DETERMINATION OF SOME BENCH BLAST PARAMETERS USING VORONOI DIAGRAM CONCEPT

A THESIS SUBMITTED IN PARTIAL FULFILLMENT

FOR THE DEGREE OF

B.TECH AND M.TECH DUAL DEGREE

IN

MINING ENGINEERING

By

DEBASHRIT MOHANTA

710MN1102

Department of Mining Engineering
National Institute of Technology Rourkela-769008
June 2015

DETERMINATION OF SOME BENCH BLAST PARAMETERS USING VORONOI DIAGRAM CONCEPT

A THESIS SUBMITTED IN PARTIAL FULFILLMENT

FOR THE DEGREE OF

B.TECH AND M.TECH DUAL DEGREE

IN

MINING ENGINEERING

By

DEBASHRIT MOHANTA

710MN1102

Under the Guidance of

Dr. MANOJ KUMAR MISHRA

Department of Mining Engineering
National Institute of Technology Rourkela-769008

June 2015

National Institute of Technology
Rourkela

CERTIFICATE

This is to certify that the thesis entitled "**Determination of some Bench Blast parameters using Voronoi diagram concep**t" submitted by Sri DEBASHRIT MOHANTA (710MN1102), in fulfillment of the requirements for the award of Bachelor of Technology & Master of Technology Dual Degree in Mining Engineering at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

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

Date**:**

(Dr. M. K. MISHRA)

Dept. Of Mining Engineering
National Institute of Technology
Rourkela – 769008

ACKNOWLEDGEMENT

My heart throbs with the thrill for tendering appreciation to those persons who helped me in completion of the project. I wish to express my profound gratitude and indebtedness to **Dr. M. K. Mishra**, Department of Mining Engineering, NIT Rourkela for introducing the present topic and for his inspiring guidance, constructive criticism and valuable suggestion throughout the project work. His able knowledge and supervision with unswerving patience guided my work at every stage mainly while visiting the mines for data and analysis, for without his warm affection and encouragement the fulfilment of the task would have been difficult.

DEBASHRIT MOHANTA

710MN1102

ABSTRACT

In this twenty-first century surface mining activities contribute around 90% of the mineral production in our country. This milestone is achieved through the deployment of high capacity excavation machineries- earth moving machines, large hole drilling machines, etc. As these machineries involve high investment, effective utilization is a must for higher production. But their performance depends upon the fragmentation size, which in turn depends upon the Blast Design. Thus Blast design contributes a major role in reducing cost and increasing production. Due to varying geological conditions as well as rock properties, there exists multiple approaches for the design of blasting operations. Those suffer from many drawbacks as inaccurate assumptions in rock mass characteristics, rick analysis not included, inadequate data bank, etc. Veronoi design is a new method to calculate and analyze some of the parameters of bench blast. An analytical solution for row and blasthole spacing is first calculated based on explosive charge maximization. Then Voronoi diagram is generated for the blast area utilizing the reference co-ordinates of the blastholes. Charge mass of each blasthole is calculated by volume formula utilizing voronoi diagram. A code is developed for hole-by-hole initiation sequence in Microsoft visual studio considering voronoi concept. The investigation analyses the applicability of the concept in two iron ore mines.

CONTENTS

Title	Page no
CERTIFICATE	iii
ACKNOWLEDGEMENT	iv
ABSTRACT	v
LIST OF FIGURES	ix-x
LIST OF TABLES	xi
CHAPTER 01 **INTRODUCTION**	1
1.1 Overview	2-3
1.2 Aim and Specific objectives	4
1.3 Methodology	4-5
CHAPTER 02 **LITERATURE REVIEW**	6
2.1 Blasting	7
2.1.1 Rock properties	7-8
2.1.2 Volume of Rock Being Blasted	8-9
2.1.3 Explosive characteristics	9-11
2.2 Study Of Models And Methods Developed For Bench Blast Design	12-16
CHAPTER 03	17

METHODOLOGY	
3.1 Field visit and Data collection	18
3.1.1 Mine-1	18-19
3.1.2 Mine-2	19-20
3.1.2.1 Patch-1(599ML)	21-23
3.1.2.2 Patch-2 (599ML)	23-27
CHAPTER 04 **CALCULATION AND RESULT**	28
4.1 Explosive charge mass	30-33
4.1.1 Patch-1 (Mine-2)	34-35
4.1.2 Patch-2 (Mine-1)	36-39
4.1.3 Graph	39-41
4.2 Burden and Spacing	41-42
4.3 Blast sequence Analysis	42
4.3.1 Algorithm for blast sequence identification for patches of Mine-1	43-44
4.3.2 Program generated	44-55
4.3.3 Output for the blast sequence of Mine-1	55-56
4.4 Algorithm for blast sequence in accordance with delay pattern	57
4.4.1 Generated program for the algorithm considering delay time	58-59
4.4.2 Output of the program for blast sequence considering delay time	60
CHAPTER 05 **CONCLUSION AND FUTURE SCOPE**	61
5.1 Conclusion	62

5.2 Future scope	62
CHAPTER 06 **REFERENCES**	63-66

LIST OF FIGURES

Figure No.	Title	Page No.
1	Flow chart to the step by step method adopted in the project	5
2	Blasted ore from patch-1 Mine-2	20
3	Voronoi diagram top blast area for Patch-1	31
4	Voronoi diagram bottom blast area for Patch-1	32
5	Voronoi diagram top blast area for Patch-2	33
6	Voronoi diagram bottom blast area for Patch-2	34
7	Graph for Charge mass Vs Average area(S) for Patch-1	40
8	Graph for Charge mass Vs Average area(S) for Patch-2	41
9	Charge mass Vs Hole depth for Patch-1 Mine-2	41
10	Charge mass Vs Hole depth for Patch-2 Mine-2	42
11	Blast sequence generated for PATCH-2 mine-1	56

12	Blast sequence generated for PATCH-1 mine-1	57
13	Output of the blast sequence considering delay time	61

LIST OF TABLES

Table No.	Title	Page No.
1	Co-ordinates for the blastholes of patch-1 Mine-2	21-22
2	Boundary co-ordinates of top blast area patch-1 Mine-2	22
3	Boundary co-ordinates of bottom blast area patch-1 Mine-2	22-23
4	Co-ordinates for the blastholes of patch-2 Mine-2	23-26
5	Boundary co-ordinates of top blast area patch-2 Mine-2	27
6	Boundary co-ordinates of bottom blast area patch-2 Mine-2	28
7	Charge mass for blastholes of patch-1 Mine-2	35-36
8	Charge mass for blastholes of patch-2 Mine-2	37-40

CHAPTER 01

INTRODUCTION

INTRODUCTION

1.1 Overview and background

Mining industry is the backbone for the development of any nation. In mining the basic aim is to achieve maximum extraction of minerals keeping in view the environmental, economic and lease constraints. With the advancement of civilization, the requirement of different minerals has increased manifold to meet this demand. There is an upsurge in interest and action in opencast mining because of the improved productivity, recovery and safety of mining operation.

Improvement in production has been achieved with the help of large capacity opencast machineries, continuous mining system with improved design, development of modern generation, explosives and accessories, process innovations and application of information technologies and increased adoption of computerized mine planning and control.

In achieving the required fragmentation which has to suit accordingly to the machinery size, Blasting covers a major role in enhancing production. Bench blast is blasting a series of blastholes which may be vertical or inclined towards a free face. Blasting in overburden is done to fragment and shatter the rock and to displace the rock in mine area by casting the overburden. In coal and ore it is done to achieve the fragmentation.

Important factors which governs the optimal bench blast design are:

- Physico-mechanical properties of rock which includes compressive strength, tensile strength, poisson’s ratio, density, hardness etc.
- Geology

- Pit geometry which comprises of thickness of orebody, bench height, bench slope angle, height to width ratio etc.
- Explosive characteristics
- Characteristics of blasting accessories such as burden, spacing, ratio of burden to spacing, depth of hole, diameter of blastholes, toe and sub-grade drilling
- Blasting techniques which includes drilling pattern, charging pattern, delay pattern, initiation sequence.

There are several methods which are being introduced to improve and optimize the bench blast parameters. They are divided into four categories as:

1) Empirical formulae based on field measurement and simplified analytical equation
2) Numerical modelling
3) Prevention hazard of bench blast
4) Artificial neural network and computer aided blast design

The above mentioned methods are not 100% accurate as the Empirical formulae based method has assumptions made upon rock mass and explosive and several factors are neglected. The numerical method is very time consuming and some factors in this case are difficult to determine. The design of bench blast in case of Prevention hazard method is a compromise between the lower hazards and the best blasting results. In ANN and CAD, a large no of data sets are required to train the process/network. The Vernoi concept analyses the charge mass for each blast-hole incorporating rock mass as well as explosive characteristics, and then suggests the sequence of blasting. This investigation was an attempt to evaluate its applicability in iron ore mines.

1.2 AIM AND SPECIFIC OBJECTIVES

The aim of this investigation was to reduce the manual intervention for data input in the hole-by-hole initiation of the blasting process.

The specific objectives of this project are:

- Determination of Charge mass for Blastholes using Voronoi concept
- Estimation of row and hole Spacing using Explosive Charge Maximization concept
- Determination of Blast Initiation Sequence.

1.3 Methodology

The aim and objectives of this investigation are achieved by the following step-by-step approach shown in the below flow chart fig.1. Extensive literature review has been carried out to realize different bench blast parameters which affect the optimum blast design. Existing relationships and methods for bench blast design were also reviewed. A new concept voronoi diagram has been evaluated to calculate the charge mass of the blastholes. Then an analytical approach called Explosive charge maximization is used to calculate the row and hole spacing for blast configurations of iron ore mines from which data was collected. Then a program has been developed to determine the blast initiation sequence in accordance with the Voronoi concept in Microsoft visual studio.

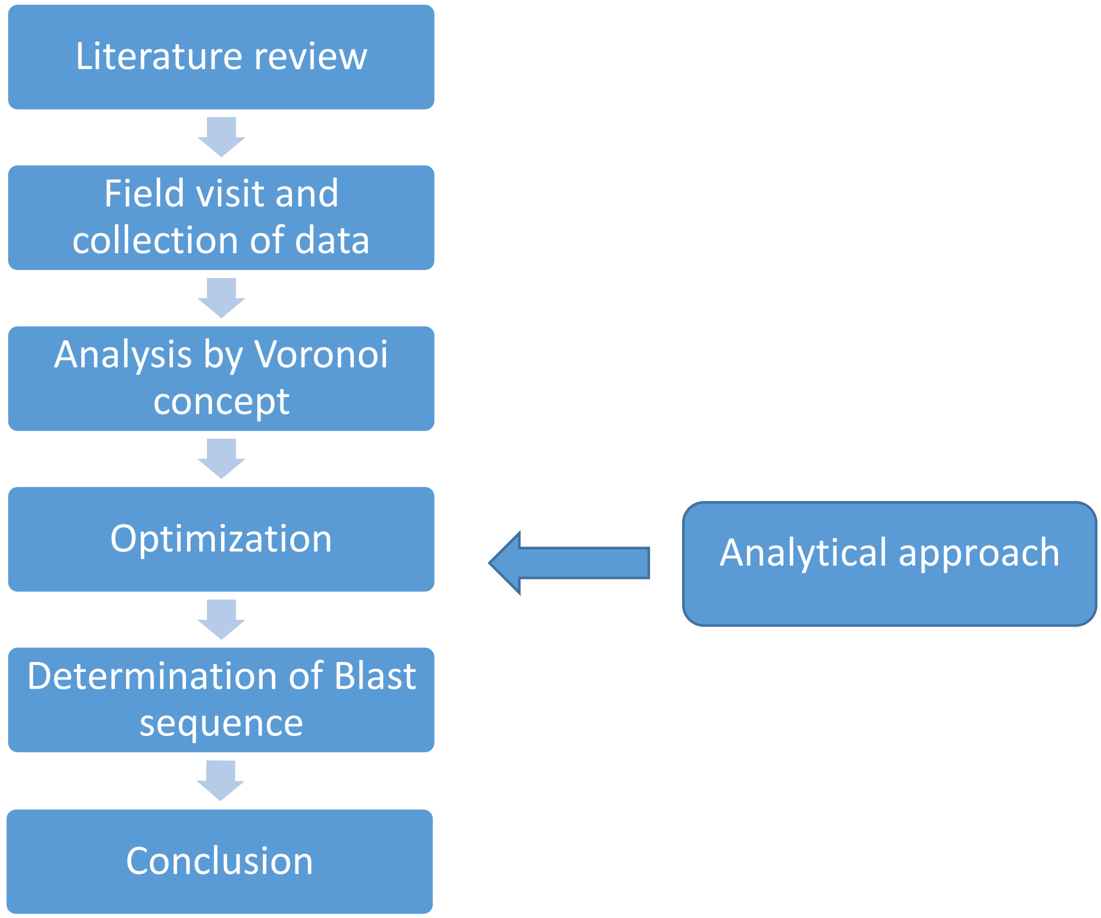

Fig. 1. Flow chart to the step by step method adopted

CHAPTER 02

LITERATURE REVIEW

LITERATURE REVIEW

2.1 BLASTING

Bench blast is blasting a series of blastholes which may be vertical or inclined towards a free face.

