

# INTEGRATED TECHNOLOGY SOLUTION FOR OPTIMISED AND ENVIRONMENTALLY CONTROLLED BLASTS

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# BLASTING: NOT A PRECISE TOOL

- Difficult to control fragmentation sizes
- Damages excavation walls and slopes
- Safety and Social concerns
  - Fly rock
  - Misfires and accidental initiation
- Environmental Concerns
  - Noise & Vibrations
  - Fumes
  - Dust & Fines

# ADVANCED TOOLS AND TECHNIQUES

Innovative techniques to design and execution of blasts are needed to carryout large blasts. Several Modern Tools &Techniques are available:

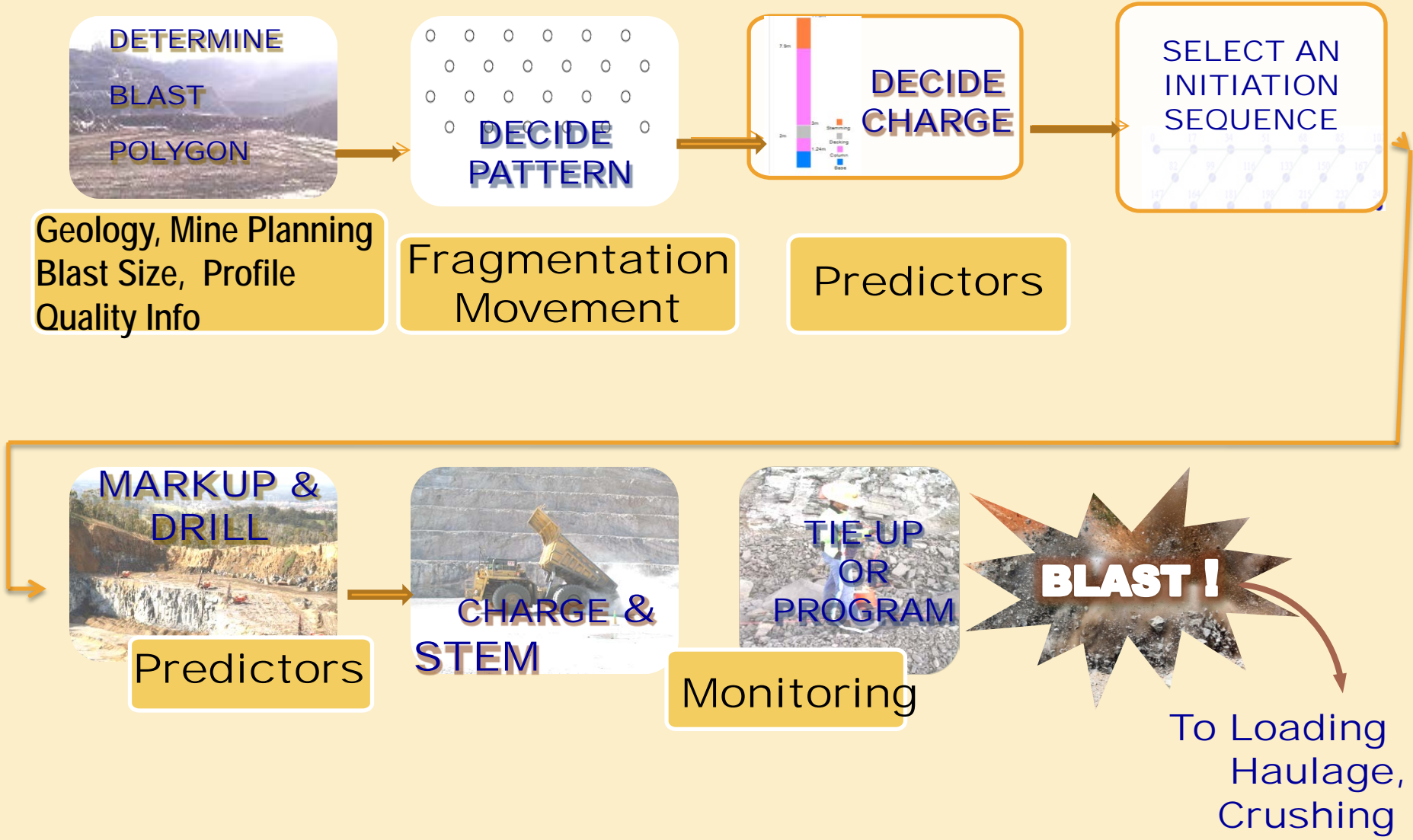
- Face Profiler
- Measurement of Deviation & Rock Properties while Drilling Hole
- GPS Controlled Drill Positioning
- Bulk explosives and delivery system
- Shock Tube/Signal Tube
- Electronic Detonators

## Information Technology Applications

- Design, Charging & Execution
- Data Collection and Analytics
- Impact Predictors and Controls
- Mobile and Web applications

# MANAGING BLASTING OPERATIONS NOT ENGINEERING

THERE ARE NO POINTS OF MEASUREMENT OR CONTROL



- Difference in designed and actual drilled hole pattern in the field, charging and tieup.
- Complete control on results and adverse impacts
- Appropriate data collection after drilling and data analysis and results can be predicted then charging, stemming, delay sequences and delay time can be changed to get optimised fragmentation and to control environmental impacts.
- This is possible with the use of Integrated Information Technology applications which can give real time data monitoring and analysis that can lead to optimisation and control of results.

# INTEGRATED INFORMATION TECHNOLOGY APPLICATIONS FOR BLASTING

- An integrated modular software solution developed for blasting operations (design, operational data collection, prediction and reporting subsequent analysis).
- Software has several modules – Blast Designer, Blast Information Data Management, ground and air vibration predictor, wave front reinforcement analyser, fragmentation size predictor, data analysis and advanced reporting.
- Software has integration tools allowing import and export of data/design from other key software packages (mining operational tools, etc), global positioning system (GPS), vibration equipment and has ability to upload photos and videos.

