Prabhat Kumar Sinha
Chairman-Cum-Managing Director

MCL

ମହାନଦୀ କୋଲ୍‌ଫିଲ୍‌ଡସ୍ ଲିମିଟେଡ୍
महानदी कोलफील्ड्स लिमिटेड
Mahanadi Coalfields Limited
(A Subsidiary of Coal India Limited)
A Mini Ratna Company

It gives me immense pleasure to learn that THE INDIAN MINING & ENGINEERING JOURNAL will be releasing its Diamond Jubilee Publication and I congratulate the entire team for its contribution and untoward dedication for achieving 60 years of knowledge dissemination for the betterment of the entire Indian Mining Industry. The Indian Mining Engineering Journal had motivated young budding scientists into paths of innovation and felicitated stalwarts of mining sector to strive for optimum operational excellence.

INDIAN MINING & ENGINEERING JOURNAL had been an integral part of MCL's Journey and the plethora of ideas which are highlighted in its forum had inspired us to adopt breakthrough technology in mining. Sustainable practices like use of Surface Miners, Fog Cannons for Dust Suppression, Coal loading through SILOs & Pipe Conveyors, Vertical Rippers for Blast-free OB Removal, Mechanical Road Sweepers for Dust suppression, Robotic Nozzles for Firefighting, Wheel Washing Systems & diversifying through Solar is already in operation. MCL is strengthening the Rail Network through Mahanadi Coal Railway Limited (JV of MCL, M/s IRCON and IDCO) and also setting up a JV with NALCO for 0.5 MT Smelter plant and 1350 MW Power Plant at **Dhenkanal, Odisha.**

I am hopeful that this bond shared between Mining Industries and Indian Mining Journal flourishes further in the coming years and I convey my good wishes for success of this publication.

Prabhat Kumar Sinha

Bulk Explosive and Packaged Explosive

Initiating System and Accessories

Electronic Initiating System

Defense Products

SOLAR INDUSTRIES INDIA LIMITED

Solar House 14, Kachimet, Amravati Road,
Nagpur – 440023
Website: www.solargroup.com

THE INDIAN MINING & ENGINEERING JOURNAL

(Incorporating Mineral Markets: The Founder Publisher & Editor: J.F. De. Souza, Mumbai)
www.theimejournal.com

VOLUME 60: Number 08-09 **AUGUST-SEPTEMBER 2021** ISSN 0019-5944

Published Monthly by IME Publications.
Annual Subscription : Rs.650/- (Incl. Postage), Unit Price: Rs.50/-
FOREIGN: £ 75 OR US $ 150 (By Air Mail)
Payment by Cheque/Draft. Cheques drawn outside Bhubaneswar must include Rs.50/- (Overseas £1 or US$2) as bank charges and should be drawn in favour of ***"The IM& E JOURNAL"*** *payable at Bhubaneswar*

IME PUBLICATIONS

Correspondance Address
The IM& E Journal 1457, Fishery Tank Road, Chintamaniswar, Laxmisagarpatna, Bhubaneswar - 751006, Odisha
Mobile: +919861008387, **Mail:** indianminingjournal61@hotmail.com
Branch office:Near TV Tower, JODA, Dt. Keonjhar 758034
Phone: 06767-273173

Contents

Technical Papers

The IME Journal Readers' Forum

Regd. Office : IMEJournal, Laxmisagarpatna, Bhubaneswar 751 006
E-mail : indianminingjournal61@hotmail.com Mobile: +919861008387

Prof.(Dr.) S. Jayanthu

President
Prof. (Dr.) S. Jayanthu
(Editor-in-Chief, The IM&E Journal)

General Secretary and CEO
Editor, The IME Journal : **S.K.Mahanta**

Council Members

Elected Council Members
Representative from R&D Bodies:
Dr. M Ramulu, CSIR-CIMFR
Academics
(Prof.) Khanindra Pathak,IIT(Kharagpur)
Coal mining sector
Er. Nirmal Kumar, GM, SECL
Explosives
A.K. Das, Navbharat Explosives, Bhubaneswar

Ex-Officio Council Members
Dr. T.N.Singh
Dr. A.K. Sarangi
Dr. S.S.Rathore
Dr N.R.Thote
Dr. Manoj Pradhan
Er. V. Srikant
Prof. (Dr) G. K Pradhan
Dr. K Ramchandar, NIT(K), Surathkal
Special Invitees
Manish Agrawal, Asst. Prof., Faculty of Engg. & Tech., AKS University, Satna (M.P)
Naman Soni, Mining Engineer, JK Cement, Panna (M.P)

Treasurer : A.Sahoo
(Nominated by Publisher of The IME Journal)
Solicitor & Advocate
Amrit K N Pradhan, New Delhi
Web Designed by: AKS University

IME JOURNAL READERS' FORUM

The Indian Mining & Engineering Journal
1457, Fishery Tank Road, Chintamaniswar,
Laxmisagarpatna, Bhubaneswar - 751 006
Ph.0-9861008387
E-mail : indianminingjournal61@hotmail.com

Membership Form
Individual / Corporate

Name...
Present address for communication to mail the journal*
....
....

Phone:(O)...................... (R).......................................
E-Mail...

for individual Life Membership

Educational Qualification(s)..
Year of passing...
Age..................
Date of birth...................
Year of Passing................................
Institution/University..
Experience...
....
....
Areas of specialisation...
....

Date Signature

Payment particulars Individual Life Membership Rs.1500/- & Corporate Membership Rs.12,000/-respectively. This is towards **THREE years subscription** of The Indian Mining & Engineering Journal, and entitles LIFE MEMBERSHIP of the Forum. All members are entitled to participate in all the events conducted by the Journal on subsidised rates. All payments may please be made in favour of '**The IME Journal**'. Demand Draft is payable at Bhubaneswar Bank. Please add Rs.50/- for outstation Cheque.

DD/Cheque No.......................Date......................
Drawn on............................ Rs...........................

** For corporate membership please include name of 5 persons to receive the journal for 3 years.*
*** Revised since 1st June 2002*

Editorial

Mines of Coal India consume largest quantities of explosives and accessories. At a time the coal mining industry had a vital role to meet rising electrical energy need of the country, Coal India had laid emphasis on surface mining. Over the years it had adopted bulk SME explosives in a big way and also switched most blast to non-electric vis-à-vis shock tube initiation. CIL had also successfully adopted them and benefitted in the form of operational efficiency, safety in initiation, controlling blast vibration and other frequency related problems, contributed by Electronic Delay Detonators in complex dragline blasting as well as in sensitive blasting being undertaken close to human habitation.

In order to review the current practices adopted in CIL mines, several seminars and workshops are being organized by the coal companies. The initiative in this regard was made first at Northern Coalfields Ltd this month. NCL had the unique distinction of undertaking some of the very large volume complex blasts with SME for the dragline benches. The just concluded NCL seminar deliberated on safe and productive use of explosives, accessories like shock tubes and electronic delay detonators. Sri P.K.Sinha, Chairman-cum-Managing Director of NCL and MCL, in his inaugural address at NCL, laid emphasis on safety and productivity together with training of the blasting engineers and supervisors. I had the opportunity to speak on a subject of Safe and Productive Use of Explosives and Accessories as a Key Note Speaker.

As a step further, Sri P.K. Sinha who also is the Chairman-cum-Managing Director of MCL, initiated plans to have a similar Seminar at MCL H.Qrs during this month. MCL today is one of the fast growing coal producer and has a record of introducing some of the state-of-the-art technologies in Coal Mining and excavation. It had pioneered the use of Surface Miners in coal mining in 90's and today the use of surface miners had grown several times and had contributed to a blast-free solution to mine coal.

Ammonium Nitrate Fuel Oil (ANFO) made a significant entry in coal mining at Reliance Sasan Coal Mines in both shovel and dragline benches. ANFO which is the most popularly used explosives globally in most strata conditions had been used on experimental basis at MCL mines. One of the technical papers *"Application of Digital Image Analysis for Monitoring the Behavior of Factors that Control the Rock Fragmentation in Opencast Bench Blasting: A Case Study Conducted Over Four Opencast Coal Mines of the Talcher Coalfields, India" by B K Singh of CMPDI and others* (reproduced from Journal of Sustainable Mining 18(2019) 247-256 pages and published in this volume) had highlighted the suitability of ANFO vis-à-vis powder factor, size distribution in the muck pile, etc in Mines of MCL. In order to ensure effective use of explosive energy, use of ANFO is an encouraging step, and MCL can immensely benefit economically as well as from productivity view point. Every tonne of high explosive used in blasting releases 0.20 tonnes of CO_2 into the atmosphere. By increasing use of ANFO and also alternate oxidizer and fuel in SME, CO_2 release can be further reduced.

In this one day deliberations papers were authored by the field engineers and managers. Use of bulk SME, permitted explosivesuse (in UG mines), use of Electronic delay detonators, adoption of X-centric Rippers in OB removal, special techniques of blasting in complex strata and geographical locations, and one paper highlighting use of ANFO, Highwall Mining etc are some of the topics form the rich crop of papers being published in this special volume of The IME Journal. Authors had incorporated several steps, undertaken and executed, at the mines of MCL for safe blasting and maintaining productivity also.

The Indian Mining & Engineering Journal published since 1961 has attained 60th year of its publication. The Diamond Jubilee volumes are supported b y NCL and MCL and publishing technical papers from the coal mines, will enrich our readers to know the various technological advancement made in Coal Mining.

I on my own behalf and on behalf of my editorial team thank MCL and NCL management under the leadership of Shri P.K.Sinha for using our platform in technical dissemination of knowledge in the mining sector

G.K.Pradhan
Recipient of National Geoscience Award 2012(from Govt. of India)
Technical Editor and
Prof. of Mining & Dean, Faculty of Engineering & Technology.
AKS University, Satna

Indian Mining Industry News

MINING NEWS

NCL ORGANISED A KNOWLEDGE SHARING SEMINAR ON BLASTING

NCL is the highest volume handling coal mining company of the nation, with increasing coal production targets NCL is expected to handle more than 550 Million Cubic Meter by 2023-24.

Northern Coalfields Limited (NCL) organised a knowledge sharing Seminar on Improvement in Blasting Performance on Sunday at MDI CETI campus.Adressing the seminar CMD NCL Shri P K Sinha said that NCL is committed to adopt Safe & best blasting practices in its mines. Giving safety the utmost priority, he said such knowledge sharing Seminar nurture and improve the domain knowledge, which ultimately helps in safe blasting practices and optimum utilisation of explosive. He also highlighted the importance of Quality explosive and advanced technology in this field.

Director (Technical/Operations) Dr Anindya Sinha, Director(Technical/Project and Planning) Shri S S Sinha, All-Area Heads, Blasting Teams from Projects and Explosives Suppliers gathered, exchanged ideas and shared experiences through technical presentation in the seminar for overall improvement of Blasting.

Dr. G K Pradhan, Dean & Faculty, AKS University Satna gave the Key Note lecture of the seminar highlighting the development of explosives and improvement of Blasting techniques overtimes.NCL is the highest volume handling coal mining company of the nation, with increasing coal production targets NCL is expected to handle more than 550 Million Cubic Meter by 2023-24. Blasting is one of key activity in Mining process having direct impact on production, economy, environment and HEMM performance. Sri P K Sinha, CMF of NCL& MCL released the diamond jubilee special number on NCL of the Indian Mining and Engineering Journal Different technical session of seminar gave brief insight of Blasting Techniques and innovation from respective areas.

MINERAL PRODUCTION DURING AUGUST, 2021 (PROVISIONAL) GOES UP BY 23.6 PER CENT

The index of mineral production of mining and quarrying sector for the month of August, 2021 (Base: 2011-12=100) at 103.8, was 23.6% higher as compared to the level during last year. The cumulative growth for the period April- August, 2020-21 over the corresponding period of previous year has increased 25.1 per cent.

Production level of important minerals in August, 2021 were: Coal 539 lakh tonnes, Lignite 37 lakh tonnes, Natural gas (utilized) 2851 million cu. m., Petroleum (crude) 25 lakh tonnes, Bauxite 1737 thousand tonnes, Chromite 175 thousand tonnes, Copper conc. 10 thousand tonnes , Gold 89 kg, Iron ore 197 lakh tonnes, Lead conc. 33 thousand tonnes, Manganese ore 180 thousand tonnes, Zinc conc. 133 thousand tonnes, Limestone 311 lakh tonnes, Phosphorite 123 thousand tonnes, Magnesite 10 thousand tonnes and Diamond 38 carat. The production of important minerals showing positive growth during August, 2021 over August, 2020 include: Chromite (189.2%), Lignite (74.2%), Magnesite (57.9%), Iron Ore (52.2%), Bauxite (38.5%) and Coal (20.8%). The production of other important minerals showing negative growth is: Diamond (-97.1%), Gold (-3.3%), Petroleum (Crude) (-2.3%).

NCL CONFERRED WITH 03 PRESTIGIOUS ICC PSE EXCELLENCE AWARDS

Northern Coalfields Limited (NCL), The Miniratna Company of the Government of India, has been conferred with 03 prestigious ICC (Indian Chamber of Commerce) PSE Awards on Monday during the 10th India Public Sector Agenda 2020 online meet. Awards were presented by the Indian Chamber of Commerce (ICC), one of the nation's premier body of business and industry. NCL has received these accolades for the Best and innovative practices in HR Management, Contribution of Women in Public Sector, and Operational Performance Excellence. On behalf of NCL, CMD Shri Prabhat Kumar Sinha received the award in an online event. On the occasion, CMD and Functional Directors of the company congratulated the team NCL and dedicated these awards to employees of the company. The '10th India Public Sector Agenda @ 2020' and 'PSE Excellence Award' were organized through online mode due to the COVID-19 pandemic which saw the wide participation of PSE from the nation. Notably, NCL is a Miniratna coal company that has brought the glory of its outstanding performance and excellent work culture. NCL had met all its production, dispatch targets in 2019-20, and moving on targets in the current fiscal in the odd time of COVID.

प्रभात कुमार सिन्हा
अध्यक्ष-सह-प्रबंध निदेशक

Prabhat Kumar Sinha
Chairman-cum-Managing Director

MCL
A Miniratna Company

ମହାନଦୀ କୋଲଫିଲ୍ଡସ ଲିମିଟେଡ
महानदी कोलफील्ड्स लिमिटेड
MAHANADI COALFIELDS LIMITED
(A Subsidiary of Coal India Ltd.)
P.O. Jagruti Vihar, Burla
Sambalpur – 768020 (Odisha)
Telephone : (0663) 2542855 (Off.)
E-mail ID : cmd.mcl.cil@coalindia.in
Web : www.mahanadicoal.in

MESSAGE

I am extremely happy to note that a Seminar is being organized by Mahanadi Coalfields Limited on "Improving the Safety Standards in Blasting & Blast performance" on 21.10.2021 and there will be release of Diamond Jubilee Special Number on MCL of "The Indian Mining & Engineering Journal" on the occasion.

Mahanadi Coalfields is taking several initiatives to improve safety, environment, quality & productivity. Safety at workplace plays an important role in mining operation. The effective management of Blasting and Blast performance is of utmost importance to develop a safety culture that is self-sustainable and fostering deep commitment to safety while improving the blast performances in its mines.

I hope the Seminar will provide fruitful learning, lively interactions and experience sharing among speakers and participants and help in scouting new ideas towards enhancement in safety standards in Blasting as well as Blast performances at workplaces. It will also help in establishing collaborative committed approach towards achieving "Zero Harm", "Best safe working environment" with optimum production of Coal and Overburden Removal in respect of MCL.

My best wishes for the great success of the Seminar.

(Prabhat Kumar Sinha)
Chairman-cum-Managing Director

ମହାନଦୀ କୋଲଫିଲଡ୍ସ ଲିମିଟେଡ୍
महानदी कोलफील्डस लिमिटेड
Mahanadi Coalfields Limited
(A subsidiary of Coal India Limited)

Om Prakash Singh
Director (Technical/Operations)
At/Po : Jagruti Vihar, Burla,
Sambalpur-768020(Odisha)
Phone -(0663) 2542775
E-mail : dt-op.mcl@coalindia.in, dtopmcl@gmail.com

Message

It gives me immense pleasure to learn that Mahanadi Coalfields Limited is going to organize a Seminar on "Improving the Safety standards in Blasting & Blast performance" at MCL HQ on 21/10/2021. The release of Diamond Jubilee Special Number on MCL of "The Indian Mining & Engineering Journal" on this occasion will further widen the reach of the Seminar output among all stakeholders.

This Seminar is a forum for exchange of on-going practices, innovative ideas, technical expertise for technological advancements as well as improving the safety standards etc. in this field. The papers, discussions, and interactions during the conference will bring forth multiple view points and address issues of critical importance. My best wishes to all participants of the Seminar to make the most out of this event by learning innovative and advanced technologies along with practicing of safe operations in the mines.

I am confident that Mahanadi Coalfields Limited will continue to strive towards achieving the best safety standards in Blasting & Blast performance in its mines.

Finally, I congratulate the team members and participants for their efforts in organizing and participating in this Seminar and wish the Seminar a grand success.

(Om Prakash Singh)
Director (Tech/Operations)

K.R.Vasudevan
Director(Finance)

Office of the Director (Finance)
At/PO: Jagruti Vihar, Burla
Sambalpur-768020(Odisha)
Ph: 0663-2542628 Fax: 0663-2542914

MCL

MESSAGE

I am delighted to learn that Mahanadi Coalfields Limited is organizing a Seminar on "Improving the Safety standards in Blasting & Blast Performance" on 21/10/2021 at MCL HQ. I am also happy to learn that there will be release of Diamond Jubilee Special Number on MCL "The Indian Mining & Engineering Journal" on the occasion.

Blasting is a hazardous operation where ensuring safety is of paramount importance. The Seminar on "Improving the Safety standards in Blasting & Blast performance" would definitely enhance the safety consciousness and awareness level of officials involved in the blasting operation. Many innovative as well as practical concepts on various facets of safety that will evolve during the seminar must be materialized into day to day practice.

I extend my good wishes for success of the Seminar and congratulate the organizers & all stakeholders.

(K.R.Vasudevan)
Director(Finance)

ମହାନଦୀ କୋଲଫିଲଡସ ଲିମିଟେଡ
महानदी कोलफील्डस लिमिटेड
Mahanadi Coalfields Limited
(A subsidiary of Coal India Limited)

Keshav Rao
Director (Personnel)

MESSAGE

Coal mining worldwide is recognized as a hazardous industry wherein ensuring safety is vital for survival, sustenance and progress. Adopting the best practices in operations is not just an imperative but needs a continuous improvement in work, which leads to a much desired safe work environment.

I am glad to note that Safety department of Mahanadi Coalfields Limited is organizing a Seminar at MCL HQ on 21/10/2021. The theme chosen for the Seminar "Improving the Safety standards in Blasting & Blast performance" is quite relevant and important.

I hope this Seminar will lead to emergence of ideas with practical recommendations to help in establishing a safe working environment as far as blasting is concerned.

I wish all the success for the event.

(Keshav Rao)
Director (Personnel)

बबन सिंह
Baban Singh
निदेशक (तक./परियोजना एवं योजना)
Director (Technical/P&P)
Mahanadi Coalfields Limited
Jagriti Vihar, Sambalpur - 768020

MESSAGE

I am very much excited to learn that One Day Seminar on "Safe and productive Excavation and Blasting in Mines with special reference to MCL" is going to be organised on 21st October 2021 at MCL Auditorium, MCL HQ. Many high level dignitaries will be participating to shower their experiences on the theme.

MCL, one of the major producing Subsidiary Companies of CIL, whose working is very hazardous in nature, present in close proximity of the villages has been constantly, gradually & confidently striving hard to serve nation by producing and marketing the planned quantity of coal efficiently and economically in an eco-friendly manner with due regard to safety, conservation and quality.

I am sure practising Mining and Excavation Engineers attending this programme will gain a lot from the scientific session and discussions and will prictise in actual operations for optimum evacuation of both OBR and Coal in coal mines, safely & efficiently.

I extend my hearty wishes towards the successful orgaisation of the above Seminar.

(Baban Singh)
Director(Tech./P&P)

MESSAGE

It gives me immense pleasure to learn that S&R Department of MCL is organizing a Seminar on **"Improving the Safety Standards in Blasting & Blast Performance"** on 21/10/2021 at HQ. I am also happy to note that there will be release of Diamond Jubilee Special Number on MCL of the "Indian Mining & Engineering Journal" on this occasion.

Safety has been an integral part of the core values of Mahanadi Coalfields Limited and the Company is constantly striving to achieve "Zero Harm" at its Mines/Workplaces. I believe this Seminar will give immense scope for exchanging and Standardizing the Safety Norms at various Areas of MCL as well as propagate the Company's Safety Norms among employees and other stake holders living in and around Mining Areas.

I am sure that the participants of this Seminar will share their experiences, practices and perspectives to accelerate the changes in the environment of today's world. I am also sure that the participants of the Seminar will get maximum benefits to improve the Safety Standards in Blasting & Blast Performances in MCL's Coal Mines.

I wish the S&R Department, MCL grand success in all its endeavors.

(Pranab Kumar Patel)
Chief Vigilance Officer

अमरनाथ पाण्डेय
महाप्रबंधक (सुरक्षा एवं बचाव)

Amarnath Pandey
General Manager(Safety & Rescue)

महानदी कोलफील्ड्स लिमिटेड
(भारत सरकार का एक उपक्रम)
एक मिनी रत्ना कंपनी

Mahanadi Coalfields Limited
(A Subsidiary of Coal India Ltd.)
A Mini Ratna Company

MESSAGE

It is a matter of pride that Mahanadi Coalfields Limited is organizing a Seminar at MCL HQ on 21/10/2021 on the theme **"Improving the Safety standards in Blasting & Blast performance".** Also, I am delighted to learn that there will be release of Diamond Jubilee Special Number on MCL of **"The Indian Mining & Engineering Journal"** on the occasion.

Significant progress has been made in the reduction of serious injuries and fatalities resulting from mine blasting operations. Despite the progress, injuries and fatalities continue to occur. One of the greatest challenges, which a blaster faces in mining, is to accurately determine the bounds of the blast area. Safety should continue to be of paramount importance in all blasting operations. The goal is to send every miner home safe and healthy after each shift. With these perspectives, the Seminar will try to figure out what is wrong, and find ways to make it better. I am hopeful that more and more good blasting practices will be identified, integrated and developed by all projects in the days to come.

I am sure that the Seminar will certainly act as a motivating factor for the employees and wish the Seminar a grand success.

Amarnath Pandey
General Manager (Safety & Rescue)

The Indian Mining & Engineering Journal, Vol. 60, No.08-09, August-September 2021, pp.xv-xvii
Printed in India, @ IME Publications, ISSN 0019-5944

Comprehensive Study for use of ANFO with Low Density Porous Prilled Ammonium Nitrate for Dry Hole Blasting at Mines of MCL as an Alternate Blasting Technique/System - A Case Study

O.P. Singh* S. K Dash** H. K. Lahuriya***

ABSTRACT

Globally India is one of the largest consumer of High Explosives in cartridge and Bulk form. Use of popular variety like ANFO which dominates global blasting scenario had limited application. While Non-coal mines have adopted it in manual mix format, few have gone for bulk use. Unlike the advanced western mining economies where the strata conditions determine the choice of explosives, in India the selection of explosives is predominantly decided by its availability. This means that even if the strata conditions necessitate the usage of ANFO explosives, Emulsion explosives get used because it is readily available. Low Density Porous Prilled Ammonium Nitrate needs to be mixed with the fuel oil to prepare ANFO explosives. This mixing process and subsequent usage of ANFO is only allowed for captive consumption in India. Because of this, Explosive manufacturers in India are not allowed to transport ANFO to the Mines, while they are allowed to transport Emulsion explosives to the same mines.Several attempts have been made in Indian coal mines to use ANFO in mechanised mixed system.At MCL mines, studies have been conducted to study its techno-economic feasibility in line with AN Rule of 2012.

INTRODUCTION

Mahanadi Coalfields Ltd has to remove over 143 Million M^3 of OB in the current financial year. To meet this target the total annual requirement of explosive is about 43993.83 tonnes of explosives. The trend of growth in MCL has been OB removal at 53% over 2019-20 & for explosive is at 43%. While bulk emulsion meets majority of requirement it is drawn from IOCL, Solar Industries, SBL, and others. The frequent disruption in explosive availablility had severely disruption in explosive availabilkty had severely affected production in mines of MCL.

The loss of OB production from September 2020 to December 2020 due to non-supply of explosives is 4.4MCum. Considering the current stripping ratio in OCPs of MCL is 1.031. There is resultant loss of coal exposure of 4.26MTe due to poor OB removal. This translates into a loss of profit of 2511Cr. (Progressive Dec'20 for MCL OC mines profit is Rs. 589.48/Te). This has compelled to explore the possibility for an alternative system of blasting which will reduce dependency on SME than the existing one.

*Director Technical Operation, MCL
**General Manager (Mining), SECL
***Deputy Manager (Mining), MCL

ANFO use in Coal Mining

Unlike the advanced western mining economies where the strata conditions determine the choice of explosives, in India the selection of explosives is predominantly decided by its availability. This means that even if the strata conditions necessitate the usage of ANFO explosives, Emulsion explosives get used because it is readily available, and mines are not allowed to commercially procure ANFO explosives due to statutory restrictions. The situation is even more aggravated as none of the Explosive's manufacturer in India are allowed to sell ANFO Explosives, which might be the best suited explosives for most of the strata conditions. ANFO is allowed to be used for captive consumption only. Low Density Porous Prilled Ammonium Nitrate needs to be mixed with the fuel oil to prepare ANFO explosives. This mixing process and subsequent usage of ANFO is only allowed for captive consumption in India. Because of this, Explosive manufacturers in India are not allowed to transport ANFO to the Mines, while they are allowed to transport Emulsion explosives to the same mines.
ANFO is one of the highest energy blasting agents used in India.

Type of Explosives	Ammonium Nitrate Content
ANFO	94%
Emulsion	70% - 72%

Compared to Emulsion explosives, ANFO has a higher share of AN (94%) in the matrix. Because of 94% AN and 6% Diesel, ANFO is the purest form of explosives with no water or any other chemical or inert which can deteriorate the quality of explosives as in the case of SME. This leads to higher energy content and much better blast outcomes. ANFO has a density of 0.80 gm/cc, this leads too much lower specific consumption of explosives which directly translates to improvement in Powder Factor.

The installed production capacity in India of Low-Density Ammonium Nitrate (LDAN), which is required for ANFO, is in excess of 300 KTPA, which is sufficiently large to ensure an uninterrupted supply of LDAN in Coal Mines.

Field Trials with ANFO at WCL Mines

Western Coalfields Limited conducted field study during October 2019 to January 2020, through CMPDI,with the close association of Smartchem Technologies Limited, mine management of WCL and Singareni Colliery Companies Limited.The primary objective of the project was to find out the techno-economic efficacy of ANFO explosives, with low density, porous, thermally stabilized, prilled Ammonium Nitrate in CIL mines, vis-à-vis other commercial explosives like SME (Site Mixed Emulsion – column charge explosives), in terms of Powder Factor (PF), post blast analysis etc. for its tangible and intangible benefits with field trials in dry blast holes.(R&D report is attached)

Key Highlights from Field trials

(a) ANFO has a density of 0.83 gm/cc vs 1.2gm/cc of Bulk Emulsion. This leads to reduction in Explosives usage.
(b) The desired fragmentation can be achieved using ANFO with an average 42.63% higher powder factor than SME.
(c) Significant reduction in Blasting Cost with ANFO compared to SME
(d) Much lower ground vibration with ANFO observed in >90% of Blasts
(e) Better fragmentation with ANFO

Based on the recommendations of the Trials, WCL has processed for the procurement of 2000MT low density porous prilled Ammonium Nitrate. NCL has also processed for the procurement of Low Density Porus Prilled Ammonium Nitrate of 3000Te.

Use of ANFO as explosive variant will help in addressing the following key needs of MCL-

(i) Self-Reliance and Security of supplies– Having its own ANFO facility for captive consumption will help in catering to increasing demand of explosives for higher overburden production. Ability to use ANFO will reduce the over dependency on SME and allow scalability to increase ANFO blasting at a short notice to meet peak demand by using LDAN stored in MCL's AN Warehouse.

(ii) Consistent Quality of explosives – ANFO being the purest form of explosives has only two components in its matrix, Low Density Ammonium Nitrate Prills (94%) + Diesel Oil (6%), and it has no water or any other chemical or inert which can deteriorate the quality of explosives as in the case of SME. Through ANFO usage, MCL will improve quality control and much less quality variation compared to SME because all ingredients of ANFO will be in MCL's full control.

(iii) Lower Blasting Cost and better Fragmentation – due to low density which leads to lower specific consumption in the blast hole, and high (94%) Ammonium Nitrate content (Oxidiser), ANFO gives higher powder factor, better fragmentation and muck profile compared to conventional explosives like SME.

