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ROCK BLASTING

Prof. V. R. SASTRY

TEP
Sept. 18-20, 2014

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ROCK BLASTING

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ROCK BLASTING

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Prof. V.R. Sastry

Authors
Prof. V.R. SASTRY
RAGHU CHANDRA GARIMELLA

Other Contributors
Smt. Asha Khalwadekar, Dy. Chief Controller of Explosives, PESO
Dr. H.S. Venkatesh, Scientist-V & HOD, NIRM
P.V.S. Sarma, General Manager - Technical Services, Gulf Oil Corporation Ltd.
Dr. K. Ram Chandar, NIT K-Surathkal
Prof. D.Venkat Reddy, NIT K-Surathkal
M.M. Kamath, Former Chief Engineer and INAE Distinguished Visiting Professor

GEOLOGICAL DISCONTINUITIES & INFLUENCE ON BLASTING

Dr. V.R. Sastry, Dr. D.Venkat Reddy & G. Raghu Chandra
Professor Professor Research Scholar
NITK-Surathkal
MANGALORE – 575025

ABSTRACT

Fragmentation is the fundamental concern of rock blasting and it measures the effectiveness of blasting. Fragmentation is sensitive to not only the interrelationship among the design variables, but also is sensitive to local geology. Local geological conditions have a significant impact on the success of a blasting operation. The initial steps in these studies involved, determining the effect of rock properties on fragmentation via a literature search and the amount and quality of the geological data being utilized in blast pattern design at that time. The literature survey and then studies conducted clearly indicated that rock properties play a major role in determining both the fragmentation characteristics of a blast and the main blast pattern design parameters of burden, spacing, stemming and sub depth lengths if the same explosive and blasthole diameter is used.

INTRODUCTION

Geological conditions in the given bench being blasted have a significant impact on the success of a blasting operation. Among various parameters, the single most important geological consideration is geological structure. Different structural discontinuities like joints, bedding planes and their orientation with respect to the bench face, and mud or soft seams can have a serious influence on the blasting process both from a performance and safety standpoint.

Soft seams, such as mud layers cause severe violence and poor fragmentation. Soft seams result in instantaneous release (escape) of the gaseous energy, since they often move as a hydraulic fluid. Soft seams can be thrown to significant distances with fly rock travelling with them. Also, bedding planes in non-homogeneous rock layers, depending on their location can cause potential for rock overhangs, unexpected muck pile height, toe problems, back breakage and differences in fragmentation in each rock layer. The beds layering also may a a considerable influence on burden movement.

The most effective method of optimizing mining costs is through efficient blasting as the degree of fragmentation affects the loading, hauling and crushing functions. Therefore, many mining operations are utilizing optimum blasting defined as that blasting practice which minimizes overall mining costs. Following are the four major variables influencing the blasting results:

- Explosive parameters - explosive density, VOD, gas volume, detonation pressure etc.
- Charge loading parameters - diameter and length of explosive, stemming length, sub depth, decoupling etc.
- Blast geometry - burden, blasthole spacing, shape and size of blast, initiation sequence, delay timing etc.
- Rock properties - density, compressive strength, tensile strength, Young's Modulus, Poisson's ratio, intensity of bedding, jointing and shearing, structure etc.

JOINTING CHARACTERISTICS

Jointing is the occurrence of joint sets forming the system or pattern of joints as well as the amount or intensity of joints. The network of joints in the massifs between the weaknesses zones can according to Selmer-Olsen (1964) be characterized as 'the detailed jointing'.

Joint Sets

Field studies of several workers have shown that rocks are invariably jointed in preferential directions and occur in joint sets. Two or three prominent sets and one or more minor sets often occur; in addition random joints may be present. Pollard and Aydin (1988) propose that each continuous joint set have been formed during a single deformation episode.

The conditions of the joints in the various sets can vary greatly depending on their mode of origin and the type of rocks in which they occur. Not only can the size and average spacing of joints vary, but also the other characteristics mentioned above. Variations in these properties cause that one joint set can have very different effect on the shear strength characteristics than another.

Although some characteristics are common for joints of different sets in a structural region, it does not, however, seem to be any general connection between all joint conditions in the different types of rock. Thus, for each of the joint sets, within a structural region with similar jointing characteristics, the various properties of each set must be considered individually.

In many cases one joints set is dominant, being both larger and/or more frequent than joints of other sets in the same locality. This set is often referred to as the main joint set (or by geologists as primary joints). Often, only one more joint set is developed (Price, 1969).

Joint Spacing

Joint spacings varying from some millimetres to many metres may often seem arbitrary. There are, however, sometimes certain trends in the density of joints caused by spacings.

Nieto (1983) has observed variations in average spacing between joints from centimetres in highly tectonized rocks (folded, faulted, and intruded) of all types to more than 10 metres in massive, horizontally layered rocks. The regularity of joint spacing decreases with the amount of tectonic activity of the area.

Similarly, Pollard and Aydin (1988) mention that spacing of joints in some sets in intrusive igneous rocks is not uniform and that distances between joints range from less than 20 cm to more than 25 m, and that clusters of joints crop out sporadically.

Pollard and Aydin (1988) have further observed regular distribution of joints in sedimentary rocks and that the spacing of joints can scale with the thickness of the layer. Nieto (1983) mentions a general trend to a marked increase in the spacing or even the virtual disappearance of joints in flat-lying sedimentary sequences at depths of as little as 100m.
Pollard and Aydin (1988) suggest from field data that the following other factors also influence joint spacing:

- Two joint sets in the same lithological unit often have different spacings.
- Spacing of joints in different lithological units of comparable thickness can be different.
- Spacing can change as a joint set evolves. For example, columnar jointing - initiated at a flow base show an increase in spacing towards the interior - and the number of joints in a sedimentary unit decreases with distance from the initiation surface. The spacing of cooling joints that grow from the top of a lava flow is smaller than the spacing of those that grow up from the base. This has been attributed to a faster cooling rate at the flow top.

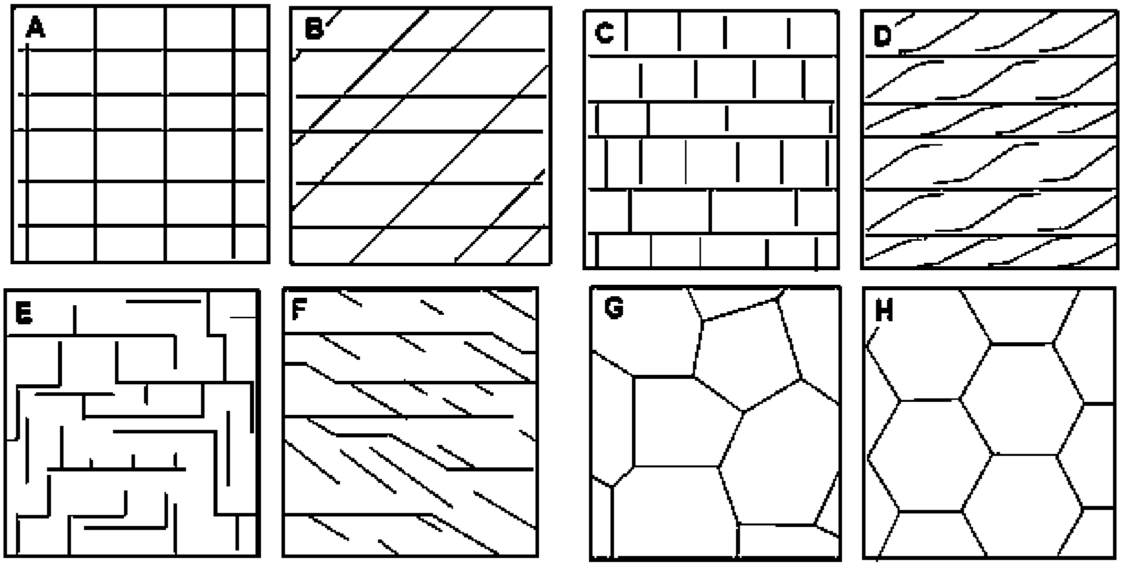
In addition two other trends should be mentioned:

- Rock masses that have undergone tectonic disturbance often present clusters of joints (joint zones).
- Often the joint Spacing is also influenced by weathering, as there often is an increase in jointing density within the zone of weathering, especially where mechanical disintegration has taken place.