# MODULES FOR INTEGRATED BLASTING SOLUTIONS

Module No.	Module Name	Client server version	Webbased version	Mobile version
A	Surface Blast Design Module	Yes	Yes	Yes
B	Blast Data Management Module	Yes	Yes	Yes
C	Fragmentation Size Predictor	Yes	Yes	Yes
D	Prediction and Control of Environmental Impacts  i. Blast vibration prediction and Compliance (Air and Ground) ii. Safety	Yes	Yes	Yes

# BLASTING CASE STUDIES



- Two limestone open pit mines (one in north India & other in South India) are using Blast Data Management software.
- Before a blast is carried out, actual drilled hole locations are measured and predictors are used to check fragmentation results, vibration and flyrock distance and if necessary explosive charge loading, delay, initiation sequence are altered for controlling environmental impacts.
- Improved safety, improved environmental impact and reduced drilling and blasting costs.
- In one year there has been improvements in excavator performance, crusher performance and overall cost.



# Vasavdatta Cement

**Blast Pattern Parameters**

**B: 5.5 m, S :10 m  
H : 10 m**

**B: 5.25 m S:11 m  
H: 10 m**

**Tonnage Mined (t)**

**4359301**

**4378717**

**Blasting Cost in Rs/ t**

**3**

**2.8**

**Powder factor t/kg**

**11.6**

**12.29**

**Total Drilling (155mm, m)**

**40069**

**39384**

**Tonnes / m of Drilling**

**108.79**

**111.18**

**Tonnes per hole t**

**1375**

**1443**

**Excavator performance t/h**

**749**

**786**

**Loader Performance(t/h)**

**318**

**340**

**Dumper Performance (t/h)**

**210**

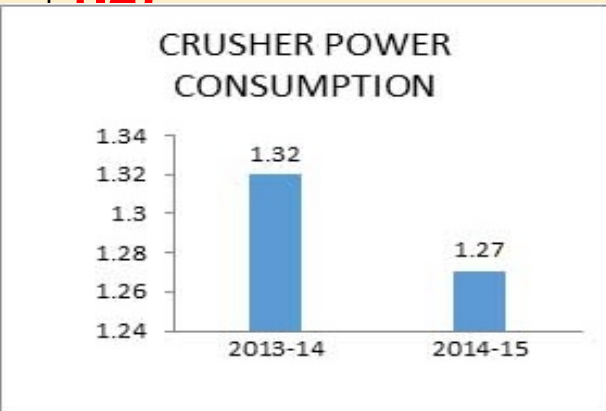
**219**

**Crusher Power**

**1.32**

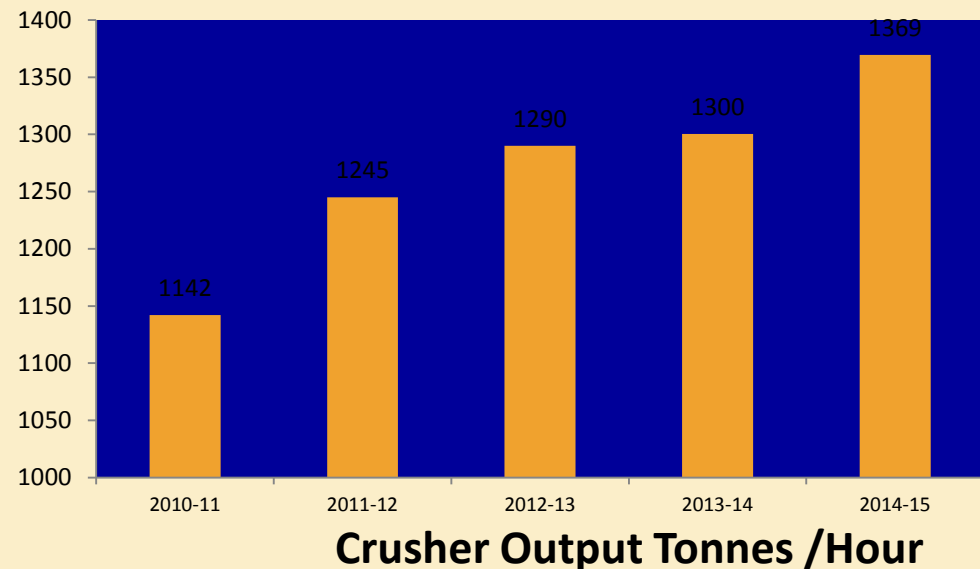
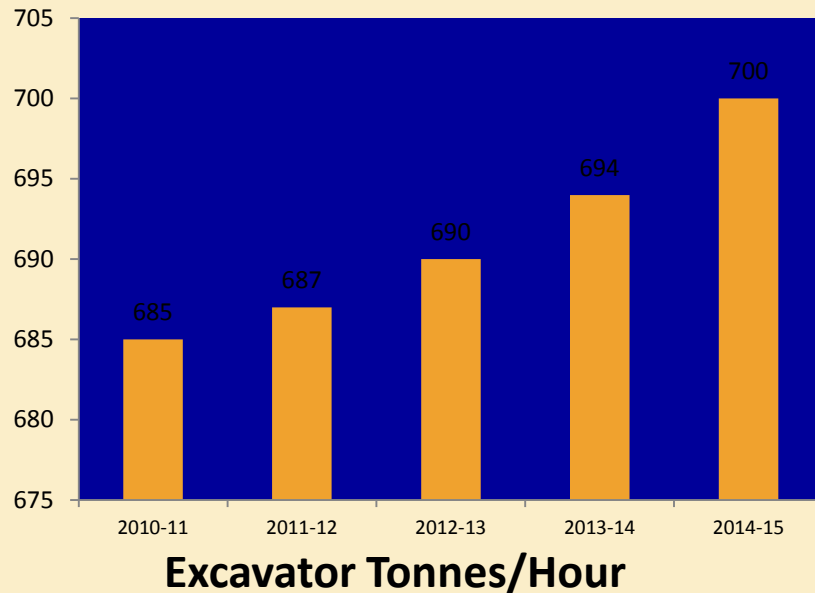
**1.27**