(iv) Vibration and Environmental control – Due to lower density of ANFO (0.8 gm/cc), the charge per meter is much lower i.e. less charge per hole which reduces the vibration level and helps conduct blast as per DGMS guidelines. Sasan Power Limited, the largest private sector Coal Mine in India with annual coal production of 18 Million Tonne, consumes approximately 40,000 Metric Tonne of explosives annually, 50% of which is ANFO. M/s Smartchem have been supplying OPTIMEX LDAN to the mine of Sasan Power Limited to the tune of 1500 MT/ month.

Case Study of One OCP of IB Valley Coalfields

The assumption for cost benefit analysis of 20 % ANFO and 80 % SME has been taken in MCL as a whole and this OCP where the of dry holes are more. Thus applicability of ANFO at 20 % of total explosive consumption at this OCP was studied and presented below :

COMPREHENSIVE STUDY FOR USE OF ANFO WITH LOW DENSITY POROUS PRILLED AMMONIUM NITRATE FOR DRY HOLE BLASTING AT MINES OF MCL AS AN ALTERNATE BLASTING TECHNIQUE/SYSTEM - A CASE STUDY

Cost Comparison of ANFO vs SME & LD Explosive					
	Approx rate of ANFO (Rs)	SME Rate RC 2019-21 from 1st Dec'2020 (RS)	RC rate of LD (Rs)- Composite Price from 1st Jan'2021	Difference in price of ANFO wrt SME (in Rs.)	Difference price in price of ANFO wrt LD (in Rs.)
Basic Rate	26300	24660	31031		
Freight	5000				
Operational cost	1500				
Diesel cost @ 75.80/liter for 70 liters (6.5 liters/100 kg) @ 0.82 Density	5306				
Landed Product price without GST	38106	24660	31031	13446	7075
Cost of 1MT (*Expl cost for 1000 kgs AN + 57.4 KG diesel (70 lit) SP gravity of diesel 0.82 =1057.4 Kgs*)	36037	24660	31031	11377	5007
Inhole Density	0.80	1.20	1.25		
In Hole Cost of Explosive	28830	29592	38788	-762	-9958

Table above shows saving of Rs762/Te in case of ANFO vis-à-vis SME (2.6%). Similarly, in case of ANFO vis-à-vis LD there will be a saving of Rs 9958/Te (25.6%).

Product	Hole Depth (Mtrs) Dia 160mm	Stemming (Mtr)	Charge (Mtr)	Density	Charge/Mtr	Charge/ Hole	Cost per Hole
SME (Cost @ 24.66/Kg/mtr)	6	3.5	2.5	1.2	24	60	1480
ANFO (Cost @ 38.10/Kg/mtr)	6	3.5	2.5	0.8	16	40	1441
							39
As per ANFO charging at Durgapur OCM (as per M/s Smartchem Tech Ltd)	6	3.7	2.3	0.8	16	37	1326
						Savings	154

Table above shows it can be considered for the standard charging pattern there is a saving of Rs39/Te in case of using ANFO vis-à-vis SME considering a standard pattern of charging of 24Kg/mtr in case of SME and 16Kg/mtr in case of ANFO. This saving has been found to be enhance to Rs.154/Te in case of Durgapur OCP, WCL.

1. Cost Benefit Analysis:

(1) If we use 80% SME + 20% ANFO in place of 100 %SME at MCL:

a) Total consumption of SME in 2019-20: 40221594 Kg

b) Total Blasted OB Production in 2019-20: 86458760 CuM

c) Powder Factor achieved 2019-20: 2.15

d) Total Cost of SME (without GST)/kg: Rs 117.58 Crores.

ii) Cost for 80% use of SME

a. Total consumption of SME for 80% of Blasted OB production in 2019-20: 32177275 Kg

b. 80% of Total Blasted OB Production in 2019-20: 69167008 CuM

c. Powder Factor achieved: 2.15

d.Total Cost of SME (without GST)/kg: Rs 94.07 Crores

iii) *Cost for 20% use of ANFO*

a. Total consumption of ANFO for 20% of Blasted OB production in 2019-20: 5639990.7 Kg

b. 20% of Total Blasted OB Production in 2019-20: 17291752 CuM

c. Powder Factor (c x 42.63%+c): 3.07

d. Total Cost of ANFO @28.81 (without GST)/kg: Rs 16.25 Crores.

Total Cost Saving= [i-(ii+iii)]: Rs.7.27 Crores

CONCLUSION

A detailed cost-benefit analyses, and experience of WCL has shown savings potential with the use of ANFO, besides ensuring smooth supply of explosives for uninterrupted OB removal at MCL.Considering the explosive crisis as prevalent for last many months, shortage of explosive will have a definite impact on OB removal and subsequently on coal exposure.


IDEAL
IDEAL PRIME
EXPLOSIVES
IDEAL
IDEAL PRIME
EXPLOSIVES
IDEAL
IDEAL POWER - 90 IDEAL POWER -
Its Ideal to be with IDEAL

The Indian Mining & Engineering Journal, Vol. 60, No.08-09, August-September 2021, pp.01-11
Printed in India, @ IME Publications, ISSN 0019-5944

Blasting Practices of Coal Mines of Jagannath Area

P.B.Reddy*

INTRODUCTION

Jagannath area is one of the major coal producing area of MCL having two active working open cast mines) one abandoned open cast mine South Balanda. Table 1 , shows the annual production target and other details.

Table 1 : Presents Ananta and Jagannath OCP details

Project	OB Target (Mill m^3/year)	Coal target (Mill. Tonnes)	Explosive consumption	Powder Factor	
Ananta	23.5	3.0	10,500	OB – 2. 1	Coal 4.96
Jagannath	7.00	7.0	2,900	2.18	4.35

Overburden is removed by drilling and blasting the blasting parameters have been maintained to ensure better fragmentation and a control on vibration level, fly rocks etc. In coal, 95% of coal production is being done by deploying surface miners and anly 5% is being done by conventional method of drilling and blasting.

Mining operations in both the mines are surrounded by densely populated villages like Hiloi, Ekdal, Bir Ramchandrapur , Rakas etc. This has been a major hurdle while conducting blasting safely with total control in respect of ground vibration, air over pressure, fly rocks etc. In Ananta Opencast mines due to non movement of benches for months some benches are under fire where blasting in hot strata is another problem. All precautions required for blasting near villages and blasting in hot strata are followed.

To ensure smooth blasting and storage of explosives and accessories, four numbers of magazines in Jagannath Area cater both the projects. Their storage capacity is given in the Table 2.

TRANSPORTATION

Transportation of shock tubes(Nonel), detonators, cast booster and LD Explosive are being done up to blasting site by EXPLOSIVE VANS in both the mines. Separate explosives vans are used for carrying detonators and explosives. SME (Site Mix Emulation) of M/s IOCL is used for blasting purpose, which is transported by the BMD vehicles to the blasting sites. Standard COPs are framed and strictly followed. The mines have well documented 'Code of Practice' for transport, use and pilferage of explosive, use of SMS/SME explosive and blasting operation.

**General Manager*

Table 2 : Presents Explosive storage capacity

Project	Magazine	Licensed capacity	Remarks
Ananta OCP	No. 2	Nitrate Mixture 6.0 MT Cast Booster 2.0 Mt Detonating fuse 5,000 M Detonators 8500 Nos.	These magazines are situated in a remote area where there is no population within 800 Mtrs. These magazines are guarded by security personnel round the clock.
	No. 3	Nitrate Mixture 5.9 MT Cast Booster .9 Mt Detonating fuse 15,000 M Detonators 8500 Nos.	
Jagannath OCP	No. 4	Nitrate Mixture 7.5 MT Cast Booster 0.5 Mt Detonating fuse 15,000 M Detonators 10000 Nos.	
	No. 5	Nitrate Mixture 8.0 MT Cast Booster 2.0 Mt Detonating fuse 5,000 M	

Hazards

In line with provisions of CMR 2017 Rule 104, 'Safety Management Plan' having hazards associated with all operations have been identified and attended to ensure safety. The hazards are identified and mitigated as per DGMS Tech.(S&T) Circular No. 15 of 3.12.2002.

1. Effect of Ground vibration
2. Effect of Air over pressure
3. Fly rock during blasting
4. Noise Pollution
5. Dust pollution
6. Blasting in hot strata

To mitigate all the hazards, controlled blasting technique is adopted in Jagannath Area. At present, the villages are located more than 500 M away from the blasting site. Proposal is initiated for scientific study of blast design for blasting within 500M and beyond 100M of villages. Till the time, meticulous efforts are made to design, implement and monitor the blasting process. Figure 1, shows location of villages.

Blast Design

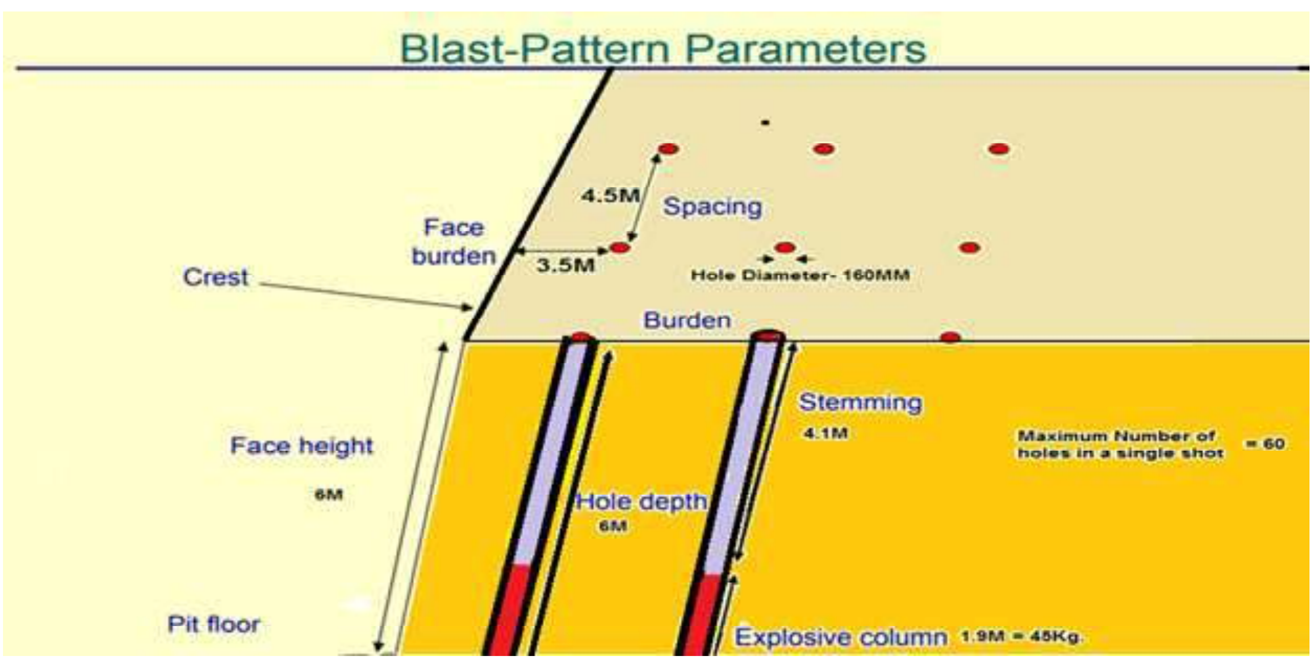
All blasts are being executed on the basis of scientific studies which were conducted during past years. Some of the salient features are - Free face, Blast Geometry (Figure 2, Burden , Spacing, sub-grade drilling in hard strata, stemming column height), Wet drilling and water spraying in drilling faces are mandatory while drilling, Charging of holes, Muffling, Vibration monitoring, etc.

Free Face

The availability of Free vertical face for blasting is the most important factor in control blasting. The availability of free face is ensured and has following advantages -

1) Increase in productivity due to better fragmentation of blasting materials.
2) The flying of rock always takes place towards the direction where there is lesser load i.e burden. Therefore, free face available gives the weaker plane for the displacement of rock. Thus in case of vertical free face the movement of rock is horizontal. Hence rock fly is avoided.
3) Free face for 2nd and subsequent rows is obtained by use of delay system in between successive rows.
4) Free movement of blasting benches will reduced the ground vibration.

Figure 1 : Aerial view of the villages



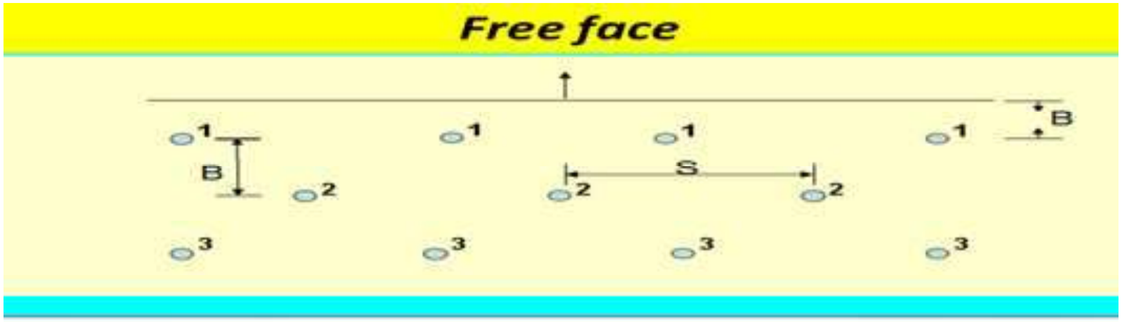


Figure 2 : Shows Blast geometry

Burden

1) The distance between the free face and the first hole/ row of hole and the distance between two rows of blast holes are also called as burden.
2) If burden is more, it will defeat the very purpose of free face and will result in formation of fly rock and higher ground vibration.
3) The burden is always less than the spacing . In practice, the burden is kept 0.6 to 0.7 of hole depth in metre for 160 mm dia.

Spacing

1) The distance between the individual hole in a row is called spacing. The spacing is measured parallel to free face.
2) The spacing is kept about 0.7 to 0.8 times of Hole depth .
3) The purpose of keeping spacing more than burden is to direct the blasting forces towards the free face and avoid fly rock and ground vibration.

Sub-grade Drilling:

- Sub-grade drilling will results in ground vibrations hence sub grade drilling is avoided while blasting near the village.

Stemming:

1) The stemming of the blast hole is necessary to ensure confinement of the blasting materials and the gases(fumes) produced after the blasting. Generally stone dust, fine earth, sand, clay may be used as stemming material.
2) In any case, stemming should not be less than 20 Diameter of blast hole.
3) Practically, Stemming height is always kept more than burden to avoid fly rock.

Wet Drilling and water spraying :

Before starting drilling operation (Figure 3) the face is properly cleaned from loose materials to avoid fly rocks.

- To avoid dust formation the drilling face is wetted before starting the drilling operation.
- Wet drilling is being ensured.

Charging of drill hole (Figure 4)

1. Holes are charged by SME of M/S IOCL. IndianOil has established a bulk emulsion manufacturing unit within Jagannath area lease hold and have storage and pump trucks to meet demand of SME of the Talcher Coalfields.
2. Electronic detonators are given preference over Nonels while blasting near the villages to avoid scattering effect.
3. Optimum quantity of explosive is charged after several field trials, over charging and under charging strictly avoided.

Figure 3 : showing drilling in OB benches

Figure 4 : Shows charging of holes in progress and stages of charging

4. Over charging will increase fly rocks and ground vibration.
5. Under charging will result in higher ground vibrations.
6. Bottom initiation is being in practice.
7. Electronic detonators are useful in reducing noise pollution after blast.

Muffling

After the connection of blast holes, the area shall be covered by wire mesh/conveyor belts and sand bags. Initially, while creating free face in existing ground this arrangement is must. Once the vertical face is prepared, the fly of rock is controlled by correct design of controlled blasting in terms of charging, delay, burden, spacing etc.

Vibration monitoring

Drilling and blasting combination is still an economical and viable method for rock excavation and displacement in mining . The adverse effects of blasting, i.e. ground vibrations, air blasts, fly rocks, back breaks, noises, etc. are not avoidable and cannot be completely eliminated but certainly minimize up to permissible level to eliminate damage to the surrounding environment with the present structures . The application of proper field controls during all steps of the drilling and blasting operation will help to minimize the ill impacts of ground vibrations, providing a well-designed blast plan that has been engineered. This design will help in bearing in mind the proper hole diameter and pattern that would reflect the efficient utilization and distribution of the explosives energy laden into the blast hole. It would also provide for the appropriate amount of time between adjacent holes in a blast to provide the explosive the optimal level of energy confinement.

When the blast is properly designed, then the ground vibrations, air blasts, fly rocks, back breaks, noises, etc are considerably reduced.

- The ground vibration within 250-300 Mtrs. of blast site recorded in each blast is kept below 3mm/s.

Summary of the procedures discussed above for control blasting:

1. Drilling pattern should be strictly monitor by an Assistant manager.
2. Sub-grade drilling strictly avoided .
3. Drill hole should be charged with optimum quantity of explosive.
4. Proper Muffling should be done .
5. Ground vibration to be monitored and if the vibration exceed the limit review the blast design.

Blast Reports and evaluation

Over the years blast reports are helpful in studying various parameters and post blast evaluation norms. Blast report of Ananta OCP, is presented at Table-3

Table 3: Presents Reporting of Blasting Parameters

Parameters	**Details**	**Remarks**
Location of blasting site	Long. & Latitude	Can be taken before charging
Bench. No.		
Excavator type	PC	
Blast hole Dia	160 mm	
No. of holes	60	
Rock type	Stone parting	
Strata	Medium hard to hard	
Blast Geometry (all dimensions are average m.)		
Burden	3.5 m	
Spacing	4.5 m	
Average hole depth	6.0 m	
Bench height	6.0 m	
Explosives and accessories		
Explosive type	Indogel 1116 (SME)	Quantity – 2700 kgs
Booster	Cast booster	6.0 kgs
Charge per hole	45 kgs	
Deonators	Nonel/shock tubes	
Delay with Nonel	No. of nonel used on trunk line with delay timings in Milli Secod(MS). Delay between holes and between rows to be recorded. Bottom hole delay timings to be recorded.	
Height of explosive column	1.9m	
Height of stemming column	4.1 m	
Maximum Charge/delay	45 kgs	

Evaluation		
Pre- blast		
Status of Free face	Mention face free from previously blasted material. No. of free faces available.	
During charging of SME	Check cup densities and observe the gassing time of the sample collected from the delivery hose.	
Block volume	5670 m^3	Length of the blasting block, width of the block to be recorded.
Status of Fire	Location, nature, average temperature before treatment with water and after water treatment, No. of holes in active fire etc.	
Blast vibration and Frequency	Measured for every blast at 500m and beyond. Results are checked with DGMS Tech. Circular No. 7 of 1997.	
Post Blast		
Powder factor	In-situ and after excavation is calculated	
No. of boulders/'000 Tonnes of excavation		
Muckpile	Tight or excessive throw to be noted	
Some other evaluation parameters are -	(a) Rate of loading, (b) Qty of explosives used in secondary blasting, (c) Hrs of engagement of rock breakers to break oversize boulders. (d) Consumption of bucket teeth per million tones of loading (e) Diesel or Electricity consumption of excavator, etc. (f) Dozing time before excavator is placed after blasting in Hrs.	

Blasting in hot strata

In Talcher Coalfields opencast workings are situated in densely populated area where land acquisition is a major problem. Due to this movement of Coal benches & OB benches remains stagnant for months & subjected to spontaneous heating. When old coal workings are exposed to the atmosphere and water for prolonged time during the opencast phase, spontaneous combustion of coal spread into overburden rocks and strata as well.

Because of burning of coal (Figure 5), due to spontaneous combustion, temperatures are intense in the surrounding overburden strata and in the coal seams. Under such elevated temperature condition, it becomes more difficult to drill and charge the overburden above the burning coal as well as in the coal benches.

Figure 5 : Showing existence of fire

Hazards related to hot holes

Spontaneous heating or burning coal deposits represent a serious problem in operations associated with the surface mining of coal seams. These sub-surface fires present a real challenge to mining operations. Blast holes drilled down into the coal to facilitate blasting operations, however, present a more specific hazard. Despite a range of pre-drilling practices, such holes, whilst initially appearing cool and safe to load with explosives, can still undergo sudden and unpredictable escalations in temperature.

In the absence of sufficient oxygen, coal is consumed by a fire at a relatively slow rate, but introduce oxygen, perhaps via a drill hole or a crack or fissure and the combustion rate and the burning temperature of the coal can increase significantly. Once hot enough, any explosives placed into the hole can be caused to initiate or ignite. This may be life threatening if there are personnel within range of the blast or its fly rock.

Some of the major hazards associated with higher ground temperature may be:

- Exposure of operators to high temperature ,
- Ignition of vapours associated with emulsion and ANFO type products,
- Softening of plastic components of initiating products,
- Melting and decomposition of bulk packaged and initiating products,
- Pre-mature detonation following decomposition.

The main problem associated with the opencast mining of fiery coal seam is drilling in hot strata, selection of suitable explosives and initiating system, charging or loading of blast-holes and thereafter blasting. It is known fact that the elements in a blast-hole that are most sensitive to temperature above about 80 degree are the initiating devices, such as detonator and booster in the primer.

Thus, for blasting in hot holes, conventional shock tubes and detonators are not used down-the-hole, as unexpected detonations would become a risk.

Charging and blasting of hot blast-holes

☞ The possibility, that despite all precautions, the reheating of a drill hole might still occur has given mine managers sleepless nights. A reheated drill hole, perhaps by now also charged with explosives, could expose any on-bench loading crew in the vicinity to real danger.

☞ The problem is getting worse because more and more coal mining operations are expanding into areas where underground fires exist. The heat, smoke and high temperature gases escaping from the burning coal deposits below can lead to unseen changes in the condition of affected blast holes. In a worst case scenario this can result in premature and uncontrolled detonation of the explosives column. Such an event could take place whilst the operators are still working on the bench.

☞ Most mines have excellent operating procedures for blasting in hot areas, however, there have been several incidents where primed but not charged holes have detonated prematurely.

☞ Generally, the problem of higher blast-hole temperature is tackled by quenching with water. Proper quenching methods are to be applied to keep the temperature within 80 degree centigrade (as per DGMS – Tech. Circulars). It has been observed that, flushing hot-holes with the mixture of water, bentonite, sodium silicate and guar gum solution help retain water to seal micro-fractures and cracks and bring the temperature down relatively easier. Holes with higher temperature should be identified and quenching of those hot-holes should be initiated at least 12hours prior to charging and blasting in order to lower down the temperature.

☞ Temperature of blast-holes is monitored and recorded soon after completion of drilling, after quenching with the help of water and just before charging of explosives. Digital temperature indicator based sensor should be used for temperature recording. Increase in temperature of charged holes, if any, also are recorded till final firing.

☞ It has been observed that slurry/ Emulsion composition including site-mixed bulk explosives and detonating fuse, generally used for mining purpose, withstand hot-hole condition up to 120 degree centigrade for about two hours without deterioration.

☞ Punctured holes are to be plugged at bottom before charging. Air-bags may be used for the purpose of plugging hole at the bottom. It is a good practice sufficient non-combustible stemming material such as sand, crushed stone chips or drill cutting should be available near the collar of each hole prior to commencing of charging operation, in order to fast accomplishing stemming and charging operation.

☞ It is advisable to charge Emulsion explosives, Detonating fuse with 'Top-Priming' of Booster in Hot holes. These primers are applied shortly before blasting time, at the top of the explosives charge, where the emulsion is relatively cooler. After primers are put, stemming, tie-up of the detonating fuse and fire are done as quickly as possible, without wasting any time.

DGMS criteria for charging and blasting in hot blast-holes: (CIR. TECH. 2/1985 & 2/1990)

It is recommended that while blasting in hot strata (either in OB or coal) the following precautionary measures should be adopted:

(a) No explosive other than slurry and emulsion explosive shall be used.

(b) Blasting shall be done with detonating fuse down-the-hole

☞ Temperature inside the blast holes shall be measured (before filling with water) and if the temperature exceeds 80°C in any hole, shall not be charged. Records of measurements of temperature in each hole shall be maintained.

- All blast holes shall be kept filled with water. When any hole is traversed by cracks or fissures, such hole shall not be charged unless it is lined with an asbestos pipe and the hole filled with the water. In addition, bentonite should be used for sealing any cracks at the bottom of holes.
- Detonating fuse shall not be laid on hot ground without taking suitable precautions which will prevent it from coming in contact with the hot strata.
- The charging and firing of the holes in any one round shall be completed expeditiously and in any case within 2 hours.
- Blasting operations shall be carried out under the direct supervision of an assistant manager.

Summary of the procedures discussed above for blasting in hot hole:

General guideline of blasting in hot holes are summarised below:

- Select the number of holes properly so that the total blasting operation should not exceed 2 hour from charging of first hole.
- Measure the temperature of the holes almost constantly till the commencement of blasting operation.
- Use water at least 12 hour before blasting to flush hot holes till the temperature comes down below 80°C.
- Record the temperature of holes at a regular interval of time. Use mixture of Bentonite, Sodium Silicate and Water in holes which do not retain water to seal micro-fractures and cracks. Guar gum up 5 % may be also be used for the same purpose.
- Only slurry or emulsion explosives, preferably bulk explosives to be used for hot-hole blasting purpose.
- Detonating fuse as initiation system only should be used. Shock tube and detonators should not be used down-the-hole.
- Adequate non-combustible stemming material should be available near the collar of each hole prior to commencing of charging operation, for fast accomplishing charging operation.
- Punctured holes are to be plugged at bottom before charging. Air-bags may be used for the purpose.
- Combination of Bulk-Loading Emulsion explosives, Detonating fuse with Top-Priming of booster is preferred. These primers are applied shortly before blasting time, at the top of the explosives charge, where the emulsion is relatively cooler. After primers are put, stemming and blasting are done as quickly as possible, without wasting any time.

Code of practice for transport, use and pilferage of explosive

The following Code of Practice is framed for prevention of pilferage of Explosives at Ananta OCP.

Check at magazine while loading of explosives

1) No Explosives shall be issued from the Magazine without valid requisition duly signed by Authorised Person (Blasting Officer, Quarry Incharge, Manager).
2) Accordingly Transit Slip will be prepared as per the requisition with due signature of the Authorised Signatories.
3) Magazine Clerk and the person so authorised to receive Explosives from Magazine shall open the seal of the Magazine in the presence of Security Guard.
4) Explosives and its accessories shall be issued from the Magazine in presence of Security Guard and loaded to Explosive Van under the personal supervision of Blasting Officer or Blasting Overman.
5) After completion of the loading of Explosive in to the Van, Van shall be locked and sealed in the presence of Security Guard.
6) The details of issue of Explosives and its accessories received from the magazine shall be entered in the Register kept with Security Guard at the Magazine apart from the registers maintained by Magazine Clerk.

Check at blast site:

a) After reaching the Explosive Van at Blast site, the lock and seal shall be opened in the presence of Blasting Officer or Overman except who has received the Explosives from Magazine.
b) At the end of the operation and during the operation the Blasting Overman shall count the number of cartridge, detonators, fuse etc. at least once and make an entry thereof in the Transit slip and sign the same.
c) During the operation the Blasting Officer/ A.C.M. shall check and sign the Transit Slip.
d) The Blasting Overman shall maintain a Pocket Diary indicating the no. of holes fired, specifying the type and quantity of Explosives, Detonators, and Fuse etc. for spot verification.
e) At the end, the Blasting Overman shall check the Explosive Van, enter the balance quantity of Explosives and its accessories in the Transit Slips and sign it.

Check at the time office

1) The Blasting Officer shall check the number of Cartridge, Detonators, and Fuse etc., make an entry thereof in the Transit slip and sign it.
2) The Blasting Officer shall lock and seal the Explosive Van and handover the key to the Blasting Overman.

Return of un-used explosives at the magazine

1) The Overman shall return the un-used Explosives and its accessories to the Magazine in presence of Security Guard.
2) The details of returns of Explosives and its accessories shall enter in the Register kept at the Magazine apart from the register kept at Security Guard.

Final check

- The Manager or Blasting Officer shall countersign every Transit Slip. He shall check the entries in the slip against the entries made in the issue and return Explosive Register.

Stock checking at the magazine

- The Manager or Blasting Officer or Assistant Manager, specially authorised by the Manager for the purpose shall once at least every week check the stock of the Explosives in the Magazine and compare it against the records maintained by the Magazine Clerk.

General

1) Blasting Personnel shall not use the Explosive Van for their transportation. However, Blasting Overman will accompany the Explosive Van.
2) Any over writing of the entries in the Transit slip shall be countersigned by the person making the same.
3) All the reports and registers relating to Explosive and Blasting are to be maintained upto date by Blasting Overman or Blasting Officer and duly countersigned by the Officer authorised by the Manager for the purpose.

