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Fragalyst 3.0: An indigenous fragmentation assessment tool based on digital image analysis – application and analysis

Fragalyst 3.0 is an advanced version of the Fragalyst 2.0 developed indigenously by CIMFR and Wavelet Group Pune. The software has multiple functions where the digital images of blasted fragments can be analysed for size distributions (BBSD) and the in situ block size distribution (IBSD) can also be determined using the joint frequencies in a blast face. The software then uses the Bond's Index to determine the explosive energy utilisation in a blast. Initially an image of the face is to be imported and joints determined by using a scanline method which in turn determines the IBSD. Once blast is carried out on the same face sufficient number of images (at least 15) need to be imported in the software and analysed for fragmentation distribution. Several options of image enhancement, resize and crop are also available along with a large combination of threshold parameters which makes edge detection easy. The detected edges of fragments can be edited using advanced tools. The analysis of all the individual images is then called for a merged analysis of the blasted fragment size distribution (BBSD). A fines correction option is now available for correcting the BBSD for fines. The area between the BBSD and IBSD curves determines the explosive energy utilised in the blast. The software results have been compared to the results obtained with imported software and results are conforming. The software has been tested at number of sites in India and significant changes in productivity have been reported. There are some advanced features included in the software such as shape factor, spherocity and other distributions of blasted fragments, distance measurements and angle calculations which can be useful to an inquisitive researcher. The paper details the capabilities of Fragalyst 3.0 along with few applications and respective analysis.

Introduction

The size distribution of fragments obtained in a blast is called as fragmentation. The mean size and the uniformity of the fragmentation can be visualised in terms of R-R distribution whereon the different sizes of fragmentation can be obtained. Fragmentation is an essential component in opencast mines that determines the performance of the loading equipment in particular and hauling equipment in general. The size distribution can be determined in a host of ways which include sieve analysis, boulder count and image analysis techniques. Sieve analysis is by far the most advantageous and accurate method but is not feasible in case of blasts as the amount of muck generated is too large. Boulder count is biased to the oversize only. Hence we are at present restricted to the method of image analysis only which in turn can be called as digital image analysis of blast fragmentation.

There are host of software(s) available in the market which is used for the purpose of blast fragmentation assessment. Indigenously software Fragalyst 3.0 was developed by CIMFR (earlier CMRI) in collaboration with the Wavelet Group of Pune.

The journey of the development of this software started some 15 years back with the Fragalyst 1.0 which was further enhanced with multiple capabilities in its Version 2.0. Version 2.0 included only fragmentation analysis along with some calculations of academic interest.

However, in 2006 the software was updated to Fragalyst 3.0 wherein in addition to fragmentation analysis that yields blasted fragment size distribution (BBSD), scanline – manual or image based – survey of the face is possible to be conducted to provide a distribution of in situ block size(s) distribution (IBSD) of the rock mass being blasted. A comparative analysis of the IBSD and BBSD is possible in Fragalyst 3.0 in a merged form which gives an idea of the energy utilisation in a blast.

Features of Fragalyst 3.0

There are a lot of features available in the Version 3.0 of the software. Fig.1 explains the flow of the events and capabilities of the software. Calibration of image imported can be done for normal and wide angle images. Image enhancement features like brightness and contrast, sharpness, crop and negate options are available. There are around 1000 combinations of the edge detection parameters to choose