**Consumption (kwh/t)**



# CASE STUDY ADITYA CEMENT

- Drilling diameter 100mm-115mm. A set of about 25 holes is blasted at a time. Bench height varies between 6m and 10.5 m Explosive used is ANFO and initiator used are Excel or Raydet.
- **IMPROVEMENTS** : Almost for a decade rock breakage of limestone powder factor was improved from 6.5 t/kg to 15 tons/kg. Drill factor was maintained around 75 tons/m. Analysis indicated and powder factor was changed to 13.8 t/kg. Crusher productivity increased from 932 tons/hour to 1369 t/hour. Reduced ground vibration to 4mm/s. Controlling fly rock and dust. Reducing costs by 50%.



# Database

## Blast Information Gateway Integration Layer

### Pre Blast

### Blast

### Post Blast

Geology  
Mine Planning  
Environmental  
Info

Blast  
Planning  
and  
Design

Blast  
Execution

Operations  
Performance  
Analysis

Operations  
Optimization

### Blast Designer

Blast Information Management System

Flyrock, Fragmentation, Vibration  
predictor. Pattern Analysis

- Face Profiler info
- Design Pattern Based on geotech & environ info and best Past Practices
- Actual Hole position
- Initiation sequence

- Explosive & initiation Management
- Vibration Monitoring info
- Report, Search and Zone & Benchwise Analysis
- Evaluation of Results
- Fragmentation analysis
- Flyrock, Video, Photos
- Accident Records

- Flyrock Estimation
- Vibration Prediction
- Wave front Reinforcement
- Fragmentation Prediction
- Dynamic adjustment

# INTEGRATED BLASTING SOFTWARE



**BLAST DESIGNER  
(BLADES)**

**BLAST DATA  
MANAGEMENT  
SYSTEM (BIMS)**

**GROUND VIBRATION  
PREDICTION**

**AIR VIBRATION  
PREDICTION**

**SIMULATION &  
WAVE FRONT  
REINFORCEMENT  
ANALYSIS**

**FLYROCK ESTIMATION**

**VIDEO, PHOTOS  
IMPORT/EXPORT**

**FRAGMENTATION  
PREDICTION**

**COST ANALYSIS**



# Blast Designer Software

The screenshot displays the 'Blast Design & Pattern' window of the Blast Designer Software. It is divided into several sections:

- Input Fields:** A list of parameters for blast design, including Burden (4.92 m), Spacing (7.38 m), Facelength (59.04 m), Stem Length (3.69 m), SubGrade Drilling (1.48 m), HoleDepth (9.93 m), Column Weight (90.54 kg), Column Length (5.03 m), Bottom Weight (22.68 kg), Bottom Length (1.26 m), Explosive Length (6.23 m), Total Charge (113.22 kg), Holes Per Blast (16), Holes Per Row (8), Metrage Drilled (159.68 m), Total Exp Used (1311.52 kg), Total Rock Broken (10863.3323 Ton), Total Rock Broken (4938.1056 cu), and Mean Fragment Size (5.15048643 m).
- Costs:** A section for calculating costs, including Drilling Cost (12774.4 Rs), Explosive Cost (1811.52 Rs), Total Blast Cost (54548.05 Rs), Cost/Ton (4.36 Rs), Total Acc Cost (1463.3 Rs), and Powder Factor (5.07).
- Data Table:** A table with columns: Row No., Hole No., X Cord., Y Cord., FiringTime, and F. It lists 7 holes with their respective coordinates and firing times.
- Pattern Diagram:** A diagram showing a grid of holes. The pattern is set to 'Square' and 'Square in line'. The diagram shows a grid of holes with labels for hole numbers (5, 10, 20, 30, 40, 50, 60, 70, 80) and a 'Free Face' line.

Several software are available and are regularly used. However, Software are needed which have been tailored according to mine blasting practices. Further, they need to be calibrated over a period of time in a mine for given bench/face.

# BLAST DATA COLLECTION AND ANALYSIS

Systematic recording of data regarding a blast face, drill and blast pattern, explosive charge distribution, initiators.

Recorded by personnel & vibration monitors, videos, photo & equipment performance & data analysis ability.

**New Blast Record**

Blast ID:      Blast Design Pattern:      Charging Sheet      Explosive & Accessories Cgst

Manpower & Associated Cost      Vibration Monitoring      Accidents & Misfires      Blast Results      Fragmentation Analysis

[ Charging Sheet ]

[ Charge Component ]  
 By Length     By Weight

[ Charge in Hole(s) ]  
 Same for all Rows     Different in each Rows     Different in each Holes

[ Hole/Row Charge Details ]

Rows	Holes	Burden	Spacing	Explosive	Weight	Hole Depth
001	001	3.00	.00	Shakti Bulk 101	129.68	9.10
001	002	3.00	7.10	Shakti Bulk 101	129.68	9.40
001	003	3.50	7.30	Shakti Bulk 101	125.69	8.80
001	004	3.10	8.00	Shakti Bulk 101	125.69	9.00

Stemming Length: [ 0.00 ]  
 Column Charge: [ 0.00 ]  
 Booster Charge: [ 0.00 ]

[ Individual Charge Distribution ]

