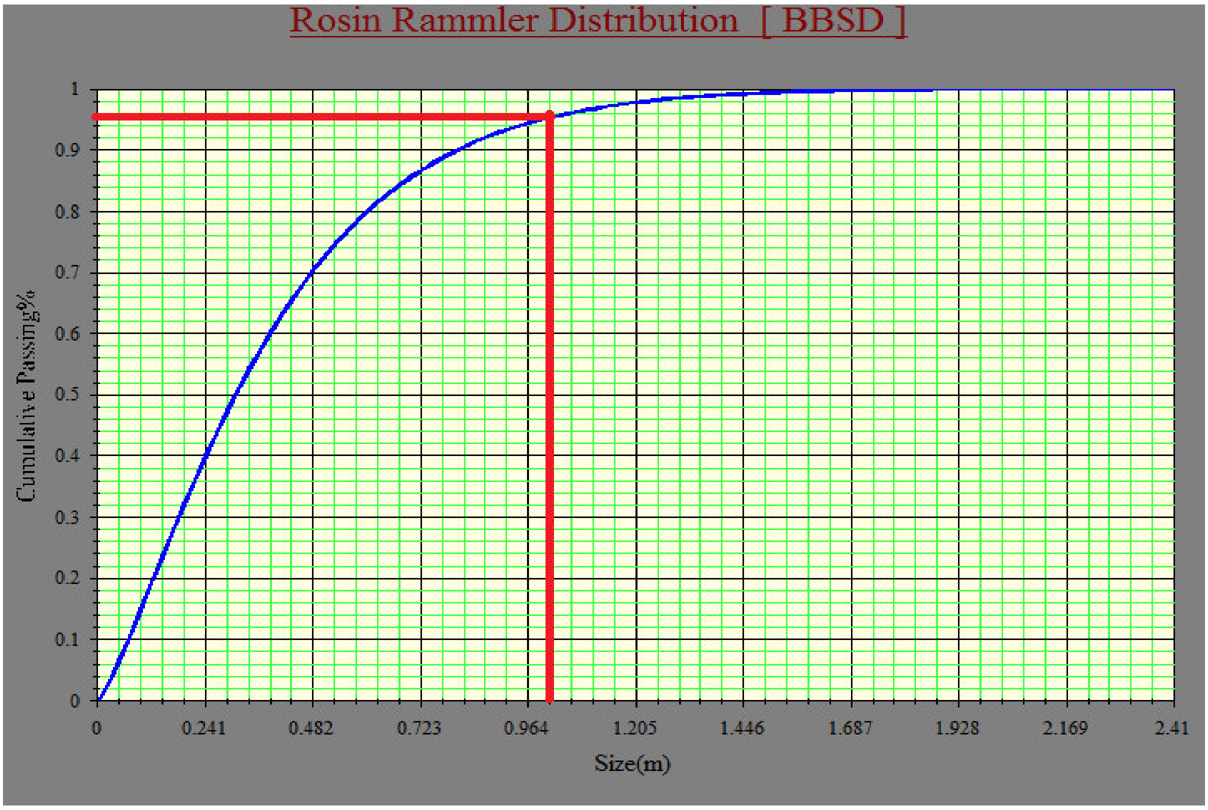
Appendix-6- Size distribution diagram for blast no. B-6



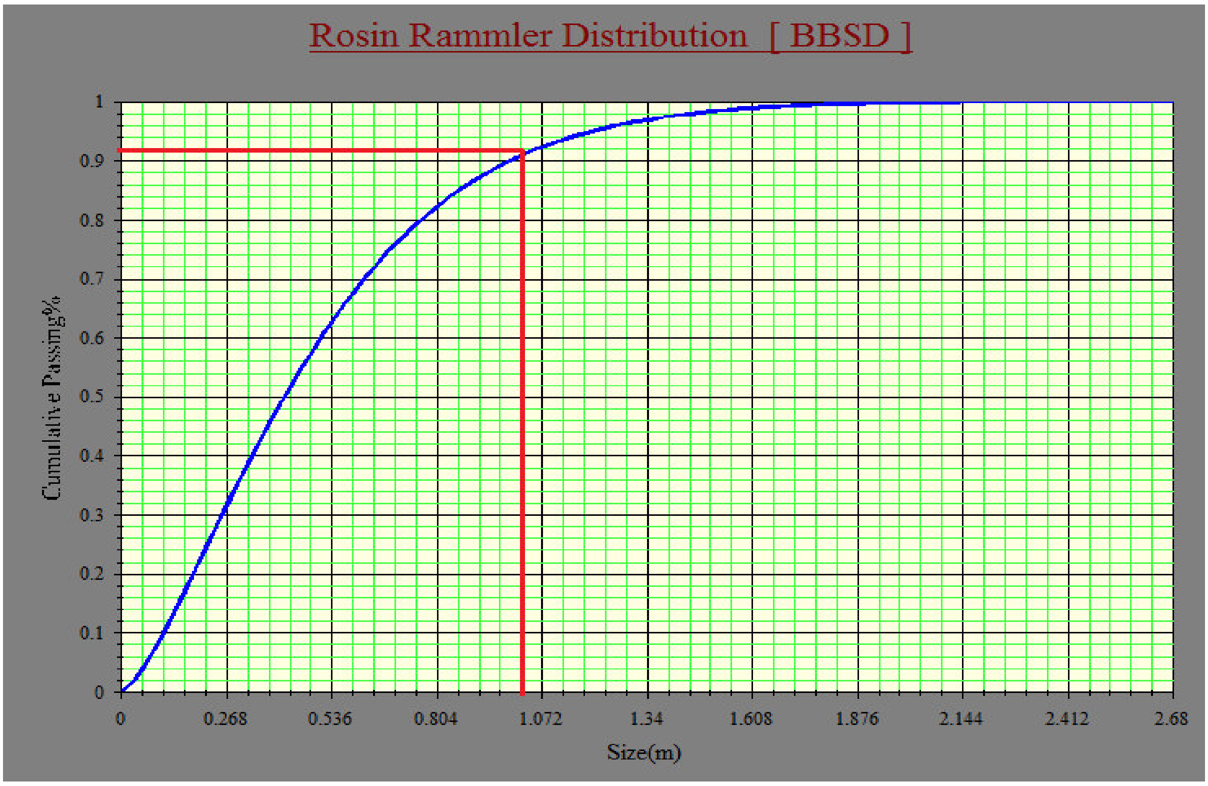
Appendix-7- Size distribution diagram for blast no. B-7



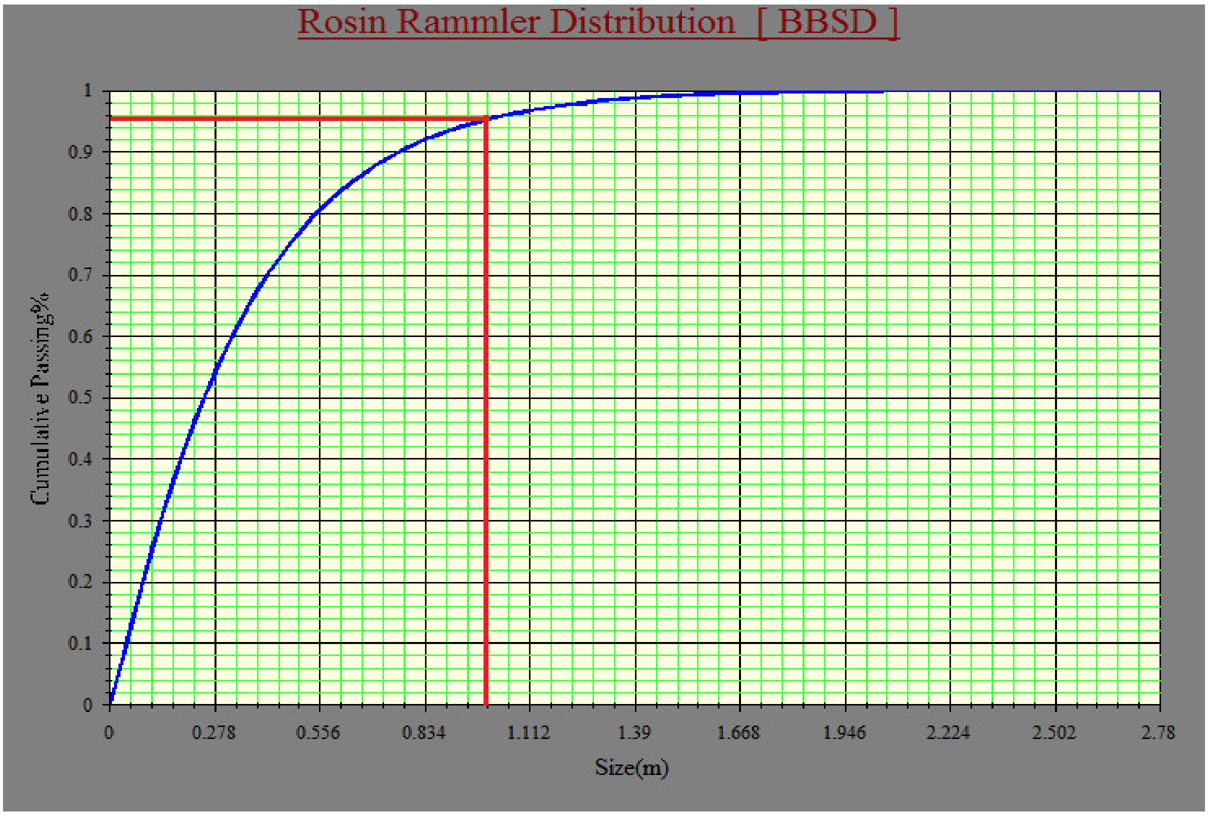
Appendix-8- Size distribution diagram for blast no. B-8



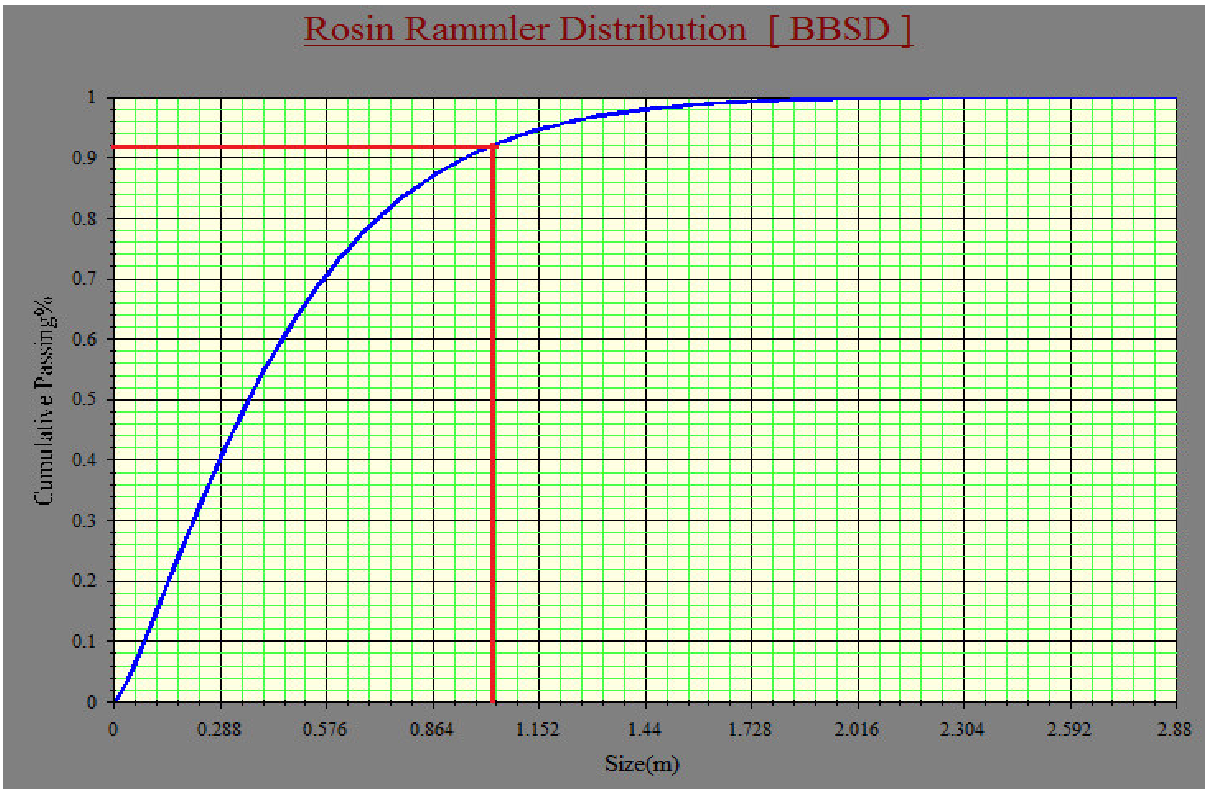
Appendix-9- Size distribution diagram for blast no. B-9



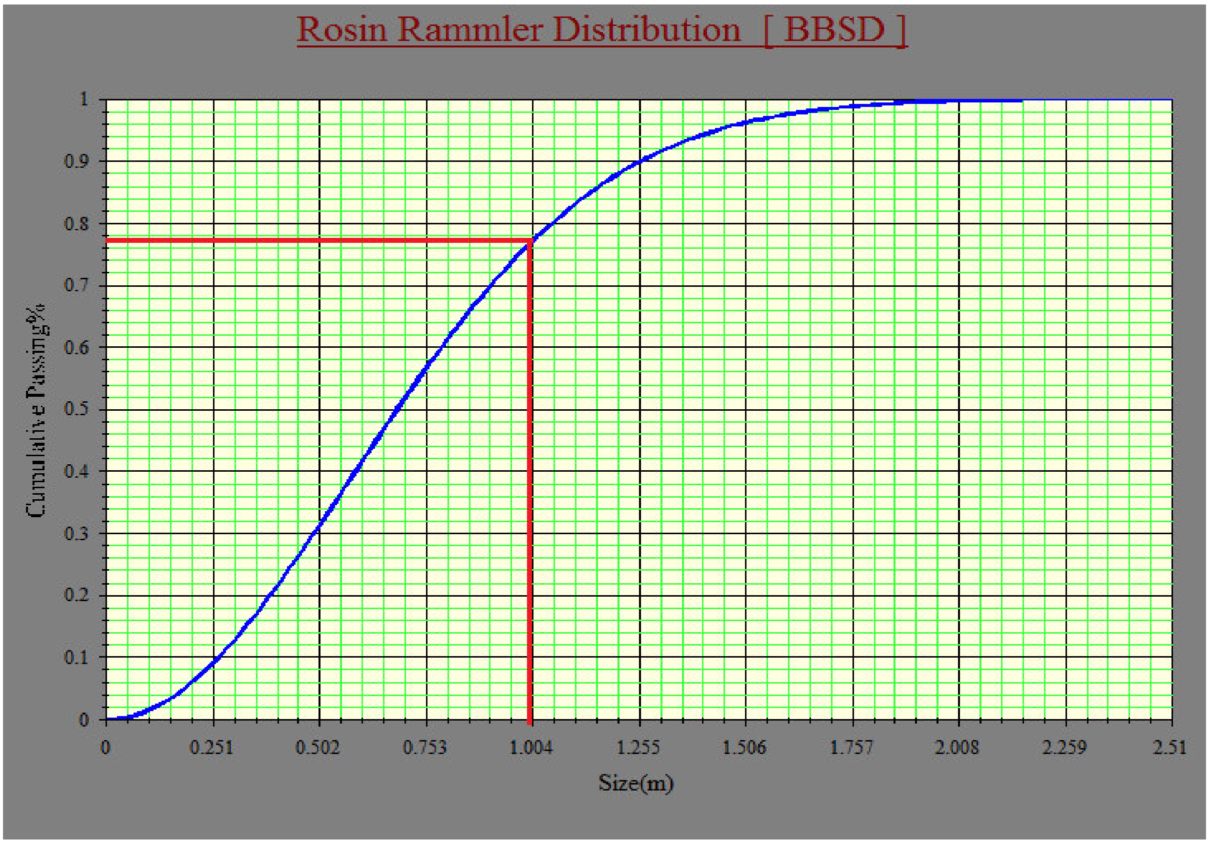
Appendix-10- Size distribution diagram for blast no. B-10



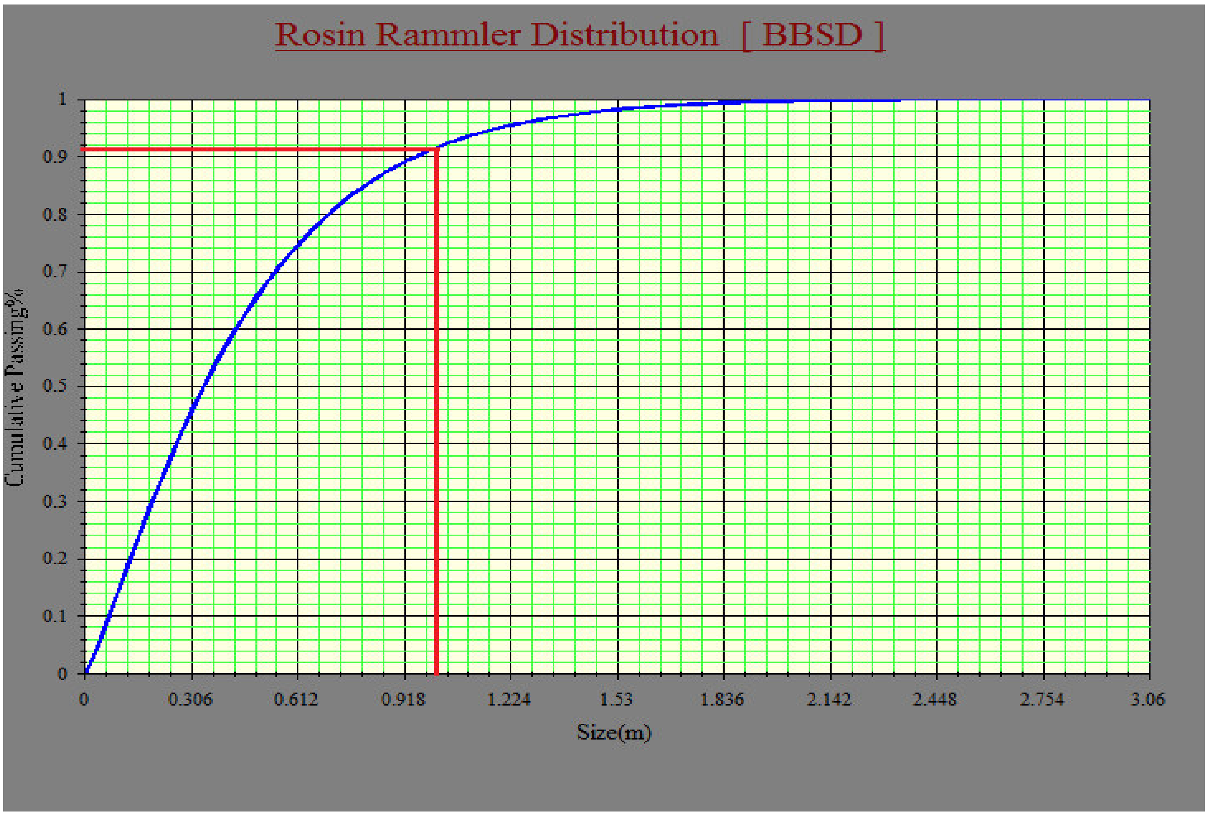
Appendix-11- Size distribution diagram for blast no. B-11



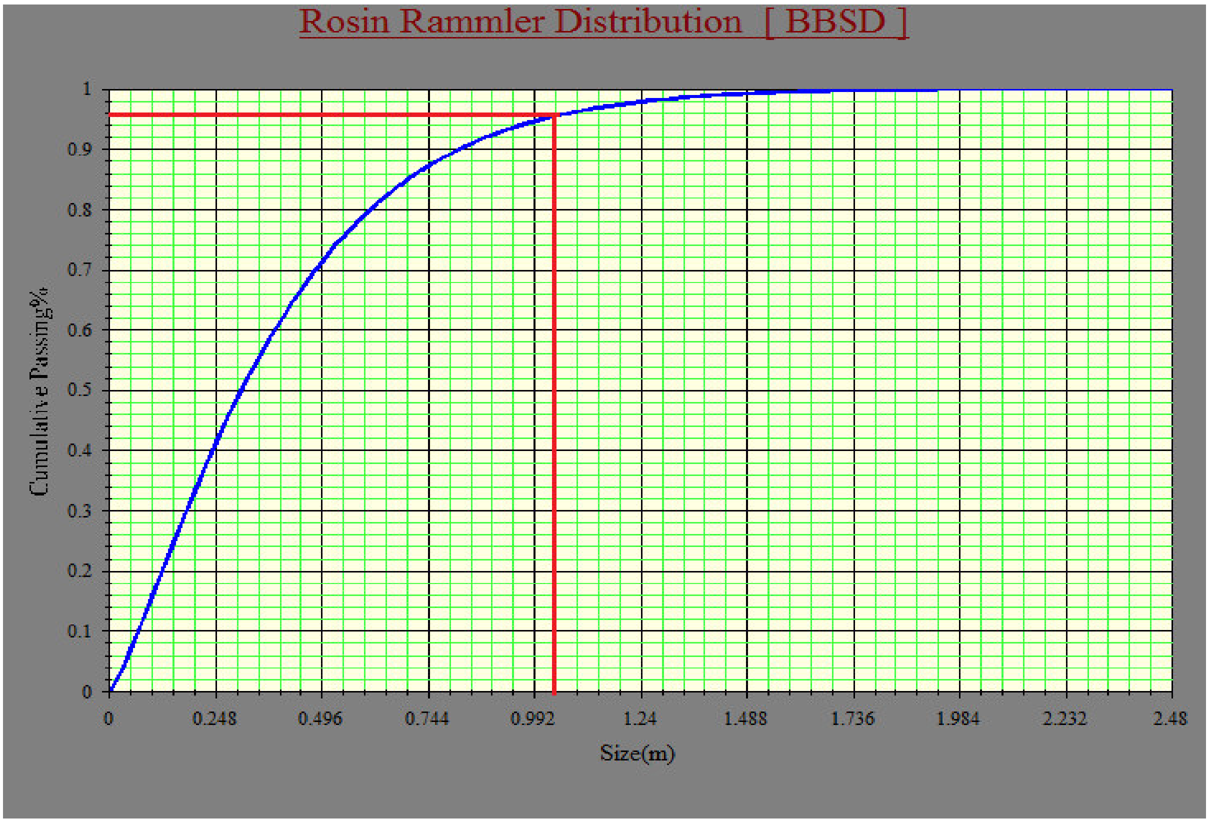
Appendix-12- Size distribution diagram for blast no. B-12



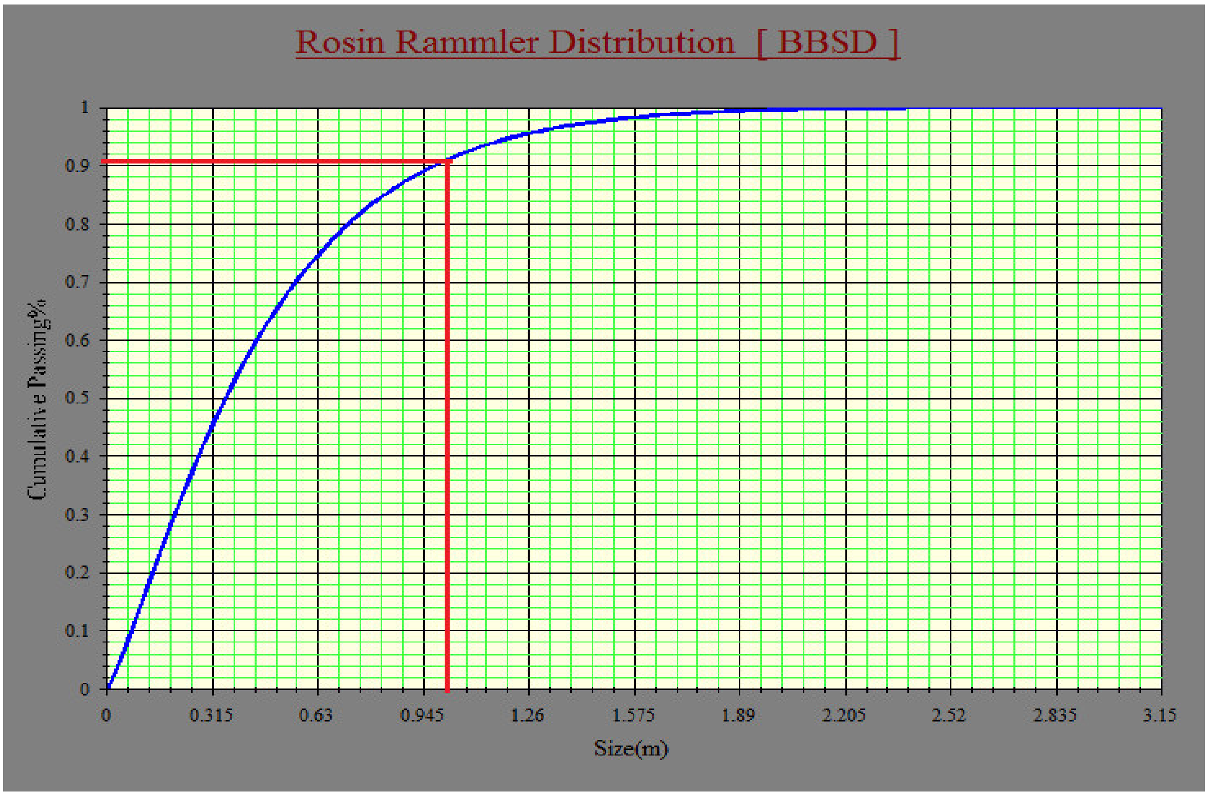
Appendix-13- Size distribution diagram for blast no. B-13



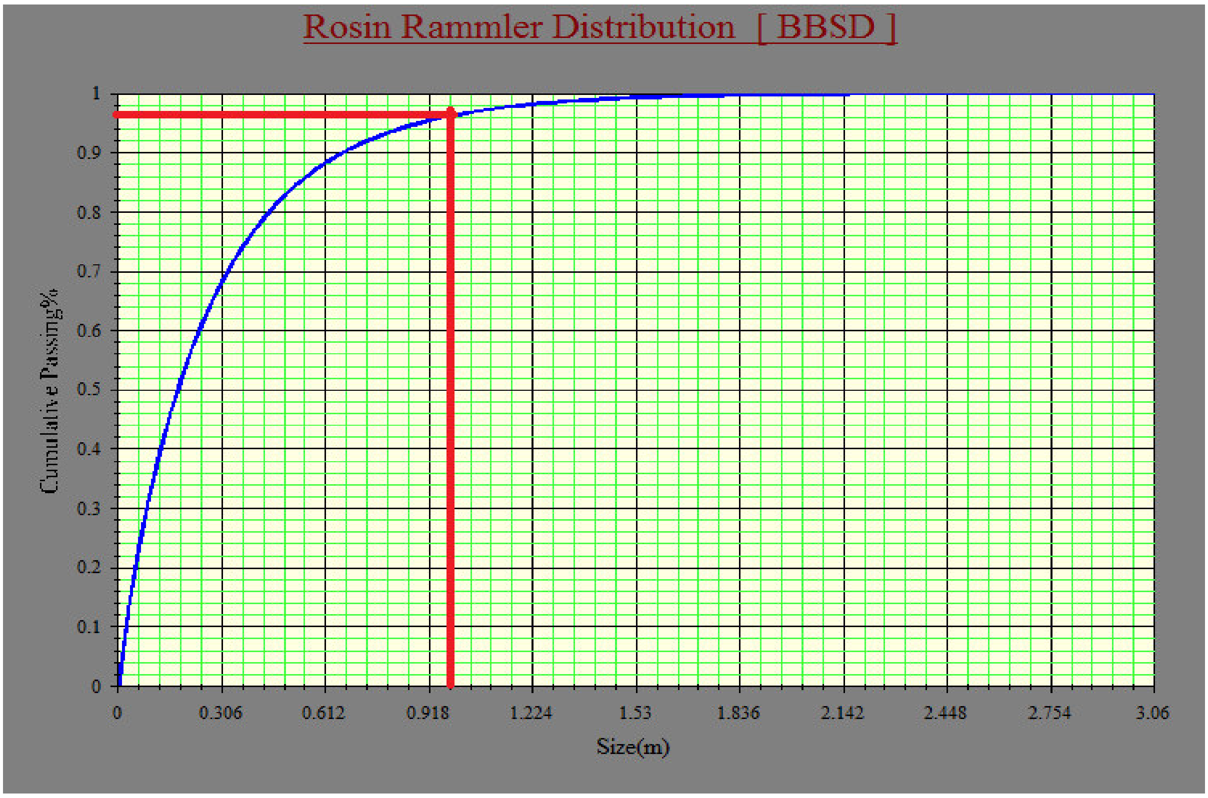
Appendix-14- Size distribution diagram for blast no. B-14