Blasting in overburden is done to fragment and shatter the rock and to displace the rock in mine area by casting the overburden. In coal and ore it is done to achieve the fragmentation.

Important factors which governs the optimal bench blast design are:

- Physico-mechanical properties of rock which includes compressive strength, tensile strength, poisson's ratio, density, hardness etc.
- Geology
- Pit geometry which comprises of thickness of orebody, bench height, bench slope angle, height to width ratio etc.
- Explosive characteristics
- Characteristics of blasting accessories such as burden, spacing, ratio of burden to spacing, depth of hole, diameter of blastholes, toe and sub-grade drilling.

2.1.1 Rock properties

The properties of rock that affect the rock breakage or fragmentation are dip, strike, compressive strength, tensile strength, shear strength, density, elastic property, bedding plane structure, presence of geological disturbances like faults, folds, fractured ground.

While blasting rocks, they are categorized into four types, resistant massive rocks, highly fissured rocks, rocks that form blocks, porous blocks. Different types of explosives are recommended for each one of these types.

Resistant massive rock formations have very few fissures and planes of weakness. As a result, an explosive is needed that creates a large number of new surfaces based on its strain energy. The strain energy is the potential energy stored in the linear part of a strained elastic solid. An explosive with a high density and detonation velocity will work well in this case. Thus slurries and emulsions would be good choices.

Highly fissured rock formations have many preexisting fissures. Explosives with high strain energy don't work in this case. ANFO is the recommended choice here because of its high gas energy.

When masses with large spacing between discontinuities that forms large blocks, and in ground where large boulders exist within plastic matrixes, the fragmentation of the rock is more based on the geometry of the blast than the properties of the explosive. Thus, you want an explosive with a balanced strain/gas energy relationship such as heavy ANFO.

In porous rock formations there are many things to consider when blasting along with selecting the proper explosive. The proper explosive would be one with low densities and detonation velocity, such as ANFO. To retain gases in the blast hole for as long as possible the blaster should:

- control the stemming material and height
- Properly sized burden
- priming the bottom
- reduce blast hole pressure by decoupling the charges

2.1.2 Volume of Rock Being Blasted

The volume of the rock being blasted will determine the amount of a certain explosive you will use for the blast. When this volume is very large you are going to want to consider the use of bulk explosives. This makes mechanized charging possible from the transports, thus lowering labor costs.

2.1.3 Explosive Characteristics

Physical properties

There are many physical attributes that must be considered in the selection of explosives. These factors affect six characteristics of the explosives: sensitiveness, water resistance, water pressure tolerance, fumes, and temperature resistance.

Sensitiveness: It is the characteristic of an explosive which defines its ability to propagate a stable detonation through the entire length of the charge and controls the minimum diameter for practical use. By determining the explosive's critical diameter you can measure the sensitivity of the explosive. The critical diameter is the minimum diameter of explosive column which will detonate reliably.

Water Resistance: Water resistance is the explosive's ability to withstand exposure to water without suffering detrimental effects in performance. Explosives have two types of water resistance: internal and external. Internal water resistance is water resistance provided by the composition of the explosive. External water resistance is the water resistance is provided by the packaging or cart ridging in which the explosive is placed.

Water Pressure Tolerance: Water pressure tolerance is the explosive's ability to remain unaffected by high static pressures. These high pressures will occur when you have deep boreholes that are filled with water. Explosives may be densified and desensitized in these conditions. Some examples of explosives that have big problems with water pressure tolerance are slurries and heavy ANFO.

Fumes: The fume class of an explosive is a measure of the amount of toxic gases produced in the detonation process. The most common gases considered in fume class ratings are carbon monoxide and oxides of nitrogen. Commercial explosives are made to get the most energy out as possible while minimizing these gases. This is done by balancing the oxygen in chemical reaction of the explosive.

Temperature Resistance: The performance of explosives can be affected a great deal if they are exposed to extremely hot or cold conditions. Under hot conditions, above 18 degrees C, many explosive compounds will slowly decompose or change properties. Shelf life will also be decreased. Cycling can occur when you store ammonium nitrate blasting agents in temperatures above 18 degrees C. This will affect not only the performance of the explosive, but also the safety.

Performance Properties

After considering all of the environmental factors, the performance characteristics of explosives must be considered in the explosive selection process. These characteristics include: Sensitivity, velocity, detonation pressure, density, and strength.

Sensitivity: The sensitivity of an explosive product is defined by the amount of input energy required for the product to detonate reliably. Other common names for this are the minimum booster rating, or minimum priming requirements. While some explosives require very little energy to detonate reliably with just a blasting cap, others require the use of a booster or primer along with a blasting cap to get a reliable detonation.

Velocity: The speed at which a detonation occurs through an explosive is called the detonation velocity. Detonation velocity is important to consider only on explosive applications where a borehole is not used. Detonation velocity is used to determine the efficiency of an explosive reaction. If it is suspected that and explosive is performing sub par then you can test the detonation velocity.

Detonation Pressure: The detonation pressure is the pressure associated with the reaction zone of a detonating explosive. It's is measured in the C-J plane, behind the detonation front, during propagation through an explosive column. This pressure can be estimated using the following formula:

$$p_d = \frac{1}{2}\rho_e {C_d}^2 10^{-6}$$

Where,

P_d = Detonation pressure (MPa)

ρ_d = Density of explosive (kg/m 3)

C_d =Velocity of detonation (m/s)

Detonation pressure is related to the density of the explosive and its reaction velocity.

Density: The density of an explosive is important because explosives are purchased, stored and used on a weight basis. Then density of an explosive determines the weight of explosive that can be loaded into a specific borehole diameter. In the bottom of the blast holes where more energy concentration is required, higher density explosives such as gelatin explosives or water gels are used. In column charges where lower density is required, ANFO based or powder explosives are used.

Strength: The strength of an explosive refers to the energy content of an explosive which in turn is the measure of the force it can develop and its ability to do work. Strength is rated in two different ways. One is on an equal volume basis, called bulk strength. The other is rated on an equal weight basis, called weight strength. Strength is measured using various methods and tests. Some of these include: the Ballistic mortar test, seismic strength test, Traulz test, and cratering.

2.2 STUDY OF MODELS AND METHODS DEVELOPED FOR BENCH BLAST DESIGN

Liu J. et. al. (2014) proposed a method which can automatically calculate blasthole positions, charge mass and initiation sequence in case of the hole-by-hole initiation in opencast bench blasting. They have developed a code in C++ for the bench blast design. The results in field application reflected that this method can reduce the design work and can improve the blast results.

Qu Shijie et.al. (2010) developed a computer aided bench blast design and simulation system, the BLAST-CODE model. It consists of a database representing geological and topographical conditions and the modules Frag+ and Disp+ for blast design and prediction of resultant fragmentation and displacement of rock mass. It allows automatic adjustment to the selected parameters such as Burden ‘B’ and spacing ‘S’. It also permits interactive parameter selection based on comparison of predicted fragmentation and displacement.

Adhikari G. R. (1998) developed equations to calculate new burden utilizing already optimized burden. During implementations of the optimized parameters in the field, some changes definitely occur and it hampers the optimization. As burden is the basic parameter which is used to calculate other blast design parameters such as spacing and stemming, field trials can be reduced by proper deduction of it. He has derived three equations for the calculations of new burden for partially changed blast design conditions.

Busuyi T. (2009) carried out research to find a way of optimizing the drilling and blasting operations in an open pit mine of Somair, in the Niger Republic. This study deduced that blasting must conform to site conditions and should not be borrowed from anywhere else where improvement has been made based on safety, economy and selective requirements. This study finds the use of statistical methods to optimize the drilling and blasting operations for smooth running of a mine.

Trivedi et.al. (2014) predicted the distance covered by blast induced flyrock using Artificial neural network and multi-variant regression analysis. Burden, stemming length, specific charge, UCS , linear charge concentration and RQD are taken as input parameters and distance travelled by flyrock is taken as the output parameter. ANN is a better tool for prediction of flyrock distance than MVRA.

Ghose et. al. (1998) described a case based reasoning system called CASEBLAST for blast design in open cast mines which enables automation in problem solving process. This modifies the solutions for the previous problem as per need of the recent problem.

Jia, Chen and Huang (2000) employed DYNA3D, a nonlinear, explicit, dynamic, three-dimensional finite element code for modelling of bench blasting. Finite element method is incorporated to identify the mechanism of rock breakage in jointed rock mass. This simulation covers bench blasting with rock deformation, failure, fragmentation and throwing trends of rock fragments.

Zhu (2009) developed a crater blasting model and a bench blast model and applied to investigate rock fragmentation mechanism involved in crater blasting and bench blasting. This study emphasizes the role of stress wave loading on rock fracturing during the initial stage of detonation in a borehole, which is a critical step in our understanding of rock fragmentation by blasting because the cracking process under stress wave loading is considered the crucial stage as the subsequent fragmentation and large-scale movement of the fractured rock mass due to continuing penetration of the explosion gases are largely guided by this initial fractured state.

Trivedi, Singh, Mudgal, Gupta (2014) studied applications of Artificial Neural Networks (ANN) in rock fragmentation by blasting and its significance in minimizing side effects to environment in particular and society at large. He found that degree of robustness or fault tolerance in ANN better than empirical and other techniques because of ability of pattern recognition and continuous learning .More over, the neural network predictor takes much less time to interpret new data than existing techniques once it is properly trained.

Shi and Chen (2011) examined the propagation of blasting induced ground vibrations and found the feasible approaches to reduce the harmful effects of vibrations induced by blasting on the final pit wall's stability.

Liu and Katsabanis (2004) examined effect of accurate delay time on rock fragmentation using a newly developed continuum damage model. They concluded that for rock blasting purposes, delay detonators having microsecond accuracy did not seem to benefit, instead, millisecond accuracy that does not depend on the length of the delay used was sufficient to achieve optimized rock fragmentation.

Adhikari (2000) generated a large number of data from Indian surface mines and verified the existing relations and recommended the most suitable blasthole diameter for a given bench height.