Jointing Pattern and Block Types

Joint *patterns* comprising of more than one set are common in nature. Piteau (1970) has observed that in instances where jointing is considered to have *random* distribution, it is usually the case that several joint sets occur simultaneously or are superimposed on earlier sets and the resulting complexity gives the appearance of randomness. Although there are many varieties of joint patterns in nature, there are few types of joint intersection geometries, which can be classified as *orthogonal* (+ intersections) and *non-orthogonal* (X intersections) (Fig. 1). Both types can be divided into three groups according to the persistence of the joints at intersections:

- All joints are persistent (crossing other joints)
- Some persistent, some non-persistent
- All joints are non-persistent



A. Orthogonal pattern, with persistent sets (+ intersection)
B. Non-orthogonal pattern, with persistent sets (X intersections)
C. Orthogonal pattern, one set is persistent (T intersections)

D. Non-orthogonal pattern, one set with persistent joints
E. Orthogonal pattern, both sets have mainly discontinuous joints
F. Non-orthogonal pattern, both sets have mainly discontinuous joints
G. Triple intersections with all joints
H. Triple intersections with 120° angles

FIG. 1 SCHEMATIC ILLUSTRATION OF MAIN JOINT PATTERNS (Pollard and Aydin, 1988)

Pollard and Aydin (1988) have observed that orthogonal joints often terminate against persistent joints. They mention, however, that there are many examples of joints that apparently cut across bedding interfaces and other joints. The + or X types of such intersections seem to contradict the notion that older discontinuities act as barriers to joint propagation, as implied by T intersections. The results from analyses carried out by Kikuchi et al. (1985) of joint connections in granitic rocks showed that most of the joints belonged to the X type, but also the T type and the + type were frequently observed. The joint termination type mainly belonged to the T type. Dershowitz and Einstein (1988) mention that 60% of joints in Stripa, Sweden terminate at T-type intersections; in other places 42% of this type has been recorded. According to Price (1969) joints frequently occur in relatively narrow zones, in which one joint is replaced *en echelon* by another joint, which is slightly off-set (Fig. 2).

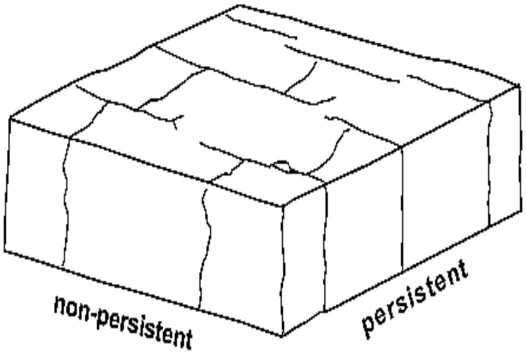
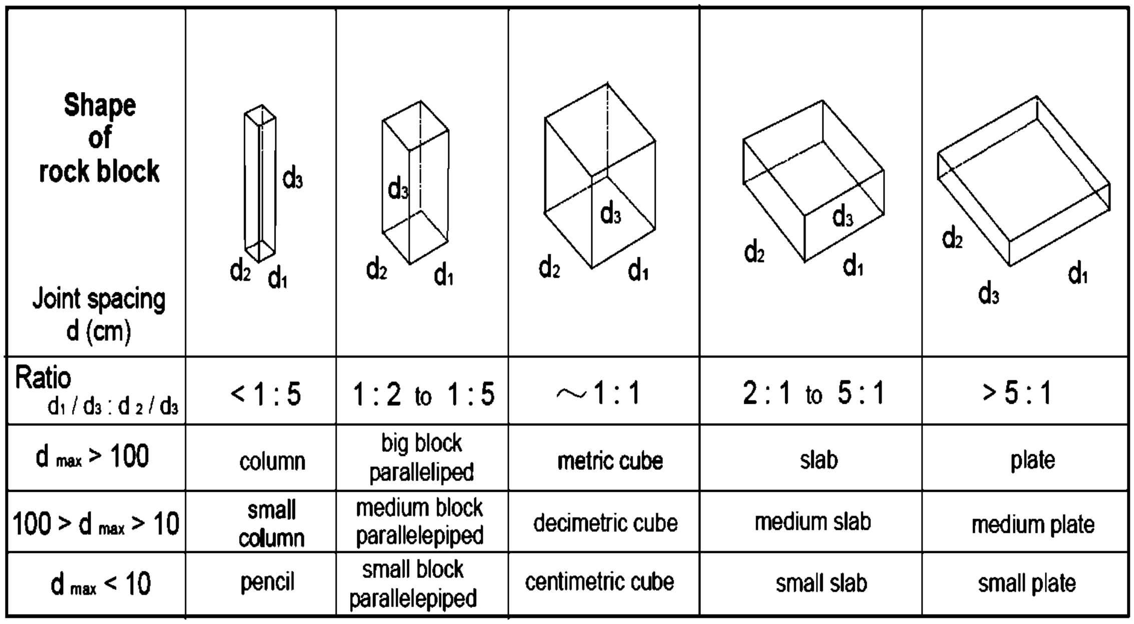


FIG. 2 JOINTS ARE SOMETIMES ARRANGED IN ZONES WITH REDUCED SPACING AND REPLACING EACH OTHER EN ECHELON (modified from Price, 1969)

Block Types and Sizes

The joint sets and possible random joints divide the rock volumes into characteristic blocks. The jointing pattern and the difference in spacing between the joints within each joint set determine the shape of the resulting blocks, which can take the form of cubes, rhombohedrons, tetrahedrons, sheets etc. Müller et al. (1970) have made the division of block shapes as shown below in Table-2.

TABLE – 2 CLASSIFICATION OF BLOCK TYPES (Müller et al., 1970)



Shape of rock block Joint spacing d (cm)	d_2 d_1 d_3	d_2 d_1 d_3	d_2 d_1 d_3	d_2 d_1 d_3	d_2 d_3 d_1
Ratio $d_1 / d_3 : d_2 / d_3$	< 1 : 5	1 : 2 to 1 : 5	∼1 : 1	2 : 1 to 5 : 1	> 5 : 1
$d_{max} > 100$	column	big block paralleliped	metric cube	slab	plate
$100 > d_{max} > 10$	small column	medium block parallelepiped	decimetric cube	medium slab	medium plate
$d_{max} < 10$	pencil	small block parallelepiped	centimetric cube	small slab	small plate

Another characterization into *block types* has been presented by Dearman (1991), based on a description by Matula and Holzer (1978) as shown in Table-3 and Fig. 3.

TABLE - 3 BLOCK TYPES AND JOINTING CHARACTERISTICS (Dearman, 1991)

Type of block	**Jointing characteristics**
Polyhedral blocks	Irregular jointing without arrangement into distinct sets, and of small joints.
Tabular blocks	One dominant set of parallel joints, for example bedding planes, with other non-persistent joints; thickness of blocks much less than length or width.
Prismatic blocks	Two dominant sets of joints, approximately orthogonal and parallel, with a third irregular set; thickness of blocks much less than length or width.
Equidimensional blocks	Three dominant sets of joints, approximately orthogonal, with occasional irregular joints, giving equidimensional blocks.
	Three (or more) dominant mutually oblique sets of joints, giving oblique-shaped, equidimensional blocks.

Sen and Eissa (1991) has given the following, simpler characterization of block types:

Prismatic block:	The three dimensions of these blocks are individually significant in their definitions.
Platy blocks :	These are similar to slabs where two of the three dimensions are relatively larger than the third dimension.
Bar blocks :	Only one dimension is significant. This division has earlier also been applied by Burton (1965).