Code of practice for use of SMS/SME explosive

1) Each SMS Explosive Supply Agency must submit the copy of the valid permission letter from the Director of Mines Safety, Bhubaneswar for the use of their product at Ananta OCP.
2) The operation of mixing SMS Explosives, Charging and Firing of shot holes shall be carried out under the supervision of Technical Officer of the Supplying Agency in addition to the supervision of Blasting Overman and Blasting Officer of Ananta OCP.
3) The pump truck carrying constituents of SMS Explosives shall be in safe operating condition and shall be driven by competent Licensed Driver.
4) The Supplying Agency shall have to deposit the Xerox copy of the RC Book of the Pump Truck.
5) Each persons engaged in charging, stemming of SMS Explosives including the Driver of the Pump truck and the Technical Supervisor of Supplying Agency have to comply the following;
   i. To mark their attendance ‘IN’ & ‘OUT’ at the Time Office before entering and leaving the mine.
   ii. To possess the Identity Card always while they are on duty.
   iii. All have to produce their VT certificate, Medical Certificate and 2 copies of passport size photographs at the Safety Officer, Ananta OCP so that their name should be registered in Form ‘B’ Register.
6) In no case the Pump Truck is to step over the power cable.
7) The Pump Truck is to be always stationed/parked at a safe place decided by Blasting Officer inside the Mine.
8) The weighment of Pump Truck shall be taken daily at the Colliery Weighbridge before and after the use of the SMS Explosives.
9) The weighment and charging details of each pump truck is to be recorded in a bound paged register which is to be signed by the representative of Explosive Agency, Blasting Officer and countersigned by the Manager or his authorised signatory.

Code of practice for blasting operation

The following Code of Practices is hereby framed for safe and effective deep hole blasting at Ananta OCP.

1) Every persons engaged in Blasting operation must be equipped with safety accessories like Helmet, Shoes and other Safety items applicable to them.
2) Every persons, departmental as well as contractual, engaged in blasting must be Vocationally trained for handling Explosives and they must marked their attendance ‘IN’ & ‘OUT’ in Form ‘D’ Register, kept for the purpose at Time Office.
3) Blasting Gang must carry all the accessories provided for conducting safe blasting such as –Blasting Cable

– 300 mtrs. Whistles, Exploder, Red & Green Flags, Caution Boards.Stemming Rod, Wire nets and sand bags for muffling (wherever necessary), HootersWalkie Talkie, Siren (van mounted).

4) Depth, burden, spacing verifications, charging, stemming of Explosives must be carried out under the personal supervision of Mining Sirdar, Overman or Blasting Officer as the case may be.
5) Centries are to be posted at the Security Barrack junction and Bhalla Road junction and at any other entries to prevent inadvertent entry of persons to the blasting danger zone.
6) Blasting siren located at Security Barrack must be sounded at the beginning and end of blasting period (8.00 AM to 9.00 AM, 1.00 PM to 3.00 PM).
7) Before firing the shots, the Mining Sirdar, Overman, Blasting Officer as the case may be must see that the Machines or equipment's within the blasting danger zone must be shifted to a safe place. If any machine is in operation during the said period the persons engaged in such operation are to be cautioned to take adequate shelter beyond the danger zone.
8) The Security Guard posted at Eastern side of the Quarry and Northern side of the is also to be cautioned to take adequate shelter and to prevent inadvertent entry.
9) The departmental and contractual workers engaged by Civil, E&M and Excavation department for any job inside the mine are to be cautioned for taking adequate shelter during firing of shots in the area falling within the danger zone.
10) The Mining Sirdar, Overman or Blasting Officer who is firing the shots must ensure that sufficient warning/ signal is given to caution the persons within the danger zone (300 Mtrs.) for taking adequate shelter and confirm the clearance signal received from different Centries posted in different locations.
11) No person should enter into the Blasting danger zone or the cautionary zone crossing the caution board or disobeying the instruction of Sentry.
12) In no case sleeping holes are to be left.
13) Drilling & Charging not be done simultaneously in the same face.
14) After completion of firing the shots, the face is to be inspected by the Mining Sirdar, Overman or Blasting Officer himself who has fired the shots and the clearance signals from the said face must be initiated by himself only.
15) In case of misfire, it is to be dealt carefully by the Mining Sirdar, Overman and Blasting Officer as the case may be with due precautions to avoid any accidental firing.
16) The worthiness and adequacy of warning signals are to be verified by the Mining Sirdar, Overman or Blasting Officer personally and if any defect is noticed, it has to be rectified on the priority basis and also has to be brought to the knowledge of Safety Officer or Manager.
17) It is the duties of the Mining Sirdar, Overman or Blasting Officer to see that Conditions stipulated for drilling, charging or firing of shots vide permission No.002698/BDH/CO-8/P-98(1) & (3) /2013/836 Dtd. 18/04/2013 is not violated and the conditions given for charging and firing of holes with bulk explosives is complied with.
18) If anybody tries to enter into the Blasting danger zone, disobeying the sentry, the blasting operation is to be suspended and blasting operation will not be resumed till such persons has taken adequate shelter beyond the blasting danger zone. Every such case must be brought to the knowledge of Safety Officer and Manager in writing.
19) Where there are chances of danger of flying fragments the shots shall be muffled with wire nets and sand bags provided.
20) Every person must follow this Code of Practice and all the statutory provisions for conducting safe blasting.
21) When there is chance of any electrical storm, the following precautions shall be taken.
22) The detonators shall be handled.
23) If charging operations have begun the work shall be discontinued till the storm has passed.
24) If the shots are is to be fired electrically all explosive wires shall be coiled up and kept covered by something other than a metal at the mouth of holes.

CONCLUSION

Blasting operations at Ananta and Jagannath OCPs continue to be challenging and involves close cooperation with all stake holders like explosive suppliers like IOCL, suppliers of explosives(cartridges and accessories), neighbouring villagers, DGMS, scientific bodies and MCL H.Qrs. Efforts have been made to conduct blasts scientifically with a view to maintain safety and productivity.

ACKNOWLEDGEMENT

Thanks are due to my team members and MCL management for giving an opportunity to present this paper.

The Indian Mining & Engineering Journal, Vol. 60, No.08-09, August-September 2021, pp.12-16
Printed in India, @ IME Publications, ISSN 0019-5944

Controlled Blasting Techniques Adopted at Lakhanpur OCP of MCL

Kumar Chandramauli* Yogesh Kumar Badariya*

INTRODUCTION

Lakhanpur OCP under Lakhanpur Area of MCL under IB Valley Coalfields, was established to mine power grade coal. It has a current annual production target of 21 million tones of coal production by removing 38 million cubic m of OB. While drilling and blasting continued to be the main rock breakage system, surface miners were introduced in this mine for the first time in coal mining in the year 1999. Surface Miner had not only enhanced the coal recovery, coal quality but also had minimized the complaints from the nearby villages from blasting vibration and air blast etc. This mine is surrounded by five villages namely, Tingismal village near quarry 3, Kairkuni village near quarry 1, Karlajodi and Khaliapali village and one brick kiln near quarry 5. Similarly near Quarry 6 Khandsar village is located.

Surface Miner had also improved productivity by directly maintaining a size of – 100mm, and also helping in selective mining. Being a very safe operation it had reduced human exposure coal mining by avoiding drilling, blasting and sizing of coal.

In OB mining, drilling and blasting continues to be sole method. Bulk SME explosive is being used along with Nonel. Experimental blasts were also conducted where Electronic Delay Detonators were used. On an average 50 to 55 Tonnes of bulk SME is blasted to blast 1000 holes per day.

ECO-FRIENDLY MINING

Apart from successfull deployment of surface miners in Indian coal mines, a number of new initiatives have been taken up in this mine to ensure green mining status. Similarly in the areas of blasting Nonel is used and trails with Electronic Delay Detonators have been completed. For the first time duel fuel HSD-LNG as a fuel will be used in dumpers. Very recently a tripartite MoU was signed on August 31 between Coal India Ltd (CIL), state gas utiltity GAIL and Indian mining equipment OEM BEML for a pilot project on use of LNG as an alternative fuel for dual fuel (diesel – LNG) operation of dump trucks. This will considerably reduce carbon emissions. The process of fitting LNG conversion kits on two 100 ton class trucks at this mine is under fast track implementation.

BLASTING PRACTICES

Explosive energy is used to break rock. However, the use of this energy is not 100 percent efficient. Some of the energy escapes into the atmosphere to generate air blast or air vibrations. Some of the energy also leaves the blast site through the surface soil and bedrock in the form of ground vibrations. Both air and ground vibrations create waves that disturb the material in which they travel. When these waves encounter a structure, they cause it to shake. Ground vibrations enter the house through the basement and air blast enters the house through the walls and roof. Ground vibrations propagate away from a blast site as Rayleigh (or surface) waves. These waves form a disturbance in the ground that displaces particle of soil or rock as they pass by. Particle motions are quite complicated. At the ground surface (free boundary), measured particle motions have the greatest displacements, and displacements decrease with depth (see the illustration below). At a depth of between 20 to 50 feet below ground surface, particle displacements are barely detectable. Structures that are well coupled to the ground tend to move with this motion; structures buried in the ground are less affected by surface motions.

Ground vibrations are measured in terms of particle *velocity and are reported in mm* per second (mm/s) or the speed at which a particle of soil or rock moves. At typical blasting distances from residential structures, the ground only moves with displacements equal to the thickness of a piece of writing paper. In terms of displacement, this equates to hundredths of an mm; visually, such movement cannot be detected.

Air blast may be audible (noise) or in-audible (concussion). When outside a house the blast may be heard because of the noise, however noise has little impact on the structure. The concussion wave causes the structure to shake and rattles objects hanging on walls or sitting on shelves. This “interior noise” will alarm and startle people living in the house.

*Lakhanpur OCP, MCL

Fly rock is debris ejected from the blast site that is traveling through the air or along the ground. Fly rock the single most dangerous adverse effect that can cause property damage and personal injury or death. Both above-ground and below-ground structures are susceptible to vibration impacts. Structures can include onsite mine offices and buildings, as well as offsite residences, schools, churches, power transmission lines, and buried pipelines. Some of these structures may include historic or cultural features sensitive to even low levels of vibrations.

The DGMS guidelines is strictly followed by taking measurement of blast vibration, sound level and frequency. The Permissible PPV(mm/s) as per DGMS(Tech) circular no. 7 of 1997 , is stated below -

Type of Structure	Dominant excitation frequency, Hz		
	<8Hz	8-25Hz	>25Hz
Buildings/ Structure not belonging to owner			
Domestic houses/structures (Kuchha brick and cement)	5	10	15
Industrial Buildings (RCC and framed structures)	10	20	25
Objects of historical importance and sensitive structures	2	5	10

In 4 nos. of quarries mining is in progress. Table 1, explains the status of blasting and controlled blasting adopted in the OB benches.

Table 1, Presents the status of blasting and controlled blasting adopted in the OB benches.

Sl No.	Distance Between Blast site and Surface structure (not belong to owner) (m)	Maximum Charge Per Delay (kg)	Maximum Charge Per hole (kg)	Pattern of holes Depth (m)	Burden (m)	Spacing (m)	Height Of deck (m)	Minimum stemming of column (m)	Max. no of Holes Per blast	Max. no of rows Per blast
1	100-125	22	30	5	3.0	4.0	1.2	2.21	16	2
2	>125-150	38	38	5	3.5	4.0	-	3.28	16	2
3	>150-200	55	55	6	4.0	5.0	-	3.51	20	2
4	>200 to any distance	55	55	6	4.0	5.0	-	3.51	30	3

Case Studies

In the following discussion, three case studies have been presented

Blast 1

Site is beyond 150m from public structure, Where Burden of 4 m, Spacing of 5 m, in a 6 m hole having 160 mm dia. Stemming was by drill cuttings and/or moist sand. Figure 1, explains the blast pattern.

Blast 2

Site is within 100 to 125m from public structure, Where Burden of 3.0 m, Spacing of 4.0 m, in a 5.0 m hole having 160 mm dia. Stemming was by drill cuttings and/or moist sand. No. of holes in a round is 16. Figure2, explains the blast pattern.

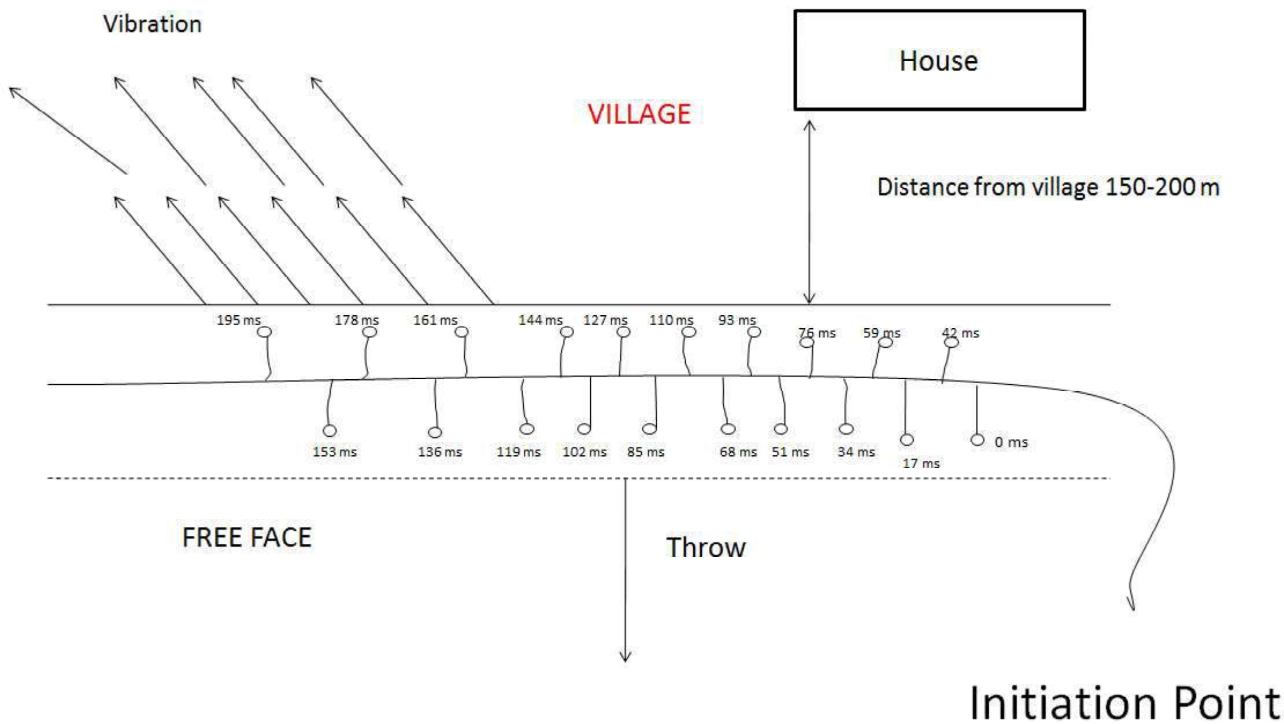
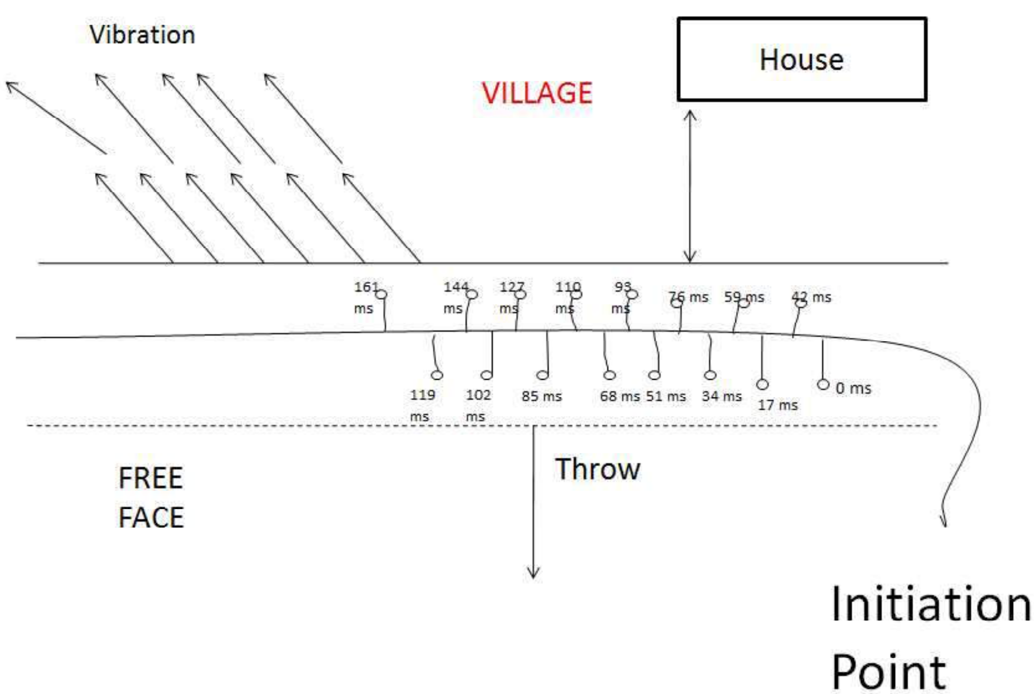


Figure 2 : Blast Pattern

Blast 3

Site is within 125 to 150 m. from public structure, Where Burden of 3.5 m, Spacing of 4.0 m, in a 5.0 m hole having 160 mm dia. Stemming was by drill cuttings and/or moist sand. No. of holes in a round is 16.Figure 1, explains the blast pattern.

Figure 3 : Blast Pattern



Photograph showing fragmentation quality

Step II : Permissible Limit Of Air Over Pressure	
AIR OVER PRESSURE	**Damage Potential**
150 dB	Cracks May Develop
170 dB	Most Cracking
180 dB	Structural Damage

Loose stemming, inadequate stemming material	Proper stemming ensured, only such stemming material that is free from pebbles ,stone chips shall be used
Watery holes	It should be ensured that explosive settled down and does not float
Inadequate stemming column	Stemming column not less than burden
Soft strata	Reducing charge per hole
Improper cleaning of face	Proper cleaning ensured
Inadequate blast geometry	Blasting patern as per permission by DGMS
Over charging	Close monitoring during charging and stemming

Step IV

In the areas of initiation Nonel has been used in almost all blasts. However, trails were conducted to use electronic delay detonators. They offer very high level of protection against stray current, static and electromagnetic radiation, very much effective in controlling ground vibration, improved rock fragmentation, increased production and productivity; reduced noise level and are Eco friendly.

By adopting control blasting practices, the mine could achieve - Good fragmentation, Ground vibration and flying

Controlled blasting measures

The very location of active mining benches close to villages, had been a major challenge for this mine. Stated below some approaches to ensure safe blasting.

Step I : Reasons And Control Measures	
REASONS	CONTROL MEASURES
Blasting Large No Of Holes In A Round	Increasing No Of Rounds
Vibrating Ground	Redusing Charge Per Delay
Gases Escaping From Detonation Of Explosive	Proper Stemming Of Holes
Use Of Detonating Fuse	Use Of Electronic Detonator
Direct Rock Displacement	By Creating Free Face

fragments within permissible limit, and Safety to human settlements, structures near the quarry.

CONCLUSION

By strictly following conditions laid down under CMR 2017, Deep Hole Blasting Permissions granted by DGMS, this mine could achieve great success in ensuring safe blasting. The Safe Operating Procedure followed is mentioned at Annexure 1. Besides, use of latest techniques in blasting is givcen due emphasis for safe and productive blasting.

ACKNOWLEDGEMENT

The authors express thanks to the Lakhanpur Area and MCL management for the presentation of this paper.

Annexure 1

SAFE OPERATING PROCEDURE FOR CONTROLLED BLASTING

1. Blasting shall be assisted by the blasting overman, who shall be present on the post during all operation of blasting and supervise the operation.
2. Following pattern of drilling and blasting shall be strictly complied
3. No blasting shall be done within 100 m from the dwellings of village near quarries and structures not belonging to the owner of mine.
4. The PPV shall be measured during every blast and record thereof shall be maintained.

5. Maximum explosive charge per delay for conducting blasting within danger zone (500m) shall not be more than charge given in table
6. Sufficient and distinct warning should be given before and after the blasting operation by means of hooter/ siren
7. Mobile telephone shall be switched off in the blasting area at the time of handling, charging and blasting of explosives.
8. The flying fragments resulting out of blasting shall not be allowed to project beyond 10m from the place of firing which shall be ensured by observing following precautions:

1. No shot hole shall be fired in crushed, broken or fractured ground/strata.
2. Top stemming column shall not be less than the burden.
3. Only such stemming material that is free from pebbles and stone chips shall be used. Moist sand shall be used for stemming of deep-holes.
4. The area failing within a distance of 60cm from the collar of each blast hole shall be cleaned of loose stones, drill cutting, debris and other loose material.
5. **Electronic initiation system shall be used for detonation of explosives in the shot hole**.
6. Variation in inclination of shot-holes shall be within 5 degree to avoid variation in crest and toe burden.
7. In case water is encountered in any shot-hole, the shot hole shall be dewatered by blowing compressed air into the hole before charging.
8. Blasting shall be conducted with muffling arrangements. Muffling shall be done in such a manner that blasting projectile shall not be able to project beyond a distance of 10 m from the site of blasting. Muffling of holes shall be done with wire netting pieces of size 1.8 m × 1.2 m overlain by 3 to 4 sand bags each of 40 kg by weight over each such hole.
9. Records of blast parameters like spacing & burden of holes, hole depth, no of holes fired in a round, charge per holes, charge per delay, and charge per round, length of explosive column, length of stemming column, initiation pattern (with proper sketch), manner of muffling, result of ground vibration observed & distance up to which flying fragment resulting out of blasting projected shall be kept maintained in a bound paged book with each round of deep holes shots fired.

TAKING VIBRATION READING

The Indian Mining & Engineering Journal, Vol. 60, No.08-09, August-September 2021, pp.17-20
Printed in India, @ IME Publications, ISSN 0019-5944

Safety Procedures in Blasting and Blast Performance in Underground mines

Vemula Abhilash*

INTRODUCTION

Underground coal mining in MCL is restricted to Nandira Colliery, Orient Colliery Mine No. 1 & 2. Against a target of 0.75 million tonnes coal produced from UG in Talcher area, production touched 0.76 lakh tonnes. Similarly at IB Valley-Orient Area against 7.85 lakh tonnes target production achieved was 4.59 lakh tonnes. OMS of UG mines is 0.60 for 2020-21.

The Orient Colliery Mine No. 1&2 is having three workable sections of Hingir Rampur Seam. The three workable section are HR Sec-I, Sec-III & Sec-IV. The parting between HR Section-I & HR Section-III is 18.5M and the parting between HR Section-III & HR Section-IV is 3.5M. Sec-III and Sec-IV are contiguous working. Table 1, presents the explosive consumption trend of last five years and Consumption so far during the 2021-22 F.Y is also presented.

Table 1 : Explosive consumption and production trend of last 5 years and current F.Y.

Year	Production	Manshift	Detonator (in nos.)	Detonator Factor	Explosive (in kgs)	Powder Factor
2016-17	284901	181054	361990	0,79	148080.652	2.20
2017-18	358076	168944	479968	0.75	175561.486	2.06
2018-19	319732	153815	406855	0.77	151214.453	2.08
2019-20	314000	142648	306875	0.98	142131.484	2.13
2020-21	203591	132869	197721	0.95	93104.636	2.02
Blast performance during the current F.Y. 2021-22 in respect of OC-1&2 Mine						
2021-22	116225	69301	93040	0.88	51299.972	1.96

CASE STUDY

Method of Working: The seam (description of seams stated at Fig. 1), is developed through Bord & Pillar method working with conventional method of Roof Bolting as per approved SSR. One development panel is being developed at 136NL, HR Sec-III and drifting work is carried out from HR Sec-IV to HR Sec-I for development of panels in HR Sec- I. Depth of Cover at Working location: Max Cover from Surface to Roof- 237.53 m, and Max Cover from Surface to Roof- 224.20 m. Degree of Gassiness: Degree II

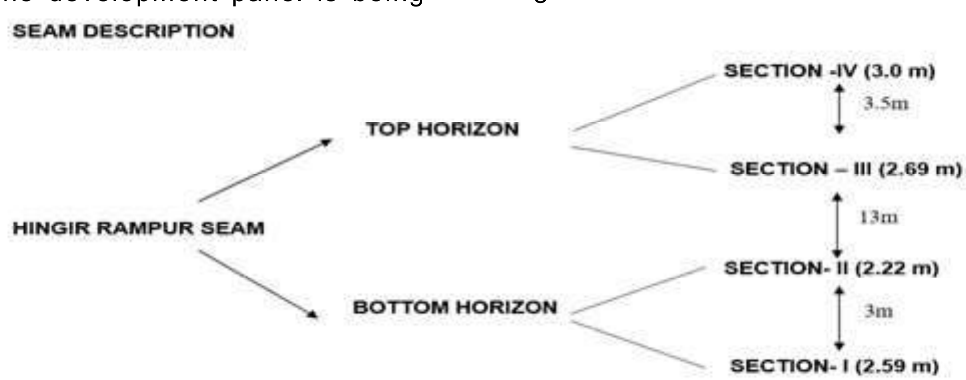


Fig. 1, Description of Coal seams being mined is shown

BLASTING PRACTICE

Permitted P5 explosives is used alongwith Copper Delay Detonator. As per Permission of DGMS vide reference no.: 010685|SEZ|Bhubaneshwar Region|Perm|2021|9463, dated : 09/08/2021, – Blasting off Solid through Wedge Cut pattern is adopted. Fig. 2, explains the major operations associated with blasting.

Size of Gallery : 4.2 x .6 m
Number of hole : 13 nos.
Charge per hole : 565 gms

*Dy. Manager (Min), Orient Colliery Mine No. 1&2, Orient Area, M.C.L.

Total charge : 6.48 kga
Blasting raio : 2.00 to 2.20Tonnes/kg
Yield per detonator : 0.9 to 1.00 tonnes
Pull : 0.85 to 0.90 m

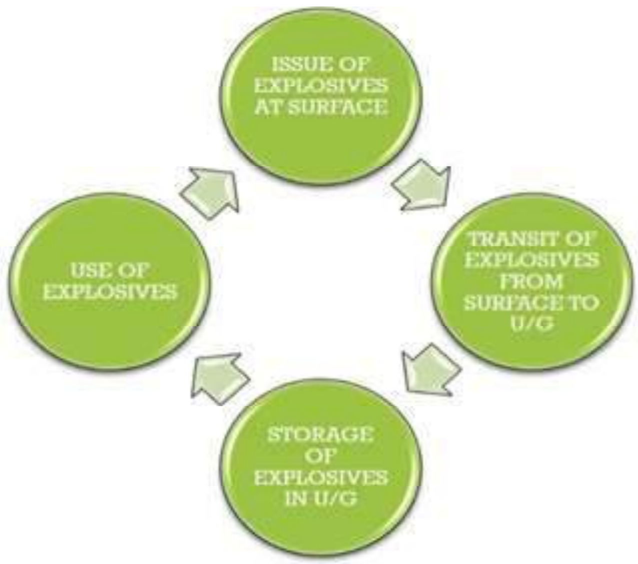


Fig 2 : A flow chart showing all the major operations from surface to underground related to issue, handling, transportation and use of explosives

SAFETY PROCEDURES DURING ISSUE OF EXPLOSIVES

The conditions as laid down in the permission granted by DGMS as well as the S-O-P drawn keeping provisions of CMR 017 and various technical circulars issued by DGMS, blasting is undertaken in the mine. Some of the salient features are –

- Only statutory and competent persons deployed in blasting operation.
- Antecedants of all persons involved in blasting operation are verified.
- Boxes/Containers used for carrying of explosive and detonators are differently coloured for three shifts.
- Explosive and detonator kept in separate boxes with secured lock and key system.
- Keys kept only under the possession of Shot Firer/ Mining Sirdar.
- Explosives with proper shelf life are only used.
- Explosive issue and Return voucher i.e, transit slip is prepared by Shift Incharge/Overman considering the balance coal left in the previous shift.
- The no. of explosive cartridges & detonators issued to shotfirer is counted by magazine clerk
- Magazine clerk enters the same in the transit slip.
- Magazine clerk then hand over the transit slip & key of the box to the shot firer.

SAFETY PROCEDURES DURING TRANSPORT OF EXPLOSIVES

- At the incline mouth, every box of explosive and detonators is opened and checked by the attendance clerk.
- Attendance clerk note down the amount of explosives found inside and make the entry in the transit slip.
- Attendance clerk then signs the slip and puts the transit slip inside the box.
- The attendance clerk then hands over the key to the shot firer.
- The explosive carriers then proceed to belowground after boxes are checked at the surface.