Zhu, Dai and Jiang (2002) carried out on the overall movement process of rock breakage by blasting based on the general principles of discontinuous deformation analysis (DDA) method. The results of blasting simulation clearly showed the expansion of blasthole, initiation of failure and the subsequent kinematic process of jointed rock mass under applied explosion gas load.

Monjezi, Rezaei and Yazdian (2009) developed a predictive models based on fuzzy set theory and multivariable regression for predicting backbreak in Gol-E-Gohar iron mine of Iran. Application of this model in the Gol-E-Gohar iron mine considerably minimized backbreak and improved blasting efficiency.

Adhikari and Venkatesh (1995) suggested that drilling and blasting cost in any project can be as high as 25% of the total production cost.They observed that to achieve a certaindegree of refinement in blast design, scientific and systematic approach is needed. Withinstruments like VOD probes, laser profiling system, etc the monitoring becomes easier, efficient and cost effective.

Voronoi diagram

It is a unique kind of distribution of a given area into smaller cell which are called as seeds or sites. Centre point of the voronoi cell is called as reference point which is the given blasthole in this consideration. The property of a Voronoi ploygon of a point is that all points with that polygon are closest to that point i.e. Suppose *P* is a set of *n* distinct points in the plane, i.e., $P=\{p_1,p_2,\ldots\ldots,p_n\}$, if a point *q* lies in a cell containing p_i , the Voronoi cell T_i can be expressed as

$$T_i = \{ q:d(q,p_i) < d(q,p_j) \mid p_i , p_j € P, p_i \neq p_j , 1\leq i , j \leq n \}$$

QGIS software

It was previously known as Qantum GIS. This is a cross-platform free and open-source desktop geographic information system (GIS) application that provides data viewing, editing, and analysis capabilities. Similar to other software GIS systems QGIS allows users to create maps with many layers using different map projections. Maps can be assembled in different formats and for different uses. QGIS allows maps to be composed of raster or vector layers. Typical for this kind of software the vector data is stored as either point, line, or polygon-feature. Different kinds of raster images are supported and the software can perform geo-referencing of images. It has vector platform in which voronoi polygons can be generated for the given blast holes through Geometry tools.

CHAPTER 03

METHODOLOGY

METHODOLOGY

3.1 Field visit and data collection

For proper investigation and field implementation, collection of real mine data is required. For this purpose two active iron ore mines in nearby area were visited and several data were collected.

3.1.1 Mine -1

This deposit is a part of the Daitari -Tomka basin. The strike of the ore body swings between NNW-SSE and E-W with steep dip due west and south. The mine lease is bounded between latitude 21^0 05' 04'' to 21^0 07' 08''N & longitude 85^0 45' 30'' to 85^0 49' 7'' E. Data were collected from Patch-1 and Patch- 2 of 820ML bench.

Parameters

The investigation collected the following data.

- Drill hole:
    1. Height = 6.5m (avg)
    2. Stemming length = 2.2m
- Blast geometry:
    1. Spacing = 2.5m
    2. Burden = 2m
    3. Staggered type hole distribution pattern
- Density of rock = 3.47 g/cc
- Charge factor = 0.6
- Charge density = 1.2 g/cc
- Sub-grade drilling = 0.5m
- Catrige based slurry explosive (Booster and Column)

Blasting pattern adopted was row-by-row relay blasting with 42ms relay between rows.

3.1.2 Mine-2

The mine lease is bounded between $21^0\,53^{'}\,10^{''}$ to $21^0\,54^{'}\,40^{''}$ N latitude and $85^0\,13^{'}\,05^{''}$ to $85^0\,15^{'}\,60^{''}$ E longitude is located in mining belt of Sundargarh. The average altitude of the mine is around 590m above mean sea level. The required data were collected from 599ML bench as Patch-1 and Patch-2.

Parameters

The investigation collected the following data.

- Drill hole:
    3. Height = 7.4m (avg)
    4. Stemming length = 2.4m
- Explosive:
    1. Type: Catrige based slurry explosive (Booster and Column)
    2. Quantity = 20-40 Kg/hole (Total)
- Blast geometry:
    4. Spacing = 3m
    5. Burden = 2.5m
    6. Staggered type hole distribution pattern
- Charge factor(q) = 0.3
- Charge density = 766.89 Kg/m^3
- Sub-grade drilling = 0.4m
- Bench height = 7m

- Empirical co-efficient(λ) = 1.2
- Rock density = 4130 Kg/m^3

Blasting pattern followed here were V pattern with 25ms nonel in trench line and within the blast area 42ms nonel.

Image of the blasted ore from Mine-2

Insufficient Blasting results into formation of large sized boulders

Fig. 2. Blasted ore from patch-1 Mine-2 indicating many boulder formation

3.1.2.1 Blast Hole Positions:

The global coordinates of each blast hole investigated are as below.

Patch-1(599ML)

Sl No	X(m)	Y(m)
1	317064.3948	2422955.7621
2	317067.3474	2422956.2936
3	317070.2999	2422956.8250
4	317073.2525	2422957.3565
5	317076.2050	2422957.8880
6	317079.1576	2422958.4194
7	317082.1101	2422958.9509
8	317085.0627	2422959.4823
9	317088.0152	2422960.0138
10	317090.9678	2422960.5452
11	317093.9203	2422961.0767
12	317096.8729	2422961.6082
13	317099.8254	2422962.1396
14	317102.7780	2422962.6711
15	317105.7305	2422963.2025
16	317108.6831	2422963.7340
17	317111.6356	2422964.2655
18	317114.5882	2422964.7969
19	317117.4895	2422965.5599
20	317120.3909	2422966.3228
21	317123.2923	2422967.0858
22	317126.1676	2422967.9415
23	317122.2589	2422964.3596
24	317119.3575	2422963.5966
25	317116.4561	2422962.8337
26	317113.5548	2422962.0707

27	317110.6022	2422961.5393
28	317107.6497	2422961.0078
29	317104.6971	2422960.4764
30	317101.7446	2422959.9449
31	317098.7920	2422959.4134
32	317095.8395	2422958.8820
33	317092.8869	2422958.3505
34	317089.9344	2422957.8191
35	317086.9818	2422957.2876
36	317084.0293	2422956.7561
37	317081.0767	2422956.2247
38	317078.1242	2422955.6932
39	317075.1716	2422955.1618
40	317072.2191	2422954.6303
41	317069.2665	2422954.0988
42	317066.3140	2422953.5674

Table-1. Co-ordinates for the blastholes of patch-1 Mine-2

X(meter)	Y(meter)
317062.00	2422956.05
317089.06	2422961.01
317127.06	2422969.96
317128.11	2422963.01
317064.10	2422951.01

Table-2. Boundary co-ordinates of the top blast area PATCH-1

X(m)	Y(m)
317062.13	2422958.49
317090.14	2422963.52
317126.90	2422972.37
317128.11	2422963.01
417064.10	2422951.01

Table-3. Boundary co-ordinates of the bottom blast area PATCH-1

3.1.2.2 The global coordinates of each blast hole investigated are as below for Patch-2(599ML)

SL NO.	X	Y
1	316919.0925	2422914.8592
2	316921.6873	2422916.3648
3	316924.2620	2422917.8587
4	316927.0239	2422919.0300
5	316929.7858	2422920.2012
6	316932.5477	2422921.3725
7	316935.3096	2422922.5438
8	316938.0814	2422924.1158
9	316940.8422	2422925.2897
10	316943.6031	2422926.4635
11	316946.3639	2422927.6374
12	316949.1247	2422928.8112
13	316951.8855	2422929.9851
14	316954.6463	2422931.1589
15	316957.4071	2422932.3328
16	316960.1679	2422933.5066

17	316962.9287	2422934.6805
18	316965.6895	2422935.8543
19	316968.4504	2422937.0282
20	317002.1506	2422945.5975
21	316999.3389	2422944.5477
22	316996.4756	2422943.6522
23	316993.6124	2422942.7567
24	316990.7492	2422941.8612
25	316987.8859	2422940.9657
26	316985.0227	2422940.0702
27	316982.1595	2422939.1747
28	316979.2962	2422938.2792
29	316976.4330	2422937.3837
30	316973.5563	2422936.4825
31	316970.8090	2422935.3144
32	316968.0482	2422934.1406
33	316965.2873	2422932.9667
34	316962.5265	2422931.7929
35	316959.7657	2422930.6190
36	316957.0049	2422929.4452
37	316954.2441	2422928.2713
38	316951.4833	2422927.0975
39	316948.7225	2422925.9236
40	316945.9617	2422924.7498
41	316943.2009	2422923.5759
42	316940.4400	2422922.4021
43	316937.6580	2422921.2191
44	316934.8961	2422920.0479
45	316932.1342	2422918.8766
46	316929.3723	2422917.7053

47	316926.6104	2422916.5341
48	316924.0357	2422915.0401
49	316921.4408	2422913.5345
50	316918.8460	2422912.0289
51	316916.2729	2422910.4866
52	316913.4974	2422909.3478
53	316910.7177	2422909.0430
54	316907.7179	2422909.0763
55	316904.7180	2422909.1040
56	316901.8205	2422908.3265
57	316899.1458	2422906.9679
58	316896.4710	2422905.6093
59	316898.2409	2422903.8919
60	316900.9157	2422905.2505
61	316903.5904	2422906.6091
62	316907.2513	2422906.5785
63	316910.2512	2422906.5508
64	316913.2510	2422906.5175
65	316916.0264	2422907.6563
66	316918.5996	2422909.1987
67	316921.1944	2422910.7043
68	316923.7892	2422912.2099
69	316926.3841	2422913.7155
70	316929.1460	2422914.8868
71	316931.9079	2422916.0580
72	316934.6698	2422917.2293
73	316937.4317	2422918.4006
74	316940.1936	2422919.5718
75	316942.9555	2422920.7431
76	316945.7174	2422921.9143

77	316951.2413	2422924.2569
78	316954.0032	2422925.4281
79	316956.7651	2422926.5994
80	316959.5270	2422927.7706
81	316962.2889	2422928.9419
82	316965.0508	2422930.1132
83	316967.8127	2422931.2844
84	316970.5746	2422932.4557
85	316973.3365	2422933.6269
86	316976.1998	2422934.5224
87	316978.9983	2422935.6033
88	316981.8615	2422936.4988
89	316984.7248	2422937.3943
90	316987.5880	2422938.2898
91	316990.4512	2422939.1853
92	316993.3144	2422940.0808
93	316996.1777	2422940.9763
94	316999.0409	2422941.8718
95	317001.9041	2422942.7673

Table-4. Co-ordinates of blast holes for patch-2 Mine-2

X(m)	Y(m)
316894.9	2422907.8
316913.3	2422913.7
316946.4	2422929.8
316969.8	2422939.3
316982.8	2422941.9
317001.9	2422947.7
317004.6	2422940.5

316949.5	2422921.4
316921.3	2422908.4
316907.7	2422903.5
316896.9	2422900.9

Table-5. Boundary co-ordinates of the top blast area PATCH-2

(m)	Y(m)
316893.5	2422908.4
316912.1	2422915.9
316921.2	2422930.1
316963.5	2422937.6
316985.3	2422943.8
317003.1	2422949.4
316949.5	2422921.4
316921.3	2422908.4
316907.7	2422903.5
316896.9	2422900.9

Table-6. Boundary co-ordinates of the bottom blast area PATCH-2

CHAPTER 04

RESULT

AND

ANALYSIS

CALCULATIONS AND RESULT

4.1 Explosive charge mass

Voronoi diagram Generation

For calculation of charge mass voronoi diagram for the blastholes are first generated. It is a unique kind of distribution of a given area into smaller cell which are called as seeds or sites. Centre point of the voronoi cell is called as reference point which is the given blasthole in this consideration. The property of a Voronoi ploygon of a point is that all points with that polygon are closest to that point i.e. Suppose P is a set of n distinct points in the plane, i.e., $P=\{p_1,p_2,\ldots\ldots,p_n\}$, if a point q lies in a cell containing p_i , the Voronoi cell T_i can be expressed as

$$T_i = \{ q:d(q,p_i) < d(q,p_j) \mid p_i , p_j € P, p_i \neq p_j , 1\leq i , j \leq n \}$$

Then this voronoi diagram was generated in QGIS software which is a cross-platform free and open-source desktop geographic information system (GIS) application that provides data viewing, editing, and analysis capabilities. This option is available in vector operation of the software as Geometry tools. For the generation of voronoi diagram, the software takes the co-ordinates of the blastholes as csv or custom delimited file. Then voronoi diagram was generated by taking 20% buffer to minimize the error. After that the generated voronoi diagram was restricted to the given blast areas by importing the boundary co-ordinates for both the top and bottom blast area and then clipping the generated voronoi diagram with that boundary area by Geo-processing tool called clip.

