cmpdi
A Mini Ratna Company

ISSN 0970-7204

खनन विज्ञान
minetech

खण्ड 41, अंक 3 Volume 41, No. 3
जुलाई–सितम्बर 2020 July-Sept. 2020

SPECIAL ISSUE ON "R&D IN COAL SECTOR"

खनन विज्ञान
minetech

खनन, गवेषण एवं सम्बन्धित विषयों का
मुख्य भारतीय त्रैमासिक

सीएमपीडीआई प्रकाशन

वार्षिक शुल्क: ₹ 800 (Handling and postage charges ₹ 50 per copy extra)

A CMPDI PUBLICATION
Inland ₹ 800 (Annually) (Handling & postage charges ₹ 50 per copy extra)
Overseas US $ 200 (including airmail)

For free internal circulation within CIL Subsidiaries

India's premier quarterly journal of mining, exploration and allied subjects

कोड नं. 015 : 8/एमटी
खण्ड : इकतालिस
अंक : तीन
जुलाई–सितंबर, 2020

Code No. 015 : 8/MT
Volume : **FORTY ONE**
Number : **Three**
July-Sept. 2020

प्रकाशक

सेन्ट्रल माइन प्लानिंग एंड डिजाइन इन्स्टीच्यूट लिमिटेड, गोंदवाना प्लेस, काँके रोड, राँची – 834 008

Published by

CENTRAL MINE PLANNING & DESIGN INSTITUTE LIMITED, GONDWANA PLACE, KANKE, ROAD, RANCHI - 834 008

मुद्रक

कैलाश पेपर कन्वर्शन प्रा. लि.,
3rd पार्ट, कोकर इण्डस्ट्रियल एरिया,
राँची - 834001

Printed at

Kailash Paper Conversion Pvt. Ltd.
3rd Part, Kokar Industrial Area,
Ranchi - 834001

Printed October 2020

शेखर सरन
अध्यक्ष–सह–प्रबंध निदेशक

Shekhar Saran
Chairman-cum-Managing Director

सेन्ट्रल माईन प्लानिंग एण्ड डिजाइन इन्सटीच्यूट लिमिटेड
(कोल इण्डिया लिमिटेड की अनुषंगी कम्पनी / भारत सरकार का एक लोक उपक्रम)
गोन्दवाना प्लेस, काँके रोड, राँची –834 008, झारखण्ड (भारत)

Central Mine Planning & Design Institute Limited
(A Subsidiary of Coal India Limited/Govt. of India Public Sector Undertaking)
Gondwana Place , Kanke Road , Ranchi -834 008, Jharkhand (India)

MESSAGE

India's coal sector plays an important role in the country. From an energy security perspective, it is the country's most abundant non-renewable fuel and coal-fired power dominates electricity generation. It also makes an important economic contribution. Coal mining and power generation are two major industries in India and together account for around a tenth of the country's industrial production, and employed around half a million people.

The need for a strong Science and Technology (S&T) base for mining Research and Development (R&D) is well recognized. Research in mining & allied activities are essential prerequisite for generating reliable data and new R&D knowledge relevant to Indian conditions for ensuring sustainable development. The Ministry has taken a number of new initiatives to strengthen scientific research in the area of mining sciences. The Ministry has given clear guidelines for support to Research in Mining & Allied activities to provide renewed scientific impetus to address the emerging mining challenges, broaden the participation of stakeholders, introduce the concept of cost-sharing and make the research in Mines more productive, with an emphasis on outputs and outcomes.

In order to disseminate the research results of successful research Projects amongst the mining community and to seek wider application of research findings, CMPDI has been, for the last few years, bringing out various publications which have been well received by the users. However, this illustrated booklet briefly gives industrial applications and benefits derived from some of the prominent research projects.

It is hoped that this special issue of 'Minetech' will serve its purpose for further and wider application of these scientific findings for benefit of the industry.

I extend my greetings and best wishes to the authors and the officials of CMPDI for their dedication and hard work put in to bring out this publication.

(Shekhar Saran)

Ph: =91-651-2230001 & 2230002, Fax: + 91-651-2230003 E-mail: cmd.cmpdi@coalindia.in

के.के. मिश्रा
निदेशक तकनीकी (अभियंत्रण सेवायें)

K.K. Mishra
Director Technical (Engg. Services)

सेन्ट्रल माईन प्लानिंग एण्ड डिजाइन इन्सटीच्यूट लिमिटेड
(कोल इण्डिया लिमिटेड की अनुषंगी कम्पनी/भारत सरकार का एक लोक उपक्रम)
गोन्दवाना प्लेस, काँके रोड, राँची –834 008, झारखण्ड (भारत)

Central Mine Planning & Design Institute Limited
(A Subsidiary of Coal India Limited/Govt. of India Public Sector Undertaking)
Gondwana Place , Kanke Road , Ranchi -834 008, Jharkhand (India)

MESSAGE

The mining industry typically operates in a cyclic fashion with periods of strong growth followed by inevitable downturns. The industry is currently in the throes of a downturn. In India, coal is the most important energy resource as also the main contributor to the basket of commercial energy of the country. India is the third largest coal producer in the world after China and USA.

I believe, it is right time for mining industry, to be given its long over-due recognition as a core industry as in the case in developed countries such as Australia, Canada and USA. Emphasis on research and development on exploration to continuously augment the resource / reserve base of the country and harness the existing resources through scientific and sustainable mining including beneficiation technologies and focusing on zero waste mining.

The Industry on date is depending upon the foreign sources for most these machines/ equipment while the nation has capability to develop them at own. I understand, quite a large number of these projects have been fruitful and have found commercial application in Coal and lignite Sectors. The findings of these projects have been compiled by CMPDI in this publication.

I am sure that this publication will serve the purpose of disseminating information of these successful research projects, and further the cause of wider application of the findings for the benefit of society at large, and for the Coal & Lignite Sectors, in particular.

(K.K. Mishra)

Ph: =91-651-2230040, Fax: + 91-651-2232143 E-mail: dtes.cmpdi@coalindia.in

रबीन्द्र नाथ झा
निदेशक तकनीकी (आरडी एण्ड टी)

Rabindra Nath Jha
Director Technical (RD & T)

सेन्ट्रल माईन प्लानिंग एण्ड डिजाइन इन्सटीच्यूट लिमिटेड
(कोल इण्डिया लिमिटेड की अनुषंगी कम्पनी/भारत सरकार का एक लोक उपक्रम)
गोन्दवाना प्लेस, काँके रोड, राँची –834 008, झारखण्ड (भारत)

Central Mine Planning & Design Institute Limited
(A Subsidiary of Coal India Limited/Govt. of India Public Sector Undertaking)
Gondwana Place , Kanke Road , Ranchi -834 008, Jharkhand (India)

MESSAGE

Research & Development activities of Ministry of Coal and Coal India Ltd. always thrived in providing thought leadership. The creation of innovative products not only adds new revenue streams but also increases brand visibility. The costs associated with undertaking R&D activities can be surmounted by credibly seeking public sector grants for innovation and development. This also opens up avenues for collaboration and public-private partnerships.

The recent Information and Communication systems (ICT) along with WSN (Wireless Sensor Network) systems for all aspects of mining industry can be widely implemented in opencast and underground mines for reliable monitoring of coal quality, measurement of excavated coal & OB and in many other related activities. R&D is also focused on sustainable development and livelihood generation of project affected people.

In this regard I am extremely happy and proud that at this critical juncture, the S&T Division CMPDI unanimously felt the need of highlighting the issues and concerns for technological upliftment towards harnessing coal present across the country as one collated document.

This handy information would be of immense help to the engineers and researchers in the field of mining and allied subjects and I hope, will serve the purpose of sharpening the focus for future R&D projects in order to benefit the indigenous coal industry and will add the knowledge bank in the area of R&D in coal sector.

I extends my complements to all those, who have made painstaking efforts and contributed for bringing out this special issue of 'Minetech'.

(R. N. Jha)

Ph: =91-651-2230010, Fax: + 91-651-2233066 E-mail: dirrdt.cmpdi@coalindia.in

अनिल कुमार राना
निदेशक तकनीकी (पी एण्ड डी)

Anil Kumar Rana
Director Technical (P & D)

सेन्ट्रल माईन प्लानिंग एण्ड डिजाइन इन्सटीच्यूट लिमिटेड
(कोल इण्डिया लिमिटेड की अनुषंगी कम्पनी/भारत सरकार का एक लोक उपक्रम)
गोन्दवाना प्लेस, काँके रोड, राँची –834 008, झारखण्ड (भारत)

Central Mine Planning & Design Institute Limited
(A Subsidiary of Coal India Limited/Govt. of India Public Sector Undertaking)
Gondwana Place , Kanke Road , Ranchi -834 008, Jharkhand (India)

MESSAGE

Research & Development plays a pivotal role for advancement of any sector & ultimately contributes for boosting the economy. Organised research for overall development of the coal sector started after nationalisation of the coal industry, since 1975.

CMPDI, apart from the activities of Exploration, Planning & Design, Mining related Consultancy, has been acting as a Nodal agency for Ministry of Coal & Coal India Limited for coordination & monitoring of research activities in the coal sector.

In order to disseminate the outcome of successful R&D Projects amongst the mining community and to seek wider application of research findings, CMPDI is bringing out this publication.

It is hoped that this booklet will illustrate the outcome of some successful research projects which can be replicated in the mining industry for further improvement.

(A.K. Rana)

Ph: =91-651-2230030 Fax: + 91-651-2230446 E-mail: dtpnd.cmpdi@coalindia.in

सत्येन्द्र कुमार गोमास्ता
निदेशक तकनीकी (सीआरडी)

Satyendra Kumar Gomasta
Director Technical (CRD)

सेन्ट्रल माईन प्लानिंग एण्ड डिजाइन इन्सटीच्यूट लिमिटेड
(कोल इण्डिया लिमिटेड की अनुषंगी कम्पनी/भारत सरकार का एक लोक उपक्रम)
गोन्दवाना प्लेस, काँके रोड, राँची –834 008, झारखण्ड (भारत)

Central Mine Planning & Design Institute Limited
(A Subsidiary of Coal India Limited/Govt. of India Public Sector Undertaking)
Gondwana Place , Kanke Road , Ranchi -834 008, Jharkhand (India)

MESSAGE

Coal is the most abundant fossil fuel resource in the country. India, currently, stands fifth in terms of total World Coal Resources, whereas it is third from the point of view of identified reserves. With increase in complexities & Depth of Coal Deposits coupled with concern about climate change and strong social expectations, there is an urgent need of introducing innovative exploration and mining technologies. Further, for the sustainability of coal industry, eco-friendly strategies and policies are also to be adopted.

The R&D activities in Coal sector are administered through an apex body namely, Standing Scientific Research Committee (SSRC) with Secretary (Coal) as its Chairman. It is doing wonderful job in bringing the culture of innovation and research bridging the educational institutes with the industry.

Since the launching of 'Coal Science & Technology Plan' by the Government of India in the year 1975, number of S & T projects have been undertaken in the thrust areas of Mining & Exploration, Coal Beneficiation, Coal Utilization and Environment & Ecology. I understand, quite a large number of these projects have been fruitful and have found end uses in Coal and lignite Sectors. The brief of some of the projects have been compiled by CMPDI in this publication. It is hoped that the Publication will prove useful in disseminating information amongst mine planners/designers, research & academic personnel.

I congratulate CMPDI for bringing out this Publication.

S.K. Gomasta

(S.K. Gomasta)

Ph: + 91-651-2230020 Fax: + 91-651-2232138 E-mail: dtcrd.cmpdi@coalindia.in

ISSN 0970-7204

खनन विज्ञान
minetech

विषय सूची
Contents

खण्ड 41, अंक 3
जुलाई-सितम्बर, 2020

Volume 41, No. 3
July-Sept, 2020

Sl.No.	Title	Author	Page No
1	*Indigenous Development of Integrated Dumper Collision Avoidance System*	*Mohan Lal, S. N. Singh, Dr. Tarique Sajjad*	*8-18*
2	*Coal Sampling Machine for Instant Coal Ash & Moisture Analysis from Trucks*	*Sudhir Kumar Kashyap, Lalan Kumar, AVLN Rao*	*19-24*
3	*Online Coal Washability Analyser for Treating Indian Coals*	*K M P Singh, T Gouricharan, K M K Sinha, G V Ramana, Lingraj Sahoo, Pradeep K Singh*	*25-32*
4	*Blast Design Parameters for Rock Fragmentation–A Key to Productivity*	*Murari P Roy, Pradeep K Singh, Suraj Kumar, Ranjit K Paswan*	*33-43*
5	*Self-Advancing Goaf Edge Support (SAGES) for Depillaring Operation in Underground Coal Mines*	*Upendra K. Singh, Dheeraj Kumar, N.V.N. Reddy*	*44-55*
6	*Forest Landscape Restoration of reclaimed open cast mines in BCCL Dhanbad and sustainable livelihood to communities*	*Sudipto Chatterjee*	*56-58*
7	*OBR Check Measurement by CMPDI using Terrestrial Laser Scanner (TLS)*	*Rajneesh Kumar, Mohit Rastogi, Subhomoy Sinha*	*59-64*

Indigenous Development of Integrated Dumper Collision Avoidance System

Mohan Lal [1], S. N. Singh [2], Dr. Tarique Sajjad [3]

ABSTRACT

In Surface Mines, the most important cause of accident is those caused by Dumpers/Dump Trucks. Due to sheer size of dumpers, it becomes almost impossible for the person driving the dumpers to have even 180-degree of view. This leads to frequent accidents and loss of costly equipment. Out of total fatal accidents in surface mines, data shows that 42.96% of the accidents are caused by dumpers and 43.70% are caused by trucks/tippers, thereby, making them the largest cause group contributing the fatal accidents in opencast coal mines. Analysis also revealed that 12.07% of the accidents caused by dumpers are due to head on collision, 18.97% due to hit by dumpers, 24.14% due to run over while reversing & about 20.69% are due to topping.

Directorate General of Mines Safety (DGMS) has issued guidelines to ensure the safety of dumpers having circular no. DGMS (Tech)/cir.no.009 dated 02-12-2008. As per this circular dumper should be equipped with anti collision system to avoid head to tail collision between dumpers and proximity warning along with reverse safety system to avoid collision between dumpers and blind objects.

INTRODUCTION

The accidents, discussed above are mostly preventable through by managing the surrounding of dumpers in motion by the use of latest RADAR technologies and development of interface software by using on line satellite positioning data.

For this purpose Indigenous Integrated Dumper Collision Avoidance System for open cast mines has been taken up by joint team of BEL and CMPDI under CIL R&D grant. Objective of the overall system development is to protect loss of equipments and human life and thus ensure safe and efficient coal mining.

SYSTEM OVERVIEW

Dumper Collision Avoidance System (DCAS) has been designed to avoid collisions between Dumper to Dumper & other objects and to avoid toppling of Dumpers during unloading. It is required to provide situational awareness to the Dumper Operator in approx. 100 meters of radial distance. It is also required to have suitable alert mechanism using Audio and visual information.

[1]Sr. DGM (Development & Engineering, Bharat Electronics Ltd.), [2]HOD/DGM (Mining Electronics) [3]Chief Manager (E&T), CMPDI (HQ), Ranchi-834008.

Methodology

1) Dumper is fitted with a GPS enabled main unit which receives position information from GPS.

2) The main unit predicts trajectory of the host dumper and broadcast the trajectory by RF.

3) RF coverage range is about to 100 meter so as to detect possible collision threats within 100 meters vicinity.

4) The other dumpers within the range will receive and process this transmission and compare incoming vehicles trajectories to their own.

5) If a unit detects a convergence, it will alarm its driver according to the threat level.

6) The display is in the form of LED or suitable indication and the color of display will change (Green/Yellow/Red) according to the distance.

7) There is two different layers of Display:

i.) Outer Layer for indicating Direction/ Distance of other dumpers.

ii) Inner Layer for indicating Direction/ Distance of nearby objects

If any object detects within 20 meter range the Outer Layer Red LED will blink and audio alarm will be generated. Similarly if any blind object is coming in the vicinity of Dumper less than 4 meter, the inner Red LED will blink and generate alarm.

8) Proximity warning from other objects: The dumper is having Pulsed Radar based proximity sensors at three sides to warn against impending collision with any other vehicle, human being and blind object entering in its coverage range of approx.5 meter.

9) GPRS/GSM Modem will transmit data of location co-ordinate of Dumper to central Base station through SMS.

10) The complete solution will be a combination of GPS based main unit & Pulsed Radar based proximity sensors.

Dumper Collision Avoidance System consists of following sub systems:

i) Display Unit

ii) Control unit

iii) Proximity sensors

iv) Antenna Unit

v) GPRS/GSM Modem

Dumper Collision Avoidance System (DCAS) has been developed as a safety system for Dumpers

operating in Open-Cast mines. This system provides following three layers of safety:-

a. Layer 1 provides safety by detecting objects within 10 Meter range. This layer consists of proximity sensors mounted on Dumpers on three sides.

b. Layer 2 provides Distance & Directional information of other dumpers present in the vicinity of 100 Meters thus enabling operator to have better view of the situation. This layer consists of GPS, RF Link and RS232 Interface.

c. Layer 3 provides Positional information of the Dumper through GPRS to central base station by sending SMS. This layer consists of GPRS module and RS232 interface.

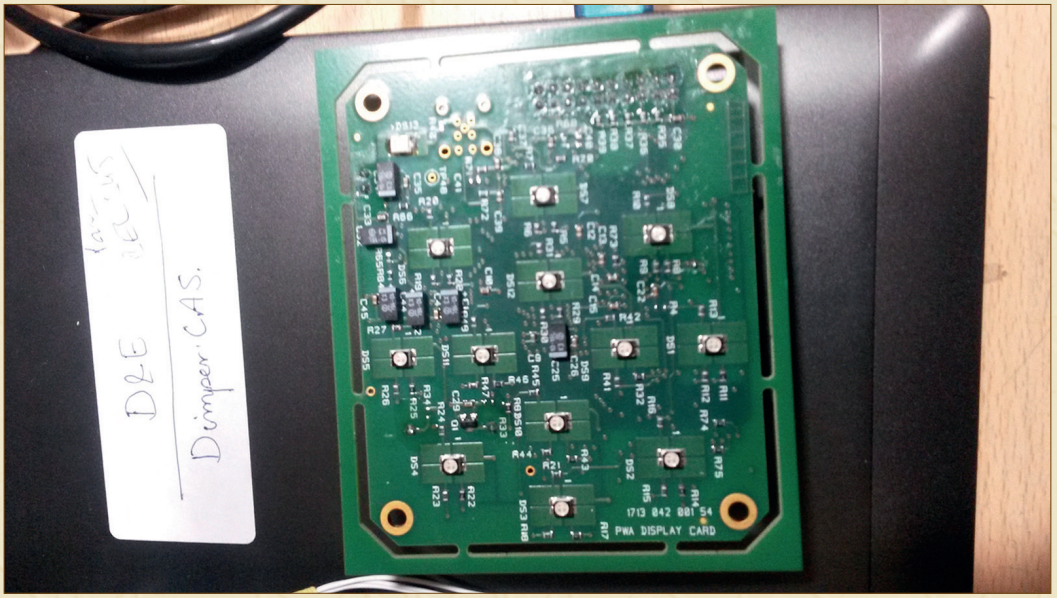
DISPLAY UNIT

It is micro controller based design, which provides Situational Awareness data to the Dumper Operator. Display Unit is placed in Driver's cabin in front of Driver.

Specifications of Display Unit

- Supply voltage : 5.0±0.2 V
- Operational current : 200 mA
- Luminous Intensity : 50 Milli Candela (Minimum)
- Angle of Half Intensity : ± 60 degree
- External Interface : RS 232

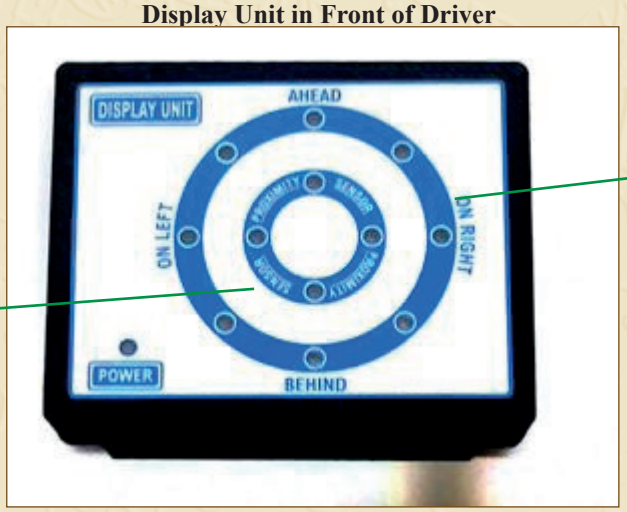
Front Portion of Display Unit



Back Portion of Display Unit

Display Unit in Front of Driver

Inner Layer for indicating Direction/ Distance of nearby objects



Outer Layer for indicating Direction/ Distance of other dumpers

COMPLETE DISPLAY UNIT

INNER LAYER COLOR CODES

Sl. No	LED Color Code (Inner Circle)	Distance of Object from sensor
1	RED	< 4 m
2	BLUE	4-7m
3	GREEN	7-10m
4	NONE	>10m

OUTER LAYER COLOR CODES

Sl. No.	LED Color Code (Outer Circle)	Distance of Object from sensor
1	RED	< 20 m
2	BLUE	20-50 m
3	GREEN	50-100 m
4	NONE	100 m

CONTROL UNIT

It is a Digital Signal Processor based system. It has following functionalities:

i) Determination of exact time slot for transmission of positional and speed parameters of the dumper.

ii) Preparation of data packet for transmission on the channel.

iii) Reception of GPS signal and calculation of GPS parameters

iv) Interfacing with Proximity sensors

v) Interfacing with GPRS/GSM Modem

vi) To provide indication to the user on the Power ON and Transmission conditions

vii) Reception of data packets from other dumpers

viii) Calculation of Situational Awareness data in the vicinity of the Dumper.

ix) Interfacing with Display unit

Specifications of Control Unit

General specifications:

- Frequency Range : 2.4 to 2.483GHz
- No. of Channels : 83
- Bandwidth : 1MHz (maximum)
- Supply voltage : 12 to 24.0 V ± 0.2V DC.
- Modulation Type : MSK
- RF Power Output : 27 ± 2dBm
- RF data rate : 19.2 Kbps
- External Interface : RS 232
- Frequency stability : Carrier frequency shall be within ±20 ppm.
- Harmonic level : Harmonic level shall be < -40 dB with respect to the unmodulated carrier under Standard test conditions.
- Transmit Spurious Emission : Transmit spurious emission level shall be < -47dBm with respect to the unmodulated carrier under standard test conditions.
- Transmit current : Transmit current measured shall be maximum 1.5 Amperes.
- Receive Current : Receive current shall be maximum 100 mA.