Appendix-15- Size distribution diagram for blast no. B-15

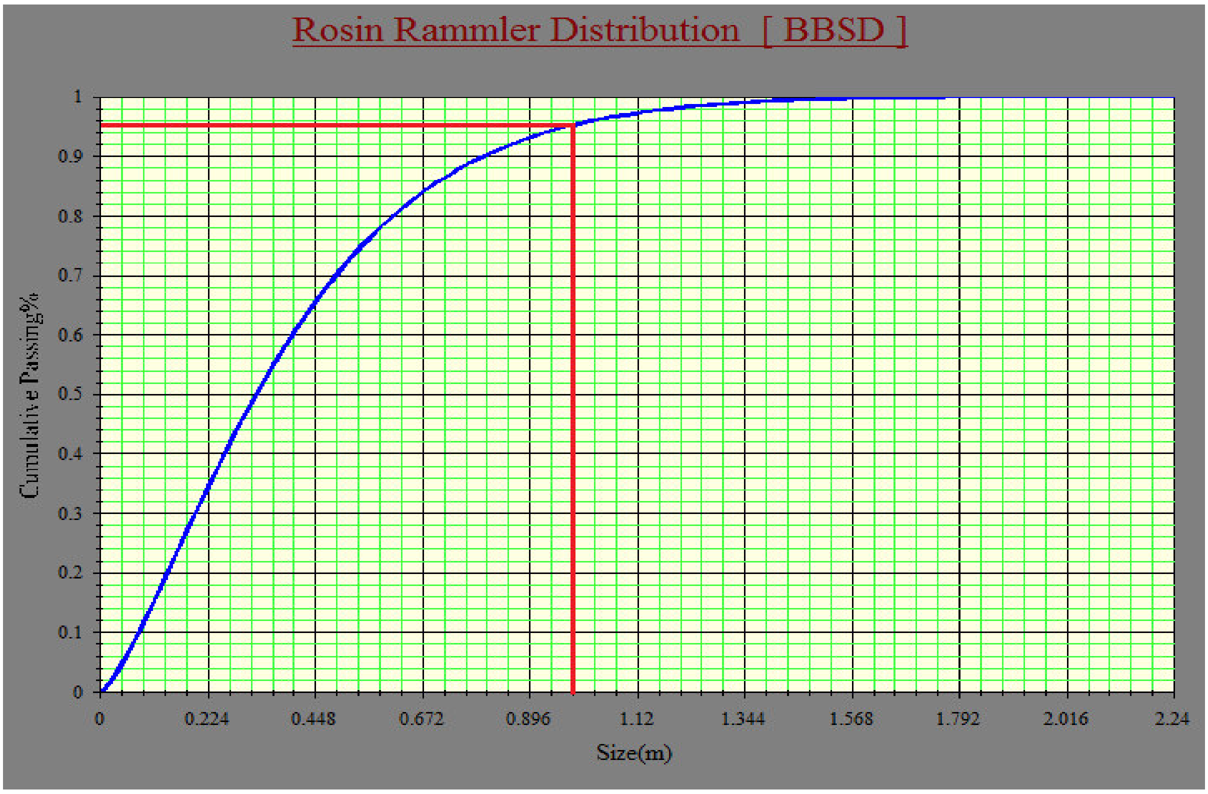


Appendix-16- Size distribution diagram for blast no. B-16

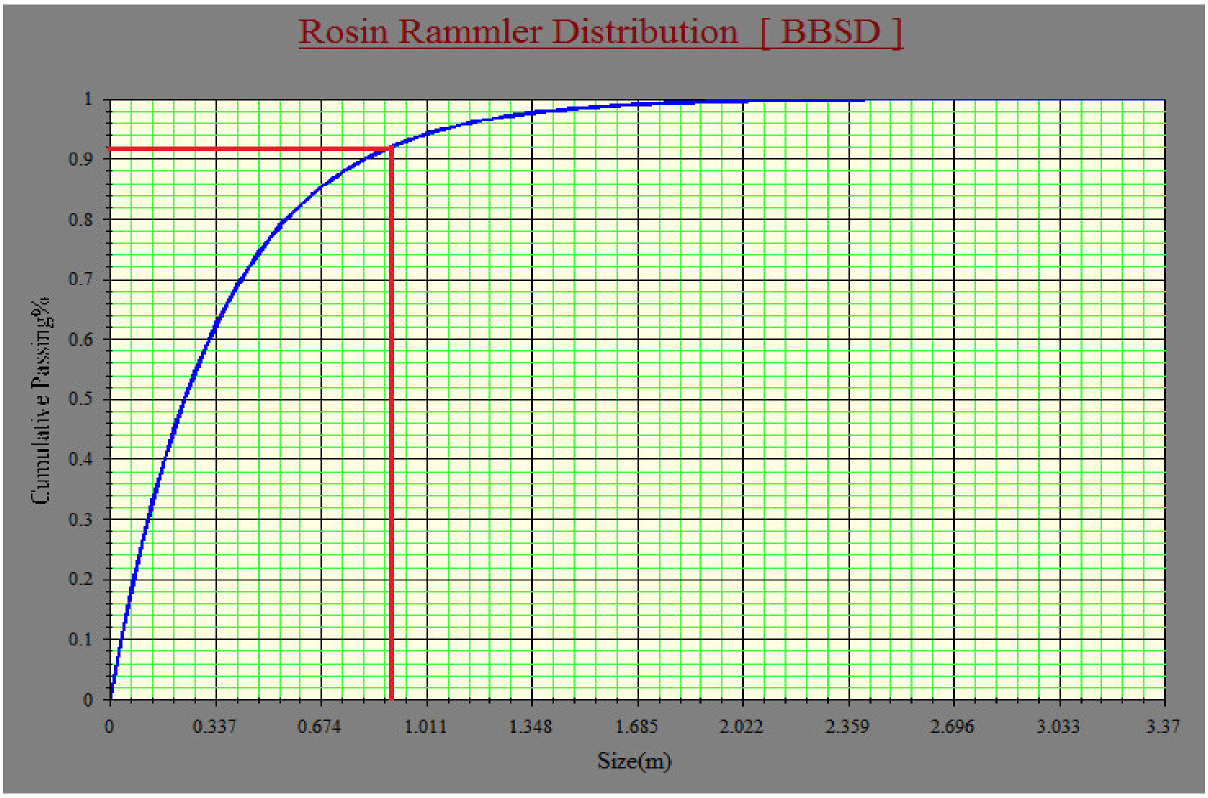


APPENDICES-B

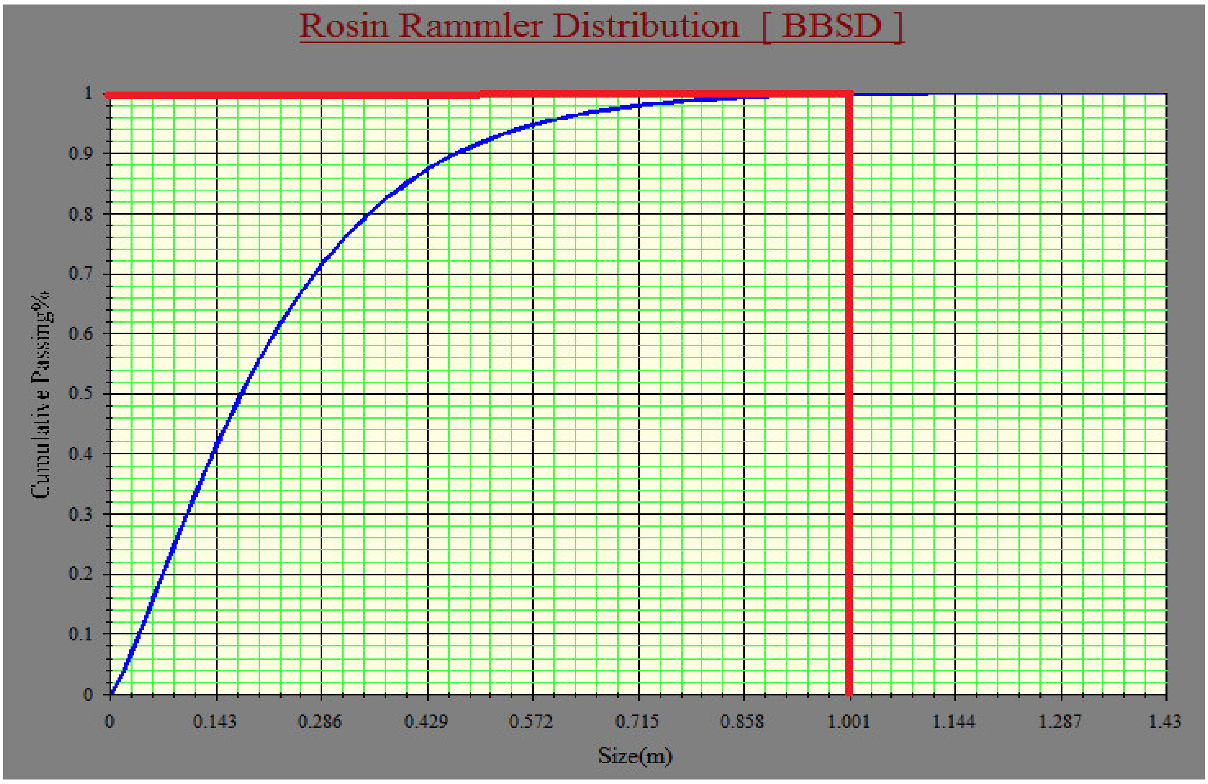
Appendix-17- Size distribution diagram for blast no. E-1



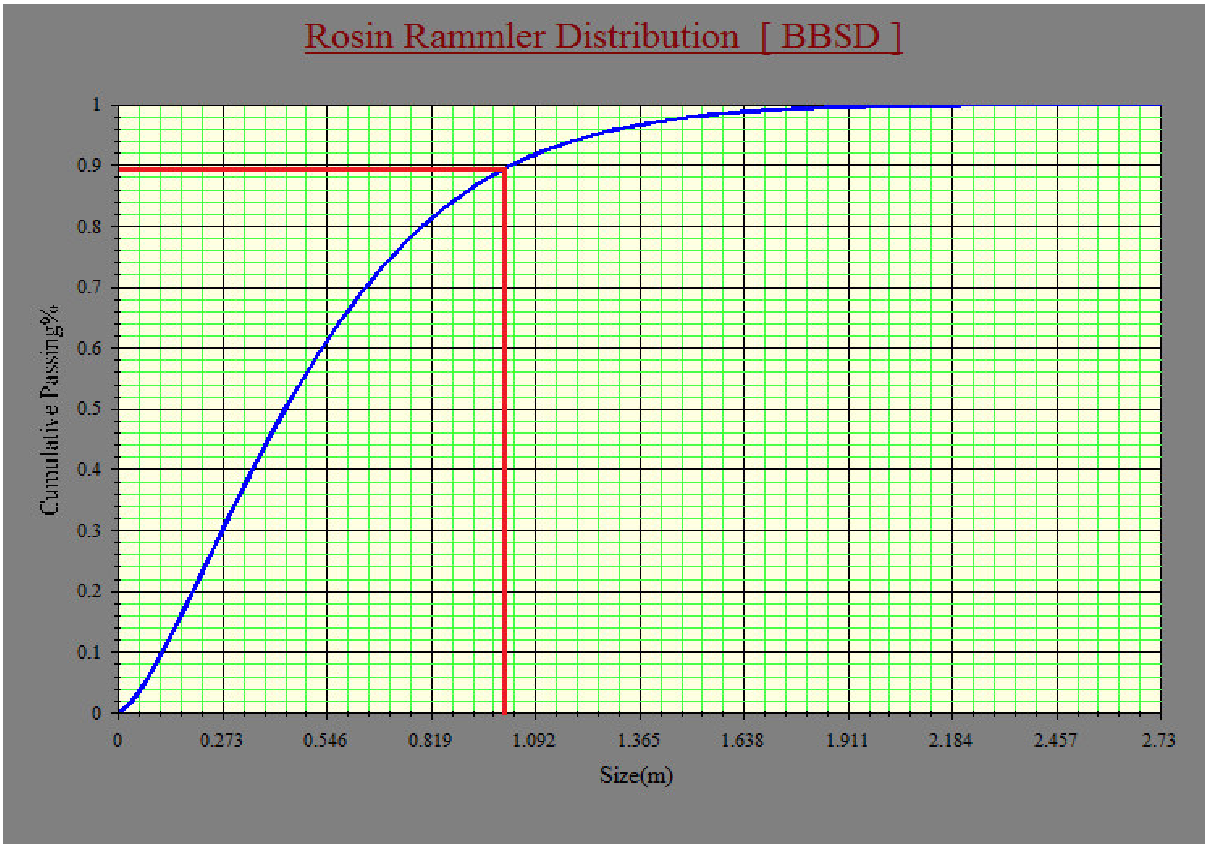
Appendix-18- Size distribution diagram for blast no. E-2



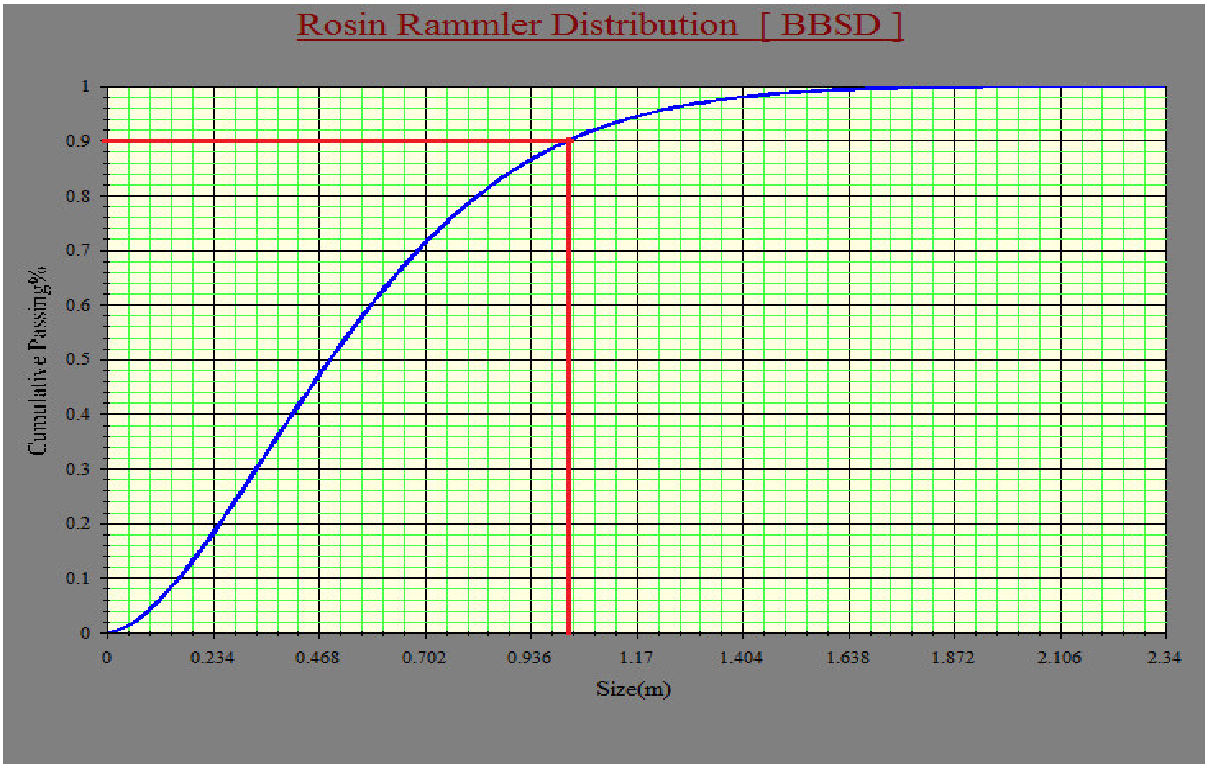
Appendix-19- Size distribution diagram for blast no. E-3



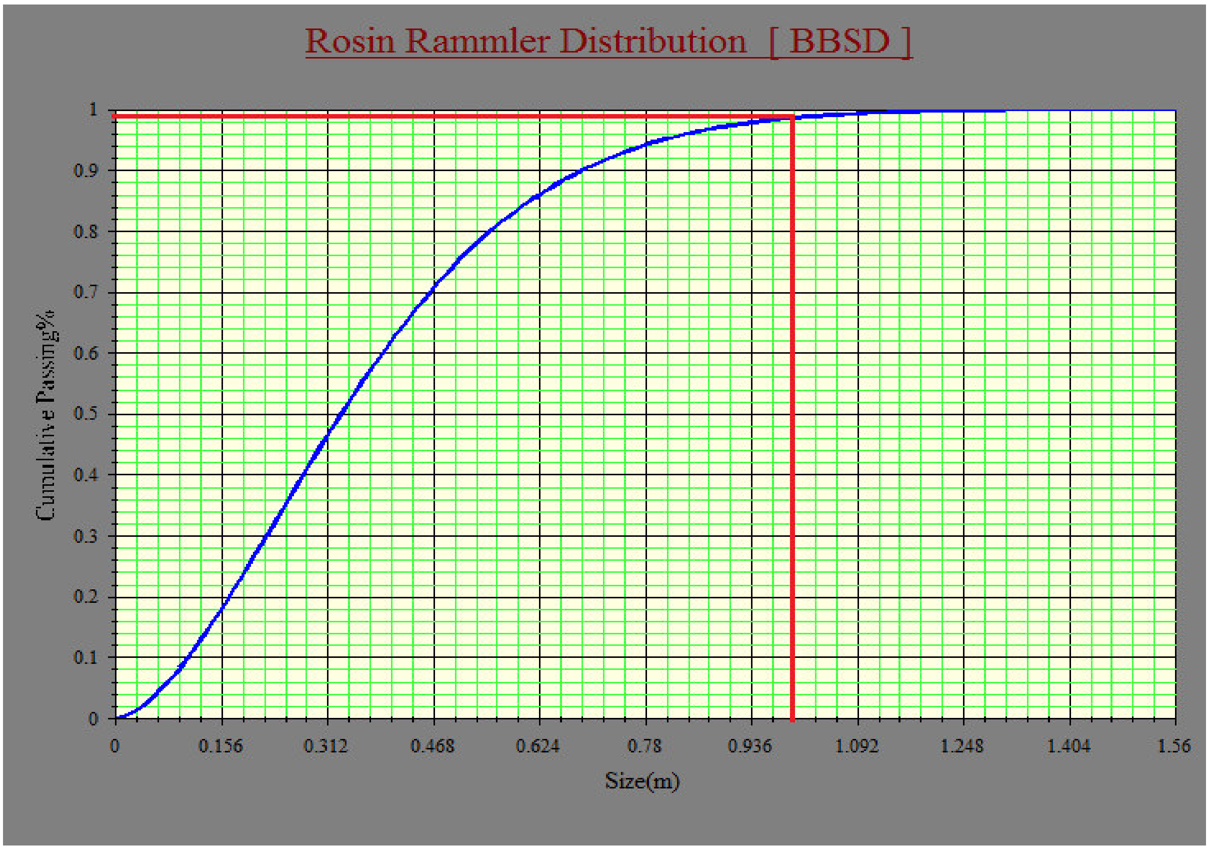
Appendix-20- Size distribution diagram for blast no. E-4



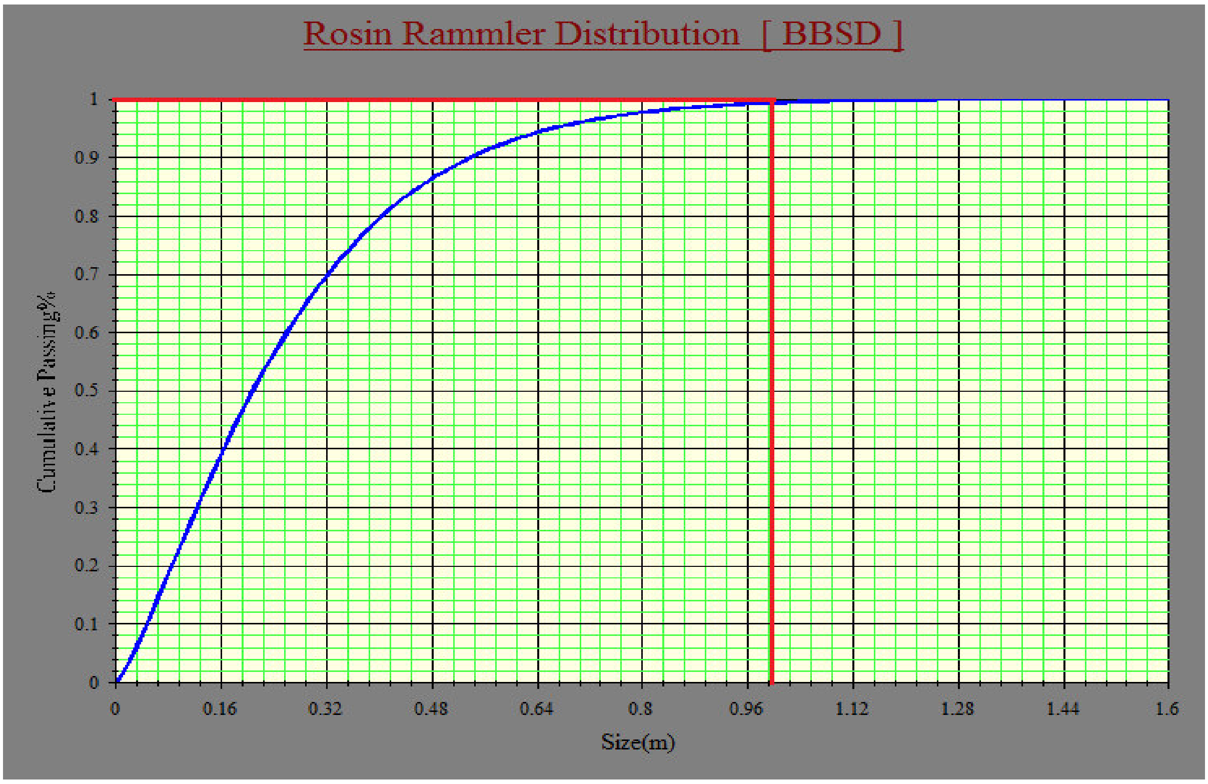
Appendix-21- Size distribution diagram for blast no. E-5



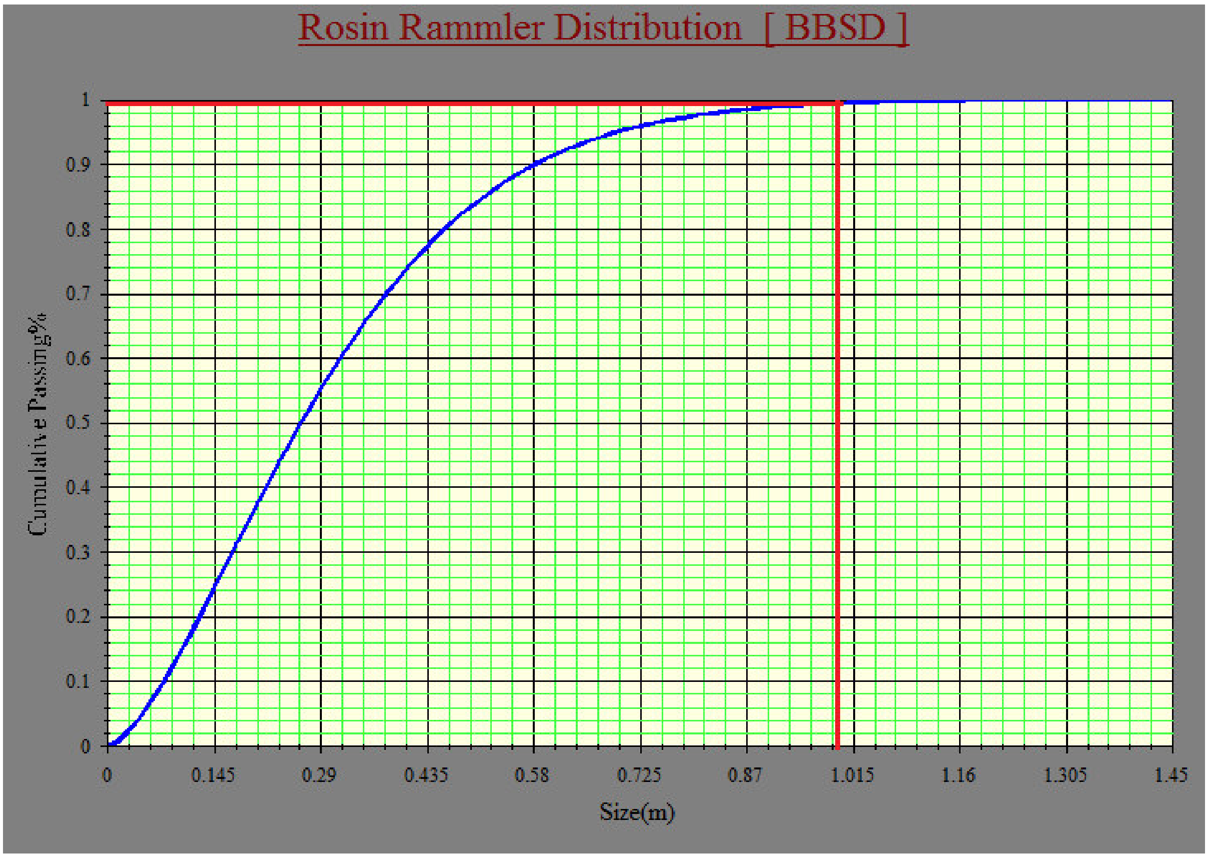
Appendix-22- Size distribution diagram for blast no. E-6