The area for each voronoi cell is generated for both the top and bottom blast area in the attribute table for both the patches. For calculation of charge mass average of both top and bottom areas for each voronoi cell was calculated as

$$S_i = (S_a + S_b)/2$$

Where, S_i = average area; S_a and S_b are the area for top and bottom voronoi cell respectively of the ith hole.

Average area was considered to get the accurate result. Then the charge mass Q_I of the ith blasthole was calculated by

$$Q_i = \rho_r H S_i q$$

Where, ρ_r is the specific gravity of the rock mass , H is the bench height, S_i is the average area of the ith voronoi cell and q is the charge factor.

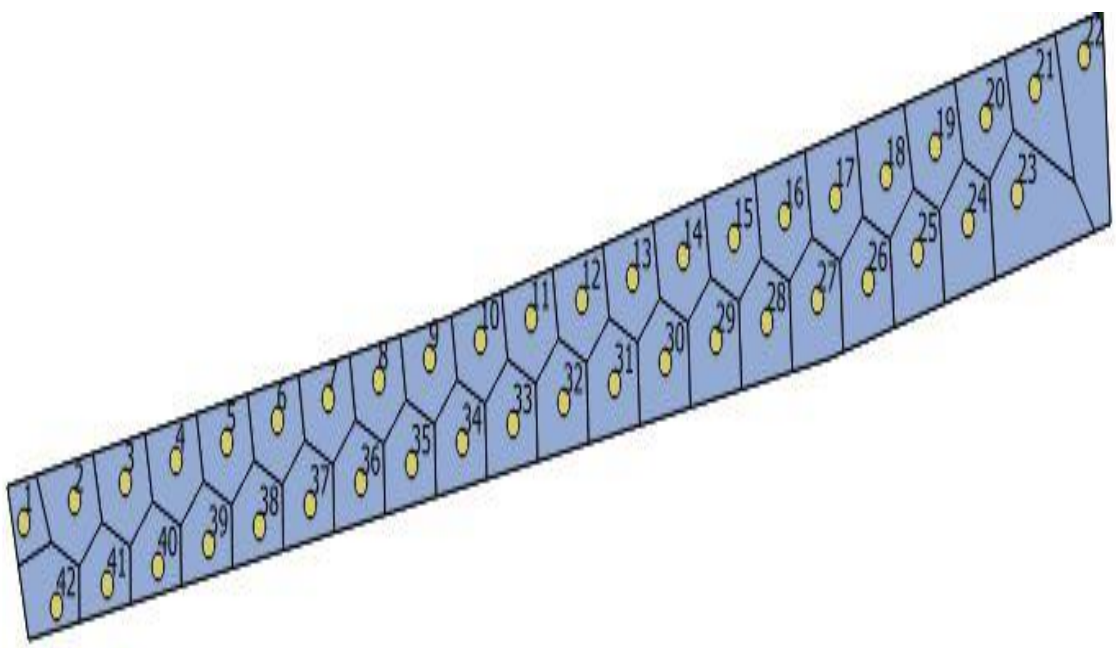

Fig.3. Voronoi diagram top blast area for patch-1

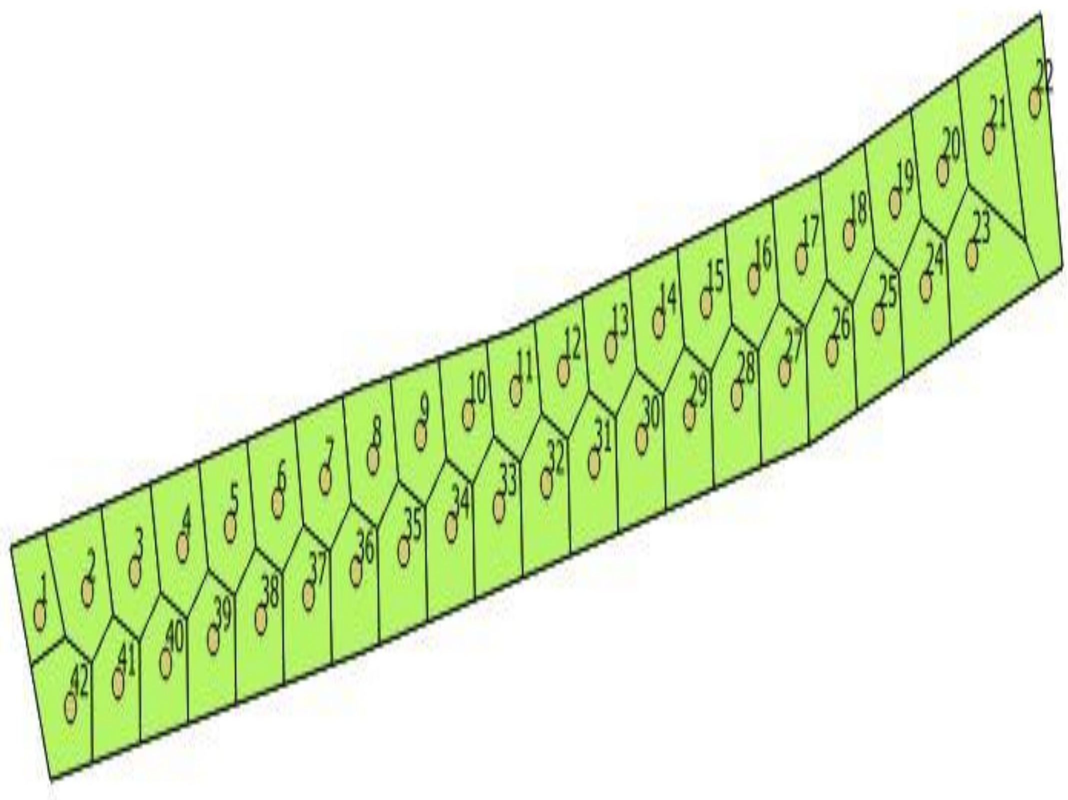

Fig. 4. Voronoi diagram bottom blast area for patch-1

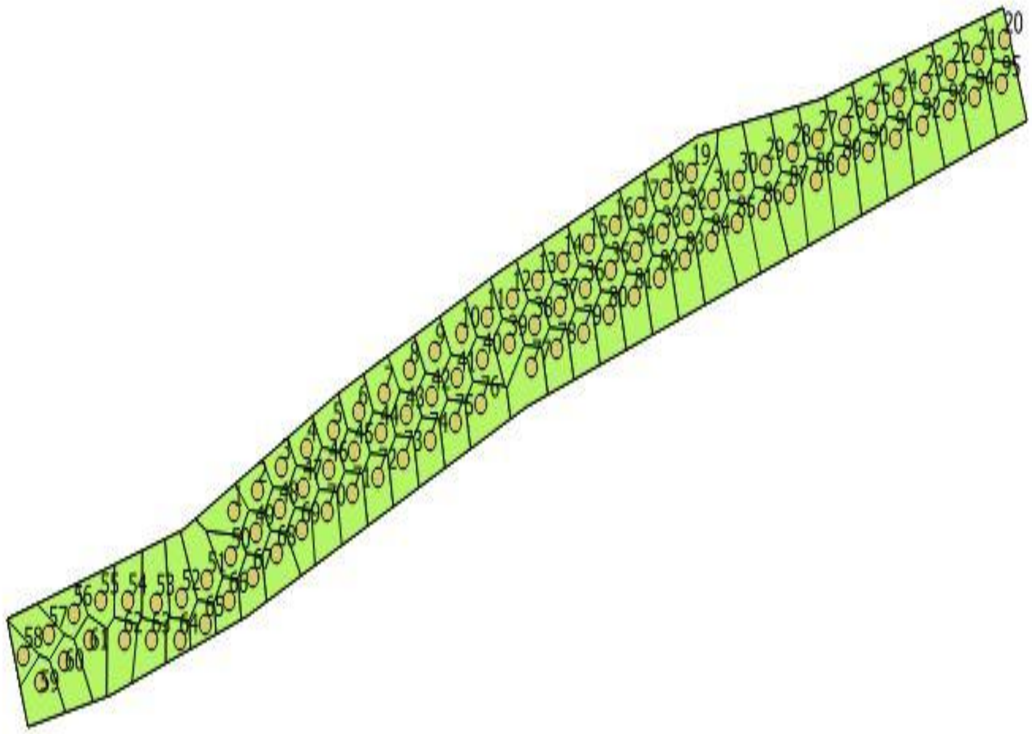

Fig. 5. Voronoi diagram top blast area for patch-2

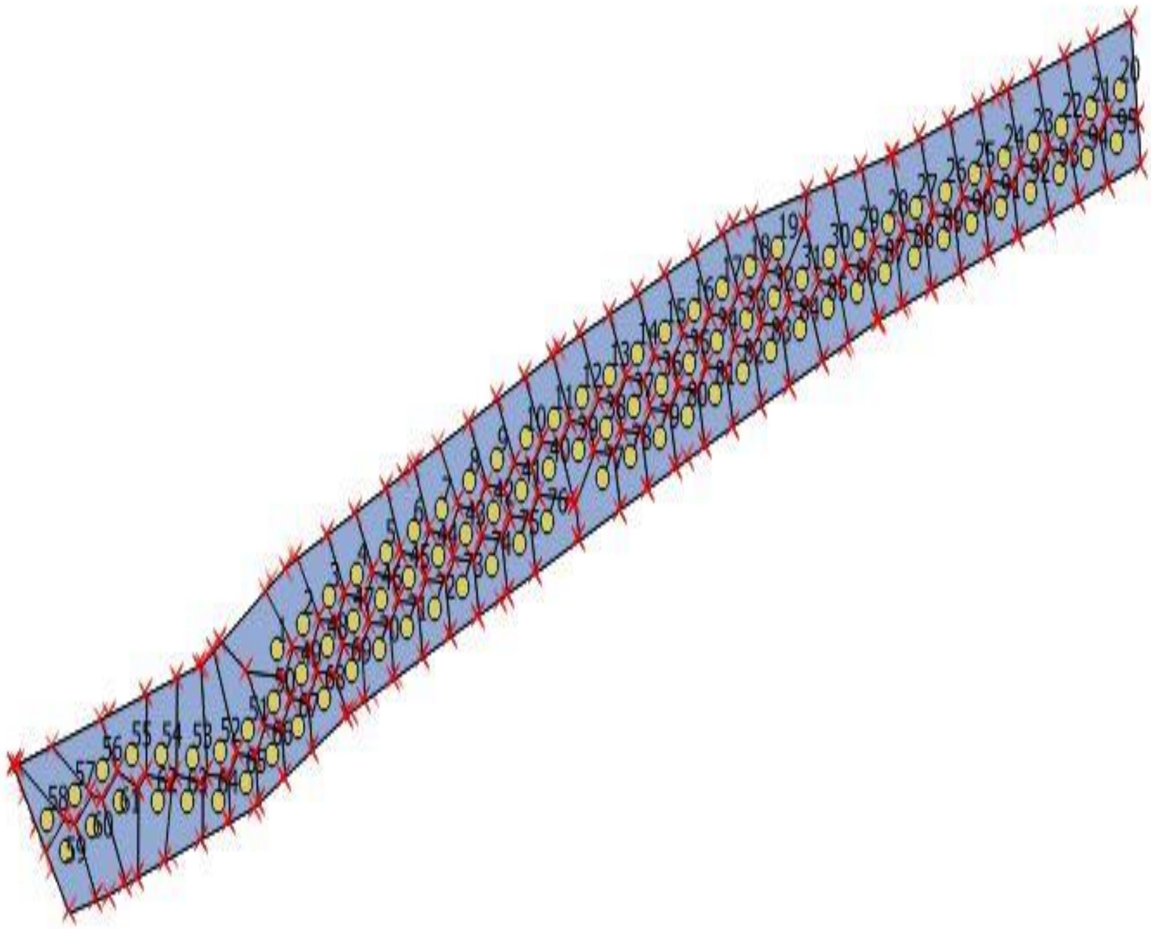

Fig. 6. Voronoi diagram bottom blast area for patch-2

4.1.1 Determination of charge mass for each blast hole for Patch-1 (Mine-2)

Sl No.	Area Top	Area Bottom	Avg Area(S)	F	Charge Mass(Kg)
1	4	6	5	8.673	43.365
2	7	10	8.5	8.673	73.7205
3	7	9	8	8.673	69.384
4	7	9	8	8.673	69.384
5	7	9	8	8.673	69.384
6	7	9	8	8.673	69.384
7	7	9	8	8.673	69.384
8	7	9	8	8.673	69.384
9	6	9	7.5	8.673	65.0475
10	7	8	7.5	8.673	65.0475
11	7	8	7.5	8.673	65.0475
12	7	8	7.5	8.673	65.0475
13	7	8	7.5	8.673	65.0475
14	8	9	8.5	8.673	73.7205
15	8	9	8.5	8.673	73.7205
16	8	9	8.5	8.673	73.7205
17	8	9	8.5	8.673	73.7205
18	8	9	8.5	8.673	73.7205
19	8	9	8.5	8.673	73.7205
20	8	9	8.5	8.673	73.7205
21	9	11	10	8.673	86.73
22	12	13	12.5	8.673	108.4125
23	14	15	14.5	8.673	125.7585
24	9	10	9.5	8.673	82.3935
25	8	9	8.5	8.673	73.7205

26	8	9	8.5	8.673	73.7205
27	8	10	9	8.673	78.057
28	8	10	9	8.673	78.057
29	8	10	9	8.673	78.057
30	8	10	9	8.673	78.057
31	8	10	9	8.673	78.057
32	8	10	9	8.673	78.057
33	7	10	8.5	8.673	73.7205
34	7	10	8.5	8.673	73.7205
35	7	10	8.5	8.673	73.7205
36	7	9	8	8.673	69.384
37	7	9	8	8.673	69.384
38	6	9	7.5	8.673	65.0475
39	6	9	7.5	8.673	65.0475
40	6	9	7.5	8.673	65.0475
41	6	8	7	8.673	60.711
42	7	9	8	8.673	69.384

Table-7 Charge mass for blastholes of patch-1 Mine-2

4.1.2 Determination of charge mass for each blast hole for Patch-2 (Mine-2)

Sl No.	Area Top	Area Bottom	Avg Area (S)	Burden	F	Charge Mass (Kg)
1	7	9	8	3.05	8.67	69.36
2	5	7	6	3.05	8.67	52.02
3	6	8	7	3.05	8.67	60.69
4	6	8	7	3.05	8.67	60.69
5	7	9	8	3.05	8.67	69.36
6	9	11	10	3.05	8.67	86.7
7	9	11	10	3.05	8.67	86.7
8	9	11	10	3.05	8.67	86.7
9	9	10	9.5	3.05	8.67	82.365
10	6	9	7.5	3.05	8.67	65.025
11	6	9	7.5	3.05	8.67	65.025
12	8	10	9	3.05	8.67	78.03