Standard test settings:

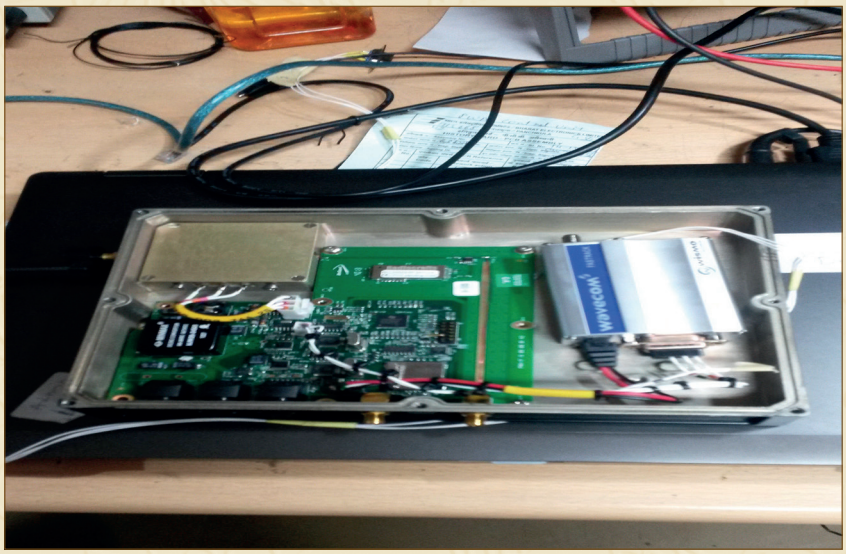
- RF termination : 50 ohms
- Standard test environment conditions:
- Relative Humidity : 45% to 75%.
- Ambient Temperature : -10°C to +50°C

GPS Receiver:

- Sensivity : -142 dBm
- Maximum update rate : 1Hz
- Protocol support : NMEA, binary
- No. of channels : 20

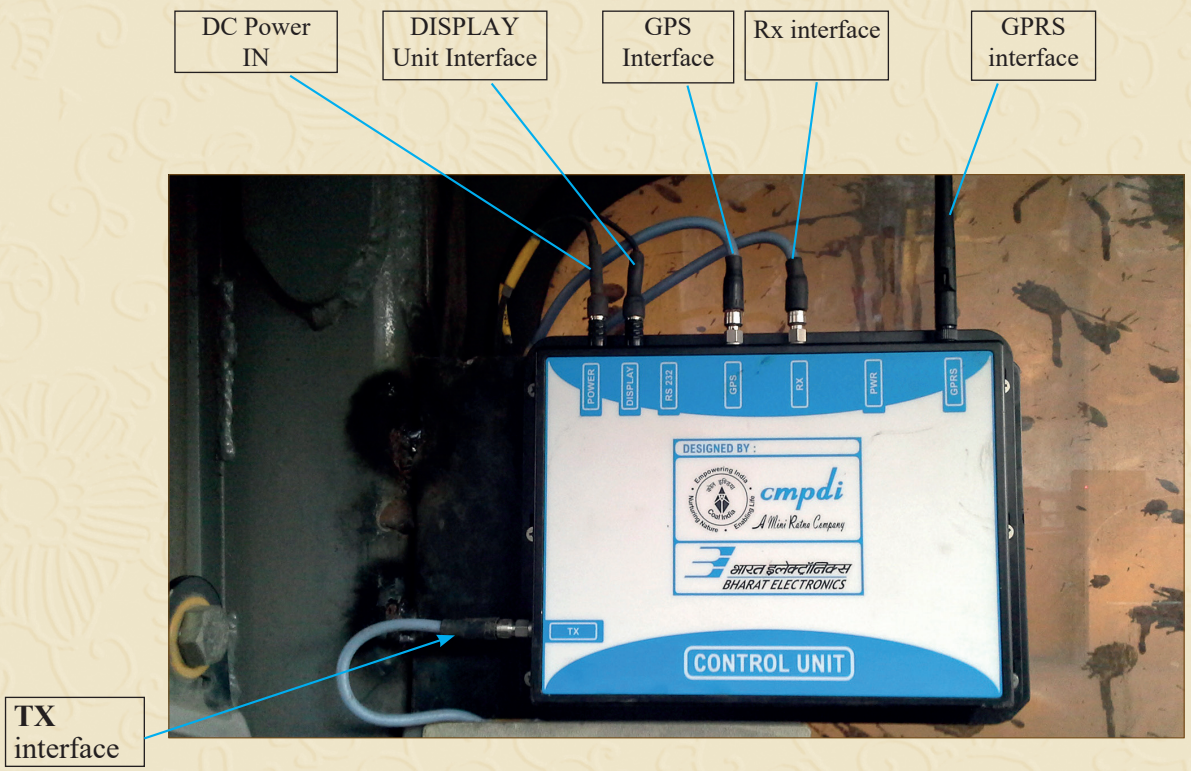
Antenna:

- Polarization : Linear
- Peak gain : 2.2dBi
- Average gain : -1.0dBi
- Average efficiency : 80%
- Maximum VSWR : 1.5:1
- Connector : SMA (M)
- Impedance : 50 ohm



Control Unit with GPRS Module

INTEGRATED CONTROL UNIT



PROXIMITY SENSORS

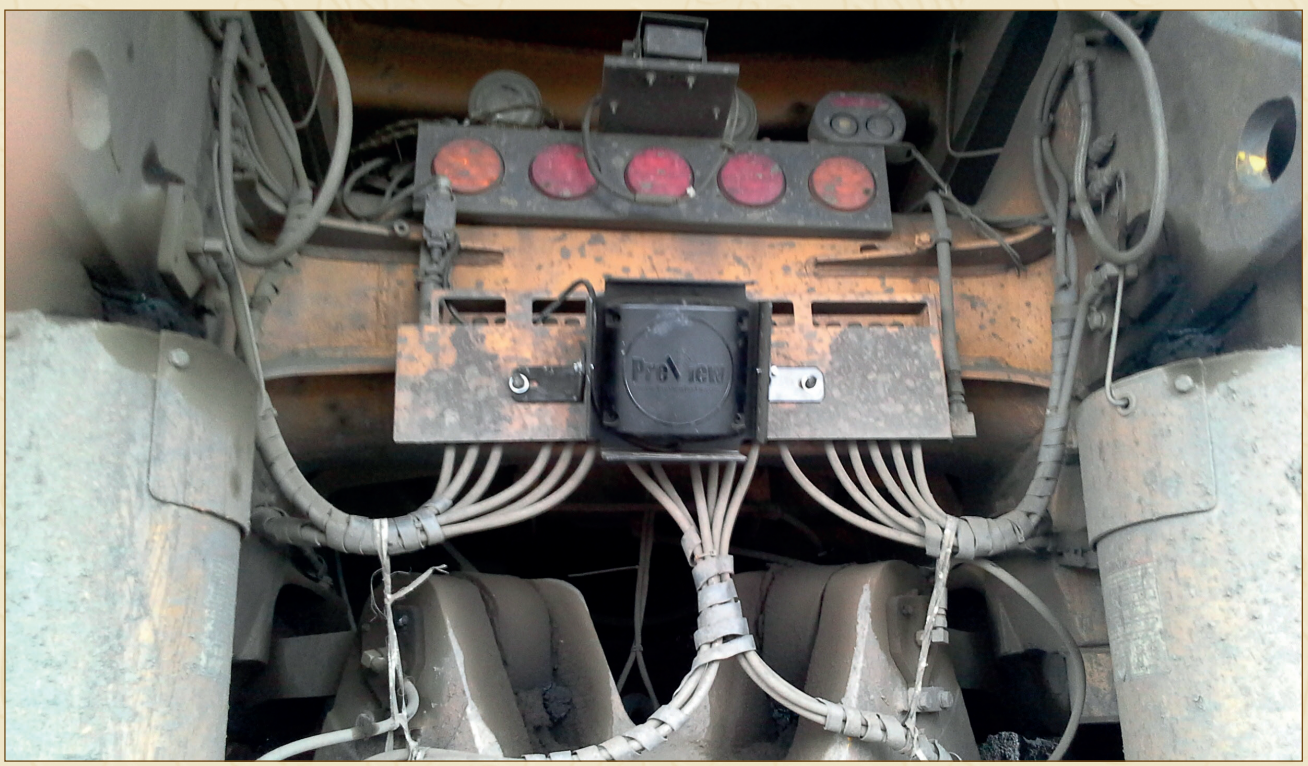
Proximity sensors are based on Pulsed Radar technology to warn against impending collision with any other vehicle, human being and blind object entering in its coverage range of approx.0-10 meters.

This sensor provides very short to long-range detection and ranging, in a compact, robust PVC housing, designed to meet IP67 water intrusion. This sensor has a new high power output along with real-time auto calibration for changing conditions (temperature, voltage or acoustic or electrical noise) that ensure you receive the most reliable (in air) ranging data for every reading taken. The low power 3.0V to 5.5V operation detects objects from 0-cm to 1068-cm (35 feet) and provides sonar range information from 20-cm out to1068-cm with 1-cm resolution. Objects from 0-cm to 20-cm range as 20-cm.

SENSOR SPECIFICATIONS (Typical)

- Extended 10m range detection and outputs
- High acoustic power output
- Real-time auto calibration and noise rejection for every ranging cycle
- Precise narrow beam continuously variable gain
- Object detection includes zero range objects
- 3.0V to 5.5V supply with very low average current draw
- Readings can occur up to every 100mS, (10-Hz rate)
- Free run operation can continually measure and output range information
- Triggered operation provides the range reading as desired
- All interfaces are active simultaneously
- Serial, 0 to Vcc, 9600 Baud 81N
- Analog, (Vcc/1024) / 2cm
- Pulse Width
- Real-time analog envelope
- Sensor operates at 42KHz

Sensor for Proximity Detection at side of Dumper



Sensor for Reverse Safety at Back Portion of Dumper

ANTENNA ASSEMBLY UNIT

Antenna Assembly Unit consists of Tx Antenna, Rx Antenna, GPS Antenna with frame base.

Tx Antenna, Rx Antenna & GPS Antenna are placed in a Dome mounted as part of Antenna Assembly near front railing of the Dumper. All the cables are routed properly to the Driver Cabin.

Antenna Unit

Antenna Assembly:

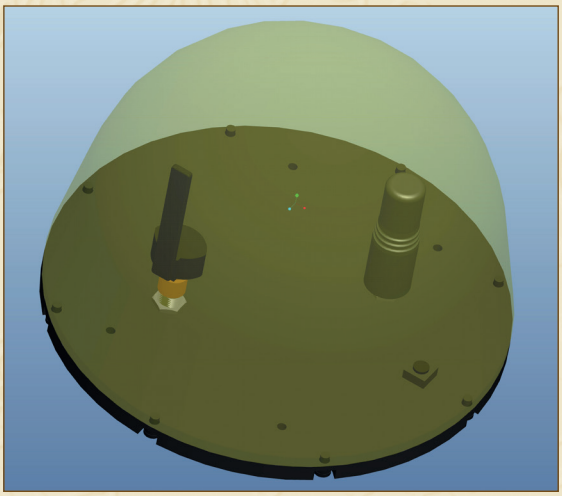
It is a dome assembly having two antennas, one for GPS receiver and another for transceiver. Dome is mounted on a mounting bracket, and two clamps hold it to fix on a pipe near rear mirror's stand on the left side of drivers cabin. Two RF cable are routed between control unit and antenna assembly.

GPRS/GSM MODEM

It is GPRS and GSM modem having dual band of GSM. It can be used for sending and receiving SMS, data and audio also.

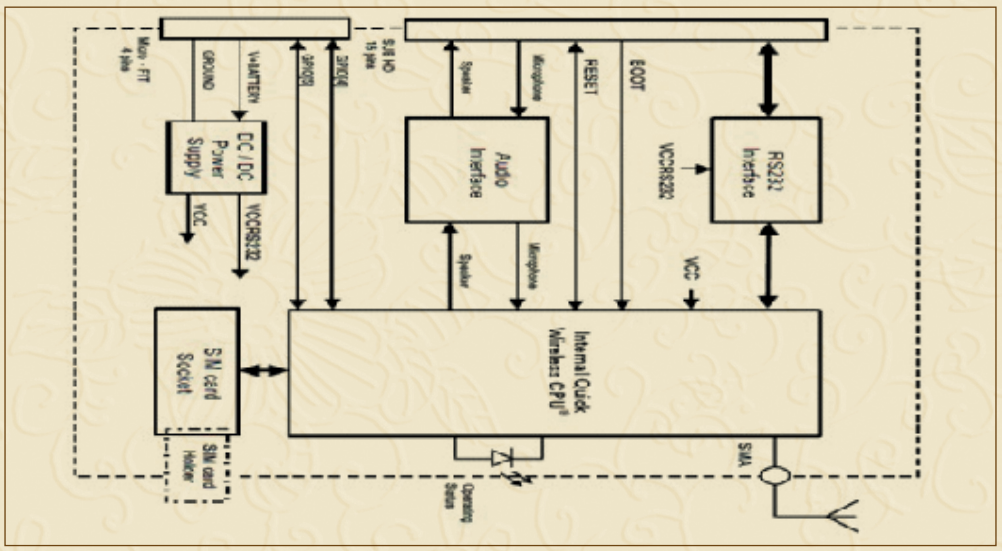
Specifications:

GSM frequency support	: 900/1800 MHz
Out put power of GSM	: 2W and 1W
GPRS coding schemes	: CS1 to CS4
Interface supported	: RS 232, 3V SIM and two GPIO
Max. transmitting speed	: 192kbps
Input voltage	: 5 to 24V
Max. Peak current	: 1A



ANTENNA ASSEMBLY

Antenna Unit



Block diagram of GPRS/GSM Modem

GPRS Module for Vehicle Tracking

SPECIAL ACHIEVEMENTS IN R&D PROJECT

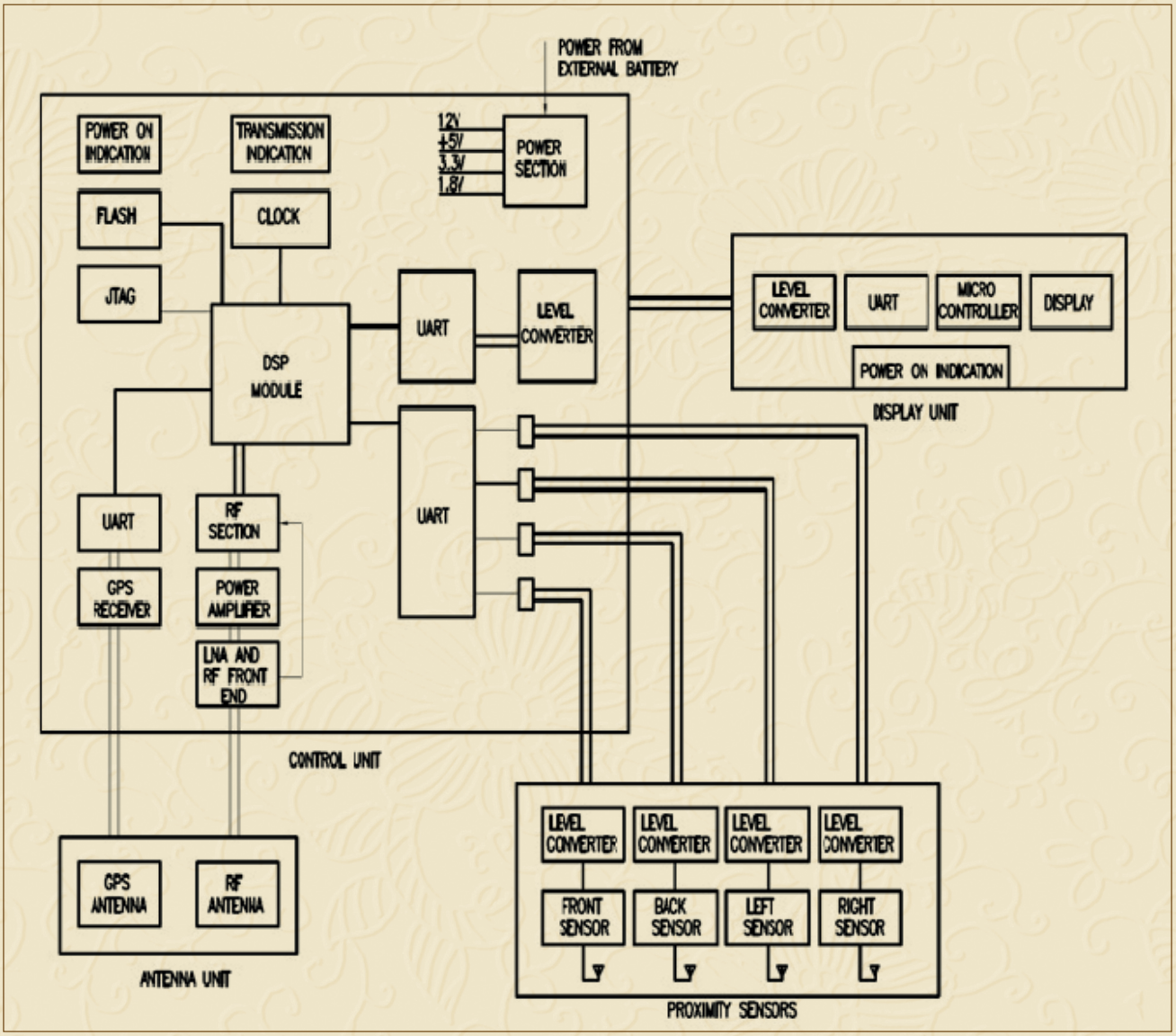
As per Directorate General of Mines safety (DGMS) guidelines and circular no. DGMS (Tech)/ cir.no.009 dated 02-12-2008 to ensure the safety of dumpers and human life, this R&D project has successfully developed the anti-collision device to avoid collision between dumpers, thus protecting the loss of equipment and human life and ensuring safe and efficient coal mining in open cast.

However apart from meeting the above main objective, the following **special additional features** are also being achieved in this R&D project:-

i) **Proximity warning from other objects:** The dumpers are equipped with Pulsed Radar based proximity sensors at three sides to warn against impending collision with any other vehicle, human being and blind object entering in its coverage range of approx.0-10 meters.

ii) **Reverse Safety System:** The System can also be used as a reverse safety system to prevent the dumpers from toppling down from the OB dump while unloading.

iii) **Vehicle Tracking Interface:** An additional feature of locating the Dumpers and its



Functional Block diagram of DCAS

tracking is also incorporated in this R&D project which was not in the scope of work initially. With the help of GPRS module incorporated in the Control Unit, the location co-ordinates of a dumper can be readily known by simply sending an SMS to that particular dumper. The location co-ordinate is automatically sent back by the system. These co-ordinates can be superimposed on Google Map with a tailor-made software, to track the exact location of the dumpers within the mine.

iv) **Vehicle Health Monitoring Interface:** The provision for health monitoring of Dumpers such as Fuel level, Tyre pressure etc. is also being kept in this developed system for future use. For this purpose, two digital & two Analog I/Os interface has also been incorporated in the control unit of the system.

CONCLUSION

We have successfully achieved and implemented the main thrust area and objective of this R&D project along with additional special achievements. 20 No of Dumper Collision Avoidance System were deployed at KDH Mines, CCL and three months field trials completed successfully.

Coal Sampling Machine for Instant Coal Ash & Moisture Analysis from Trucks

Sudhir Kumar Kashyap [1], Lalan Kumar [2], AVLN Rao [3]

ABSTRACT

In commercial term when we discuss about the coal quality monitoring, the three agencies come into the pictures i.e coal producers, coal controller and coal users. Coal quality examination with proper proximate analysis to obtain the exact value of moisture, ash content along with GCV of the produced/supplied coal at source/destination for optimization of resources is obligatory. Moreover, delays or any intermittency in the supply of quality coal in the furnaces of thermal power station & steel plant is undesirable which makes the online methodology the need of the hour for every heavy industry indulged in mass production using coal as the source of energy. Sampling and analysis are the two components for coal quality assessment. The representative coal samples collected from the truck by modified auger mechanism undergoes step by step analysis to give the instant results of ash and moisture contents with the newly developed nuclear technique methods with dual gamma rays transmission which gives impeccable results in no time. Technically this method is fast, accurate and economical and also solves the problem of coal quality monitoring encountered by Industries with surge efficiency. This paper discusses the analysis part and the design and development of mechanism for collecting the true representative of coal sample from the truck at site from where coal is being dispatched. The research & development for this innovative product/equipment i.e Truck Mounted Mobile Coal Sampler (TMMCS) could be possible by execution of a Grant-in-Aid project funded by the Government of India, Ministry of Coal.

Keywords: *Ash %, Moisture %, GCV, Nuclear techniques*

INTRODUCTION

The demand for energy is expected to increase by 95% by 2030. Since inception of coal has been fulfilling the power requirement of the nation and it will remain India's main energy source as we are third rich in producing coal in the world, grades of coal play important role in deciding the cost of the energy. In our country about 59% energy is produced by thermal power plants with coal being its sole and primary fuel. Apart from thermal sectors all large scale metal melting blast furnaces and steel melting shops for example run on the energy supplied by burning coal either by utilizing or transforming coal into suitable forms to make use of the high calorific value it supplies .

[1] Sr. Principal Scientist, [2]Principal Scientist, CSIR-Central Institute of Mining and Fuel Research, Barwa Road, Dhanbad–826015, [3]CEO, M/s Pranay Enterprises, Hyderabad, INDIA, Corresponding author : sudhirnutan@yahoo.com.

As we know that the different sectors requires different category of coal and the moisture content and ash content in that particular coal. It significantly determines the usability of coal for safer, cleaner and smoother processing with optimum wastage of resources and thus it greatly affects the output and profitability factors of an industrial firm. Therefore for optimization of resources it is needed to determine the quality of coal at source point and at destination through critical analysis of moisture and ash content in the randomly selected sample. Thus, to avoid intermittency, online and uninterrupted analysis of coal to obtain instant result has been incorporated in the methodology.

PROBLEMS & ISSUES

In the present scenario coal sampling in view of coal analysis is collected from the upper surface of the wagon for analysis to ensure suitability of use in boilers and other concerned plants. The coal representative samples are collected from the loaded truck for its quality analysis. The sample collected from the upper surface only of the wagon may not be proper for the property of the entire lot due to the heterogeneous property of coal. Thus for sampling purposes the coal sample is to be collected randomly from a full depth of the wagon for true data. The following drawbacks are also encountered with the conventional coal sampling system leading to incorrect data of coal quality.

1) Time taking and labor intensive method of collection of loose coal sample for the railway wagon for the purpose of coal analysis.
2) Improper way of collecting coal samples from a shallow depth from a railway wagon.
3) Collection of coal samples from railway wagon not in the form of core.
4) Manual ineffective method of sampling.

In recent days the coal sampling is mostly done at the dispatch end by taking representative coal samples from the belt conveyors. The coal samples thus, collected is reduced into representative lots by crushing and then the ash, moisture are analysed in the laboratories. Therefore there is a time gap between collection of coal sample and the final results of analysis to an extent of about 24 to 48 hours. Hence, there has been a requirement to develop a Mobile Coal Sampler/Analyzer suitable to take instant coal samples and analyze the same on the spot in the coal loaded and dispatched site through trucks both at the dispatch end and the receiving end.

METHODOLOGY

We require techniques which can analyse the data in a quick span of time avoiding intermittency of coal supply to the plant. There are various methodologies and techniques in the field of moisture and ash content analysis in a coal sample on an online basis for instant and uninterrupted use of coal as a primary fuel in various industrial sectors like thermal power plant, metal casting and melting shops, furnaces, boilers etc. But the most suitable technique i.e nuclear technique uses duel gamma ray transmission from a generation source with the help of radioactive elements ie. Americium and Cesium to produce them to find the required quality parameters.

Advantages of a nuclear technique for online analysis can be innumerable but the problem of radiation always exists. Thus the equipment developed had to pass through a radioactive test conducted by BARC, Mumbai. After approval from BARC, Mumbai the threat of radiation based issues were solved.

This nuclear technique consists of the radio isotopes. Isotopes are variants of a particular chemical element which differ in neutron number, although all isotopes of a given element have the same number of protons in each atom. The term isotope is formed from the Greek roots isos (ἴσος "equal") and topos (τόπος"place"), meaning "the same place". Thus, different isotopes of a single element occupy the same position on the periodic table. The number of protons within the atom's nucleus is called atomic number and is equal to the number of electrons in the neutral (non-ionized) atom. Each atomic number identifies a specific element, but not the isotope; an atom of a given element may have a wide range in its number of neutrons. The number of nucleons (both protons and neutrons) in the nucleus is the atom's mass number,

and each isotope of a given element has a different mass number.

The On-line coal quality monitoring system determines ash content by combining measurement of the intensities of narrow beams of low and high energy gamma rays, transmitted in parallel through the coal from two radioactive sources. The sources used are Americium (241 Am) for the low energy beam with peak energy of 60 KeV and Caesium (137 Cs) for high energy beam with peak energy of 662 KeV. A detector converts the quantum energy into electric pulses which are measured and computed by an adapter unit and transmitted to the computer interface. Then firstly the calibration and manipulation of the obtained data is carried out. Then the computer software program, tailored to meet specific needs of each customer, converts the pulses into readings of:–

- Calorific value of the coal
- Ash content of the coal

The basic scheme has been explained schematically in the Fig.-1.

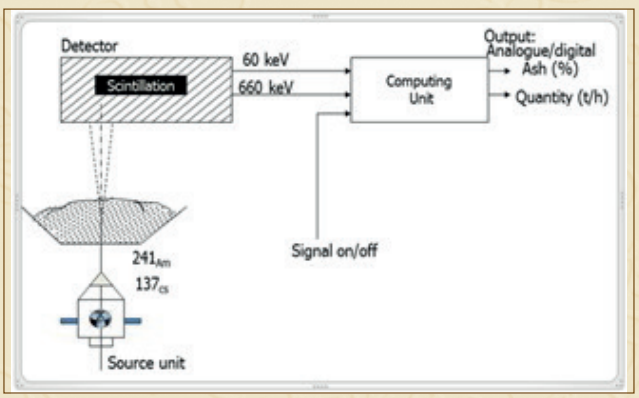


Fig-1: Schematic view of Nuclear Technique

The two radioactive sources can either be combined with one detector or located separately with two detectors. The dual energy gamma ray absorption technique is the best established one for on-line analysis of coal. It has high degree of accuracy and a wide range of measurement. It has short analysis times, good radiation safety features and is moderately priced, with payback periods as short as 12 months.