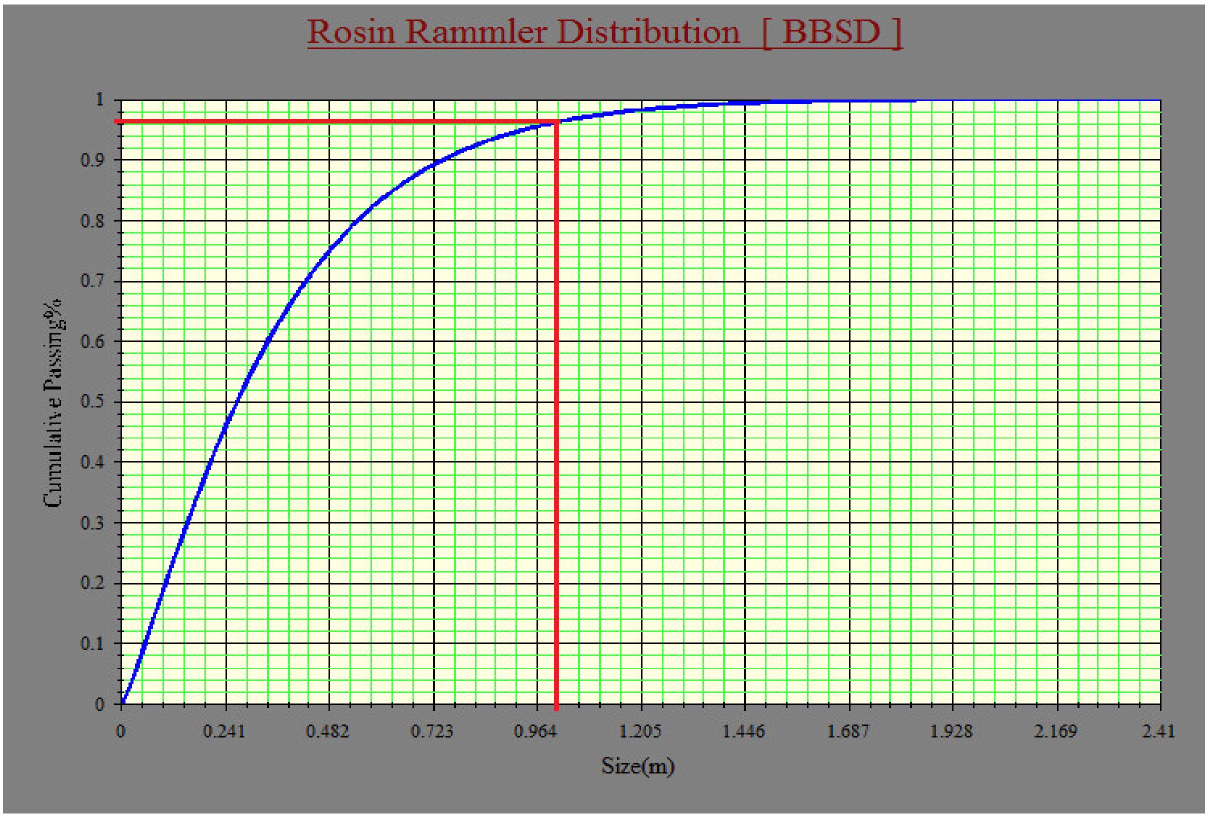
Appendix-23- Size distribution diagram for blast no. E-7



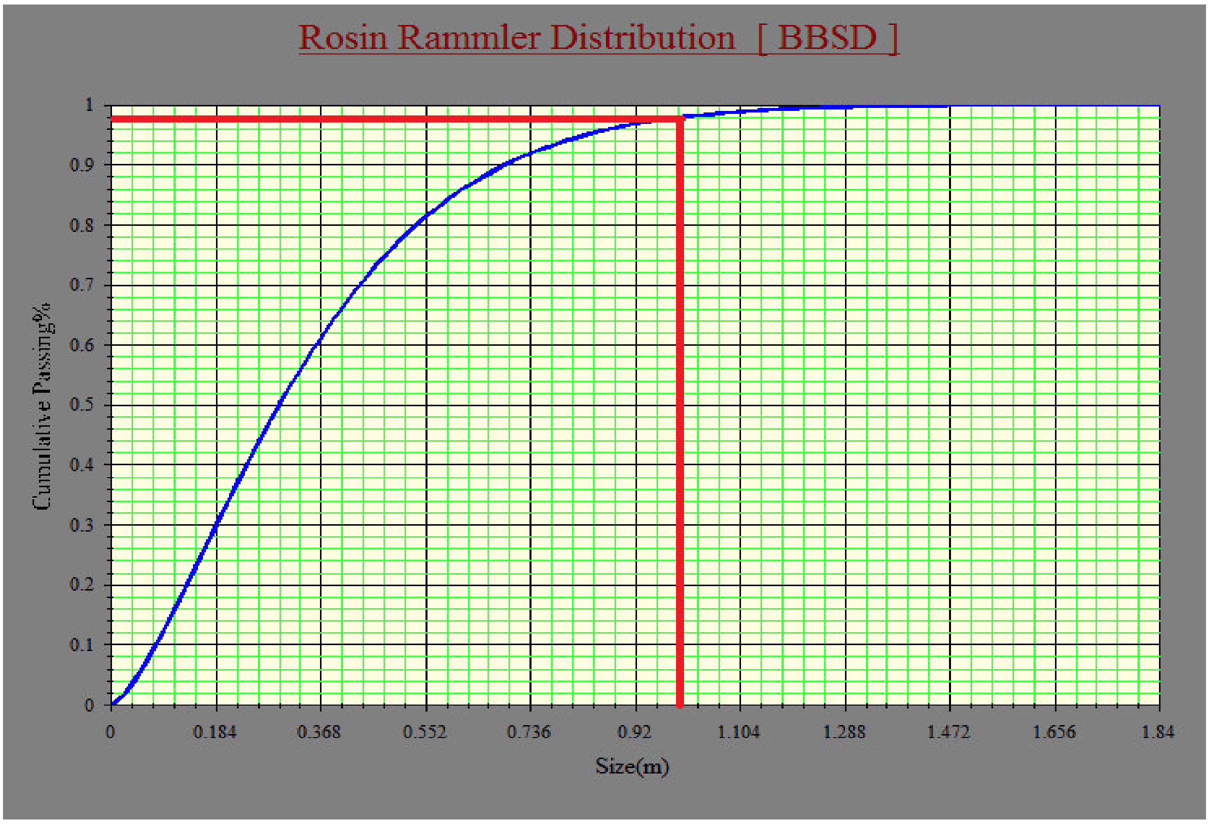
Appendix-24- Size distribution diagram for blast no. E-8



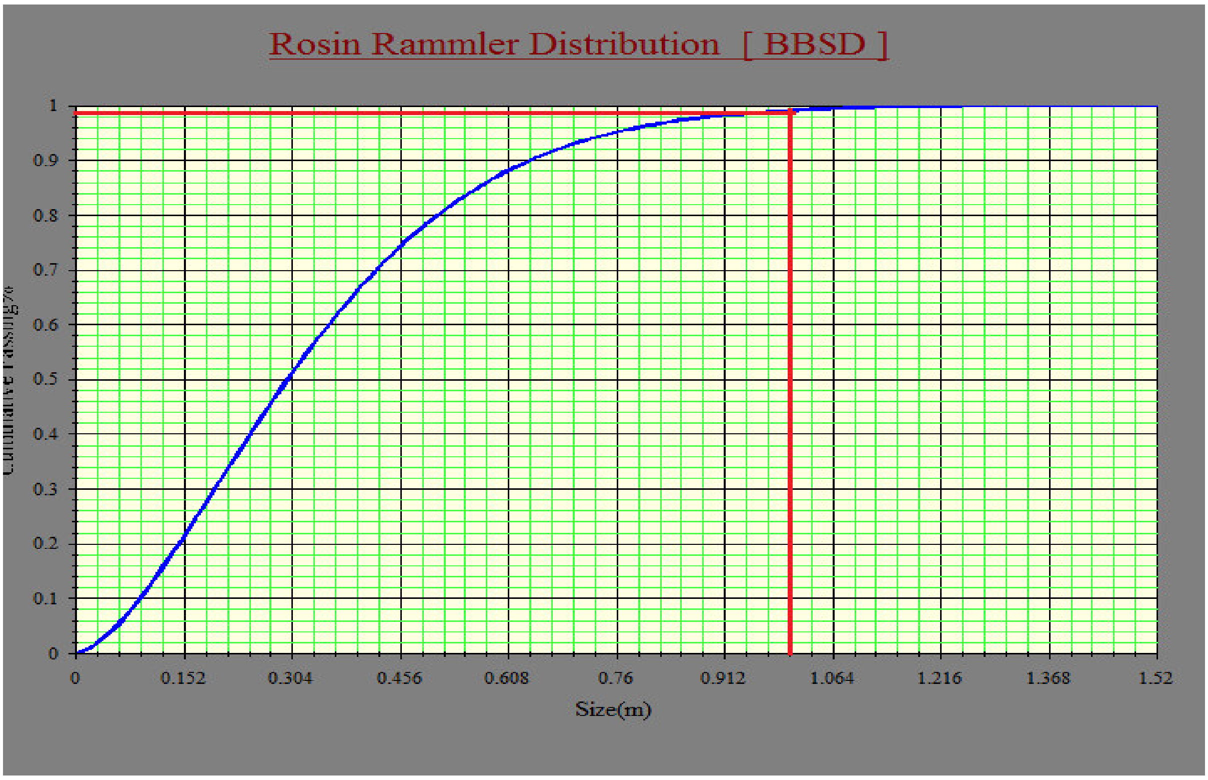
Appendix-25- Size distribution diagram for blast no. E-9



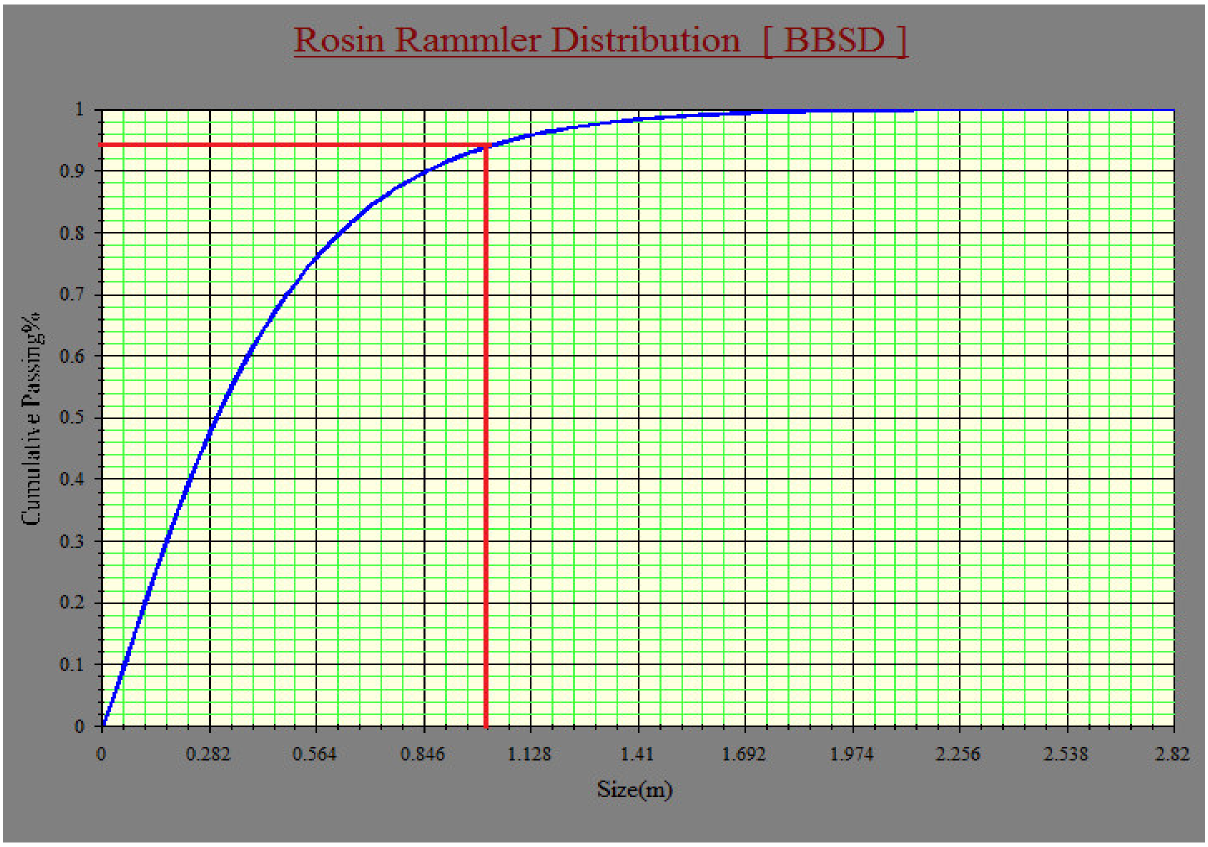
Appendix-26- Size distribution diagram for blast no. E-10



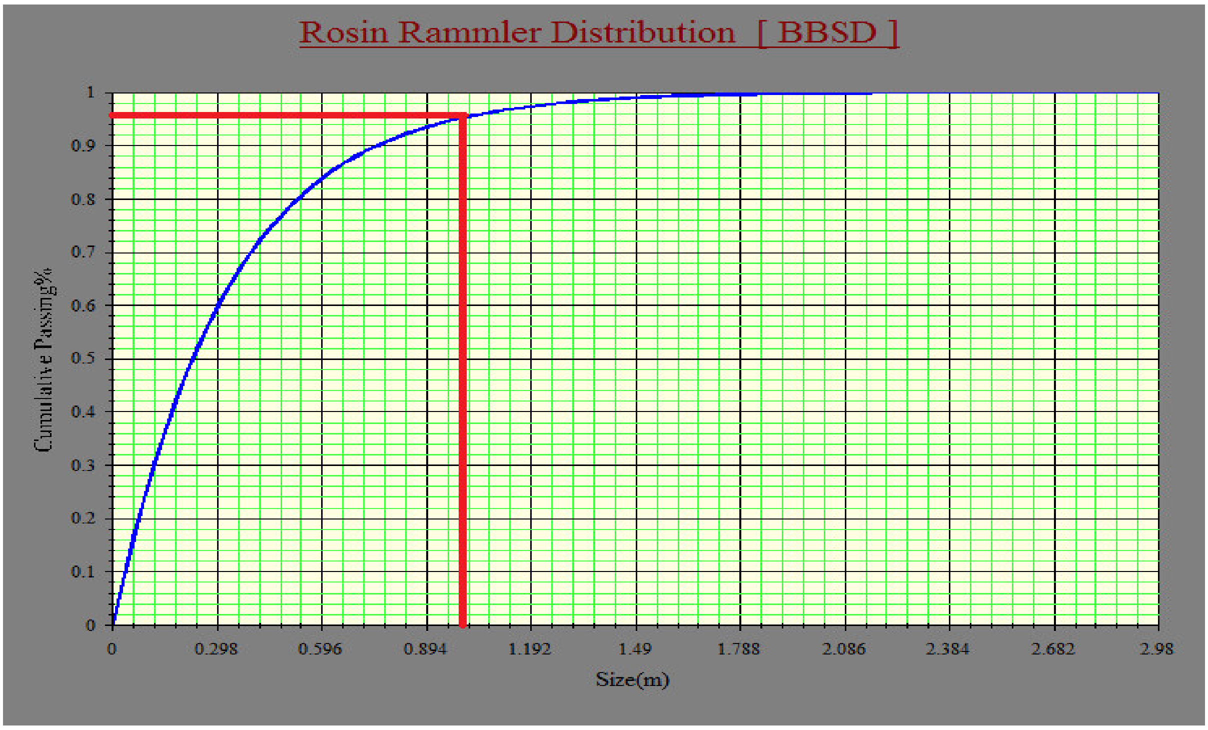
Appendix-27- Size distribution diagram for blast no. E-11



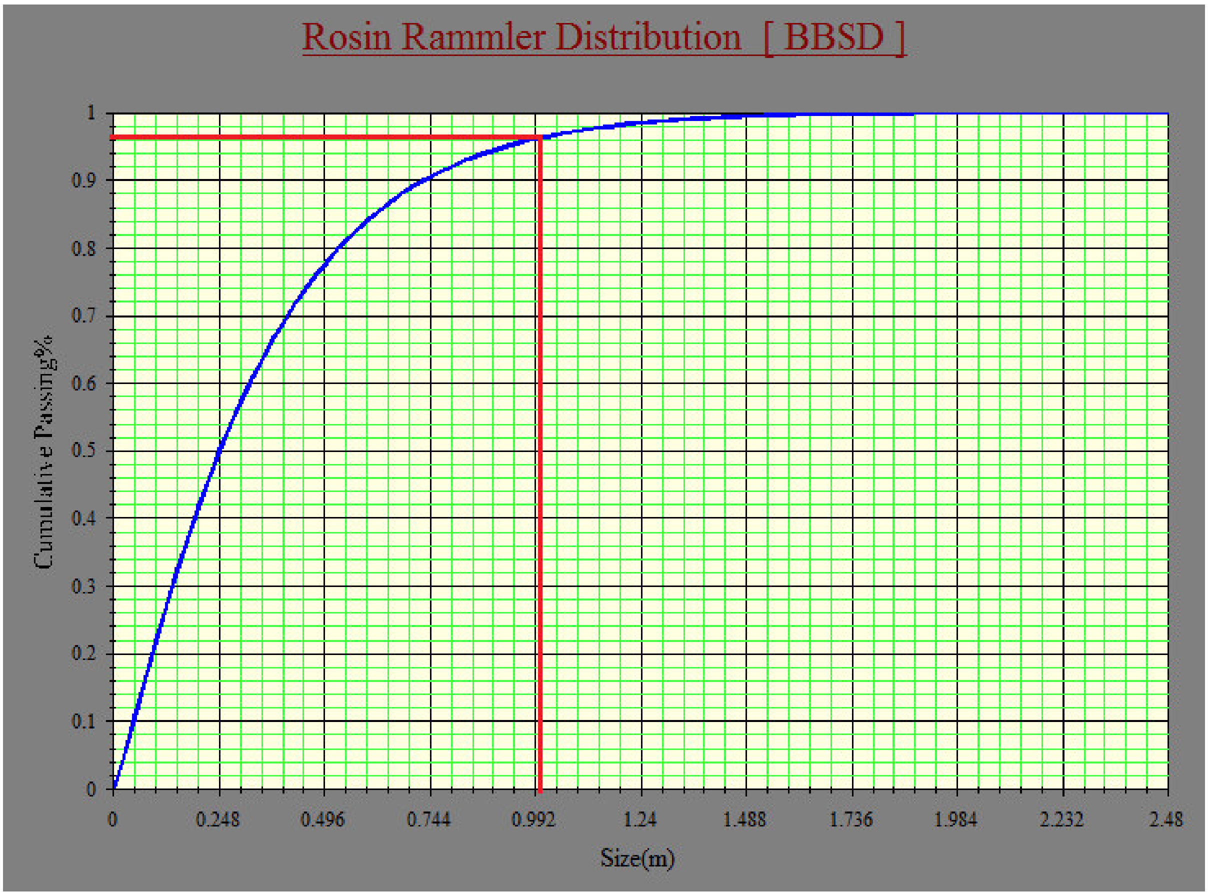
Appendix-28- Size distribution diagram for blast no. E-12



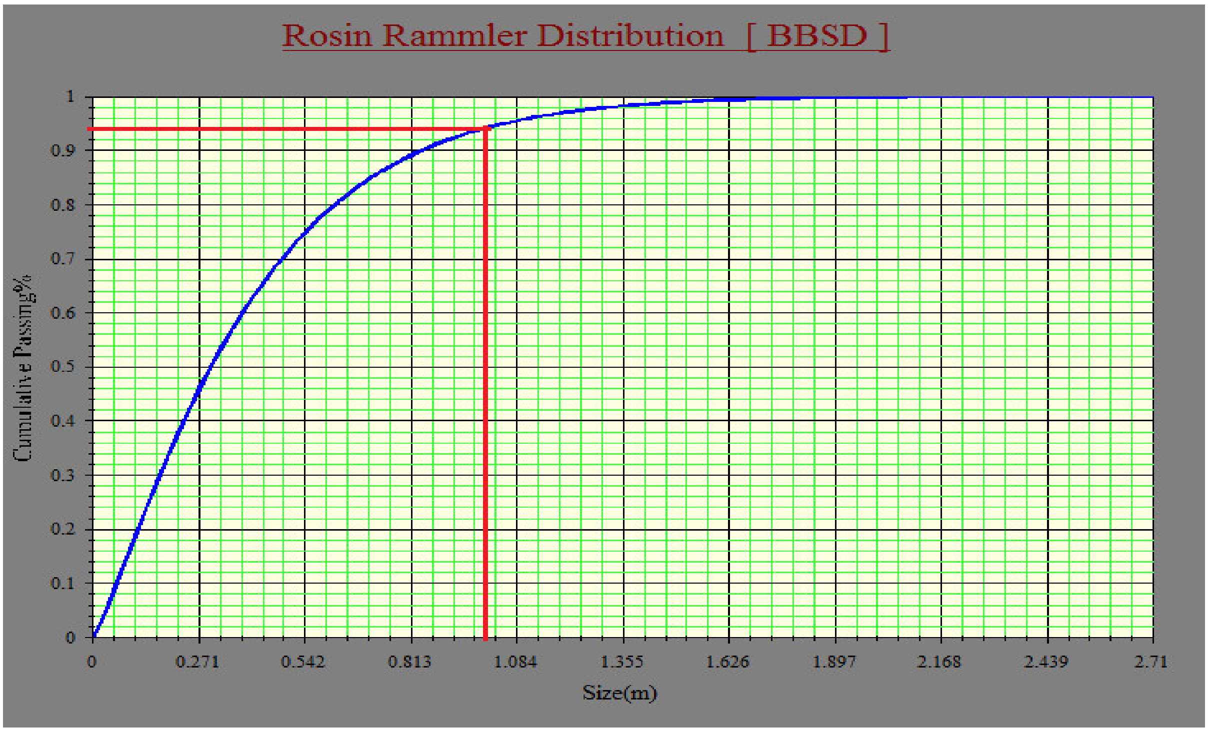
Appendix-29- Size distribution diagram for blast no. E-13



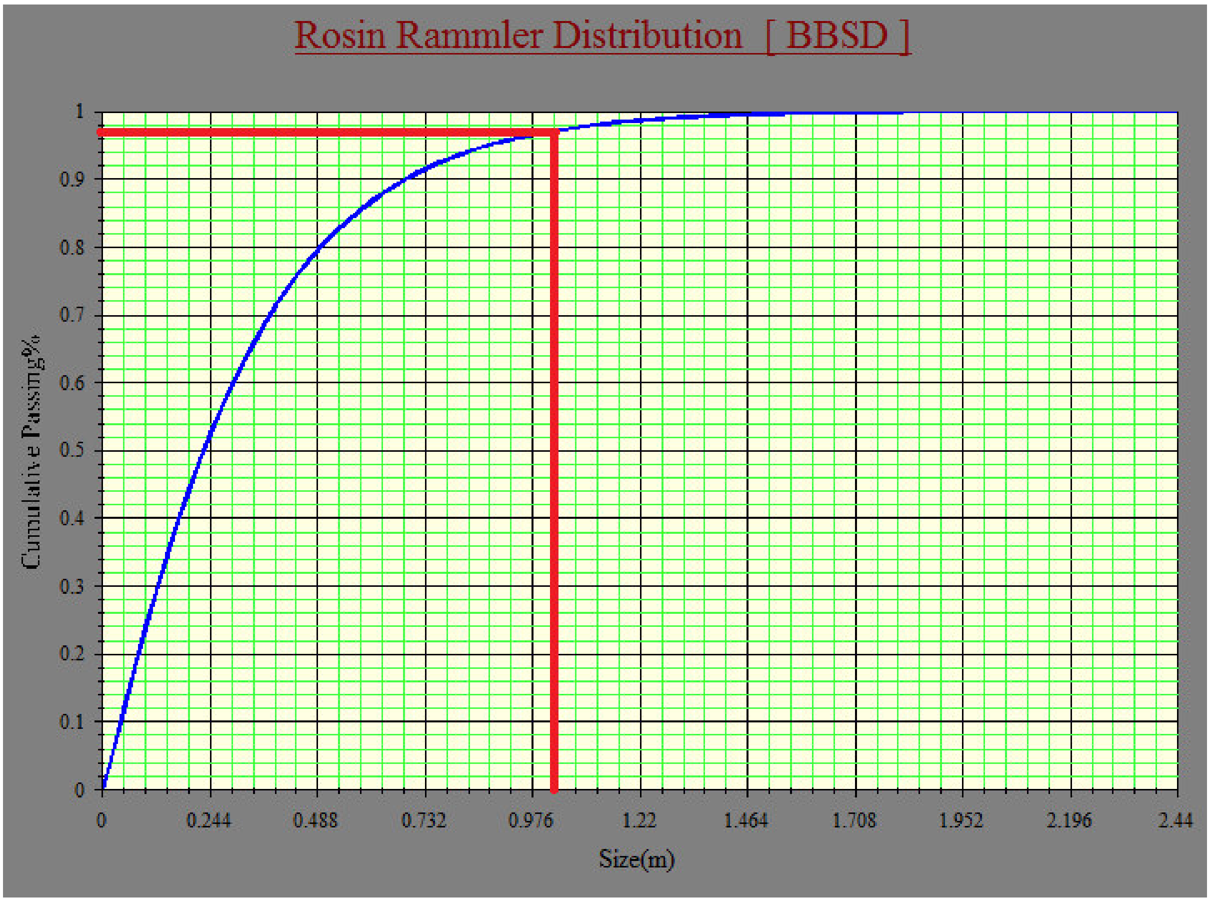
Appendix-30- Size distribution diagram for blast no. E-14



Appendix-31- Size distribution diagram for blast no. E-15



Appendix-32- Size distribution diagram for blast no. E-16



APPENDICES-C

Appendix-33- Minimate™ report for blast no. B-1

Event Report

Date/Time	Long at 13:18:07 May 4, 2018	**Serial Number**	5871 V 2.61 MiniMate
Trigger Source	Geo: 0.492 mm/s	**Battery Level**	6.3 Volts
Range	Geo :127 mm/s	**Calibration**	December 18, 2017 by UES, New Delhi
Record Time	3.0 sec at 1024 sps	**File Name**	G871HEF0.Y70

Notes
Location:
Client:
User Name:
Converted: May 22, 2018 12:15:54 (V8.12)

Extended Notes

Post Event Notes
Blasting at V No. 2 bench (N ---->S) , BID :8-7
No. of holes : 14, using DTH & TLD
Maximum charge per delay : 33.75 Kgs.
Distance from Blasting : 250 mtrs Back Side of Blasting Face

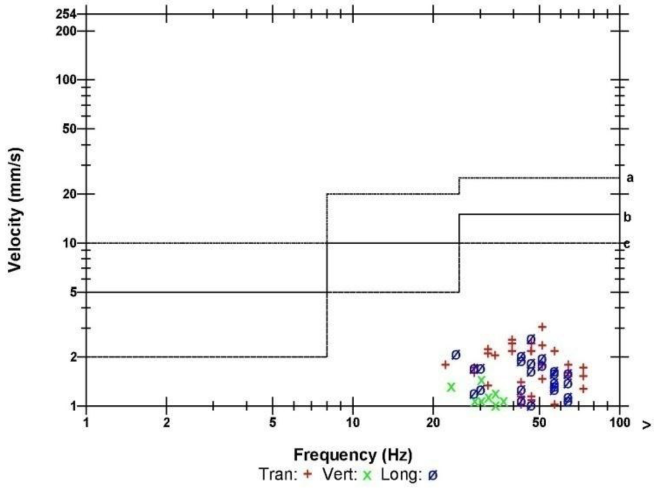
Microphone	Linear Weighting
PSPL	115.6 dB(L) at 1.234 sec
ZC Freq	64 Hz
Channel Test	Passed (Freq = 20.0 Hz Amp = 307 mv)