SAFETY PROCEDURES DURING STORAGE OF EXPLOSIVES

- Reserve station is kept clean and white washed and free from any overhangs.
- Reserve stations are established in the return side of the districts for storage of explosives.
- Reserve stations are stone dusted up to 18m of floor area
- It is ensured that the area is free of electrical installations.
- At the reserve station, the explosive & detonators boxes are kept separately

SAFETY PROCEDURES WHILE USE OF EXPLOSIVES

A. Inspection & measures before blasting operation:

a. For priming operations:

i. Only the quantity/ number of explosives and detonators necessary for immediate next round of blasting is carried to a place not less than 10 metres from the rest of the explosives.

ii. No other persons other than shot firer and his helper is present within a distance of 10 metres of the place where priming is being done.

b. Parting Faces

i. When the faces approach together in parting, the face is stopped from one side and is ensured to carry out blasting in other face.

ii. Portable boards and fencing are provided for the parting faces.
iii. Parting faces are clearly shown in field book at district.
iv. Parting faces also shown in face measurement book at the Sirdar, shot firer, overman room.
v. Chainman gets undersigned in field book by all of them.

a. Before Drilling operation:

i. Mining Sirdar of the preceding shift informs the sirdar of the present shift of any misfires to be dealt from the previous shift.
ii. Proper cleaning and dressing is ensured at face so that any misfires at floor level can be dealt easily.
iii. Face is then checked for any misfire or socket by the shotfirer.
iv. Methanometers are issued to shot firer to test for inflammable gas within a radius of 20 m from the face and instructions given as per statute to not carry out the blasting operation if the presence of inflammable gas is 0.5 % or more.
v. Blasting permitted only after face is up to date with support.
vi. UDM'S are used in districts for roof bolting work to pace up the bolting work along with production.
vii. Shot firers are provided with tools required for detecting cracks in shot holes and sufficient shot firing cable is provided for shot firers to always ensure two right angles distance from the place of firing.
viii. Shotfirers ensures the drilling of blast holes is done as per the approved drilling pattern.

b. Charging & stemming:

i. Maximum charge of explosives in a shot hole has been limited 565 gms.
ii. Stemming material is made always available at the nearest distance from face.
iii. Only non-metallic (wooden) tools are used for charging/ stemming the shot hole.
iv. Explosives are not forcibly inserted in the shot hole.
v. If any explosive is stuck in side the shot hole due to improper size of the hole, it is dealt as per statute.
vi. Quality of stemming material is always ensured for proper confinement in blasting to avoid blown out shots.
vii. Only explosives of same type and brand are charged in any shot hole and in any one round.

b. Measures during blasting operation

a. Asst. Manager ensures that the Mining Sirdar, Shotfirer and Explosive carriers have been provided with cards duly signed by the Manager or Safety officer.
b. Asst. Manager ensures spare cards are issued to the overman of the district for use in case more than regular number of assistants are required for guarding the entries.
c. Asst. Manager ensures that adequate number of assistants are on duty under the control of the Overman and the Mining Sirdar.
d. Explosive carriers in the form of guards are posted in required places of district in case of insufficient guards the overman provides the guard from different blasting gang.
e. Approved type exploder is used in blasting operation and only one key is allowed in district which is always kept under the charge of District mining Sirdar.
f. Blasting card system (Fig. 3) is followed while carrying out blasting operation in the district.

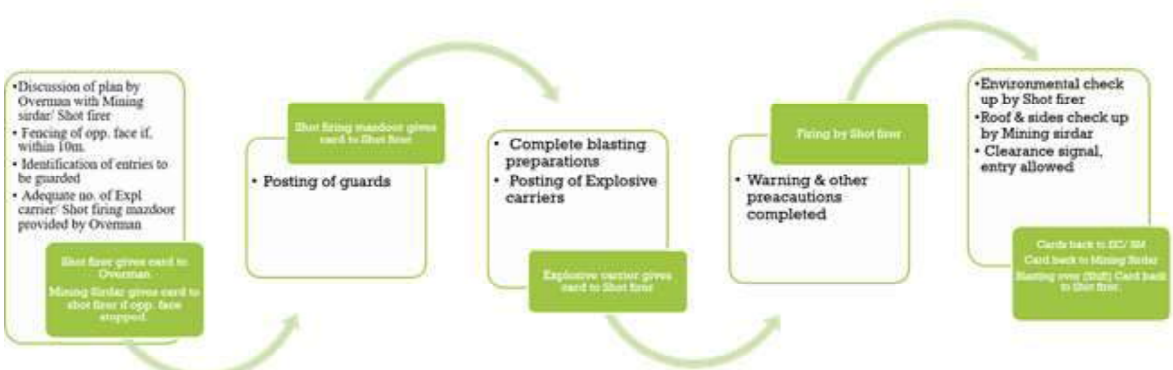


Fig 3: Blasting Card System

c. Ventilation & water spraying

a. Ventilation is ensured such that at lease 284 cu.m of air per minute reaches upto 4.5m of the face.

b. Methanometers issued to shot firer to test for inflammable gas within a radius of 20 m from the face

c. Instructions given as per statute to not carry out the blasting operation if the presence of inflammable gas is 0.5 % or more.

d. Water spraying is done for treatment of coal dust at face and within 90 metres of face.

e. Water for spraying arrangement at faces has been arranged through pipelines from surface to district.

f. Additional water spraying arrangement from the sump area of main dip provided as back up in case of failure from surface arrangement.

g. To ensure the proper dilution of blasting fumes it is always ensured in district that the ventilation stoppings are maintained along with the pace of production so that quantity of air remains adequate.

h. Adequate Ventilation ensured for dilution of Carbon monoxide and oxides or nitrogen in blasting fumes to less than 50 ppm and 5ppm respectively within a period of 5 minutes.

d. After blasting operation

a. After atmosphere in the area is free from dust, smoke or fumes, the shotfirer inspects the place for misfires, sockets or remnants of explosives.

b. If any misfires/ sockets are found, it is dealt as per statute.

c. If area is found safe with respect to atmospheric conditions and presence of sockets etc., Mining Sirdar/ Overman ensures that the roof and sides are dressed and supported.

d. After every blasting operation, shot firer notes down the no of rounds blasted showing the faces where blasting has completed.

e. At the end of the shift overman checks the boxes and looks for any balance of explosive quantity and enter the same in transit slip if any.

F**actors affecting the blast performance in underground**

A. Length of shot holes
B. Direction of shot holes
C. Improper stemming in blasting holes and improper stemming material
D. Improper delay pattern
E. Quality of explosives & detonators provided by supplier company

CONCLUSION

Blasting in underground coal mines involves adequate care in explosive selection, use of proper delays, and also a full proof system of practices during pre and post blast operations.

The Indian Mining & Engineering Journal, Vol. 60, No.08-09, August-September 2021, pp.21-23
Printed in India, @ IME Publications, ISSN 0019-5944

Handling of Misfires in Mines

Arun Kumar Sharma*

INTRODUCTION

Misfire is defined as the partial or complete failure of a blasting charge to explode. The explosive or pyrotechnical products that remain in the ground or in the muck pile as a result of misfire might be triggered during the digging, milling or crushing stages of the mining process, causing injuries or fatalities to blasters or operators.

The misfire should be avoided by every reasonably practicable means available to site managers. The emphasis should be made on prevention rather than cure. Dealing with a misfire is potentially the most dangerous activity for the site managers, Shot firers and other person dealing with it. In the event of a misfire, it is likely that unexploded charges and detonators will be left in the face or in the muck pile. These charges could be detonated if drilled into, if struck by an excavator bucket, wheels or tracks, or if inadvertently fed through a crushing plant. Unexploded charges may also be loaded out accidentally and taken either off site in road vehicles. In any of these circumstances there may be a risk of danger to the vehicle carrying the unexploded charges, to the operator, to the public , particularly from fly-rock in the event of a detonation.

Unexploded charges may need to be recovered by hand. Great care and attention to deal is required to ensure that this is carried out safely.

RECOGNITION OF MISFIRES

After firing, a proper examination must be carried out to check the condition of the blasted face, so that all the charges have been fired and that there is no indication of a misfire. Any discovery of undetonated explosives or detonating cord must be reported since their presence constitutes a misfire. Indications of a misfire can include noxious fumes, inadequate ground movement, poor fragmentation, unusual blast sound or vibration trace, fly rock or evidence of undetonated explosives at the blasted face.

POST BLAST INSPECTION

Post blast inspection is a hazardous task and in all circumstances must be carried out in accordance with the site rules.

- Hazards exist not only from the existence of undetonated explosives but also from the post blast environment.
- There is the possibility of a misfire remaining undetected even after inspection. It is therefore essential that adequately trained personnel regularly check the muck pile and blasted face throughout the loading operation.
- All personnel but especially those operating loading equipment, hauling equipment and crushers should be aware of this possibility and must be instructed to report abnormalities.
- The extent and nature of the misfire must be determined as soon as possible after the misfire has been detected.
- An exclusion zone must be demarcated and secured until such time when unexploded explosive has been collected and removed.

IN THE EVENT OF A MISFIRE

If a misfire is discovered during the post blast inspection then the “all clear” signal should not be given until a new exclusion zone has been established and secured.

- The exclusion zone must be established by the responsible person who could be either the site manager or the blasting engineer or the shot firer.
- The immediate priority must be to ensure that arrangements to safeguard personnel in the event of a misfire are adequate and complied with.
- Only those personnel directly concerned with the misfire should be allowed within the exclusion zone to deal with it.

Dealing with Misfires

The following procedures should be adopted in dealing with misfires.

- Removing stemming and re-priming the misfired shot hole.
- There may be circumstances in which it is possible to remove stemming in order to gain access and to reprime the charge. This is a potentially hazardous operation, which requires great care. It should only

*Sr. Mgr. (Mining)/Blasting Officer, Garjanbahal OCP, Basundhara Area

Fig: Uncovering misfire exp.

be attempted after detailed consideration.

- When a hole contains detonators and it is anticipated that excessive force will be required to remove the stemming then the operation must not be attempted. This could result in premature initiation of the charge, particularly if the detonator is close to the top of the main charge and is immediately below the stemming.
- If the hole contains an electric detonator the use of high velocity air to remove the stemming should not be attempted. Static charges sufficient to initiate electric detonators can be created.
- Bulk explosive can be washed out of misfired shot-holes but the utmost care must be taken in removing cartridges, particularly where detonators are involved. Under no circumstances must explosives or detonators be removed from a borehole by pulling on the detonator leads. Suitable extraction tools are available to enable cartridges to be removed. These usually take the form of a corkscrew or barb of nonferrous material which can be connected to stemming rods.

The following factors must be considered

- The use of high pressure water is unlikely to overcome the mechanical lock of stemming comprising chippings; The use of large quantities of water could desensitize any non waterproof explosive and dissolve any explosive with a high concentration of water soluble ingredients;
- In situations where multiple decks of explosives are employed, all the above considerations magnify the difficulty of gaining access to the lower decks of explosives. Irrespective of the number of explosive decks, removal of the stemming in order to gain access to the charge as to re-prime is a technique, which ranges from unattractive at best to extremely difficult.
- Any tools used inside the borehole to remove stemming must be non-ferrous.
- If all the stemming can be removed and access to the top of the charge is achieved, the charge may be reprimed and refired. However it should be noted that in the event of a partial misfire the burden on the misfired shothole can often be reduced or fractured and a careful assessment of the situation must be made before any decision is reached.

Drilling and firing relieving holes

- The hazards in drilling relieving holes are:-

a) Intersecting an explosives column, with a high risk of detonation

b) Operating a drill in unstable rock conditions

The object of such holes when fired is -

- To disturb and displace the adjacent explosive column so that any primers and detonators remaining unfired are not located within an undisturbed explosive column after this blasting;
- To break up the rock mass in the region of the misfired hole in order to facilitate the search for and retrieval of any unexploded charges, primers and detonators.
- One or more relieving holes may be drilled behind the misfired hole. The separation distance between the holes depends on the diameter, the inclination and the type of drilling equipment and the sensitiveness of the explosives. Any relieving hole must be drilled parallel to the misfired hole and to the same depth. To ensure that the holes are parallel it is essential that the information relating to the inclination and azimuth of the misfired hole is accurate. Care must be taken to drill the relieving hole at the same angle. The precise location of the relieving hole can only be established after careful assessment of the local conditions. Consideration should also be given to operating the drill rig remotely. It may be necessary to seek expert advice.
- A further option is to drill small diameter relieving holes around the collar of the misfired hole. These are systematically fired to work off the rock and expose the charge. There may be adjacent charged holes, which must be considered and their location confirmed before any action is taken.

Discovery and retrieval of explosives

- It may be necessary to move rock from the immediate vicinity of the misfire before access to the charge can be gained. The remaining rock next to any misfired charge is likely to be solid and any attempt to remove this can be fraught with danger. Remedial action can only be decided after careful inspection and appraisal of the misfire site.
- It may be possible to remove part of a misfired charge by hand from the socket of a hole but this should only be attempted by experienced personnel after due consultation with, and the approval of site management.
- Removal of some charge from a hole will allow the introduction of a primer and detonators. Some stemming may then be added to the hole to create additional confinement, before firing.
- If a misfired hole contains more than one deck of explosive, it may be necessary to deal with each deck in turn as a separate misfire, with either full retrieval of charges from each deck or re- priming. Sufficient confinement must be provided before refiring each deck.
- Explosive which is recovered should be placed in containers for storage or disposal. Detonators should be separated from the explosives and primers carefully and stored separately from explosives. Explosives should be placed in plastic bags and placed in clearly labelled boxes.
- The process of searching for explosive material in the heap may involve the use of loading equipment. Note that it is possible to utilize specially protective devices in order to protect the operators during this process.
- Material picked up by the bucket should be taken to a leve1 area, carefully deposited on the floor and searched thoroughly. The minimum number of people should be exposed during this process.
- Before excavation commences precise instructions should be given to the machine operator as to how to proceed.
- This procedure should help minimize the risk of the impact of the bucket or falling rocks detonating unexploded charges. This work must only be done under direct supervision. From the location of misfired material and information from the blast design it may be possible to determine the quantities and types of explosive involved. A search should continue until, as far as possible, all explosive material has been accounted for. Be aware that explosive material may be concealed below the floor where sub-drilling is used.
- A more serious situation occurs when explosive material is found when loading out or processing. It must be assumed that some has made its way into the product, stocking area or tip. It may even have been taken off site. An assessment must be made of the dangers and risks likely to be involved should the explosive be inadvertently detonated. Steps must be taken to arrange for the search and inspection of any location where undetonated explosives have found their way. All personnel must be instructed to report the finding of any explosive material to the shot-firer, the face foreman or the manager as soon as possible.

Misfire Investigation

After a misfire has occurred it is important that the "lessons learned" are recorded in order to attempt to prevent a repetition of the event. Reporting is an important part of this procedure and records must be maintained. This is particularly important if it is suspected that all of the misfired material has not been recovered.

CONCLUSION

In addition to the above misfires can be totally eliminated by having a scientific method of explosive selection, understanding the explosive characteristics in watery holes, hot holes and deep holes. Adequate care is to be taken as per provisions of Indian Explosive Rules and various guidelines issued by PESO and provisions of CMR 2017 and Technical Circulars issued by by DGMS, in respect of shelf life, transportation, storage and use. In case of Bulk SME, and ANFO minimizing occurrence in handling of misfires need proper understanding of the strata conditions (presence of water in case of ANFO, and muddy water in case of SME), explosive shelf life and breakage of emulsion matrix . Training of blasting crew and also the pump truck operator of SME the persons handling the delivery hose is also essential to minimize misfires. Initiators like plain detonators, delay detonators, shock tubes/Nonel, shot firing cable, circuit testers, exploders etc also had a vital contribution to misfires. Increased use of Nonel had eliminated misfires to a great extent in OCPs.

The Indian Mining & Engineering Journal, Vol. 60, No.08-09, August-September 2021, pp.24-26
Printed in India, @ IME Publications, ISSN 0019-5944

Blast Initiation By Electronic Detonator In Lingaraj Ocp- A Case Study

Sitikantha Dash* Srikanta Kumar Manik*

ABSTRACT

Rock blasting is an integral part of Open cast Coal mining. Ground vibration and noise due to blasting are major environmental issues. In current mining practice reducing PPV and Noise is of utmost importance, particularly in large opencast projects in Talcher Coal fields due to their location amongst a large number of inhabitants. This paper highlights the technological advances in blast initiation systems like Electronic Detonator. The obvious results are noted in case of Lingaraj OCP.

INTRODUCTION

Lingaraj Opencast Project is one of the largest coal producing mine in Talcher Coal fields with target of 13.5 million tones & OB of 13 million cum for FY 2021-22.Lingaraj Opencast is located at Latitude (8509'33''to 8512'12'E) & Longitude (2057'39''to 2058'18''N) in the topo sheet of Geological Survey of India. It is situated on South Eastern Part of Talcher Coal Field about 3 kms away from Talcher Railway Station and the mine is by the side of NH 23.

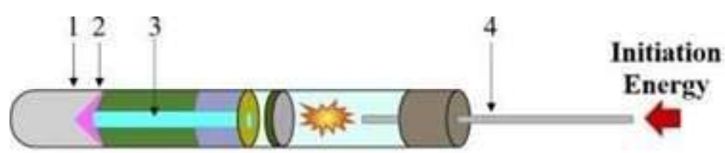
Salient features of the Mine		
1.	Mining started on	12.06.1991
2.	Brought to Revenue	01.04.1995
3	Thickness of seams	2 to 47 m.
4	Parting between seams	2 m to24 m.
5	Over Burden	Thickness Varying from 10 to 20m.
6	Amount of full dip	N10'30'W
7	Strike Length	5.00 Km
8	Depth of Quarry	Max: 272.50 Mtr and Min:20.50 Mtr
9	Total Peripheral Length	13.02 Km
10	Reserve as on 31.01.2020	200.00 Million Te
10	Lifeofmine	11years(ason01.04.2020)
11	Linkage	NTPC(Kaniha,Talcher),Other Local Consumers.

METHODS OF OB REMOVAL AND COAL EXTRACTION

In LOCP coal is cut by surface miner and loading is done by pay loader. While a small portion of around 5% is blasted. OB removal is done by blasting with SME and LD. Bulk SME is used in the mine primed by cast boosters is initiated by shock tubes. However due to growing complaints and in order to control ground vibration level, attempts were made to introduce electronic delay detonators. Very recently wireless detonators were developed and are now in various stages of use.

NON ELECTRIC DETONATOR (NONEL)

A non-electric detonator is a shock tube detonator designed to initiate explosions in blasting. Instead of electric wires, ahollow plastic tube delivers the firing impulse to the detonator, making it immune to most of the hazards associated with stray electric current. It consists of a small diameter, three-layer plastic tube coated on the inner most wall with a reactive explosive compound, which, when ignited, propagates a low energy signal, similar to a dust explosion. The reaction travels at approximately 6,500 ft/s(2,000 m/s) along the length of the tubing with minimal disturbance outside of the tube, Nonel also provides true bottom initiation and add additional delay at the point of initiation, there by ensuring better movement of blasted material towards free face.

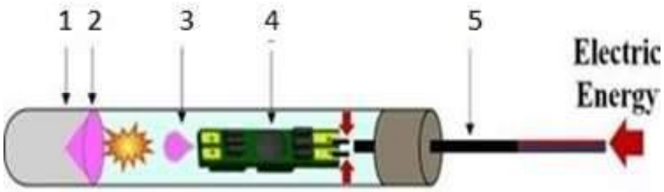


(1-Basecharge; 2-Initiatingcharge; 3-Delayelement; 4-Shock Tube)

ELECTRONIC DETONATOR

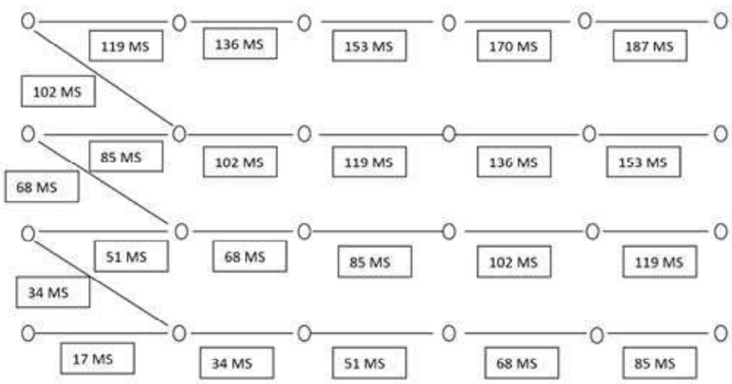
Electronic delay detonators are based on micro-chip technology. It is basically a device which stores electrical energy for a certain time and then delivers that energy as a sharp pulse at precise time to a conventional blasting cap or electric blasting circuit.With these type of detonators possibility of overlap is completely eliminated.

*Lingaraj OCP



(1-Basecharge; 2-Initiatingcharge; 3-Igniter; 4-ElectronicControlModule; 5- Copperwires)

BLASTING IN LOCP



BLASTING DELAY PATTERN IN LOCP USING NONEL

Blasting with Electronic Delay Detonators

In blasting initiation using electronic detonator each integrated electronic detonator (IED) firing cap is programmed individually using the programming console which records their order number and corresponding delay. The detonators are then linked in parallel to the firing console which is connected to the programming console. The firing console then automatically checks the integrity of the electrical connections, the efficacy of each IED firing cap and the programmed delay timings. The operator then with the help of firing console fire the electronic delay detonators.

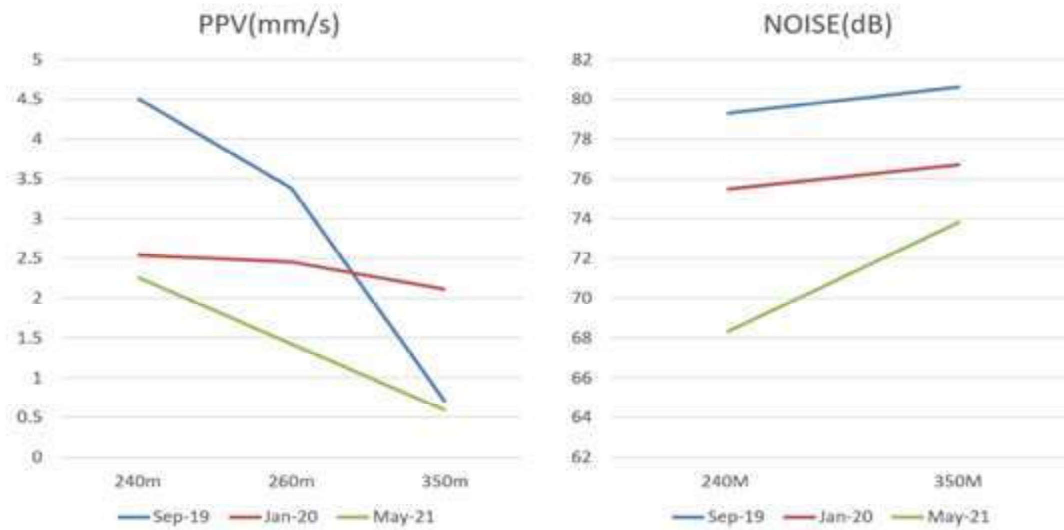
Electronic Detonator Console

ED is being used in Lingaraj OCP since Oct. 2019.Comparison of Blasting Performance after using ED with that of NONEL in Lingaraj OCP is given below

YEAR	DEPARTMENTAL OB(PF)	BENCHMARK PF(DEPT)	OUTSOURCED OB(PF)	BENCHMARKPF(OS)
2018-19	2.3	2.34	2.13	2.10
2019-2020	2.36	2.34	2.16	2.10
2020-2021	2.41	2.34	2.21	2.10

YEAR	COAL (PF)	BENCH MARK PF
2018-19	3.9	4.33
2019-20	4.68	4.33
2020-21	4.82	4.33

Comparision between Ppv And noise level of Nonel and ED Blast



Advantages Of Ed Initiation Over Nonel

- Higher precision
- Freedom of choosing from a wider range of delays compared to limited number of delays in case of NONEL.
- Better accuracy of delay due to microchip function.
- Control of back break and better fragmentation.
- Reduction of air blast.
- Reduction of ground vibration.

PRECAUTIONS

During the blasting process the data logger and exploder should be different. As sometimes it is seen that accidental blast occurs in case of the data logger is used as an exploder.

CONCLUSION

It has been found from comparisons that the blasting in Lingaraj OCP with Electronic Detonator initiation system has resulted in less ground vibration, noise.

It also resulted in good fragmentation and improved PF and DF. Due to this the blasting has become more environment friendly, efficient and safe. The ultimate higher cost of ED initiation seems to be justified due to its better result, precise and reliable controlled blasting near habitation and sensitive infrastructures like coal corridor road. Hence ED system should be preferred over earlier systems of blast initiation.

REFERENCES

1. Jha. R. N.; Jha, M. K.; Singh, B. K.; Agrawal, H, “Influence of ground vibration due to different Initiation system-A Case Study”, Page, 35-43, Mine Tech, Vol-42, No-1 Special issue on Blasting Technology.

The Indian Mining & Engineering Journal, Vol. 60, No.08-09, August-September 2021, pp.27-29
Printed in India, @ IME Publications, ISSN 0019-5944

Optimum Production by Highwall Mining

Anil Kumar Mittal* S Dasgupta**

ABSTRACT

The purpose of the Highwall Mining system is to extract coal with an auger machine or a continuous miner from exposed seams. The major factors in this system is the coal recovery and the stability of the Highwall. A large amount of coal remains isolated and undeveloped as pillars due to previous indiscriminate mining operations performed by the use of the auger or the continuous miner. Therefore, it is necessary to increase the coal extraction ratio, to reduce the threat of failure of the pillars and to reduce damage caused by subsidence at the surface.

Overall increase in production within the same resources and same condition. To increase the production by High wall Mining within existing condition maintaining the safety, reducing the thickness of web Pillar between two adjacent cuts Reducing the thickness of barrier pillar after every 20 cuts and application of backfilling in the cut, which improves the pillar stability, are the some of the areas the author studied.

INTRODUCTION

Highwall is just a combination of underground and surface mining. The coal left in the highwall can be extracted by this technology which otherwise would be lost forever. The method relies upon the self supporting capacity of the strata above the series of parallel entries driven mechanically to a considerable depth without artificial roof support and ventilation. Moreover this technology provides an economical way to extract coal reserves locked up in the highwall. The extent of opencast project is limited by the financial viability, but the coal continues to exist beyond the quarry limit. This is the reason we go for the combination of underground and opencast to extract coal within economic condition.

**Ex Area General Manager Sohagpur Area, Director (Training), AKS University, Satna, M.P.*
***Professor, Department of Mining Engineering, AKS University, Satna, M.P.*

Eventually the continuous miner used in the Underground mining of coal were developed and outfitted to also recover coal from surface high walls. Highwall mining was developed in 1990. As on now more that 60 Highwall miners are in operation in U.S. and they may account for about 4% of total U.S. coal production. This technology is also very popular in Australia.

The Indian mining giant witnessed the successful implementation of first Highwall mining in ASIA continent in SECL. At present at three places High wall Mining is in operation.

APPLICATION

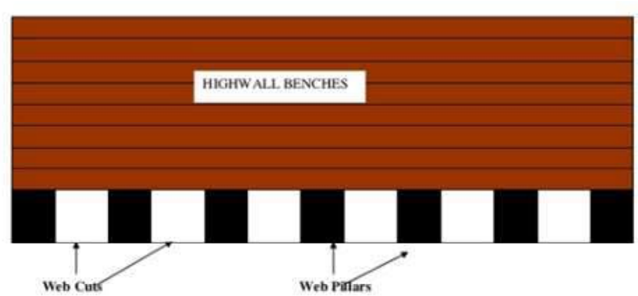
- Coal blocked in the highwalls of opencast due to un-economic stripping ratio.
- Coal blocked in the boundaries of opencast mines.
- Coal blocked in thin seams for which no conventional mining method is available or economically viable.
- Coal seams in hills and forest area.
- Coal blocked below roads, permanent surface structures and villages (very much present in Jharia, Damodar Valley, and Raniganj coalfields, etc)
- Coal where conventional extraction is constrained for various geological and social reasons

PLANNING

The major factors in the highwall mining system are coal recovery and the stability of the highwall.

The approaches to web and barrier pillar design involved three basic steps

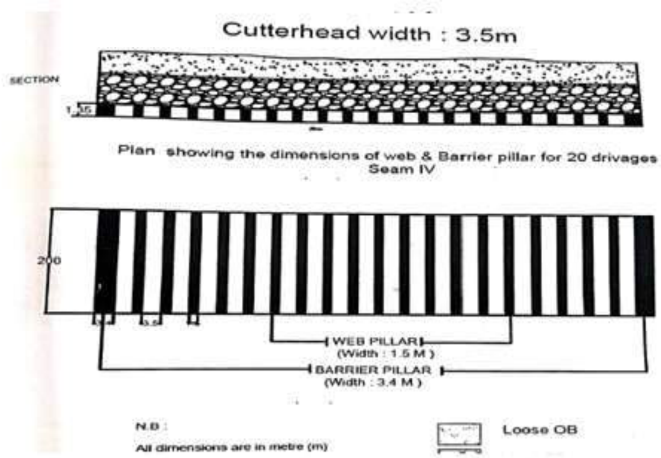
- Application of empirical formula for pillar design.
- Analysis of data from past auger operations
- Numerical modeling analysis to confirm design performance and test its robustness.