The beam at low energy is sensitive to the difference in the ratios of the mass absorption coefficients of the gamma rays between the combustibles and the mineral matter whereas the beam at high energy is not as sensitive to these components and essentially detects only the total mass.

Based on the above nuclear techniques the moisture analyser and ash analyser have been developed as shown in Fig-2 & 3.

Fig.-2: Moisture analyser

The coal ash and moisture monitoring system are coupled with the computer interface which gives the results of ash and moisture very fast and having permissible accuracy. The total coal quality monitoring systems are mounted on the truck as depicted as 'Coal Analysis Lab.'(Fig.- 4).

The online system also calculates the GCV values of the coal instantly. The curve with the required values so obtained by the devices has been presented in Fig.-5.

Fig-3: Ash analyser

Fig-4: Coal Analysis Laboratory

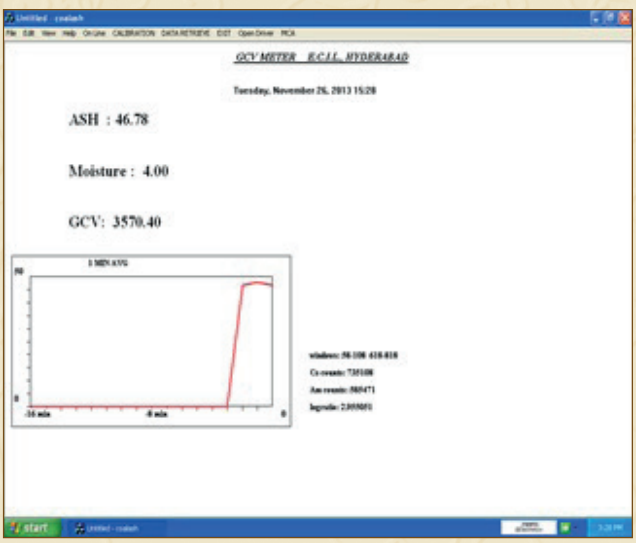


Fig.-5: Results of Computer Interface of Ash, Moisture & GCV values

COAL SAMPLING MECHANISM

After the fabrication of the drilling mechanism, integration and installation of the coal sampling machine with other necessary equipments were done on the truck as depicted in Fig.-6. A coal sampling technique was developed using a modified auger drilling mechanism which was hydraulically driven and powered by eco-friendly generators which were mounted upon a truck. The drilling mechanism consists of a drill bit which had a sample holder attached to it. The drill bits dills down the stockpile of coal carried by truck and wagon to get the true representative random samples from the interior part of the pile to represent the while lot. Several samples can be collected from different locations of the wagon from both interior and exterior part of the stock pile tackling the problem caused by heterogeneous nature of coal different locations of coal loaded on the truck and wagon. The drilling mechanism is also equipped with a crusher and mixer which crushes and mixes the sample collected to make a homogeneous mixture with similar properties in every trace of the sample. The sample thus collected and processed by crusher and mixer then travels to the sample holders and the proximate analysis for moisture and ash content is then carried out with the coupled nuclear technique discussed earlier.

Fig-6: The Hydraulic driven Drilling Mechanism mounted on the truck with other equipment.

FIELD TRIAL AND DOCUMENTATION

Further, the methodology of nuclear techniques was applied to examine its suitability in all respect and thereafter sent for field trial at SCCL. The field trials were conducted successfully at GDK-1

CHP, RG-1 area and RG-2, OCP-3 CHP in SCCL. The successful field trial operation with the truck mounted mobile coal sampler for instant coal ash and moisture analysis was shown in Fig.-7.

After field trial at SCCL mines is over, the suitability and accuracy of the nuclear techniques was verified by comparing the test results of the developed equipments TMMCS and the regional laboratory of Kothagudem of SCCL. During this period 10(ten) samples were collected from the laboratory having already tested for ash%, moisture% & GCV and then tested in developed equipment. The results obtained are as follows shown in (Table-1).

Fig.- 7 : Field trial with the developed TMMCS

ANALYSIS AND INTERPRETATION

The results obtained from the sampler machine were validated with the results of SCCL's laboratory The graphs were plotted for ten samples between ash % and sample Nos. & moistures% and samples Nos. separately for laboratory and mobile coal sampler as depicted in Fig.-8 & 9.

The beautiful characteristics curves were obtained after comparisons and it was observed that the two results are in good agreement with each other. The nature of the curve is completely similar. The value of the results obtained in case of moisture content is little different which may be due to the incomplete filing of the sample container, homogeneity of the samples (i.e there should not be any gap, cracks or holes in samples so filled in the container) or due to transportation from a long distances.

Table-1: Test Results

Sl. No.	SCCL Test		Mobile Coal Sampler	
Sample Nos.	Ash%	Moisture%	Ash%	Moisture%
Sample No.- 1	47.26	4.22	45.91	2.45
Sample No.-2	60.63	3.30	61.09	1.91
Sample No.-3	45.56	4.36	44.38	2.33
Sample No.-4	25.84	6.16	30.27	2.56
Sample No.-5	20.96	6.59	19.46	3.15
Sample No.-6	28.91	5.89	32.63	2.85
Sample No.-7	18.31	6.84	14.36	3.16
Sample No.-8	22.15	6.50	22.31	2.96
Sample No.-9	44.72	4.44	42.19	2.47
Sample No.-10	46.60	4.29	46.58	2.19

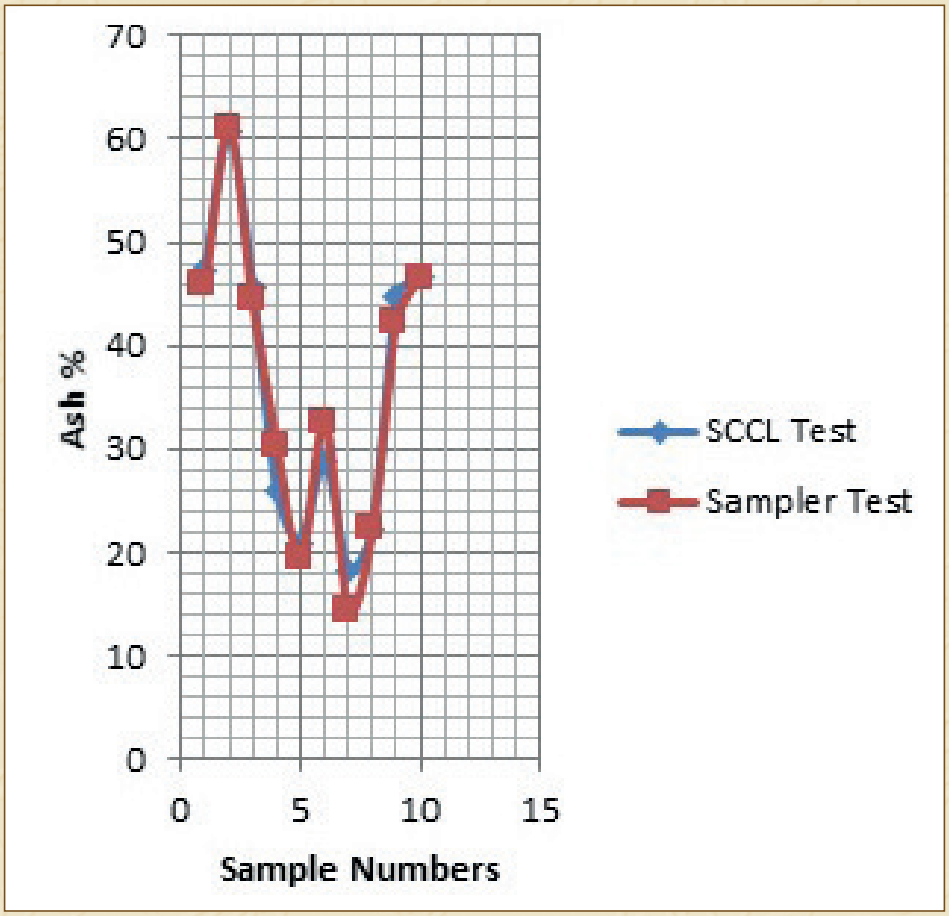


Fig.-8: Comparison between SCCL and Sampler Results (ASH %)

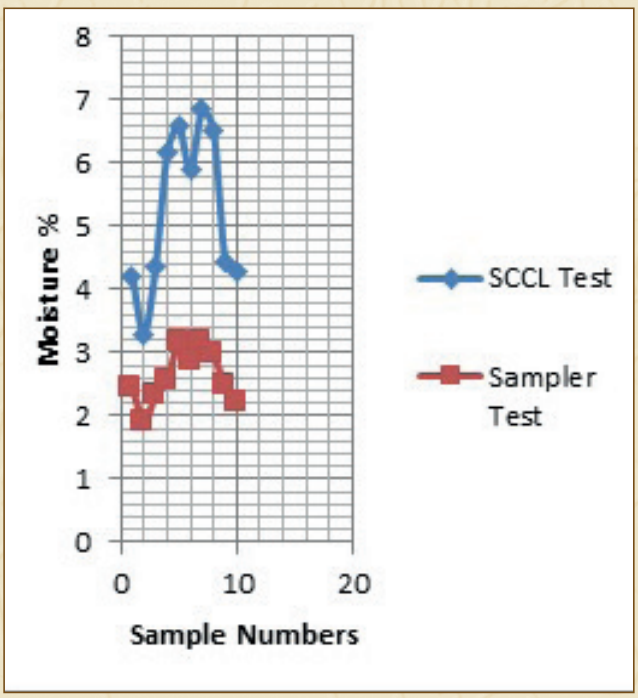


Fig.-9: Comparison between SCCL and Sampler Results (MOISTURE %)

CONCLUSION

These innovative equipments (TMMCS) were developed for the proper and accurate sampling of coal along with determination of ash, moisture & GCV values at faster rate and with high accuracy which will give the online quality assessment of coal from the railway wagons/trucks at site. These developed equipments will be helpful to the industries particularly thermal power plants, steel plants and other industries to get the actual values of coal received at their ends from the coal producers.

ACKNOWLEDGEMENT

The authors are thankful to the Director, CSIR-CIMFR, Dhanbad and Ministry of Coal, Govt. of India for his kind consent to present this paper and financial grants to carry out this research project respectively.

Online Coal Washability Analyser for Treating Indian Coals

K M P Singh [1], T Gouricharan [1], K M K Sinha [1], G V Ramana [2], Lingraj Sahoo [2], Pradeep K Singh [1]

ABSTRACT

Washability characteristic of coal is assessed prior to its commercial washing in actual practice. This is usually achieved by conducting conventional Float and Sink in laboratory under ideal static conditions. It is a time taking cumbersome process, uses hazardous chemicals (like Bromoform, Tertra-Chlore Ethylene, Benzol, Zinc Chloride, etc.) The coal washeries are being fed with coals from multiple sources/seams, which may have different washability characteristics. The performance evaluation of any washer is determined in comparisons to the standard procedure of float and sink test is the only alternative. By the time float and sink results obtained, there may be change in the feed or its ratio; the optimized results are difficult to achieve and a challenge for coal preparation researcher.

The duel energy X-ray based system are being used to characterized each and every details of particle having size +10/13 to -75/100 mm and derived required parameter for coal washability, which is used for online evaluation of coal washing. The experimental set-up with process methodology and the results in comparison with standard laboratory float and sink were discussed in the paper.

Keywords: *Coal washability, Float-Sink analysis, hazardous chemical, X-ray based analyser, online coal washability analyser, etc.*

INTRODUCTION

The conventional float & sink methods are followed to evaluate washing potential of coal, which is a time taking cumbersome process, using hazardous chemicals. The coal washeries are being fed with coals from multiple sources/seams, which may have different washability characteristics and the net/combined washability characteristics, is difficult to assess. Moreover the running plants cannot be assessed instantly, and ultimately the desired quality is still a challenge for coal preparation engineers.

To meet the MoEF mandate (use of below 34 percent coal ash) coarser fraction of thermal coal is being washed (+13/10 mm) while -13/10 mm is directly mixed with washed fraction. The challenges become more intense with the drifted origin Gondwana coal. Till date there are no such commercially available system for assessing this most fundamental aspect of coal washing characteristics. The researchers are working using available advance technology to determine the coal washability almost in real time.

[1] CSIR-Central Institute of Mining & Fuel Research, Dhanbad, [2] Ardee Hi-Tech Private Limited, Visakhapatnam

Since discovery of X-rays in 1895, among the numerous important uses it has also been applied to examine the coal. The first investigation reported was H. Couriot, in 1898, he submitted anthracite, bituminous coal and other fuels to X-rays to obtain their radiographs and nearly every detail of the intimate structure of the mineral matter. Latter on Mahadevan in 1929, followed by J Dhar & BB Niyogi, 1942, have X- Ray studies on Indian coal macerals and minerals.

The literature on on-line washability is very widely dispersed. The basic issue is that comparable results of on-line system vis-à-vis the standard F&S method. The 3D X-ray has been introduced in 1970's and since then, researcher's has also focused on 3D structure & mineralogical study to get the acceptable result.

The coal washability by applying X-ray was attempted in 1990's. The researchers like J. D. Miller, C. L. Lin, G H Luttrell, G T Adel (USA) Gianni Schena, Luca Santoro, Stefano Favretto, Jan F. Bachmann, Claus C. Bachmann, Michael P. Cipold, Helge B. Wurst, Hauke Springer (Germany) & Mel J. Laurila (USA) are working on washability. Researchers in Germany, South Africa, USA, etc. are working for online developing an online washability analyser. This is year 2012, S. Shamaila, B. Ntsoelengoe, J. Bachmann, H. Wurst, & M. Cipold; has reported for a prototype X-ray transmission washability monitor. The Atkinson and Swanson; 2016 are also working on coal washability using X-ray. The Albert Klein, Sven Reuter and Audy Zein are also working on rapid coal analysis with the online X-ray elemental analyser. Jan Bachmann, in his article, Online Washability: Comparison of Dual Parameter and Triple Parameter Analysis, 2016, argues that dual parameters lead to high inaccuracies with changing ash content in coal as has been the experience with dual energy ash gauges and proposes a triple parameter using an optical measurement technique to compensate for the changing variation of the third dimension of the particle.

The X-ray based coal washability analyser needs to measure, i.e. particle size, ash content weight and the density, almost instantaneously and process the recorded data without any further delay for washability curves. The system must be reliable, work in an on-line fashion, minimal intervention of personnel rather to say automated, which provide nearly real-time analysis. Keeping the above development in mind, a system with single source of X-ray and dual channel X-ray detector are being developed in the laboratory. The CSIR-CIMFR has worked on on-line system using dual energy X-ray techniques to assess the washability potential of coal in almost real time. The successful development of such a device is critical to the establishment of process control and automated coal washing systems. The laboratory model system was first developed and derived the required parameter to establish the concept and after getting positive result online system was installed in synchronisation with 40 tonnes per hour coal washing pilot plant at CSIR-CIMFR Digwadih campus.

LABORATORY MODEL

To establish the concept a prototype laboratory model of the coal washability analyser was designed and developed at CSIR-CIMFR in association with M/S Ardee Hi-Tech Pvt. Ltd. as depicted in Fig.-1. The system consists of a reversible motor which rotate the 200 mm width conveyor in forward and backward direction. The vibratory feeder is mounted at one end of the conveyor, ensuring monolayer of the feed particle passing through X-ray generator and detector, which is poured in the hopper.

The laboratory model setup is very simple wherein coal of selective size is poured in the hopper and feed through vibratory feeder which ensures monolayer of coal particles spread on small moving conveyor belt and passes between X-ray generator (on the top) and the detector consisting of an array of dual energy sensors. The X-ray generator source consists of an integrated X-ray tube, dual output high voltage power supply and a filament supply with control circuitry. Once initialized and enabled the generator, emits continuous spectrum of X-rays energies in the range of range of 0 – 160 KeV. The X-rays are collimated into a straight fan beam. All reflected and scattered rays are filtered out to improve measurement and reduce inaccuracies arising out of scattered rays.

Fig.-1: Laboratory model of coal washability analyser at CSIR-CIMFR

The electrically generated X-ray applied to the broad spectrum X-ray radiation which falls on the conveyor, moving at a rate of 0.3 m/s carrying the feed material to be scanned. This works like a line-scan camera, record transmitted X-rays passing through the material. The formats of recorded data's are in digital image data. The captured images of the materials are in two different X-ray energy levels (Low and High). The low/soft energy X-ray region falls from few hundred eV to 60 KeV, while high/ hard X-ray with energy higher than soft X-ray, having higher penetration efficiency is being used. The dual energy sensors are utilized to capture the X-ray image, which provide high detection efficiency and high energy resolution. The attenuation depends on both the thickness and atomic density of the material. Images of different atomic densities are transformed into images of different spectral ranges, which make it possible to assign different pseudo colour pixels according to specific atomic densities which are independent of material thickness. The connected computer is used as data acquisition and processing system. The processed data is stored in the required format through in-built database software. The output finally provides particle's area (size), mass, and ash of the particles.

Dual Energy X-ray Transmission sensor (*Weight and density determination*)

The X-rays have the ability to penetrate matter and interact with atomic composition of the particles. The material under investigation is irradiated with X-rays of known incident energy and after attenuation by the particle; the residual energy is evaluated in the dual energy sensors, separately for the high and low energies. All scattered rays are filtered out using specially designed filters and collimators.

This has been well described by Zou et al (2008) and applied for the determination of densities of materials which can be expressed as degree of X-ray transmission with material density and thickness.

$$I = IOx\ e^{-\mu\rho d}$$

Where, Io = incident radiation,

I = transmitted radiation,

d = absorption path length,

μ = absorption coefficient and

ρ = product density

Knowing the incident radiation and the constant absorption coefficient of the material and measuring the transmitted radiation using X-ray line detector the weight per area (ρd) may be derived.

ONLINE ASSEMBLY OF THE SYSTEM

After realization of the concept with laboratory model, it was applied to demonstrate with 40 TPH coal washing pilot plant at CSIR-CIMFR, Digwadih campus as shown in the Fig-2 and 3. The online X-ray analyser system was setup in between coal crushing unit and coal washing circuit in such a way that after crushing at desired size while on the way to washer before the actual feed to washer. The coal is being collected/ diverted using mechanical sampler to online coal washability analyser to have the washability data. The collected coal is poured on the vibrating screen with variable amplitude which screened out -13mm size coal and makes the feed coal in monolayer on moving conveyor i.e. feed to X-ray analyser.

Fig-2: Online System Detector

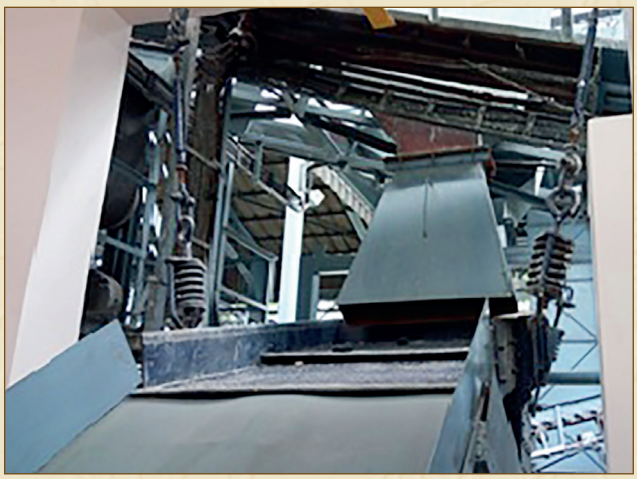


Fig.-3: Sampling and Screening Section

RESULTS AND DISCUSSION

It is a well-known fact that attenuation depends on both the thickness and atomic density of the material. The recorded, line scan data of different atomic densities are transformed into images of different spectral ranges, which make it possible to assign different colour (pseudo) pixels according to specific atomic densities, regardless of the material thickness. The recorded data than processed to generate the data in tabular format required for development of washability curve.

The system requires several levels of calibrations, it start with switching on the system, each of the electronic component is exposed to collimated multi-energy X-rays, depending on sensitivity of each pixel. There are raw counts generated due to scintillation of the sensors which are likely to vary quite drastically from pixel to pixel and are equalized through an internal gain mechanism. The second level of calibration is performed through the combination of calibration blocks with different heights and densities. The system is calibrated with respect to calibration blocks data and given logic for inclusion of the calibrated value, this enables higher level of accuracy for the size range of the materials to be analysed. Third level of re-calibration is used to compensate, higher densities and higher heights of the particles when X-ray hardening tends to disturb the attenuation curve. It is observed when mass per surface area exceeds a critical level, after this level, the attenuation curve becomes flatter due to which an erroneous reading of data at higher densities and higher heights of the particles is observed which need to be compensated.

Data generation for Washability Curve

Raw coal was crushed to 75 mm in the coal washing pilot plant using gyratory crusher. The coal feed to washing circuit is diverted to vibrating screen system with mechanical sampling system. The -13 mm size fraction of coal screen out and only +13 mm size coal allowed to be fed through analyser. This +13 mm coal feed to the moving conveyor (0.3 m/s) passing through online analyser. The X-ray based coal washability system continuously record line scan data for the particle passing through coal analyser covering entire width of conveyor. After completion of the time allotted for capturing data by the data acquisitions system, further data is processed to translate the raw data into required format i.e. particles size with densities, weight and the ash. The details of data of each and every particle are then grouped in specified size range in tabular format and from this table washability curves may be plotted as desired. The coal passed through the analyser was collected in a bin after capturing the line scan data. This X-ray tested coal was fractionated into size -75+50, -25+50 and -25 +13 mm and corresponding weights were recorded in the laboratory. The individual size fractions are subject to standard laboratory Float and Sink processes. The coal was subjected from specific gravity 1.40 to 2.20. The coal samples with respect to size and gravity fractionated were dried recorded the weights and subjected for pulverisations to determine ash.

Comparative study of Laboratory Float-Sink and X-ray based Online washability result

The X-ray based On-line coal washability analyser provides the details of each and every particle passing through the system. The software classifies each particle sizes into its respective size categories. The data of average size, weight% and ash% of all detected particle during specified times of operation is recorded. The data is then processed to develop washability curve.