However, regular geometric shapes as given above are the exception rather than the rule since the joints in any one set are seldom consistently parallel (ISRM, 1978). Jointing in sedimentary and plutonic rocks usually produces the most regular block shapes. Block size delineated by the joint planes is a volumetric expression for jointing density. Block size is determined by the joint spacings and the number of joint sets - partly also by the joint length. Individual or random discontinuities may further influence the block size.

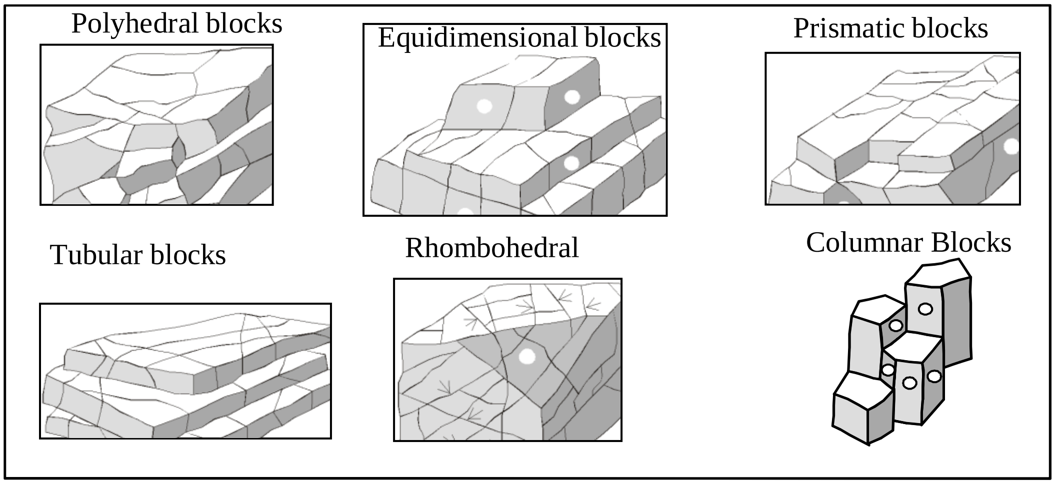


FIG. 3 VARIOUS TYPES OF JOINTING PATTERN EXPRESSED AS BLOCK SHAPE
(numbers refer to various joint sets)
(Dearman, 1991, based on data from Matula and Holzer, 1978)

ANALYSIS OF BEDDED LAYER MODELS

Case I: A shale layer is located between two layers of limestone, representing the condition in which a soft layer is present in a harder rock bench column (Fig. 4). This condition could cause severe violence and poor fragmentation, by almost instantaneous release of the explosive energy at the soft layer region. Therefore, the soft materials are thrown to a significant distance creating fly rock. Finite element analysis indicates the same behavior. In field practice, stemming across soft layers or mud seams is essential to obtain good blasting results.

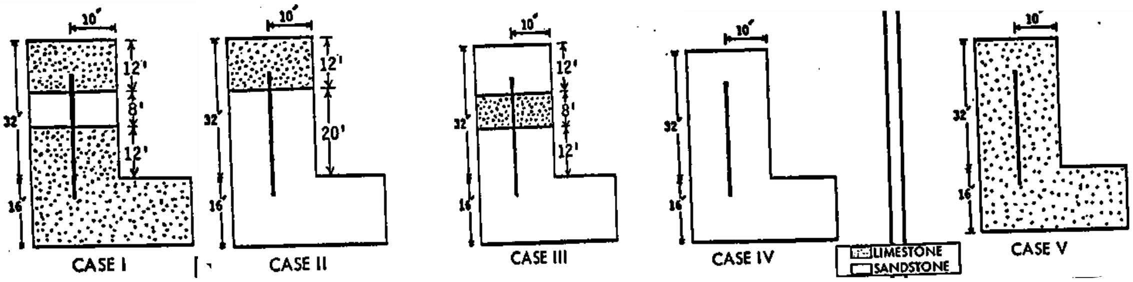


FIG. 4 DIFFERENT COMBINATIONS OF HARD& SOFT LAYERED STRATA

Case II: A limestone layer comprising the collar region of shale rock bench represents the condition of a hard layer (cap rock) at the collar region of soft bench column. In this condition there is potential for large boulders or for rock overhanging the face in the collar region. The loss of confinement and energy at the softer region of the bench column is the cause of the problem. In order to overcome the problems in this condition, a re-distribution of explosive energy along the borehole wall is required. More energy at the bench collar region could be obtained by using satellite charges to break the rock at the collar, and a lower powder factor could be obtained along the softer layer by increasing the burden distance to provide adequate confinement to control air blast and fly rock.

Case III: A limestone layer is located between two shale layers representing the condition where a hard layer is present in a softer rock bench column. In order to correct the problem of coarse fragmentation in hard layers, boosters may be used to intensify the explosive reaction and input more energy into the hard layer.

Case IV and V: The bench columns consist of homogeneous layers of sandstone and limestone respectively. Since the limestone is a harder rock than sandstone, less rock movement is expected at the free face. The finite element model shows burden displacements of 6.7 feet for case V and 10.1 feet for case IV, as shown in the deformed geometry plots.

Five different three dimensional finite element models were used to analyse the effect of rock properties and bedding on burden displacement (Fig. 5). Three models had non-homogeneous burden columns and the other two were homogeneous. Burden displacement was shown to be larger at the soft layer regions as it was expected compared to hard rock regions.

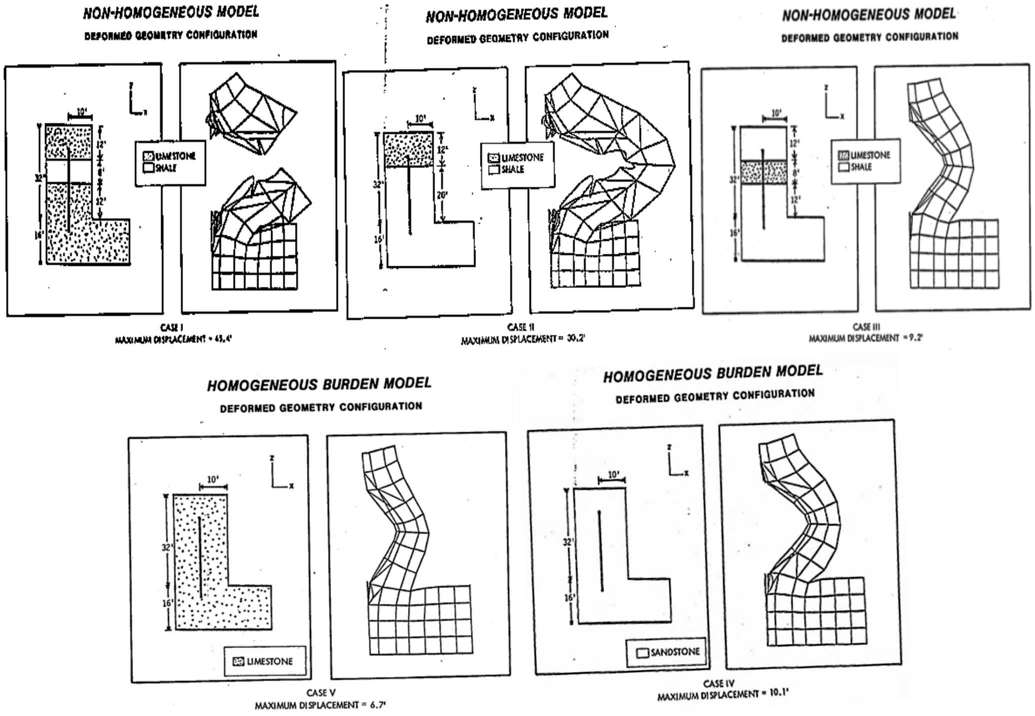


FIG. 5 BEHAVIOUR OF BENCH DUE TO BEAM BENDING MECHANISM IN THE PRESENCE OF SOFT BANDS IN BENCH

The results obtained from finite element modelling based on displacement compare well with field observation. The results confirm the hypothesis that rock breaks as a result of bending of the burden rock under stresses from the explosive gas pressure which is described by the flexural failure theory.