	Tran	Vert	Long	
PPV	3.05	1.46	2.60	mm/s
ZC Freq	47	32	47	Hz
Time (Rel. to Trig)	0.162	0.371	0.398	sec
Peak Acceleration	0.106	0.0663	0.0928	g
Peak Displacement	0.0114	0.00887	0.0103	mm
Sensorcheck	Passed	Passed	Passed	
Frequency	8.0	8.3	8.2	Hz
Overswing Ratio	3.7	3.3	3.7	

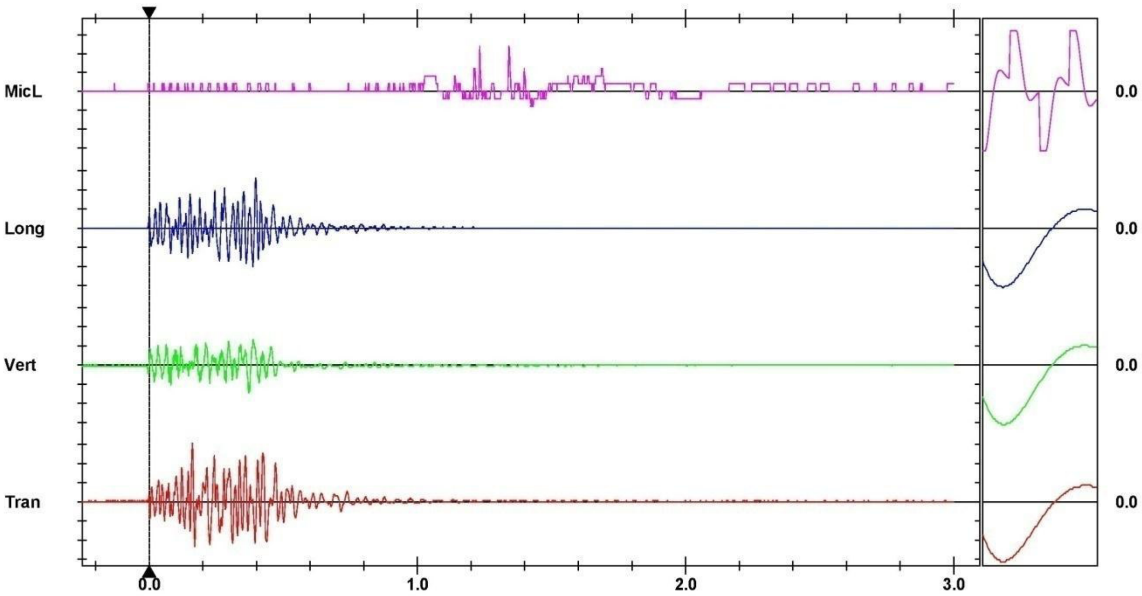
Peak Vector Sum 3.33 mm/s at 0.162 sec

DGMS India (A)

Permissible Ground Vibration



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 1.000 mm/s/div Mic: 5.00 pa.(L)/div
Trigger = ▶———◀

Sensorcheck

Printed: June 26, 2018 (V 8.12 - 8.12)

Appendix-34- Minimate™ report for blast no. B-2

Instantel® **Event Report**

Date/Time	Long at 14:19:51 May 6, 2018	**Serial Number**	5871 V 2.61 MiniMate
Trigger Source	Geo: 0.492 mm/s	**Battery Level**	6.1 Volts
Range	Geo :127 mm/s	**Calibration**	December 18, 2017 by UES, New Delhi
Record Time	3.0 sec at 1024 sps	**File Name**	G871HEIT.530

Notes
Location:
Client:
User Name:
Converted: May 22, 2018 12:15:54 (V8.12)

Extended Notes

Post Event Notes
Blasting at V No. 2 bench (N ---->S) , BID :4-12
No. of holes : 14, using DTH & TLD
Maximum charge per delay : 34.92 Kgs.
Distance from Blasting : 300 mtrs Back Side of Blasting Face

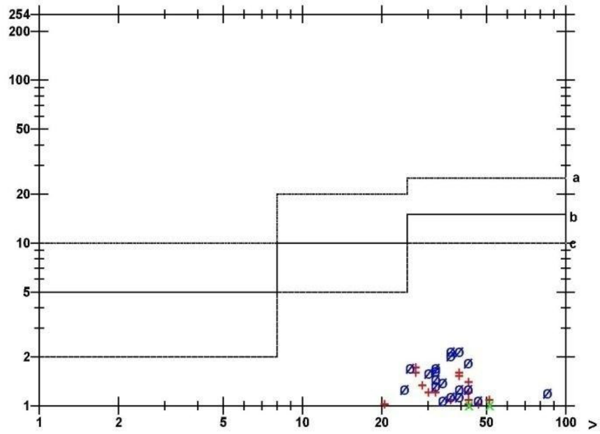
Microphone	Linear Weighting
PSPL	112.0 dB(L) at 1.191 sec
ZC Freq	20 Hz
Channel Test	Passed (Freq = 20.0 Hz Amp = 308 mv)

	Tran	Vert	Long	
PPV	1.71	1.02	2.16	mm/s
ZC Freq	27	43	39	Hz
Time (Rel. to Trig)	0.373	0.217	0.266	sec
Peak Acceleration	0.0597	0.0663	0.0663	g
Peak Displacement	0.00797	0.00406	0.00877	mm
Sensorcheck	Passed	Passed	Passed	
Frequency	7.8	8.2	8.2	Hz
Overswing Ratio	3.5	3.3	3.4	

Peak Vector Sum 2.76 mm/s at 0.266 sec

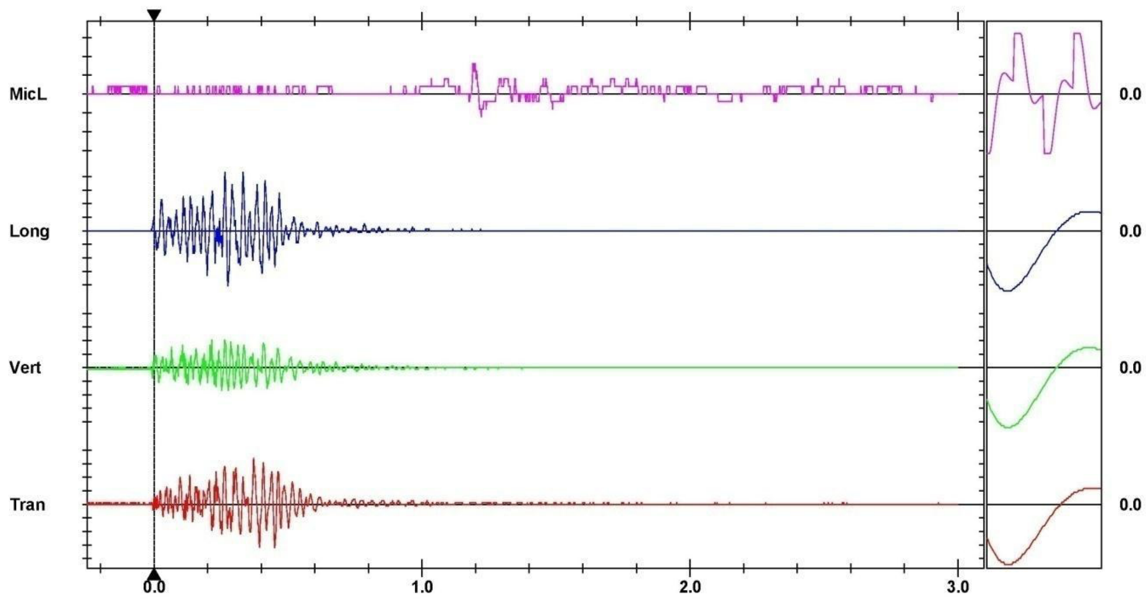
DGMS India (A)

Permissible Ground Vibration



Frequency (Hz)
Tran: + Vert: x Long: ø

a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 5.00 pa.(L)/div
Trigger = ▶———◀

Sensorcheck

Printed: July 1, 2018 (V 8.12 - 8.12)

Appendix-35- Minimate™ report for blast no. B-3

Instantel

Event Report

Date/Time	Vert at 13:26:31 May 10, 2018	**Serial Number**	5871 V 2.61 MiniMate
Trigger Source	Geo: 0.492 mm/s	**Battery Level**	5.8 Volts
Range	Geo :127 mm/s	**Calibration**	December 18, 2017 by UES, New Delhi
Record Time	3.0 sec at 1024 sps	**File Name**	G871HEQ5.C70

Notes
Location:
Client:
User Name:
Converted: May 22, 2018 12:15:54 (V8.12)

Extended Notes

Post Event Notes
Blasting at V No. 2 bench (W ---->E) , BID : 5-12
No. of holes : 16, using DTH & TLD
Maximum charge per delay : 35.28 Kgs.
Distance from Blasting : 250 mtrs Opp. Side of Inititation

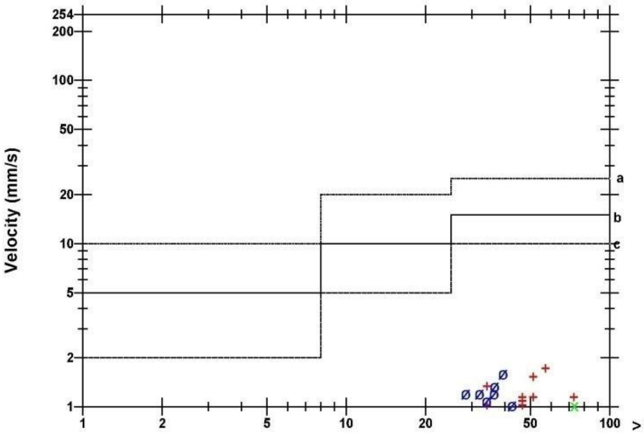
Microphone	Linear Weighting
PSPL	109.5 dB(L) at 1.097 sec
ZC Freq	32 Hz
Channel Test	Passed (Freq = 20.0 Hz Amp = 307 mv)

	Tran	Vert	Long	
PPV	1.71	1.02	1.59	mm/s
ZC Freq	57	73	37	Hz
Time (Rel. to Trig)	0.479	0.486	0.033	sec
Peak Acceleration	0.0597	0.0795	0.0464	g
Peak Displacement	0.00558	0.00391	0.00598	mm
Sensorcheck	Passed	Passed	Passed	
Frequency	7.8	8.1	8.1	Hz
Overswing Ratio	3.7	3.3	3.7	

Peak Vector Sum 2.13 mm/s at 0.033 sec

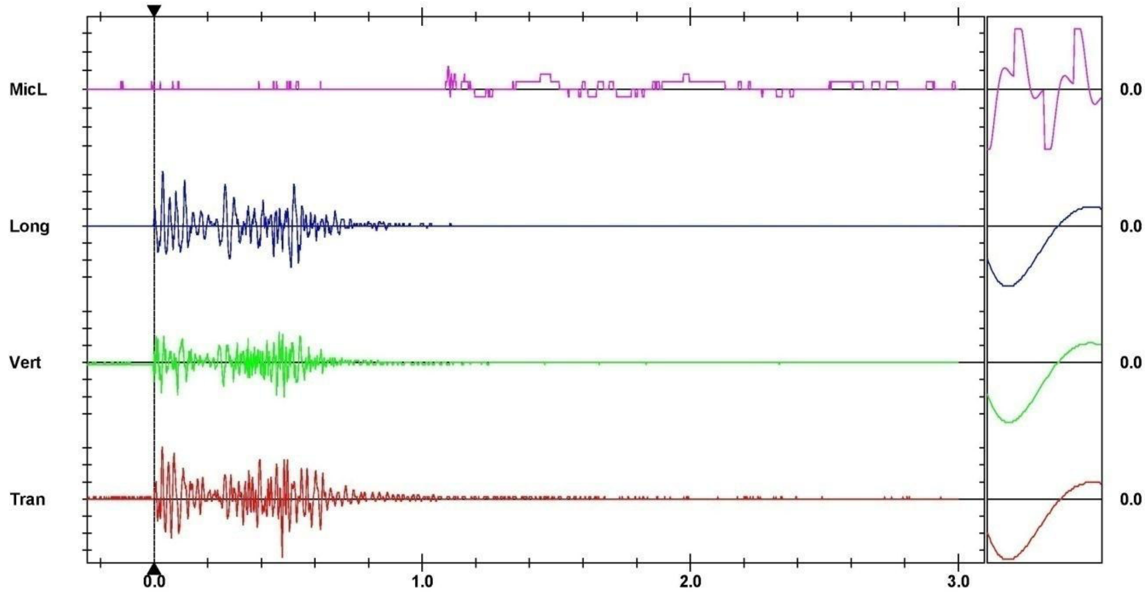
DGMS India (A)

Permissible Ground Vibration



Frequency (Hz)
Tran: + Vert: x Long: ø

a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 5.00 pa.(L)/div
Trigger = ▶————◀

Sensorcheck

Appendix-36- Minimate™ report for blast no. B-4

Instantel

Event Report

Date/Time	Tran at 15:24:03 May 13, 2018	**Serial Number**	5871 V 2.61 MiniMate
Trigger Source	Geo: 0.587 mm/s	**Battery Level**	6.2 Volts
Range	Geo :127 mm/s	**Calibration**	December 18, 2017 by UES, New Delhi
Record Time	3.0 sec at 1024 sps	**File Name**	G871HEVU.S30

Notes
Location:
Client:
User Name:
Converted: May 22, 2018 12:15:54 (V8.12)

Extended Notes

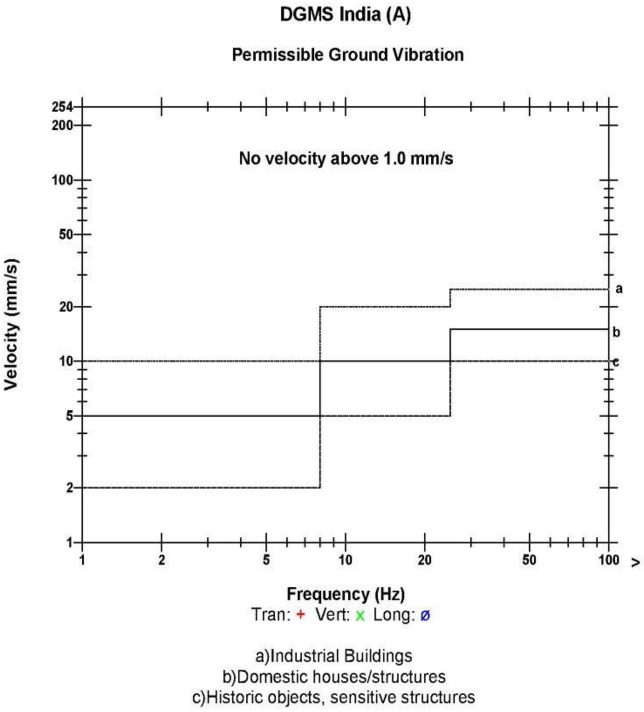
Post Event Notes
Blasting at II bench (W ---->E) , BID :3-2
No. of holes : 10, using DTH & TLD
Maximum charge per delay : 36.05 Kgs.
Distance from Blasting : 350 mtrs Back Side of Blasting Face

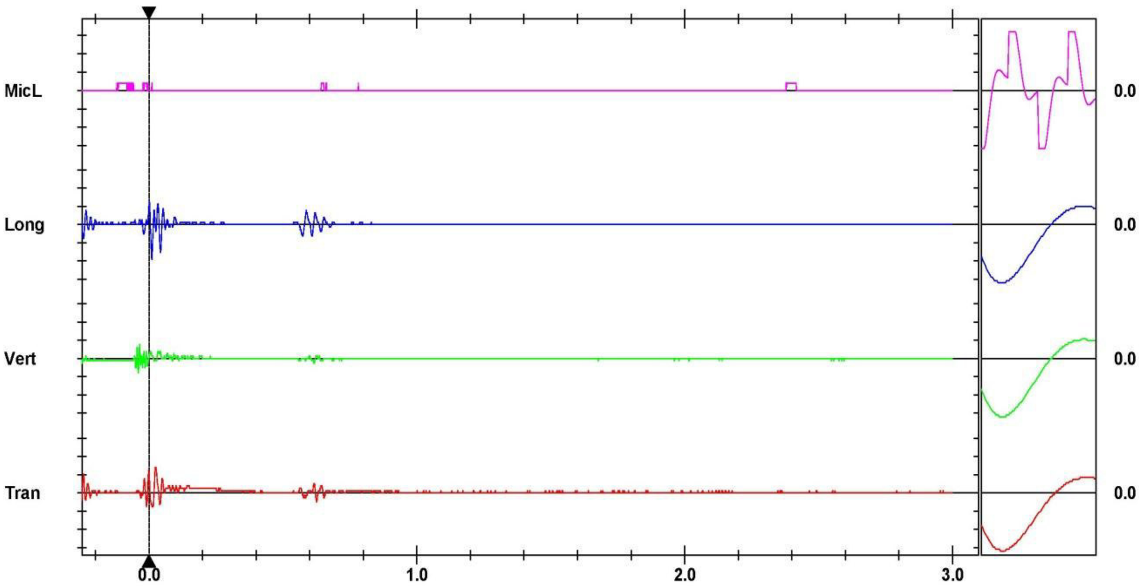
Microphone Linear Weighting
PSPL 100.0 dB(L) at -0.002 sec
ZC Freq N/A
Channel Test Passed (Freq = 20.0 Hz Amp = 307 mv)

	Tran	Vert	Long	
PPV	0.699	0.381	0.953	mm/s
ZC Freq	30	N/A	47	Hz
Time (Rel. to Trig)	0.025	-0.033	0.012	sec
Peak Acceleration	0.0265	0.0265	0.0265	g
Peak Displacement	0.00313	0.00059	0.00313	mm
Sensorcheck	Passed	Passed	Passed	
Frequency	7.8	8.2	8.2	Hz
Overswing Ratio	3.8	3.3	3.7	

Peak Vector Sum 1.03 mm/s at 0.013 sec

N/A: Not Applicable





Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 5.00 pa.(L)/div
Trigger =

Printed: June 26, 2018 (V 8.12 - 8.12)

Appendix-37- Minimate^{TM} report for blast no. B-5

Instantel

Event Report

Date/Time	Long at 13:14:31 May 17, 2018	**Serial Number**	5871 V 2.61 MiniMate
Trigger Source	Geo: 0.587 mm/s	**Battery Level**	6.3 Volts
Range	Geo :127 mm/s	**Calibration**	December 18, 2017 by UES, New Delhi
Record Time	3.0 sec at 1024 sps	**File Name**	G871HF33.G70

Notes
Location:
Client:
User Name:
Converted: May 22, 2018 12:15:54 (V8.12)

Extended Notes

Post Event Notes
Blasting at V No. 2 bench (N ---->S) , BID :5-13
No. of holes : 10, using DTH & TLD
Maximum charge per delay : 32.8 Kgs.
Distance from Blasting : 250 mtrs Back Side of Blasting Face

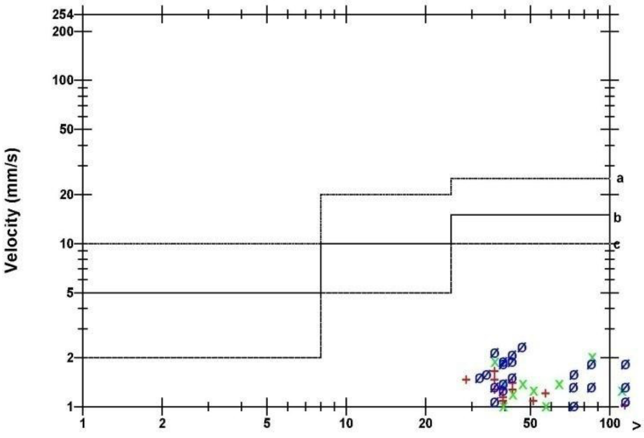
Microphone	Linear Weighting
PSPL	112.0 dB(L) at 1.285 sec
ZC Freq	85 Hz
Channel Test	Passed (Freq = 20.0 Hz Amp = 306 mv)

	Tran	Vert	Long	
PPV	1.65	2.03	2.35	mm/s
ZC Freq	34	85	43	Hz
Time (Rel. to Trig)	0.188	0.294	0.167	sec
Peak Acceleration	0.0795	0.106	0.106	g
Peak Displacement	0.00819	0.00645	0.00791	mm
Sensorcheck	Passed	Passed	Passed	
Frequency	7.7	8.2	8.3	Hz
Overswing Ratio	3.7	3.3	3.4	

Peak Vector Sum 2.97 mm/s at 0.294 sec

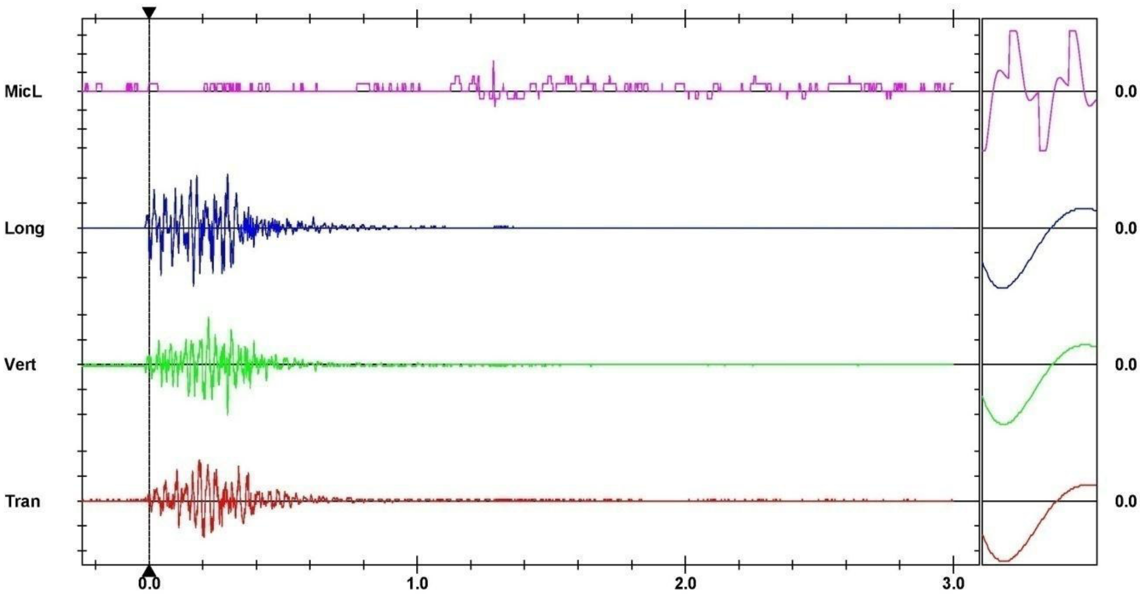
DGMS India (A)

Permissible Ground Vibration



Frequency (Hz)
Tran: + Vert: x Long: ø

a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 1.000 mm/s/div Mic: 5.00 pa.(L)/div

Sensorcheck

Trigger = ▶———◀

Printed: June 26, 2018 (V 8.12 - 8.12)

Appendix-38- Minimate™ report for blast no. B-6

Instantel® **Event Report**

Date/Time	Long at 15:16:06 May 19, 2018	**Serial Number**	5871 V 2.61 MiniMate
Trigger Source	Geo: 0.587 mm/s	**Battery Level**	6.3 Volts
Range	Geo :127 mm/s	**Calibration**	December 18, 2017 by UES, New Delhi
Record Time	3.0 sec at 1024 sps	**File Name**	G871HF6Y.EU0

Notes
Location:
Client:
User Name:
Converted: May 22, 2018 12:15:54 (V8.12)

Extended Notes

Post Event Notes
Blasting at II bench (E ---->W) , BID : 11-2
No. of holes : 16, using DTH & TLD
Maximum charge per delay : 40.43 Kgs.
Distance from Blasting : 250 mtrs Back Side of Blasting Face

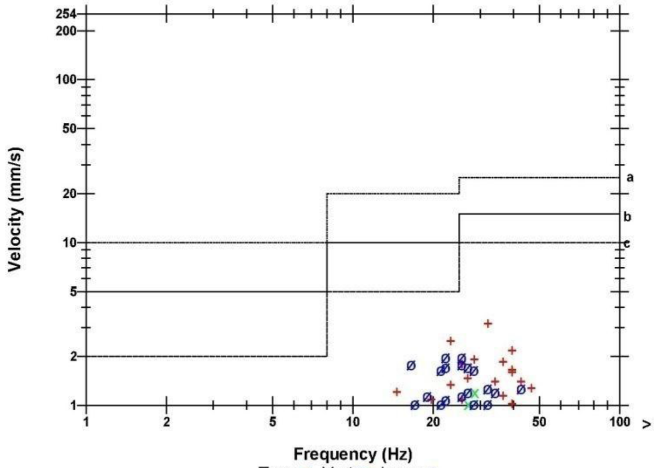
Microphone Linear Weighting
PSPL 122.9 dB(L) at 0.770 sec
ZC Freq 13 Hz
Channel Test Passed (Freq = 20.0 Hz Amp = 308 mv)

	Tran	Vert	Long	
PPV	3.18	1.21	1.97	mm/s
ZC Freq	32	21	22	Hz
Time (Rel. to Trig)	0.145	0.134	0.118	sec
Peak Acceleration	0.0663	0.0199	0.0398	g
Peak Displacement	0.0174	0.00726	0.0161	mm
Sensorcheck	Passed	Passed	Passed	
Frequency	7.8	8.2	8.1	Hz
Overswing Ratio	3.7	3.3	3.5	

Peak Vector Sum 3.25 mm/s at 0.145 sec

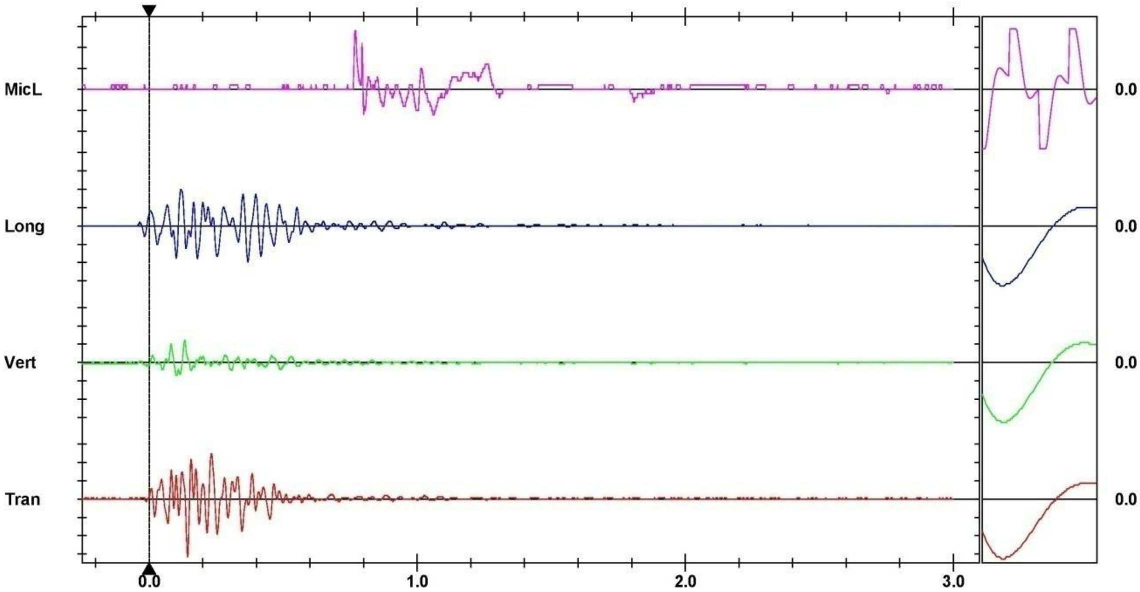
DGMS India (A)