Comparing the washability data obtained from both, the laboratory Float-Sink and X-ray based on-line coal washability analyser for the coal size faction 50-75, 25-50 and 13-25 mm respectively, with respect to ash percentage. It may be observed from the bar graphs (Fig.- 4) that gravity fractionated ash for the larger size fraction (50-75 mm) and laboratory float and sink results are in good agreement in the midrange of gravity. There is a deviation at lower and higher end specific gravity

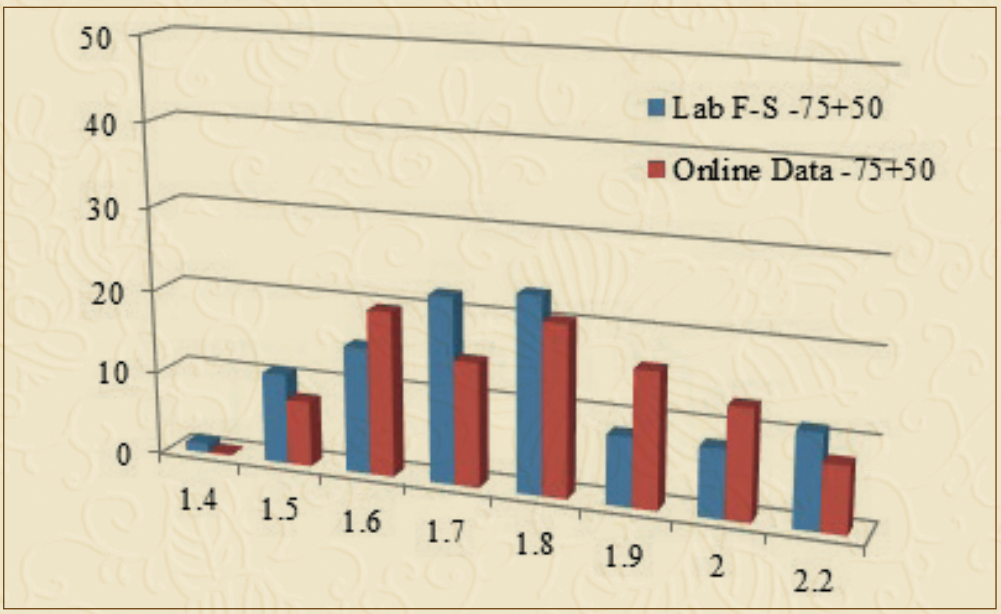


Fig- 4: Comparative results of online and Lab. F-S bar graphs of coal size -75 +50 mm

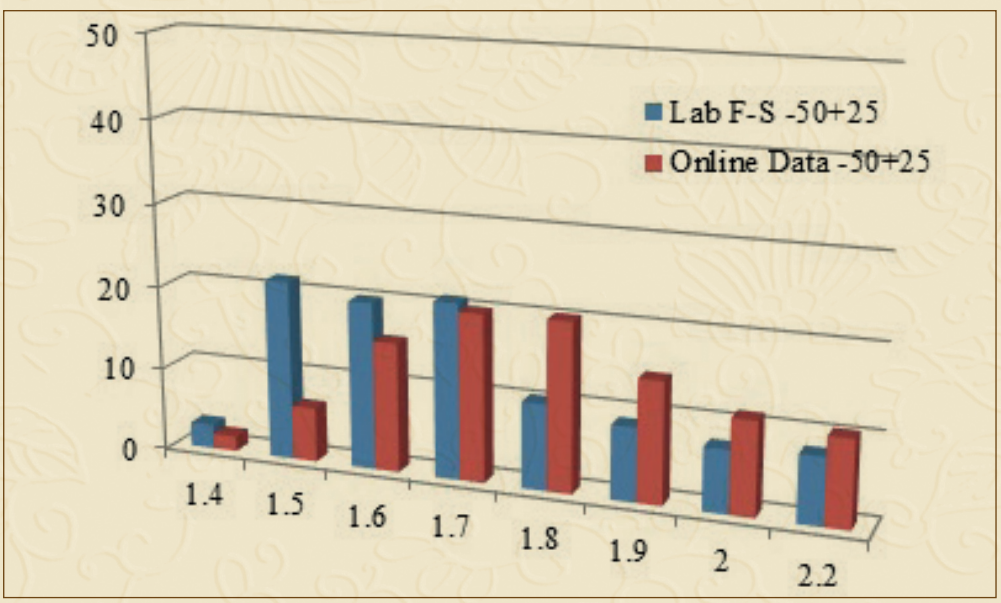


Fig - 5: Comparative results of online and Lab. F-S bar graphs of coal size -50 +25 mm

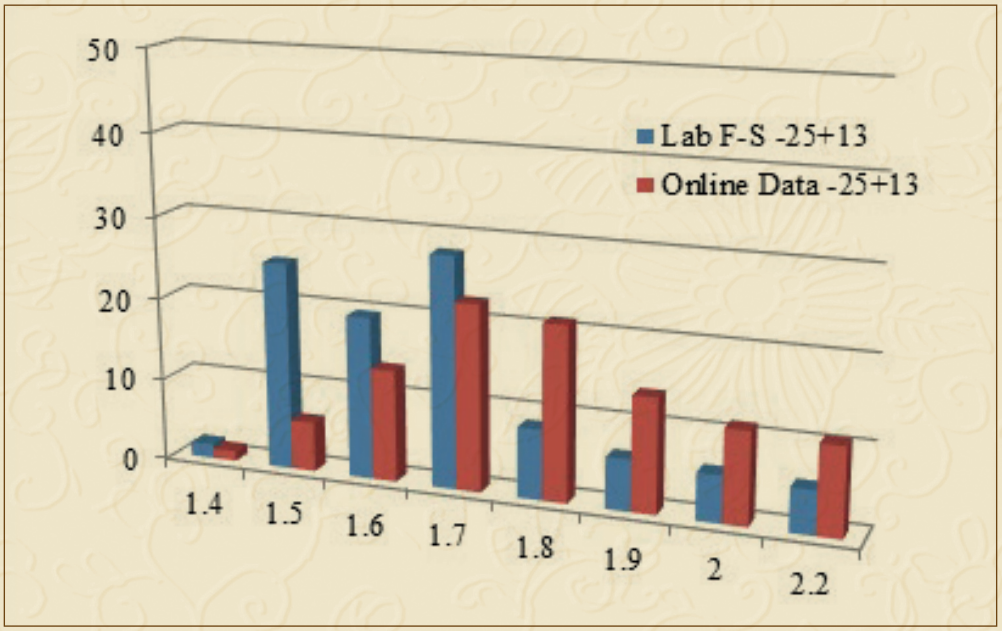


Fig.- 6: Comparative results of online and Lab. F-S bar graphs of coal size -25 +13 mm

while going towards smaller size fraction this deviation marginally is on the higher side.

CONCLUSION

The X-ray based coal washability analyser provides the washability results almost in real time without any destruction of the materials. With the varying feed ratio from multi source feed (different mines or seams) coal washeries may be equipped with optimised output results. The process is very fast to get the washability results i.e. in near real time data analysis. This results in improvement of coal preparation plant strongly and maximum possible recovery may be obtained during the process of coal washing. Working on a large number of data may compensate the laboratory results. Further data is having each and every particles detail like size, density and ash which on processing one can set the class-limits (size range) as per the desired requirements. The fact that the results are stored in a data base offers the possibility to re-evaluate entire datasets under different aspects for in-depth analysis and associated physical and chemical properties, which cannot be done with the lab results.

The entire process is not using any hazardous chemicals, and is economical.

Limitation

The detectors available/used having resolution of 1.54 x 1.50 mm and hence the combination of mineral matter/macerals below this size may not be detected properly.

ACKNOWLEDGEMENT

We express our deep gratitude to the Ministry of Coal, Government of India for funding this project and to the entire S & T team and coal preparation department of CMPDI, Ranchi for timely assistance and guidance. Authors are thankful to Director, CSIR-CIMFR, Dhanbad for his kind permission to publish the paper and all the contributors of coal preparation research group for their cooperation.

REFERENCE

1. *Science note, OTAGO WITNESS, August 25, 1898, page 54*
2. *J Dhar and BB Niyogi; X- Ray studies in Indian coals Part I, Volume VIII No 1 Published on march 18th 1942, PP-127-138*
3. *C.L. Lin, J.D. Miller, Cone beam X-ray Microtomography for three-dimensional liberation analysis in the 21st Century; Int. J. Miner. Process. 47 (1996) 61-73*

4. *C.L. Lin, J.D. Miller, Development of an On-line Coal Washability Analysis System Using X-ray Computed Tomography, Coal Preparation, Vol. 21. pp. 383-409 (2000)*

5. *C.L. Lin , J.D. Miller, G H Luttrell, G T Adel, Development of an on – line coal washability analyzer, Final Report, University of Utah, Department of Metallurgical Engineering, June, 2001.*

6. *C.L. Lin , J.D. Miller, G H Luttrell, Evaluation of a CT – based coal washability analysis system under simulated on line conditions, Minerals and Metallurgical Processing, vlo-19, No.1, 2002*

7. *A.R. Videla, C.L. Lin, J.D. Miller; 3D characterization of individual multiphase particles in packed particle beds by X-ray Microtomography (XMT), Int. J. Miner. Process. 84 (2007) 321–326*

8. *Gianni Schena, Luca Santoro, Stefano Favretto; Conceiving a high resolution and fast X-ray CT system for imaging fine multi-phase mineral particles and retrieving mineral liberation spectra, Int. J. Miner. Process. 84 (2007) 327–336*

9. *C.L. Lin, J. D. Miller, Advances in X-ray Computed Tomography (CT) for Improved Coal Washability Analysis, 16th International Coal Prep Congress (ICPC 2010), April 25-29, 2010 Lexington, Kentucky, USA*

10. *Hayley Strydom; The application of dual energy X – ray transmission sorting to the separation of coal from torbanite; M S Thesis, Johannesburg, South Africa 2010*

11. *Jan F. Bachmann, Claus C. Bachmann, Michael P. Cipold, Helge B. Wurst, Hauke Springer (Germany) & Mel J. Laurila (USA) Washability Monitor for Coal Utilizing Optical and X-Ray Analysis Techniques, 2012*

12. *S. Shamaila, B. Ntsoelengoe, J. Bachmann, H. Wurst and M. Cipold, Development of a prototype X-ray transmission washability monitor; The Journal of the Southern African Institute of Mining and Metallurgy, volume 112 March 2012, PP 179-184*

13. *Atkinson. B and Swanson A; Further development in washability prediction Using coal grain analysis XVIII international coal preparation Congress 28 June-01 July, 2016, pp 73-78*

14. *L. Von Ketelhodt and C. Bergmann, Dual energy X-ray transmission sorting of coal; The Journal of the Southern African Institute of Mining and Metallurgy, volume 110, 371-378*

15. *Helge B. Wurst, Jan F. Bachmann, Claus C. Bachmann, Michael P. Cipold, Washability Monitor for Coal Utilizing Optical and X-Ray Analysis Techniques, 17th International Coal Preparation Conference 1-6 October 2013, Istanbul, Turkey*

16. *Douglasw. Brown and Brian P. Atkin, A Method for the Rapid On-site Assessment of Handleability, Coal Preparation, Vol. 21, 2000, pp. 299-313*

17. *Hongping Liu, Sandra Rodrigues, Fengnian Shi, Joan Esterle and Emmanuel Manlapig Coal washability analysis using X-ray tomographic images for different lithotypes; Fuel 209 (2017) 162–171*

18. *Jan Bachmann, et all, Online Washability: Comparison of Dual Parameter and Triple Parameter Analysis, XVIII International Coal Preparation Congress, 2016, pp 255-260*

19. *Qian Zhu, "Coal sampling and analysis standards" Clean Coal Center, IEA publisher April 2014*

20. *C. L. Lin, J. D. Miller, T. Nguyen & A. Nguyen, 2017, "Characterization of Breakage and Washability of ROM Coal using X-ray Computed Tomography" International journal of coal preparation and utilization, doi: 10.1080/19392699.2017.1305364*

21. *G.V. Ramana, K.M.P. Singh & T. Gouri Charan; Coal Washability Analyzer– Optimizing Washery Performance, CPSI Journal, Volume7 (17) P 112-114, 2015*

22. *K M P Singh, T Gouri Charan, G V Ramana, K M K Sinha, G S Jha, Priyanka Kumari Ujala and Raj Gaurav Prasad, Coal washability based on dual energy X-ray, International Seminar on Mineral Processing Technology (MPT-2016), January 5 - 7, 2016, TCS Sahyadri Park Campus, Hinjewadi, Pune.*

23. *K M P Singh, Moumita Sarkar, Shashi Kumar, T Gouricharan, K M K Sinha, G S Jha & G Udayabhanu, Separation of coal macerals followed by acids demineralization; International Seminar on Mineral Processing Technology, K-11 (MPT-2017), Radisson Blu Resort Temple Bay, Chennai 1-3 February 2017.*

24. *K M P Singh, Priyanka Kumari Ujala, K M K Sinha, G S Jha, R G Prasad and T Gourichran; Field-Emission Scanning Electron Microscopy and energy-dispersive X-ray analysis to understand its role in Coal Beneficiation; NexGen Technology for Mining and Fuel Industries; Vigyan Bhawan, New Delhi, Feb. 15-17, 2017*

25. *K M P Singh, Shashi Kumar, Moumita Sarkar, T Gourichran, G S Jha, K M K Sinha and G Udayabhanu; A Study on coal macerals separation followed by alkali treatment, NexGen Technology for Mining and Fuel Industries, Vigyan Bhawan, New Delhi, Feb. 15-17, 2017*

26. *K M P Singh, Priyanka K Ujala, T Gouricharan, K M K Sinha, G V Ramanna, Lingaraj Sahu, Anindya Sinha and Pradeep Kumar Singh; Development of an On-line Coal washability analyser for treating coarse coal; International Seminar on Mineral Processing Technology (MPT-2018), 10-12 October2018, ISM, Dhanbad.*

27. *K M P Singh, Priyanka Kumari Ujala, K M K Sinha and T Gourichran, Studies on the characterizations of Indian coal using FE-SEM and EDS and its relevance to coal washability, JMMF, JMMF, Special issue 2018, P 397-404*

28. *K M P Singh, Priyanka Kumari Ujala, T Gourichran, G V Ramana, Anandaya Sinha and Pradeep K Singh; A New approach for studying the washability characteristics through online coal washability analyser, JMMF, Special issue 2018, P 388-396*

Blast Design Parameters for Rock Fragmentation–A Key to Productivity

Murari P Roy [1], Pradeep K Singh [2], Suraj Kumar [3], Ranjit K Paswan [4]

ABSTRACT

This paper is based on the S&T project outcome conducted at four different coal mines of India viz. Nigahi Project of NCL, Sonepur Bazari Project of ECL, Kusmunda Project of SECL, and Samleshwari Project of MCL. In this paper, attempts were made to analyse the impact of fragment size distribution on the efficiency of excavators considering the basic blast design parameter, rock conditions, and explosive & accessories qualities. To arrive at conclusion, altogether 254 trial blasts were conducted at dragline and shovel benches with varying blast design parameters. The desired velocity of detonation (VOD) and density of explosives were determined for target rock based on the impedance matching matrix concept. The resulted fragmentation of each blast was analysed using image-based fragmentation software during different stages of mucking operation. The experimental sites rocks were categorized into three categories viz. soft, medium-hard and hard formation based on the in-situ rock mass data collected at the sites and physicomechanical properties of the rock samples determined at the laboratory. The outcome of the study will help the mining industry in optimizing blast design parameters considering the optimal fragment size distribution.

Keywords: *Blast design parameter; dragline and shovel; Impedance; Rock fragmentation; fragment size distribution.*

INTRODUCTION

Muck-profile due to blasting is one of the indicators for a good or bad blast as the operational cost of other subsystem depends on the achieved blast fragmentation. Rock fragmentation distribution influences the loading and hauling efficiency of excavators along with crushing and grinding of ore in the beneficiation process [1]. Hence, to achieve the target fragments there should be appropriate knowledge of the interaction of the blast design parameters and selected explosives with the relevant rock of the blasting sites. The objective of a blast is to generate optimum muck pile for excavators so that there should be efficient loading, transportation, and milling operations. [2,3]. The overall production cost of a mine has a minimum value at Optimal fragments size distribution [4, 5]. Instead of optimum fragments size, knowledge of the size distribution and rock mass conditions for the particular blast is important for adapting any blast [6]. Some characteristics of size reduction and its impact on mineral liberation were discussed

[1,2,3,4] *CSIR-Central Institute of Mining & Fuel Research, Dhanbad-826 015, Corresponding author: mproy14@yahoo.com and mproy@cimfr.nic.in*

by Spathis [7, 8], which was mainly based on the assumption of size distribution, mean size, oversize, fine, and measurement procedure to describe the area of estimation and assessment.

Many researchers cited the Kuz-Ram model as a fragmentation prediction tool which is the resulting model based on Kuznetsov [9] and Rosin-Rammler equation [10] modified by Cunningham [11, 12]. Based on the model, fragment size distribution can be quickly estimated by blast designer which is based on the given rock parameters, blast design parameters and charge factor. An attempt was made to understand the relationship between basic blasts parameters and rock fragment size distribution at four different coal mine of India. The site specifications of each blast at all the mine were recorded and required modifications were made to achieve better fragmentation. Pre- and post-blast face profiling were recorded to calculate the shape and size of the muck pile. To achieve better fragmentation, photographs of each blasted muck pile were taken and then analysed with the help of image analysis software. The loading and hauling cycle time were recorded. The fragmentations achieved were analysed for different blast design parameters so that a general guideline can be established for improvements in mining operations.

DETAILS OF EXPERIMENTAL SITES

Sonepur Bazari Project (SBP) being a part of Eastern coalfields Limited and is mapped along the Raniganj Coalfields (Eastern part). The topography of the mine is marked by a synclinal basin having Gondwana deposits of upper Permian age lying unconformably over the archean basement. The area consists of various faults of varied magnitude. The trend of the beds is E-W, thicker in the east, dipping 3° to 11° S. The deposits of the mine are managed in 10 horizons assigned as seams R-I to R-X ranging in thickness from 1m to11m, out of which coal seams labeled as R-IV to R-VII are exposed in the mine.

Nigahi Project (NGH) is situated in the Sidhi district of Madhya Pradesh and forms a part of Singrauli Coalfields. It is located to the west of Jayant project as discussed further. The major part of the mine is deposited by lower Gondwana sediments of Permian age. These deposits overlie unconformably above the meta-sediments of Archean age, constituting schist, phyllites, quartzites, and gneisses as dominant lithology. Bottom & top coal seams of Purewa, the combined seam of Purewa and seams named Turra are the three coal seams found with thickness 11-12m, 7-9m, and 13-17m respectively. These seams are dipping 10-40° northerly having an E-W strike direction.

Kusmunda Project (KUS) has a flat terrain topography with some minor undulations. The coal seams area comprises of doubly plunging anticlinal trend. The dip of the strata ranges from 4°-10° in S and SW direction having strike NW-SE to E-W in a major part of the block.

The topography of the Samleshwari Project (SAM) is flat. The surface elevations within the block vary from 218 to 257 m above MSL. Three coal seams viz. Lajkura, Rampur, and IB seams found to occur in descending order from top to bottom in the area under consideration. Figure-1 depicts the map showing the experimental site.

METHODOLOGY AND BLAST DETAILS

Controllable and uncontrollable parameters affect the blasting in terms of energy utilization of explosives. In this study, for monitoring blast efficiency in terms of fragmentation, firstly, intact rock properties, and existing blast design parameters were studied for each mining bench at all experimental sites. Secondly, muck pile photographs after the blast were taken and the cycle time of excavators was recorded during the mucking operations. Finally, analysis of the blast fragment size predictions with image analysis tools [13, 14] was conducted for each blast. The rock samples were collected from the experimental sites and the mechanical properties of the rocks were determined in the laboratory for designing the blast based on rock strata. The obtained value of measured physicomechanical properties of the rocks of the different sites is presented in Table-1. Nigahi and Sonepur Bazari project have a dragline as well as shovel and dumper combination to tackle overburden whereas the Kusmunda and Samleshwari project has only shovel and dumper combination to tackle overburden. The summarized

Figure-1: Map showing study area locations

blast details for 254 trial blasts conducted at four different mines for dragline and shovel bench with varying blast design is shown in Table-2.

ANALYSIS OF RECORDED DATA

The basic blast dimensional parameters viz. Burden, Spacing, Hole depth, Hole diameter, Bench height, top stemming, etc. were collected from all the four experimental sites. The collected data from 254 experimental were further analysed to study the impact of design parameters on rock fragmentation. The analysis of rock fragmentation also carried out in terms of rock mass properties, type of strata conditions, and explosive properties.

Table-1: Physicomechanical properties of rock samples collected from the experimental sites.

SITES	NIGAHI PROJECT, NCL		SONEPUR BAZARI PROJECT, ECL		KUSMUNDA PROJECT, SECL		SAMLESHWARI PROJECT, MCL	
Rock Type	Sandstone	Shale	Sandstone	Shale	Sandstone	Shale	Sandstone	Shale
Compressive Strength	29.6-31.7	19.3-20.6	36.5-37.3	23.6-25.6	26.59	20.6-23.2	33.15	21.6-23.5
Tensile Strength	3.41-3.53	2.83-3.11	3.41-3.46	2.91-3.63	2.14	2.19-3.32	3.87	2.09-2.88
Density	2.01-2.05	2.25-2.40	2.28-2.32	2.21-2.46	2.01	2.16-2.24	2.16	2.20-2.26
Poisson's Ratio	0.21	0.32	0.23	0.31	0.25	0.32	0.24	0.30
Youngs Modulus	3.25-3.41	5.33-5.68	7.02-7.05	5.03-5.28	5.57	5.23-5.28	4.32	5.31-5.58

Table-2: Summarized details blast parameters and fragmentation at Experimental Sites

BLASTING DETAILS		NGH	SBP	KUS	SAM
Number of blasts		27	63	36	128
Number of blast holes detonated in a round		8 - 452	4 - 500	4 - 138	12 - 70
Depth of blast holes	Dragline	42 - 43.5	21 - 31	-	19
	Shovel	9.5 - 19	4.5 - 20	4.2 – 20.5	4.4 – 8.3
Total weight of explosives detonated in a blast round (kg)		3360 - 236290	800 - 29480	2020 - 53400	505 - 13040
Explosive weight per delay detonated (kg)		420 - 6400	65-1380	45-1140	30-1050
Charge factor (kg/m^3)		0.46-0.74	0.38-0.78	0.34-0.72	0.31-1.67
Mean fragment size (m)		0.412-0.856	0.353.0.796	0.212-1.158	0.125-0.692
Index of uniformity (*n*)		1.29-2.23	1.096-2.546	1.34-2.19	1.34-2.19

The recorded data were also analyzed in terms of excavator performance.

Analysis of Explosive relating to rock mass

The knowledge of explosive characteristics plays a very pivotal role in achieving desired blast performance for a given geo-mining condition. The rock mass of the experimental sites was classified into three categories as soft, medium-hard and hard formation. The impedance of rock and explosives were calculated to match the acoustic impedance, Z, for knowledge of rock and explosive interactions. The rock impedance (Z_1) may be approximated by the product of rock propagation velocity and rock density whereas explosives impedance (Z_2) may be approximated by the product of detonation velocity of explosives and its density. To maximize the transfer of explosives energy to the rock mass, the impedance of the explosives should be close to that of the rock mass. When the impedance of the explosives is close to that of the rock, explosives energy is better transmitted to the target rock. Under such conditions, the maximum pressure transmitted to the rock is nearly equivalent to the detonation pressure generated inside the pressurized borehole. This is the standard case for the massive rock formation. It was observed that in the case of highly jointed and/or fractured rock mass, the energy utilization of the explosives with high VOD resulted in over crushing of the rock fragments. The desired minimum VOD of explosives has been computed by matching or equalizing the rock impedance and explosives impedance matrix. The calculated values of acoustic impedance and explosive impedance are given in Table-3.

The acoustic impedance data reveals that the explosives being used at the respective mines are adequate for the medium-hard to hard formation whereas for soft formation explosives having a velocity of detonation in the range of 3000 m/s to 3500 m/s will be more effective in terms of better energy transmission for fragmentation and less generation of vibration.

Rock Fragmentation Analysis

Rock fragmentation analysis output is a good indicator for evaluation, efficiency and productivity of surface mining. Rock fragmentation analysis was performed at different stages of mucking operations. At first, it was analysed by visual inspection just after

Table-3: Acoustic Impedance versus Explosive Impedance

Experimental Site	Recorded VOD (m/s)	Explosive density (g/cc)	Explosive impedance [kg/m²s]	Acoustic impedance [kg/m²s]			Impedance ratio		
				Soft formation	Medium hard formation	Hard formation	Soft formation	Medium hard formation	Hard formation
NGH	4894.7-5125.3	1.1	5384.2-5637.8	3075	4950	5280	1.75-1.83	1.08-1.14	1.02-1.06
SBP	3807.6-5228.0	1.1	4188.4-5750.8	3420	5140	5412	1.22-1.68	0.81-1.12	0.77-1.06
KUS	4451.9-4647.4	1.1	4897.1-5112.1	3015	4752	4928	1.62-1.69	1.03-1.07	0.99-1.03
SAM	4307.0-4341.5	1.1	4737.7-4775.6	3240	4840	4972	1.46-1.47	0.98-0.99	0.95-0.96

the blasts. Secondly, with image analysis software after taking photographs at regular intervals during mucking operations. Finally, it was analysed on the performance of excavator involved in mucking operations. The views of the blasted muck resulted in experimental sites are presented in Photograph -1.

Assessment based on visual inspection

The primary prediction of blast fragmentation just after the blasts was done by the visual inspection which includes the inspection of overall muck pile in terms of muck pile size and shape, the average mean fragment size, uniformity index, percentage of oversize or fines, etc. but this method is tedious and not much accurate. Muck pile profile has great impacts on the production and productivity of surface mining operations. Pre and post-blast bench profile helps us to evaluate the performance of the blast. Muck pile characteristic mainly depends on bench specification, geometry, desired swell distribution and excavator characteristics, etc.