13	8	10	9	3.05	8.67	78.03
14	12	14	13	3.05	8.67	112.71
15	7	8	7.5	3.05	8.67	65.025
16	7	8	7.5	3.05	8.67	65.025
17	7	8	7.5	3.05	8.67	65.025
18	7	10	8.5	3.05	8.67	73.695
19	7	10	8.5	3.05	8.67	73.695
20	7	10	8.5	3.05	8.67	73.695
21	12	14	13	3.05	8.67	112.71
22	12	15	13.5	3.05	8.67	117.045
23	9	10	9.5	3.05	8.67	82.365
24	9	10	9.5	3.05	8.67	82.365
25	5	8	6.5	3.05	8.67	56.355

26	6	10	8	3.05	8.67	69.36
27	7	9	8	3.05	8.67	69.36
28	7	9	8	3.05	8.67	69.36
29	7	9	8	3.05	8.67	69.36
30	6	7	6.5	3.05	8.67	56.355
31	10	12	11	3.05	8.67	95.37
32	10	12	11	3.05	8.67	95.37
33	10	12	11	3.05	8.67	95.37
34	4	6	5	3.05	8.67	43.35
35	5	7	6	3.05	8.67	52.02
36	5	7	6	3.05	8.67	52.02
37	5	7	6	3.05	8.67	52.02
38	6	8	7	3.05	8.67	60.69
39	6	8	7	3.05	8.67	60.69
40	4	7	5.5	3.05	8.67	47.685
41	5	9	7	3.05	8.67	60.69
42	5	9	7	3.05	8.67	60.69
43	14	15	14.5	3.05	8.67	125.715
44	6	9	7.5	3.05	8.67	65.025
45	6	9	7.5	3.05	8.67	65.025
46	6	9	7.5	3.05	8.67	65.025
47	8	10	9	3.05	8.67	78.03
48	8	10	9	3.05	8.67	78.03
49	8	10	9	3.05	8.67	78.03
50	7	9	8	3.05	8.67	69.36
51	7	9	8	3.05	8.67	69.36
52	7	9	8	3.05	8.67	69.36
53	7	9	8	3.05	8.67	69.36
54	7	9	8	3.05	8.67	69.36
55	8	9	8.5	3.05	8.67	73.695

56	8	9	8.5	3.05	8.67	73.695
57	8	9	8.5	3.05	8.67	73.695
58	8	9	8.5	3.05	8.67	73.695
59	8	9	8.5	3.05	8.67	73.695
60	8	9	8.5	3.05	8.67	73.695
61	8	9	8.5	3.05	8.67	73.695
62	9	9	10	3.05	8.67	86.7
63	9	11	10	3.05	8.67	86.7
64	9	11	10	3.05	8.67	86.7
65	9	11	10	3.05	8.67	86.7
66	9	11	10	3.05	8.67	86.7
67	9	11	10	3.05	8.67	86.7
68	9	11	10	3.05	8.67	86.7
69	9	11	10	3.05	8.67	86.7
70	10	12	11	3.05	8.67	95.37
71	10	12	11	3.05	8.67	95.37
72	10	12	11	3.05	8.67	95.37
73	10	12	11	3.05	8.67	95.37
74	10	12	11	3.05	8.67	95.37
75	10	12	11	3.05	8.67	95.37
76	10	12	11	3.05	8.67	95.37
77	10	12	11	3.05	8.67	95.37
78	6	8	7	3.05	8.67	60.69
79	6	8	7	3.05	8.67	60.69
80	6	8	7	3.05	8.67	60.69
81	6	8	7	3.05	8.67	60.69
82	7	10	8.5	3.05	8.67	73.695
83	7	10	8.5	3.05	8.67	73.695
84	7	10	8.5	3.05	8.67	73.695
85	7	10	8.5	3.05	8.67	73.695

86	12	15	13.5	3.05	8.67	117.045
87	12	13	12.5	3.05	8.67	108.375
88	12	13	12.5	3.05	8.67	108.375
89	7	9	8	3.05	8.67	69.36
90	8	10	9	3.05	8.67	78.03
91	9	11	10	3.05	8.67	86.7
92	9	11	10	3.05	8.67	86.7
93	9	11	10	3.05	8.67	86.7
94	9	11	10	3.05	8.67	86.7
95	9	11	10	3.05	8.67	86.7

Table-8. Charge mass for blastholes of patch-2 Mine-2

4.1.3 Mutual Relation

Analyses were carried out to predict the relation between chatge mass vrs average voronoi area, and charge mass vrs hole depth.

4.1.3.1 Charge mass vs Average Voronoi area(S)

4.1.3.1.1 Patch-1 Mine-2

It is observed that there exists strong linear relation between average voronoi area being blasted with the charge mass for both cases (Fig 7 and 8).