Front view of Highwall mining face

DRIVAGES UPTO 250M

LENGTH OF DRIVAGE



Factors Influencing Production
(Sharda HighWall, Sohagpur Area, SECL)

Year	Target (T)	Achievement (T)
2016-17	500000	5,20,028
2017-18	610000	5,28,396
2018-19	600000	5,68,322
2019-20	850000	8,43,396
2020-21	850000	6,59,423

1. Machine operates remotely from active working zone hence no exposure of work persons to dust humidity etc. i.e. safe mode of operation.
2. High production potential from 2500 tpd in thin seams to 7200 tpd for thick seams
3. OMS can be as high as 100-200 as only 3-4 persons are required in operation.
4. Production capital investment is much less than as compared to similar capacity of other underground mines.
5. Conservation of coal up to 70%
6. Environmental friendly technology with regards to dust, noise & vibration.

Tata Steel West Bokaro with one system reported an annual coal production of 5.3 lakh tonnes, and monthly production of about 80,000 Tonnes.

SELECTED REFERENCES

1. **CIMFR**, Extraction strategy and pillar design for Highwall Mining at RG OCP-II of SCCL
2. **Rao Nageshwar**, General Manager, SRP,SCCL. Summary of Highwall Mining at OC-II, of SCCL
3. **Takeshwar Mahto**, DDMS, Safety, Bilaspur Region
4. **Afrouz AA (1994**) Placement of backfill. Min Eng 153:205–211
5. **Anwar HZ**, Shimada H, Ichinose M, Matsui K (1999) Slaking durability of the improvement of coal mine shales behavior. Proceeding of the international symposium on mining science and technology, Beijing, pp 343–346
6. **Matsui K**, Yabuki A, Shimada H, Sasaoka T, Ueda T, Yuasa T (2003) A practical trial to increase the coal recovery in highwall auger mining in Australia.
7. **Carr,** Hari Prasad, P.: Highwall Mining-Current Technology Trends– Opportunity in India (unpublished)Google Scholar
8. **Prasanta**, Highwall Mining- A Mass Production Technology for Safe Extraction of Blocked Coal. In: Mine Tech 2007: National Seminar on Mining Technology-Present and Future, Bhubaneswar, India (2007)Google Scholar
9. Management of sharda High wall, Sohagpur Area, SECL

The Indian Mining & Engineering Journal, Vol. 60, No.08-09, August-September 2021, pp.30-42
Printed in India, @ IME Publications, ISSN 0019-5944

Application of Digital Image Analysis for Monitoring the Behavior of Factors that Control the Rock Fragmentation in Opencast Bench Blasting: A Case Study Conducted Over Four Opencast Coal Mines of the Talcher Coalfields, India

Binay Kumar Singh[1] Debjeet Mondal[2] Mohd Shahid[1] Amit Saxena[3] Paresh Nath Singha Roy[4&5]

ABSTRACT

Drilling and blasting play a very important role in driving the economy of op e ncast mines, as various mining activities related to strata handling are dependent on the size of the rock mass created due to blasting. Thus the analysis of fragments created from rock explosion is essential in order to monitor its compatibility with the deployed mining machineries/ HEMMs(s uch as shovel, dumper, dragline, etc.). As over fragmentation as well as under fragmentation both tend to increase the cost of mining, the generation of fragment size in the desired range is necessary. Several factors control the rock fragmentation in blasting, such as the burden, bench height/ drilling dept h, stemmingcolumn, powder factor and hole diameter. The assessment of rock fragmentation with respect to the aforementioned parameters helps to enhance the blast performance and, hence, this study intends to carry out digital image analysis for monitoring the mean fragment size and boulder percentage. A highly consistent result has been obtained using forty blasting datasets carried out in the four different opencast mines of the Talcher Coalfield (India), namely Bairam OCP, Ananta OCP, Lakhanpu r OCP, and Lajkura OCP.

Keywords: Digital image analysis Rock fragmentat ion Bench blasting Mean fragment size Boulder percentage

INTRODUCTION

Coal acts as a major driving force for the Indian economy, by ser- ving 64% of the total primary energy requirements of the country in various forms (Monda! et al., 2017). The majority of Indian coal is mined through opencast mines (Annual productio n in 2013-14 through (a) Opencast mines: 426.31 Mt; (b) Underground mines: 34.36 Mt) (Ghose, 2001), whic h are mainly situated in Central and South Eastern parts of the country, in the states of Chhattisgarh, Madhya Pradesh, Jha rkhand and Orissa, and are mostly controlled by various subsid iar ies of Coal India Lim ited (CIL).

The economic susceptibility of an opencast mine is very much de- pendent on drilling and blasting activities, which is also the most common method for breaking rocks in mines. The importance of blasting in the Indian mining industry can be inferred from the heavy consumption of explosives during the production years 1976- 2014 (Fig. 1). Accord ing to the Directorate General of Mines Safety (India), approximately 585.1 Mt of explosives were used in 567 coal mines in the country in various forms in 2014 (DGMS, 2014); 460 of these mines belonged to CIL and, the annual explosive consumption was about 438.4 Mt. It was also seen that the Northern Coalfields Ltd., Mahanadi Coalfields Ltd. and South Easte rn Coalfields Ltd., which contained the majority of the Indian opencast mines had the highest consumption of explosives of about 126.04 Mt, 61.59 Mt and 90.02 Mt, respect ively, therefore highlighting the importa nce of explosives and rock blasting in opencast mines.

Blasting is a very expensive operat ion and the explosives themselves represent 5% of the tot al coal production cost. Therefore, explosive costs play a vital role in maintai ning the econom ic feasi bility of open-cast mines. The main objective of blasting in opencas t mines is to create a muckpile of the desired fragment size, which can be easily transported using the

[1]"Blasting and S&T Departmen CMPDI (Coal India Limited) , India
[2]Innovation Cell ([CT), CMPDI (Coal India Limited), India
[3]SECL(Coal India Limited}, India
[4]Geology and Geophysics Departmen Indian Institute of Technology (Kharagpur), India
[5]The Abdus Salam InternationalCentre for Theoretical Physics, Trieste, Italy

equipment (draglines, shovels and dumpers) deployed in the mine. Therefore, the optimization of blasting is highly necessary for sustainab le minin g and it is said to be optimized when both the cost of blasting as well as the handling of fragmented rocks are kept to a minimum (Morin and Ficarazzo, 2006). Presentl y, investigations are being carried out to optimize the blasti ng for overall profitability rather than some specific operations, which is also known as the 'mine to mill' blasting approach (Grundstrom et al., 2001). The response of blasting over rock fragmentation is very complex, due to the heterogeneous and anisotropic behavior of the bench rock. Therefore it is very difficult to obtain a mathematical relatio n between the rock fragmentat ion and blast design parameters, which are broadly categorized into two groups: [a] Controllable parameter s, and [bl Uncontrollable para meter s (Hudaverdi et al., 2012). The blast design parame ters, such as burden, spacing, hole inclination, bench height, hole depth and diameter, stemming length, sub drilling pattern, blasting initiation etc. are con- trollable parameters (Kulatilake et al., 2010). In opencast mining, bench design

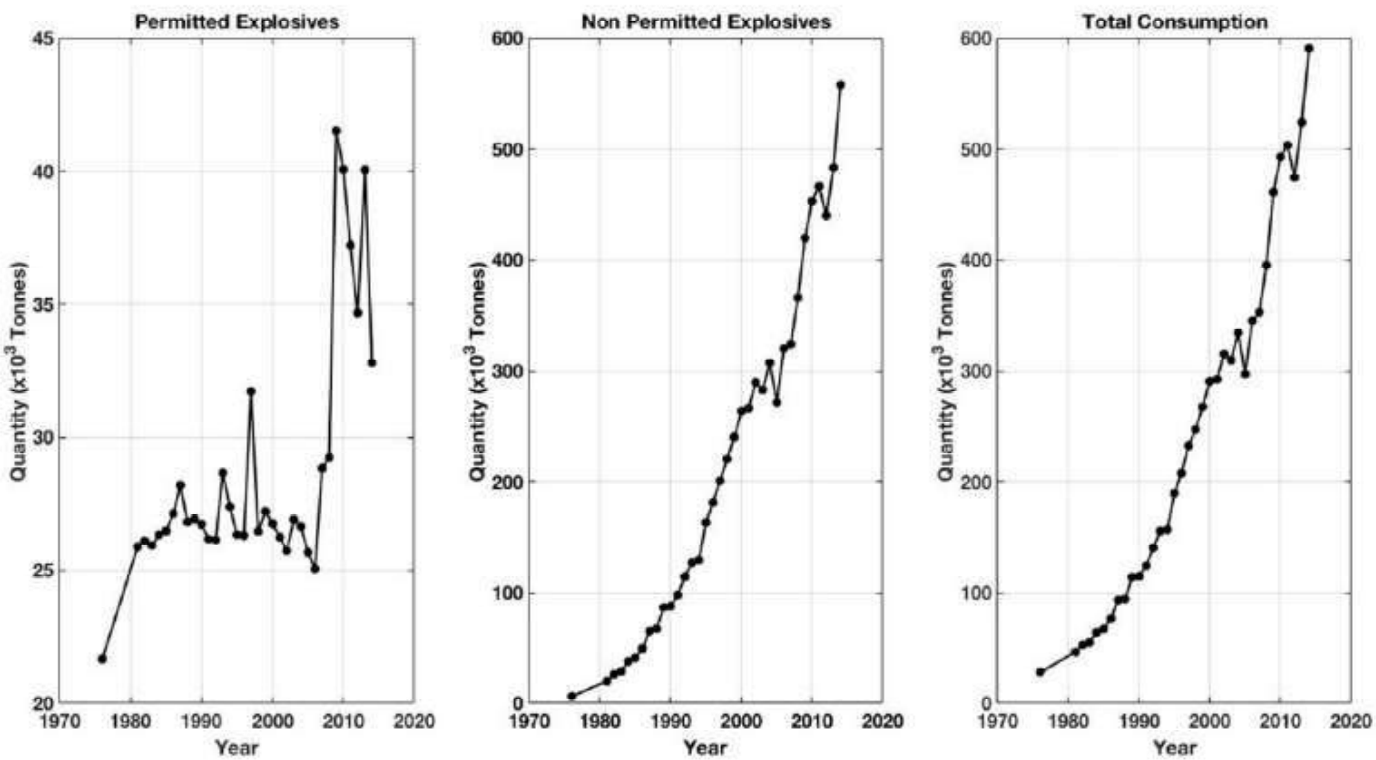


Fig. 1. Consumption of permitted and non-permittedexplosives in India for the production years 1976—2014.

and blasting is a common method for overburden re-moval. The basic layout of a bench in an opencast coal mine and the blast design parameters are shown in Fig. 2a, b). The distance between the blast hole and free space is known as the burden *(B),* i.e. it is the load that is to be displaced by the explosives, whereas the distance between two consecutive blast holes is known as the spacing (S). The total depth of the blast hole drilled is called the hole depth *(HD)* and the extra depth drilled below the floor for obtaining clear breakage is called the subdr illing. The blast drill holes are partly filled with explosives and the remaining top end portion of the hole is filled with inert materia ls for stori ng the explosive energy for a longer period of time in order to increase rock fracturi ng, this portion is known as the ste mming lengt h(D. These are all contro lled paramete rs, whereas the rock propert ies, such as rock mass structure, orientation, rock density, compressive stre ngth *(UCS),* shear strength, elastic properties of rock, grain size, etc. are uncontrollable parameters (Kulatilake et al., 2010).

The rock fragments that result from blasting are also divided into three broad categories: [a] Oversize (further fragmentatio n is required in the form of secondary breaking before handling, effectively *MP uc* > 300 mm; *MPoc* > 1000 mm, where *MPuc* and *MPoc* are the mean particle sizes for underground and opencast mines, respectively), [b] Mid-range (significant particle size and easy to handle), and [c] Fines (very fine grains and difficult to handle; for coal *MP- 6* mm) (Cunningham, 1996). However, the afore mentione d categories may vary depending on the equipment deployed for handling the blast fragments, and the cost of mining is minimal when optimum/ desired fragmentation is achieved as per the instrumentation setup and con- veyor system (Mackenzie, 1967). This paper uses forty opencast bench blasting datasets from four opencast mines of India for monitorin g blast induced rock fragmentation with respect to various con trolled blast parameters, such as spacing, burden, stemming depth, powder factor, hole diameter and hole depth/bench height.

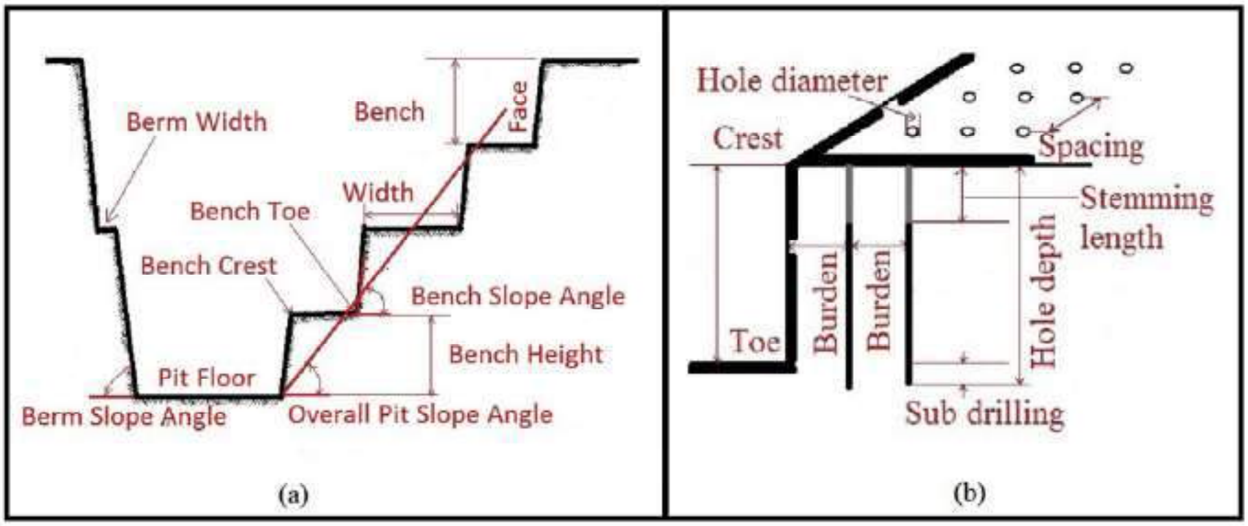


Fig. 2. (a) Layou t of a bench in opencast coal mine. (b) Basic blast design parameters.

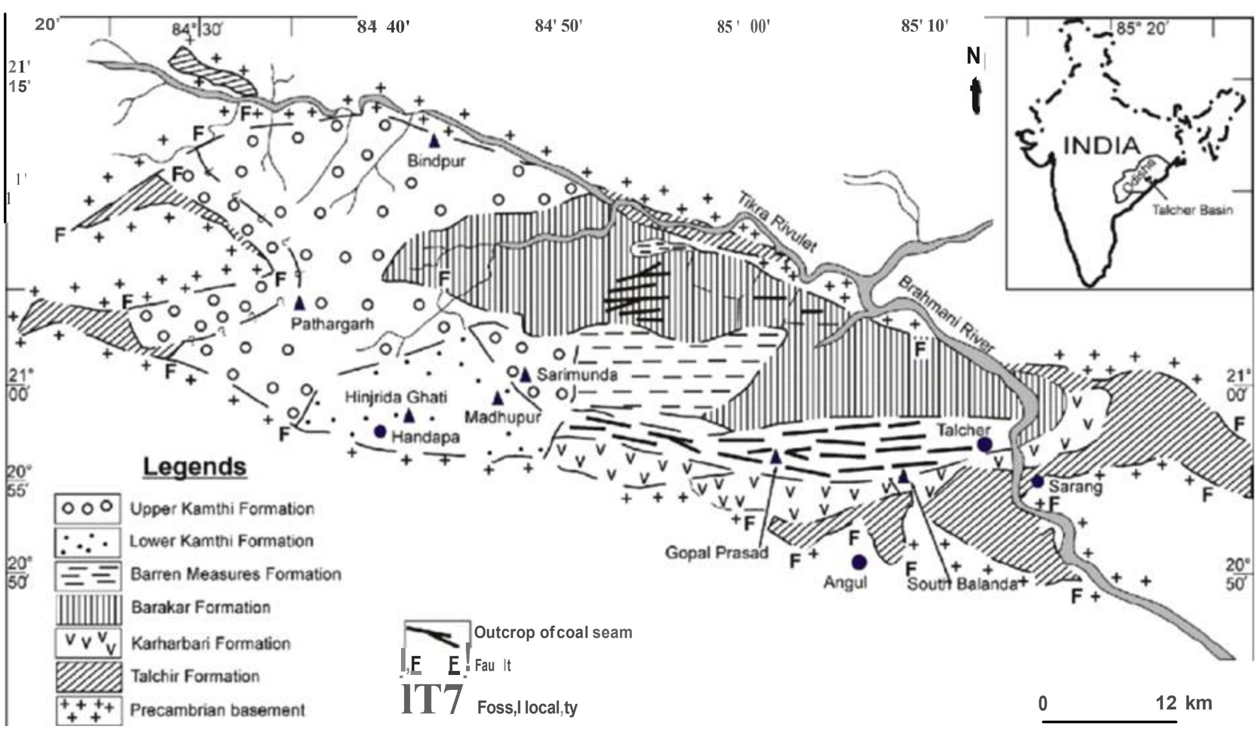


Fig. 3. Locat ion and geology of Talcher coalfield, India (Saxena et al., 201 4)

Table 1
Stratigraphic succession of Talchercoalfield.

Age	Formation	Lithology
Recent		Alluvium and laterite
Late Permian to Triassic	**Kamthi**	**Fine to medium grained sandstone, carbonaceous shale, coal bands with greenish sandstone, pink clays and pebbly sandstone at the top** (2500 m+)
	Barakar	Medium to coarse grained sandstone, a coal seam with oligomictic conglomerate at its base (500 m+)
Early Permian	Karharbari	Medium to coarse grained sandstone, shale and coal seams (1270 m)
	Talchir	Diamictic, fine to medium grained greenish sandstones, shale, rhythmites, turbidites etc. (170 m+)
		- UNCONFIRMITY-
Archaean		**Granite, gneisses, amphibolites, migmatites etc.**

Table 2
The bucket capacities and allowed fragment size for the four opencast mines under study.

Bucket size (m^3)	Boulder size maximum fragment size (mm)	Optimum size	
		Lower limit (mm)	Upper limit (mm)
3.0	1077	180	239
4.0	1185	198	262
4.6	1240	207	275
6.5	1390	232	308
10.0	1603	267	355
12.5	1726	288	382
20.0	2015	336	446
24.0	2140	357	474

STUDY AREA AND METHODO LOGY

Geology of the mine

The opencast mines under investigation are situated in the Talcher Coalfield of Orissa (India), which is situated in the south-eastern part of the Lower Gondwana basins within 85°28' N-84 °20'N longi tudes and 20°50'E-2 1°13'E latitudes (Pareek, 1963). The coalfield spans over an area of about 1860 km^2 and has a coal-bearing area of about 1000 km^2 (Fig. 3; Saxena, Singh, & Goswami , 2014). The geology of the coalfield was first studied by Blanford , Blanford and Theobald in 1856 , and later it was carried out by the Geological Survey of India in 1963-65 and 1971-75. The stratigraphic sequence ofTalcher Coalfield is given in Table **1;** Singh (2016). The Talchir formatio n symbols the initiation of the Gond wana deposits, which rests over the basement rock and is se- parated by an unconformity. The coal bearing sedimentary deposits mainly belong to the Talchir, Karharbari, Barakar and Kam th i Forma- tion, whereas basement rocks are mostly Arc haean . The other compo- nents of the formations are sandstone (FG-MG/ MG-CG), shale, turbi- dites, rhythmites, etc.

Blasting configurations used

The opencast mines used in this study belong to Mahanadi Coalfields Lim ited (MCL), which is one of the major coal producing subsidiaries of Coal India Limited. The majori ty of the coal production of MCL comes from opencast mines, and total production for the fi- nancial years 2014-15 and 2015-16 was approximately 120.10 Mt and 136.789 Mt, respect ively, where production from underground mines was only 1. 28 Mt and 1.11 2 Mt respecti vely. Therefore, blasting frag- ment analysis played an import ant role in production and profitability for opencast projects. The blasting configurations used for the four opencast mines in this study are mentioned below:

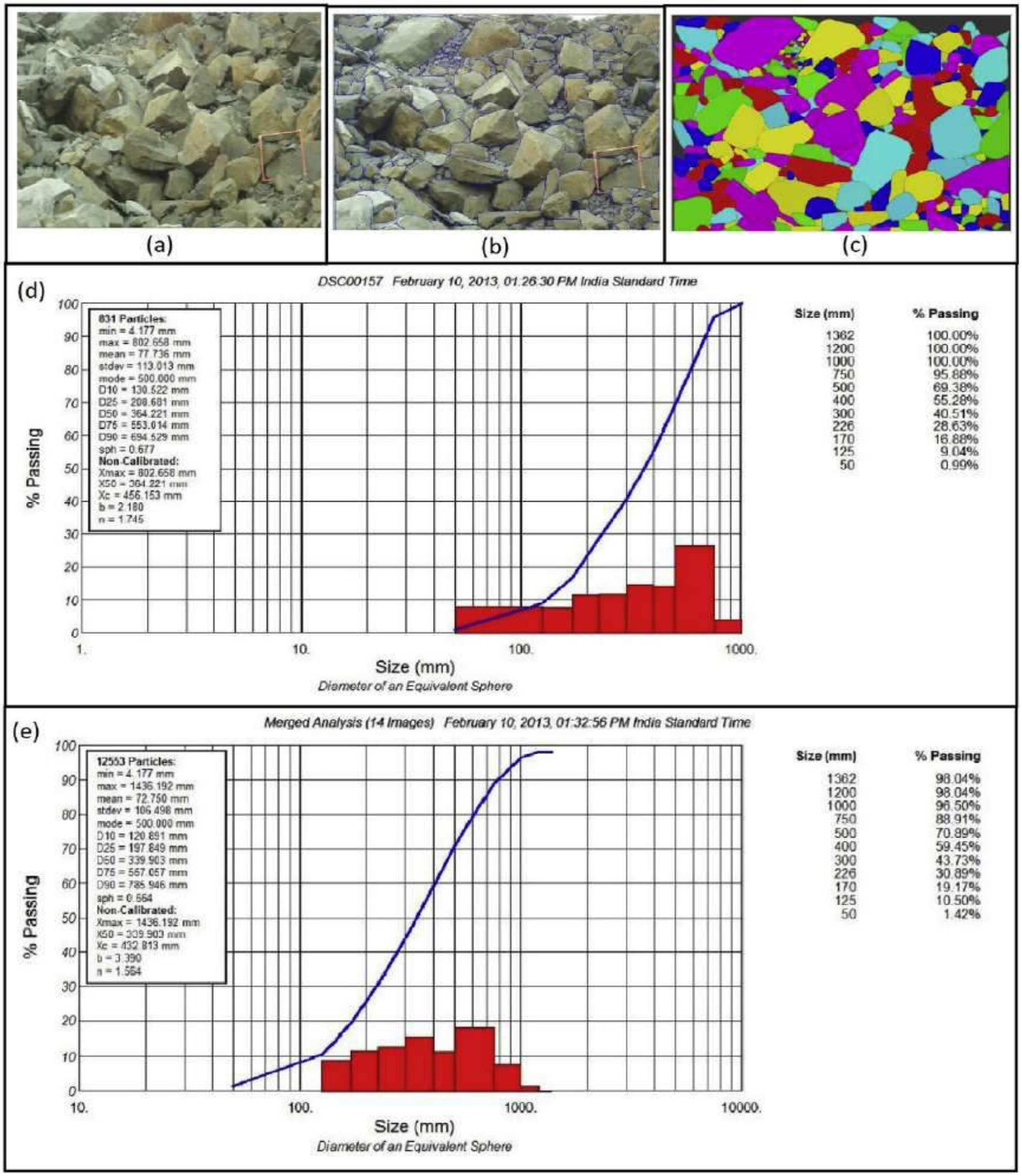


Fig. 4. (a) Muckpile created from the blast LAJ/ 1, (b) Nett ing diagram, (c) Sieve diagram. (d) Histogram analysis and cumulative curve view of the image (e) Histogram analysis and cumulative curve view of all the images taken for LAJ/ 1 (i.e. merged analysis for fourteen images).

[a] Bair am OCP (max/ min values): (i) Drill diameter (mm) - 260/ 160; (ii) Avg. drill depth (m) - 16.3/ 6; (iii) Avg. burden (m) - 5.5/ 3.5; (iv) Avg. spacing (m) - 6/ 4.5; (v) Avg. st emmi ng len gth (m) - 11. 3/ 2.56; (vi) Pow der factor (m^3/k g) - 2.77/ 1. 25; (vii) Explosives used - ANFO.

[bl Ananta OCP (max/ min values): (i) Drill diameter (mm) - 260/ 160; (ii) Avg. drill depth (m) - 9/ 6.8; (iii) Avg. bur de n (m) - 5 / 3.5 ; (iv) Avg. spacing (m) - 6/ 4; (v) Avg. stemming length (m) - 6.3/ 3.8;

Table 3: Blasting dataset *(B, S, T, D, N, V,* M, *PF, E PY, PI* & A) for Bairam OCP, Anant a OCP, Lakhanpur OCP and Lajkura OCP.

Blast record	Date	Drill dia. (mm)	Avg. depth (m)	Avg. burden (m)	Avg. spacing (m)	Total drilling depth (m)	Total in situ volume (m^3)	Explosive (kg)	Powder factor (mJ/kg)	Specific energy (MJ/ m^3)	Productive yield (m^3 /m)	Area (m^2)	Stemming length (m)
BAL/1	15.12.12	260	12	3.5	5	48.5	1408.08	1122.4	1.255	2.192	29.033	117.34	7.85
BAL/2	17.12.12	260	15.5	4	5	77.5	1990.76265	1503	1.325	2.076	25.687	128.436	10.9
BAL/3	17.12.12	160	6	4.5	5	634.8	9318.12	5410.6	1.722	1.597	14.679	1553.02	2.56
BAL/4	19.12.13	260	15.6	4	5	376.3	12377.352	7111.9	1.740	1.580	32.892	793.42	11.27
BALIS	16.12.12	160	11	4	5.5	87.8	2708.42	1412.3	1.918	1.434	30.848	246.22	4
BAL/6	18.12.1 2	260	12	4.5	5.5	130	3478.08	1733	2.007	1.370	26.754	289.84	8.55
BAL/7	16.12.12	160	6	4.5	5	144.6	2531.52	1232.4	2.054	1.339	17.507	421.92	4
BAL/8	16.12.12	260	16.3	4.7	6	81.5	3593.335	1703	2.110	1.303	44.090	220.45	11.3
BAL/9	19.12.12	160	10	5.5	5.5	231.1	5370.5	2504.6	2.144	1.282	23.239	537.05	5.65
BAL/10	15.12.12	160	13	3.5	4.5	258.7	5814.9	2096	2.774	0.991	22.477	447.3	7.9
ANA/I	14.12.12	260	8.9	4.5	4.5	123.9	1188.15	3075.3	0.386	7.118	9.590	133.5	6.25
ANA/2	14.12.1 2	260	9	4.5	4.5	119.3	1382.22	3065.2	0.451	6.098	11.586	153.58	5.8
ANA/3	15.12.12	260	9	4	4.5	125.4	2205	2885.6	0.764	3.599	17.584	245	6.3
ANA/4	16.12.12	260	8.9	5	6	124.2	2029.2	2554.2	0.794	3.461	16.338	228	3.8
ANA/5	15.12.12	260	8.8	5	6	149.3	2974.4	2925.1	1.017	2.704	19.922	338	4
ANA/6	15.12.12	260	8.9	5	6	71.3	1606.45	1312.4	1.224	2.247	22.531	180.5	4.35
ANA/7	16.12.12	160	6.8	3.5	4	95.2	1104.184	731.4	1.510	1.822	11.599	162.38	5.05
ANA/8	17.12.12	160	6.9	3.8	4	206.6	2500.422	1653	1.513	1.818	12.103	362.38	5.05
ANA/9	16.12.1 2	160	6.8	3.5	4	109.3	1317.092	821.6	1.603	1.715	12.050	193.69	5.15
ANA/ 10	14.12.12	160	7.6	4.5	5	106.7	1750.28	901.5	1.942	1.416	16.404	230.3	4.95
LAK/1	26.01.1 3	250	8.32	5	5.5	141.4	1971.84	2495.1	0.790	3.480	13.945	237	5.4
LAK/2	27.01.1 3	250	8.8	4.5	5.5	123.4	2640	2234.5	1.181	2.328	21.394	300	6.55
LAK/3	25.0 1.13	250	9.4	4	5.25	281.4	5969	4999	1.194	2.303	21.212	635	6.3
LAK/4	29.01.1 3	250	9.1	4.5	5.5	300.3	5987.8	4799.7	1.248	2.204	19.939	658	6.05
LAK/5	26.01.1 3	250	8	5	5.8	312.4	8120	5310.9	1.529	1.799	25.992	1015	5
LAK/6	25.01.13	250	8.8	5.5	6	219.6	6124.8	3897.5	1.571	1.750	27.891	696	6.15
LAK/7	26.01.1 3	160	7.1	3.5	4.5	178.7	2144.2	1272.5	1.685	1.632	11.999	302	4.9
LAK/8	28.01.1 3	160	5.7	4	6	200.5	3229.05	1898.5	1.701	1.617	16.105	566.5	3.4
LAK/9	27.01.13	160	6	4	5.5	161	3402	1602.7	2.123	1.296	21.130	567	3.65
LAK/10	27.01.1 3	160	6	4	5.5	475.8	11676	4768	2.449	1.123	24.540	1946	3.6
LAJ/ 1	25.01.1 3	260	9.6	3	4	258.5	4856.736	5410.8	0.898	3.064	18.788	505.91	5.3
LAJ/2	28.01.13	260	8.4	3.5	4	312.3	4935	5251.1	0.940	2.926	15.802	587.5	5.75
LAJ/ 3	28.0 1.13	260	8.5	4.5	5.2	253.8	4998	4269	1.171	2.349	19.693	588	5.75
LAJ/ 4	26.01.1 3	260	7.3	3.5	4	131.4	2350.6	1800	1.306	2.106	17.889	322	5.25
LAJ/ 5	25.01.13	160	6	4	4	305.2	4439.04	3000	1.480	1.859	14.545	739.84	4.25
LAJ/ 6	25.0 1.1 3	260	7.5	4	4.5	285	4687.5	3107.6	1.508	1.823	16.447	625	5.25
LAJn	24.01.13	160	6	3	4	324.2	4560	2945.5	1.548	1.776	14.065	760	3.75
LAJ/ 8	24.01.13	160	6	3.5	3.5	265.9	3960	2480.5	1.596	1.723	14.893	660	3.75
LAJ/ 9	24.0 1.1 3	16 0	6	3.5	4	472.2	7560	4383	1.725	1.594	16.010	1260	3.75
LAJ/ 10	26.01.1 3	260	7.4	3.5	4.8	88.8	2249.6	1200	1.875	1.467	25.333	304	5.25

(vi) Powder factor (m^3/k g) - 1.94/ 0.38; (vii) Explosives used -**ANFO.**

[c] Lakhanpur OCP (max/ min values): (i) Drill diameter (mm) - 260/160; (ii) Avg. drill depth (m) - 9.4/ 5.7;(iii) Avg. burden (m) - 5.5/3.5; (iv) Avg. spaci ng (m) - 6/ 4.5; (v) Avg. stemming length (m) -6.55/ 3.4;(vi) Powder factor (m^3/k g) - 2.44/ 0.79; (vii) Explosives used - ANFO.