Permissible Ground Vibration



Tran: + Vert: x Long: ø

a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 1.000 mm/s/div Mic: 10.00 pa.(L)/div Sensorcheck
Trigger = ▶———◀

Printed: June 26, 2018 (V 8.12 - 8.12)

Appendix-39- Minimate™ report for blast no. B-7

Instantel

Event Report

Date/Time	Vert at 13:40:21 May 20, 2018	**Serial Number**	5871 V 2.61 MiniMate
Trigger Source	Geo: 0.587 mm/s	**Battery Level**	6.2 Volts
Range	Geo :127 mm/s	**Calibration**	December 18, 2017 by UES, New Delhi
Record Time	3.0 sec at 1024 sps	**File Name**	G871HF8O.N90

Notes
Location:
Client:
User Name:
Converted: May 22, 2018 12:15:54 (V8.12)

Extended Notes

Post Event Notes
Blasting at V No. 2 bench (S ---->N) , BID :5-14
No. of holes : 10, using DTH & TLD
Maximum charge per delay : 32.5 Kgs.
Distance from Blasting : 250 mtrs Back Side of Blasting Face

Microphone	Linear Weighting
PSPL	106.0 dB(L) at 1.341 sec
ZC Freq	9.1 Hz
Channel Test	Passed (Freq = 20.0 Hz Amp = 302 mv)

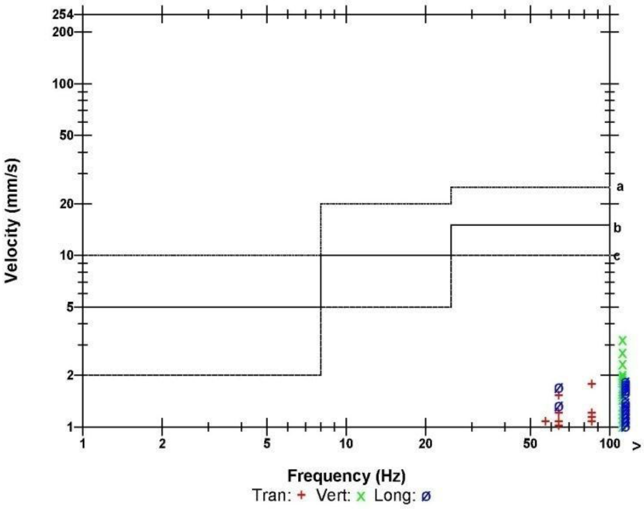
	Tran	Vert	Long	
PPV	1.78	3.24	1.84	mm/s
ZC Freq	73	N/A	>100	Hz
Time (Rel. to Trig)	0.220	0.211	0.229	sec
Peak Acceleration	0.126	0.298	0.166	g
Peak Displacement	0.00378	0.00329	0.00369	mm
Sensorcheck	Passed	Passed	Passed	
Frequency	7.8	8.2	8.2	Hz
Overswing Ratio	3.7	3.3	3.7	

Peak Vector Sum 3.59 mm/s at 0.211 sec

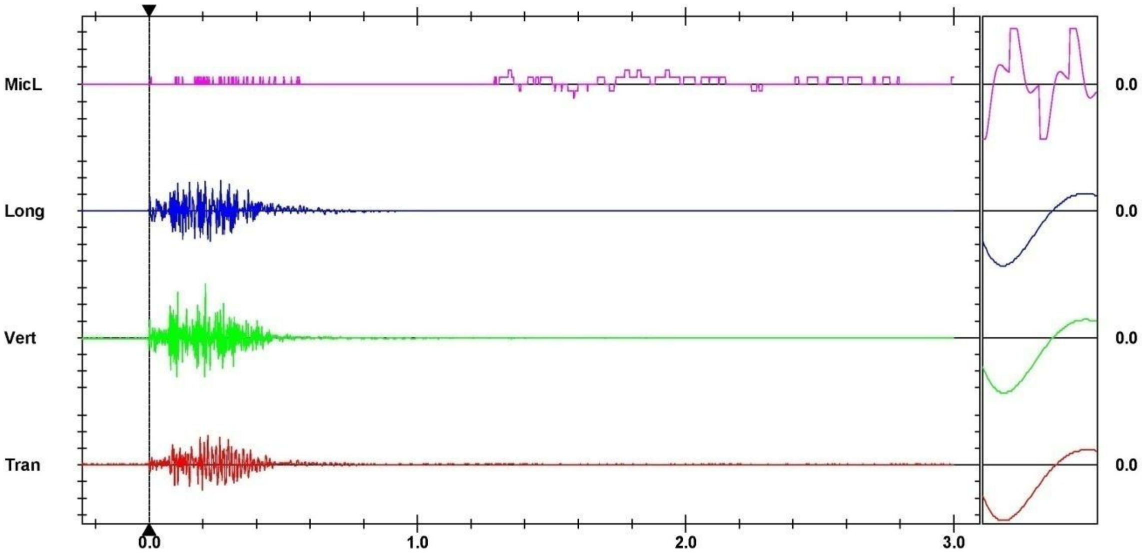
N/A: Not Applicable

DGMS India (A)

Permissible Ground Vibration



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 1.000 mm/s/div Mic: 5.00 pa.(L)/div Sensorcheck
Trigger = ▶————◀

Printed: June 26, 2018 (V 8.12 - 8.12)

Appendix-40- Minimate™ report for blast no. B-8

Instantel

Event Report

Date/Time	Vert at 13:12:35 May 21, 2018	**Serial Number**	5871 V 2.61 MiniMate
Trigger Source	Geo: 0.587 mm/s	**Battery Level**	6.4 Volts
Range	Geo :127 mm/s	**Calibration**	December 18, 2017 by UES, New Delhi
Record Time	3.0 sec at 1024 sps	**File Name**	G871HFAI.0Z0

Notes
Location:
Client:
User Name:
Converted: May 22, 2018 12:15:54 (V8.12)

Extended Notes

Post Event Notes
Blasting at V No. 2 bench (N ---->S) , BID :5-15
No. of holes : 10, using DTH & TLD
Maximum charge per delay : 32.5 Kgs.
Distance from Blasting : 225 mtrs Back Side of Blasting Face

Microphone	Linear Weighting
PSPL	109.5 dB(L) at 1.371 sec
ZC Freq	10 Hz
Channel Test	Passed (Freq = 20.0 Hz Amp = 307 mv)

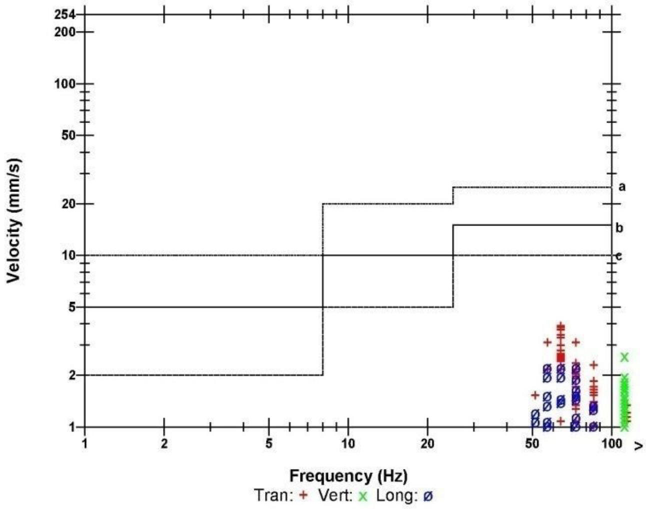
	Tran	Vert	Long	
PPV	3.87	2.60	2.22	mm/s
ZC Freq	64	N/A	64	Hz
Time (Rel. to Trig)	0.333	0.310	0.225	sec
Peak Acceleration	0.172	0.225	0.0928	g
Peak Displacement	0.00980	0.00304	0.00645	mm
Sensorcheck	Passed	Passed	Passed	
Frequency	8.1	8.2	8.2	Hz
Overswing Ratio	3.6	3.3	3.8	

Peak Vector Sum 4.06 mm/s at 0.255 sec

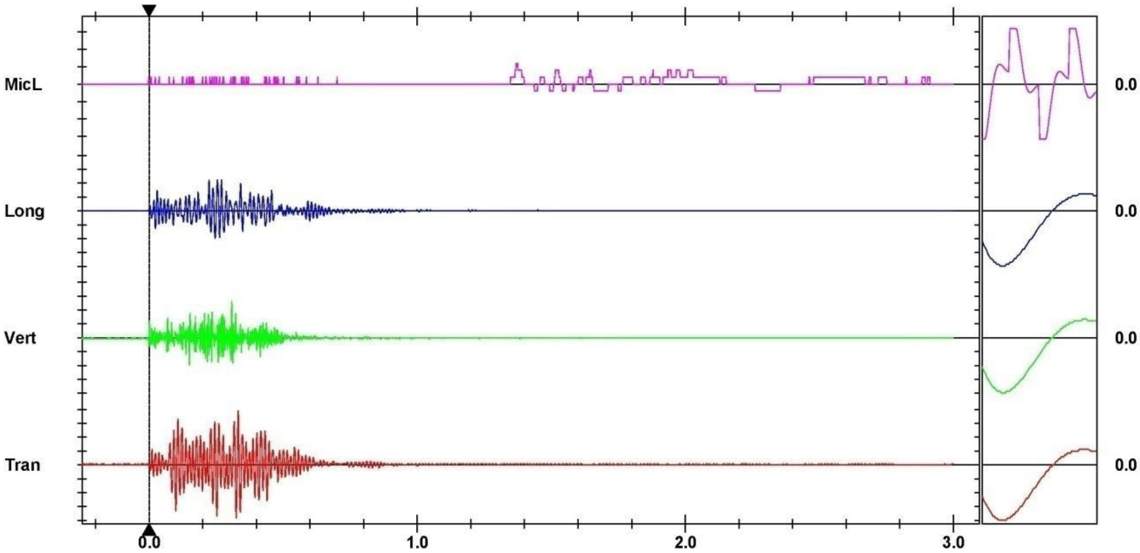
N/A: Not Applicable

DGMS India (A)

Permissible Ground Vibration



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 1.000 mm/s/div Mic: 5.00 pa.(L)/div
Trigger = ▶————◀

Sensorcheck

Printed: June 26, 2018 (V 8.12 - 8.12)

Appendix-41- Minimate^{TM} report for blast no. B-9

Instantel®

Event Report

Date/Time	Vert at 14:35:17 May 25, 2018	**Serial Number**	5871 V 2.61 MiniMate
Trigger Source	Geo: 0.587 mm/s	**Battery Level**	6.0 Volts
Range	Geo :127 mm/s	**Calibration**	December 18, 2017 by UES, New Delhi
Record Time	3.0 sec at 1024 sps	**File Name**	G871HFI0.IT0

Notes
Location:
Client:
User Name:
Converted: June 3, 2018 10:21:10 (V8.12)

Extended Notes

Post Event Notes
Blasting at V No. 2 bench (N ---->S) , BID :4-21
No. of holes : 14, using DTH & TLD
Maximum charge per delay : 32.67 Kgs.
Distance from Blasting : 350 mtrs Back Side of Blasting Face

Microphone Linear Weighting
PSPL 106.0 dB(L) at 1.160 sec
ZC Freq 8.0 Hz
Channel Test Passed (Freq = 20.0 Hz Amp = 307 mv)

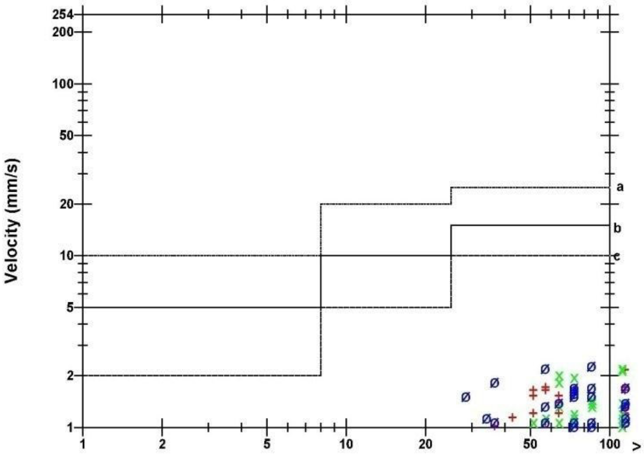
	Tran	Vert	Long	
PPV	2.16	2.22	2.29	mm/s
ZC Freq	N/A	N/A	85	Hz
Time (Rel. to Trig)	0.118	0.128	0.112	sec
Peak Acceleration	0.179	0.166	0.139	g
Peak Displacement	0.00462	0.00434	0.00750	mm
Sensorcheck	Passed	Passed	Passed	
Frequency	7.8	8.2	8.1	Hz
Overswing Ratio	3.7	3.3	3.7	

Peak Vector Sum 2.67 mm/s at 0.286 sec

N/A: Not Applicable

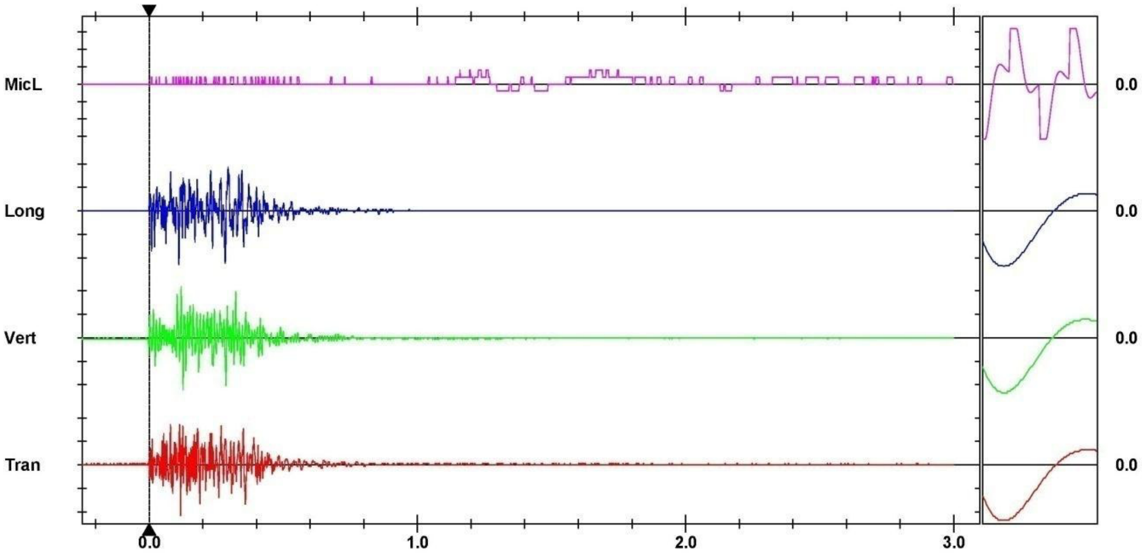
DGMS India (A)

Permissible Ground Vibration



Frequency (Hz)
Tran: + Vert: x Long: ø

a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 1.000 mm/s/div Mic: 5.00 pa.(L)/div
Trigger = ▶———◀

Sensorcheck

Printed: June 26, 2018 (V 8.12 - 8.12)

Appendix-42- Minimate^{TM} report for blast no. B-10

Instantel

Event Report

Date/Time	Vert at 13:23:00 May 28, 2018	**Serial Number**	5871 V 2.61 MiniMate
Trigger Source	Geo: 0.587 mm/s	**Battery Level**	5.8 Volts
Range	Geo :127 mm/s	**Calibration**	December 18, 2017 by UES, New Delhi
Record Time	3.0 sec at 1024 sps	**File Name**	G871HFNH.6C0

Notes
Location:
Client:
User Name:
Converted: June 3, 2018 10:21:10 (V8.12)

Extended Notes

Post Event Notes
Blasting at V No. 2 bench (N ---->S) , BID :4-23
No. of holes : 10, using DTH & TLD
Maximum charge per delay : 32.5 Kgs.
Distance from Blasting : 350 mtrs Back Side of Blasting Face

Microphone Linear Weighting
PSPL 109.5 dB(L) at 1.310 sec
ZC Freq 5.0 Hz
Channel Test Passed (Freq = 20.0 Hz Amp = 307 mv)

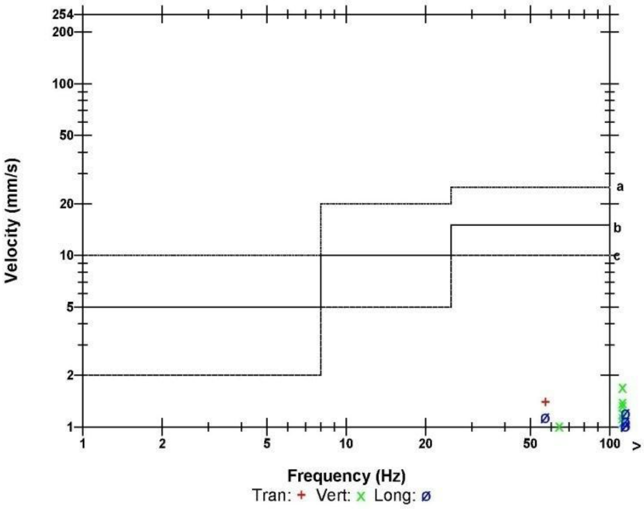
	Tran	Vert	Long	
PPV	1.40	1.71	1.21	mm/s
ZC Freq	57	N/A	N/A	Hz
Time (Rel. to Trig)	0.084	0.220	0.055	sec
Peak Acceleration	0.0928	0.159	0.0928	g
Peak Displacement	0.00425	0.00260	0.00316	mm
Sensorcheck	Passed	Passed	Passed	
Frequency	7.7	8.2	8.2	Hz
Overswing Ratio	3.8	3.3	3.7	

Peak Vector Sum 1.79 mm/s at 0.220 sec

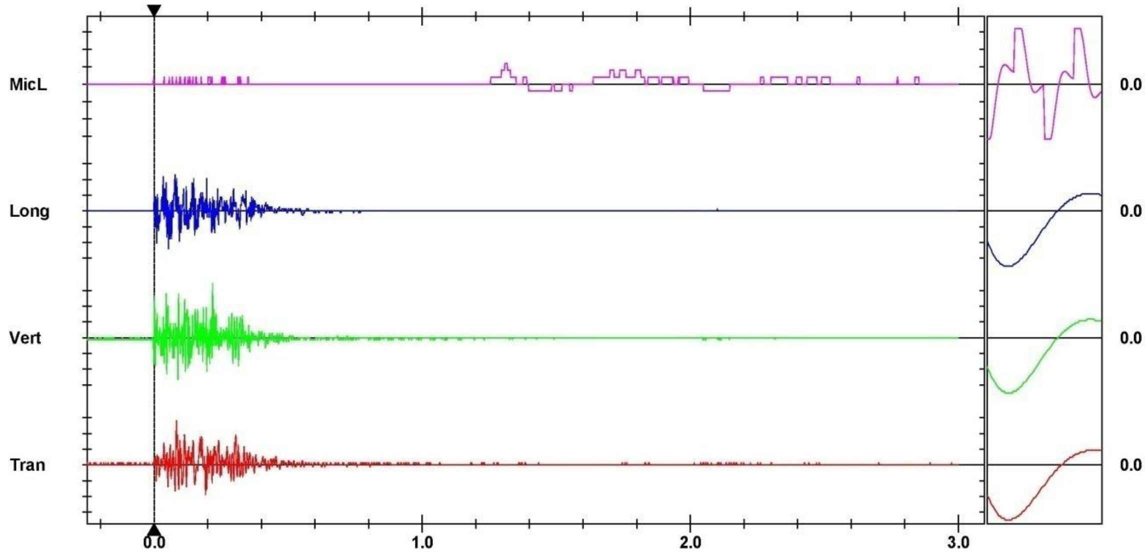
N/A: Not Applicable

DGMS India (A)

Permissible Ground Vibration



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 5.00 pa.(L)/div
Trigger = ▶———◀

Sensorcheck

Printed: June 26, 2018 (V 8.12 - 8.12)

Appendix-43- Minimate™ report for blast no. B-11

Instantel®

Event Report

Date/Time	Long at 14:33:29 May 31, 2018	**Serial Number**	5871 V 2.61 MiniMate
Trigger Source	Geo: 0.587 mm/s	**Battery Level**	6.1 Volts
Range	Geo :127 mm/s	**Calibration**	December 18, 2017 by UES, New Delhi
Record Time	3.0 sec at 1024 sps	**File Name**	G871HFT4.FT0

Notes
Location:
Client:
User Name:
Converted: June 3, 2018 10:21:10 (V8.12)

Extended Notes

Post Event Notes
Blasting at V No. 2 bench (N ---->S) , BID :4-24
No. of holes : 14, using DTH & TLD
Maximum charge per delay : 33.21 Kgs.
Distance from Blasting : 250 mtrs Back Side of Blasting Face

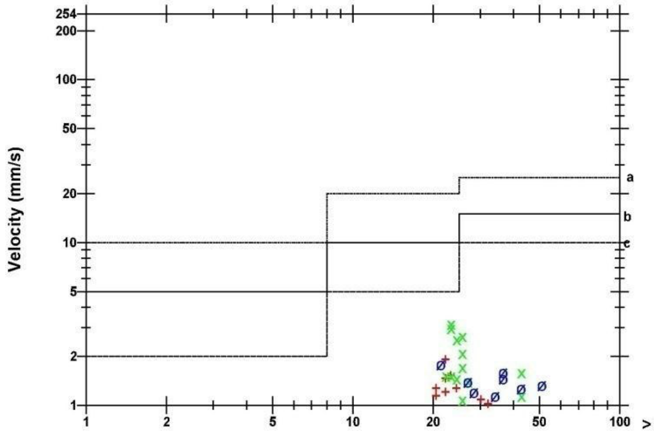
Microphone	Linear Weighting
PSPL	120.0 dB(L) at 0.929 sec
ZC Freq	9.1 Hz
Channel Test	Passed (Freq = 20.0 Hz Amp = 309 mv)

	Tran	Vert	Long	
PPV	1.91	3.18	1.78	mm/s
ZC Freq	20	23	21	Hz
Time (Rel. to Trig)	0.296	0.284	0.145	sec
Peak Acceleration	0.0398	0.0597	0.0398	g
Peak Displacement	0.0110	0.0187	0.0125	mm
Sensorcheck	Passed	Passed	Passed	
Frequency	7.7	8.1	8.2	Hz
Overswing Ratio	3.4	3.3	3.4	

Peak Vector Sum 3.38 mm/s at 0.284 sec

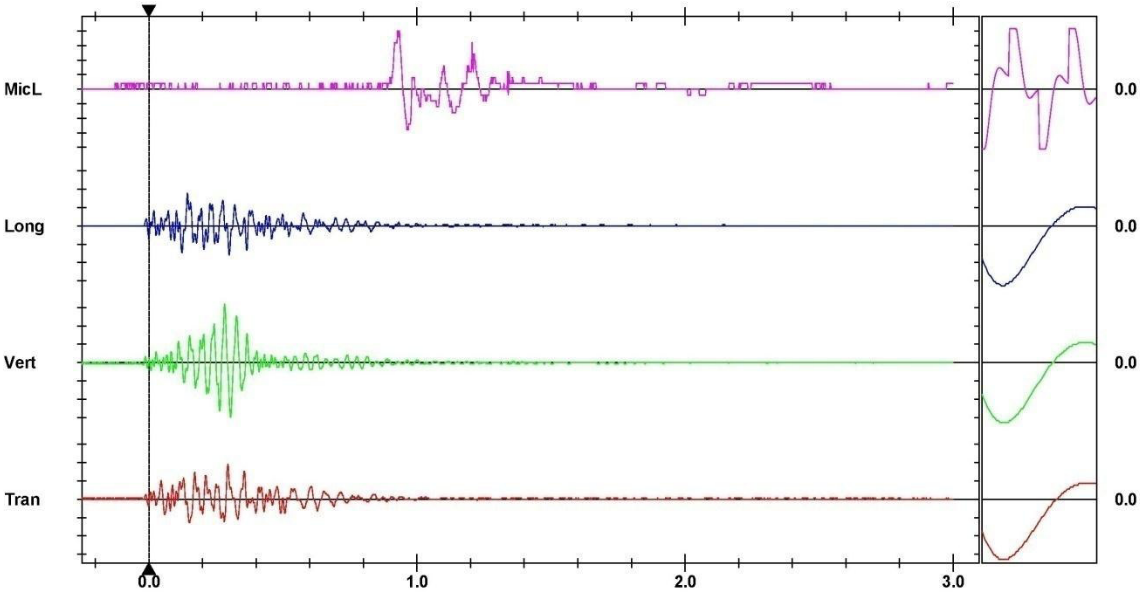
DGMS India (A)

Permissible Ground Vibration



Frequency (Hz)
Tran: + Vert: x Long: ø

a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 1.000 mm/s/div Mic: 5.00 pa.(L)/div

Sensorcheck

Trigger = ▶———◀

Printed: June 26, 2018 (V 8.12 - 8.12)

Appendix-44- Minimate^{TM} report for blast no. B-12

Instantel®

Event Report

Date/Time	Vert at 13:19:43 June 1, 2018
Trigger Source	Geo: 0.587 mm/s
Range	Geo :127 mm/s
Record Time	3.0 sec at 1024 sps

Serial Number	5871 V 2.61 MiniMate
Battery Level	6.0 Volts
Calibration	December 18, 2017 by UES, New Delhi
File Name	G871HFUV.OV0

Notes
Location:
Client:
User Name:
Converted: June 3, 2018 10:21:10 (V8.12)

Extended Notes

Post Event Notes
Blasting at V No. 2 bench (N ---->S) , BID :4-25
No. of holes : 10, using DTH & TLD
Maximum charge per delay : 35 Kgs.
Distance from Blasting : 300 mtrs Back Side of Blasting Face

Microphone	Linear Weighting
PSPL	112.0 dB(L) at 1.371 sec
ZC Freq	21 Hz
Channel Test	Passed (Freq = 20.0 Hz Amp = 300 mv)