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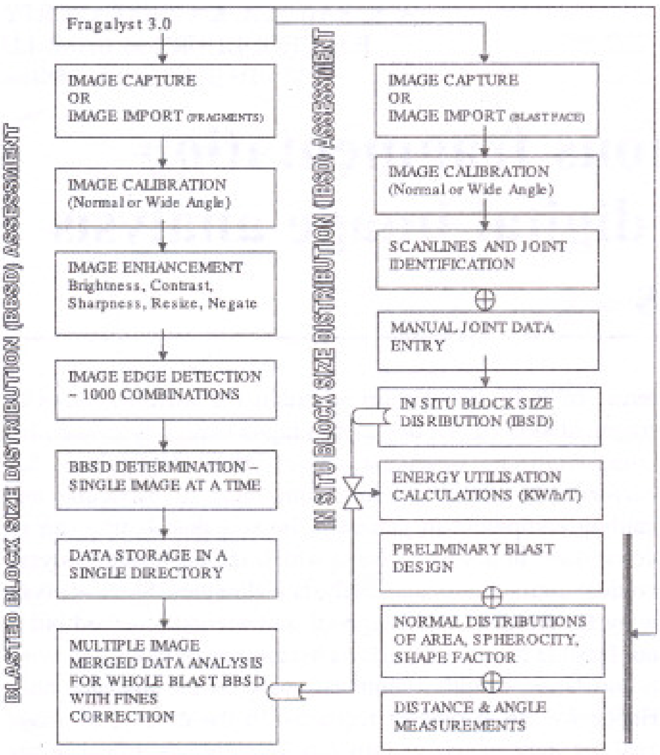

Fig.1: Capabilities of the Fragalyst Version 3.0 (Released 2006)

from so that excellent networks for segmentation and fragment delineation are obtained. This feature is expected to be automatic in Version 4.0 of the software. Excellent tools for edit network are available where host of operations can be performed to get proper fragments as observed in the original image including ignoring certain portions which actually are not fragments. The in situ block size distribution can be attained manually and entered into the software manually or based on image of a face the scanlines can be drawn to identify the joint spacing and joint lengths. There are some other additional features as describe in the Fig.1.

Some visual screen obtained while analysis in the software are shown in Fig.2 (a-d).

Case study

In order to assess the fragmentation of overburden blasting in Opencast II of the Prakasham Khani (PK OC-II), Singareni Collieries Co. Ltd. (SCCL), a study was undertaken by the CIMFR Regional Centre, Nagpur applying digital image analysis technique using Fragalyst 3.0 software. The present paper describes various observations and analysis of the study.

PK OC-II is a mine under Manuguru area adjacent to Manuguru village which is a mandal head quarter in Khammam district of Andhra Pradesh. The mine is situated nearly 65 km away from Kothagudem where the SCCL headquarter is positioned. The mine is designed to produce nearly 2.75 Mt of coal per annum. The coal seam thickness varies from 6.12 m to 31.19 m having a gradient of 1:6.5. The average stripping ratio of the mine is 1:3.68. The present depth of the mine is 135 m and the planned maximum depth is 155 m. The overburden constituted by sandstone and soil is being handled by 6 shovels each of 10 m^3 bucket capacity. Those shovels are named as Godavari, Krishna, Kaveri, Yamuna, Ganga and Tungabhadra. The overburden drilling is done by 250 mm diameter drill machines. The dumper capacity is 85t. The average capacity utilisation of the shovels and dumpers are reported as 76 per cent. An amount of nearly 3700 t of site mixed emulsion explosives (SME) have been consumed in the past few years for excavation of more than 10 Mm^3 of overburden with an average specific charge of 0.36 kg/m^3. Overburden removal in a portion of the mine was being carried out by contractor (IDL) using 150 mm diameter drill, 12 t dumper and 2.7 and 3 m^3 shovels.

Field investigations

1. Rock mass properties
   a. Volumetric joint count was made and the RQD of the rock was worked out in this manner used standard equation.
   b. In situ block size was determined with the help of Fragalyst 3.0
2. Blast design

Blast design data of 22 blasts were collected in the initial phase and around 120 blast data was obtained in the 2nd confirmatory phase. Some relevant details of the blast design are reproduced over here. Table 1 provides the average data of the initial study conducted earlier.

Table 2 lists the average and standard deviations of the data obtained in confirmatory blasts and validation studies

3. Determination of fragmentation and other parameters using Fragalyst 3.0
4. Collection of pick consumption data

Analysis

Some basic analysis of the data obtained in 2 phases viz. Phase–I (January-March, 2008) and Phase–II (April-September, 2008). In Phase–I existing blast practice was monitored and no changes were done to the blast design. In Phase–II some changes were made in the blast design particularly, different designs in different rock mass conditions.