Row No	Hole No	Hole Depth	Burden	Spacing	Water Depth
		9.10	3.00	.00	.00

Charge Type	Material	Charge Length	Weight	Cost/Unit	
Column Charge	Shakti Bulk 101	6.50	129.68	22.05	
Booster Charge	Cast Booster	.35	8.89	.00	
Bottom Charge	A.N.F.O.	.00	.00	16.50	
Initiator (1) Used	Detonating Fuse	75.00	4.00	4.00	
Initiator (2) Used	NONE	2.00	1.00	1.00	
Delay Used	TLD Device one1	3.00	.00	.00	
Decking Length	.00	Start at	.00	Stemming Length	2.25

Ok    Not Ok

Save    Close    << Back    Next >>

**New Blast Record**

Blast Detail      Blast Design Pattern      Charging Sheet      Blast Cgst      Manpower & Associated Cost

Vibration Monitoring      Accidents & Misfires      Blast Results      Fragmentation Analysis

[ Blast Result ]

[ Blast Result ]

Theoretical Production in Volume	4860.00	Cu.M	Tonnage recovered from Face	13000	Ton
Theoretical Production(Tonnage)	12441.60	Tonne	Total Charge Weight	0	m
Total Explosive Consumed	1924.29	Kgs.	Total Stemming Length	100	m
Powder Factor	.15	Kg/Ton	Drill Meterage	243.00	m
Drill Factor	51.20	m/Ton			

[ Performance ]

Flyrock (m)	20	Stemming Ejection	Yes
Heave/Swell	Good	Muck Profile	Tight Muckpile
Boulder Count	20	Blasting Fumes	Yes
Displacement (m)	10	Overbreak (m)	1.2
Comments	Blast was Ok		
Photo	D:\NewBIMS\BIMS17032005\Photos\SHK2912200402P.jpg		
Video	D:\NewBIMS\BIMS17032005\Videos\SHK2912200402V.MPG		

Save    Cancel    << Back    Next >>

# GROUND & AIR VIBRATION MONITORING INFORMATION

**New Blast Record**

Blast Detail | Blast Design Pattern | Charging Sheet | Blast Cost | Manpower & Associated Cost

Vibration Monitoring | Accidents & Misfires | Blast Results | Fragmentation Analysis

[ Vibration Monitoring ]

[ Weather Information ]

Weather: Clear Sky | Wind Speed: Mild Breeze  
Wind Direction: East | Temperature: 0

Comments: [Yellow Highlighted Area]

[ Vibration Monitoring ]

Station	Nothing	Easting	Reduce Level	Distance	Instrument
Dapta-Ka-Badia	0	0	0	300	Blastmate DS 6

Buttons: Add, Edit, Delete

[ Details of Vibration Monitoring ]

Station: Dapta-Ka-Badia | Instrument: Blastmate DS 677 - InstanTel | Vibration File: 005PhotostSHK3012200401Vib003.jpg

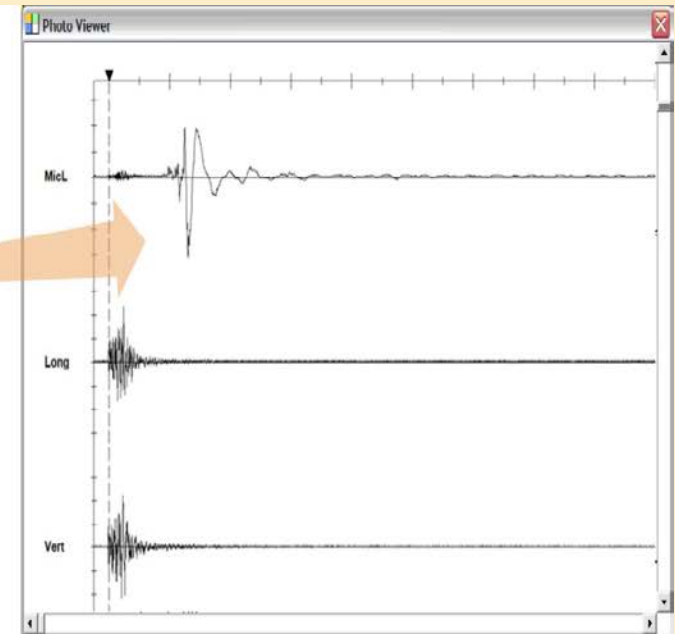
Nothing: 0 | Coupling: Plastibond

Easting: 0 | Longitudinal: 2.46 mm/s | Air Blast: 9.5 | Operator: SBHANDARI

Reduce Level: 0 | Transverse: 3.25 mm/s | Peak Vector Sum: 3.62 mm/s | Witness: GLNANDWANA

Distance: 300 | Vertical: 1.83 mm/s | Analyst: SBHANDARI

Buttons: Save, Cancel, << Back, Next >>



# REPORTS/SEARCHING



## Blast Detail

<b>Blast No.</b>	AC1008201301	<b>Blast Date</b>	10/08/2013	<b>Blast Time</b>	11:44:48
<b>Mine Name:</b>	Aditya Limestone Mines	<b>Operation:</b>	Production Blasting		
<b>Pit Name:</b>	Pit1	<b>Rock Type:</b>	LIMESTONE		
<b>Bench Name:</b>	Bench 3	<b>Material Blasted:</b>	High Grade		
<b>Zone Name:</b>	Zone 2002				

### FACE DETAILS

Hole Diameter	115	mm
Face Length	21	m
Hole Angle	0	Degree
Sub Grade	0	m
HoleDepth	10	m

### BLAST PATTERN

Pattern	Staggered	
Rows No.	2	
Total Holes	8	
Burden	4.5	m
Spacing	7	m

### BLAST RESULT

Volume Broken	0.00	Cu.m
Tonnage Recovered	0.00	Ton
Explosive	0.00	Kgs.
Powder Factor	0.00	Ton/Kg
Drill Factor	0.00	Ton/m
Blast Fumes	Yes	