[d] Lajkura OCP(max/ min values): (i) Drill diameter (mm) - 260/ 160;(ii) Avg. drill depth (m) - 9.6/ 6;(iii) Avg. burden (m) - 4.5/ 3;(iv) Avg. spaci ng (m) - 5.2/ 3.5; (v) Avg. stemming length (m) - 5.75/3.75; (vi) Powder factor (m^3/k g) - 1.87/ 0.89;(vii) Explosives used-**ANFO.**

The ex plosives used in all the a fo re me n tio ned mine s were ammo-niu m n itrate / fuel oil (ANFO; also known as AN/FO), which consists of

Table 4

Equations used to calculate volume, powder factor, specific energy, productive yield, performance indicator, normalized productive yield, normalized powder factor and normalized energy.

Volume	Powder factor	Specific energy
$V = A \times M$	$PF = {}^{V}/_{M}$	$E = 2.75 \times {}^{M}/_{V}$
Productive yield	Normalized (PF)	Normalized (E)
$PY = {}^{V}/_{N}$	$PF_{norm} = {}^{PF}/_{PF_{max}}$	$E_{norm} = {}^{E}/_{E_{max}}$
Normalized (PY)	Performance indicator	
$PY_{norm} = {}^{PY}/_{PY_{max}}$	$PI = (PF_{norm} + PY_{norm}) - E_{norm}$	

940/o a m m oniumnitrate (NH_4NO_3), w h ic h acte d as an oxidizer, and 6% number 2 fuel oil. The bucket capacities and allowed fragment size for the opencast mines under study are provided in Table 2.

Digital image processing using WipFrag

The use of d igital im a ge processing can be very useful for fragment analysis, and has been widely preferred in industry over traditional sieving (screening), as it is very fast and can be carried out for multiple images for analysis with very low error percentage (Maerzet al., 1996). All forty blastings created muckpiles in the desired range and the throws were also within the expected limit. The images of the muck-piles along with the scaling objecta, which were taken from a SONY digital camera, are fed into the WipFrag software in JPEG format (.jpeg). Suitable measures were taken for tilt correction (Lyana et al., 2016), as the line of observation was not perpendicular to the muckpile surface and would have resulted in improper fragment analysis. The image processing algorithms of the WipFrag softw a re iden tifie s the individual rock samples, and differentiate them using black outlines, also called the netting of image. The output of the software consisted of the number of particles exposed on the surface, statistical analysis of fragment size (minimum, maximum, **mean,** mode and standard deviation) and sieve ana lysis CD10, D2s, Dso, *D1s* and D90). Similar analysis was carried out for multiple images for the same blast case study that were snapped from various directions, and the results were merged to get the final output. The working of WipFrag is described with a blast case study. Here, Fig. 4a shows the image of a muckpile that was created due to LAJI I (blasting no.) in Lajku ra OCP on *2510 11* 2013. The blast used 5410.8 kg of ANFO industria l explosives in 27 boreholes with an average drill diameter and depth of about 260 mm and 9.6 m, respectively. The nett ing and sieve of the muckpile created by the software are shown in Fig. 4 (b & c). The analysis of Fig. 4a is shown in Fig. 4d, and it can be seen that a total of 831 particles was exposed on the surface, which were used for fragmentation analysis and the maximum, minimum and mean fragment size obtained was 4.177, 802.658 and 77.736 mm, respectively. In the same way, fourteen images were taken from different directions for LAJI l a nd sim ila r a nalysis was carr ied out. The collective results of the all fourteen images (also known as the "merged analysis") formed the final result for fragmentat ion analysis for LAJI I (Fig. 4e). Thus, for LAJI l the max- imum, minimum and mean fragment size obtained are 4.177, 1436.192 and 72.750 mm, respectively.

The datasets used for the study

The opencast mine used for the present study are Bairam OCP, Ananta OCP, Lak hanpur OCP, and Lajkura OCP. All of these mines are situate d in the Talcher Coalfield of Orissa (India), and are operated by Maha nadi Coalfields Limited. The forty blasting datasets used for the study consisted of ten blasting case studies from each of the opencast mine. The field trials and study were carried out from December 13, 2012 to December 20, 2012 (for Bairam and Ananta mine) and January 23, 2013 to January 29, 2013 (for Lakha npur and Lajkura mine). The raw dataset consisted of the following parameters: spacing (S), burden *(B),*

Table 5: PFnom1, Enorm and P Ynorm for Bairam OCP, Anania OCP, Lakhanpur OCP and Lajkura OCP.

Blast **record**	Normalized powder factor (PF_{00} ,m)	Normalized specific energy (SEnorm)	Normalized productive yield (P Yno,m)
BAI./1	0.452198065		0.658 484403
BAL/2	0.477429809	0.947150883	0.582609662
BAI./3	0.62077168 4	0.728445058	0.332928736
BAI./4	0.627322881	0.720837831	0.746025075
BAL/5	0.691 25467 4	0.654169993	0.6996509
BAI./6	0.723419202	0.62508441	0.606814732
BAL/7	0.74042095 4	0.610 7310 48	0.39707539
BAL/8	0.76055756	0. 59456 1265	1
BAI./9	0.772903675	0.585063934	0.527077742
BAL/10	1	0.452198065	0.509806916
ANA/1	0.198994886	1.00000004	0.545367131
ANA/2	0.232261105	0.856772356	0.658909429
ANA/3	0.393577802	0.505604973	1.000000117
ANA/4	0.409192895	0.486310726	0.929163736
ANA/5	0.523741257	0.379948861	1.132996474
ANA/6	0.630462301	0.315633296	1.281346764
ANA/7	0.777579183	0.255915922	0.659619514
ANA/8	0.77910966	0.255413203	0.688290837
ANA/9	0.825683893	0.241006147	0.685306646
ANA/10	0.99999984	0.198994926	0.93289358
LAK/1	0.322 71 9931	1	0.499991575
LAK/2	0.482464808	0.668898386	0.767059744
LAK/3	0.487596 427	0.661858688	0.760532731
LAK/4	0.5094 42608	0.633476522	0.714911655
LAK/5	0.624352676	0.51688724	0.931934582
LAK/6	0.641723377	0.502895707	0.999999999
LAK/7	0.688096855	0.469003642	0.430210656
LAK/8	0.694554358	0.464643159	0.577431959
LAK/9	0.8668 10463	0. 372307379	0.7576 1551
LAK/10	0.999999797	0.322719997	0.879852905
LAJ/1	0.478805225	1.000000091	0.741637479
LAJ/2	0.501317348	0.955094155	0.623767714
LAJ/ 3	0.62 451 9441	0. 766677924	0.777342394
LAJ/ 4	0.69659779	0.687348245	0.706140444
LAJ/ 5	0.789302847	0.606617942	0.574132655
LAJ/ 6	0.80 4622242	0.595068398	0.649238313
LAJ/7	0.8258 1 2935	0.579798703	0.555212905
LAJ/ 8	0.851592 485	0.56224694	0.587874427
LAJ/ 9	0.92008 1271	0. 52039 4539	0.63 1980288
LAJ/ 1 0	0.999999822	0.478805354	1.000000132

average drilling depth (= bench height) *(H)* , hole diamete r (D), total drilling (N), total insitu volume (V}, charge size (M), powder factor *(PF),* stemming length CD, specific energy of explosives (E), productive yield *(PY),* performance indicator *(PI)* and area (A) (Table 3). The blast parameters such as volume, powder factor, specific energy, productive yield, performance indicator, normalized productive yield, normalized powder factor and normalized energy are calculated using the formula in Table 4, and the calculated values of the normalized powder factor (PF110 , 11)1, specific energy (E110,m) and productive yield (PY110 m,) are show n in Table 5 and Fig. 5 a, b, c & d for Bairam , Ananta, Lakhan pur and Lajkura OCP, respect ively. Previous studi es on blasting have used ratios of the physical para meters used for fragmentation analysis, such as spacing to burden *(SIB),* drill depth to burden *(HI B),* ste mmin g le n gth to burden *(T I B)* and burden to hole diameter *(BID),* a nd a si- milar approach has been utilized by this study for rock fragment ana- lysis (Aler, Mouza, & Arnould, 1996; Chakraborty et al., 2004). Thus, the calculated values for *SI B, HI B, BID* and *TIB* are given in Table 6. The statistical description (maximum, minimum, mean and standard deviation) of the aforementioned ratios *(S IB, HI B, BID* and *TI B)* and powder factor *(PF)* are given in Table 7.

Results and discussion

The digital image analysis (using WipFrag) of the muckpile created from blasting was used to calculate the mean fragment size and the boulder percentage, and their variation with respect to *SIB, HI B, BI D, TIB* and *PF* for the four opencast mines are collectively shown in Fig. 6 and Fig. 7. The results of the stu dy are discussed below:

The effect of spacing to burden ratio (SIB)

The spacing (S) and burden *(B)* are essential parameters of rock blasting. The large burden tends to minimize rock displaceme nt alo ng with increase the workload of the explosives, reduce the penetration of explosion gases into the rock fractures and also increase the vibration levels. However, a smalle r burden induces excessive crushi ng and pushing of rock fragments in an uncontrolled manner, which migh t result in higher muckpile throw. Depen ding on the bench rock char- acteristics, the burden length can be 20-40 times the diameter of the blast drill hole (Ash, 1963). The spacing (S), which is the distance be- tween two successive blast holes depends on burden *(B),* delay timing *(L'>t)* between blast holes and the initiation sequence. Large spa cing leads to insufficient fracturing between the blast holes, which results in irregular faces with toe problems. On the other hand, smaller spacing causes excessive crushi ng and superficial crater breakage (Singh et al., 2016). Thus, an increase in both spacing and burden tends to increase the fragment size. The variation of the mean fragment size and boulder percentage with respect to *SIB* ratio are shown in Figs. 6a and 7a. The results show that there is a decrease in mean fragment size with an increase in

SIB for Bairam , Lakhanpur and Lajkura OCP. Hence , it ca n be inferred that this shows that the effects from the burden have dominated the results, as lower burden (corresponding to higher *SIB)* has resulted in lower fragment size. On the other hand, there is an in- crease in fragment size with an increase in *SIB* for Ananta OCP. The refo re, it can be inferred that the effects from spacing have domi- nated the result as a higher fragment size is obtained with higher spacing. The boulder percentage has shown a random variation with respect to *SIB* hence no inferences can be made.

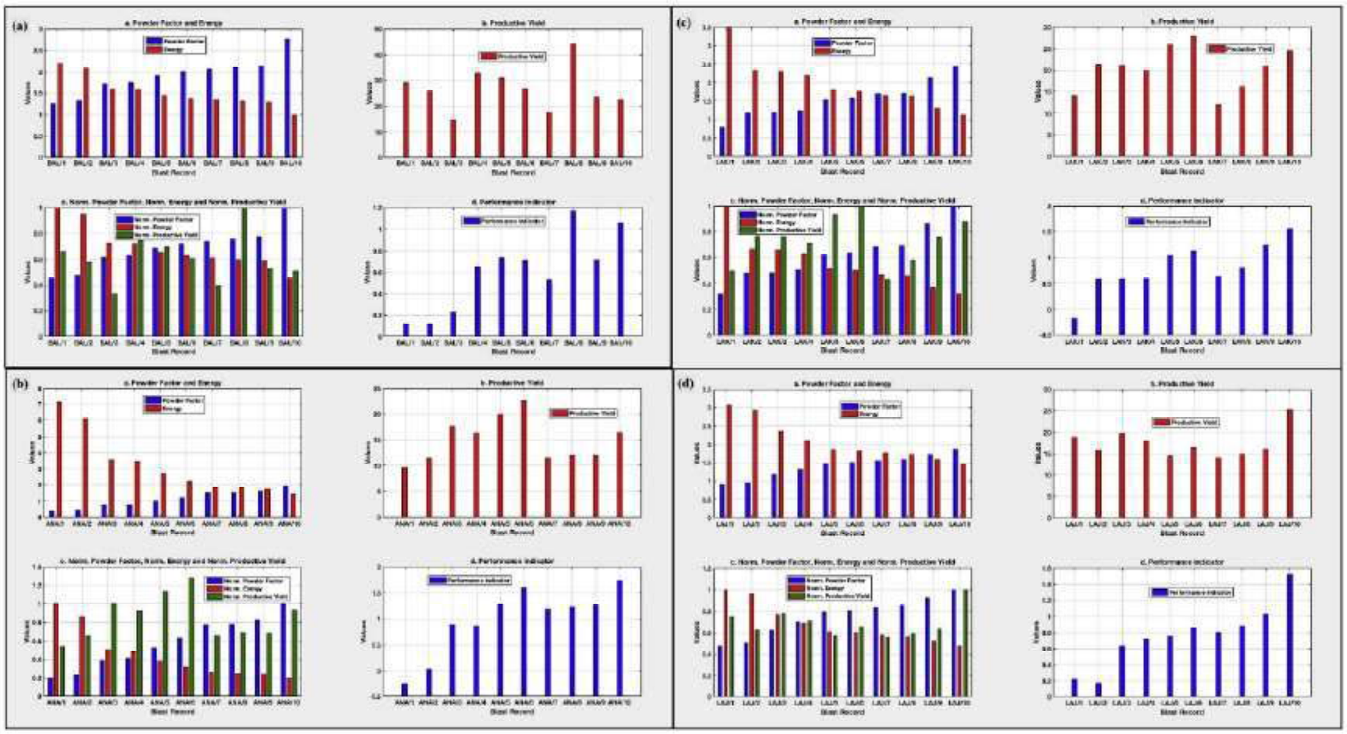


Fig. 5. Powder factor (PF), specific energy (E), productive yield (PY), performance indicator (PI), normalized productive yield (PYnorm), normalized powder factor (PF_{00} .,, 1) and normalized energy (Enom,) for (a) Bairam OCP, (b) Ananta OCP, (c) Lakhanpur OCP and (d) Lajkur a OCP.

Ta ble 6: Calculated values for *SIB, HI B, BI D* and *TI B* for Bairam OCP, Ananta OCP, Lakhanpur OCP and Lajku ra OCP.

SI. No.	Blast record	*SIB*	*HI B*	*BID*	*TIB*	SI. No.	Blast record	*SIB*	*HIB*	*BID*	*TI B*
	BAU1	1.428571429	3.428571429	13.46153846	2.242857143	21	LAK/1	1.1	1.664	20	1.08
2	BAU2	1.25	3.875	15.38461538	2.725	22	LAK/2	1.222222222	1.955555556	18	1.455555556
3	BAU3	1.111111111	1.333333333	28.125	0.568888889	23	LAK/3	1.3125	2.35	16	1.575
4	BAU4	1.25	3.9	15.38461538	2.8175	24	LAK/4	1.222222222	2.022222222	18	1.344444444
5	BAUS	1.375	2.75	25	1	25	LAK/5	1.16	1.6	20	1
6	BAU6	1.222222222	2.666666667	17.30769231	1.9	26	LAK/6	1.09090909 1	1.6	22	1.1 181818 18
7	BAU?	1.111111111	1.333333333	28.125	0.888888889	27	LAK/7	1.285714286	2.028571429	21.875	1.4
8	BAUS	1.276595745	3.468085106	18.07692308	2.404255319	28	LAK/8	1.5	1.425	25	0.85
9	BAU9	1	1.818181818	34.375	1.027272727	29	LAK/9	1.375	1.5	25	0.9125
10	BAl/10	1.285714286	3.714285714	21.875	2.257142857	30	LAK/10	1.375	1.5	25	0.9
11	*ANNI*		1.977777778	17.30769231	1.388888889	31	LAJl 1	1.333333333	3.2	11.5 3846 154	1.766666667
12	*ANN2*		2	17.30769231	1.288888889	32	LAJ/2	1.142857143	2.4	13.46153846	1.642857143
13	*ANN3*	1.125	2.25	15.38461538	1.575	33	LAJl 3	1.155555556	1.888888889	17.30769231	1.277777778
14	*ANN4*	1.2	1.78	19.23076923	0.76	34	*LAJl 4*	1.142857143	2.085714286	13.46153846	1.5
15	ANNS	1.2	1.76	19.23076923	0.8	35	LAJI S		1.5	25	1.0 625
16	*ANN6*	1.2	1.78	19.23076923	0.87	36	LAJl 6	1.125	1.875	15.38461538	1.3125
17	ANA/7	1.142857143	1.942857143	21.875	1.442857143	37	*LAJn*	1.333333333	2	18.75	1.25
18	*ANNB*	1.052631579	1.815789474	23.75	1.328947368	38	LAJI S	1	1.714285714	21.875	1.071428571
19	*ANN9*	1.142857143	1.942857143	21.875	1.471428571	39	*LAJl 9*	1.142857143	1.714285714	21.875	1.071428571
20	ANNlO	1.111111111	1.688888889	28.125	1.1	40	LAJ/10	1.371428571	2.114285714	13.46153846	1.5

The effect of bench height (drilling depth) to burden (H! B)

As subdr illing was negligible, bench height was almost equal to the drilling depth. The drill depth/ blast hole depth (H) is another highly important parameter in blasti ng and it is dependent on spacing (S). Ideally, the spacing should not be greate r than one half of the blas t hole depth, i.e. $S < 0.5H$. The ratio of bench height (H) to burden *(B)* is also referred to as stiffness. High st iffness eit her results from deepe r drill depth or smaller burden length. Therefore, high stiffness leads to easier deformation. Moreover, shallow drill depth or larger burden length tends to lead to smaller stiffness, thus resulting in poor fragmenta tion (Ash, 1985). The variations in the mean fragment size and boulder percentage with *H/ B* are sho wn in Figs. 6 b and 7b. The results show that fragment size has decreased with an increase in *H/ B* for Bairam, Ananta and Lajkura OCP, which shows that high stiffness (due to greate r hole depth and lower burden) has resulted in better fragmen- tation. It can also be seen that higher boulder percentages are obtained for lower stiffness values

The effect of burden to hole diameter (BID)

Drill hole diameter (D) is an important parameter in the optimization of blasting, as several other controlled para meters, such as burden and stemming length, are dependent on it. The drill hole diameter plays an important role in blast design. Smaller drill diameter reduces the amount of explosives that can be loaded in to the blast hole, which in turn reduces the explosive energy per hole. Usually, it is believed tha t a smaller drill hole diameter results in finer fragments, but in this case study higher borehole diameters have been used, i.e. 160, 250 and 260 mm. Therefore variation in the *BID* ratio is mostly due to variation in burden. Hence, increasin g *BID* will result in higher fragment size and boulder percentage. The variations of mean fragment size and boulder percentage with *BI D* a re give n in Figs. 6c and 7c. The mean fragment size increased with an increase in *BID* for Bairam , Ananta and Lajk u ra OCP. Thus , it can be concluded that the effect of burden has dominated the results, as higher burden (corresponding to high *BID)* has resulted in higher mea n fragment size. Whereas, for Lakh a n pur OCP, there is a decrease in mean fragment size with an increase in *BI D.* Here it can be concluded that the effect of the borehole diameter has dominated the result, as a lower borehole diameter (corresponding to higher *BID)* has resulted in better fragmentation. The results also show that higher boulder percentage was obtained for higher *BID.*

Table 7: The statistical variation (maximum, minimum, mean and standard deviation) of *S I B, HI B, BI D, TI B* and powder factor *(PF)* for Bairam OCP, Ananta OCP, Lakhanpur OCP and Lajkura OCP.

Blast Reco rd	**Parameters**	**Max**	**Min**	Mean	Standard deviation
BAL/1-10	*PF*	2.77 40	1.25 5	1. 9049	0.4355
	SIB	1.4286	1	1.2310	0.1281
	HI B	3.9	1.3333	2.8287	1.0177
	BI D	34 .375	1 3.4 615	21.711 5	6.9458
ANA/ 1-10	*PF*	1. 942	0.3 86	1.1 204	0.5224
	SI B	1.2		1.11 74	0.0772
	HI B	2.25	1.6889	1.8938	0.1639
	BI D	28 .1 25	15.384 6	20 . 3317	3.7 05 6
LAK/1-10	*PF*	2.449	0.79	1.5471	0.4842
	SIB	1.5	1. 0909	1. 2644	0.130 9
	HI B	2.35	1.425	1.7645	0.3046
	BID	25	**16**	21.0875	3.2436
LAJl 1-10	*PF*	1. 875	0.898	1. 4047	0.3222
	SIB	1.3714	1	1.1747	0.1316
	HIB	3.2	1.5	2.0492	0.4758
	BI D	25	11. 5385	17.2 11 5	4.5 245

The effect of stemming depth to burden (T/ B)

The proper capping of a drill hole is essential so that as much of the energy obtained from the explosives can be utilized in rock breakage, and also to mitigate the hazards of fly rock. Thus, stemming length is a very important parameter in blast rock fragmenta tion analysis, espe- cially when the collar zone of the blasting hole contains hard rock. Usually, the stemming length is almost equal to burden *(T = B),* but can be up to 1. 5 times the burden to avoid the fly rock problem *(T* = 1.5B). The ste mmin g length also depends on the borehole diameter (D). Further dependence on the burden rock type and explosives, leads to the use of a minimum stemming length, i.e. 25 times the hole diameter *(D)* i.e. $T > 25D$ (Jimeno et al., 1995). Long stem ming columns are often suggested when the burden rock has natural fractures, while for large compact burden rock the stemming length can be kept shorter. Higher values of *T/ B* can be achieved by increasing the stemming length, i.e. reducing the explosive charge column in drill holes, which might result in poor rock breakage. The variations in the mean frag- mentation size and boulder percentage with respect to *T/ B* are shown in Figs. 6d and 7d. The data collected from the opencast mines shows that there is a decrease in mean fragment size with an increase in *T/ B.* The dataset agreed with the expected results as higher stemming depth and lower burden (corresponding to higher *T/ B)* has resulted in reducing the fragment size, and therefore higher boulder percentages were seen for lower values of *T/ B.*

The effect of the powder factor (PF)

The powder factor *(PF)* is the amount of explosives requ ired to break 1 m^3 or 1 tonne of rock, and is the ratio of the quantity of rock broken to the total amount of explosive used (Jimeno et al., 1995). The powder factor is related to the geology of the rock and acts as a deciding parameter for the choice of the amount of explosi ve to be used and also its initiation sequence. Thus, it helps to maintain the cost effectiveness of minin g operat ion. Soft/ sedimentary formations usually have a lower powder factor (soft laminated rock: 0.1-0.25; med-ha rd sa ndstone: 0.3- 0.45), whereas harder formations have relatively higher values of powder factor (quartzite/ granite: > 0.65; doleri te: 0.9- 1. 2). However, if an explosive with the same density is used, then it can be seen that higher powder factor *(PF)* will result in oversized boulders, whereas lower powder factor *(PF)* tends to lead to more crushing of the rocks. The variations of mean fragmentatio n and boulder percentage with powder factor are shown in Figs. 6e and 7e. The results obtained from the four opencast mines show that high mean fragment size are obtained for higher values of powder factor. Also, high boulder per- centages are seen for higher values of powder factor.