Presentation of mean fragment data vis-à-vis optimum and maximum sizes

A graphical presentation of the mean fragment size(s) obtained in all the blasts in Phase–II are given in Fig.5. As can be observed from the figure that most of data is falling in the optimum range (Chakraborty et al. 2002) and almost 95% of the data falls within optimum range (international criterion). There

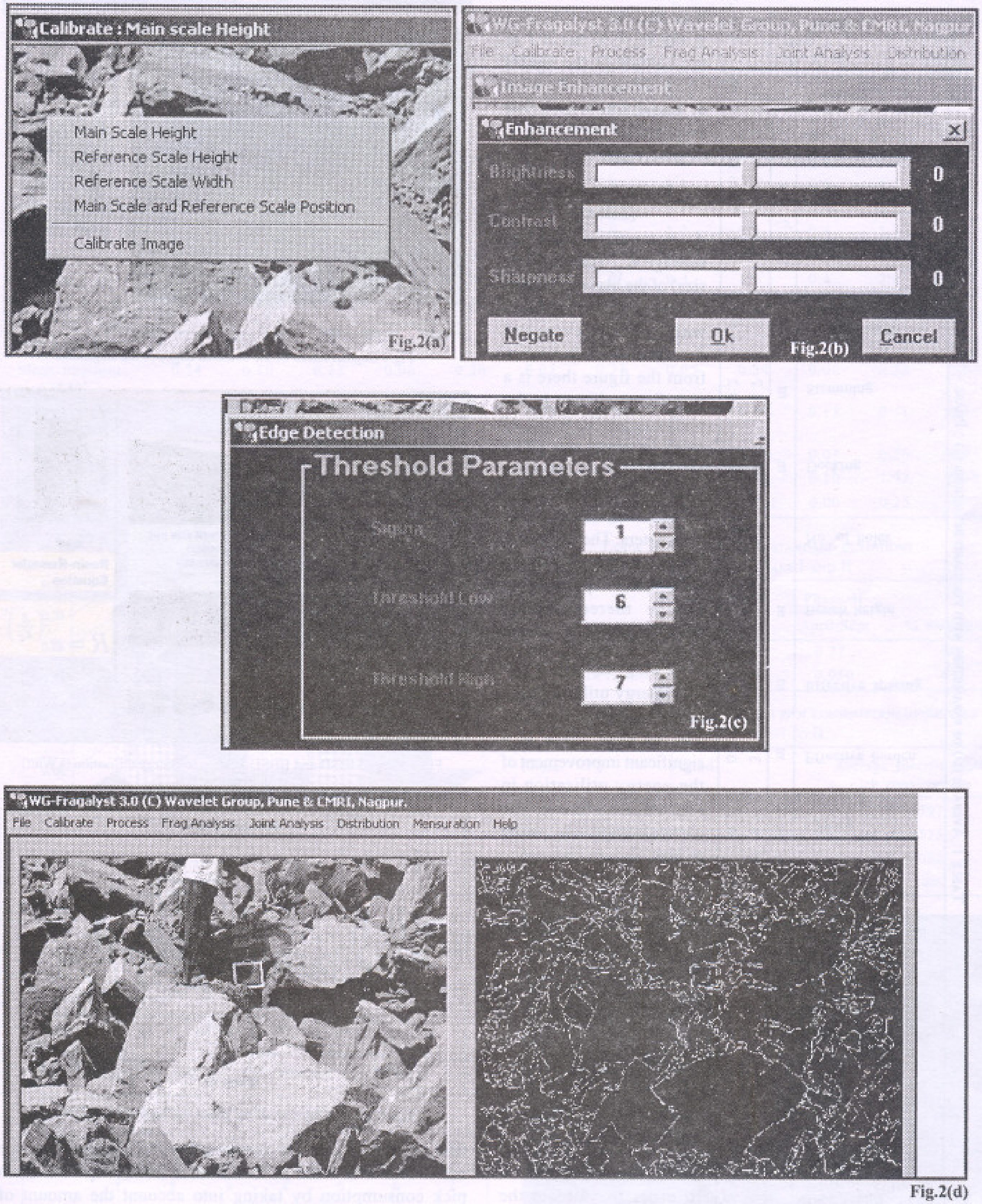

Fig.2 (a): Calibration of the open image, (b): Image enhancing facility, (different options), (c): Threshold parameters for edge detection with (10 x 10 x 10) options (d) Edges of fragments detected automatically after threshold parameters are properly selected