### POST BLAST EVALUATION

Flyrock	0.00	m
Boulder Count	0.00	Nos
Over Break	0.00	m
Heave / Swell	Good	
Muck Profile	Scattered Muckpile	
Stemming Ejection	Yes	
Fragmentation	Good	



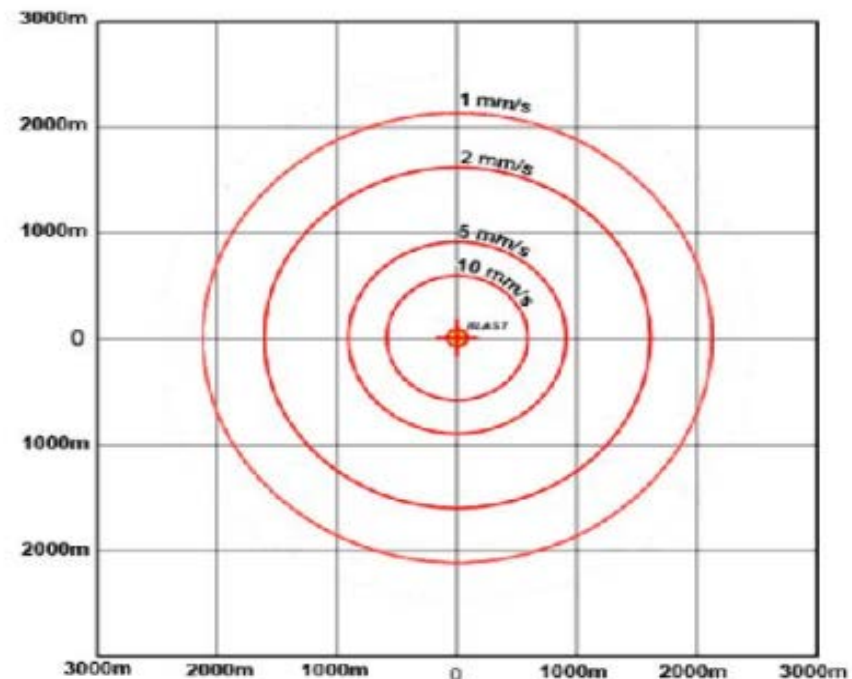
# Ground Vibration Prediction & Control

- Determination of site constant and exponent from ground vibration readings
- Determining minimum charge per delay

Determination of PPV (mm/s) based on Charge and Distance

Charge (kg)	Distance(m)										
	5	10	20	50	100	200	500	1000	2000	5000	10000
0.25	38.72	14.67	5.56	1.54	0.58	0.22	0.06	0.02	0.01	0	0
0.5	62.9	23.84	9.03	2.5	0.95	0.36	0.1	0.04	0.01	0	0
0.75	83.55	31.66	12	3.33	1.26	0.48	0.13	0.05	0.02	0.01	0
1	102.19	38.72	14.67	4.07	1.54	0.58	0.16	0.06	0.02	0.01	0
1.5	135.72	51.43	19.49	5.4	2.05	0.78	0.22	0.08	0.03	0.01	0
2.5	194.07	73.54	27.87	7.73	2.93	1.11	0.31	0.12	0.04	0.01	0
5	315.26	119.46	45.27	12.55	4.76	1.8	0.5	0.19	0.07	0.02	0.01
7.5	418.73	158.67	60.12	16.67	6.32	2.39	0.66	0.25	0.1	0.03	0.01
10	512.14	194.07	73.54	20.39	7.73	2.93	0.81	0.31	0.12	0.03	0.01
15	680.23	257.76	97.67	27.08	10.26	3.89	1.08	0.41	0.15	0.04	0.02