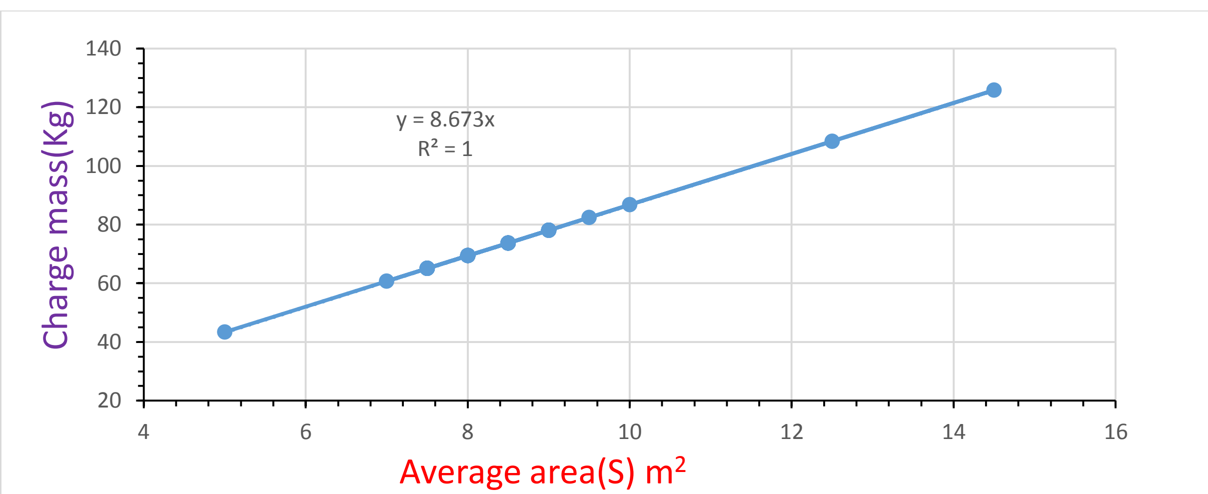

Fig. 7. Graph for Charge mass Vs Average area(S) for Patch-1

4.1.3.1.2 Patch-2 Mine-2

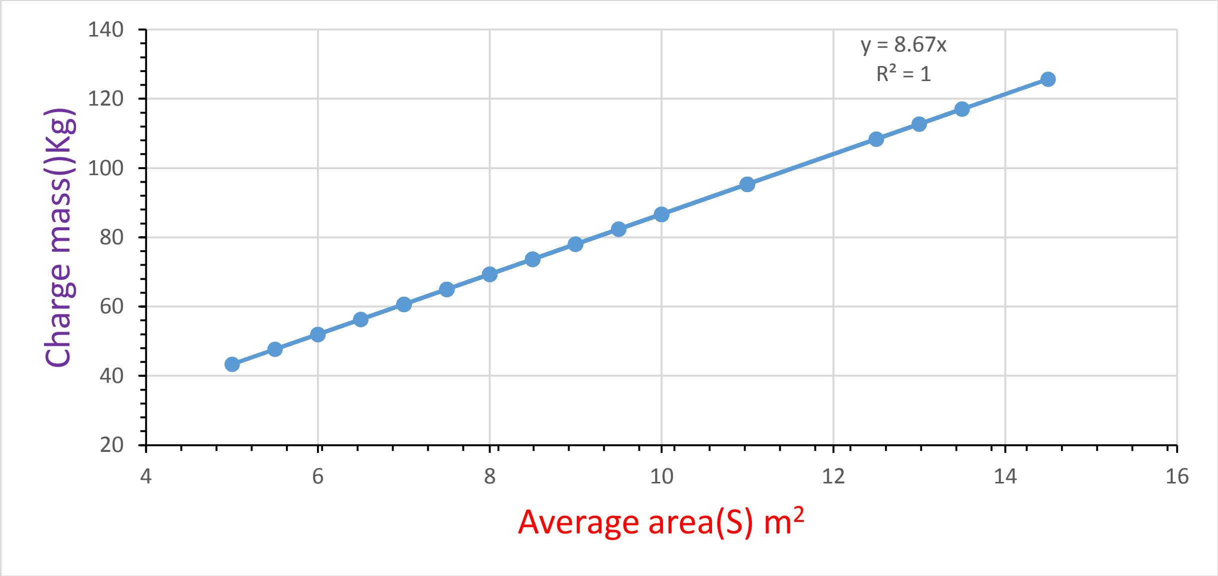

Fig. 8. Charge mass Vs Average area(S) of Patch-2

4.1.3.2 Charge mass Vs Hole Depth

4.1.3.2.1 Patch-2 Mine-2

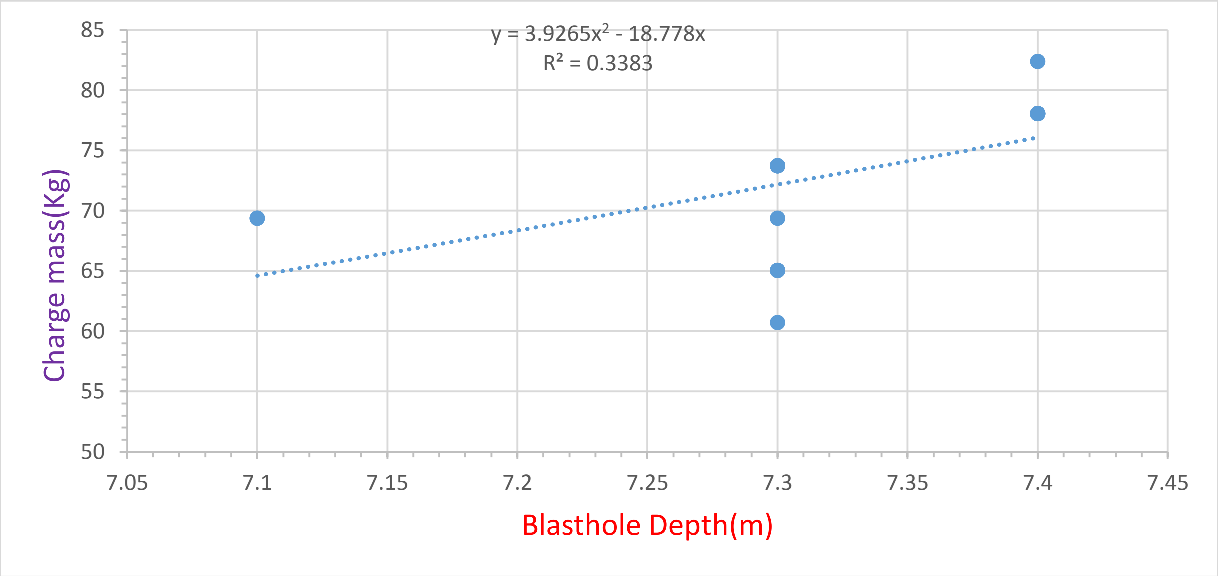

Fig. 9. Charge mass Vs Hole depth for Patch-1 Mine-2

4.1.3.2.2 Patch-2 Mine-2

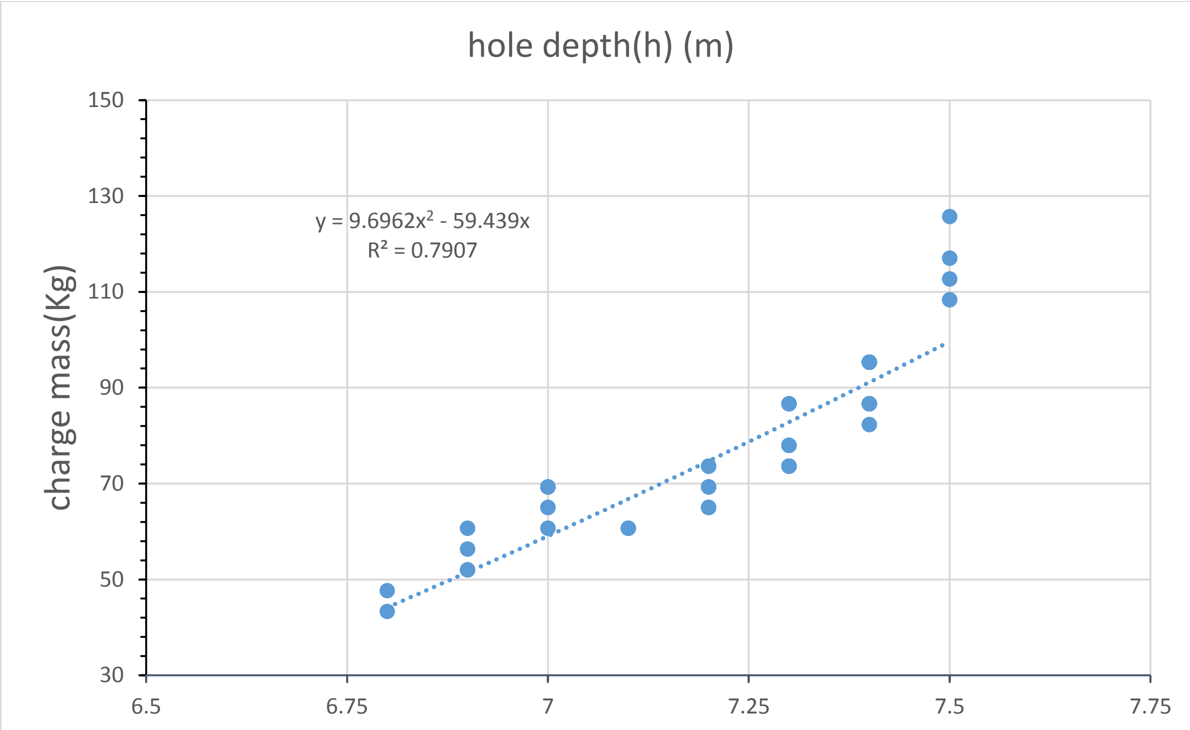

Fig. 10. Charge mass Vs Hole depth for Patch-2 Mine-2

It is observed that the co-relation of charge mass vs hole depth for Patch-2 of Mine-2 is more accurate than Patch -1of Mine-2, but the correlation is not that strong as R^2 is 0.79.

4.2 Burden and spacing

Burden of a blasthole is the minimum distance from the blasthole to the free faces that are created by its blasted neighboring blastholes. In this case the burden and spacing for the holes are same as the hole-by-hole blasting is considered. So, Square distribution pattern for the blastholes in each patch was adopted.

The row and hole spacing is calculated by explosive charge maximization concept. This defines all blastholes should be charged as much explosive as possible since the aim of creating a blasthole is to contain enough charge so that cost of secondary blasting can be avoided.

So, the spacing was calculated as

$$a = \frac{d\sqrt{\pi\rho_e(\lambda^2\pi d^2\rho_e + 16Hqh)} - \lambda\pi d^2\rho_e}{8Hq}$$

Where, λ is the empirical co-efficient d is the diameter of the blasthole, ρ_e is the charge density. For both the patches of this mine spacing was found to be 3.052 as all the specifications for both the patches were same.

4.3 Blast initiation sequence analysis

Voronoi diagram concept was employed to identify the hole-by-hole initiation sequence. As the voronoi cell is convex polygon, it shares a side with each of its neighbors. Since the blasting is happening through hole-by-hole method when a hole is blasted, it creates an extra potential free face for the next hole which is neighbor of the blasted hole. This concept is utilized to identify the blast initiation sequence. So, a blasthole would be initiated if the no of its free faces reach or exceed 2 and if the free faces of multiple holes reach 2 or more, in that case a blasthole whose row no is smaller than the rest is first initiated.

4.3.1 Algorithm for blast sequence identification for patches' of Mine-1

1. Define sets: i) *iniholeno* is used to store blasthole nos to be initiated.

ii) *Allblastsequence* is used to store blasthole nos in the sequence in which they are to be initiated.

iii) Define blastholes which stores the total no of blastholes in the grid.

iv) *Blastcounter* is used to store the no of blasthole initiated.

v) *Maxfreeface* is used to store maximum free face of any blasthole.

2. The blasthole nos are input in the appropriate places in the grid [][][1].
3. Loop: for i=0, i<max no. of rows, i=i+1

   for j=0, j< max no of column, j=j+1

   if blasthole exists in grid[i][j][1] ,then

   {

   if thee blasthole is at the edge assign its free face to 1 and store it in grid [i][j][3].
4. Grid is in the display for inspection.
5. Input the first blasthole in iniholeno that to be initiated first.
6. Blast the first blasthole in inihole no and increase the free face of its neighbors by 1 and store the value in Allblastsequence.
7. Search for the blasthole with the maximum free face, blast it and increase the free face of its neighbors by 1 and store the value in Allblastsequence.
8. Repeat step 7. till all the blastholes are initiated.
9. Display the Allblastsequence
10. End