INVESTIGATIONS

The experiments for evaluating the influence of joint orientation were conducted in three stages with joints running parallel, perpendicular and angular to the face. In each set, studies were conducted with different joint orientation angles. Tests at each orientation angle were performed with two burdens, 20 mm and 25 mm in models with joints running parallel and perpendicular to face. Only 25 mm burden was used in models with joints running angular to the face. Forty eight models were blasted (Figs. 6, 7, 8 and 9).

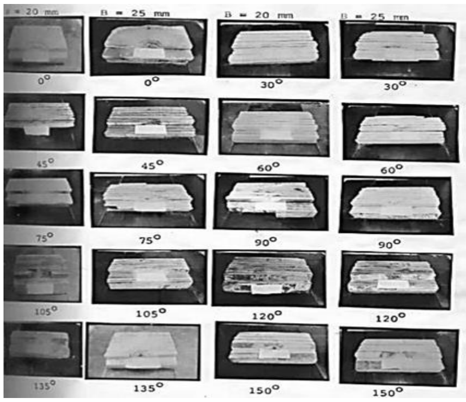


FIG. 6 MODELS WITH JOINTS RUNNING PARALLEL TO THE FACE AFTER BLASTING

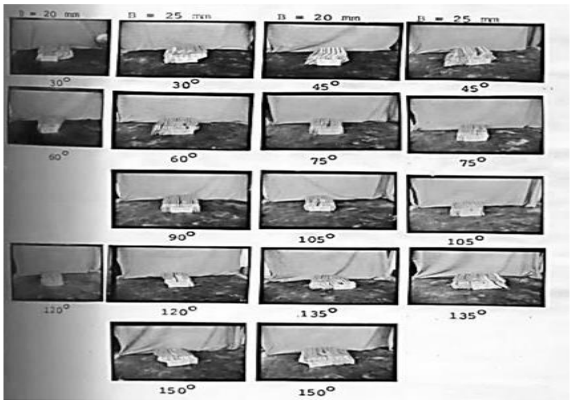


FIG. 7 MODELS WITH JOINTS RUNNING PERPENDICULAR TO THE FACE AFTER BLASTING

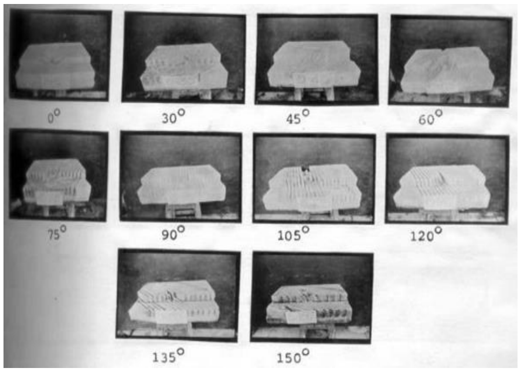


FIG. 8 MODELS WITH JOINTS RUNNING ANGULAR TO THE FACE AFTER BLASTING

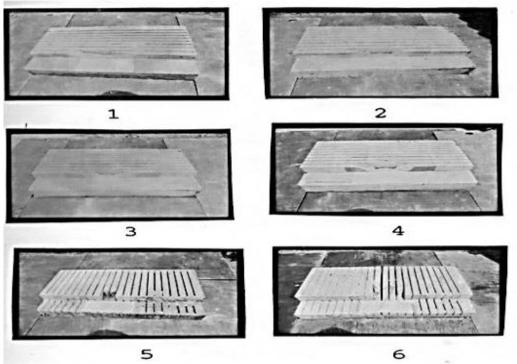


FIG. 9 JOINTED MODELS WITH DOUBLE HOLES AFTER BLASTING

Results of the blasts were analysed in terms of Average Fragment Size, Mass of fragments produced, New-Surface Area created and Mass Surface Area obtained from the blast. Significance tests were conducted to assess the influence of various parameters. It was concluded from studies that the joints were having highest influence on blast results.

FIELD OBSERVATIONS

The following conditions are quite common in the field in the presence of structural discontinuities (Fig. 10). Fig. 11 depicts the escape of gaseous energy through weak planes in the bench as shot by high speed video camera. Results are poor fragmentation, noise and fly rock.

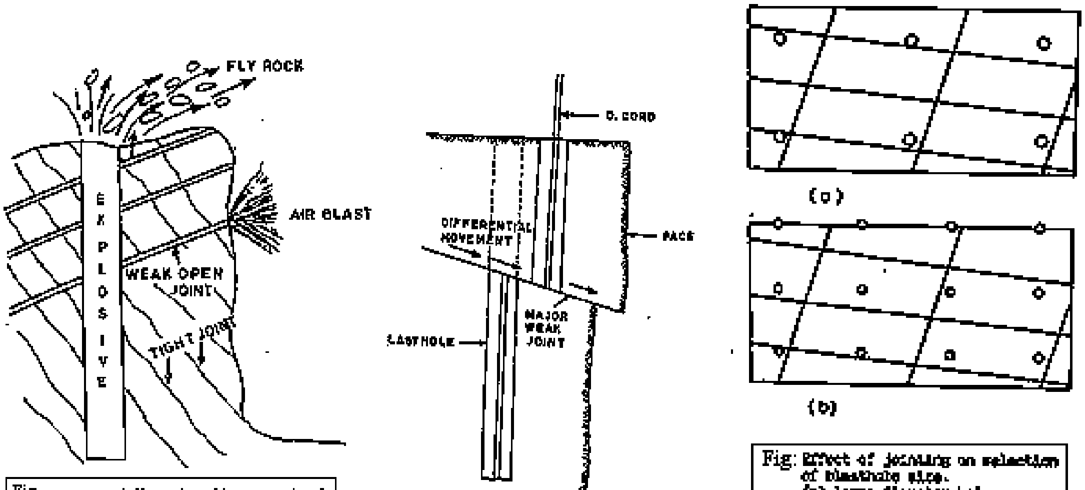


Fig Air blast and fly rock problems associated with jointed rock mass.

Fig Blasthole cutoff caused by differential movement of the beds (Dick et al., 1983).

Fig: Effect of jointing on selection of blasthole size.
(a) large diameter holes
(b) small diameter holes