Table 1: Average (μ) of parameters with standard deviations (σ); Phase – I

Parameter	Unit	μ	σ
Rock factor (Kuznetsov, 1973)		9.1	2.2
RQD	%	62.7	7.0
Rock factor (Chakraborty et al., 2002)		10.7	7.5
Hole dia	mm	250.0	0.0
Burden	m	6.7	0.5
Spacing	m	8.7	0.5
Effective burden	m	3.9	0.2
Effective spacing	m	14.6	0.9
Bench height	m	13.4	0.6
No. of holes		18.2	5.5
Decking	m	2.5	0.3
Stemming	m	4.7	0.2
Charge length, m (hole depth-stemming)	m	8.7	0.7
Specific charge	(kg/m^3)	0.4	0.1
Total charge	Kg	4967.5	1396.1
K_{50} (BBSD)	m	0.33	0.09
K_{50}(IBSD)	m	1.4	0.4

is no incidence of the data going beyond the 2/3 of the volume of the bucket size which is considered to be maximum permissible fragment size for the shovel of $10m^3$ capacity.

Reduction in size (BBSD)

A comparison of the average K_{50} (mean block size) of the blasted material has been given in Fig.6 with the relative standard deviations. As is indicative from the figure there is a significant change in the performance in terms of mean fragment size and a consistency in the data obtained as shown the values of the said parameters. The values are presented in Table 3 along with the percentage change thereof in the BBSD(K_{50})

Energy utilisation

The energy utilised in the blasts is given in Fig.7. As can be seen there is a significant improvement of the energy utilisation in Phase–II vs. Phase–I. The change is imperative owing to blast design changes.

The energy utilised has fallen by some degree in the months of July and August (month 5 and 6 in Fig.7) due to heavy rains which can be attributed to improper stemming due to watery holes. There is a significant i.e. 33% increase in the energy utilisation in Phase–I and Phase–II.

Pick consumption

In order to validate the results obtained with the use of Fragalyst 3.0, the data of shovel tooth pick consumption was obtained from the mine. This data could be transformed into the specific tooth pick consumption by taking into account the amount of material handled by the shovels in particular months and is given in Table 4 and graphically in Fig.8.

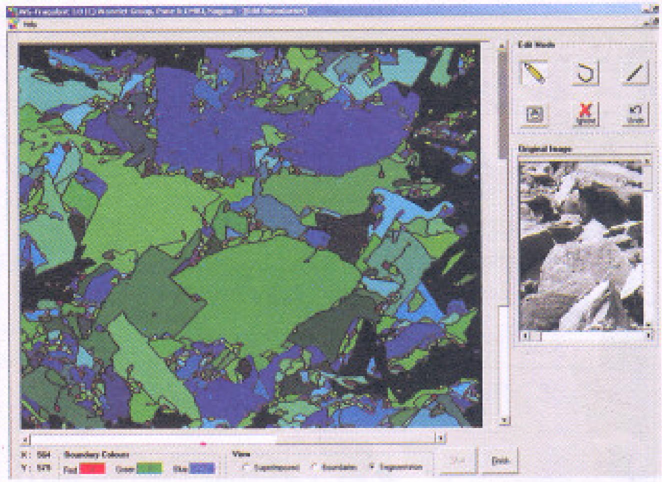

Fig.3 Segmentation of the detected edges of the fragments

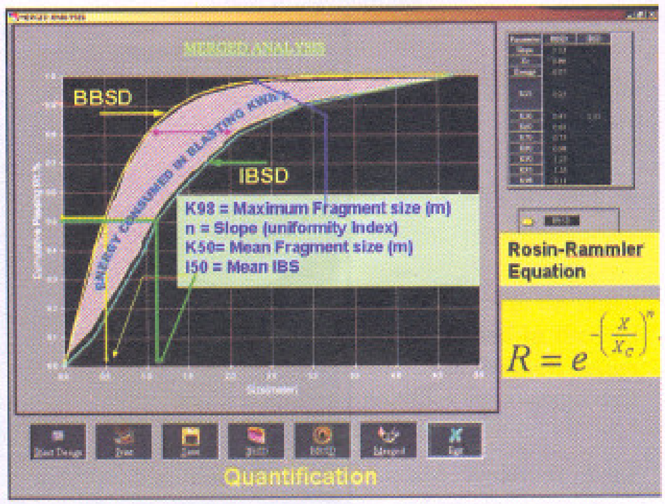

Fig.4 Merged IBSD and BBSD leading to energy utilisation (kWh/t) with Fragalyst 3.0