4.3.2 Program generated

```
// program for generating initiation sequence for the  MINE-1

#include "stdafx.h"

#include "conio.h"

#include <iostream>

#include <math.h>

using namespace std;

int _tmain(int argc, _TCHAR* argv[])

{

int temp=0;

int grid[7][24][4];

//Enter Preset Here

cout<<"Do you want to use the preset of 73 holes??"<<endl<<"Enter 1 for preset 0 for Man-ual
Entery"<<endl;

cin>>temp;

if(temp==1)

{

int counter=1;

		for(int i=0;i<7;i++)


{

for(int j=0;j<24;j++)

{
```

```
if(counter<74)
{
if(i==1)
{
counter=48;
if(j==0)
grid[i][j][1]=0;
else
grid[i][j][1]=48-j;
}
else
grid[i][j][1]=counter++;
}
else
grid[i][j][1]=0;
grid[i][j][3]=-1;
}
}
for(int i=0;i<7;i++)
{
for(int j=0;j<24;j++)
{
cout<<grid[i][j][1]<<" ";
```

```
}
cout<<endl;
}
}
//Enter Preset Here
int o=7,p=24,i=0,j=0;
int xspace,yspace;
cout<<"Enter the Spacing of grid along X axis."<<endl;
cin>>xspace;
cout<<"Enter the Spacing of grid along Y axis."<<endl;
cin>>yspace;

//Loop to set default values and show the Grid
if(temp==0)
{
for(i=0;i<o;i++)
{
for(j=0;j<p;j++)
{
grid[i][j][1]=0;
grid[i][j][3]=-1;
cout<<grid[i][j][1]<<" ";
}
```

```
cout<<endl;
}
}
//Input Loop and Defining Blast hole no and Blast Sequence variable
int BlastHoles=0;
if(temp==0)
{
cout<<"Press 1 for yes and 0 for No"<<endl;
for(i=0;i<o;i++)
{
for(j=0;j<p;j++)
{
cout<<"Is there a Blast Point at X= "<<j<<" and Y= "<<i<<endl;
cin>>temp;
if(temp==1)
{
cout<<"Enter The Blast Hole Number"<<endl;
cin>>grid[i][j][1];
grid[i][j][3]=0;
BlastHoles++;
}
}
}
```

```
}
else
BlastHoles=73;
//Loop to assign Freeface Values of Edge Blast Holes
for(i=0;i<o;i++)
{
for(j=0;j<p;j++)
{
if (grid[i][j][1]>0)
{
if((i==0)||(j==0))
{
grid[i][j][3]=1;
}
}
}
}

//Display of Input Grid
for(i=0;i<o;i++)
{
for(j=0;j<p;j++)
{
```

```
cout<<grid[i][j][1]<<" ";
}
cout<<endl;
}
//Display of Input Free Face
for(i=0;i<o;i++)
{
for(j=0;j<p;j++)
{
cout<<grid[i][j][3]<<" ";
}
cout<<endl;
}

//Starting the Initialization sequence
int IniHoleNo=0;
int AllBlastSequence[336];
//Emptying the All Blast Sequence Variable form Garbage Values.
for(i=0;i<336;i++)
AllBlastSequence[i]=0;
int blastcounter=0;
int maxFreeFace=0;
int mi=0,mj=0;
```

```
cout<<"Enter the Initial Blasting Hole"<<endl;
cin>>IniHoleNo;
//Loop Start
do
{
//Checking for Previous Blasts
if(blastcounter==0)
{
//Searching For the Initial Blast Hole in Grid
for(i=0;i<o;i++)
{
for(j=0;j<p;j++)
{
if(IniHoleNo==grid[i][j][1])
{

//Setting the Blast Hole in Blast Sequence
AllBlastSequence[blastcounter]=grid[i][j][1];
//Blasting the Blast Hole
blastcounter++;
grid[i][j][1]=-1;
grid[i][j][3]=0;
//Increasing the Neighbouring Blast Hole Free Faces
```

```
if(grid[i][j-xspace][1]>0)
grid[i][j-xspace][3]+=1;
if(grid[i][j+xspace][1]>0)
grid[i][j+xspace][3]+=1;
if(grid[i-yspace][j][1]>0)
grid[i-yspace][j][3]+=1;
if(grid[i+yspace][j][1]>0)
grid[i+yspace][j][3]+=1;
if(grid[i-yspace][j-xspace][1]>0)
grid[i-yspace][j-xspace][3]+=1;
if(grid[i+yspace][j-xspace][1]>0)
grid[i+yspace][j-xspace][3]+=1;
if(grid[i-yspace][j+xspace][1]>0)
grid[i-yspace][j+xspace][3]+=1;
if(grid[i+yspace][j+xspace][1]>0)
grid[i+yspace][j+xspace][3]+=1;
}
}
if(IniHoleNo==grid[i][j][1])
break;
}
if(IniHoleNo==grid[i][j][1])
break;
```

```
}
//For Initialising the Rest of the Blast Sequence and Blasting the rest of the Blast Holes
else
{
//Searching For the Blast Hole with Maximum Free Face
maxFreeFace=0;
for(i=0;i<o;i++)
{
for(j=0;j<p;j++)
{
if(grid[i][j][3]>maxFreeFace)
{
mi=i;
mj=j;
maxFreeFace=grid[i][j][3];
}
}
}
i=mi;
j=mj;

//Blasting the Blast Hole with Maximum Free Face
AllBlastSequence[blastcounter]=grid[i][j][1];
```

```
blastcounter++;
grid[i][j][1]=-1;
grid[i][j][3]=0;
//Increasing the Free Face of Neighbouring Blast Holes
if(grid[i][j-xspace][1]>0)
grid[i][j-xspace][3]+=1;
if(grid[i][j+xspace][1]>0)
grid[i][j+xspace][3]+=1;
if(grid[i-yspace][j][1]>0)
grid[i-yspace][j][3]+=1;
if(grid[i+yspace][j][1]>0)
grid[i+yspace][j][3]+=1;
if(grid[i-yspace][j-xspace][1]>0)
grid[i-yspace][j-xspace][3]+=1;
if(grid[i+yspace][j-xspace][1]>0)
grid[i+yspace][j-xspace][3]+=1;
if(grid[i-yspace][j+xspace][1]>0)
grid[i-yspace][j+xspace][3]+=1;
if(grid[i+yspace][j+xspace][1]>0)
grid[i+yspace][j+xspace][3]+=1;
}
BlastHoles--;
}
```

```
while(BlastHoles>=0);
cout<<" "<<endl;
//Loop To Display the Grid After Blasting
for(i=0;i<o;i++)
{
for(j=0;j<p;j++)
{
cout<<grid[i][j][1]<<" ";
}
cout<<endl;
}
cout<<" "<<endl;
//Loop To Display the Free Face Grid After Blasting
for(i=0;i<o;i++)
{
for(j=0;j<p;j++)
{
cout<<grid[i][j][3]<<" ";
}
cout<<endl;
}
cout<<" "<<endl;
//Loop To Display the Blasting Sequence
```

```
for(i=0;(AllBlastSequence[i]>0&&(i<336));i++)

cout<<AllBlastSequence[i]<<" ";

}
```

4.3.3 Output for the blast sequence of mine-1

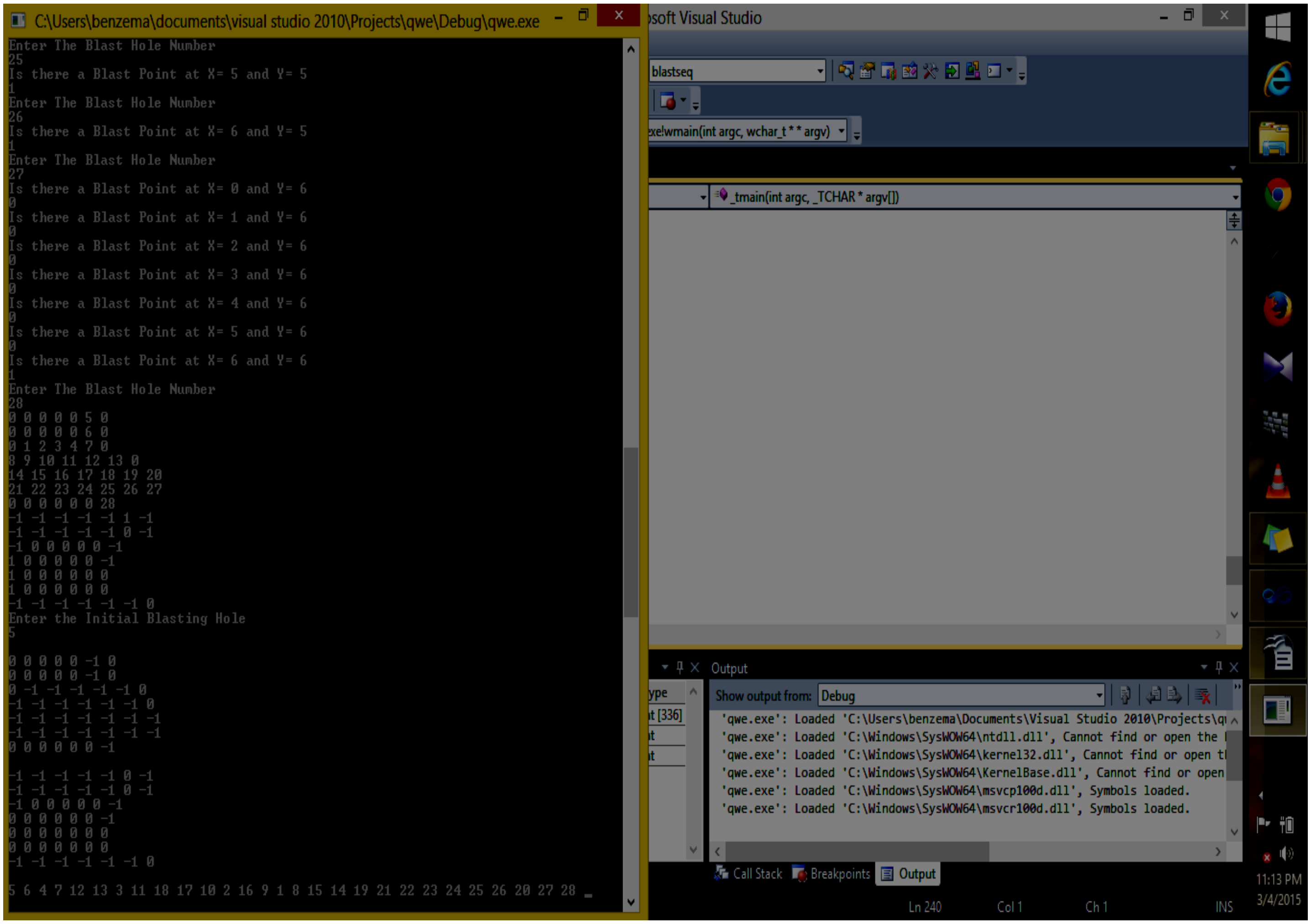

Fig. 11. Blast sequence generated for PATCH-2 mine-1

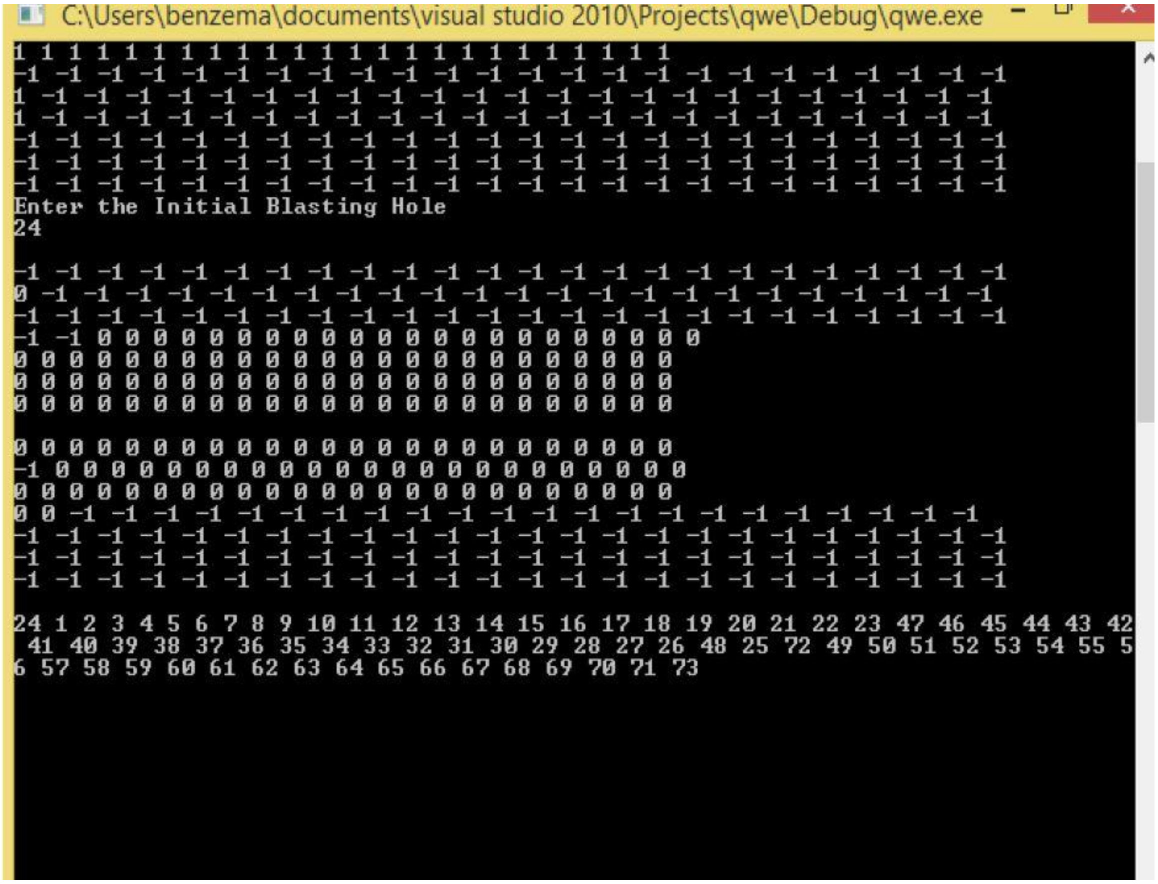

Fig. 12. Blast sequence for Patch -1 mine-1

4.4 Algorithm for blast sequence in accordance with the delay pattern

An algorithm has been adopted to generate a blast initiation sequence considering delay time between the holes.