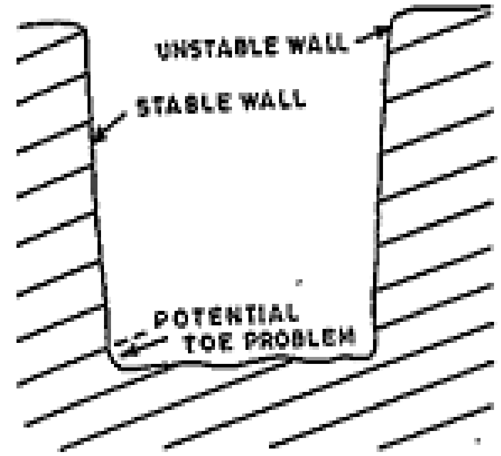
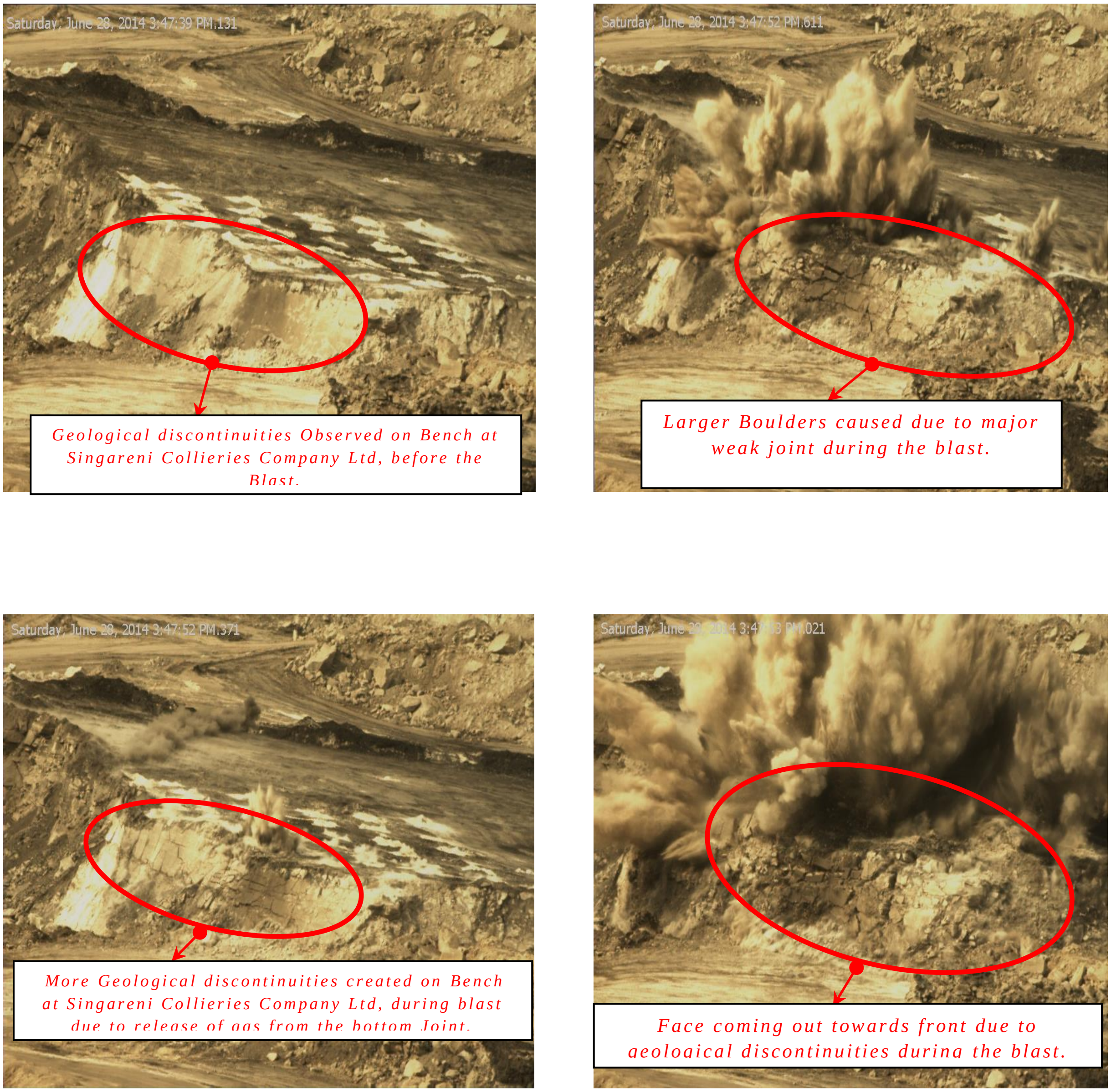


Fig Effect of dip of jointing on blasting.

FIG. 10 EFFECT OF STRUCTURAL DISCONTINUITIES



Geological discontinuities Observed on Bench at Singareni Collieries Company Ltd, before the Blast.

Larger Boulders caused due to major weak joint during the blast.

More Geological discontinuities created on Bench at Singareni Collieries Company Ltd, during blast due to release of gas from the bottom Joint.

Face coming out towards front due to geological discontinuities during the blast.

FIG. 11 ESCAPE OF GASEOUS ENERGY FROM THE BENCH LEADING TO POOR BLAST

CASE STUDY

Field investigations were carried out in a limestone mine in Southern India. The limestone formation is a heavily jointed rock mass and the mine has been developed in benching method. Fig. 12 shows view of the limestone mine where the studies was carried out. Generally 115mm diameter blastholes are drilled for 8m height benches with 4m burden and 5m spacing. Each blasthole is charged with around 55kg of explosives and initiated with shock tube detonators. After the blast, muck pile images were taken for fragmentation analysis using WipFrag software (Fig. 13). In total, nine production blasts were monitored in the field which were conducted with different blast patterns and charge configuration. The same blasts were simulated using JKSim Blast software, to assess the energy distribution. The bench rock formation images were taken and analysed using SIROVISION^{TM} to assess the characteristics of joint features.

The bench face was found to have a significant number of joints. The average joint spacing was determined for the benches where the blasts were conducted. The mean joint spacing is given in Table-4. The product of the vertical and horizontal joint spacing is called as meshing area. In practice, the meshing area is the area of a mesh formed due to the intersection of the horizontal and vertical joints much like a chequered square in a chess board, which influences fragmentation to a great extent.

FIG. 12 VIEW OF TADIPATRI LIMESTONE MINE

FIG. 13 CALIBRATOR FOR FRAGMENTATION ASSESSMENT USING WIPFRAG

TABLE - 4 JOINT SPACING AND FRAGMENTATION INFORMATION FOR BLASTS

Blast	**Vertical Discontinuity Spacing (m)**	**Horizontal Discontinuity Spacing (m)**	**Meshing Area (m^2)**	**K_{25} (mm)**	**K_{50} (mm)**	**K_{75} (mm)**
1	0.499	0.401	0.200	39.001	143.308*	421.815
2	1.337	0.078	0.104	45.776	117.842	451.431
3	3.664	0.070	0.260	54.000	306.531	715.257
4	0.575	0.348	0.340	36.371	189.564*	429.952
5	2.002	0.075	0.151	30.304	131.266	395.607
6	2.484	0.075	0.187	32.061	181.157	650.531
7	2.643	0.073	0.193	39.11	277.584	501.443
8	0.778	0.081	0.063	20.313	92.112	377.302
9	2.774	0.071	0.197	40.774	292.495	625.153

***** These blasts were carried out using a charge per hole of 96 kg/hole unlike the other blasts which had 55 kg/hole, due to which they have not been considered for the regression analysis.

Figs. 14 to 17 detail the different SiroJoint outputs for a typical bench. Fig. 5 shows the traced lines denoting horizontal and vertical joints on the 3D image of a typical bench face. The horizontal joints have been marked by green traces while the vertical joints have been marked by red traces. Figs. 4 and 5 denote the histogram of the horizontal and vertical spacing respectively, giving the average discontinuity spacing and standard deviation on the top-centre of the graph. The x-axis shows the set spacing in metres and y-axis shows the number of joints. Fig. 6 gives the spatial orientation of the joint sets in a 3D frame of reference. This feature is made useful by the application of the Georeferencing option where the actual spatial coordinates in the form of latitude, longitude and reduced level can be added. It shows the use of the software in analysing the horizontal and vertical joint, which intersect to form a mesh, constituting the meshing area.