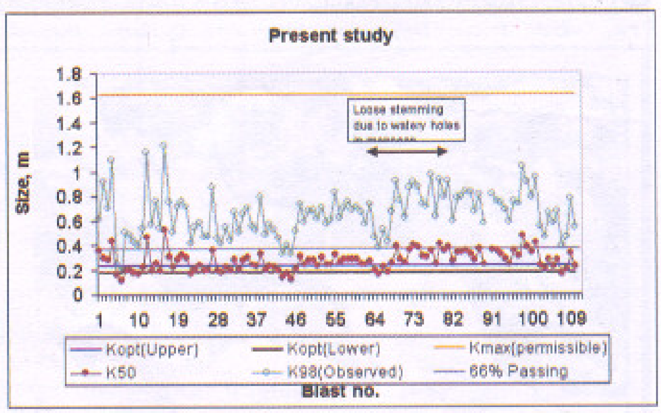

Fig.5 Size fractions of all the blasts in Phase–II, with limits

Table 2: Average and standard deviations of the data; Phase–II

Pre-blast data	April μ	April σ	May μ	May σ	June μ	June σ	July μ	July σ	August μ	August σ	September μ	September σ
Rock type/joint spacing (m)	1.69	0.13	1.37	0.50	1.15	0.38	1.76	0.48	1.71	0.49	1.19	0.15
Number of holes	15	6	20	13	19	8	22	9	19	9	21	10
Hole depth (m)	13.3	1.2	11.9	2.3	12.2	1.2	12.8	1.6	13.1	0.8	13.0	2.8
Burden (m)	5.9	0.8	6.0	0.9	6.1	0.6	5.7	0.6	5.3	0.6	5.2	0.8
Spacing (m)	7.5	1.0	7.2	1.1	7.1	1.0	7.2	0.7	6.5	0.7	6.5	1.1
Charge length (m)	6.6	1.1	5.9	1.5	5.7	0.9	5.9	1.2	6.0	0.4	5.9	1.7
Stemming length (m)	5.1	0.6	4.9	0.4	5.0	0.4	5.1	0.4	5.2	0.2	5.1	0.6
Decking length (m)	1.7	0.6	1.2	0.8	1.5	0.6	1.8	0.3	1.9	0.4	2.0	0.7
Specific charge (Kg/m^3)	0.47	0.16	0.54	0.15	0.50	0.08	0.54	0.10	0.70	0.14	0.70	0.21
Post blast data												
Mean fragment size (K50)	0.24	0.10	0.22	0.06	0.26	0.07	0.31	0.05	0.34	0.06	0.22	0.04
Maximum frag size (K98)	0.61	0.25	0.55	0.16	0.65	0.17	0.77	0.13	0.79	0.13	0.51	0.11
Xc	0.31	0.17	0.27	0.08	0.32	0.08	0.38	0.07	0.41	0.07	0.26	0.05
n	1.90	0.31	1.89	0.06	1.83	0.16	1.90	0.12	2.00	0.10	1.92	0.08
Energy	0.248	0.07	0.253	0.07	0.229	0.04	0.210	0.05	0.201	0.06	0.25	0.07