Assessment and analysis using image analysis software tools

The rock fragment sizes were analyzed using Wip-frag software of M/s WipWare Inc., Canada [13] and Split desktop software, USA [14]. The output of the rock fragmentation was analysed based on exposed fragmented lumps, mean, mode, minimum and maximum size of fragmented rocks,

Photograph-1: A view of the blasted muck resulted in different experimental sites

sieve analysis in terms of percentile size viz. D_{10}, D_{25}, D_{50}, D_{75} & D_{90}. (D_{10} is the ten-percentile, which indicate that 10% by weight of the sample is finer and rest 90% coarser, hence 10% by weight of the sample would pass through a sieve and so on for another percentile).

The outputs of the detailed analyses of the fragment size are depicted in Figure-2 and Figure-3. The mean size of the block at all the sites was in the range of 0.125-1.158 m (diameter equivalent to a sphere) and the range of the most common size of the block is 0.247-0.584 m (diameter equivalent to a sphere) after excluding the fine size of the fragmented rock in the analyses. The maximum size of the boulder is 2.154m (diameter equivalent to a sphere).

The analysis of the size of the fragments of the blasts and results was further compared with the blast design parameters to quantify the effect of basic blast design parameters on the fragmentation of rock mass. This scientific approach subsequently leads to an improvement in the efficiency of operating excavators and the productivity of the mine.

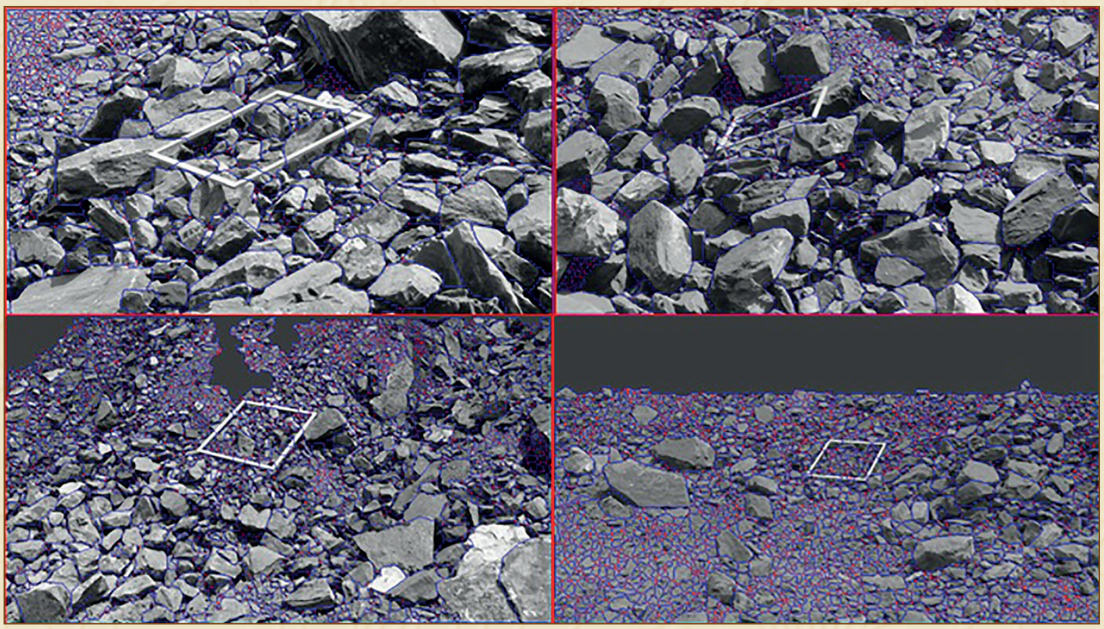


Figure-2: Netting of the block size of fragments resulted in different experimental sites

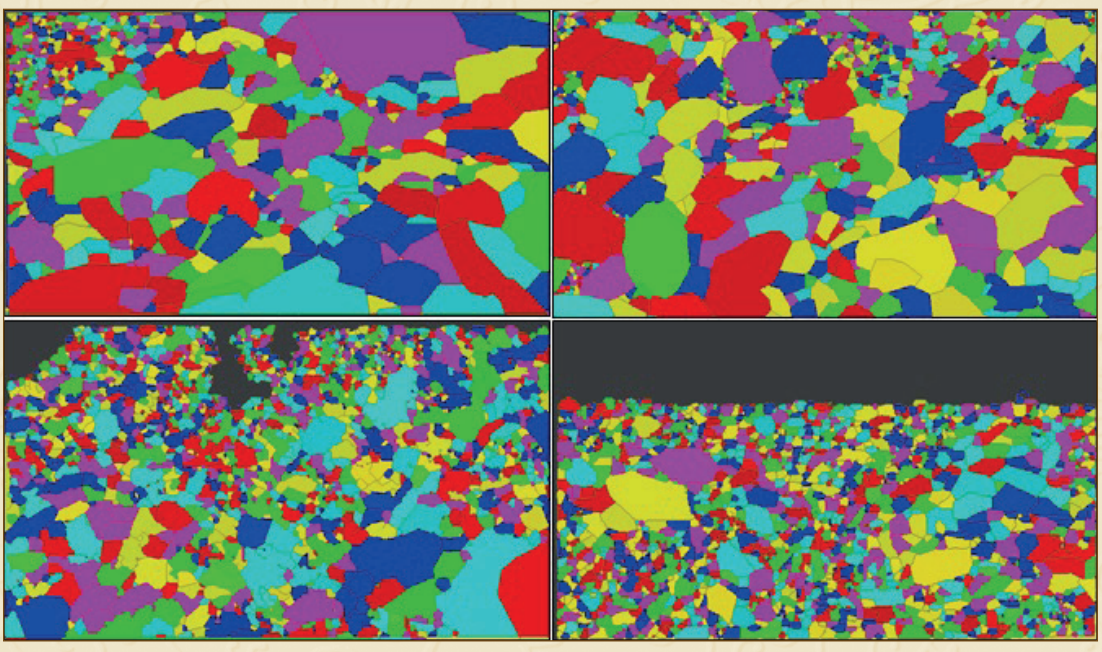


Figure-3: Contouring of block sizes of fragments resulted in different experimental sites

Assessment and analysis based on excavator performance

Excavator performance includes dig time, hauling time, swing time, dumping time and return time. The cycle time of the excavator is greatly affected by blast fragment size. It would be convenient to excavate the muck pile from the operating bench/ face to the dumper if it has an optimal index of uniformity. The cycle time of excavator was recorded during mucking operation at each blasted face and average cycle time was compared with the mean fragment size and index of uniformity (Fig.- 4 and Fig.- 5). The plots reveal that the average cycle time of excavator decreases with a decrease in average mean size and also decreases with an increase in the index of uniformity (n).

Analysis of blast design parameters with resulted fragment size

The efficiency of the blasts depends on the rock mass properties and blasting parameters. The controllable parameters of the blast are the regulating parameters for rock fragmentation. Hence, a blast designer needs to have adequate knowledge of the dependency of blast design parameters with the resulted fragment size. The blast design parameters for all the 254 blasts were compared individually with the size of the respective fragments. The basic

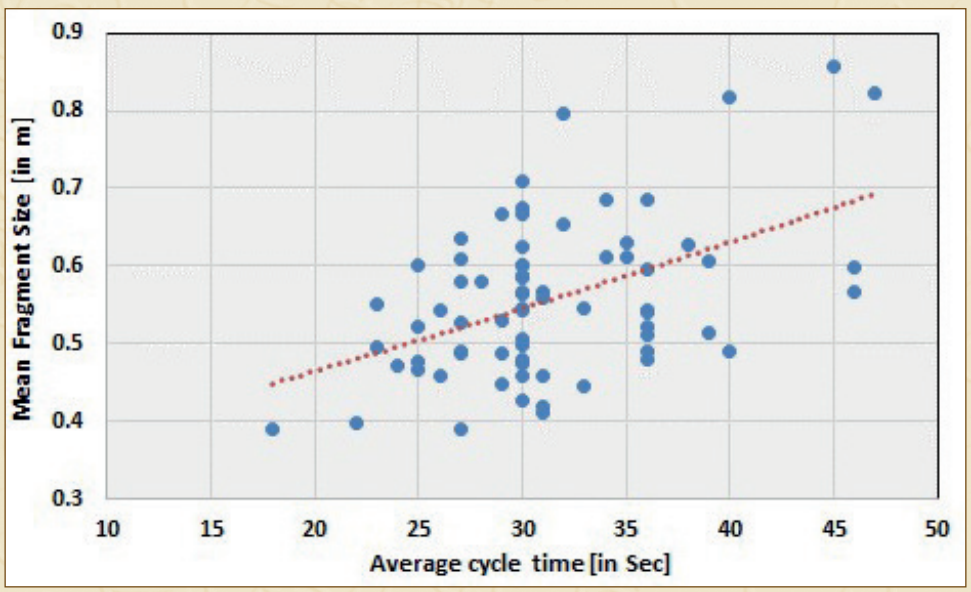


Fig.- 4 : The plot of the average cycle time of excavator vs average mean fragment size

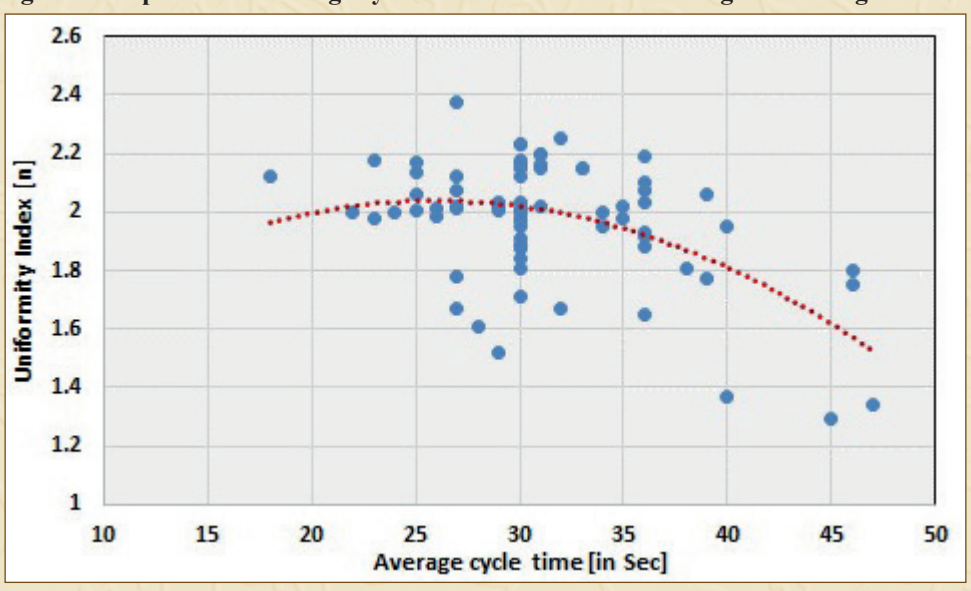


Fig.- 5 : The plot of the average cycle time of excavator vs index of uniformity (n)

parameters considered for the analysis are spacing to burden ratio, the burden to hole diameter ratio, top stemming length, stiffness ratio, type of explosives and its quantity, mode of initiation and charge factor. The comparative results of the analysis are depicted in Fig.- 6.

Analysis of Decking and Continuous charging on Mean fragment size

Experimental blasts were conducted at Nigahi Project and Sonepur Bazari project to assess the impact of decking on rock fragmentation. The results of experimental blasting for decked and continuous explosive charges are compared with the mean fragment size. The plot of mean fragment size recorded for decked charging and continuous charging for Nigahi project and Sonepur Bazari Project is depicted in Figure-7 and Figure-8 respectively.

Establishment of the relationship between rock properties, charge factor and rock fragment size

The term charge factor/powder factor is often used to relate explosive mass and consequently broken rock. In general, with increasing charge factor the average fragment size decreases for a given rock mass volume although the charge factor/powder factor criteria itself are not considered significant decisive parameters for designing a good blast. Based on the extensive field trials of 254 blasts, an attempt was made to establish the charge factor/powder factor for a particular blast after performing the details analysis of fragment size, muck profile and loading efficiency of excavators. During the study period charge factors varied in between 0.308 kg/m3 and 0.78 kg/m3 for dragline and shovel bench blasting depending on the rock formation (i.e. soft, medium-hard and hard formation), bench height and blast hole diameter. Recommendations were formulated based on the results obtained from the four experimental sites and presented in Table-4.

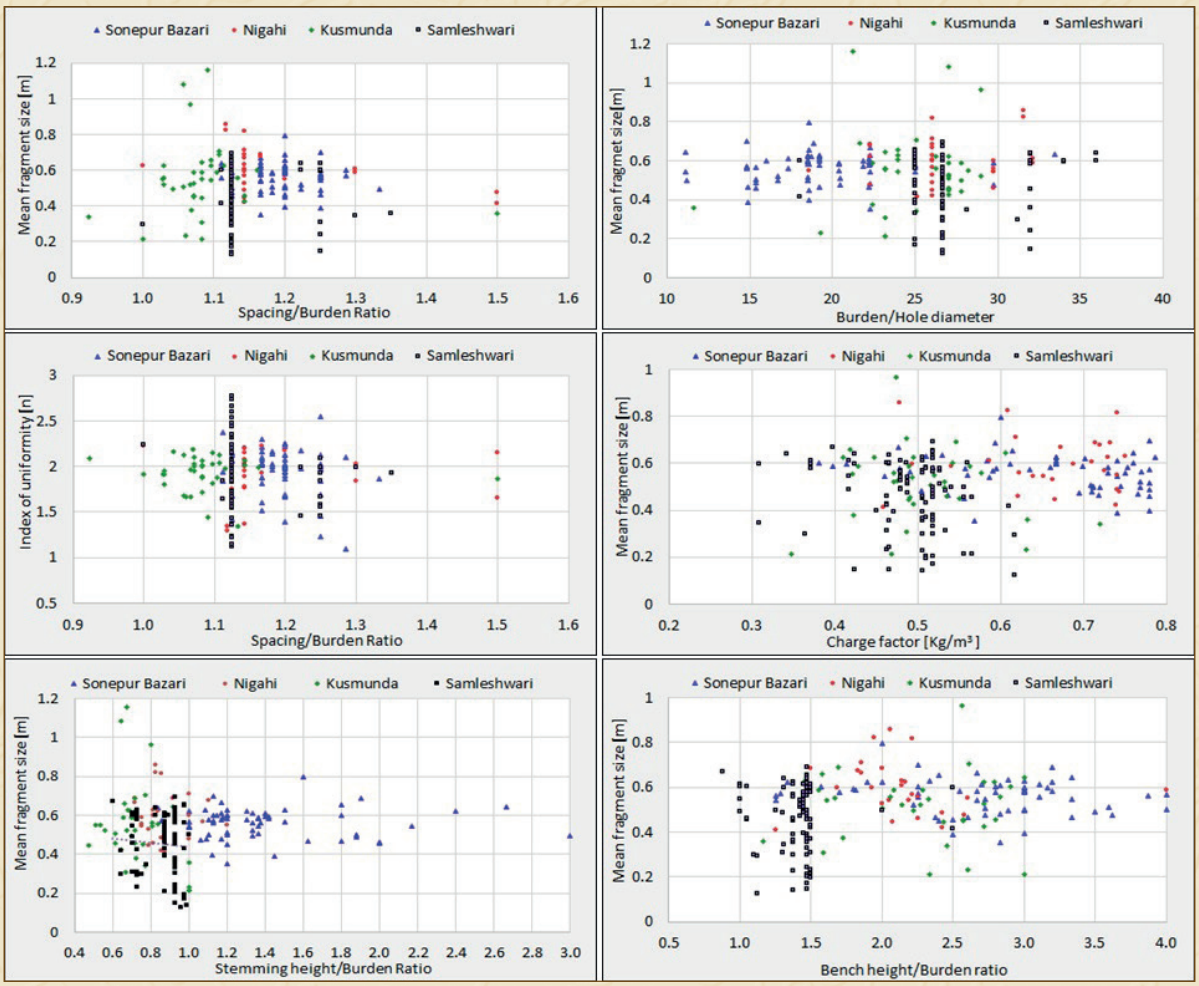


Fig-6 : The comparative plot of blast design parameters and mean fragment sizes

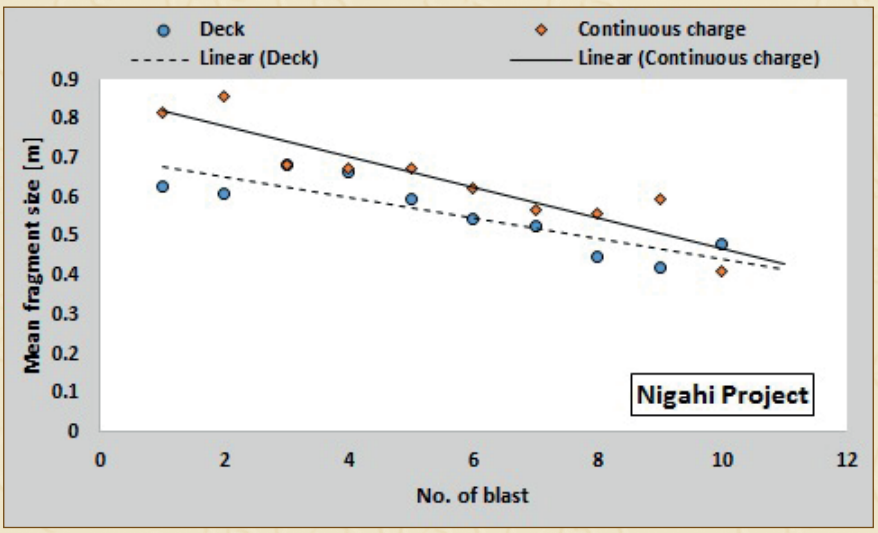


Fig. -7: The plot of average mean fragment size with deck blast and non-deck blast Nigahi Project, NCL

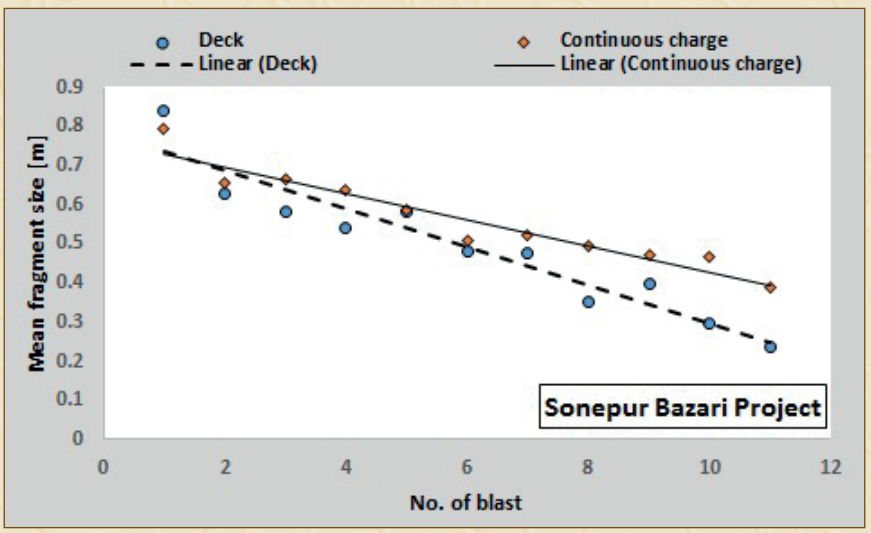


Fig. - 8 :The plot of average mean fragment size with deck blast and non-deck blast at Sonepur Bazari Project, ECL.

Table-4: Recommended charge/powder factors and hole diameter for various bench height of different rock formation

Rock formation	Bench height (m)	Recommended hole diameter (mm)	Recommended charge factor (kg/m^3)	Recommended Powder factor (m^3/kg)
Soft [P-wave: 500-1500 m/s]	6 -12	100-160	0.31 -0.45	2.2 - 3.2
	>12 – 18	250 - 270	0.42 - 0.5	2.0 - 2.4
Medium hard [P-wave:1500-2200m/s]	6 -12	100-160	0.53 - 0.62	1.6 - 1.9
	>12 – 18	200 - 270	0.56 - 0.67	1.50 - 1.8
	>18 – 27	260 - 270	0.59 - 0.69	1.45 - 1.7
	>27 – 45	270- 311	0.62 - 0.71	1.4 - 1.6
Hard [P-wave:>2200 m/s]	6 -12	100-160	0.56 - 0.67	1.5 - 1.8
	>12 – 18	200 - 270	0.59 - 0.69	1.45 - 1.7
	>18 – 27	260 - 270	0.62 - 0.71	1.4 - 1.6
	>27 – 45	270- 311	0.65 - 0.74	1.35 - 1.55

RESULTS AND DISCUSSION

The extensive study was conducted at the four experimental sites during the study period and the fragmentation achieved were analysed for different blast design parameters so that a general standard can be established for improvements in mining operations. The major outcomes obtained from the study are as follows:

- From the observation of impedance value, it was observed that for getting optimal fragmentation results, 80 % of the acoustic impedance value is suitable. When the impedance of the rock is less than the impedance of the explosives, then the major part of the explosive's energy transmitted to rock mass will be reflected as tensile wave and will be responsible for the breakage of the rock.
- From the Plot of the cycle time of excavators with mean fragment size and index of uniformity, it is clear that the average cycle time of excavator decreases with a decrease in average mean size and with an increase in the index of uniformity (n).
- The experimentation with deck charge and continuous charge imply that the mean fragment size was less in case of decked charges in comparison to continuous charging. The possible reason is that in case of decked charging the explosive column distributed properly throughout the blasthole column.
- Based on the analyses of recorded blast design and fragmentation analysis data it was concluded that for soft formations of the experimental sites the hole diameter of 100 mm to 160 mm will be more effective for the benches having heights 6 m to 12 m and for benches having bench height of >12 -18 m, the recommended hole diameter is 250 – 270 mm. It was concluded that for medium hard and hard formation the blasthole diameter for bench height of 6-12 m, > 12-18 m, > 18-27 m and > 27-45 m are 100-160 mm, 200-270 mm, 260-270 mm and 270-311 mm respectively for optimum rock fragmentation.
- The powder factor for soft formations having bench height of 6-12 and > 12-18 will be in the range of 2.2-3.2 m^3/kg and 2.0-2.4 m^3/kg respectively. For the medium-hard formations of bench height of 6-12 m, >12-18 m, > 18-27 m, and > 27-45 m the powder factor should be in the range of 1.6-1.9 m^3/kg, 1.5-1.8 m^3/kg, 1.45-1.7 m^3/kg and 1.4-1.6 m^3/kg respectively. Similarly, for hard formations of bench height of 6-12 m, >12-18 m, > 18-27 m, and > 27-45 m the powder factor in the range of 1.5-1.8 m^3/kg, 1.45-1.7 m^3/kg, 1.4-1.6 m^3/kg and 1.35-1.55 m^3/kg respectively for better rock fragmentation.

CONCLUSION

The fragmentation of rock and the blast design parameters are mutually related and desired fragmentation will only be achieved if the blast design parameters are scientifically analysed through experimentations in the field. The acoustic impedance data reveals that the explosives being used at the respective mines are adequate for the medium-hard to hard formation whereas for soft formation explosives having velocity of detonation in the range of 3000 m/s to 3500 m/s will be more effective in terms of better energy transmission for fragmentation and less generation of vibration. The mean fragment size was lesser in case of decked charges in comparison to continuous charging. The average cycle time of excavator decreases with a decrease in average mean size and with an increase in the index of uniformity.