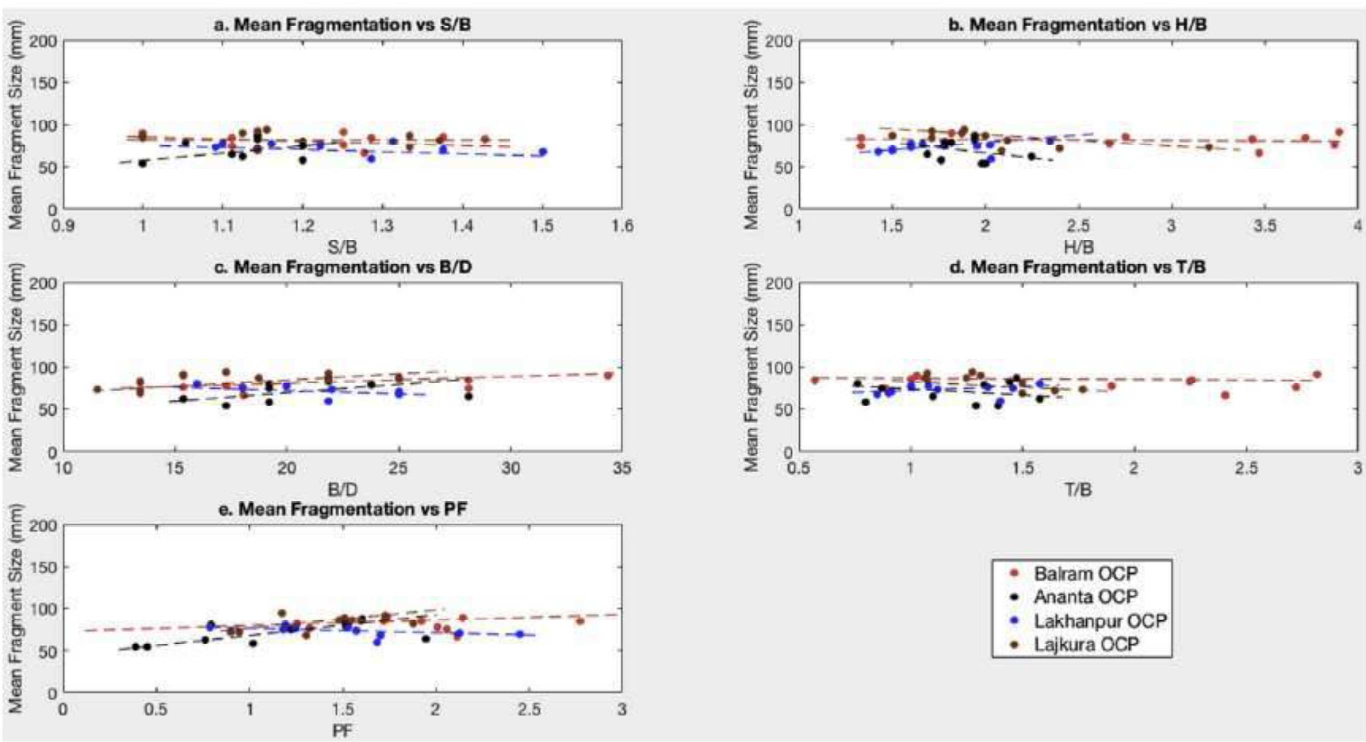


Fig. 6. Variation of mea n fragmentsize (mm) with respect to (a) *SI B,* (b) *HI B,* (c) *BI D,* (d) *TI B* and (e) *PF.*

CONCLUSIONS

The following conclusions can be drawn:

(i) The mean fragment size is directly proportional to both spacing and burden. Hence dependence of fragment size on *SIB* is gov- erned by the individual effec t of the aforement ioned para meters. As for Balram , Lakhanpur and Lajku ra OCP the effect of burden has resulted in a decrease in mean fragment size with an increase in *SI B.* Whereas for Anania OCP, the effect of spacing has resulted in higher fragment size with an increase in *SI B.*

(ii) As high *H/ B* correspon ds to higher borehole depth and lower burden, the combined effect of borehole depth and burden has resulted in low mean fragment size for higher values of *H/ B.* In addition, high boulder percentage can be seen for lower values of *H/ B.*

(iii) The effect of burden has resulted in high mean

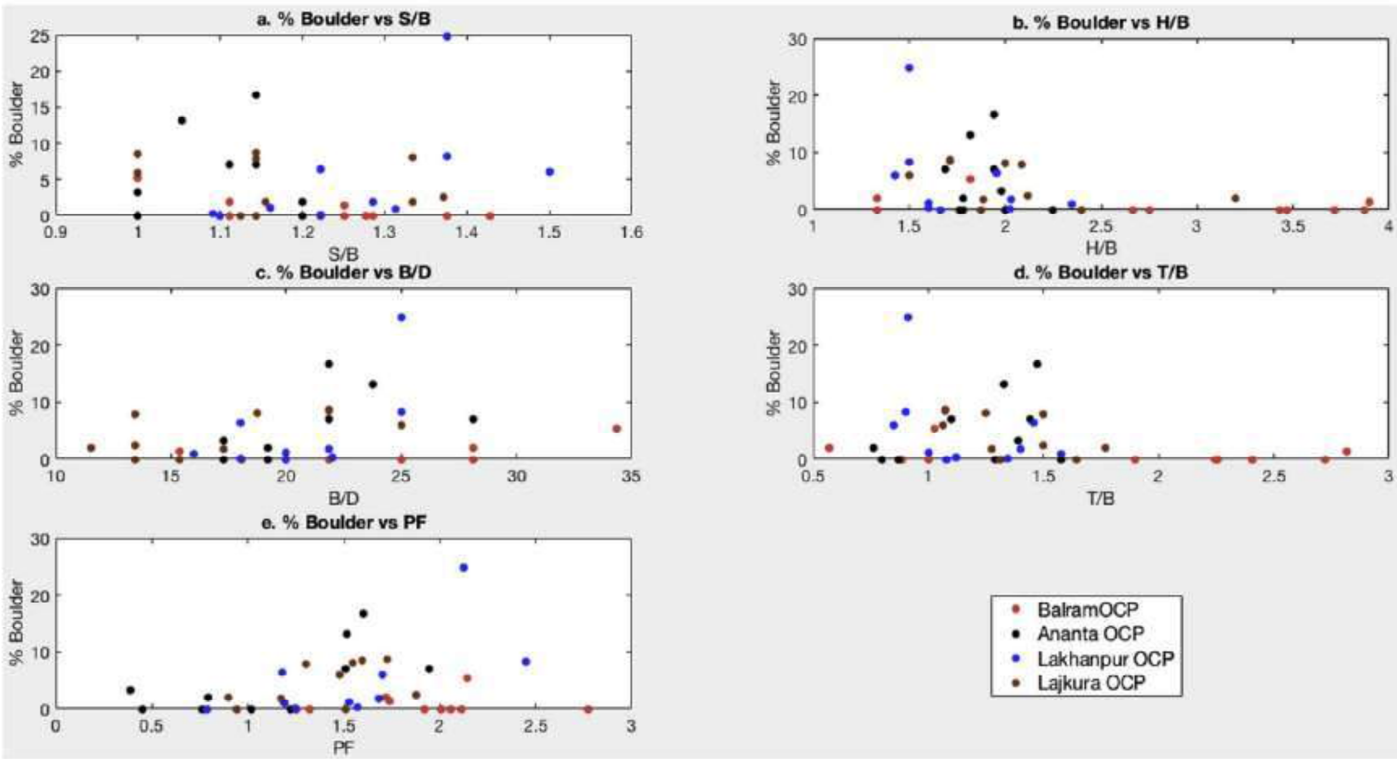


Fig. 7. Variation of boulder percentage with respect to (a) *S/ B,* (b) *H/ B,* (c) *BID,* (d) *T/ B* and (e) *PF.*

fragment size with an increase in *BID* for Bairam Ananta and Lajkura OCP, as high bu rden leads to poor fragmentation. Whereas in Lakhanpur OCP, the effect of the borehole diameter tends to lower fragment size as *BID* increases , as s maller borehole diameter leads to better frag- mentation. High boulder percentages were obtained for higher values of *BI D.*

(iv) The combined effect of stemming depth and burden has resulted in lower fragment size for higher values of *T/ B,* as high stemming depth and lower burden reduces the fragment size. Therefore, high boulder percentages were seen for lower values of *T/ B.*

(v) The resu lts obtained from the opencast mines show that the means fragment size was directly proportional to the powder factor. Thus, higher fragment size and boulder percentage were obtained for higher values of powder factor.

CONFLICT OF INTEREST

The aut hors sta te that there is no conflict of interest.

ETHICAL STATEMENT

The authors state that the research was conducted according to ethical standards.

FUNDING BODY

The authors are very grateful to Central Mine Planning and Design Insti tute and Mahanadi Coalfields Limited for generating such valuable data and providing them for the present study.

ACKNOWLEDGEMENT

The authors are also grateful to Mr. S. Saran (Chairman cum Managing Director, CMPDI), Mr. B. N. Shukla (Chairman cum Managing Direc to r, MCL), Mr. K. K. Mishra (Director T/ES, CMPDI), Mr. A. K. Rana (Director T/ P&D, CMPDI), Mr. R. N. Jh a (Director T/ CRD +RD&T, CMPDI), Mr. Manoj Kum a r (Regional Director RI-III, CMPDI), Mr. A. K. Das (HOD Blasting / S&T, CMPDI), Mr. A. Majumder (HOD Innovation Cell/ JCT, CMPDI), Mr. B. Srinivasu (Genera l Manager JCT, CMPDI), Mr. A. Das (Innovation Cell, CMPDI), Mr. Himanshu Sharma (Innovation Cell, CMPDI), Mr. Mayank Ahuja (Blasting/ S&T, CMPDI) and other executives of CMPDI (Coa l India Limite d) for their constant support and motivation.

REFERENCES

- Aler, J. , Mouza, J. D., & Amould , M. (1996). Evaluation of blast fragmentation efficiency and its prediction by multiva riate analysis proced ures. *International Journal of Rock Mechanics and Mining Sciences, 33 ,* 189 - 196 . https: / / doi.org/10.1016 / 0148-9062(95) 00055-0 .
- Ash, R. L. (1963). The mechanics of rock breakage. *Journal of Pit and Quany , 56 ,* 98-100 . Ash, R. L. (1985). Flexural rupture as a rock breakage mechanism in blasting. In W.
- Forney, R. Boade, & L. Costin (Eds.). *Fragmentation by blasting* (pp. 24—29). Bethel, USA: Society for Experimental Mechanics .
- Blanford , W. T., Blanford , H. F., & Theobald , T. (1856). On the geological structure and relations of Talcher coalfield in the district of Cuttuck. *Memoirs of the Geological Survey of India,* 1(1), 1- 98.
- Chakraborty, A. K., Raina, A. **K.,** Ramu l u, M., Choudhury, P. B., Haldar , A., Sahu, P. C., et al. (2004). Parametr ic study to develop guidelines for blast fragmentation im- provement in jointed and massive formations. *Engineering Geology, 73,* 105—116. https: / / doi.org/ 10.1016 / j.eng geo. 2003.12.003.
- Cunningham, C. V. B. (1996). Optical fragmentation assessment - a technical challenge. *Proceedings of the FRAGBLAST 5 Work.shop Measurement of Blast Fragmentation, Montreal (Quebec, Canada)* (pp. 13-19). .
- DGMS (2014). Directorate general of mine safety. *Statistics of Mines in India,* Jhttp:/ / www.dgms.gov.in/ writereaddata/U ploac1File/VO LUMEI(C0 AL)% 202014636129985l 00886136.pdf.
- Ghose, A. K. (2001) . Are Renewable Energies realistic alternatives to fossil fuel and nu- clear power generation for Asia. *Proceedings of World Congress of Safety of Modem Technical Systems. Congress Documentation* (pp. 234-245). Saarbrucken: TIJV Saarland Foundation.
- Grundstrom , C., Kanchibotla , S. S., Jankovich, A., & Thornton, D. (2001). Blast fragmentation for maximising the sag mill throughput at Porgera Gold Mine. *Proceedings of the 27th Annual Conference on Explosives and Blasting Technique, Orlando (Florida): Vol 1,* (pp. 383-399).
- Hudaverdi, T., Kuzu, C., & Fisne, A. (2012). Investigat ion of the blast fragmentation using **the mean fragment size and fragmentation index.** ***International Journal of Rock*** *Mechanics and Mining Sciences, 56,* 136—145. https: / / doi.or g/ 10.1016 / j.ijr mms.2012. 07.028.
- Jimeno, C. L., Jimeno , E. L., & Francisco, J. A. C. (1995). Drilling and blasting of rock. In
- A. A. Balke ma, R. D. Ramiro, & Y. Visser (Vol. Eds.), *Drilling and blasting of rock: Vol 30 ,* (pp. 56—61). (translated to English).
- Ku latila ke, P. H. S. W., Qiong, W., Hudaverdi, T., & Kuzu, C. (2010). Mean part icle size prediction in rock blast fragmentation using neural networks. *Engineering Geology, 114(3-4),* 298—311. https: / / doi.org/10.1016 / j.enggeo.2010.05.008 .
- Lyana , K. N., Hareyani, Z., Shah, A. K., & Hazizan, M. H. M. (2016). Effect of geological condition on degree of fra gmentation in a Simpang Marble Quarry. *Procedai Chemistry, 19 ,* 694- 701. https: / / doi.or g/ 10.1016 / j.proche.2016.03.072 .
- Mackenzie, A. S. (1967). Optimum blasting. *Proceedings of the 28'1' Annual Minnesota Mining Science,* 9(2), 181- 188.
- Maerz, N. H., Palangio, T. C., & Franklin, J. A. (1996). WipFrag image based granulo- metry system. *Proceedings of the FragBlast 5 Work.shop on Blast Fragmentation, Montreal* (pp. 91- 99). .
- Monda! , D., Roy, P. N. S., & Behera , P. K. (20 17). Use of corre lation fractal dimension **signatures for understanding the overlying strata dynamics in longwall coal mines.** *International Journal of Rock Mechanics and Mining Sciences, 91,* 210—221. https: / / doi. org/ 10.1016 / j.ij rmms.2016.**l** 1.019.
- Morin , **M.** A., & Ficarazzo, F. (2006). Monte Carlo simulation *as* a too l to predict blasting fragmentation based on the KuzeRan1 model. *Computers & Geosciences,* 32(3), 352- 359. https:/ / doi.org/ 10.1016 / j.cageo.2005.06.022.
- Pareek, H. S. (1963). Petrology of talcher coals. *Economic Geology, 58,* 1089- 1109. https: / / doi.org/ 10.2113 / gsecongeo .58.7.1089 .
- Saxena, A., Singh, K. J. , & Goswami, S. (2014). Advent and decline of the genus glos-sopteris brongniart in the talcher coalfield, Mahana di basin, odisha , India.
- *Palaeobotany,* 63(2), 157-168. http:/ /h dl.handle.net/ l 23456789/2 098.
- Singh, A. K. (2016). Petro g raphic and geoc hemical cha racte ri zation of coal from tal cher coal field, Mahanad i basin, India. *Journal of the Geological Society of India, 87 ,* 525—534. https:/ / doi.org/ 10.1007 / sl 2594-016 -0426 -5.
- Singh, P. K., Roy, M. P., Paswan , R. K., Sarim, M., Kumar, S., & Jha, R. R. (2016). Rock fragmentation control in opencast blasting. *Journal of Rock Mechanics and Geotechnical Engineering,* 8(2), 225—237 . https: / / doi.or g/ 10.1016 / j.j rmge.2015.10. 005.

The Indian Mining & Engineering Journal, Vol. 60, No.08-09, August-September 2021, pp.43-45
Printed in India, @ IME Publications, ISSN 0019-5944

Special Blasting Techniques Adopted in Hard Strata : Case Study of Lajkura OCP

Saurabh Singh*

INTRODUCTION

The blasting operation plays a pivotal role in the overall economics of opencast mines. Blasting as primary fragmentation can significantly decrease the cost of loading, transport and other operations. In addition to the fragmentation, blasting should be optimized such that the fly rock and vibration associated with the blast, is minimum and within range. This paper describes the real time problem while dealing with the hard strata and how the blast design parameters was changed to provide better fragmentation along with the less vibration and the flyrock. Use of Reject cartoon or corrugate sheet boxes as muffle is also described. All the studies were executed and continuously monitored at Lajkura OCP, IB Valley Area.

GEOLOGY

Ib Valley coalfields forms the south- eastern part of NW-SE trending son- Mahanadi valley Gandwana basin. It forms a linear sub basin of large tract of lower Gandwana from Korba in the west through Mand Raigarh Coalfield. The coalfields occupy an area of about 1460 Sq Kms with potential coal bearing area of about 1050 Sq. Kms. The topography of the block is generally flat barring from hillocks in the extreme dip of the property. The highest altitude above mean sea level is 278 mtr and the lowest is 232 mtr in the area. Lajkura coal horizon occur in Lajkura II block of Ib valley fields. The seam occurs in Barakar and Karharbari formation of lower Gondwana. The overburden of Lajkura OCP is medium hard coarse grained sand stone with shale bands and clay beds at places. The area is free from any major fault.

Lajkura block consist of 4 seams, namely Parkhani(1.33-3.64 m), Local-3(0.20- 3.18m), Local-2(0.43- 4.15 m), Lajkura (17.59- 22.24 m); covers an area of 4.4 SqKms.

DEALING WITH HARD STRATA

The overburden of Lajkura OCP is medium hard coarse grained sand stone with Carbonaceous shale bands and clay beds at places.OB deposit below Local-3 coal seam (Figure 1) consists of 2-2.5 m of carbonaceous shale, succeeded by Granular Sandstone having thickness about 3.5-4 m.Large sized boulders was often observed in this patch after blasting.

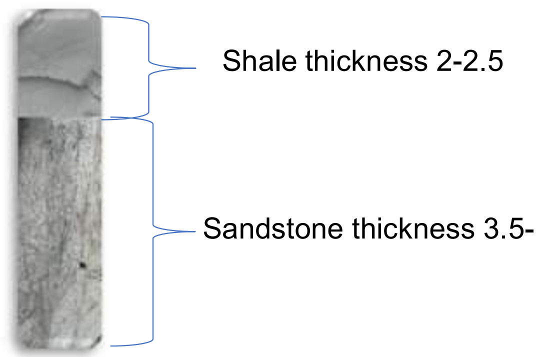


Fig. 1: Strata Below L3 Coal Seam

To avoid boulder formation, this patch was heavily charged. The main objective was to bring the explosive column near to the hard shale, so that proper fragmentation can be achieved. One of the reasons for formation of the boulder was due to the porous nature of the granular sandstone, most of the explosive energy was consumed at lower portion of the strata. Figure 2 shows the blast design layout. 150 mm dia holes having depth 6 m was drilled in this patch. 60 kg bulk explosive was charged in the holes at front row, back row and sideways and remaining holes were charged with 70 kg.

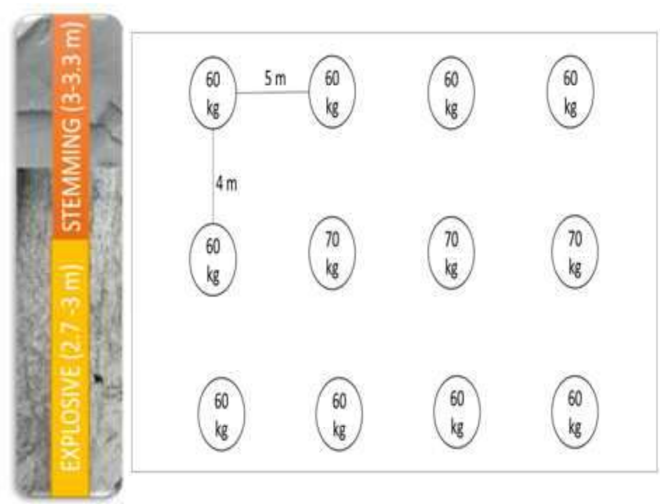


Fig 2: Blast Design layout

*Dy. Manager (Mining), Lajkura OCP

Following shortcomings were observed in this blast layout :

1. High Vibration: Since the charge per delay was increased (max- 70kg/delay), high vibration was felt during blasting.
2. High Fly Rock generation: It was seen that the fly rock travelled to approx. 70-100 m. Due to this reason, the blast design cannot be followed within 500 m of any private structure/village.
3. Back Break: This was the major problem in these strata. Fig 3, shows the back break formed after blasting in this patch.

Fig 3: Back Break

To overcome the above demerit, the entire Blast was redesign. The depth of hole was reduced from 6m to 4m and Spacing was reduced to 4m. Only 30 kg was charged in each hole. Figure 4 shows the blast design layout.

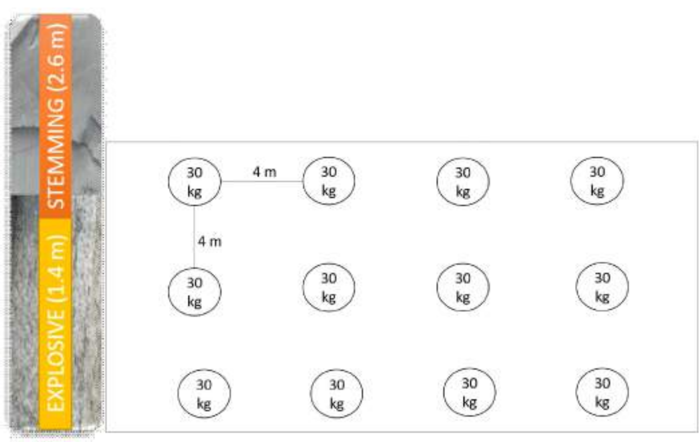


Fig 4: Blast design layout

Improvements observed after changes were made in the blast design. They include -

1. Fly rock was restricted to about 50 m
2. Less vibration
3. No Back Break was observed
4. Better fragmentation, less cycle time of machine

Muffle With Rejected Cardboard boxes

The Cardboard box/carton are used by suppliers for packing of LD Explosive and accessories. In Mine these are rejected after consumption of LD Explosive and accessories.

There are situations encountered by every blasting officer, when any structure such as pump, lighting arrangements etc are within 50-100 m of blast site, which cannot be shifted and blasting is required to be done. For dealing with such scenario, rejected cardboard boxes as muffle were used.

Fig 5: Muffling with Rejected Cardboard boxes

Hole depth varied from 2.9 m to 3.5 m. Each hole was watery. Pumping structure was within a distance of about 80 m from the blast site. The carton was kept on neck of each shot hole. Each cartoon was filled with fine drill cuttings. Fig 6-7 shows different time lapses of the same blast site after initiation.

CONCLUSION

By maintaining proper blast design pattern, numerous problems can be solved. Post blast observations significantly helps in changing the blast design so as to have desired results. Generation of flyrock could be checked and limited within 30 m from blast site, after using cardboard boxes on each hole as muffle.

Fig 6 & Fig 7 : Shows different time lapses of the same blast site after initiation

The Indian Mining & Engineering Journal, Vol. 60, No.08-09, August-September 2021, pp.46-48
Printed in India, @ IME Publications, ISSN 0019-5944

Blast Free Technology - Case study of Kaniha OCP

K.K. Roul* LMC Pujari**

INTRODUCTION

In India, coal deposits are formed along river side for about 290-360 million years and are located mostly besides the rivers where thickly populated areas are witnessed. Winning coal being a site specific operation, land acquisition for planning a project for coal extraction has had been a tedious process all the ages. In case of Kaniha OCP, though the mine was planned to be started in the year 2007, the same could be materialized only in 2010 due to delay in land acquisition as several villages are located in and around

BLAST FREE MINING

In spite of several attempts made by the mine management and district administration, suitable resettlement site for the PDFs of the near by villages could not be finalized, for which the mine faced frequent land constraints for its working/expansion with conventional method of mining till the year 2020. Later on, for enhancement of mining activities towards the acquired village area, it was decided to introduce blast free method of mining. MCL had the unique distinction of introducing blast free mining techniques in early '90s in the form of Surface Miners at Lakhanpur OCP under IB Valley coalfields. Since then major coal in MCL is produced by surface miners only.

Upto 2020-21 February out of 129821.43 thousand tonnes of coal produced by MCL, departmental Surface Miners produced 29864.876 thousand tones and 93928.140 thousand tones by contractual agencies. In case of OB benches several [problems related to [proximity to villages and public roads etc, caused stoppage of OB removal by blasting. To ensure smooth production of OB, rippers were considered. X-centric/vertical ripper attachm,ent attached to hydraulic excavator was adopted on trail basis.

RIPPER

X-centric/vertical ripper attachment mounted on excavators broke the OB layer and the broken material was handled by shovel-dumper system. At Kaniha OCP 03 nos. of MAX BRIO BR55 model vertical ripper machines are in use (Fig. 1),and the specification details are depicted below.

Fig. 1 : Showing deployment of X-centric/vertical ripper attachment mounted on Hydraulic Excavator in operation at sandstone OB bench

*General Manager, Kaniha Area**Deputy Manager(Mining), KOCP

DESCRIPTION OF THE RIPPER ATTACHMENT

The Xcentric ripper is a hydraulic excavator attachment used for mass extrction of rock in mining. In general practice, ripper is fixed in a back hoe shovel replacing its bucket. It is a safe and easy alternative to *drilling and blasting*. The tooth of the ripper with the help of the vibration generated by the ripper penetrates the surface/ rock and breaks the rocks into pieces upto a depth of 1.3 mtrs in one go. The operator digs the rock at a spacing of 30cms one after another and the earmarked area is excavated which is loaded into dumpers for exposure of coal seams. It is designed for high volume production in quarries with low noise and high performance.

MAX BRIO BR55 model vertical Ripper	Technical Specifications
	Height (A) (mm): 3018 Length (B) (mm): 1486 Width (C) (mm): 928 Tooth (D) (mm): 575 Applicable weight (ton): 43 ~ 55 Frequency (vpm): 1700 Setting pressure (psi): 3556 Oil flow (l/min): 290 ~ 310 Air pressure (bar): 3 Main body weight (kg): 4360

Cost benefit analysis of Blasting Vs Ripper

	Blasting Cost/ M^3. (in Rs.)	Ripping Cost Rs./ M^3
Drilling cost	6.25	
Blasting(Explosives & Accessories)	17.04	
Manpower cost	5.00	
Total	28.29	Rs. 45.91

From the above it is seen that Ripping Cost/CuM by Xcentric ripper is Rs.17.62 more than conventional blasting. But the benefits gained from the use of the ripper are worth the cost.

DIRECT & INDIRECT BENEFITS OF BLAST FREE METHOD OF WORKING OVER CONVENTIONAL METHOD OF MINING.

Direct Benefits

a) Mine working can be extended upto 45 mtrs from the structures not belonging to the owner resulting maximum extraction of coal.
b) Uninterrupted Mining operations.
c) Continuous production and higher productivity can be achieved.
d) More precisions for the separation of the rock & coal layers.
e) No requirement of statutory permission for blasting operation.
f) Less damage to environment.

Indirect Benefits

a) Elimination of Hazards due to blasting operations.
b) Better mine working environment.
c) Better stabilization of Benches (OB, Coal & Dump yard).
d) Elimination of Fly rock/debris .
e) Less disturbances to the surrounding.

Moreover, blast free method of working has larger positive impact on environment and the living beings residing in the periphery of the mining working areas, which is illustrated below.

ENVIRONMENTAL IMPACT DUE TO BLASTING OPERATIONS WHICH CAN BE TOTALLY ELIMINATED BY GOING BLAST-FREE

AIR POLLUTION

a. The blasting is the predominating method of breaking rocks in various open cast mines. Blasting operations cause several adverse environmental effects such as ground vibrations, air blast, fly rock, generation of fines, fumes and dust.
b. Blasting operations can generate large quantities of fugitive dust which, when released in an uncontrolled manner, can cause widespread nuisance and potential health concerns for on-site personnel and surrounding communities.
c. Though the blasting dust plume is raised for few minutes but most of the dust settles in and around mining area and some of it is dispersed before settling down. Depending on meteorological conditions the dust dispersal can travel to substantial distances endangering health of communities.
d. In blasting process toxic gases are also encountered, such as: carbon monoxide, sulfur dioxide, nitrogen oxides and others depending on the blasting conditions.

NOISE POLLUTION

For the coal mining area, the permitted noise level by the DGMS is 90 dBA.

a. Blasting operations can have unacceptable noise and vibration impacts.
b. The noise is now being recognized as a major health hazard; resulting in annoyance, headache, partial hearing loss and even permanent damage to the inner ear after prolonged exposure.
c. Air blast is a measure of explosive energy inefficiency in series of blasting round. Both these problems are associated with each other and jointly or singly can cause structural damage.

Soil & Water Pollution

a. In some occasion, if commercial explosives are spilled on the ground or left undetonated at a blast site, ammonium and nitrate can reach into ground and surface water and can cause chemical contamination of soil and water.

CONCLUSION

By adopting blast free method of mining, huge quantum of in situ coal trapped due to land acquisition problem all over the mining industry can be extracted to fulfill the energy demand of the country. Not only coal production but coal production with lesser environmental damage which is a major concern now-a-days throughout the world can also be achieved by adapting such blast free technologies. Environmental impact have compelled many western countries to shut down their mining operations but in India, where coal is still the measure source of energy and mining is still the livelihood of millions of Indians we need to adapt newer and better technologies so as to sustain in the industry without harming our world and our future. With all the benefits it provides, there is no doubt, the above blast free method of mining will be acceptable to the mining community in larger prospect.

The Indian Mining & Engineering Journal, Vol. 60, No.08-09, August-September 2021, pp.49-50
Printed in India, @ IME Publications, ISSN 0019-5944

Storage of Explosive: Case Study of Basundhara (West) OCP, Mahalaxmi Area

Paberus Toppo*

INTRODUCTION

Basundhara (West) OCP, Mahalaxmi Area consumes eOB and coal bench blasting. The uninterrupted supply of explosives is maintained by having five magazines. Explosives stored here is also supplied to three other OCPs. Basundhara West-)CP management is the licensee and they maintain the safety and storage responsibilities as per the Indian Explosives Rules and CMR 2017. Annexure 1, presents the details of Magazine. Magazines are located at the site which are (a) having maintained safe distance between the Magazine and the Dwelling Houses, (b) Roads and other places regularly visited by the security persons, (c) built on well-drained sloping ground, (d) having proper approach road to the Magazine throughout the year, and (e) maintained the distance between the Magazine and Overhead Power Transmission Lines not be less than 90 M.

SAFETY PRECAUTIONS

- Apart from providing fire Extinguishers, there should be adequate quantity of water & sand in water tank and sand tank respectively.
- No contrabands like Biri, Cigarette, Match Box, &Even Smart Phones shall be allowed inside the Magazine Premises.
- Explosives and Detonators shall not be kept in same Magazine.
- Emergency contact details like Fire Station, Rescue Station, Blasting Officer,Magazine I/C, Project Officer,Manager,Safety Officer are necessary to be prominently displayed in Security Room.
- Regular cutting/cleaning of grass & bush from Explosive Magazine complex.
- At least 2(Two) Arm Guards security personnel are deployed in each shifts at the Magazine Complex Gate to avoid pilferage of explosive as well as issue / return of explosives.
- Magazine shall be properly fenced with both brick wall & barbed-wire.Apart from this, watch towers in all directionsshould be installed for use of security guards for clear & distinct vision.
- Two types of Siren(Mechanical & Electrical) as well as telephonic communication should be provided for emergency warning in case of any untoward incidents.
- Adequate lights shall beprovidedaround the Magazine complex.
- Natural Angle Transverse(NAT) of earthen mounds has shall be provided around the storage building.
- Transverse height should benot less than 2.4 Mt.
- Registers RE-3,RE-4,RE-5,should be maintained by the Magazine In-charge as per Explosive Act-2008.