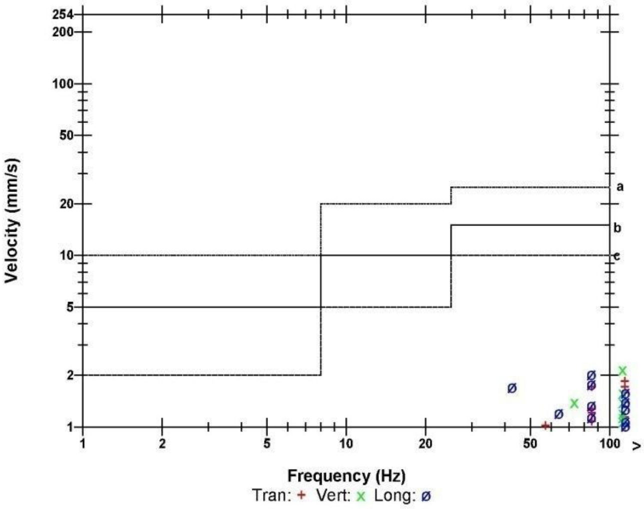
	Tran	Vert	Long	
PPV	1.84	2.16	2.03	mm/s
ZC Freq	N/A	N/A	85	Hz
Time (Rel. to Trig)	0.079	0.120	0.115	sec
Peak Acceleration	0.119	0.186	0.133	g
Peak Displacement	0.00338	0.00279	0.00561	mm
Sensorcheck	Passed	Passed	Passed	
Frequency	7.7	8.1	8.0	Hz
Overswing Ratio	3.8	3.4	3.8	

Peak Vector Sum 2.22 mm/s at 0.115 sec

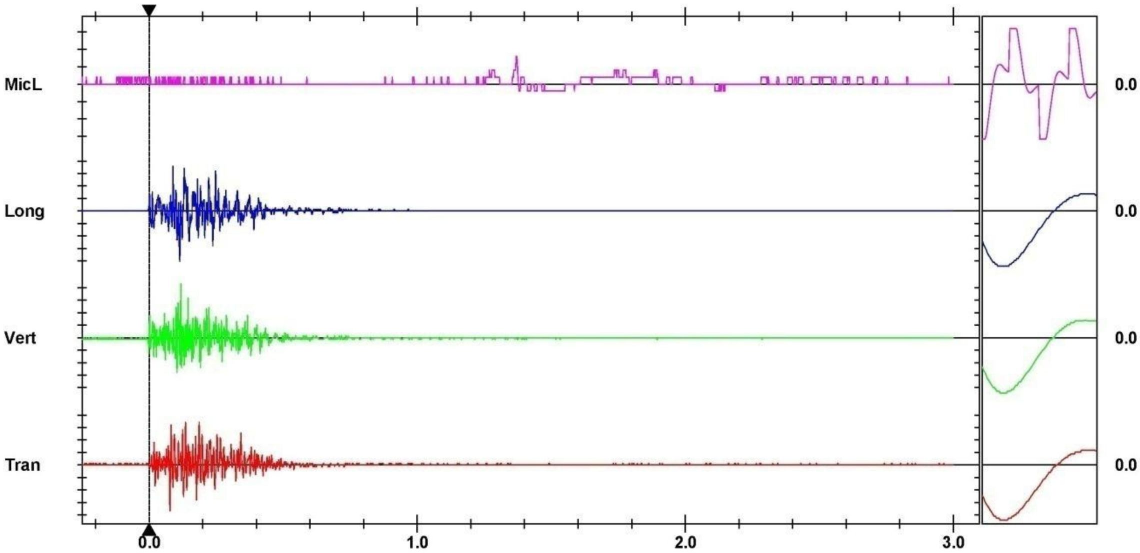
N/A: Not Applicable

DGMS India (A)

Permissible Ground Vibration



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 5.00 pa.(L)/div

Trigger = ▶———◀

Sensorcheck

Printed: June 26, 2018 (V 8.12 - 8.12)

Appendix-45- Minimate^{TM} report for blast no. B-13

Event Report

Date/Time Vert at 13:03:05 June 5, 2018
Trigger Source Geo: 0.587 mm/s
Range Geo :127 mm/s
Record Time 3.0 sec at 1024 sps

Serial Number 5871 V 2.61 MiniMate
Battery Level 6.2 Volts
Calibration December 18, 2017 by UES, New Delhi
File Name G871HG29.L50

Notes
Location:
Client:
User Name:
Converted: June 22, 2018 08:42:22 (V8.12)

Extended Notes

Post Event Notes
Blasting at V No. 2 bench (N ---->S) , BID :4-27
No. of holes : 10, using DTH & TLD
Maximum charge per delay : 37.5 Kgs.
Distance from Blasting : 250 mtrs Back Side of Blasting Face

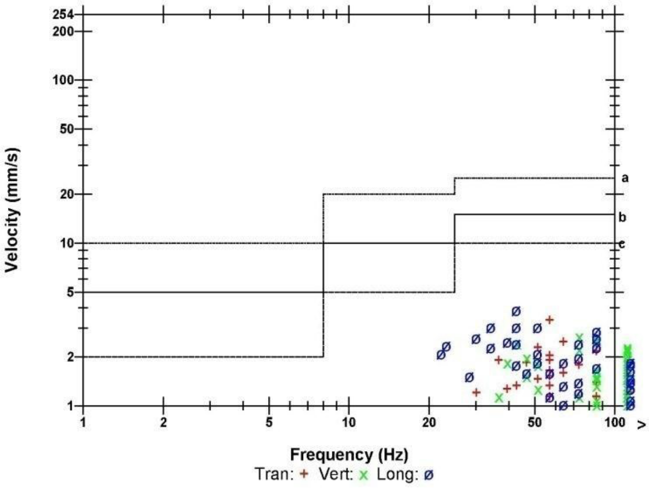
Microphone Linear Weighting
PSPL 106.0 dB(L) at 1.120 sec
ZC Freq 5.0 Hz
Channel Test Passed (Freq = 20.0 Hz Amp = 307 mv)

	Tran	Vert	Long	
PPV	3.37	2.67	3.87	mm/s
ZC Freq	57	73	43	Hz
Time (Rel. to Trig)	0.255	0.338	0.271	sec
Peak Acceleration	0.139	0.212	0.159	g
Peak Displacement	0.00899	0.00868	0.0131	mm
Sensorcheck	Passed	Passed	Passed	
Frequency	7.8	8.2	8.1	Hz
Overswing Ratio	3.8	3.3	3.8	

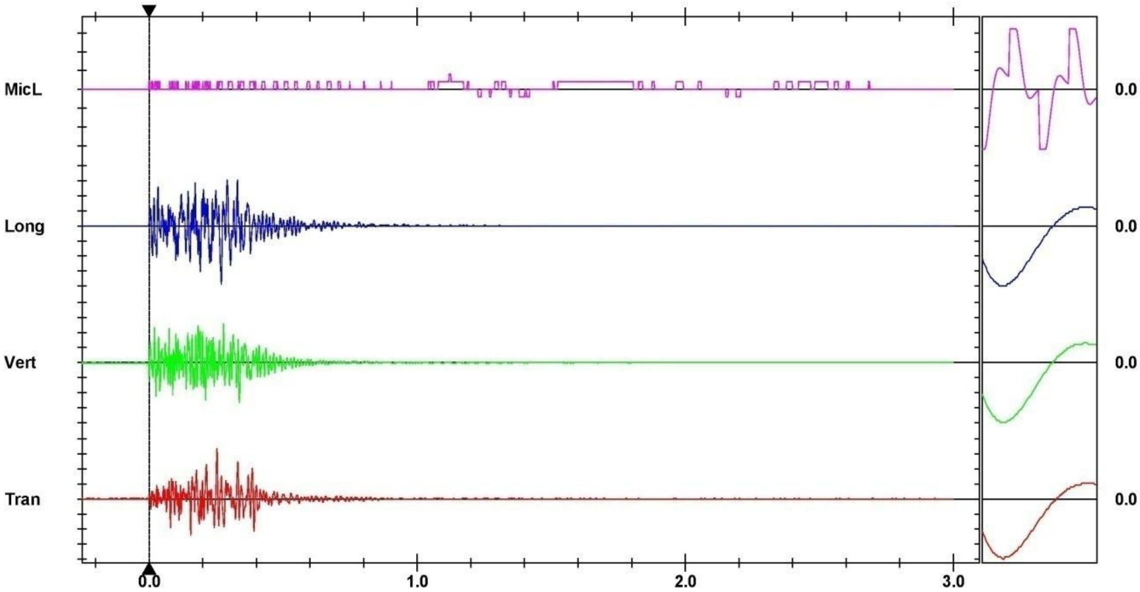
Peak Vector Sum 4.16 mm/s at 0.271 sec

DGMS India (A)

Permissible Ground Vibration



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 1.000 mm/s/div Mic: 5.00 pa.(L)/div
Trigger = ▶———◀

Sensorcheck

Printed: June 26, 2018 (V 8.12 - 8.12)

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Appendix-46- Minimate^{TM} report for blast no. B-14

Instantel

Event Report

Date/Time	Vert at 13:11:06 June 7, 2018	**Serial Number**	5871 V 2.61 MiniMate
Trigger Source	Geo: 0.587 mm/s	**Battery Level**	6.4 Volts
Range	Geo :127 mm/s	**Calibration**	December 18, 2017 by UES, New Delhi
Record Time	3.0 sec at 1024 sps	**File Name**	G871HG5Z.AI0

Notes
Location:
Client:
User Name:
Converted: June 22, 2018 08:42:23 (V8.12)

Extended Notes

Post Event Notes
Blasting at V No. 2 bench (N ---->S) , BID :4-28
No. of holes : 10, using DTH & TLD
Maximum charge per delay : 35 Kgs.
Distance from Blasting : 300 mtrs Back Side of Blasting Face

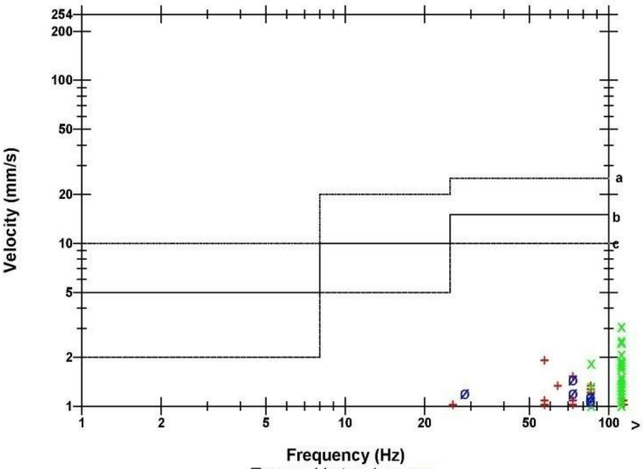
Microphone	Linear Weighting
PSPL	121.6 dB(L) at 1.238 sec
ZC Freq	17 Hz
Channel Test	Passed (Freq = 20.0 Hz Amp = 307 mv)

	Tran	Vert	Long	
PPV	1.91	3.11	1.46	mm/s
ZC Freq	57	>100	85	Hz
Time (Rel. to Trig)	0.097	0.201	0.198	sec
Peak Acceleration	0.0862	0.205	0.0994	g
Peak Displacement	0.00403	0.00481	0.00595	mm
Sensorcheck	Passed	Passed	Passed	
Frequency	7.8	8.2	8.2	Hz
Overswing Ratio	3.7	3.3	3.7	

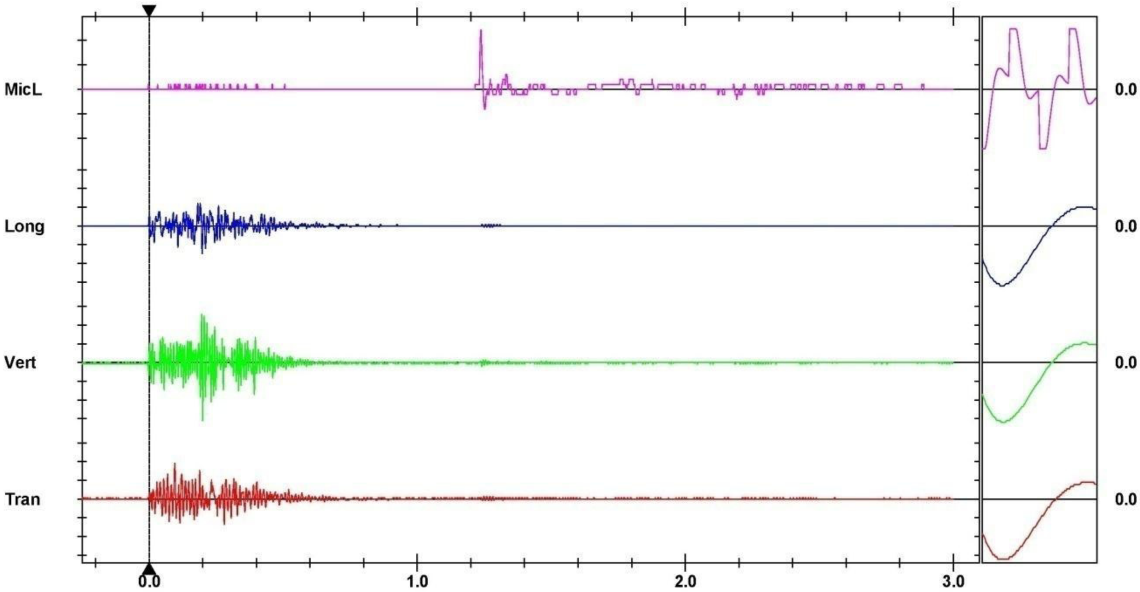
Peak Vector Sum 3.29 mm/s at 0.201 sec

DGMS India (A)

Permissible Ground Vibration



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 1.000 mm/s/div Mic: 10.00 pa.(L)/div
Trigger = ▶————◀

Sensorcheck

Printed: June 26, 2018 (V 8.12 - 8.12)

Appendix-47- Minimate^{TM} report for blast no. B-15

Instantel® **Event Report**

Date/Time	Tran at 13:04:46 June 8, 2018	**Serial Number**	5871 V 2.61 MiniMate
Trigger Source	Geo: 0.587 mm/s	**Battery Level**	6.3 Volts
Range	Geo :127 mm/s	**Calibration**	December 18, 2017 by UES, New Delhi
Record Time	3.0 sec at 1024 sps	**File Name**	G871HG7T.NY0

Notes
Location:
Client:
User Name:
Converted: June 22, 2018 08:42:23 (V8.12)

Extended Notes

Post Event Notes
Blasting at IV No. 3 bench (W ---->E) , BID :8-8
No. of holes : 16, using DTH & TLD
Maximum charge per delay : 30.62 Kgs.
Distance from Blasting : 400 mtrs Back Side of Blasting Face

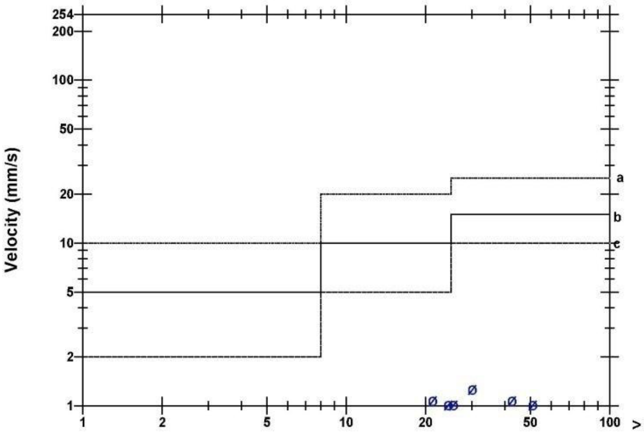
Microphone	Linear Weighting
PSPL	114.0 dB(L) at 1.251 sec
ZC Freq	9.1 Hz
Channel Test	Passed (Freq = 20.0 Hz Amp = 307 mv)

	Tran	Vert	Long	
PPV	0.889	0.953	1.27	mm/s
ZC Freq	37	22	28	Hz
Time (Rel. to Trig)	0.148	0.325	0.323	sec
Peak Acceleration	0.0398	0.0398	0.0398	g
Peak Displacement	0.00394	0.00561	0.00598	mm
Sensorcheck	Passed	Passed	Passed	
Frequency	8.2	8.2	8.1	Hz
Overswing Ratio	3.5	3.3	3.7	

Peak Vector Sum 1.52 mm/s at 0.324 sec

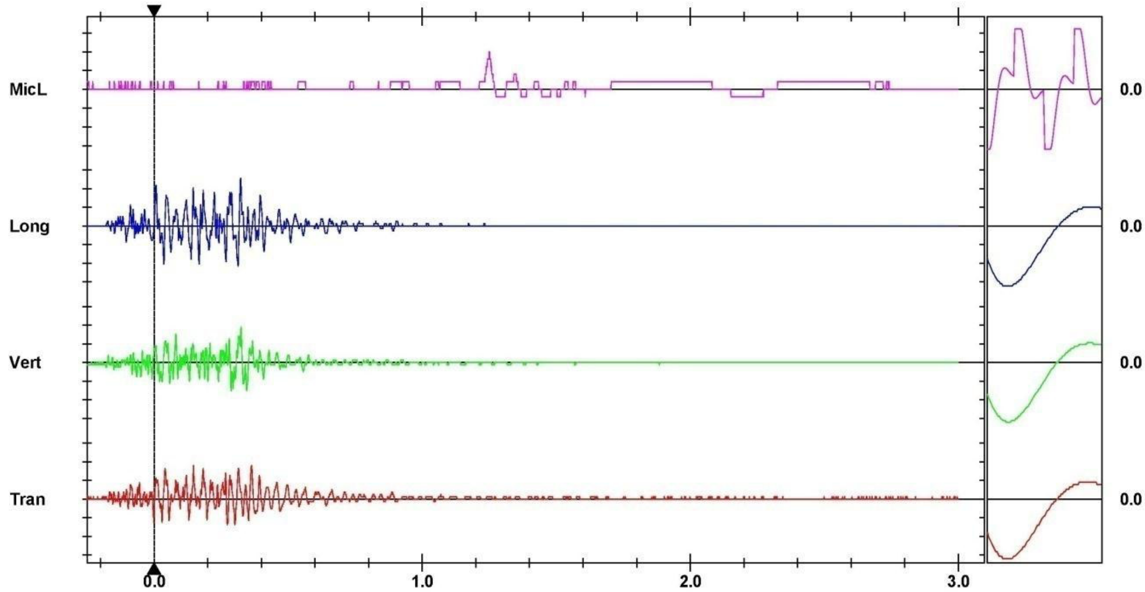
DGMS India (A)

Permissible Ground Vibration



Frequency (Hz)
Tran: + Vert: x Long: ø

a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 5.00 pa.(L)/div
Trigger = ▶———◀

Sensorcheck

Printed: June 26, 2018 (V 8.12 - 8.12)

Appendix-48- Minimate™ report for blast no. B-16

Event Report

Instantel

Date/Time	Long at 15:41:07 June 9, 2018	**Serial Number**	5871 V 2.61 MiniMate
Trigger Source	Geo: 0.587 mm/s	**Battery Level**	6.1 Volts
Range	Geo :127 mm/s	**Calibration**	December 18, 2017 by UES, New Delhi
Record Time	3.0 sec at 1024 sps	**File Name**	G871HG9V.KJ0

Notes
Location:
Client:
User Name:
Converted: June 22, 2018 08:42:23 (V8.12)

Extended Notes

Post Event Notes
Blasting at II bench (S ---->N) , BID :3-7
No. of holes : 12, using DTH & TLD
Maximum charge per delay : 35.83 Kgs.
Distance from Blasting : 400 mtrs Back Side of Blasting Face

Microphone Linear Weighting
PSPL 100.0 dB(L) at -0.071 sec
ZC Freq N/A
Channel Test Passed (Freq = 20.0 Hz Amp = 306 mv)

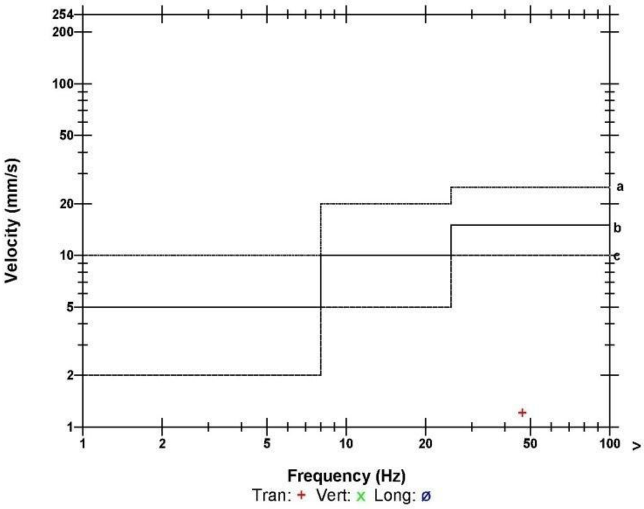
	Tran	Vert	Long	
PPV	1.21	0.572	0.762	mm/s
ZC Freq	47	N/A	64	Hz
Time (Rel. to Trig)	0.011	0.003	0.008	sec
Peak Acceleration	0.0398	0.0464	0.0331	g
Peak Displacement	0.00350	0.00056	0.00211	mm
Sensorcheck	Passed	Passed	Passed	
Frequency	8.2	8.1	8.1	Hz
Overswing Ratio	3.7	3.4	3.6	

Peak Vector Sum 1.25 mm/s at 0.011 sec

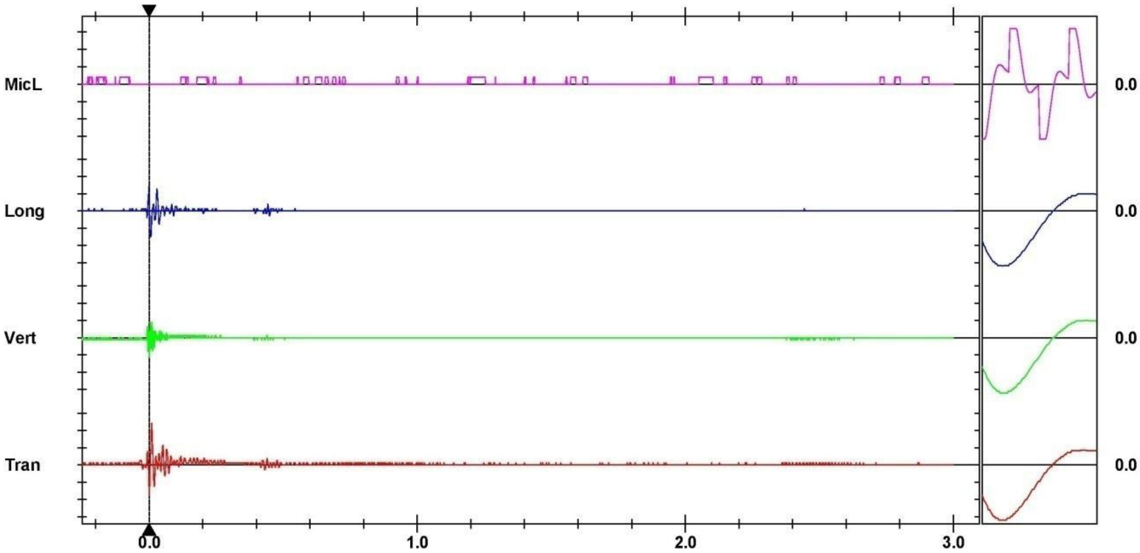
N/A: Not Applicable

DGMS India (A)

Permissible Ground Vibration



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 5.00 pa.(L)/div
Trigger = ▶————◀

Sensorcheck

Printed: June 26, 2018 (V 8.12 - 8.12)

APPENDICES-D

Appendix-49- Minimate^{TM} report for blast no. E-1

Instantel

Event Report

Date/Time	Vert at 14:19:35 June 19, 2018	**Serial Number**	5871 V 2.61 MiniMate
Trigger Source	Geo: 0.587 mm/s	**Battery Level**	6.3 Volts
Range	Geo :127 mm/s	**Calibration**	December 18, 2017 by UES, New Delhi
Record Time	3.0 sec at 1024 sps	**File Name**	G871HGSA.GN0

Notes
Location:
Client:
User Name:
Converted: June 22, 2018 08:42:23 (V8.12)

Extended Notes

Post Event Notes
Blasting at V No. 2 bench (N ---->S) , BID :4-30
No. of holes : 14, using DTH & TLD
Maximum charge per delay : 32.73 Kgs.
Distance from Blasting : 400 mtrs Back Side of Blasting Face

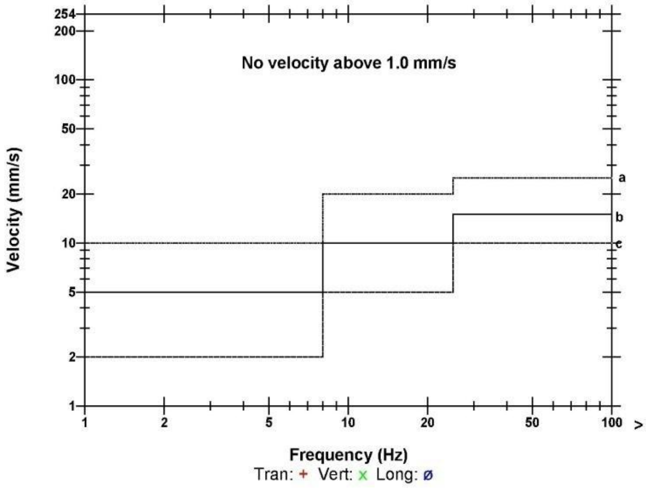
Microphone Linear Weighting
PSPL 100.0 dB(L) at -0.014 sec
ZC Freq 85 Hz
Channel Test Passed (Freq = 20.0 Hz Amp = 307 mv)

	Tran	Vert	Long	
PPV	0.826	0.953	0.826	mm/s
ZC Freq	37	51	>100	Hz
Time (Rel. to Trig)	0.003	0.000	0.008	sec
Peak Acceleration	0.0331	0.0530	0.0795	g
Peak Displacement	0.00462	0.00496	0.00102	mm
Sensorcheck	Passed	Passed	Passed	
Frequency	7.7	8.1	8.2	Hz
Overswing Ratio	3.8	3.3	3.6	

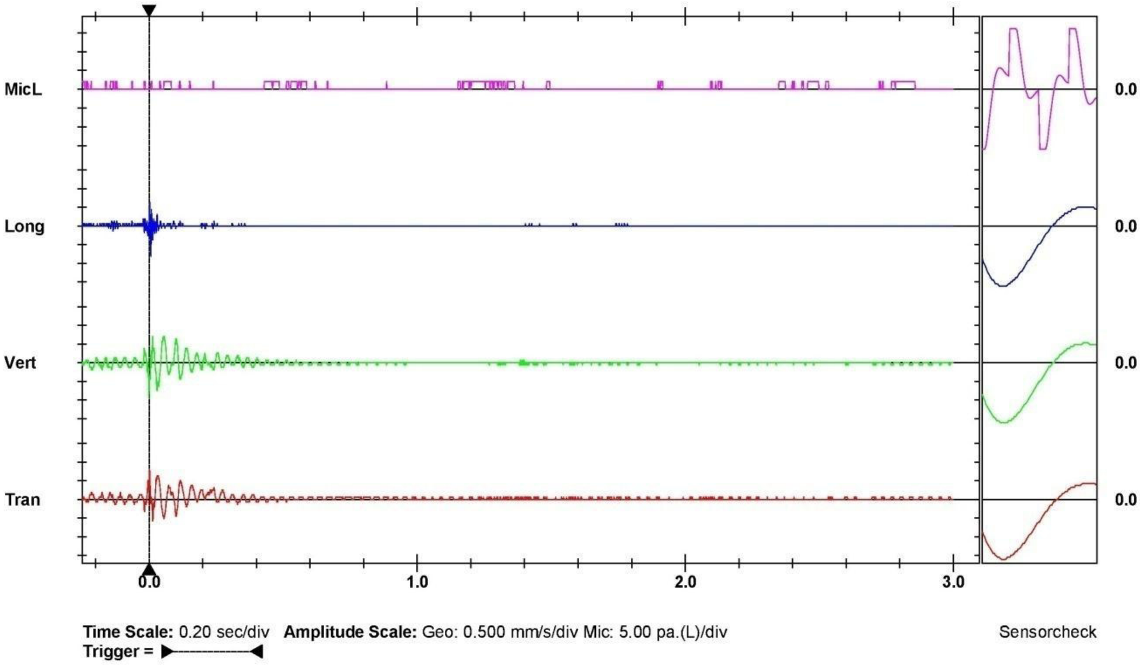
Peak Vector Sum 1.13 mm/s at 0.003 sec

DGMS India (A)