REFERENCES

1. *Michaud, P R; Lizotte, Y C and Scoble, M J. Rock Fragmentation and Mining Productivity: Characterisation and Case Studies. In: Proceedings of 23rd Annual Conference on Explosives and Blasting Technique 1997. pp 275-279 (International Society of Explosive Engineers: Austin).*
2. *Singh SP, Narendrula R, Duffy D. Influence of blasted muck on the productivity of the loading equipment, in 3rdEFEE conference on explosives and blasting, 2005; pp 347–353. (https://www.researchgate.net/publication/268816506_Influence_of_blasted_muck_on_the_performance_of_loading_equipment)*

3. *Singh PK, Roy MP, Paswan RK, Sarim Md, Kumar S, Jha RR. Rock fragmentation control in opencast blasting. J Rock Mech Geotech Eng. 2016; 8(2): pp -225–237. (https://doi.org/10.1016/j.jrmge.2015.10.005)*

4. *Mackenzie, A.S., 1967. Optimum blasting. In: Proceedings of the 28th Annual Minnesota Mining Symposium. Duluth, MN, pp. 181–188.*

5. *Morin MA, Ficarazzo F. Monte Carlo simulation as a tool to predict blasting fragmentation based on the Kuz-Ram model. Computers & Geosciences 2006; 32(3): 352–359. (https://doi.org/10.1016/j.cageo.2005.06.022)*

6. *Engin, I C. A practical method of bench blasting design for desired fragmentation based on digital image processing technique and Kuz-Ram model, in Proceedings 9th International Symposium on Rock Fragmentation by Blasting FRAGBLAST – 9. Granada, Spain, September 13-17 2009; pp 257-263 (https://miningandblasting.files.wordpress.com/2009/09/a-practical-method-of-bench-blasting-design-for-desired-fragmentation-based-on-digital-processing-technique-and-kuz-ram-model-i-c-engin.pdf)*

7. *Spathis AT. Formulae and techniques for assessing features of blast-induced fragmentation distributions, in Proceedings 9th International Symposium on Rock Fragmentation by Blasting FRAGBLAST–9, Granada, Spain, September 13-17, 2009, pp 209-219.*

8. *Spathis AT. A brief review of blasting effects on comminution and mineral liberation. Orica Technical Report No. 58561, Kurri Kurri, Australia 2002.*

9. *Kuznetsov VM. The mean diameter of the fragments formed by blasting rock. Soviet Mining Science 1973; 9(2):144-48.*

10. *Rosin R, Rammler E. Laws governing the fineness of powdered coal. J Institution Fuel. 1933; 7:29-36.*

11. *Cunningham CVB. The KuzeRam model for prediction of fragmentation from blasting. In: Holmberg R, Rustan A, editors. Proceedings of the 1st International Symposium on Rock Fragmentation by Blasting; 1983. p. 439-53.*

12. *Cunningham CVB. Fragmentation estimations and the KuzeRam model - four years on. In: Proceedings of the 2nd International Symposium on Rock Fragmentation by Blasting; 1987. p. 475-487.*

13. *Wip Frag 1986 (https://wipware.com/products/wipfrag/)*

14. *Split Desktop 1997 (https://www.spliteng.com/products/split-desktop-software/)*

NOTICE TO THE AUTHORS

As per the decision taken, the payment of honorarium to the authors whom articles are published in this magazine through multi-city cheques has been stopped. In future, it will be done through NEFT/RTGS only.

As such authors are requested to submit the following details alongwith their articles :

Name of a/c holder-
Name of bank & Bank account no-
IFSC Code-
Mobile no/e-mail id-

Authors are also requested to send only Unpublished and Original articles for publication in 'Minetech' and a declaration in this respect is to be furnished alongwith the article. For any clarification pl contact HoD (IMS), CMPDI at Mob no. 8987788928 or e-mail-hodims.cmpdi@coalindia.in

Self-Advancing Goaf Edge Support (SAGES) for Depillaring Operation in Underground Coal Mines

Upendra K. Singh [1], Dheeraj Kumar [1], N.V.N. Reddy [2]

ABSTRACT

A medium duty 2x200t capacity Self Advancing Goaf Edge Support (SAGES) has been designed and developed for depillaring operations in underground coal mines jointly by Indian Institute of Technology (ISM), Dhanbad and Jaya Bharat Equipment Pvt. Ltd., Hyderabad. Financial support was provided by the Ministry of Coal, Govt. of India. SAGES are operated by radio remote control which eliminates workers from exposure to hazardous roof conditions associated with withdrawal and setting up of conventional supports. They facilitate higher percentage of recovery of coal pillars. They can replace the prevailing system of closely spaced cogs erected on steel frames with corner props backed up by a guard row of closely set props at each Goaf Edge during depillaring operations in underground coal mines. The SAGES have been successfully undergone field trails in depillaring panels of (a) Bastacola underground coal mine, Bharat Coking Coal Limited (BCCL), Dhanbad and (b) RK7 Incline underground coal mines, Srirampur Area, Singareni Collieries Companies Limited (SCCL). During the field trials, several modifications in design were incorporated in SAGES. The final design specification is given in Table-1. This paper describes salient features of SAGES, their field trial and cost benefit analysis.

A Discounted Cash Flow (DCF) analysis of cost benefit of use of SAGES reveal that the use of SAGEAS at all the Goaf Edges in a panel will lead to economic benefits to the mines besides enhanced safety of work places near the Goaf edges.

After the successful field trial of SAGES at RK7 Mines of SCCL, the Directorate General of Mines Safety (DGMS) has approved for the full-scale deployment in underground coal mines.

The development of SAGES for safe, economically and efficient extraction of locked in coal in pillars in underground coal mines paves the path of Make in India mission for manufacturing of equipment for mechanized underground coal and metal mines in India.

[1]Department of Mining Engineering, IIT (ISM), Dhanbad-826004, email- singhuk@iitism.ac.in, dheeraj@iitism.ac.in,
[2]Jaya Bharat Equipment Pvt Ltd, Hyderabad.

Table-1: Specifications of SAGES model SAGES-200t-M02

Sl. No.	Item	SAGES-200t-M02
1	Support capacity	2x200t
2	Hydraulic legs	2 nos, 200mm dia bore
3	Hydraulic pressure in legs at 200t load on support	318 kg/cm^2
4	Setting load of the support	100t
5	Hydraulic pressure in legs at the setting load	150 kg/cm^2
6	Support Closed height	1850mm
7	Support Extended Height	3200mm
8	Overall Length x width	2500 x 1500mm
9	Canopy Length x width	2000 x 1400mm
10	Canopy Tilt	Axial: 15^o , Lateral: 15^o
11	Base Length x width	720 x 680 mm (in contact with the floor
12	Support Density	71.4 t/m^2 (7.1 kg/cm^2)
13	Floor Pressure of the base at full load	400 t/m^2 (40 kg/cm^2)
14	Traction max. gradiability	35 degrees
15	Electric Motor	18.5 KW
16	Hydraulic Pump	2 x 31 LPM
17	Crawler Speed	800 m/h
18	Track Drive Torque at Sprocket	12,440 N-m
19	Drawbar Pull	10,080 kg
20	Support weight:	9 t
21	Support operation:	RF remote control

INTRODUCTION

Safe extraction of locked coal in standing pillars (depillaring) in underground coal mines is only possible by effective roof control and proper support design. Accident due to roof collapse (strata movement) in underground coal mines had been a major concern for the mining industry & its largest contributing factor of underground coal mine accident. To reduce strata movement monitoring of strata & proper design of a proper support system is essential. Due to non-availability of light weight, low cost and reliable Mobile Roof supports, the Coal Mining industry, in India, is facing many hardships including safety concerns in dealing with supports of the Goaf edges while extracting coal from underground coal mines by depillaring with caving of the strata.

IIT (ISM), Dhanbad in collaboration with Jaya Bharat Equipment Pvt. Ltd., Hyderabad has unveiled a medium duty 2x200t capacity Self-Advancing Goaf Edge Support (SAGES) for depillaring operations in underground coal mines in the EOI project of Ministry of Coal, Govt. of India. To differentiate them from the conventional Mobile Roof Supports, they are named as “Self-Advancing Goaf Edge Support” (SAGES). The

unique design of SAGES facilitates substantial reduction in their weight and cost up to 70% of the mobile Goaf Edge supports available in the international market. In the conventional mobile supports, the crawlers are designed to withstand the rated capacity of support including its weight. In the present support (SAGES), Fig.-1, the base and the crawlers are designed such that the support load is transferred to the base only and crawlers are free. After release of load and lowering of canopy, the base is lifted and the support weight is transferred to the crawlers. Thus, the crawlers in the present support system are designed to carry the weight of the support only. This feature of the SAGES makes it lighter and cheaper compared to that of the mobile supports available in the international market. Further, the SAGES use two hydraulic cylinders with canopy stabilizers compared to that of four to seven hydraulic cylinders in conventional mobile supports.

With the application of the above-mentioned unique features i.e., the base lift mechanism and canopy stabilization, the SAGES has become compact, lightweight and cost effective with minimal maintenance. The hydraulic circuit of SAGES is operated by a self-contained power pack through solenoid valves. The solenoid valves are operated by a RF based remote hand set unit from a distance up to 30m. The SAGES are covered from three sides by foldable steel plates for preventing the coal and rock debris entering inside the support during side spalling and rock falling from the roof. An electronic data logging and display system having battery backup unit, facilitates continuous monitoring of the roof load and convergence. An audio-visual warning system is in-built into the system for giving warnings related to status of strata load on supports.

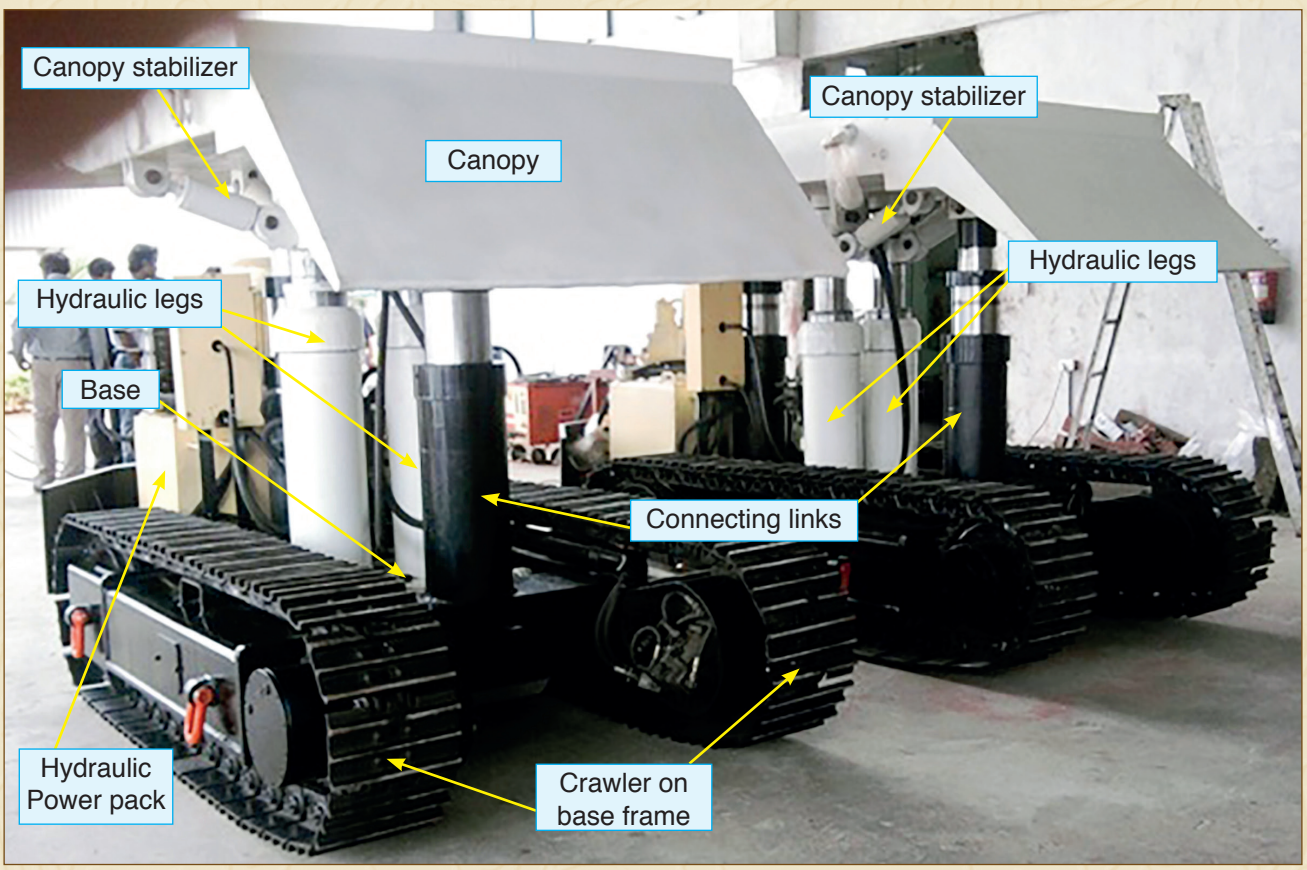


Fig.-1: Components of SAGES

SELF ADVANCING GOAF EDGE SUPPORTS (SAGES)

The developments of the SAGES were progressive. The SAGES were designed and developed in S&T Project of Ministry of Coal, GoI in Phases I and II. In Phase I, SAGES were deployed in Bastacola mine, BCCL (having average thickness of the coal seam between 5-6 m) for their field trials. Bord & Pillar development was done along the floor with 4.5m wide and 3m high gallery. The roof consisted of coal. During the field trials, the support performance was evaluated. Accordingly, modifications in the SAGESs were made. However, the study was limited to support performance under coal roof with average gallery height of 3m. The influence of SAGESs on the ground behavior at goaf-edge were not carried out during this phase. At the same time, economic evaluation of deployment of SAGES in the depillaring panels were also beyond the scope of the study.

In the above backdrop, another project was taken under Phase – II with an objective to carry out field trials of 6 nos. of SAGES in depillaring panel of a 2.2 to 3.1m thick seam with sandstone as immediate roof.

Important Features of SAGES

Major sub-assemblies (Fig.-1)

a. Crawler driven under carriage with an integral Power Pack, Electrical control box, Links and Plough

b. Base with Double Telescopic Legs.

c. Canopy with Stabilizers

The unique design of the Support permits the "Base" to slide inside the under carriage

a. In "Support mode", when the Support Legs are extended, the base gets lowered and rests on the floor. Further, leg extension lifts up the canopy till it touches the roof.

b. In "Mobile mode" when legs are lowered, first the canopy gets lowered and later the base gets lifted up.

c. In "Support mode" the roof load directly gets transmitted to the floor through canopy, legs and base.

Remote control

- The solenoid operated direction control valves can be actuated by a remote radio-transmitter through a radio-receiver located inside the F.L.P control box.

Digital display and monitoring

a. Continuous digital Load and convergence display

b. A push button switch pressed twice in one second to initialize the convergence to zero.

c. Dial type load level indicator for each leg is installed above the FLP box.

d. Audio visual warning as given in Table-2. The warning conditions can be rest. Continuous Load and convergence data logging unit in side FLP enclosure

e. Battery backup for the data logging system for duration of 10 days.

Table-2: Audio Visual Warning matrix

Sl.No.	Condition	LEDs			Audio
		Green	Yellow	Red	
1	50 t < Load < 150 t	Glow	OFF	No action	No action
2	150t <= Load <190 t	OFF	Glow	No action	No action
3	Load > = 190 t	OFF	Glow and blink	No action	No action
4	10 mm < Conv <20 mm	No action	No action	Glow	Slow Beep
5	Conv >= 20 mm	No action	No action	Glow and blink	Fast beep

Other features

a. A pilot operated non-return valve (NRV) is fitted in each leg. This NRV ensures positive pressure in the legs when the pumping is stopped and power to the support is disconnected (Fig.-2).

b. A yield valve in each leg allows the support to yield at the rated load of 200t.

c. The two through axial piston motors and planetary reduction gear boxes, wet multi disc parking brakes are integral to the drive modules. The parking brakes prevent inadvertent support movement on steep gradients. The tracks are powered by two independent pump outputs.

d. The support under carriage, canopy and base are box type fabrications using high tensile welded steel plates. The legs are made out of high strength cold drawn Steel (CDS) Tubes.

e. 550 volts 3-phase electrical supply to the SAGES is fed by a flexible trailing cable from a remotely placed Gate End Box.

Distinct Advantages of the SAGES over conventional Goaf Edge supports

- At a Goaf Edge, two SAGES provide positive setting load of 100 x 2 = 200t equivalent to 0.35 MPa to roof. This prevents early separation of layers of strata in the roof.
- Further, during yielding, two SAGES continue to apply 200x2 = 400t, equivalent to 0.70 MPa thrust to the roof allowing its controlled deformation. This prevents deterioration of working place at the Goaf Edge till SAGES are withdrawn, advanced and set to next Goaf Edge. Yielding of supports occurs when strata deformation imparts load on the support exceeding their capacity. Progressive extraction of slices usually leads to excessive deformation of the strata in its vicinity.
- Performance of SAGES is superior as a breaker line support compared to that of the rock bolts type installed at a Goaf Edge. A rock bolt type breaker line support loses its efficacy once the adjacent rib pillar yields and bed separation takes place in roof. In such cases, the SAGES remain effective in supporting the roof.
- SAGES eliminate workers from the exposure to the hazardous roof conditions associated with withdrawal and setting up of the conventional supports.
- SAGES eliminate the usage of timber. Therefore, the workmen are not required to transport and set up the timber supports at the Goaf Edges.

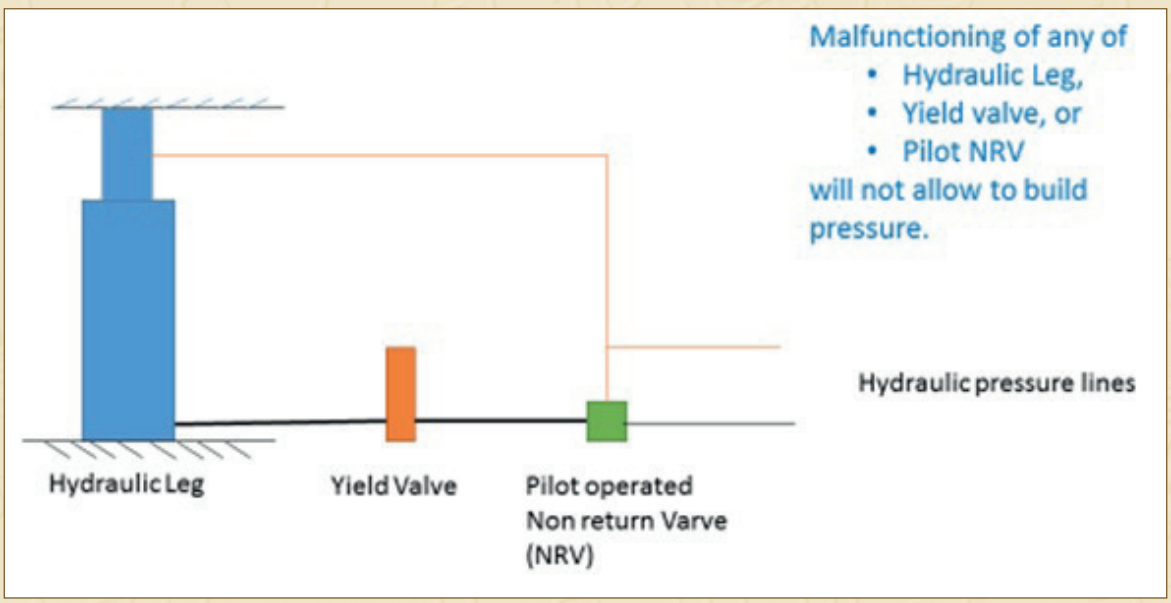


Fig.-2: Hydraulic circuit of a leg in SAGES

- SAGES can be set instantaneously within few minutes as compared to the conventional supports systems consisting of chocks and props requiring a shift time. Thus, available time for production is substantially increased.
- SAGES facilitate higher percentage of recovery of the coal pillar.

FIELD TRIAL OF SAGES

First field trial of two numbers of SAGES was undertaken in II-D panel, seam no. 2, Victory pit, Bastacola underground mine, BCCL (Fig.-3). Based on feedback data from the field trial, another two SAGES were modified and their field trail was conducted in I-D panel, seam no. 1 in Victory pit. The seam thickness was 4.5 m. Development galleries were 2.5 m high, 4.2 m wide driven along the floor leaving 2 m coal in roof. Two SAGES were installed against the coal roof at a Goaf Edge as seen in Fig.-3.

Some problems in operation were identified during the field trial such as poor traction and blockage of the control valves. A few shortcomings in design of SAGES were also identified during the field trial in Bastacola.

All six SAGES were refurbished on the basis on feedback from the field trial in Bastacola, BCCL. The final trial began on January, 2017 in panel 2AN13 (Fig.-4) in RK7 Incline mine, SRP area, SCCL under project SAGES Phase –II of the Ministry of Coal (MoC), Govt of India. Fig.-5 shows two SAGES installed in Block B of panel 2AN13. Details of the panel 2AN13 are given in Table-3.

Response of SAGES at Goaf Edges were continuously recorded at an interval of 1 minute using a Data logger installed in each SAGES. Once in a month data, load and convergence of SAGES were finally downloaded using a field computer and data storage space in the logger was emptied for storing the data for next one month. A typical response of SAGES with time is given in Fig.-6. We observe, in Fig-6, that yielding of legs in SAGES-1 begin at mid night of 28th September, 2017. The yielding process continued till morning of 30th September till it was withdrawn from the Goaf

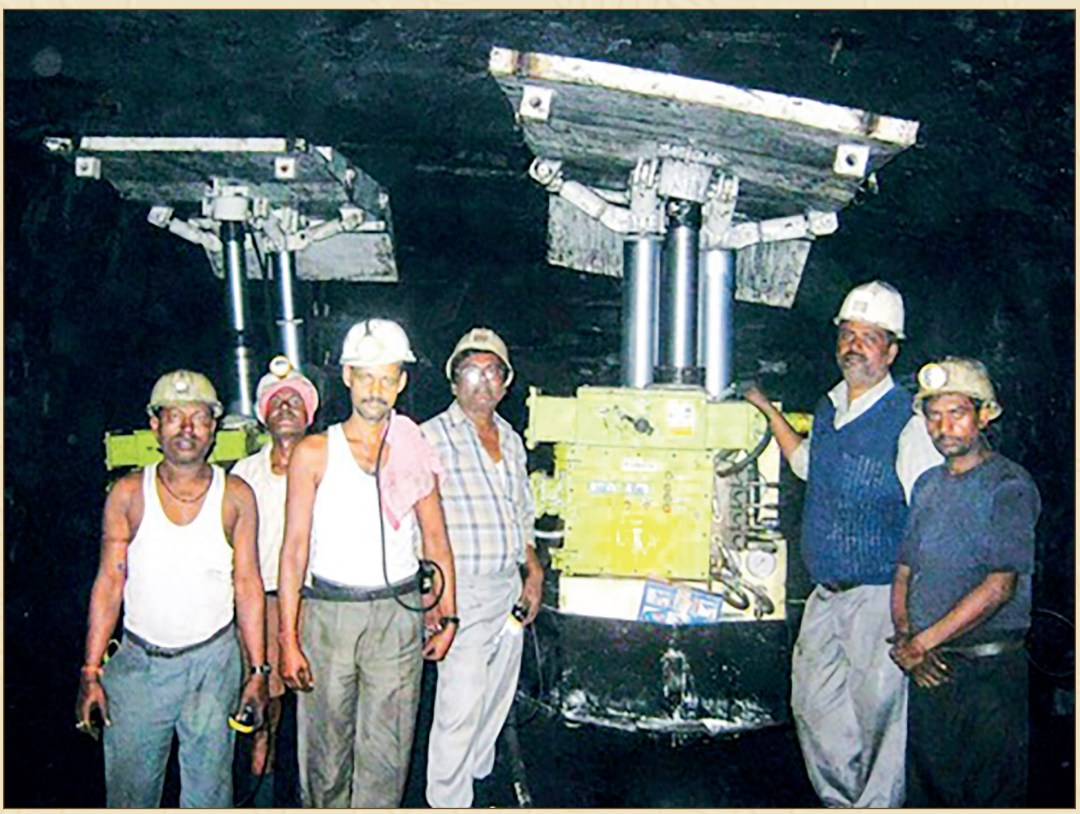


Fig.-3: SAGES at installed at a Goaf Edge in II-D panel, seam no. 2, Victory pit, Bastacola underground mine, BCCL

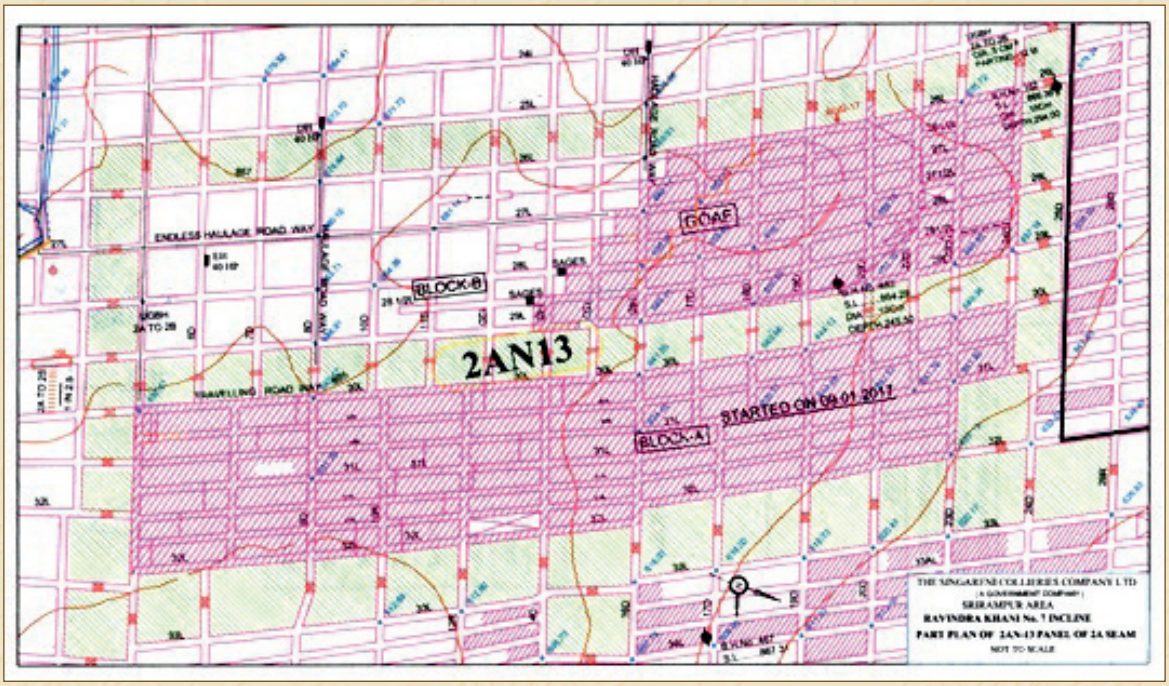


Fig.-4: Plan of Block A and Block B of panel 2AN13, RK7 underground mine

Table-3: Details of pillars and slices in panel 2AN13

S.No.	Average size of pillars (Centre to Centre)	30 m x 30 m
1	Panel width	30*3 = 90 m
2	Depth of cover	192 m – 244 m
3	Split width not more than	4.50 m
4	Slice width not more than	4.0 m
5	Rib width not less than	2.0 m
6	Last (out bye) rib width not less than	3.0 m
7	Average seam thickness	2.4 m
8	Date of commencement of panel	09.01.2017

Edge. SAGES-1 & 2 were installed in morning shift of 26th September at the Goaf Edge of slice no. 57 in Block A. SAGES-1 was set on the dip side and SAGES-2 was on rise side.