1. Define sets: $InitiationTime$ is used to store all blastholes' initiation time; To easily draw initiation sequence diagram of all blastholes, define a set $IniSeqDrawing$, which is used to store blasthole number sets that have the same delay time between the neighboring blastholes.
2. Loop: for $k = 0$, $k < sizeof(AllHoleNo)$, $k := k + 1$.
   (1) Loop: for $i = 0$, $i < sizeof(AllBlastSequence)$, $i := i + 1$.
      (a) Loop: for $j = 0$, $j < sizeof(AllBlastSequence[i])$, $j := j + 1$.
         (I) If $AllBlastSequence[i][j] = k$, let
            $IniV = i \cdot RowDelayTime + j \cdot HoleDelayTime + InsideDelayTime$, push
            $IniV$ into $InitiationTime$.
         (II) End if.
      (b) End loop.
   (2) End loop .
   (3) Clear $NeiNo$.
3. End loop.
4. Define a temporary set of integer, $TmpHoleNo$.
5. Loop: for $i = 0$, $i < sizeof(AllBlastSequence)$, $i := i + 1$.
      Push $AllBlastSequence[i][0]$ into $TmpHoleNo$.
6. End loop.
7. Push $TmpHoleNo$ into $IniSeqDrawing$.
8. Loop: for $i = 0$, $i < sizeof(AllBlastSequence)$, $i := i + 1$.
   (1) Clear $TmpHoleNo$.
   (2) Loop: for $j = 0$, $j < sizeof(AllBlastSequence[i])$, $j := j + 1$.
         Push $AllBlastSequence[i][j]$ into $TmpHoleNo$.
   (3) Push $TmpHoleNo$ into $IniSeqDrawing$.
   (4) End loop.
9. End loop.

4.4.1 Generated program for the algorithm considering delay time

```
#include "stdafx.h"
#include <iostream>
using namespace std;
int _tmain(int argc, _TCHAR* argv[])
{
	//grid defination
	int i=0,j=0;
	int grid[5][5][2];
	for(i=0;i<5;i++)
	{
	for(j=0;j<5;j++)
		grid[i][j][0]=0;
	}

//grid value entry
	cout<<"Enter the Blast hole number . Use 0 for no blast hole"<<endl;
	for(i=0;i<5;i++)
	{
	for(j=0;j<5;j++)
    {
	cout<<"Blast Hole NUMBER in X= "<<j<<" and Y= "<<i<<" coordinate"<<endl;
	cin>>grid[i][j][0];
	}
	}

   //input of base delay
	cout<<"Enter the Base Delay"<<endl;
	int basedelay,it,jt;
```

```
}

        cin>>basedelay;

        //delay timming calculation

        for(i=0;i<5;i++)
        {
        for(j=0;j<5;j++)
        {
        if(grid[j][i][0]!=0)
{
        grid[j][i][1]=basedelay+(i*42)+(j*25);

        }
        }
        }

for(i=0;i<5;i++)
        {
        for(j=0;j<5;j++)
                cout<<grid[i][j][0]<<" ";
        cout<<endl;
        }
for(i=0;i<5;i++)
        {
        for(j=0;j<5;j++)
                cout<<grid[i][j][1]<<" ";
cout<<endl;
        }

        return 0;
}
```

4.4.2 Output of the program for blast sequence considering delay time

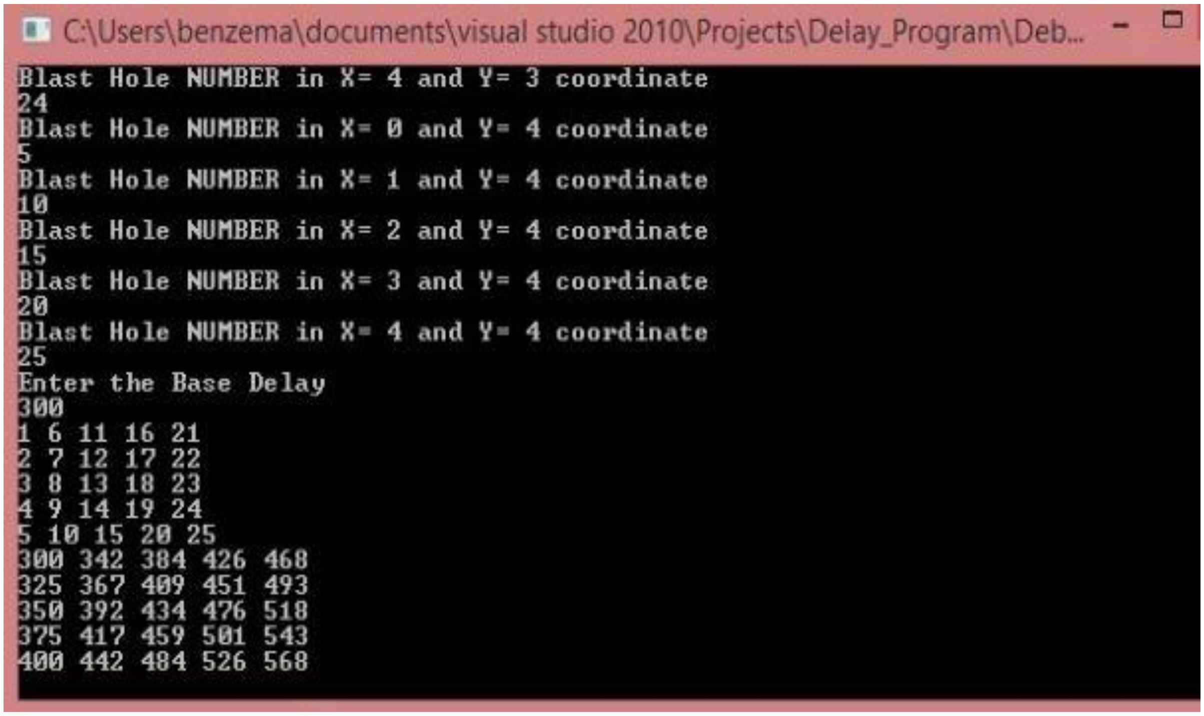

Fig. 13. Output of the blast sequence considering delay time

As displayed in the Fig. 13 the initiation sequence according to the delay time was coming as 1 2 6 3 7 4 11 8 5 12 9 16 13 10 17 14 21 18 15 22 19 23 20 24 25. The delay time was in the range 300-568ms considering an initial delay of 300ms. It came as a diagonal like pattern.

CHAPTER 05

CONCLUSION

AND

FUTURE SCOPE

CONCLUSION AND FUTURE WORK

5.1 Conclusion

This investigation involved study of two active iron ore mine. There were formation of many boulders as shown in fig. 2 requiring secondary breaking process. The blasting pattern, amount of explosive etc. were used to evaluate the applicability of Voronoi concept. The conclusions drawn are as below:

- The amount of charge mass used in the conventional blasting was in the range 20-40 Kg/hole. Using the Voronoi concept the charge /hole calculated was in the range 50-80 which is around two times more than the conventional blasting. This signifies that the charge mass utilized for the conventional blasting was not proper and has to be increased to get the proper fragmentation which in turn will reduce the cost.
- Blast initiation sequence determined through this voronoi concept gives the sequence as diagonal V shape which can be practiced as it creates a significant free face for the holes to be blasted and as the jumping and bending of the initiation is not that complex, the wire which connects the holes will not be hampered while blasting.

5.2 Scope for Future work

This investigation was undertaken as a part of final year project with a fixed time limit. Hence many other parameters were not determined. In future research may be carried out to determine other parameters considering a number of field blastings. If automation is achieved in determining these parameters, then this would provide a sophisticated and reliable method for bench blast design.

CHAPTER 06

REFERENCES

REFERENCES

Adhikari, G.R., (1995). Burden calculation for partially changed blast design conditions. International Journal of Rock Mechanics and Mining Sciences 36,253-6.

Liu, J., Sun, P., Liu, F., Zhao, M**.**, 2014. Design and optimization for bench blast based on Voronoi diagram. International Journal of Rock Mechanics & Mining Sciences 66, 30-40.

Liqing, L.,Katsabanis, P. D., 1997. A numerical study of the effects of accurate timing on rock fragmentation. International Journal of Rock Mechanics & Mining Sciences 34 , 817–835.

Cho, S. H., Kaneko, K**.,**2004. Rock fragmentation control in blasting. Mater Trans 45,1722–1730.

Cheimanoff, N., Adda, M., Duchene, M., Puntous, R**.,** 1990. An expert system for rock blasting planning in open-pit mines. In: Proceedings of the 14th world mining congress, Beijing, 799–804.

Kennedy, B.A., 1990. Surface mining, Maryland: Port City.

Das S. K., 1993. Blasting Practices in Surface Mines. Explosives and Blasting Practices in Mines, Chapter-2, 162-186.

Qu, S. J., Hao, S. H., Chen, G. P., Li B. H., Bian, G. Z.,2002. The BLAST-CODE model- A computer-aided bench blast design and simulation system. International Journal for Blasting and Fragmentation 6, 85-103.

Jia, Z., Chen, G., Huang, S., 1998. Computer simulation of open pit bench blasting in jointed rock mass. International Journal of Rock Mechanics and Mining Sciences 35, 476.

Trivedi, R., Singh, T. N., Mudgal, K., Gupta N**.,** 2014.Application of Artificial Neural Network for Blast Performance Evaluation. International Journal of Research in Engineering and Technology 05, 564-574.

Monjezi, M., Rezaei, M., Yazdian, A., 2010. Prediction of backbreak in open-pit blasting using fuzzy set theory. Expert Systems with Applications 37, 2637-43.

Adhikari, G. R., 1999. Selection of blasthole for a given bench height at surface mines. International Journal of Rock Mechanics and Mining Sciences 36, 843-7.

Yang, H. S., Rai, P., 2011. Characterization of fragment size vis-à-vis delay timing in quarry blasts. Powder Technology 211, 120-6.

Liqing, L., Katsabanis, P. D., 1997. A numerical study of the effects of the accurate timing on rock fragmentation. International Journal of Rock Mechanics and Mining Sciences 34, 817-35.

Shi, X. Z., Chen, S. H. R., 2011. Delay time optimization in blasting operations for mitigating the vibration-effects on final pit walls' stability. Soil Dynamics and Earthquake Engineering 31, 1154-8.

Zhu, Z. M., 2009. Numerical prediction of crater blasting and bench blasting. International Journal of Rock Mechanics and Mining Sciences 46, 1088-96.