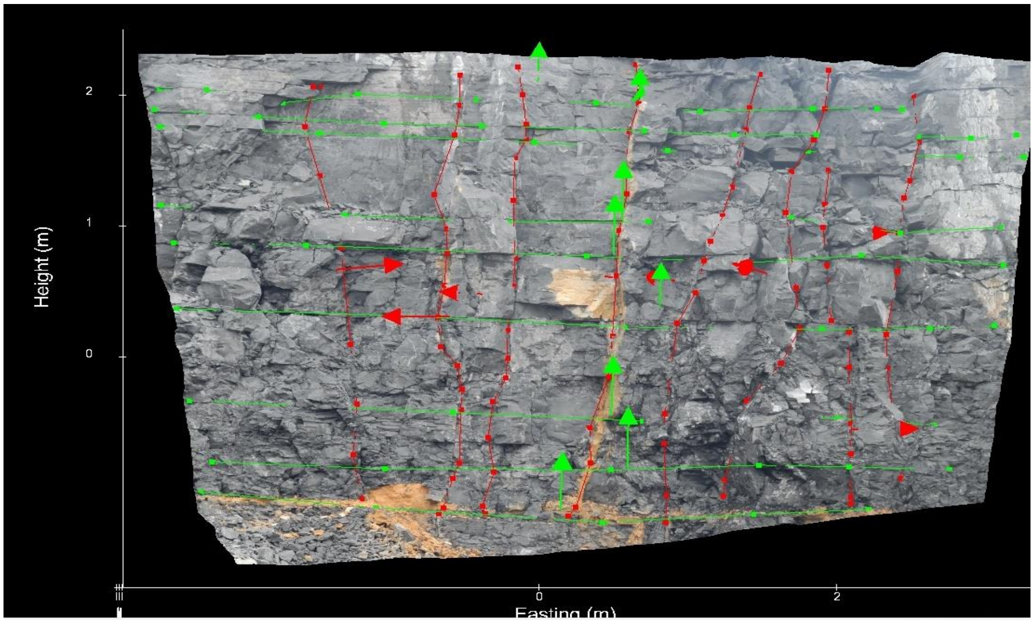


FIG. 14 HORIZONTAL (GREEN) AND VERTICAL (RED) TRACES OF JOINTS ON 3D IMAGE OF BENCH 1

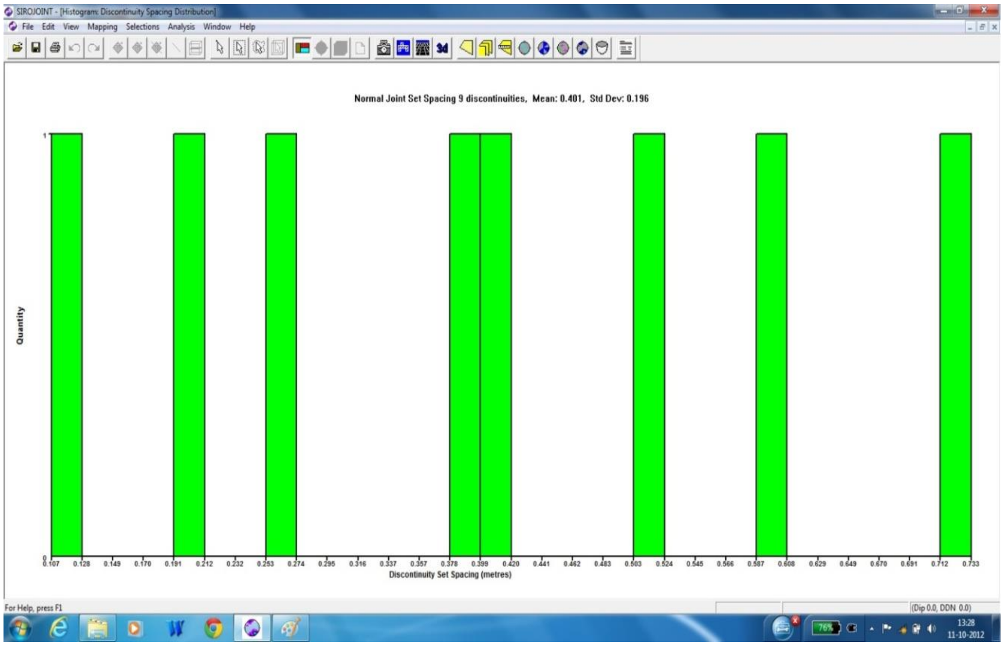


FIG. 15 HORIZONTAL JOINT SPACING GENERATED BY SIROJOINT FOR BENCH 1

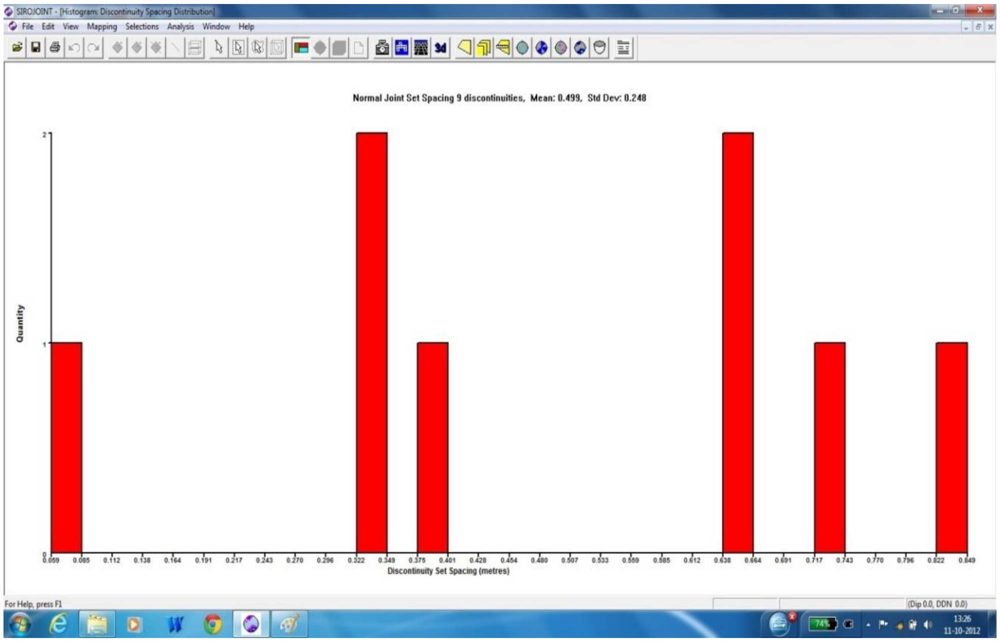


FIG. 16 VERTICAL JOINT SPACING GENERATED BY SIROJOINT FOR BENCH 1

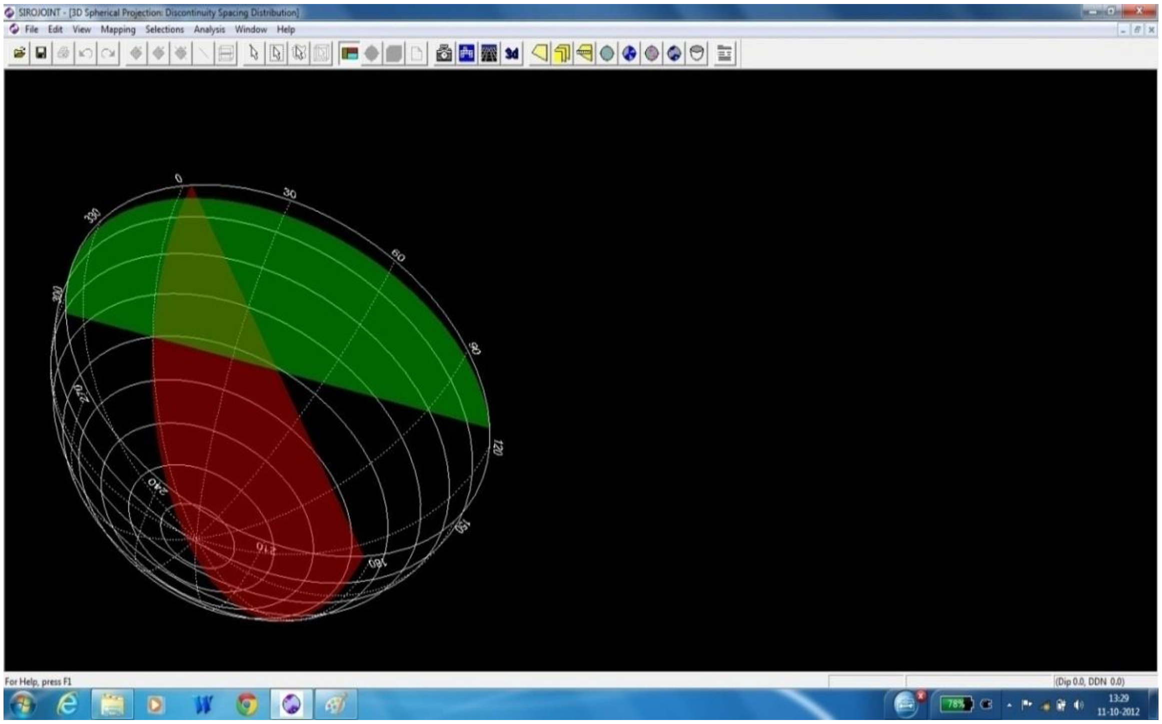


FIG. 17 3D PLOT OF JOINTS IN BENCH 1

The meshing area has been used to correlate the joint spacing to the fragmentation of the blasts. The images of fragmentation of all the blasts were assessed systematically, layer by layer as the muck pile was cleared by the shovel. Table-4 summarizes the average fragment size (K_{50}) values of the blasts and Fig. 18 shows the result of the regression between meshing area and mean fragment size.