The setting load and load at time of withdrawal of the SAGES are plotted in Fig.-7 as function of slice number. SAGES 1 and 2 have been used as Goaf Edge support in 67 slices, i.e. they are subjected to 67 cycles of loading and SAGES 3 and 4 have been used as Goaf Edge support in 36 slices. The load and convergence data downloaded from the SAGES have been analysed. The responses of SAGES to strata Behaviour at Goaf Edges are summarized in Tables-4, 5, 6 and 7 respectively.

We find that :-

(a) In almost all slices, the setting loads were close to the specified setting load of 100 t (Table-4 and Fig.-7)

(b) The mean value of strata loads on the SAGES was 130t after completion of slices. However, more than 190t load close to it capacity was observed only in 6% and 14% of slices in rise and dip side SAGES respectively.

(c) Yielding of rise and dip sides SAGES have been observed in 8% and 19% of slices respectively.

(d) Mean value of roof floor convergence were 3 mm on rise side and 7 mm on dip side. More than 15mm convergence was observed only in 1% slice on rise side and 8% on the dip side.

(e) Ground condition at the working area remained normal and did not deteriorate up to 15 mm convergence at the Goaf Edges. Spalling of coal from ribs and galleries, fractures in roof and sounds rock fracturing do occur when convergence increases more than 15 mm at the Goaf Edges.

(f) Average slice extraction duration was 4 days.

Fig.- 5: SAGES 3 & 4 installed at a Goaf Edge in Block B of Panel 2AN13

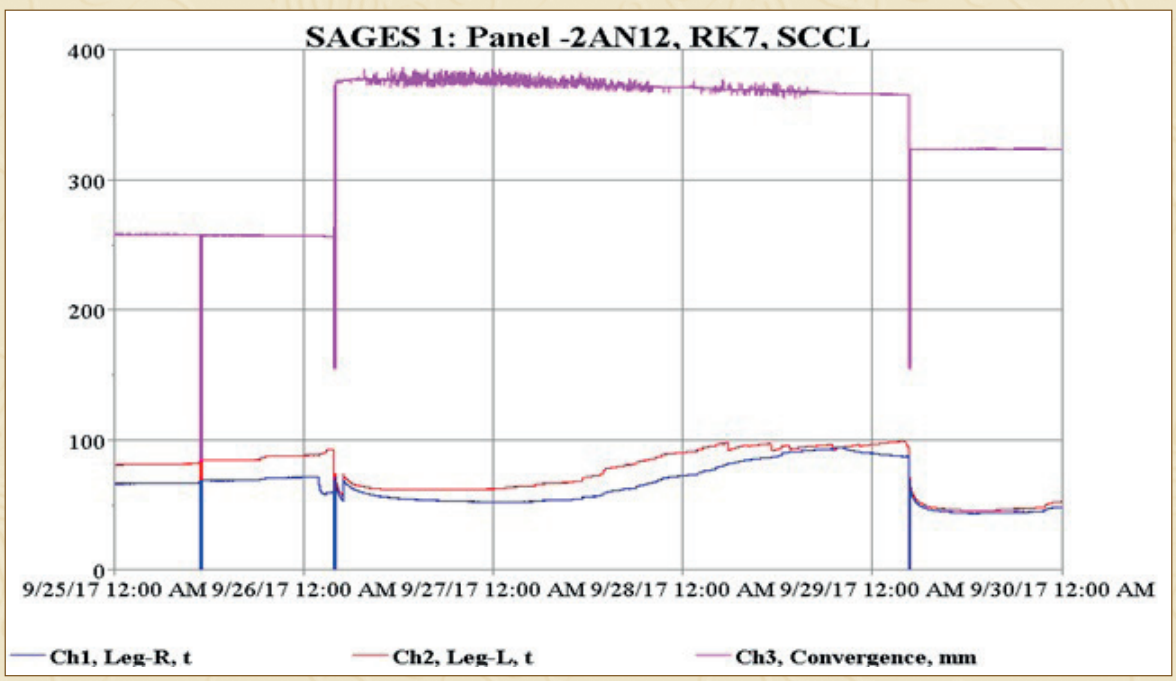


Fig.- 6: Plots of strata load and roof floor convergence showing yielding of SAGES -1 during extraction of slices in Slice no. 57, Block A

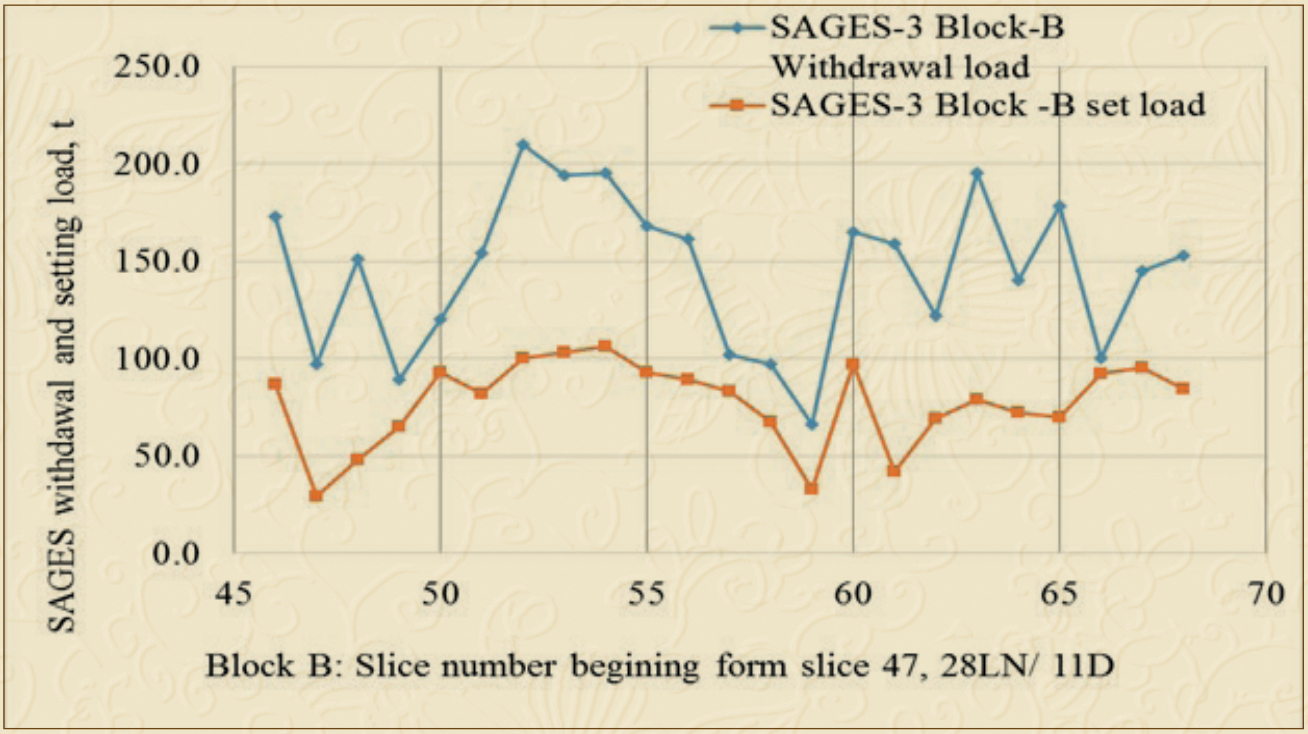


Fig.-7: Withdrawal and setting loads of SAGES-4 in slices, Block B, Level 28LN

Table - 4: Response of SAGES to strata load at Goaf Edges

Sl. No.		Location of SAGES in level drive at Goaf Edges					
		Dip side	Rise side	Dip side	Rise side	Dip side	Rise side
		1	2	3	4	1&3	2&4
1	**Setting Load of SAGES**						
a)	Mean value, t	77	101	77	101	98	105
b)	>95t, %	82	72	22	65	60	69
c)	>50t, %	100	100	83	96	94	98
2	**Load at Withdrawal of SAGES**						
a)	Mean value, t	129	120	129	120	132	125
b)	>190t, %	3	3	14	6	8	4
c)	>100t, %	85	77	64	61	75	69
3	**Yielding events of SAGES**						
a)	In no. of slices	6	1	6	4	12	5
b)	% of no. of slices	15	3	26	17	19	8
% - Percentage of numbers of extracted slices							

Table-5: Roof-floor convergence of strata at Goaf Edge supported by SAGES

Sl. No.	Roof floor convergence recorded by SAGES	Location of SAGES in a level drive at Goaf Edge					
		Dip side	Rise side	Dip side	Rise side	Dip side	Rise side
		1	2	3	4	1 &3	2&4
a)	Mean value, mm	6	3	7	3	7	3
b)	>10 mm, %	18	10	25	6	21	8
c)	>15 mm, %	8	0	8	3	8	1
% - Percentage of numbers of extracted slices							

Table - 6: Slice extraction duration with SAGES at Goaf Edge

Sl. No	Slice extraction duration	SAGES in a level drive at Goaf Edge		
		1&2	3&4	1,2,3&4 combined
a)	Mean value, days	4	5	4
b)	>5 days, %	28	33	31
c)	>8 days, %	8	14	11
% - Percentage of numbers of extracted slices				

Table-7: Duration of withdrawal, movement and setting of SAGES at Goaf Edges

Sl. No.	SAGES withdrawal and setting duration	SAGES in a level drive at Goaf Edge		
		1&2	3&4	1,2,3&4 combined
a)	Mean value, min	22	40	31
b)	>40 min, %	15	25	20
c)	>60 min, %	3	17	9
% - Percentage of numbers of extracted slices				

Outcome of the Field Trial

(a) The SAGES (named model "SAGES-200t-M01", Specification as mentioned in Table-1) has been found suitable to be used as a Goaf edge support in underground coal mines for extraction of pillars.

(b) Technical and operation details of SAGES have been standardized and they are ready for commercial manufacturing.

(c) With SAGES at Goaf edges, a safe practice has been formulated for drilling and blasting in slices for inducing caving. This may be required when roof is not easily caving and causing stress buildup in working area.

(d) This is safe and cost effective over conventional supports being used at present. A cost benefit analysis shows that investment for 12 nos. of SAGES at 6 Goaf Edges in a panel with pillars of size of 30 x 30 m center to center will be recovered from saving made during extraction of 940 nos of pillars over 10 years.

(e) The SAGES are techno-economically viable for commercial use in underground coal mines.

COST BENEFIT ANALYSIS

Direct Cost Benefit

There is direct cost benefit of using SAGES at Goaf Edges. By using SAGES in each slice, we save in manpower required for withdrawal and setting of conventional Goaf Edge supports, loss of timer in Goaf and, breaker line support consisting of 'W' strap and bolts. Savings in one slice, in Rupees, are:

i. Saving of Manpower = 18,000

ii. Saving of 10% loss of timber = 3,283

iii. Saving of 'W' Strap and bolts = 2,454

iv. Total saving per slice (Rs.) = **23,737**

Direct annual saving in using SAGES at all Goaf Edges in a panel

(a) Pillar size, corner to corner = 26 x 26 m

(b) Nos. of slices in the pillar = 6

(c) Saving in using SAGES at all the Goaf Edges of 6 nos. of slices in a pillar @ Rs. 23,742 = 6 x 23,737 = Rs.142,452

(d) Amount of coal in the pillar in seam of thickness 2.4 m, = 26 x 26 x 2.4 x1.4 = 2, 271t

(e) Amount of coal extracted from the pillar assuming 70% extraction = 1,590t

(f) Production per day from a sub panel of size 3 x 15 = 45 pillars = 500t / day.

(g) No. of pillars extracted in a 300 working days in a year = 500 x 300/1590 = 94

(h) Annual saving in using SAGES at Goaf Edged in 94 pillars = 94 x 142,452 = Rs. 134 Lakhs.

Indirect cost benefit

(a) Higher rate of production due to saving in time of

- Withdrawal and setting conventional supports,
- Regular practice of drilling & blasting holes in each slice for inducing caving.

(b) Shortening in duration of completion of a slice prevents deterioration of working area. It means we will be able to abandon the slice before ground condition deteriorates.

(c) Increase in percent of extraction from the ribs.

(d) Increase in size of a panel for a given incubation period due to higher rate of production with SAGES as Goaf Edge support. Thus, saving in cost of isolation stopping of panels.

(e) Safety aspects outlined in section 2.2 of the paper.

These benefits have bearing on cost saving in depillaring operations. It is expected that these benefits will lead to 2-5% increase in production with the present setup of depillaring operations in underground coal mines. Thus, for a daily production of 500t from a panel, there will be 10 to 25t of additional production per day with SAGES installed at all the Goaf Edges of a panel. This could be easily achieved by one to two extra rounds of drilling, blasting and loading in view of indirect benefits of SAGES stated above.

Discounted Cash Flow (DCF) analysis of the direct and indirect cost benefits of SAGES

A DCF analysis of cost benefit of use of SAGES at Goaf Edges has been performed over a period of 10 years accounting direct and indirect cost benefits stated in sections 4.1 and 4.2. Discount rate of 12% and linear depreciation over a period of 10 years have been accounted. Maintenance and operation costs increase as SAGES becomes older. Interest rate of 30% on profit and royalty of 14% on sale value of coal are accounted. Table-8 contains results of the DCF analysis. It reveals that NVP (Net Present Value) over a period 10 years is positive for all the three cases of 0%, 2% and 5% increase in production. It means that even if there is no increase in production, the use of SAGEAS at all the Goaf Edges in a panel will lead to economic benefits to the mines besides enhanced safety of work places near the Goaf Edges.

FUTURE DEVELOPMENT OF HIGHER CAPACITY SAGES FOR USE WITH CONTINUOUS MINERS

The 200t SAGES (specifications as given in Table-1) have been found technically and

Table-8: Discounted Cash Flow Analysis of Cost Benefit of SAGES

Sl. No.	Item	Increase in extraction of coal using SAGES		
		0	2%	5%
Initial Investment in Sages				
1	No. of SAGES in a sub panel of size 3 x 15 = 45 pillars	12.0	12.0	12.0
2	Price of SAGES in Lakhs (unit cost of SAGES, Rs.39 Lakhs)	468	468	468
Saving form using SAGES at all the Goaf Edges replacing breaker line bolts and conventional timber supports				
3	Annual saving in using SAGES, Lakhs (4.1.1h)	134.0	134.0	134.0
Increase in extraction				
4	Annual increase in production, t (annual production (4.1.1g): 150,000 t)	0	3,000	7,500
5	Sale realization @ 2700/t, Lakhs	0	81.0	202.5
6	Expected reduction in loss after deducting 50% operational costs and 14% royalty on sale value of coal, Lakhs.	0	29.2	72.9
Saving in Strata monitoring instrumentation cost, Lakhs / yr		20.0	20.0	20.0
***NPV over 10 years, Lakhs at discount rate of 12%**		**76**	**191**	**364**
PVR (Present Value Ratio): Return per unit investment		**1.16**	**1.41**	**1.78**

** SAGES operating and maintenance cost: Year 1-3 = 5%; Year 4-6 = 8%; Year 7-10 = 12% of price of SAGES (2); Linear depreciation of SAGES over 10 years and Income Tax 30%.*

economically viable to be used at Goaf Edges in depillaring panels with seam height up to 3m, using LHD and SDL for loading of blasted coal. SAGES of 500t capacity are being designed and developed to be used with Continuous Miner suitable for seam thickness in the range of 2.5 – 4.5m.

ACKNOWLEDGEMENT

The successful development and field trial of SAGES would not have been possible without sincere effort and full cooperation of GM (Bastacola Area), Agent and Manager, Victory underground coal mine. We also received full cooperation of concerned officials and work persons of Victory mine during the field trial. They provided valuable feedback for improvement in performance of SAGES. We duly acknowledge their contributions. The final trial of improved SAGES has been successfully conducted in RK7 mines of SCCL under project SAGES Phase-II. We duly acknowledge sincere effort and full cooperation of Director (P&P), GM (R&D), GM (Srirampur Area), Agent RK7 mines, Manager RK7 mines. We received full cooperation of concerned officials and work persons of RK7 mine during the field trial. They provided valuable feedback for improvement in performance of SAGES.

We sincerely acknowledge the overwhelming support of DGMS in providing permission for field trial of SAGES followed by approval for deployment of SAGES (200T) as Goaf-Edge support to be used in underground coal mines.

The financial support was provided by the Ministry of Coal, Govt. of India in two phases of the project through CMPDIL, Ranchi. Technical review and support provided by officials of S&T Department of CMPDI, Ranchi are duly acknowledged. We, finally, acknowledge administration of IIT (ISM) for smooth financial and administrative management of SAGES development project.

Forest Landscape Restoration of reclaimed open cast mines in BCCL Dhanbad and sustainable livelihood to communities

Sudipto Chatterjee [1]

INTRODUCTION

Threats and pressures of development often leads to degradation of land and in the recent past, restoring degraded ecosystems to restore the ecosystem services they provide has emerged a global priority. India has committed to the Bonn Target on restoring 2.3 m ha of degraded land. UN has declared 2021-2030 as decade of Ecosystem Restoration

Mining is a developmental activity and with the support from Ministry of Coal, Govt of India, in May 2015, TERI School of Advanced studies (TERI SAS) joined hands Central Mine Planning and Design Institute Limited (CMPDI, Ranchi) and Bharat Coking Coal Limited (BCCL), Dhanbad, Jharkhand in their ongoing efforts in restoring reclaimed opencast mines. A 15 acre post mining OB dump/ land was chosen for restoration at Muraidih, Barora, BCCL .TERI SAS not only attempted restoration through a plantation drive through species native to the region but also explored linking restoration to livelihood security to local communities in vicinity. TERI SAS being an institution of higher scientific learning engaged itself in the science of restoration and regenerated a forest, a micro-watershed and an agro-ecosystem.

OBJECTIVES

The project has the following objectives :

1. To assess through application of Systematic multi criteria evaluation framework, the suitability potential of post mining, land use for ecologically beneficial and socioeconomically productive outcome.
2. To develop permanent green cover on burdened dumps/backfilled mine land area using mycorrhiza and various plant species of economic importance.
3. To develop entrepreneurship and vocational skill among members of the local Self Help Groups (SHGs) for community with focus on women and other weaker sections of the society.

APPROACH

Forest Landscape Restoration

Restoration of a landscape requires a reference site. The project identified the Belmi Forest Reserve near Ranchi as a pristine habitat, undertook a vegetation analysis to recognize 17 tree species native to the region and authenticated the same with Flora of Bihar and Orissa authored by Haines in 1922. To commence with 6 species viz., Sal (*Shorea robusta*), Shisham (*Dalbergia sissoo*), Bel (*Aegle marmelos*), Arjun (*Terminalia arjuana*), Gamaru (*Gmelina arborea*) and Kachnar (*Phanera variegata*) could be raised at the site nursery followed by their plantation in around 5 acres of land during the monsoons of 2016 and 2017. To overcome the harsh conditions of soil less land the seeds of the grasses,

[1]*Associate Professor and Head, Dept of Natural Resources, TERI School of Advanced Studies, New-Delhi.*

Stylosanthe shamata and *Pennisetumpedicellatum* (Dinanath) were spread using seed ball techniques to enhance the Soil Organic Carbon and Nitrogen. 14000 saplings have been planted in two phases. The saplings were inoculated with mycorrhiza to impart strength and vigour to the plants. The local soil is being enriched with Mycorrhiza using Sorghum and Maize. Drip irrigation pipes watered the plants in the root zone. Ten individuals of each of the six-planted species were monitored every month for their growth in terms of height and girth. Nurseries are being prepared to enhance the tree diversity. Regular washing of saplings undertake removal of accumulated coal dusts. Survival rate was around 80%. Care ensured high survival except for the species *Shorea robusta*.

Baseline data was collected to calculate the biomass of the tree species, reptiles birds and insect species at the end of the project period for anticipated future monitoring. A low lying area was left free for future development as a water body. Data on soil quality parameters including microorganisms in restored and degraded soil were collected and analyzed.

Livelihood security

The interlinkage of forests regeneration with livelihood, the project attempted cultivating medicinal plants and seasonal vegetables and planted fruit trees suitable to the region. While the production of vegetation and medicinal plants have been encouraging, the project is presently undertaking laboratory tests of the edible plant parts to ensure the food safety standards. A micro-watershed development plan was initiated to create a manmade wetland ecosystem. A weather station had been installed to create a data set for research on micro – environment of restored forests.

Need assessment and resource assessment survey in eight villages of Baghmara block was conducted for possible sustainable livelihoods. The purpose of the study was to capture the needs of the local people and also various livelihood opportunities. Along with this the capacity building activities and financial linkages were discussed with the villagers. Post completion to the need assessment survey, the expert team from TERI SAS initiated capacity building programmes for the local communities.The training programmes were held in various phases at Barora Vocational Training Centre, Muraidih. Each of these training programmes facilitated the participants about the market and financial linkages in the respective sector of work. Motivation from TERI SAS team helped them start their own enterprises for which initial hand-holding support was also provided.

Forest Landscape Restoration and Higher Learning

The project has been a learning opportunity for the students of TERI SAS. The scholars at the institute have initiated long term ecological research on return of the ecosystem services. Soil health in terms of macro and micro nutrients and the dynamics, the microbes and biological diversity, the carbon sequestration of a regenerated forest, plant productivity, the physiological responses of a plants in stressed environment are some of the research that have been initiated. Using GIS and Remote sensing techniques assessment is being made on the restoration efforts undertaken by BCCL in the entire Jharia Coal basin.

Mining Land Suitabilty Analysis (MLSA)

While the present policy environment does not permit, land use change, post reclamation as per Minerals and Mine Development Act, 1950 and reclaimed land have to be returned to the state it was procured, the project explored post mining land suitability analysis. Land use options were sought from 50 individuals comprising of officials of MoEF and CC, State Forest Department, Govt of Jharkhand, BCCL, Tourism, Industrial bodies, State Pollution Control Board, Academicians, Village politicians and village community members. The options of post mining land uses viz., Forest landscape restoration, development of pasture land, plantations with economically important species, return of land to community, development of an ecotourism complex, creation of a residential complex and agro-forestry. The analysis was carried out in DEFINITE Software which used the AHP (Analytical Hierarchical Process). The criteria and sub-criteria (in parenthesis) against which ranking

were made are Legal and Policy Environment (National Legislations and Mine Closure plans), Site Characteristics (Baseline environmental conditions, Topography, support systems), Impacts on surrounding landscapes (Vegetation, Air, Water and Soil) and benefit to local communities.