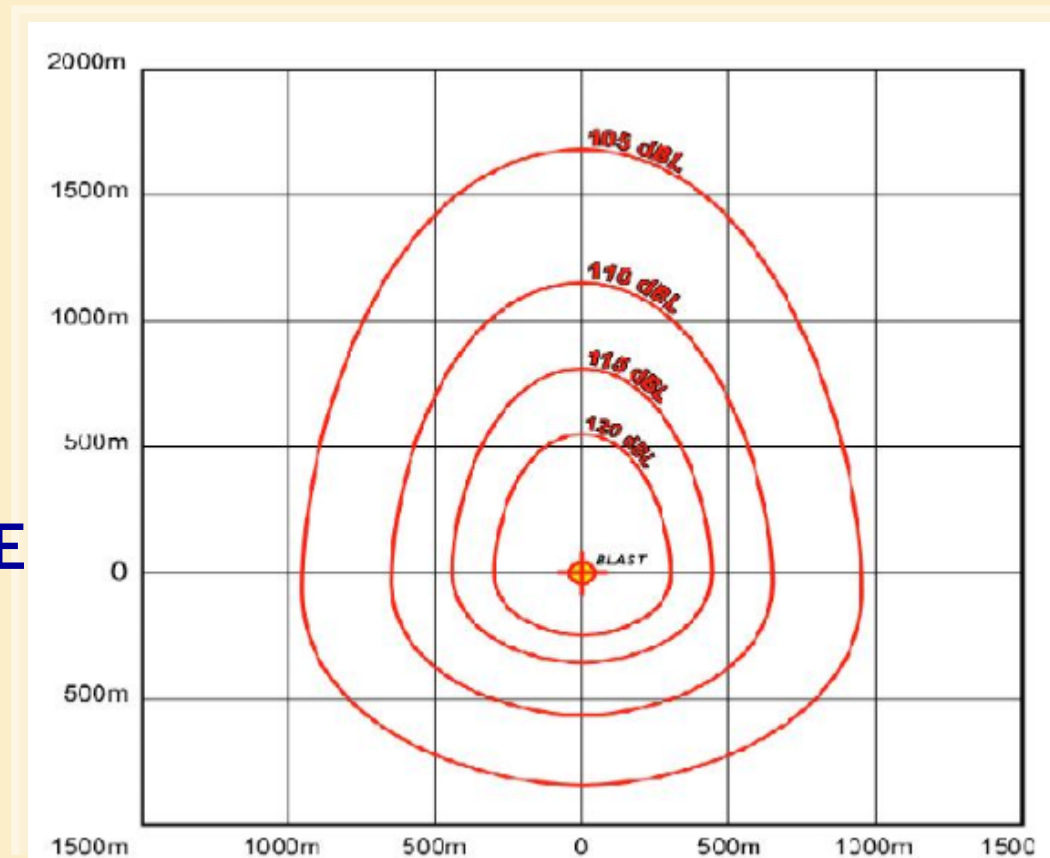
1 2 3



Ground Vibration Contours for 320 kg

# AIR BLAST PREDICTIONS

VIBRATION TABLE  
VIBRATION PLOT  
VIBRATION LIMIT TABLE



# Simulation

# Airblast & Ground Vibration Reinforcement

# Time window Analysis

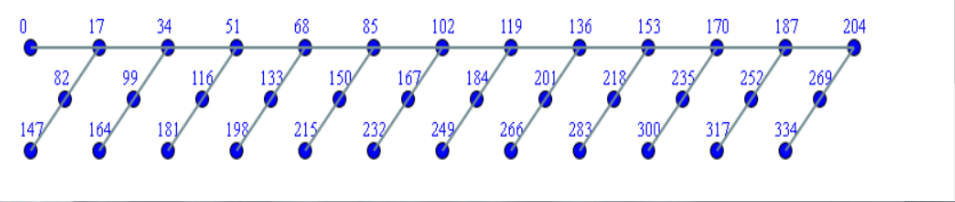
New Design

## Basic Design Parameters

Number of Rows : 3  
Number of Holes per Row : 13  
Burden Type :  All burdens are equal  
 Only first and last values are different  
 All values are to be...

Delay: 65 ms   Change Delay   Undo   Redo   Zoom in   Zoom out   Show Extra Holes   Clear All   image

Burden=6   Spacing=10   No. of Rows=3   No. of Holes=13



The diagram shows a 3x13 grid of holes. The top row has holes numbered 0, 17, 34, 51, 68, 85, 102, 119, 136, 153, 170, 187, 204. The middle row has holes numbered 82, 99, 116, 133, 150, 167, 184, 201, 218, 235, 252, 269. The bottom row has holes numbered 147, 164, 181, 198, 215, 232, 249, 266, 283, 300, 317, 334.

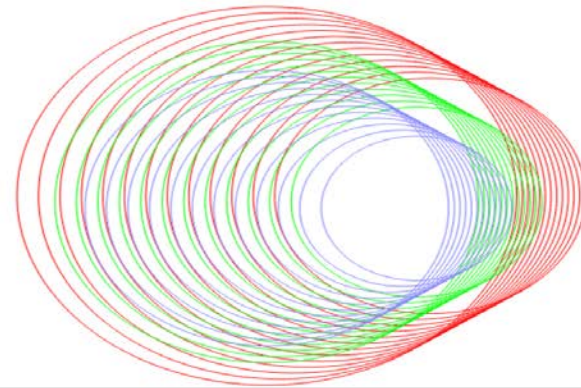
Pattern Analyzer - Untitled   Pattern Analyzer Web