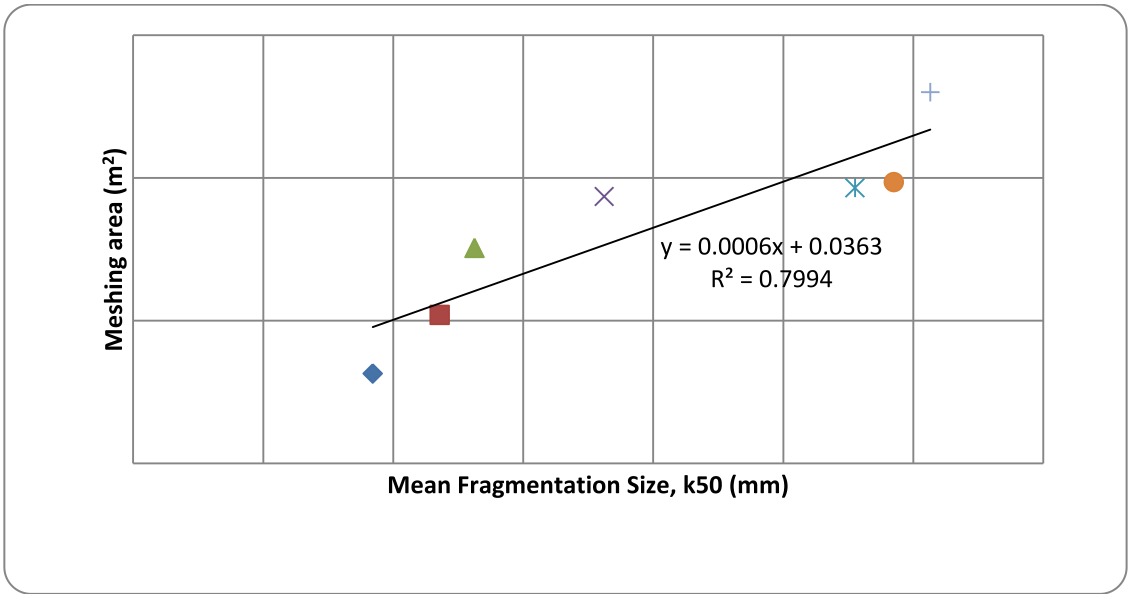


FIG. 18 MESHING AREA VS MEAN FRAGMENTATION

JKSim Blast software used to simulate the blast with actual field parameters and simulate the blast to obtain energy distribution around the blastholes. Figs. 19 through 24 show the output where JKSim Blast was used for the estimation of the energy contours. The contours were produced in vertical slices from the surface (0 m) to a depth of 10 m. Fig. 25 is a screenshot of the legends used for the colours of the energy contours. In Fig. 19 shows the simulation of the blast at 0m depth i.e. the surface of the blast, which is marginal as compared to energy at deeper levels of the blast due to the stemming. Similarly the Figs. 20, to 24 represent the energy emanated by the blast at lower depths along the blast at every 2m intervals respectively. At each depth, a representative area of the given demarked simulated area and a quantitative number which denotes the amount of area which lies in a given range is obtained. Since the range can be specified by the user, the software can depict the energy released. Now this result will give a pristine idea about the use and release of energy due to the blast. it can be seen that at a depth of -10 m, the blast releases about 5MJ/m^3 in blast 1 for 2.81% of the total area simulated. In this manner, a fair idea of the energy released by the blast can be concluded based on the use of this blast simulation. Table-5 shows a comparison of energy distribution at 8m and 10m depth of blastholes.

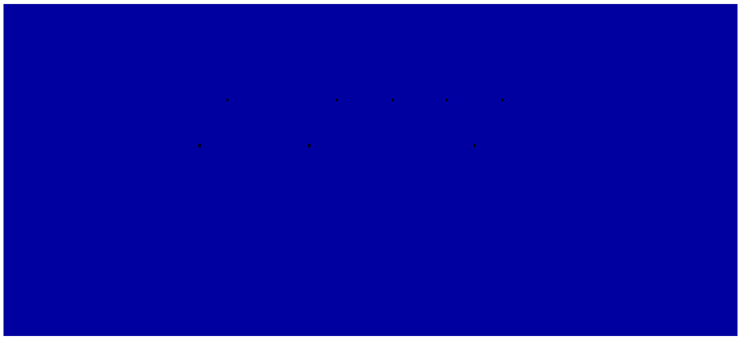


FIG. 19 BLAST ENERGY DISTRIBUTION AT 0m (Surface)