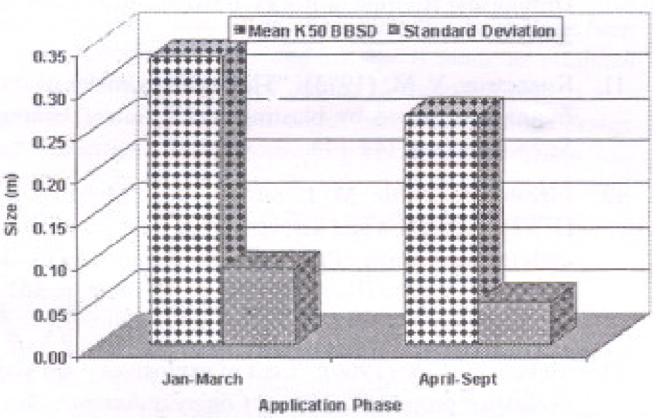

Fig.6 Graphical representation of the change in mean fragment size in two phases

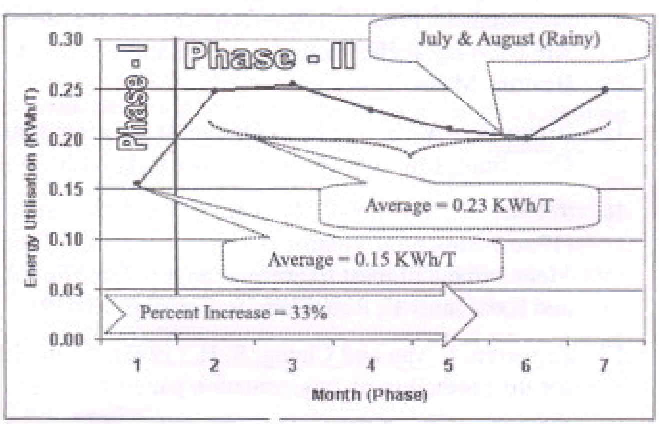

Fig.7 Change in energy utilisation in Phase–I and Phase–II

Table 3: K_{50}, mean and standard deviations compared in Phase I and II

	Phase–I	Phase–II	
	Jan-March	April-Sept	% Reduction
Mean K_{50} BBSD	0.33	0.27	20
Standard Deviation	0.09	0.050	42

Table 4: Change in specific tooth pick consumption of shovels from Phase–I to II

Phase	Period	Average specific tooth pick consumption
I	Jan-March	0.00597
II	April-Sept	0.00515
	Difference in Phase–I and II	0.00082
	Reduction from Phase–II to I	14%

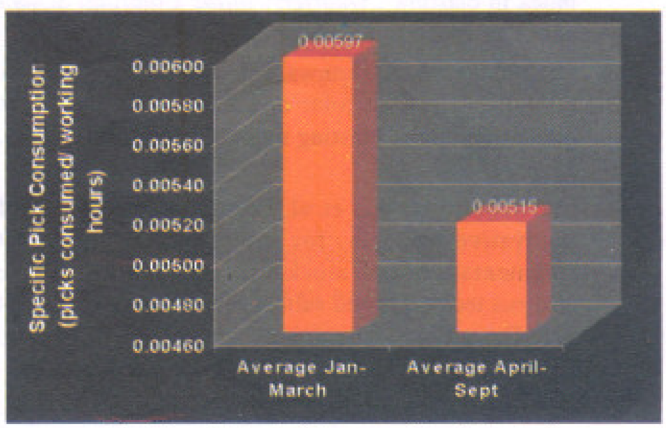

Fig.8: Specific tooth pick consumption of shovels in Phase–I and Phase–II

Future of Fragalyst 3.0

Fragalyst 3.0 will shortly be updated to version 4.0 and will be an excellent tool for image analysis. The most important feature that will be added to the software is "automated networking detection". Several automatic routines will be incorporated to give user the best network and most representative segmentation of an image. There are several other features including better functionality that will be incorporated in Version 4.0 of the software.

Summary and conclusions

Fragalyst 3.0 has been discussed here with all capabilities and features along with a case study of a large Indian coal mine. The data collection and interpretation has been touched to some extent in this paper. The software as demonstrated gives a reason to introspect and analyse the production patterns adopted in a mine, since all relevant data is monitored. Hence there is every chance of analysis, design or redesign or classification of blast designs in varying geo-mining conditions, particularly due to frequent change in the rock mass characteristics. Such systems are definitely an advantage over the old qualitative methods where engineering judgement and application is a distant proposition. With measurement of fragmentation in opencast mines with the help of digital image analysis method, it is possible to monitor and predict the productivity.

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