Permissible Ground Vibration



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 5.00 pa.(L)/div
Trigger = ▶——◀
Sensorcheck

Printed: June 26, 2018 (V 8.12 - 8.12)

Appendix-50- Minimate™ report for blast no. E-2

Event Report

Date/Time	Long at 13:18:21 June 22, 2018	**Serial Number**	5871 V 2.61 MiniMate
Trigger Source	Geo: 0.587 mm/s	**Battery Level**	6.4 Volts
Range	Geo :127 mm/s	**Calibration**	December 18, 2017 by UES, New Delhi
Record Time	3.0 sec at 1024 sps	**File Name**	G871HGXR.ML0

Notes
Location:
Client:
User Name:
Converted: July 3, 2018 09:32:50 (V8.12)

Extended Notes

Post Event Notes
Blasting at III bench (S ---->N) , BID :11-12
No. of holes : 14, using DTH & TLD
Maximum charge per delay : 28.37 Kgs.
Distance from Blasting : 300 mtrs In the line of Inititation

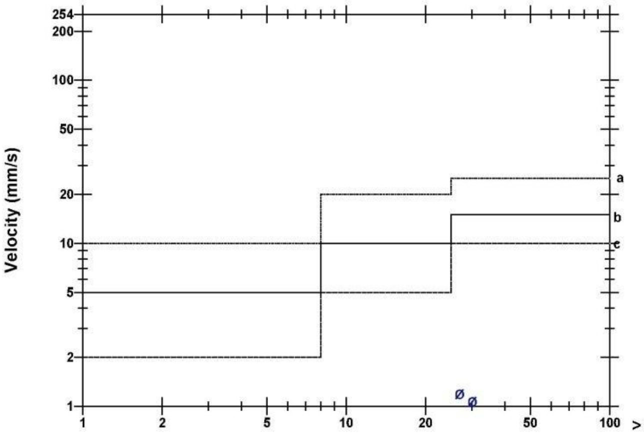
Microphone	Linear Weighting
PSPL	114.0 dB(L) at 1.050 sec
ZC Freq	12 Hz
Channel Test	Passed (Freq = 20.0 Hz Amp = 306 mv)

	Tran	Vert	Long	
PPV	0.762	0.508	1.21	mm/s
ZC Freq	20	32	27	Hz
Time (Rel. to Trig)	0.061	0.241	0.060	sec
Peak Acceleration	0.0265	0.0199	0.0331	g
Peak Displacement	0.00378	0.00233	0.00592	mm
Sensorcheck	Passed	Passed	Passed	
Frequency	7.7	8.1	8.2	Hz
Overswing Ratio	3.8	3.5	3.8	

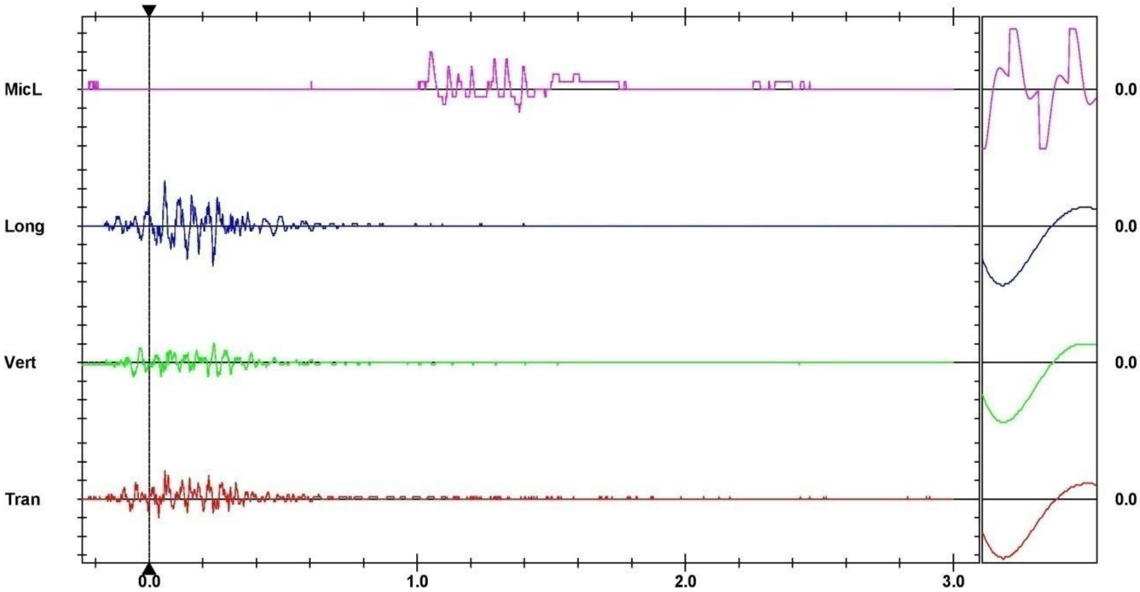
Peak Vector Sum 1.38 mm/s at 0.061 sec

DGMS India (A)

Permissible Ground Vibration



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 5.00 pa.(L)/div
Trigger = ▶———◀

Sensorcheck

Printed: July 3, 2018 (V 8.12 - 8.12)

Appendix-51- Minimate™ report for blast no. E-3

Instantel

Event Report

Date/Time	Long at 13:50:38 June 23, 2018	**Serial Number**	5871 V 2.61 MiniMate
Trigger Source	Geo: 0.587 mm/s	**Battery Level**	6.3 Volts
Range	Geo :127 mm/s	**Calibration**	December 18, 2017 by UES, New Delhi
Record Time	3.0 sec at 1024 sps	**File Name**	G871HGZN.SE0

Notes
Location:
Client:
User Name:
Converted: July 3, 2018 09:32:50 (V8.12)

Extended Notes

Post Event Notes
Blasting at II bench (W ---->E) , BID : 3-10
No. of holes : 10, using DTH & TLD
Maximum charge per delay : 35.27 Kgs.
Distance from Blasting : 350 mtrs In the line of Inititation

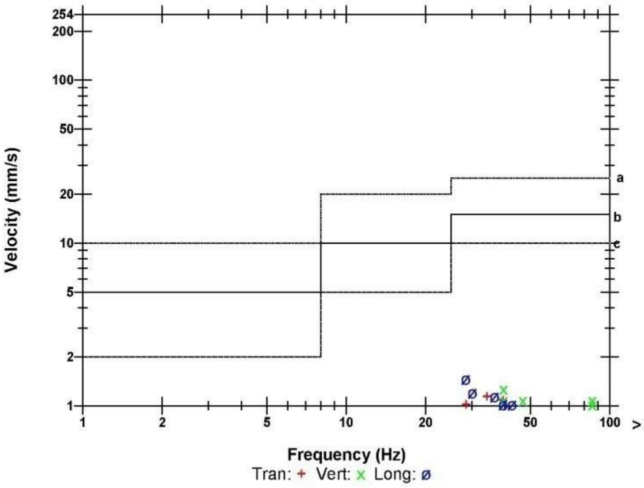
Microphone Linear Weighting
PSPL 124.1 dB(L) at 1.145 sec
ZC Freq 14 Hz
Channel Test Passed (Freq = 20.0 Hz Amp = 307 mv)

	Tran	Vert	Long	
PPV	1.14	1.27	1.46	mm/s
ZC Freq	34	39	28	Hz
Time (Rel. to Trig)	0.096	0.068	0.212	sec
Peak Acceleration	0.0530	0.0663	0.0530	g
Peak Displacement	0.00543	0.00524	0.00716	mm
Sensorcheck	Passed	Passed	Passed	
Frequency	7.8	8.1	8.2	Hz
Overswing Ratio	3.7	3.4	3.7	

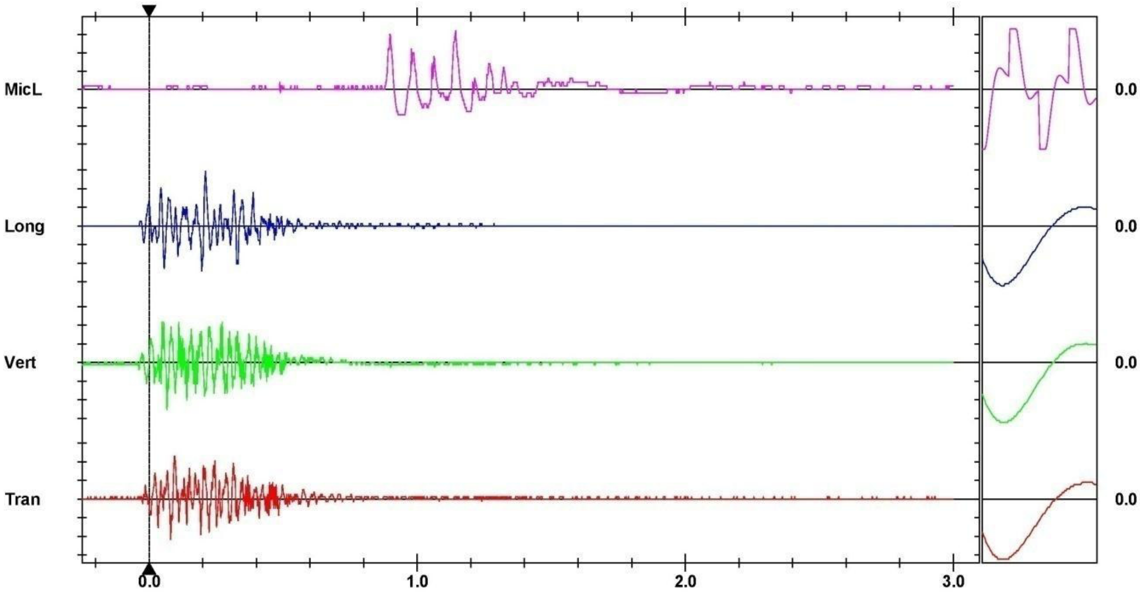
Peak Vector Sum 1.76 mm/s at 0.211 sec

DGMS India (A)

Permissible Ground Vibration



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 10.00 pa.(L)/div
Trigger = ▶————◀

Sensorcheck

Printed: July 3, 2018 (V 8.12 - 8.12)

Appendix-52- Minimate™ report for blast no. E-4

Event Report

Date/Time	Long at 13:40:03 June 24, 2018	**Serial Number**	5871 V 2.61 MiniMate
Trigger Source	Geo: 0.587 mm/s	**Battery Level**	6.4 Volts
Range	Geo :127 mm/s	**Calibration**	December 18, 2017 by UES, New Delhi
Record Time	3.0 sec at 1024 sps	**File Name**	G871HH1H.YR0

Notes
Location:
Client:
User Name:
Converted: July 3, 2018 09:32:50 (V8.12)

Extended Notes

Post Event Notes
Blasting at IV No. 3 bench (S ---->N) , BID :5-16
No. of holes : 13, using DTH & TLD
Maximum charge per delay : 35.25 Kgs.
Distance from Blasting : 250 mtrs Opp. Side of Inititation

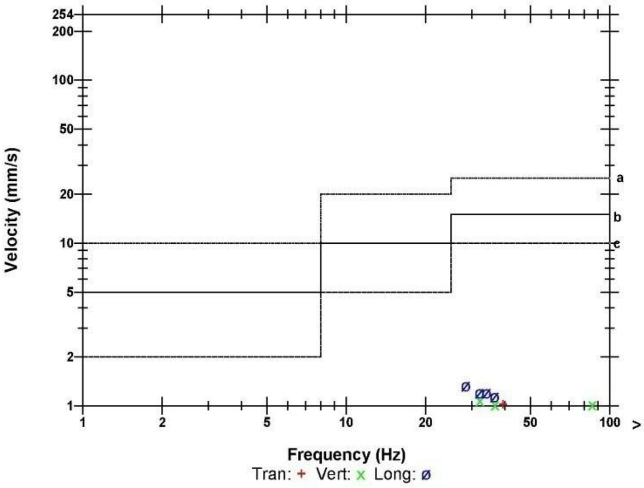
Microphone	Linear Weighting
PSPL	118.1 dB(L) at 1.169 sec
ZC Freq	21 Hz
Channel Test	Passed (Freq = 20.0 Hz Amp = 307 mv)

	Tran	Vert	Long	
PPV	1.02	1.08	1.33	mm/s
ZC Freq	37	32	28	Hz
Time (Rel. to Trig)	0.183	0.393	0.461	sec
Peak Acceleration	0.0530	0.0597	0.0331	g
Peak Displacement	0.00419	0.00388	0.00676	mm
Sensorcheck	Passed	Passed	Passed	
Frequency	7.8	8.1	8.2	Hz
Overswing Ratio	3.6	3.3	3.4	

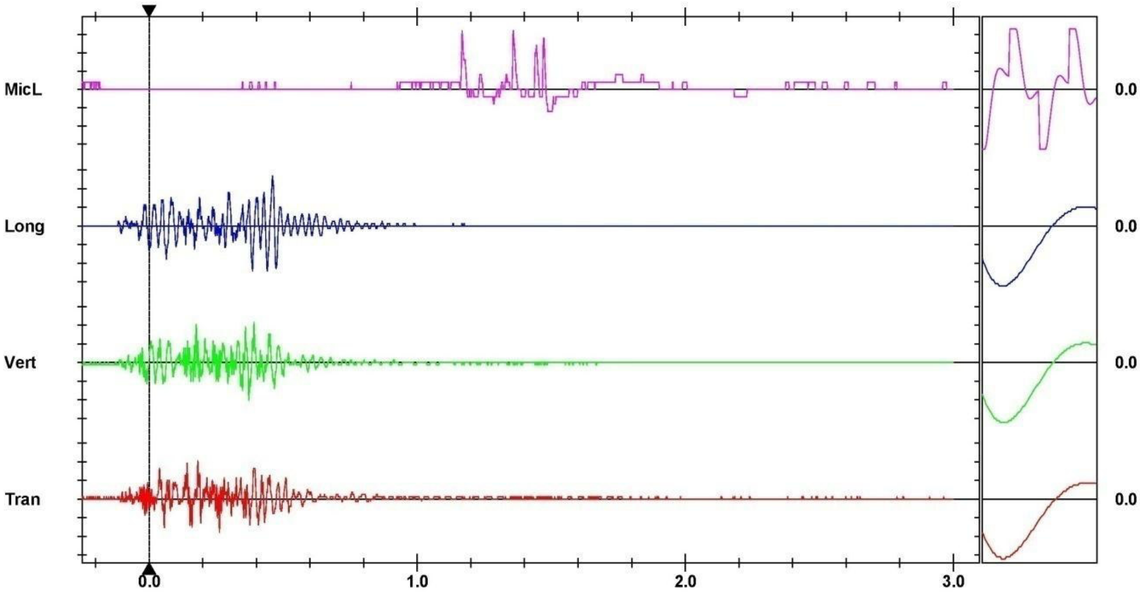
Peak Vector Sum 1.41 mm/s at 0.462 sec

DGMS India (A)

Permissible Ground Vibration



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 5.00 pa.(L)/div Sensorcheck
Trigger = ▶————◀

Printed: July 3, 2018 (V 8.12 - 8.12)

Appendix-53- Minimate™ report for blast no. E-5

Instantel

Event Report

Date/Time	Tran at 13:12:47 June 25, 2018	**Serial Number**	5871 V 2.61 MiniMate
Trigger Source	Geo: 0.587 mm/s	**Battery Level**	6.4 Volts
Range	Geo :127 mm/s	**Calibration**	December 18, 2017 by UES, New Delhi
Record Time	3.0 sec at 1024 sps	**File Name**	G871HH3B.DB0

Notes
Location:
Client:
User Name:
Converted: July 3, 2018 09:32:50 (V8.12)

Extended Notes

Post Event Notes
Blasting at V No. 2 bench (N ---->S) , BID :4-32
No. of holes : 12, using DTH & TLD
Maximum charge per delay : 34.72 Kgs.
Distance from Blasting : 300 mtrs Back Side of Blasting Face

Microphone	Linear Weighting
PSPL	109.5 dB(L) at 0.975 sec
ZC Freq	12 Hz
Channel Test	Passed (Freq = 20.0 Hz Amp = 307 mv)

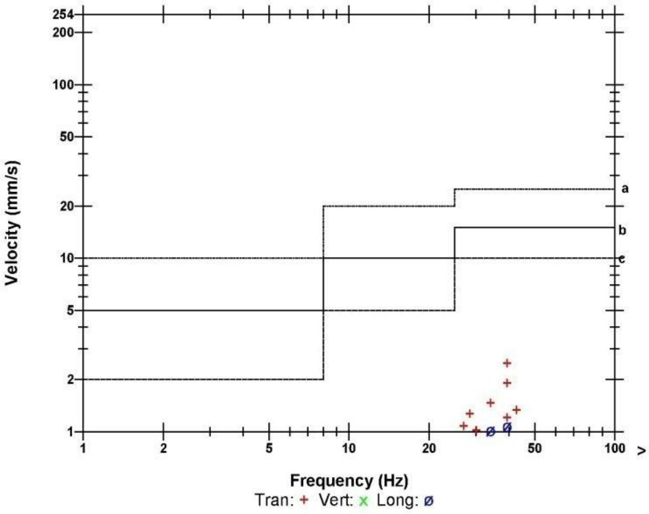
	Tran	Vert	Long	
PPV	2.48	0.889	1.08	mm/s
ZC Freq	39	N/A	39	Hz
Time (Rel. to Trig)	0.147	0.210	0.083	sec
Peak Acceleration	0.0795	0.0729	0.0464	g
Peak Displacement	0.0108	0.00347	0.00493	mm
Sensorcheck	Passed	Passed	Passed	
Frequency	7.8	8.2	8.5	Hz
Overswing Ratio	3.8	3.3	3.5	

Peak Vector Sum 2.49 mm/s at 0.147 sec

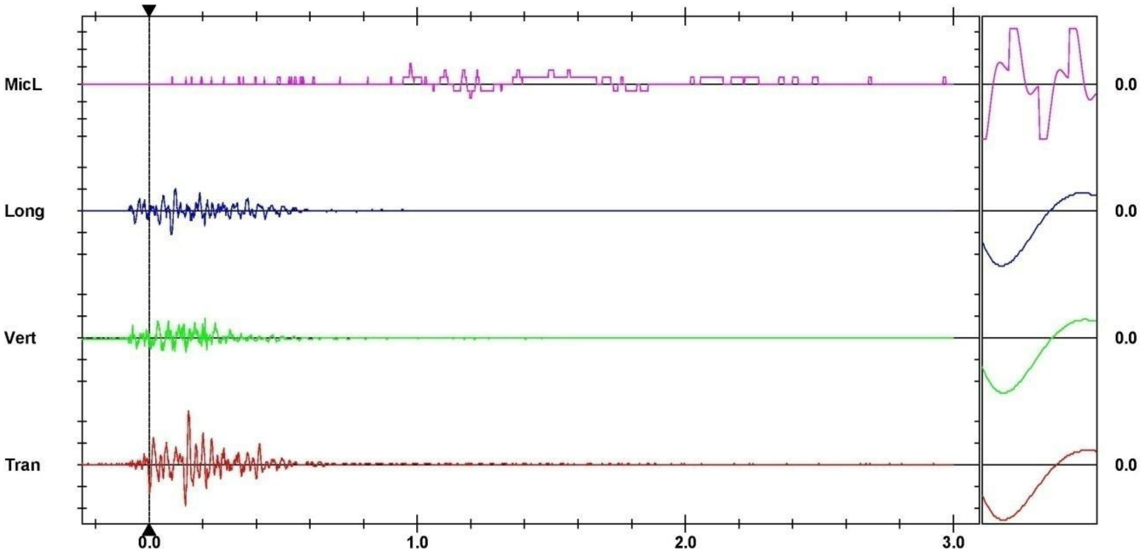
N/A: Not Applicable

DGMS India (A)

Permissible Ground Vibration



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 1.000 mm/s/div Mic: 5.00 pa.(L)/div
Trigger = ▶——◀

Sensorcheck

Printed: July 3, 2018 (V 8.12 - 8.12)

Appendix-54- Minimate^{TM} report for blast no. E-6

Instantel® **Event Report**

Date/Time	Vert at 12:19:25 June 29, 2018	**Serial Number**	5871 V 2.61 MiniMate
Trigger Source	Geo: 0.587 mm/s	**Battery Level**	6.0 Volts
Range	Geo :127 mm/s	**Calibration**	December 18, 2017 by UES, New Delhi
Record Time	3.0 sec at 1024 sps	**File Name**	G871HHAN.KD0

Notes
Location:
Client:
User Name:
Converted: July 3, 2018 09:32:50 (V8.12)

Extended Notes

Post Event Notes
Blasting at IV No. 3 bench (S ---->N) , BID :5-18
No. of holes : 15, using DTH & TLD
Maximum charge per delay : 34.90 Kgs.
Distance from Blasting : 250 mtrs Opp. Side of Blasting Face

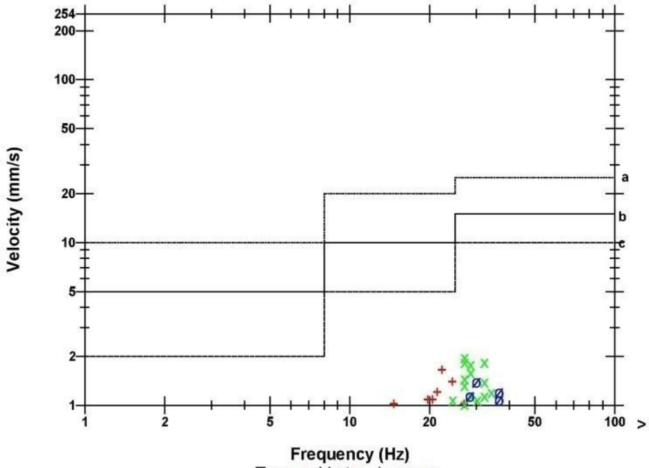
Microphone	Linear Weighting
PSPL	121.6 dB(L) at 1.239 sec
ZC Freq	39 Hz
Channel Test	Passed (Freq = 20.0 Hz Amp = 304 mv)

	Tran	Vert	Long	
PPV	1.65	1.97	1.40	mm/s
ZC Freq	22	27	32	Hz
Time (Rel. to Trig)	0.109	0.136	0.299	sec
Peak Acceleration	0.0331	0.0398	0.0398	g
Peak Displacement	0.00986	0.0119	0.00716	mm
Sensorcheck	Passed	Passed	Passed	
Frequency	7.6	8.1	8.3	Hz
Overswing Ratio	3.8	3.5	3.7	

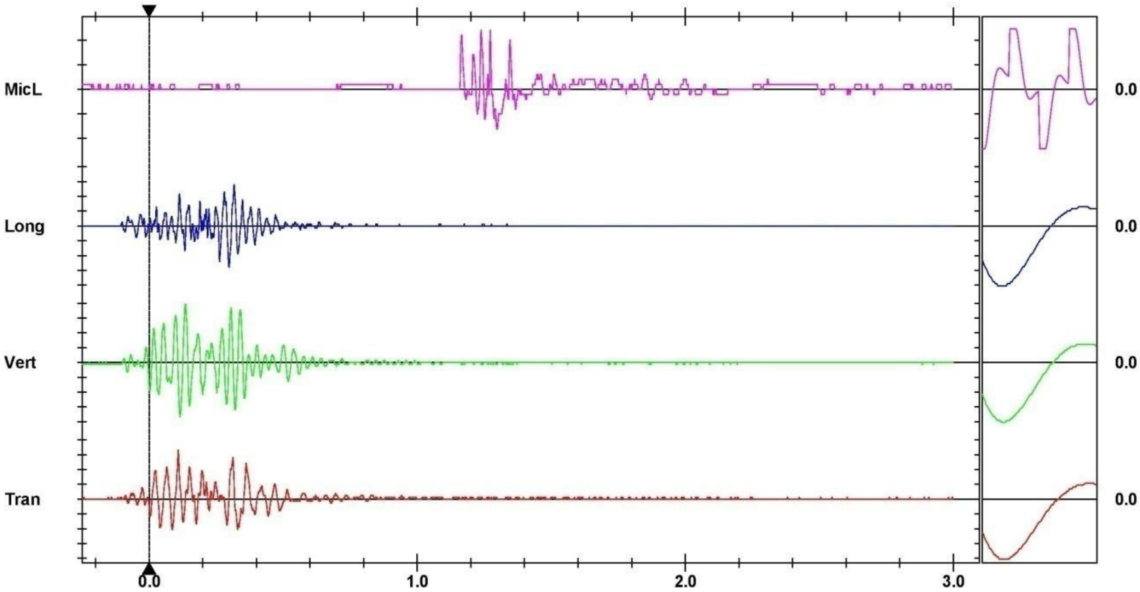
Peak Vector Sum 2.17 mm/s at 0.307 sec

DGMS India (A)

Permissible Ground Vibration



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 10.00 pa.(L)/div
Trigger = ▶———◀

Sensorcheck

Printed: July 3, 2018 (V 8.12 - 8.12)

Appendix-55- Minimate^{TM} report for blast no. E-7

Instantel® **Event Report**

Date/Time	Vert at 12:52:18 July 1, 2018	**Serial Number**	5871 V 2.61 MiniMate
Trigger Source	Geo: 0.587 mm/s	**Battery Level**	5.9 Volts
Range	Geo :127 mm/s	**Calibration**	December 18, 2017 by UES, New Delhi
Record Time	3.0 sec at 1024 sps	**File Name**	G871HHEE.F60

Notes
Location:
Client:
User Name:
Converted: July 3, 2018 09:32:50 (V8.12)

Extended Notes

Post Event Notes
Blasting at IV No. 3 bench (S ---->N) , BID :5-19
No. of holes : 15, using DTH & TLD
Maximum charge per delay : 37.73 Kgs.
Distance from Blasting : 200 mtrs Opp. Side of Blasting Face

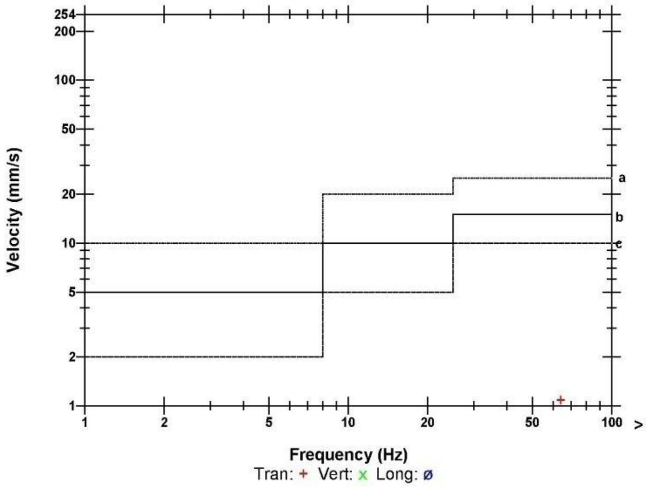
Microphone	Linear Weighting
PSPL	123.5 dB(L) at 1.143 sec
ZC Freq	15 Hz
Channel Test	Passed (Freq = 20.0 Hz Amp = 306 mv)