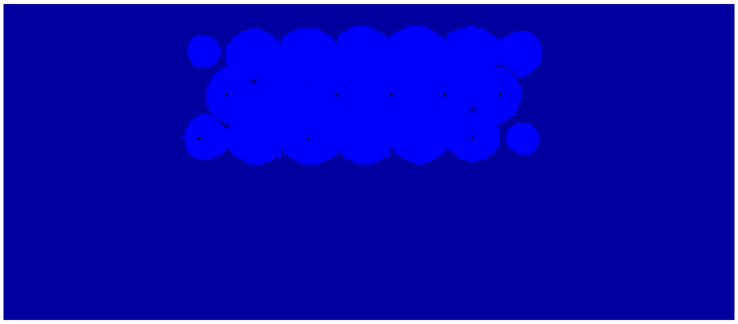


FIG. 20 BLAST ENERGY DISTRIBUTION AT 2m

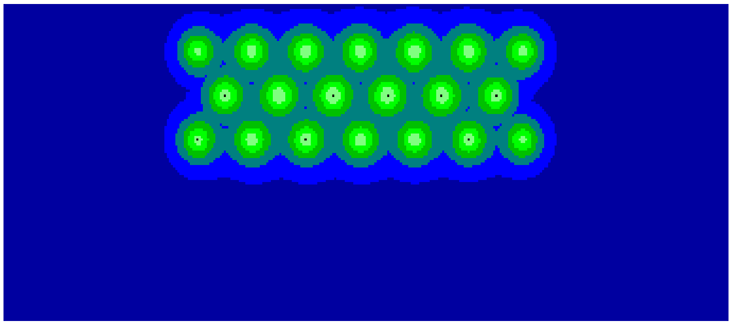


FIG. 21 BLAST ENERGY DISTRIBUTION AT 4m

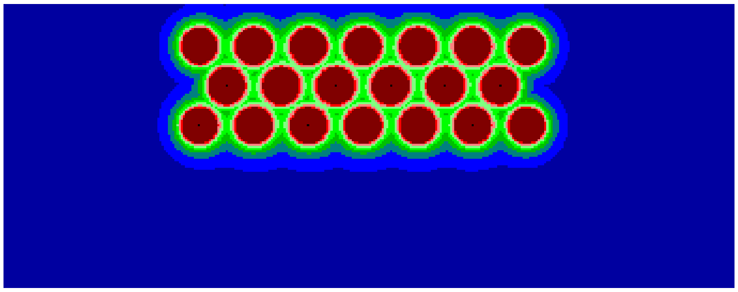


FIG. 22 BLAST ENERGY DISTRIBUTION AT 6m

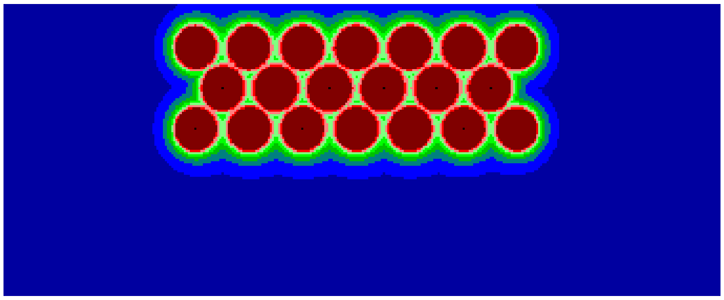


FIG. 23 BLAST ENERGY DISTRIBUTION AT 8m

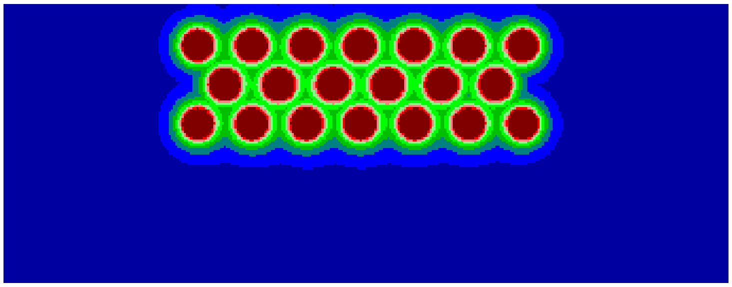
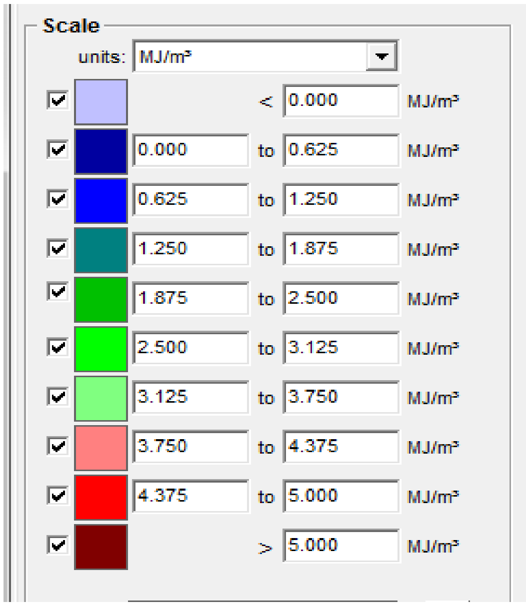


FIG. 24 BLAST ENERGY DISTRIBUTION AT 10m (Hole Bottom)



Scale

units: MJ/m^3

☑	🟪		<	0.000	MJ/m^3
☑	🟦	0.000	to	0.625	MJ/m^3
☑	🟦	0.625	to	1.250	MJ/m^3
☑	🟦	1.250	to	1.875	MJ/m^3
☑	🟩	1.875	to	2.500	MJ/m^3
☑	🟩	2.500	to	3.125	MJ/m^3
☑	🟩	3.125	to	3.750	MJ/m^3
☑	🟥	3.750	to	4.375	MJ/m^3
☑	🟥	4.375	to	5.000	MJ/m^3
☑	🟫		>	5.000	MJ/m^3

FIG. 25 SCREENSHOT OF SCALE USED IN JKSIM BLAST

Table-5 gives an indication of the use of the software JKSim Blast and the importance of energy assessment in blast design. The table represent the amount of area shown in the figures 10 through 15, that this range of energy covers, i.e. a value of 2.3 will mean that at a depth of 10 meters below the blast hole, the energy in the range of 4.375 to 5 MJ/m^3 , is present or represents 2.3 % of the total area of simulation of the blast. Hence more the percentage of covered area more is the energy of the blast in that particular energy range. The information for the 10m slice and 8 m slice have been presented. The blast has to be analysed in sections; therefore the energy of the blast will have to be analysed in sections of the blast, i.e. 10m below the surface or 8m below the surface of the blast. Fig. 26 shows the correlation between the energy of the blastholes with the K_{50} value. It can be seen that there is a very good correlation exists between the energy and the fragmentation, as the percentage of area increases the K_{50} value decreases. Aberrations are seen in blast 1 and 4 since the charge per hole is almost double as compared to the other blasts. Hence they have not been considered for making the regression analysis.

TABLE – 5 ENERGY DISTRIBUTION AT DIFFERENT DEPTH OF BLASTHOLES ESTIMATED USING JKSIM BLAST

Blast No.	**% Area in 8m slice**		**% Area in 10m slice**		**K_{50} (mm)**	**Charge per hole (kg)**
	Energy between 4.375 - 5 (MJ/m^3)	**Energy > 5 (MJ/m^3)**	**Energy between 4.375 - 5 (MJ/m^3)**	**Energy > 5 (MJ/m^3)**		
1	2.71	14.77	2.11	8.68	143.3	95
2	8.34	14.62	2.38	9.07	117.842	55
3	2.1	0.23	0	0	306.53	55
4	2.56	14.36	3.11	9.54	189.56	96

5	6.34	12.34	1.71	9.25	131.26	55
6	2.58	11.67	1.15	6.29	181.15	55
7	2.71	8.62	0.17	2.16	277.58	55
8	4.64	17.51	6.8	12.4	92.11	55
9	2.60	8.12	0.15	1.23	292.495	55

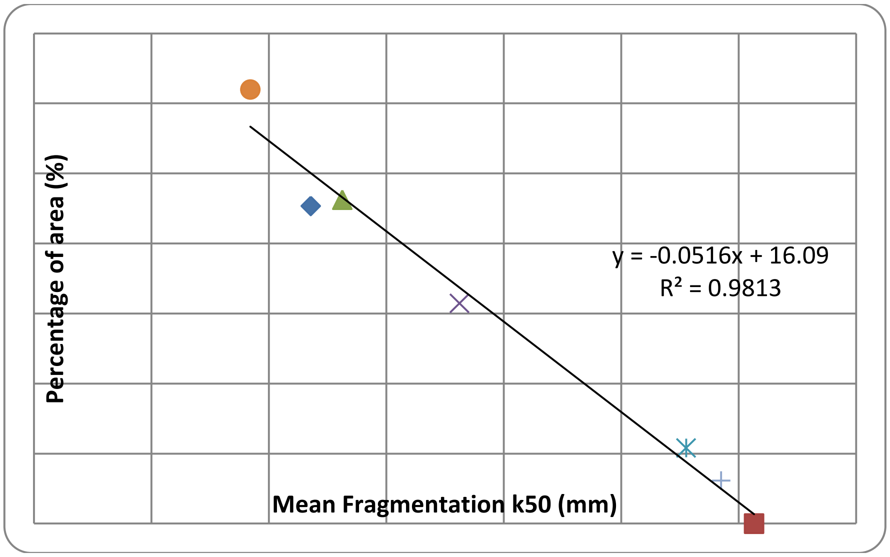


FIG. 26 PERCENTAGE OF AREA WITH ENERGY GREATER THAN 5 MJ/m^3 VS.

MEAN FRAGMENT SIZE

The results intensify the use of the given methods in blast assessment. The use of JKSim Blast software gives an output of the energy of a given blast at specific points. The software however does not include the inclusion of joints or other structural discontinuities into the software which will shorten the bridge between the simulation and the actual blast results. Hence the use of Sirovision in this venture will turn out to be more useful. Along with the energy produced in a given blast, the mapping of the joints will provide the blasting engineer with an idea of the bench and the parameters to vary to increase the efficiency of the blast.

Sirovision will give a comprehensive view of the vertical and horizontal spacing of the joints. This can be combined to form the meshing area which will have a significant effect on the blast as they compose the planes of weaknesses. The product of the given horizontal and vertical joints will give us the meshing area, and higher area will result in higher K_{50} value as shown in Table-4.

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CONCLUSIONS

- Geology plays a very important role in blasting process.
- Rock fragmentation mechanisms get altered, due to inhibition of radial cracking and reflection breakage mechanisms.
- Presence of weak planes leads to escape of gaseous energy resulting in noise, fly rock coupled with poor fragmentation.
- Survey of the benches is very essential for the blast design.

- There is very good correlation between number of joint sets and their frequency and the fragmentation resulting from the blasts.
- Tools like SIROVISION, JKSimBlast and fragmentation assessment softwares become quite useful in predicting and assessing the blast results.

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