patternanalyser.earthsourcectechology.com/Analysis.aspx

No. of Holes per row: 13

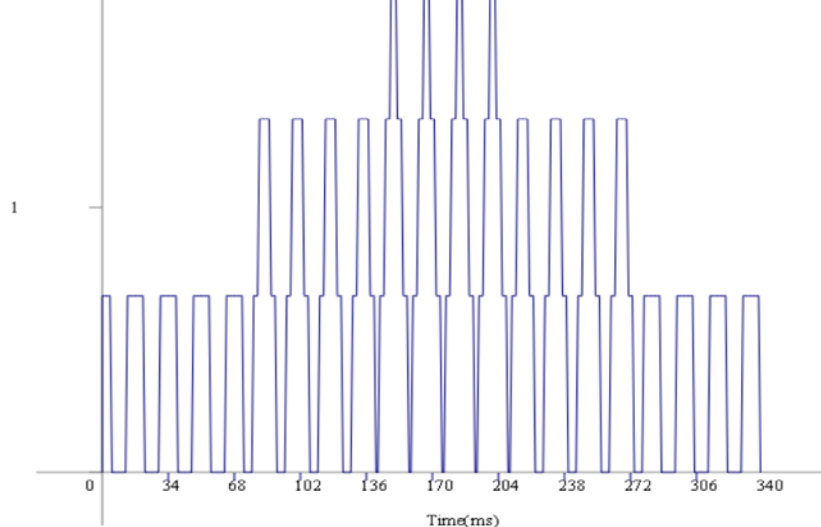
Burden: 6

Spacing: 10



earthsourcectechology.com/analysis.aspx

No. of Holes going off



No. of Holes per row: 13

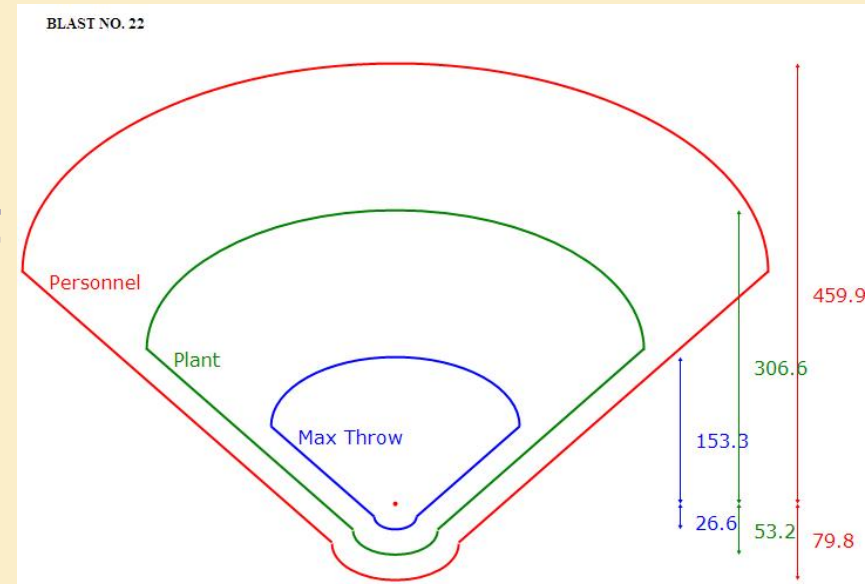
Burden: 6

Spacing: 10

# FLYROCK PREDICTION SOFTWARE

- Inputs are:
  - Charge mass
  - Burden or stemming height
  - Site calibration

- Output is the distance that rock will be thrown & this quantification can be used to establish both safe clearance distances



- Zone of flyrock travel is indicated by this tool. Using safety factors danger zones for machinery and persons respectively. If it is not possible to remove any structure or person then one can change charging of holes.



## Blasting Predictors & Control Tools

Wavefront  
Reinforcement

Fragmentation  
Prediction

Blast Clearance Zone  
Estimator

Ground Vibration

Air Vibration

Blast Information  
System (BIMS)

# FRAGMENTATION ANALYSIS & PREDICTION

## Design Parameters

Blast Design Info

Rock Property Info

Explosive Info

Bench Height (m)	<input type="text" value="15"/>
Hole Diameter (mm)	<input type="text" value="235"/>
Hole Depth (m)	<input type="text" value="15"/>
Subgrade (m)	<input type="text" value="0"/>
Burden (m)	<input type="text" value="3.7"/>
Spacing (m)	<input type="text" value="12.3"/>
Stemming (m)	<input type="text" value="2.02"/>
Drilling Accuracy (m)	<input type="text" value="0.1"/>
Spacing to Burden Ratio	<input type="text" value="3.32"/>
Drill Pattern	<input type="text" value="Staggered"/>

## Design Parameters

Blast Design Info

Rock Property Info

Explosive Info

Specific Gravity (SG)	<input type="text" value="2.8"/>
Young's Modulus (GPa)	<input type="text" value="60"/>
USC - Compressive Strength (MPa)	<input type="text" value="100"/>
Rock Mass Description	<input type="text" value="13"/>
Vertical Joint Spacing (JPS)	<input type="text" value="20"/>
Joint Plan Orientation (JPO)	<input type="text" value="20"/>
Sonic Velocity (Vp)	<input type="text" value="100"/>

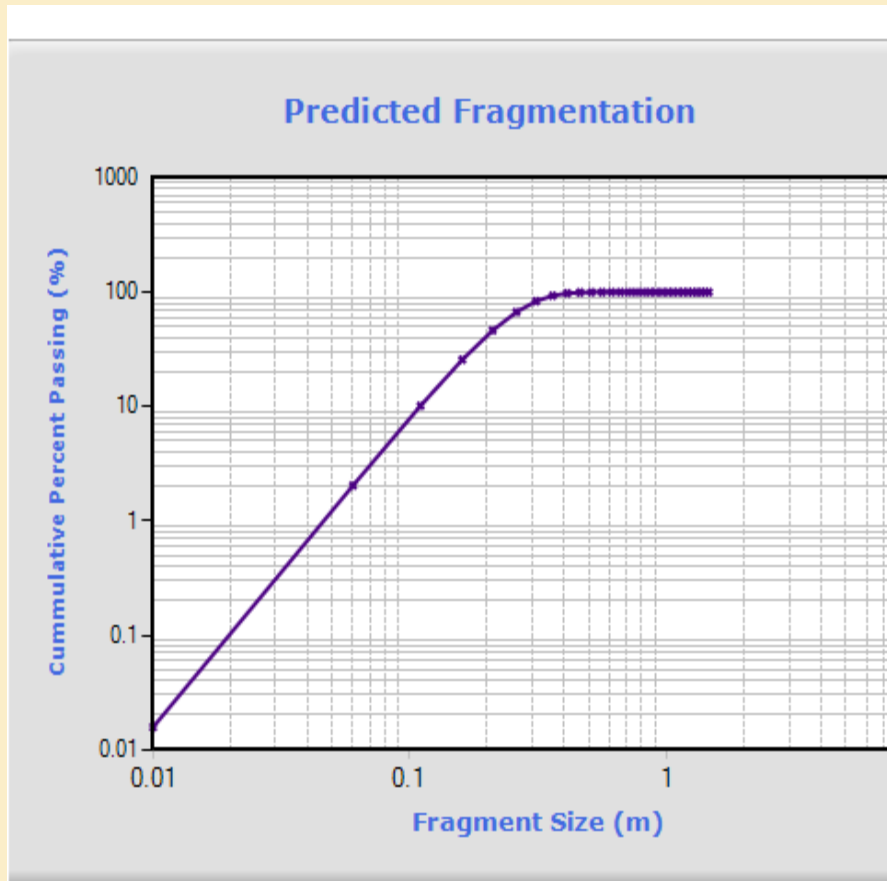
Blast Design Info

Rock Property Info

Explosive Info

Explosive Diameter (mm)	<input type="text" value="100"/>
Explosive Density (ton/m3)	<input type="text" value="0.9"/>
REE (RWS to ANFO)	<input type="text" value="1"/>

# FRAGMENTATION PREDICTOR RESULTS



**Tabular Format**

Size (m)	Percentage Passing (%)
0	0%
0.05	1.2%
0.1	7.9%
0.15	22.1%
0.2	42%
0.25	63.2%
0.3	80.6%
0.35	91.8%
0.4	97.2%
0.45	99.3%

1 2 3 4

Fragmentation Predictor allows user to design blasts for desired fragmentation size

# MOBILITY SOLUTION

- There is growing convergence of “consumer” technologies such as iOS and Android phones, devices such as camera, motion sensors, and GPS systems.
- Use of Mobile devices makes it easier for mining personnel to collect On-Site blasting data. As part of the technology solution a Mobile App has been developed.
- Mobile technology is being used to streamline blasting project management, operations, safety eliminate delays, and reduce overall project costs.