Of the aforementioned options, Agroforestry models, Forest landscape Restoration and Development of Ecotourism Complex in the network of restored sites by BCCL received highest rankings.

Learning experiences Project Impact Future scope of Work

The TERI SAS- TERI- CMPDI- BCCL initiative of forest landscape restoration and livelihood though not unique, had certainly new dimensions. The zonation of the open cast mines available for restoration and livelihood to forests. Agriculture, horticulture economically important plants including medicinal plants and micro watershed unleashed the scope of multiple land uses of reclaimed open cast mines. Mining Land Suitability Analysis (MLSA) was undertaken possibly for the first time in degraded coal mine site in India and our studies indicate that given the present legal and policy environment, afforestation with native tree species will remain the best possible options.

Our pilot experiments using mycorrhiza in growing crops and vegetables are promising, however, we have recommended rigorous laboratory tests for food and safety standards. Results of samples of medicinal plants sent to Himalayan Drugs, reveal that coal particles apart , no additional issues are anticipated.

Livelihood from restored coal sites will have to wait as land will not be accessible to local communities at large. Building capacities of local communities in vicinity, for women in particular, certainly have placed the Coal Company in good light.

Forest Landscape Restoration in 15 acres of land has opened up an opportunity to undertake a Long Term Ecological Monitoring. There are few such long term monitoring stations in India, and possibly none in restored open cast mines. The initiative is also an opportunity to undertake scientific studies on how restoration enhances ecosystem ecosystem services, soil and water quality, terrestrial, and subterranean and aquatic biodiversity. Newer studies on impact of pollution on stress to ecosystems is a need for future.

TERI have proposed a way forward through a network of restored sites. Jharia coal mines has around 42 restored sites. A network of such sites will not only be of scientific interest but also be opened to public for awareness on restoration. This will secure revenue through tourism in restored sites.

The present initiatives was judged 4 best projects among 40 by UN-Global Compact Network India (UN GCNI) for implementation of Sustainable Development Goals in May 31, 2019.

TERI-SAS's endeavors to restore degraded landscapes and develop a deeper understanding of restoration and ecosystem health shall continue. The success story has the potential to be replicated and scaled up in other degraded landscapes at reclaimed Coal Mines.

ACKNOWLEDGMENT

Project team, place in record its deep gratitude to Ministry of Coal, Govt of India for the funding support for implementation of this project.

REFERENCE

i. *Chatterjee Sudipto, Manab Das and Sapna Narula (Eds). 2019. Sustainable livelihood on reclaimed open cast mines: A technology enabled integrated approach in the Indian coal sector. TERI School Advanced Studies, New Delhi, Bharat Coking Coal Limited, Dhanbad and Central Mine Planning and Development Institute, Ranchi.*

OBR Check Measurement by CMPDI using Terrestrial Laser Scanner (TLS)

Rajneesh Kumar [1], Mohit Rastogi [2], Subhomoy Sinha [3]

BACKGROUND

Coal remains the primary & economic source of energy in India over the last few decades & Coal India Limited is the key producer of Coal since its nationalization in 1973. To meet up the increasing demand for coal, open-pit method of mining was adopted since last decade of nineteenth century. Open pit mining has been proved very economical for coal lying at shallow depth and there are lots of scopes to increase the production. In India, around 90-94 % of the coal is produced by open pit mining method. Timely removal of overburden (OB) is a challenge in opencast mining operation to extract the coal locked under the earth. Removal of OB is always associated with huge expenditure making it obligatory for a third party verification. CMPDI was appointed as a third party agency after several meetings at CIL and subsequent approval of competent authority. OBR check measurement was made mandatory by CIL in May 2001 in all OC mines having OB production > 3 million CuM in 4th CMD's Meet. This has been further modified in February 2003 making it mandatory for all OC mines having Coal production > 1 M.Te.in 22nd CMD's Meet.

Conventional ground survey method using ETS (Electronic Total Station) for measurement of the OB volume was deployed successfully by CMPDI for 3rd party OBR verification, but it was time taking and manpower intensive technology. In last few decades, horizon of surveying has also been extended with the development of mining technology and other branches of engineering. Automated Survey System has brought radical change in surveying technology. CMPDI, Coal India Limited and its subsidiaries felt the necessity for a quick and reliable method of Survey System comprising of advanced electronic survey instruments for data acquisition and suitable computer hardware/ software for processing the survey data, preparation of plans/ sections and computation of area & volume of in-situ OBR. Therefore, to augment the existing capability of OB measurement, it was indispensable to evolve a new technique to measure the OB in time-cost effective manner on regular basis. A proposal titled *"Development of Methodology for Rapid Volumetric Analysis of Excavated In-Situ Overburden Integrating High Resolution Satellite, Airborne Laser Terrain Mapper (ALTM) and Terrestrial Laser scanner (TLS) data supported with ETS through Digital Photogrammetric Technique"* was approved in 18th meeting of CIL R&D Board held on 01.07.2006 at Kolkata.

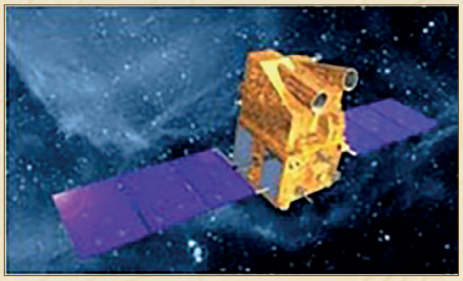
The project was done in collaboration between CMPDI and NRSC (National Remote Sensing Centre), Hyderabad. Belpahar OC in IB Valley coalfield (Fig.-1.1) and Gevra OC in Korba coalfield (Fig.-1.2) were selected as test sites for the R & D project based on : i) ETS, ii) TLS, iii) ALTM & iv) CARTOSAT-I stereo satellite data.

[1] General Manager, [2] Chief Manger (Civil/Survey), [3] Asstt. Manager (Survey), Geomatics Division, CMPDI Ltd., Ranchi

ETS

TLS

ALTM



HIGH RESOLUTION SATELLITE

Fig.-1.1: Belpahar OC, Ib Valley Coalfield

Fig.-1.2: Gevra OC, Korba Coalfield

Table- 1: Evaluation of ETS, TLS, ALTM & Satellite in Pilot Study Area

Parameters		Sensors			
		ETS	Terrestrial Laser Scanner	ALTM	Satellite
1	Data acquisition time	8 days	3 days	1 hour	In minutes
2	Data Processing Time	15 days	2-3 days	2-3 days	2-3 days
3	Manpower	7	3	3	Nil
	(a) for data acquisition	(Surveyor: 1 Chainman: 1 Labour: 5)	(Surveyor: 1 Labour: 2)	(Pilot: 1 Technician: 1)	Nil
	(b) for data processing	2	1	1	1
4	Statutory clearance	Not required	Not required	MoD clearance required	HRC clearance required for high resolution satellite data.
5	Data capturing grid	<15m	1.4m	2.0m	2.5m
6	Vertical accuracy	3mm	10mm	10-15m	4.0m
7	Measurement Rates	5 points/minutes	11000 points/ second	20000 points/ second	&
8	Cost of equipment	10 to 12 lakhs	100 to 135 lakhs	40 crore including aircraft	(i) @ Rs.12000/- 700 per sq. km.- CARTOSAT-I (ii) @ Rs.80000/- per sq. km. QUICK BIRD
9	Safety	Data cannot be acquired for inaccessible area.	Data can be acquired for inaccessible area.	Data can be acquired for inaccessible area.	Data can be acquired for inaccessible area
10	Variance in OB volume with respect to ETS	-	1.18% to 1.40 %	0.80% to 1.39 %	215%

Evaluation of ETS, TLS, ALTM & Satellite data was carried out based on *data acquisition and data processing time, manpower requirement, cost and accuracy* to determine the most suitable technology for routine OB measurement in coal mines.

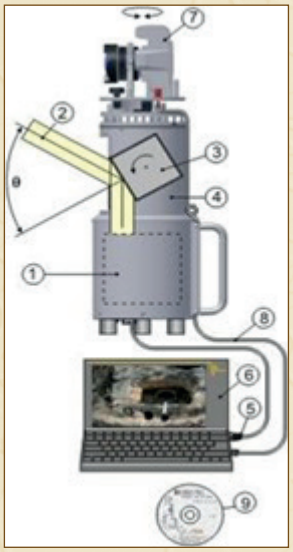
Volume calculation using different techniques for two pilot areas, viz. Belpahar OC and Gevra OC reveals that, the variance of volume calculated by TLS for the two areas are only 1.18% & 1.40% which is minimum in comparison with the results derived by ALTM & satellite photogrammetric methods. The results from Terrestrial LiDAR and Airborne LiDAR were comparable and indicated that Terrestrial LiDAR was the cost-effective solution of OBR measurement in Coal India Ltd. Finally CMPDI adopted Terrestrial Laser Scanner (TLS) survey for OBR measurement purpose due to its higher accuracy, lesser manpower requirement and faster process than ETS.

In the R&D Project, DTM to DTM method of volume computation was adopted in case of TLS, Airborne LiDAR and Satellite data, in which two surfaces were generated for the two periods of survey and volume was computed through software. The DTM to DTM method is faster method of volume computation between two surfaces, but it lacks tangibility. CMPDI was using Cross-sectional method of volume computation through ETS. As all the subsidiaries were conversant with tangible cross-sectional method of volume computation, the same procedure of volume computation using cross-sections was also applied in case of TLS, by CMPDI. Riegl LMS z420i TLS, procured through R&D Project was deployed initially by CMPDI for regular job of OBR Check Measurement. Later, Riegl VZ 1000 and VZ 4000 TLS were procured and deployed.

METHODOLOGY OF OBR MEASUREMENT WITH TLS (Riegl VZ 4000)

RECONNAISSANCE SURVEY

- Reconnaissance survey for determination of suitable & minimum number of Scan-position to cover the entire area to be surveyed so as to have sufficient data overlap & minimum scan-shadow.



Setting up of TLS

Retro-reflectors (Tiepoints) placed around the TLS

SETTING UP OF TLS

- Setting up of TLS, connecting Laptop & Battery
- Placing Reflectors (Tie-points) around the TLS for Geo-referencing Purpose

DATA & IMAGE ACQUISITION

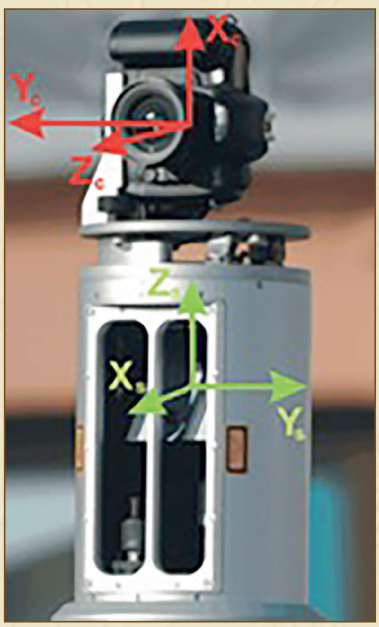
Data Acquisition

Transmission of LASER and subsequent reception of the same is done by rotating prism inside the Terrestrial Laser Scanner. Riscan Pro software is essential for controlling the scanner during surveying. It helps to steer the movement of the scanner, visualises object points during scanning in 2D or 3D view. The scanning interval in horizontal and vertical direction should be equivalent and small enough to allow for capturing all the desired details. It is determined by setting an angular value (e.g.0.02deg = 0.349 metres spacing

at 1000 metres). TLS acquires millions of Point Cloud data within minutes & these measurements are recorded and translated to the final model.

Photo Texturing

A built-in camera or external camera allows automatic texturing of the 3D model. Proper photo-texturing is required for avoidance of over-or under-expositions and the occurrence of Shadows.



Fine Scanning & ETS Referencing

During scanning of the visible mine area from each scan position, 4 to 5 Reflectors (Tie-points) are placed surrounding the TLS. Co-ordinates (X, Y, Z) of these retro-reflective targets are to be determined using ETS. A closed circuit traverse survey is conducted by ETS from the permanent reference Stations to achieve & verify desired level of accuracy.

The same procedure is followed for all the subsequent scan position to cover up the desired area with sufficient overlapping in each scan position.

Survey field work thus comes to an end.

Backup of voluminous field survey data prior to initiation of data processing is kept. Each Regional Institute of CMPDI & HQ is equipped with High end Work Stations & software for further processing of TLS data.

DATA PROCESSING

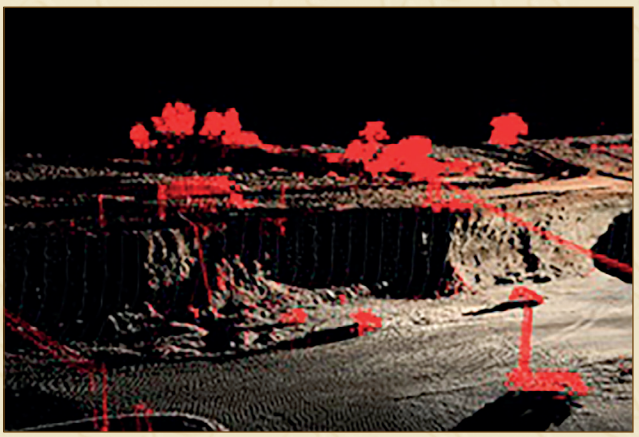
Processing of raw data into measurable 3D models is the most cumbersome and time consuming task and it is done using high end workstation. The major steps are as follows:

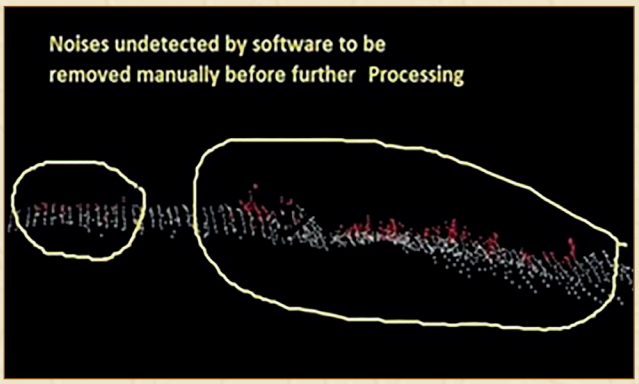
Data Registration

Joining of the point-clouds gathered at the sequence of scan positions into one model, and further geo-referencing of the model to a desired coordinate system, is done through software. When object surfaces are rich in distinguished features, the joining of point-clouds can best be done by feature matching rather than using targets as tie point (x, y, z, using Electronic Total Station). Feature matching allows the use of a dense set of well distributed natural tie points and so results in improved quality of the final 3D model. However, tie points surveyed with local reference are essentially used for transforming the entire model into local reference

REMOVING NOISE OF POINT CLOUD DATA

TLS during the process of scanning using the laser emission and receiving, captures data for all available features like vegetation & trees, electric wires & poles, mining equipment, men & machineries and dust particles, etc. Though the software provides some algorithms to eliminate the noises, yet as of today, much more improvement of software in this segment is required. The desired area needs to be minutely checked & cleaned prior to further processing.

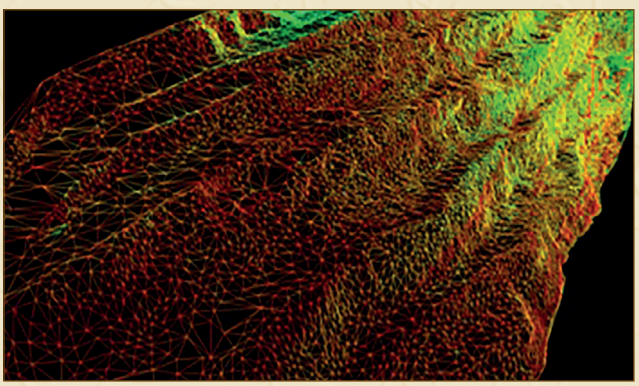




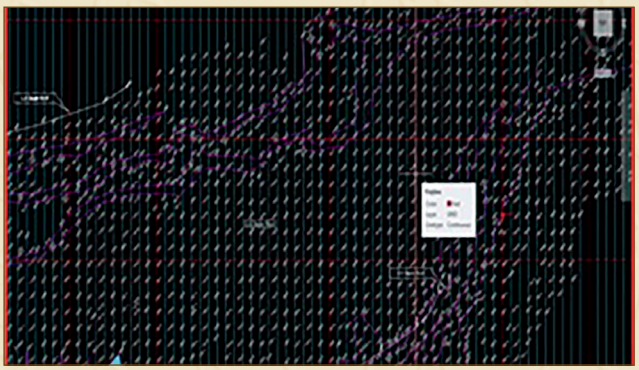
DTM GENERATION, CROSS SECTION PREPARATION, CONTOURING AND PREPARATION OF PLAN

After removal of unwanted noises, the Point Cloud Data is exported to Liscad/ Surpac and AutoCAD software for:

1) DTM/ TIN (Triangulation of Irregular Network) generation.
2) Preparation of Plan & Cross Sections at desired interval.
3) Generation of Contours etc.



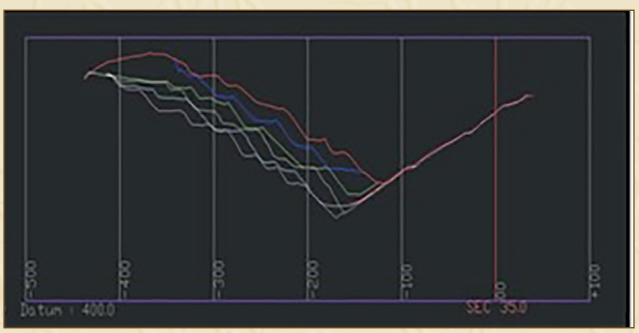
TIN generated in Software



Plan Showing benches & selective RLs to visualise the general topography of the Mine

SUPERIMPOSITION OF CROSS SECTIONS OF TWO SPELLS COMPUTATION OF SECTIONAL AREA & VOLUME OF EXCAVATION

Cross sections at required intervals (eg. 5m/10m/15m) are generated using any of the suitable survey software like Liscad or Surpac etc. The set of two spells of cross sections are then superimposed, the cross-sectional area between two spells for all the cross sections are obtained from the software (Auto CAD) & volume calculated by trapezoidal rule using spreadsheet like MS Excel or any other similar format.



Superimposed cross section profiles of different spells

ADVANTAGES AND LIMITATIONS OF TLS IN OBR MEASUREMENT

Advantages:

- Overall increase in productivity as data capturing is much faster.
- Dense point cloud data generated through TLS, represents better visualisation of DTM/Surface/Terrain. All the necessary information are collected in minute details

even in the inaccessible/ unapproachable areas like fire, steep slope, cavings etc.

- Higher accuracy of measurement is very similar to Electronic Total Station
- Representation of data in colourised 3D model, which imparts better visualisation of the terrain on a Computer Screen.
- Reduces manpower as compared to ETS Survey.

Limitations

- The need for a high initial investment
- Sophisticated software for processing of point clouds, results in specific training requirements and experience
- High-end hardware (Work Station) for data processing
- TLS cannot acquire data in dense vegetation and waterlogged areas
- Less reflective surfaces reduces the range of TLS

ROLE OF CMPDI IN TLS SURVEY

As per decision taken in 98th CMD's Meet held on 19.10.2015 at Kolkata, CMPDI shall conduct the measurement of OBR (Initial, Annual and Final Survey) in outsourced OC patches, as per standing methodology adopted by CMPDI.

In the meeting on OB measurement of outsourced OC patches, with General Manager (Production), CIL, Survey Heads of subsidiaries and GM (Mining/ Vigilance) presided by Director (T), CIL, held on 22.12.2015 with the initiatives of CVO, CIL, it was directed by CVO, CIL that CMPDI will do Initial (OGL), Annual and Final Survey for outsourcing OC patches of all the subsidiaries of Coal India Ltd..

In the Annual Review meeting of Secretary (Coal), MOC with CVOs of CIL & subsidiaries on 29.01.16 at Bhubaneswar, it was decided that CMPDI shall conduct initial, annual and final OB measurement of all patches.

CMPDI is well equipped with 10 nos. of high end TLS scanners (9 nos. Riegl VZ 4000 & 1 no. Riegl VZ 1000), 23 nos. of high end ETS (17 nos. Topcon DS 101 AC & 6 nos. Trimble S7 robotic total station) along with associated data processing software procured phase-wise. Presently, a dedicated group of technically qualified and skilled survey, civil, mining, E&M and geology personnel are engaged in OBR measurement job.

In FY 2019-20, check measurement survey has been done in 23 departmental mines as well as 206 contractual patches. Original Ground Level (OGL) and volume measurement survey has also been done in three projects of M/s NTPC, viz. Pakri-Barwadih, Dulanga & Talaipalli & one project of M/s NLCIL, viz. Talabira II & III.

CONCLUSION & RECOMMENDATIONS

The Coal vision 2025 estimates that the total domestic coal production is projected to increase to 1061 MT in 2025, of which the majority will be through opencast production. To meet up the huge task of OBR measurement related to the increased targeted production, it is recommended that:

- Terrestrial Laser Scanner should be used widely on routine basis for measuring the excavated volume of the overburden in big opencast coal mines.
- For rapid and accurate measurement, total excavated volume should be measured and volume of coal excavated from the mine should be deducted from the total excavation volume to determine the volume of excavated overburden.
- Areas for OGL survey should be dozed for removal of vegetation & bushes.
- To minimise the complexities of data compilation, the number of surveys for Part Initial or Part Final may be reduced, as far as possible.
- Implementation of DTM to DTM method of volume computation.

CMPDI Publications (हमारे प्रकाशन)

क्रमांक	पुस्तकों के नाम	मूल्य (₹)
1	कोयले की गवेषणा (सजिल्द)	200
2	कोयला शैलिकी	100
3	खुली खान का आयोजन	100
4	झेन प्रबंधन तकनीक	100
5	खनन इलेक्ट्रॉनिकी	100
6	खान की गैसें	030
7	विस्फोटकों का सुरक्षित उपयोग	100
8	सपोर्ट प्लान एवं डिजाईन का मार्गदर्शन	070
9	रियर डम्पर प्रचालकों के लिए नियमावली	030
10	नियमावली चाल एवं कांती की सुरक्षा एवं सपोर्ट	030
11	करणीय एवं अकरणीय: सूक्ष्मतर चूर्ण कोयला परिष्करण संयंत्र	050
12	करणीय एवं अकरणीय: मैग्नेटाइट प्रिपरेशन प्लांट	030
13	बेल्ट कन्वेयर के लिए क्या करें, क्या न करें	030
14	क्रशर के लिए क्या करें, क्या न करें	030
15	कोल बेड मिथेन: एक स्वच्छ ऊर्जा स्रोत	600
16	Coal Combustion	150
17	Mine Winders and Winding Systems	150
19	Coal Atlas of India	2000
20	Information on Indian Coal	1000
22	Mine Pumps for Underground Drainage	150
23	Do's & Dont's for Belt Conveyors	030
24	Do's & Dont's for Crushers	030
25	Mine Fans & their use in Mine Ventilation	075
26	Electricity in Underground Coal Mines	200
27	Environment in Underground Coal Mines	100
28	Underground Mines Fire & Explosion	100
29	Coal Mine Roof Support	200
30	Underground Coal Mining in India	200
31	Artificial Recharge and Rainwater Harvesting Techniques	100
32	Coal : Its Properties & Characterizations	820
33	A Handbook on Dragline dump profile in Surface coal mines of India	750
34	Handbook of Coal Petrography	380
35	Rock Bolting in Indian Mines *	----

** Not for sale, books are being sent to mining executives of CIL*

New Facility for Obtaining Technical Books

In case of Coal India & its subsidiaries Offices, the books can be had by contacting Office of the respective Regional Director of RIs or Dy.GM (IMS), Ranchi. Cost of books will be realised through inter company transaction.
For outsiders, DD in favour of **CMPDI** may be sent to, The Dy.GM (IMS), CMPDI Ltd.
Gondwana Place, Kanke Road, Ranchi (Jharkhand), PIN-834031.

cmpdi

A Mini Ratna Company

Sustainable Unearthing of Mineral Resources Begins Here

Services Offered :-

- Exploration
- Plannings & Designs UG & OC Mines
- Coal Preparation
- Management Services
- Research & Development
- ICT Service
- Environment
- Mining Electronics
- Geomatics
- Specialised Services
- Laboratory Service
- Coal Bed Methane
- Management Systems

1952_20_Design & Print: Kailash Paper, Kanchi