	Tran	Vert	Long	
PPV	1.08	0.826	0.953	mm/s
ZC Freq	64	37	85	Hz
Time (Rel. to Trig)	0.133	0.255	0.153	sec
Peak Acceleration	0.0398	0.0265	0.0464	g
Peak Displacement	0.00409	0.00453	0.00431	mm
Sensorcheck	Passed	Passed	Passed	
Frequency	7.7	8.2	8.2	Hz
Overswing Ratio	3.8	3.4	3.7	

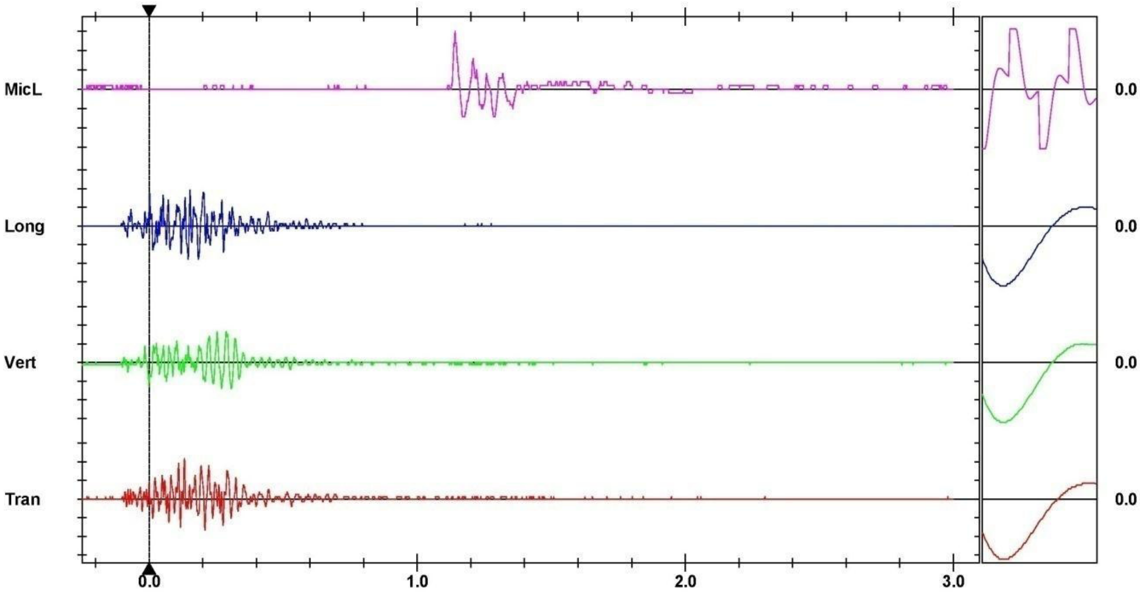
Peak Vector Sum 1.14 mm/s at 0.133 sec

DGMS India (A)

Permissible Ground Vibration



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 10.00 pa.(L)/div
Trigger = ▶———◀

Sensorcheck

Printed: July 3, 2018 (V 8.12 - 8.12)

Appendix-56- Minimate^{TM} report for blast no. E-8

Instantel®

Event Report

Date/Time	Long at 12:38:49 July 3, 2018	**Serial Number**	5871 V 2.61 MiniMate
Trigger Source	Geo: 0.587 mm/s	**Battery Level**	6.3 Volts
Range	Geo :127 mm/s	**Calibration**	December 18, 2017 by UES, New Delhi
Record Time	3.0 sec at 1024 sps	**File Name**	G871HHI3.4P0

Notes

Location: Maliakhera Mine
Client: J.K. Cement Works, Nimbahera
User Name: Pradeep Kumar Dawer
Converted: July 6, 2018 14:53:47 (V8.12)

Extended Notes

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Post Event Notes

Blasting at IV No. 3 bench (S ---->N) , BID :5-20
No. of holes : 14, using DTH & TLD
Maximum charge per delay : 30.85 Kgs.
Distance from Blasting : 300 mtrs Opp. Side of Blasting Face

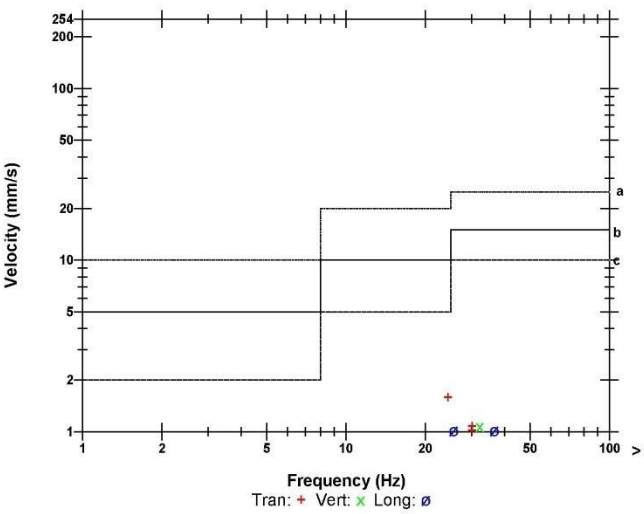
Microphone	Linear Weighting
PSPL	123.5 dB(L) at 1.352 sec
ZC Freq	39 Hz
Channel Test	Passed (Freq = 20.0 Hz Amp = 306 mv)

	Tran	Vert	Long	
PPV	1.59	1.08	1.02	mm/s
ZC Freq	24	30	37	Hz
Time (Rel. to Trig)	0.171	0.165	0.145	sec
Peak Acceleration	0.0331	0.0265	0.0199	g
Peak Displacement	0.00995	0.00546	0.00580	mm
Sensorcheck	Passed	Passed	Passed	
Frequency	7.6	8.2	8.5	Hz
Overswing Ratio	3.8	3.5	3.6	

Peak Vector Sum 1.76 mm/s at 0.171 sec

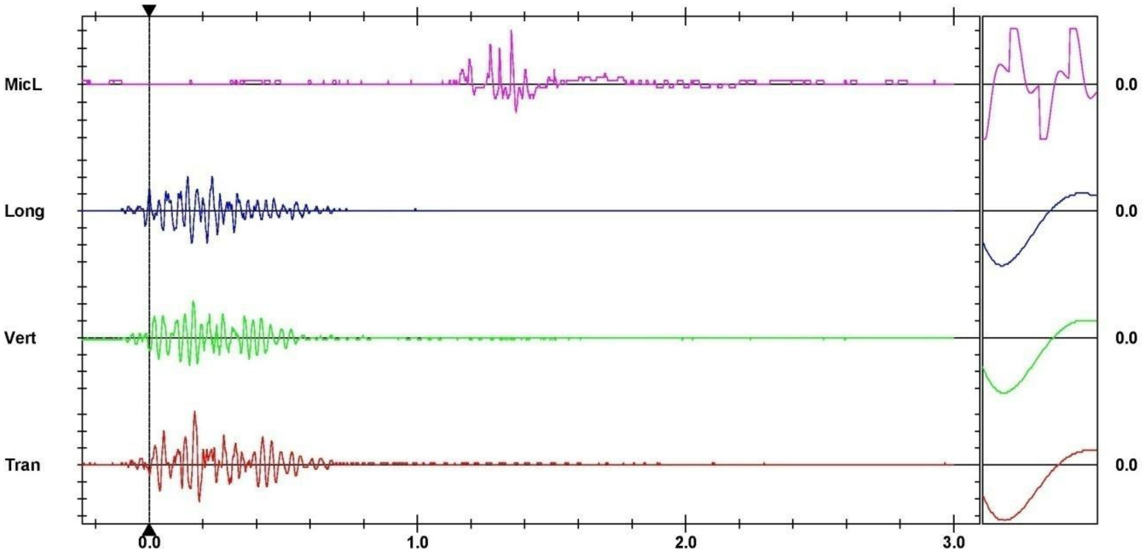
DGMS India (A)

Permissible Ground Vibration



Frequency (Hz)
Tran: + Vert: x Long: ø

a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 10.00 pa.(L)/div Sensorcheck
Trigger = ▶——◀

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Appendix-57- Minimate^{TM} report for blast no. E-10

Instantel®

Event Report

Date/Time	Long at 13:09:18 June 15, 2018	**Serial Number**	5871 V 2.61 MiniMate
Trigger Source	Geo: 0.587 mm/s	**Battery Level**	6.1 Volts
Range	Geo :127 mm/s	**Calibration**	December 18, 2017 by UES, New Delhi
Record Time	3.0 sec at 1024 sps	**File Name**	G871HGKS.JI0

Notes
Location:
Client:
User Name:
Converted: June 22, 2018 08:42:23 (V8.12)

Extended Notes

Post Event Notes
Blasting at V No. 2 bench (N ---->S) , BID :4-29
No. of holes : 13, using DTH & TLD
Maximum charge per delay : 33.46 Kgs.
Distance from Blasting : 350 mtrs Back Side of Blasting Face

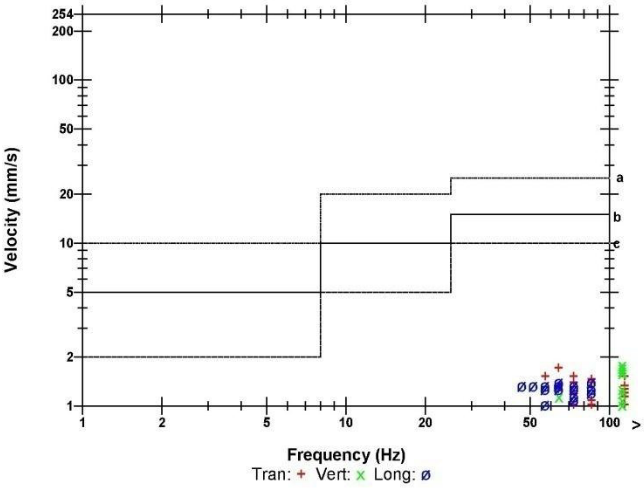
Microphone Linear Weighting
PSPL 109.5 dB(L) at 1.229 sec
ZC Freq 7.0 Hz
Channel Test Passed (Freq = 20.0 Hz Amp = 306 mv)

	Tran	Vert	Long	
PPV	1.71	1.78	1.40	mm/s
ZC Freq	64	>100	85	Hz
Time (Rel. to Trig)	0.143	0.126	0.095	sec
Peak Acceleration	0.0928	0.133	0.0729	g
Peak Displacement	0.00446	0.00288	0.00508	mm
Sensorcheck	Passed	Passed	Passed	
Frequency	7.7	8.2	8.1	Hz
Overswing Ratio	3.8	3.5	3.8	

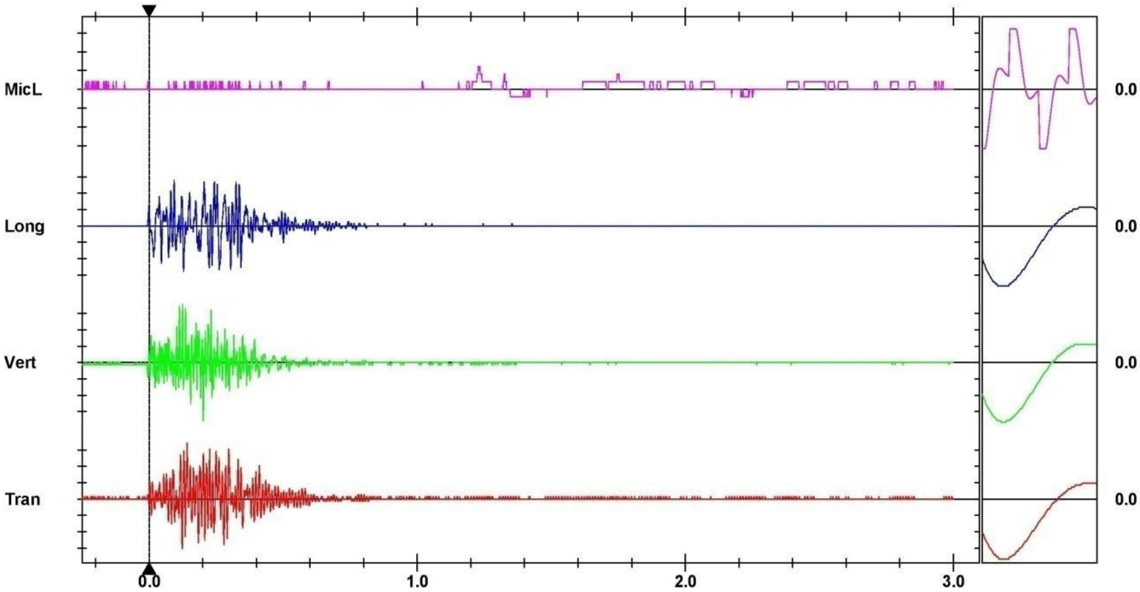
Peak Vector Sum 2.27 mm/s at 0.204 sec

DGMS India (A)

Permissible Ground Vibration



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 5.00 pa.(L)/div
Trigger = ▶———◀

Sensorcheck

Printed: June 26, 2018 (V 8.12 - 8.12)

Appendix-58- Minimate™ report for blast no. E-11

Instantel® **Event Report**

Date/Time	Long at 13:49:18 June 21, 2018	**Serial Number**	5871 V 2.61 MiniMate
Trigger Source	Geo: 0.587 mm/s	**Battery Level**	6.4 Volts
Range	Geo :127 mm/s	**Calibration**	December 18, 2017 by UES, New Delhi
Record Time	3.0 sec at 1024 sps	**File Name**	G871HGVY.E60

Notes
Location:
Client:
User Name:
Converted: June 22, 2018 08:42:23 (V8.12)

Extended Notes

Post Event Notes
Blasting at III bench (S ---->N) , BID :11-11
No. of holes : 16, using DTH & TLD
Maximum charge per delay : 31.94 Kgs.
Distance from Blasting : 250 mtrs In the line of Inititation

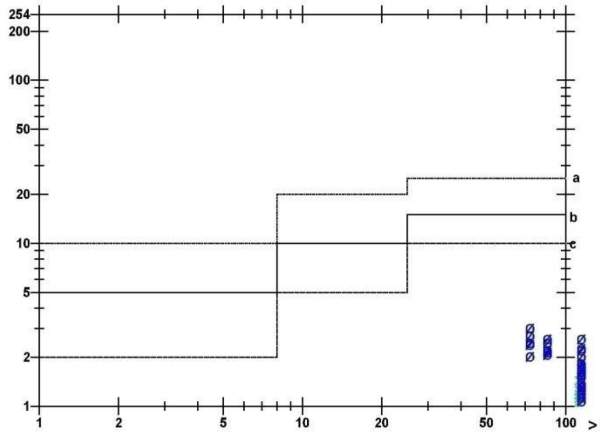
Microphone	Linear Weighting
PSPL	115.6 dB(L) at 0.867 sec
ZC Freq	8.0 Hz
Channel Test	Passed (Freq = 20.0 Hz Amp = 308 mv)

	Tran	Vert	Long	
PPV	1.78	1.46	3.05	mm/s
ZC Freq	85	64	37	Hz
Time (Rel. to Trig)	0.218	0.233	0.091	sec
Peak Acceleration	0.0928	0.0862	0.126	g
Peak Displacement	0.00505	0.00471	0.00946	mm
Sensorcheck	Passed	Passed	Passed	
Frequency	7.7	8.1	8.2	Hz
Overswing Ratio	3.8	3.3	3.6	

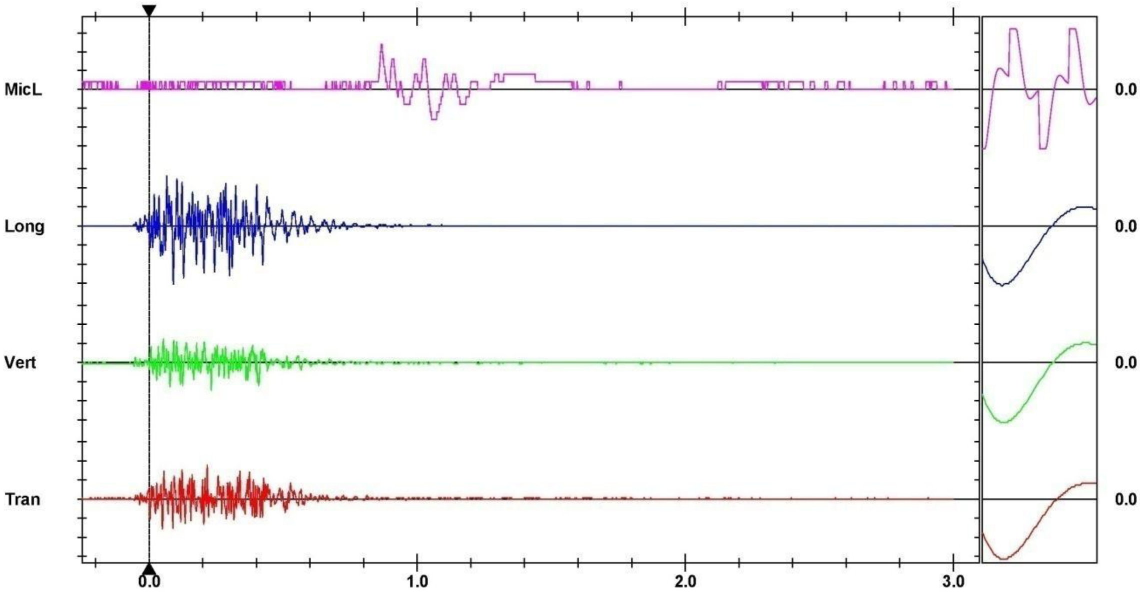
Peak Vector Sum 3.32 mm/s at 0.091 sec

DGMS India (A)

Permissible Ground Vibration



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 1.000 mm/s/div Mic: 5.00 pa.(L)/div Sensorcheck
Trigger = ▶———◀

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Appendix-59- Minimate^{TM} report for blast no. E-13

Instantel

Event Report

Date/Time	Tran at 12:59:55 July 6, 2018	**Serial Number**	5871 V 2.61 MiniMate
Trigger Source	Geo: 0.794 mm/s	**Battery Level**	6.3 Volts
Range	Geo :127 mm/s	**Calibration**	December 18, 2017 by UES, New Delhi
Record Time	2.0 sec at 1024 sps	**File Name**	G871HHNO.3V0

Notes

Location: Maliakhera Mine
Client: J.K. Cement Works, Nimbahera
User Name: Pradeep Kumar Dawer
Converted: July 9, 2018 13:13:48 (V8.12)

Extended Notes

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Post Event Notes

Blasting at II SE bench (E ---->W) , BID :11-15
No. of holes : 9, using DTH & TLD
Maximum charge per delay : 30.33 Kgs.
Distance from Blasting : 250 mtrs Diagonally Side of Inititation Sou

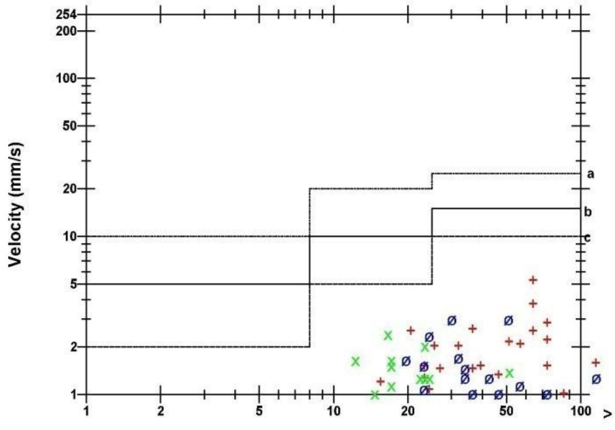
Microphone	Linear Weighting
PSPL	109.5 dB(L) at 0.576 sec
ZC Freq	8.0 Hz
Channel Test	Passed (Freq = 20.0 Hz Amp = 306 mv)

	Tran	Vert	Long	
PPV	5.27	2.41	2.98	mm/s
ZC Freq	73	16	30	Hz
Time (Rel. to Trig)	0.240	0.174	0.212	sec
Peak Acceleration	0.186	0.0663	0.106	g
Peak Displacement	0.0131	0.0197	0.0151	mm
Sensorcheck	Passed	Passed	Passed	
Frequency	7.7	8.2	8.5	Hz
Overswing Ratio	3.8	3.4	3.5	

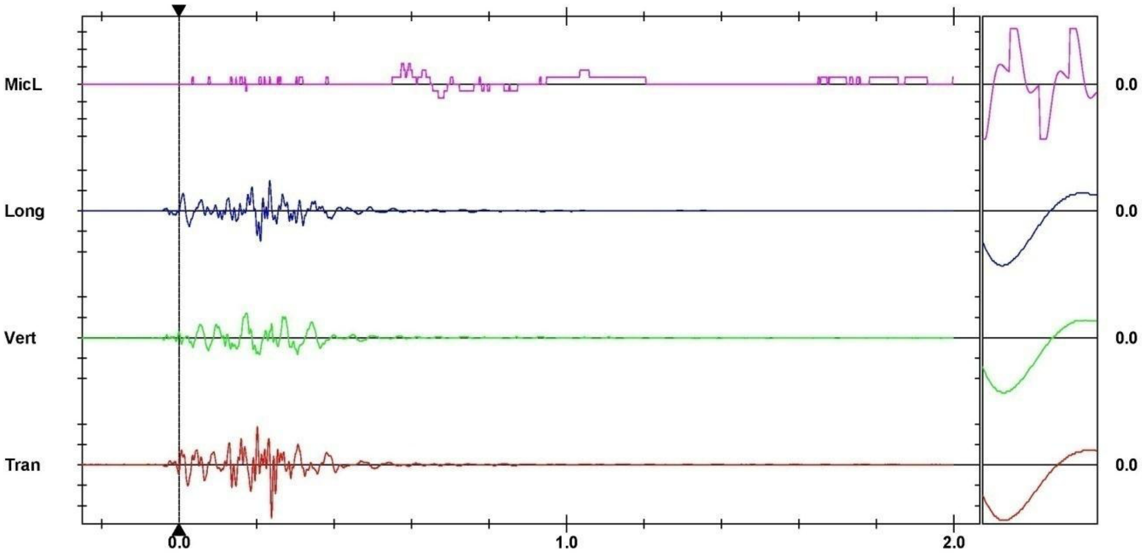
Peak Vector Sum 5.49 mm/s at 0.240 sec

DGMS India (A)

Permissible Ground Vibration



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 2.00 mm/s/div Mic: 5.00 pa.(L)/div
Trigger = ▶———◀

Sensorcheck

Printed: July 29, 2018 (V 8.12 - 8.12)

Appendix-60- Minimate™ report for blast no. E-15

Instantel

Event Report

Date/Time	Long at 13:18:00 July 10, 2018	**Serial Number**	5871 V 2.61 MiniMate
Trigger Source	Geo: 0.794 mm/s	**Battery Level**	6.3 Volts
Range	Geo :127 mm/s	**Calibration**	December 18, 2017 by UES, New Delhi
Record Time	2.0 sec at 1024 sps	**File Name**	G871HHV3.M00

Notes
Location: Maliakhera Mine
Client: J.K. Cement Works, Nimbahera
User Name: Pradeep Kumar Dawer
Converted: July 10, 2018 15:09:22 (V8.12)

Extended Notes

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Post Event Notes
Blasting at II N bench (N ---->S)
No. of holes : 14, using DTH & TLD
Maximum charge per delay : 34.52 Kgs.
Distance from Blasting : 250 mtrs in the lineof Inititation

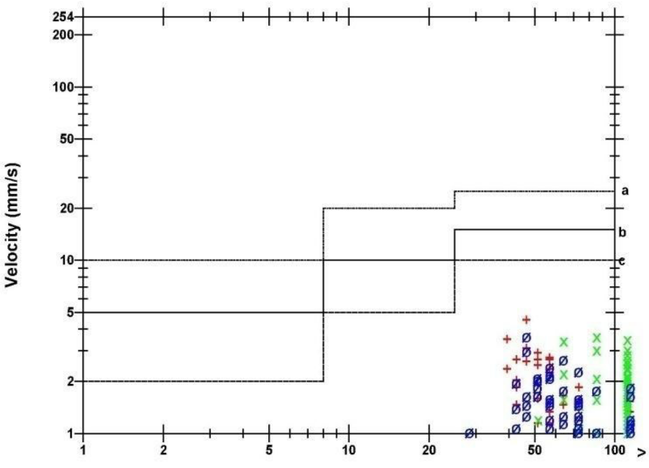
Microphone Linear Weighting
PSPL 115.6 dB(L) at 0.900 sec
ZC Freq 6.0 Hz
Channel Test Passed (Freq = 20.0 Hz Amp = 305 mv)

	Tran	Vert	Long	
PPV	4.51	3.62	3.62	mm/s
ZC Freq	47	85	51	Hz
Time (Rel. to Trig)	0.387	0.285	0.330	sec
Peak Acceleration	0.166	0.292	0.133	g
Peak Displacement	0.0137	0.00744	0.00825	mm
Sensorcheck	Passed	Passed	Passed	
Frequency	7.7	8.2	8.1	Hz
Overswing Ratio	3.8	3.5	3.7	

Peak Vector Sum 4.60 mm/s at 0.387 sec

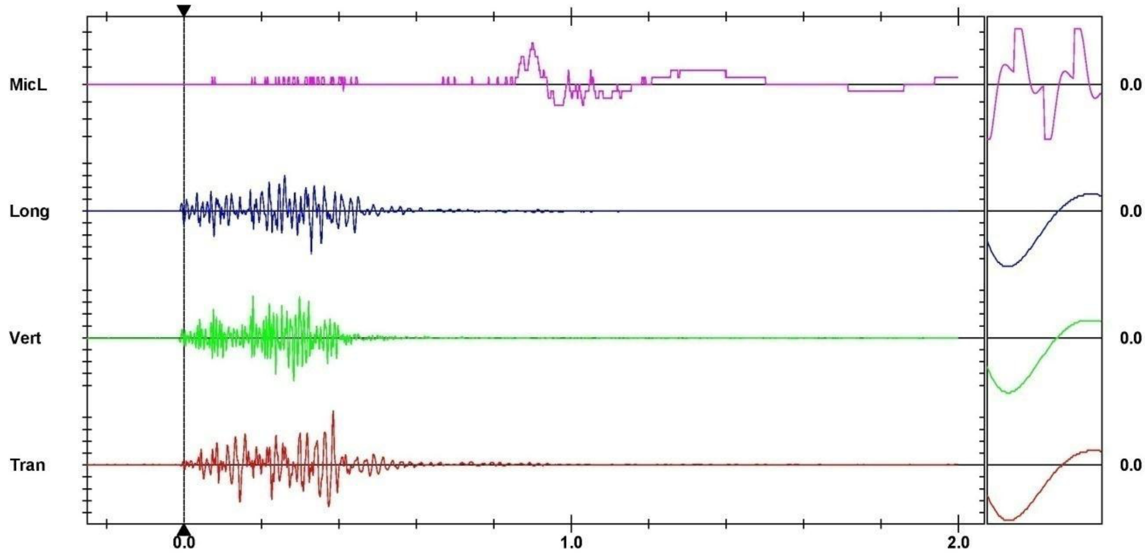
DGMS India (A)

Permissible Ground Vibration



Frequency (Hz)
Tran: + Vert: x Long: ø

a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 1.000 mm/s/div Mic: 5.00 pa.(L)/div

Trigger = ▶————◀

Sensorcheck

Printed: July 29, 2018 (V 8.12 - 8.12)