On Site Blasting Tools an Integrated Blast Mobility Application

Limitation



# Integrated Blast Mobile App


- Charge Details
- FlyRock Prediction
- Fragmentation Prediction
- Wave Reinforcement Prediction
- Ground Vibration Prediction
- Air Vibration Prediction
- Estimate Cost
- Export Blast Data
- GPS



### Charge Details

Hole to hole delay:	<input type="text" value="25ms"/>
Row to Row Delay:	<input type="text" value="17ms"/>
Number of DTH:	<input type="text" value="1"/>
Number of Surface Initiator (Hole to Hole):	<input type="text" value="15"/>
Number of Surface Initiator (Row to Row):	<input type="text" value="1"/>
Hole Depth:	<input type="text" value="9"/>
Burden:	<input type="text" value="3"/>
Spacing:	<input type="text" value="4.5"/>
Water Depth:	<input type="text" value="0"/>
Stemming Length:	<input type="text" value="3.2"/>
Coordinates (Format : X,Y):	<input type="text" value="0,0"/>

# Flyrock Predictor

 Integrated Blasting Predictors

Charge Details

FlyRock Prediction

Fragmentation Prediction

Wave Reinforcement Prediction

Ground Vibration Prediction

Air Vibration Prediction

Estimate Cost

Export Blast Data

GPS



## FlyRock Predictor

**Front Throw is 63.68 m and Back Throw is 11.06 m**

Burden (m):	<input type="text" value="3.0"/>
Charge Mass (kg/m):	<input type="text" value="8.8"/>
Drill Hole Angle (degrees):	<input type="text" value="5"/>
Drill Hole Diameter (mm) :	<input type="text" value="102"/>
Stemming Ht (m) :	<input type="text" value="2.5"/>
Constant :	<input type="text" value="20"/>
Hole Depth (m) :	<input type="text" value="10"/>
Plant Equipment Safety Factor :	<input type="text" value="2"/>
Personal Safety Factor :	<input type="text" value="4"/>
Throw(Front of face) (m) :	<input type="text" value="63.68"/>
Throw(Back of face) (m):	<input type="text" value="11.06"/>

# Fragment Size Distribution Predictor

## INPUT PARAMETERS

Done Integrated Blasting Predictors

### Blast Design Info

Bench Height (m):

Hole Diameter (mm) :

Hole Depth (m):

Subgrade (m) :

Burden (m) :

Spacing (m) :

Stemming (m) :

Drilling Accuracy (m) :

Spacing to Burden Ratio :

Drill Pattern :

Back Set Default Next

---

### Rock Property Info

Specific Gravity (SG):

Young's Modulus (GPa) :

USC - Compressive Strength (MPa):

Rock Mass Description :

Vertical Joint Spacing (JPS) :

Joint Plan Orientation (JPO) :

Sonic Velocity (Vp) :

---

### Explosive Info

Explosive Diameter (mm):

Explosive Density (ton/m3) :

REE (RWS to ANFO):

Back Set Default Next

## FRAGMENTATION RESULT

Done Integrated Blasting Predictors

### Fragmentation Target Predictor

Over Size (m):

Optimum (m) :

Under Size (m):

Back Predict Fragmentation

---

Done Integrated Blasting Predictors

Calculations	
Blastability Index	6.48
Average Size of Material (cm)	26.61
Uniformity Exponent	1.63
Characteristic Size (m)	0.33
Percent Oversize	14
Percent in Range	81.5
Percent undersize	4.5

Back Next

# Ground and Air Vibration Prediction

**Integrated Blasting Predictors**

**Ground Vibration**

**Ground vibration is 1.79 mm/sec**

Distance:  m

Charge per delay:  kg

Site Law Exponent:

Site Law Constant:

Back    Vibration Limit Table    Display



**Integrated Blasting Predictors**

**Vibration Limit Table**

**Charge per meter 50.01 kg**

Distance:  m

Site Law Exponent:

Site Law Constant:

Ground Vibration:  mm/sec

Back    Ground Vibration Table    Display

**Integrated Blasting Predictors**

**Air Vibration Prediction**

**Decibels Linear (dBL) is 137.21 m**

Distance:  m

Charge per delay:  kg

Site Law Exponent:

Site Law Constant:

Back    Vibration Limit Table    Display



**Integrated Blasting Predictors**

**Vibration Limit Table**

**Charge per meter 14.96 kg**

Distance:  m

Site Law Exponent:

Site Law Constant:

Sound Intensity Level:  m

Back    Air Vibration Table    Display

# CONCLUSIONS

- Blasting operations needs to use innovative technology. Several technologies are being adopted to make blasting operations efficient and reduce environmental impact.
- Data storage and analysis helps to quickly respond to information and remain successful in today's competitive market place.
- An integrated blasting software solution used in a couple mines , though some individual modules have been in use in many mines in Australia as Terrock tools. This is convenient since it can be used by medium range and smaller operations to improve results and control adverse impacts.
- Integrated Mobility solution provides an important "ON-SITE BLASTING TOOL".