Statutory Provision for Storing Explosives

Regulation 184 of CMR 2017

1. No Owner ,Agent or Manager shall store / knowingly allow any other person to store within the premises of mine any explosives otherwise than in accordance with the provisions of the rules under Indian Explosives Act 2008.
2. Explosives shall not be taken into or kept in any building except a magazine duly approved by the licensing authority under the Explosives Act 2008 provided that the RIM may permit the use of any store or premises specially constructed at or near the entrance to a mine subject to some condition.
3. Explosives shall not be stored below ground except with the approval in writing of the CIM and subject to such condition as he may specify therein.Such storage shall be done in a magazine duly licensed as per Explosives Act 2008.
4. Every Licensee granted by the Licensing Authority for the storage of explosives or a true copy thereof shall

**Manager (Mining), Blasting Officer*

be kept at office of the Mine.

Reg.185 CMR 2017

1. Every Magazine or Store or Premises where explosives are stored shall be in charge of a competent person who shall be responsible for the proper receipt,storage and issue of explosives.
2. Explosives shall not be issued from Magazine unless they are required for immediate use. If any explosives are returned to the magazine or store or premises ,they shall be reissued before fresh stock is used.
3. Explosives shall be issued only to the competent person upon the written requisition signed by the short-firer or by the official concerned authorized for the purpose and only against their signature or thumb impression . Such requisition shall be preserved by the competent person in charge of the Magazine or store or premises.
4. The competent Person in charge of the Magazine or store or Premises shall maintain in bound paged book kept for the purpose a clear and accurate record of explosives issued to each competent person and a similar record of explosives returned to the magazine or premises.

Regulation 60 of CMR 2017 , Duties of Magazine In-charge

1. Subject to the orders of superior officials be responsible for the proper receipt,storage and issue of explosives in and from the magazine
2. Maintain such records of explosives received,stored and issued under clause (a) asare required under Provision of Explosives Act 2008.
3. Not allowed any unauthorized person to enter the magazine

Precautions against Pilferage of Explosives

1. At least,2(Two) Arm Guards should be deployed in each Shifts at the Magazine Complex gate to avoid pilferage of explosive.
2. Magazine shall be properly fenced with both brick walls and barbed-wire .Apart from this watch towers in all directions shall be installed for use of security guard for getting distinct vision.
3. Adequate lighting shall be necessary around magazine complex, lights shall be focused towards outside of the magazine.
4. Two types of siren(Mechanical & electrical) as well as telephonic communication are necessary for emergency warning in case of any untoward incident.
5. Only authorized persons shall enter into the magazine complex.Proper records of persons entering into and leaving from the magazine and reasons of visit should be duly entered in a bound-paged register.
6. Only such persons should be appointed as Magazine In-Charge, Blasting Overman/Shot firer and Explosive Carriers who have been found trustworthy.Senior Officials should frequently have surprise check on the amount of explosives with carriers and shotfires at different times during the shift.
7. The antecedents of all persons including Blasting Officer shall beChecked.The details of Blasting Overman/ Shotfirer (Name,Father's Name,Address,Kind of Certificates etc.)are necessary to be submitted at DGMS and Supt of Police.

CONCLUSION

The availability of sufficient quantities of SME will reduce the storage capacity for cartridged explosives. After increase use of Bulk SME, these magazines will store Nonel/ accessories or for Ammonium Nitrate (as per AN Rules of 2012). Efforts are being made to enhance safety around the magazines to make it pilferage free.

Annexure 1
Details of Magazine of

- License for Possession for Storage & Use –LE-3
- Licensing Authority-Project Officer, Basundhara (West)OCP, Mahalaxmi Area
- Validity of all 5 magazine is 31.03.2023
- Authorization to receive, Store & issue of explosive inside the magazine- Magazine I/C
- Explosive & Detonators are kept in Separate Magazine
- Magazine of Basundhara(West) OCP is catering 3 Projects i.e.Kulda OCP, Garjanbahal OCP,Basundhara (West)OCP

Capacity Details

MAGAZINE NO-01- LD-2125 KG(CL2,DIV0),CB-250 KG(CL3,DIV2),DF-10000 MTRS(CL6,DIV2)
MAGAZINE NO-02- LD-2125 KG(CL2,DIV0),CB-250 KG(CL3,DIV2),DF-10000 MTRS(CL6,DIV2)
MAGAZINE NO-03- LD-2125 KG(CL2,DIV0),CB-250 KG(CL3,DIV2),DF-10000 MTRS(CL6,DIV2)
MAGAZINE NO-04- LD-2125 KG(CL2,DIV0),CB-250 KG(CL3,DIV2),DF-10000 MTRS(CL6,DIV2)
MAGAZINE NO-05-DETONATOR-40000 NOS

The Indian Mining & Engineering Journal, Vol. 60, No.08-09, August-September 2021, pp.51-52
Printed in India, @ IME Publications, ISSN 0019-5944

Selection and use of Fly Ash as Stowing Material in Underground Metal Mines

Umeshwar Charpe*

ABSTRACT

India is facing shortage of river sand due to its demand in infrastructure sector development, and also ban on use of sand due to several regulations. That lead the mine management to think about an alternate stowing material easily available in the nearby of mine with minimum cost. Fly ash, the waste from thermal power plants are available in plenty. It also needs large land area for its disposal, and also a possible source of pollution of air, water and land. In order to use fly ash, government of India had launched several steps including Fly Ash Mission. In the mining sector attempts have been madse to use fly ash in back filling of voids created by underground and opencast mines. In underground metal mines, fly ash is also considered as an alternate river sand as a stowing material. An attempt has been made to study various aspects of stowing vis-à-vis fly ash in underground metal mines.

INTRODUCTION

The prime function of fill materials in mine is to assist in managing the stability of mining voids. There are many ways of managing mine voids. Fill is used to increase the flexibility of ore extraction strategies and often allows for an improved recovery of ore bodies. The use of different types of fill , their specific functions and engineering requirement are related to mining methods, mining strategies and mining sequences of operations. The mine fill may be divided into three types: Hydraulic Fill, Paste fill, and Rock fill**.**

FACTORS TO BE CONSIDERED FOR SELECTION OF AN APPROPRIATE FILL SYSTEM

Availability of fill material is one of the essential features of any selection method. Any underground metal mine, which operates on the basis of an approved Mining Plan, duly approved by Indian Bureau of Mines. The approval also indicate the voids to be created and the fill material to be used based on the initial documentation of the mine. Besides, the Fill properties and production rates required to achieve the target in accordance to the mining plan. Capital and operating cost of procurement to site, storage, handling and transport to UG levels are equally important. Rate of filling and fill mass properties are also some of the factors influences in selecting a fill material.

STOWING PARAMETERS

Apart from studying the geo-technical and geo-mining conditions in the field, physical properties such as specific gravity, bulk density, grain size distribution and porosity, Water percolation characteristic, Settlement characteristic, and Compressibility characteristic are essential components of any study and model.

BACKFILL OF THE UG VOIDS

By aadopting stowing/backfilling left out pillars (mostly Sill pillars) can be recovered . It also serves as aworking platform, in addition to providing Ground support. Backfill creates space below ground thereby creating sites of Waste disposal and help in the Mining on top. As a replacement of river sand crushed overburden material, Plant Mill tailing, Fly ash, bottom ash, and pond ash can be used as backfill material.

Any adoption of backfill material needs proper evaluation of the effect of backfill on mine stability, conditions during pillar removal and with time lag. It also necessitates, study of relative vertical displacements in the backfill by field measurements with the help of embedment strain gauges and vertical extensometers. There are other instruments also used including Earth Pressure Cells (to identify loading trends in the backfill), Borehole extensometers(to measure relative displacement changes in the mine roof and support pillars) and Biaxial Stress Meters (to measure stress changes in several support pillars and abutments).

USE OF FLY ASH

In 019-20, with 197 power plant using non-coking coal containing an average of 33.32 ash percentage, the amount of fly ash generated is 226.13 million tonnes. At the 2019-20 level of fly ash utilization, only 187.81 million tones are

**Chief Manager(Mines), MOIL Ltd, Nagpur*

being used in manufacturing cement, building materials like bricks etc, land fills etc. India's fly ash utilistaion is quite high and stands at 83.05 percentage (CEA, Min. of Power)..

Fly ash is composed of silt-sized material. Its diameter ranges from 0.01-100 micrometer. It is also 25 % lighter than river sand , favorable for hydraulic transportation. It does not need any elaborate screening arrangement at the stowing plant . The Finer particle sizing and spherical particle shape enhances flow ability and blend freely in mixture. It is also lesser hydrostatic pressure on barricade

Use of flyash as backfill material

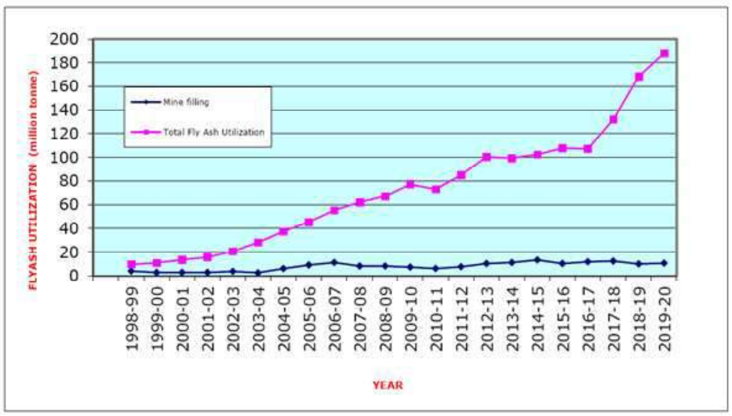


Figure 1 : Shows the progressive utilization of fly ash in mine back filling/ stowing during the period 1998-99 to 2019-20 [Source : CEA(2020)]

The above graph shows that 4.17 million tonnes of fly ash is being used for backfilling/stowing during 1998-99 to 2019-20 period. Opencast filling using fly ash and overburden (JSPL-Tamnagr, Manipur opencast mines, Gidhumuri and paturia opencast mine. Underground coal mine backfilling –Jitpuri colliery (SAIL) laboratory and field experimental of bottom ash as stowing material. Mahagiri mine, IMFA – Cemented hydraulic filling upgraded and higher filling rate achieved . Proper backfilling of underground stopes resulted in free standing backfill wall after extraction of adjacent stope . Also experimentation were conducted to use OB as a backfilling material for underground metal mine. Paste backfilling- fly ash replacement in paste backfill in Rampura agucha mine and Rajpura Dariba Mine of HZL. Attempts are being made to use this system in underground coal mine- Sarni UG Mine, Patharkhera area, WCL

PRESENT STUDY

The present study, aims at developing a suitable paste fill material from fly ash and its transportation system to UG coal mine for stabilization of working as an alternative of sand stowing for increasing % of extraction of coal & to ascertain its cost effectiveness with due regard to safety and environment . Preliminary experimentation of mix optimization is in progress. Also, with the use of flyash and other waste from thermal power plants the MoEFCC guidelines for 100% utilisation can be to some extent met with. MoeFCC guidelines of 1999 and subsequent norms of 2003, 2009 and 2016 have clearly demarcated the thrust to be given to use fly ash in backfilling.,

CONCLUSION

Fly ash which is available in abundance near underground Manganese mines of MOIL, will be an effective material to backfill the voids. Several researchers have demonstrated its efficacy in stowing, and as a replacement material to river sand for stowing in underground mines and backfilling in opencast mines. Policy framework and national strategy can make it possible to utilize all possible fly ashes in gainful manner. It would mitigate environmental threat , provide sustainable mining and cleaner environment. One area of caution is the chemical composition of fly ash and also its settling characteristics as well as water retention properties. Detailed research and model studies are required before its use in any underground mines.

ACKNOWLEDGEMENT

The study is a part of the M.Tech (Mining) thesis work, and in partial fulfilment of the M.Tech(Mining) course work being pursued at AKS University, Satna. Thanks are due to management of MOIL for according permission to pursue M.Tech on Part Time mode. The views expressed are of the author and not of the organisation he represents. Thanks are also due to Dr G.K.Pradhan, for his guidance.

SELECTED REFERENCES

1. Report on fly ash generation at coal / lignite based thermal power stations and its utilization in the country for the year 2019 – 20, Central Electricity Authority Thermal Civil Design Division, New Delhi, Ministry of Power (Govt. of India), p. 78.

The Indian Mining & Engineering Journal, Vol. 60, No.08-09, August-September 2021, pp.53-59
Printed in India, @ IME Publications, ISSN 0019-5944

Safe Transition of India's Largest Open Pit Copper Mine to Underground Mine - A Case Study of Malanjkhand Copper Project

Amlan Das*

ABSTRACT

As the open pit mine gets deepen it is often burdened with excessive waste stripping leading to increasing in overall cost of ore production. Transitioning to underground mining is sometimes considered a strategy to maximize both the value of the project and resource recovery. Hindustan Copper Limited is operating Malanjkhand Copper Project, a highly mechanized open pit mine, in the state of Madhya Pradesh. It is operating since 1979. Till 01.04.2019, the MCP mine has produced 73.9 Million Tonneof ore with 1.091%. The present production capacity is 2.5 MT of ore per annum with matching capacity copper concentrator plant. The approximate remaining open pit balance as on 01.04.2019 is 4.1 MT with 1.00% Cu hence open pit mine is expected to be exhausted by 2020-21 by restricting the depth of about 240m from the surface. Below the open pit, estimated reserve is 160 MT copper ore of 1.34% grade containing over 2 MT Copper. The remaining ore reserve below open pit cannot be extracted due to increase in depth of open pit mine and additional waste stripping. The increase in depth of current open pit poses economical and technical limitations such as cost increase, slope stability and excessive haulage distance. Bearing in mind these limitations of continuing with the open pit mining operation, the further deepening of the pit is not planned and the extraction of ore from underground mining was proposed. An underground mine of 5.0MPTA ore production capacity was proposed below the existing pit at Malanjkhand. This amounts to a daily ore production target of about 14,000 tpd. Open pit mines allow for heavy machinery and workers to do their jobs in the open therefore there isn't as much of a danger of cave-ins, roof fall, gas emissions.However, underground operations usually cause many more difficulties than normally occur in open pit mines due to working in closed spaces. Due to the difference in nature of mining and additional hazards present in the underground mining operation, the transition of open pit mine to underground mine features needs to be planned carefully keeping in view the safety aspects of mine design. In this paper we have discussed important aspects related to transition of open pit mine to underground.

Keywords:Transition, open pit mine, underground mine, copper, Malanjkhand copper mine

INTRODUCTION

Ore reserves can be mined by open pit, underground mining methods or both. The deposits located near earth surface are generally preferred for extraction by open pit mining method whereas deeper deposits are mined using underground mining method.Some deposits have a continuous ore body from surface to deeper levels. In such cases, the ore body could be mined by either method, and a choice has to be made. This choice is made upon consideration of economic and technical factors. Deciding where to finish the open pit and start the underground is referred to as the transition from open pit to underground. **Nilsson (1981)** gave a good account of the factors that need to be considered when planning a transition from open pit to underground mining, including geotechnical interactions, economic considerations and operational challenges. He recognized that the optimal pit design changes if deeper parts of the ore body can be mined by an underground mine and his illustration of the difference is included in Figure 1.

A crown pillar is a body of rock left in place above the shallowest part of an underground mine to ensure stability in the ground above. The need for stability is driven by the land use, which in some cases is open cut mining. The crown pillar also acts to reduce or avoid the ingress of water to the underground mine and to ensure the stability of the cavity below. An indication of the position of a crown pillar is provided in Figure 2 **Chen et al. (2003).**When crown pillars are used, their design must take into account the geotechnical characteristics of the native rock and the planned sizes and shapes of the underground stopes **(Carter (2000)).**

****Manager (Mines), Hindustan Copper Ltd, Malanjkhand Copper Project***

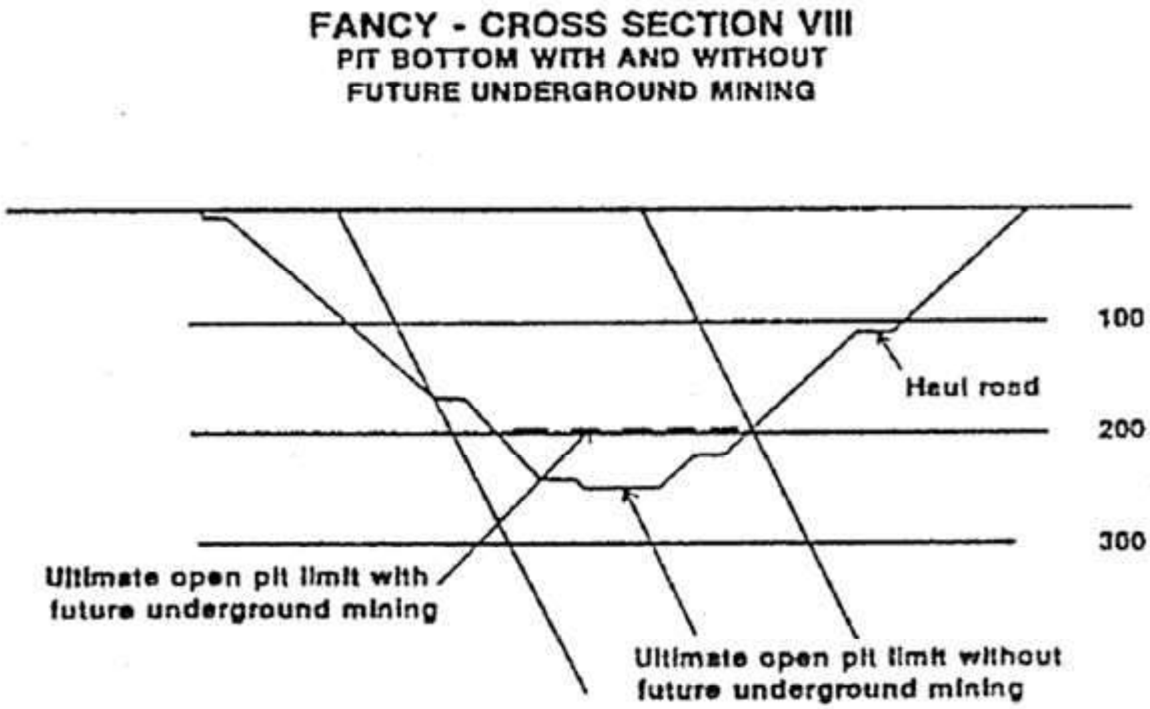


Figure 1: The change in the shape of the open pit mine as a result of the underground opportunity (Nilsson 1981)

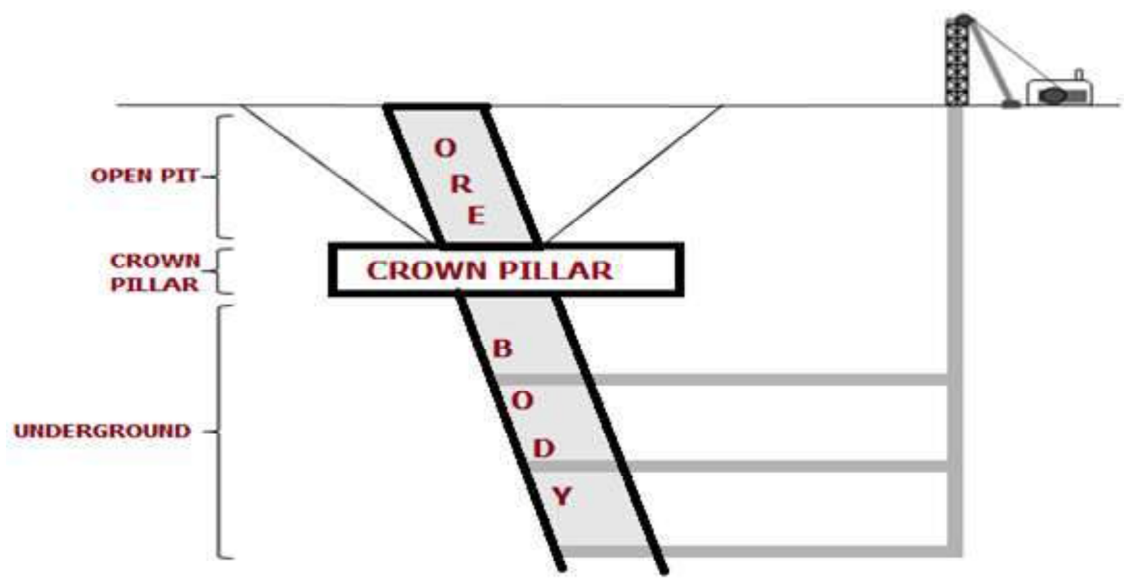


Figure 2: Illustration of a crown pillar between an open pit and underground mine

Case Study
Location

The study area Malanjkhand copper project is located in the deep, dense, green forests of Baihar sub-division of the Balaghat district near the town of Malanjkhand, 90 km North-East of Balaghat town of Madhya Pradesh in the central eastern part of India. It is the largest open-cast copper mine in India own owned and operated by M/s Hindustan copper limited, a government of India undertaking. The total land area of the project 2016.77 ha out of which 479.90 ha is the mining lease area. Malanjkhand copper project has coordinates 22^{O}0'54''N and 80^{O}43'20''E.**(Mining Plan, 2013)**

Figure 3: Location of Mines and Concentrator Plant

GEOLOGY& MINING PROCESS

The principal ore is chalcopyrite ($CuFeS_2$) with 1.0% copper content.Quartz reef is the principal host of mineralization and varies in composition from pure quartz to quartz feld-spathic rock. The quartz reef is positioned in an arcuate shape over a length of 2.6 km in north-south direction dipping 60^o-70^o due east with an average width of 65 to 70 m.Besides quartz reef, silicified altered granitic rocks are also seen hosting the Sulfide mineralization. The most predominant minerals occurring in quart reef and granitoids in order of abundance are chalcopyrite ($CuFeS_2$), chalcocite and malachite.**(Mining Plan, 2013)**

Malanjkhand copper open pit mine was designed by M/s. RTZC (Rio Tinto Zinc Corporation) during the year 1978 to produce 2.0 MT (Million Tonnes) of ore per annum. The deposit is being continued to be worked by open pit mining method**. (Figure 3)**The mining operations are fully mechanized using Rotary Percussive Drills operating at high pressure, Electric Rope Shovels with the bucket capacity of 9.2 m3, Hydraulic Excavators with bucket capacity of 4.5 m3 and 50T/85 T/100T/60T Dumpers.The length of the pit is 2.2 km in strike length with an average width of 500 m and with pit bottom at 340mRL. (Figure 4)

TRANSITION FROM OPEN PIT TO UNDERGROUND MINE

Malanjkhand deposit extends from 580 mRL to (-) 300 mRL. The ultimate pit bottom has a depth of 240 m (i.e. 340 mRL). Due to Economic considerations, open pit mining has been planned for a depth of 240 m (i.e. up to 340 mRL). As on 01.04.2017, the balance life of the open pit shall be approximately 5 years. Below this depth, open pit mining is not financially viable as cost of ore production shall be more when compared with the cost of production by underground mining. The only way out for extracting the balance copper ore reserve is through Underground mining method. It is planned to mine the balance ore reserves by developing an under-ground (U/G) mine below 300 mRL leaving a crown pillar of 40 m.The Cabinet Committee on Economic Affairs (CCEA) has approved an investment proposal of Hindustan Copper Limited (HCL) for Rs1856.36 crores on 30.09.2011 to develop an Underground Copper Ore Mine of 5 million tonnes per annum capacity at Malanjkhand Copper Project (MCP), Madhya Pradesh with matching capacity Concentrator plant.After completion of the project, Malanjkhand will be the biggest Underground Mine for base metals in the country with ore production capacity of 5 MTPA

Figure 4: Mining process at Malanjkhand copper project

FEATURES OF THE PROPOSED UNDERGROUND MINE

The ore body is divided into two parts due to existence of aplite intrusion in the central section**(Figure 5)**.

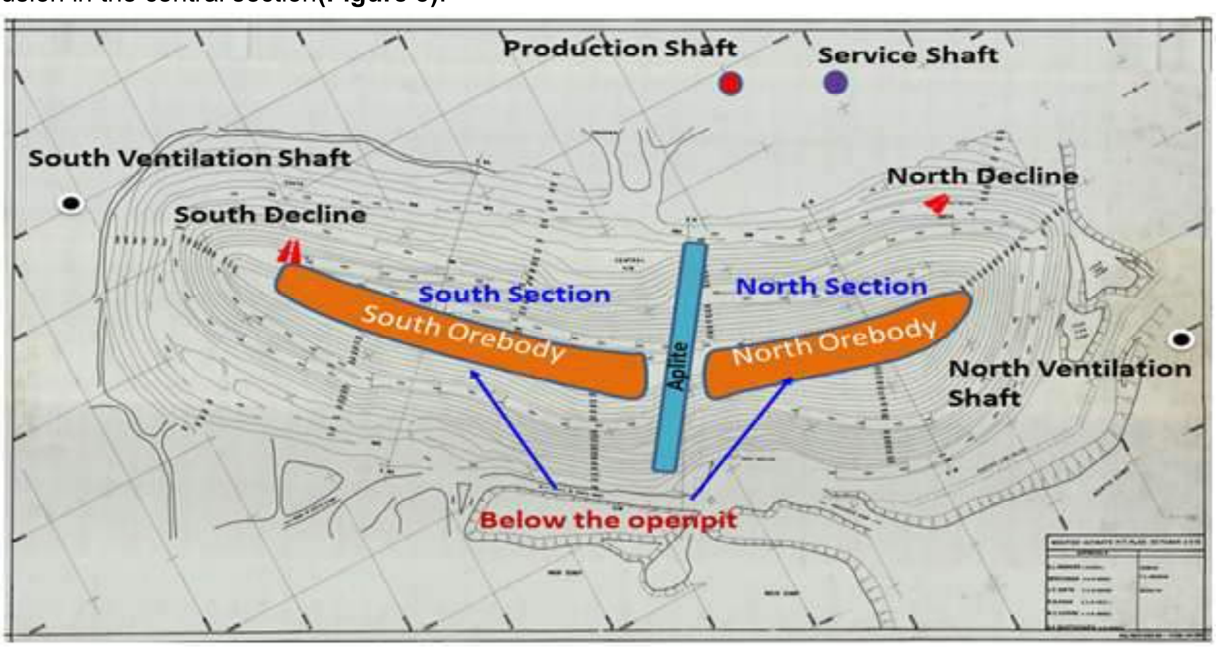


Figure 5: Layout of the Underground Mine

DECLINES & DRIVES

Two declines each for north and south mine are designed. The dimensions of these declines are selected as an extended D-shape section with dimension of 5.5 x 5.0 m. The mouth of the north mine decline is located at 532 mRL and south mine decline at 436 mRL on the footwall side. The declines will be maintained at least a distance of 60 m away from the ore body to protect it from possible damage from underground blast practices.

The slope of decline is recommended at a gradient of 1 in 7. The turning radius is taken to be 50 meters considering the low profile dumper trucks used for hauling and transporting the material. The total length of decline driven in waste rock for the north and south mine are 2477.5 m and 1592.1 m respectively.

Footwall and hanging wall drives of dimension of 5.5 m x 5m, are driven to serve the purpose of transportation of men, material and ventilation. Both the drives are driven in the waste rock maintaining a distance of 15 meters away from the ore body. The dimensions of all the drives and crosscuts remain same for both north and south mine.**(IIT Report, 2014)**

SHAFTS

The service shaft and production shaft are common for both north and south mine located at the middle portion of the deposit on the footwall side around 100 m away from open pit boundary. The ventilation shaft for south mine is located on the south western side of the mine and the ventilation shaft for the north mine is located northern side of the mine. The details of shafts and decline are provided in Table 1.

Table 1: Details of Shaft and Declines

Type of shaft/Entry	Depth (m)	Collar (mRL)	Bottom (mRL)	Size/ Gradient
Production shaft	695	585	-110	Diameter: 7.0 m
Service shaft	665	585	-80	Diameter: 6.5 m
North Ventilation shaft	633	573	-60	Diameter: 6.5 m
South Ventilation shaft	640	580	-60	Diameter: 6.5 m
North Decline	4610	532	-60	(WxH) 5.5 m x 5.0m/ 1 in 7 (8 °)
South Decline	3860	436	-60	(WxH) 5.5 m x 5.0m/ 1 in 7 (8 °)

Mining Method

Large diameter blast holestoping (LDBH) method is selected for extraction of orebody. Mining will be done alongtransverse direction that is perpendicular to the strike direction of the orebody. Crown pillar witha minimum thickness of 40 m will be kept below the ultimate open pitwhich provides stability to the stopes and other underground structures. **(Figure 6)**Large diameter holes of *89-115*mm will be drilled from the drill drive.Stope drilling will be conducted by Jumbo drill machine having a maximum diameter of *89-105* mm and for trough drilling; the diameter of the hole will be 57 mm.

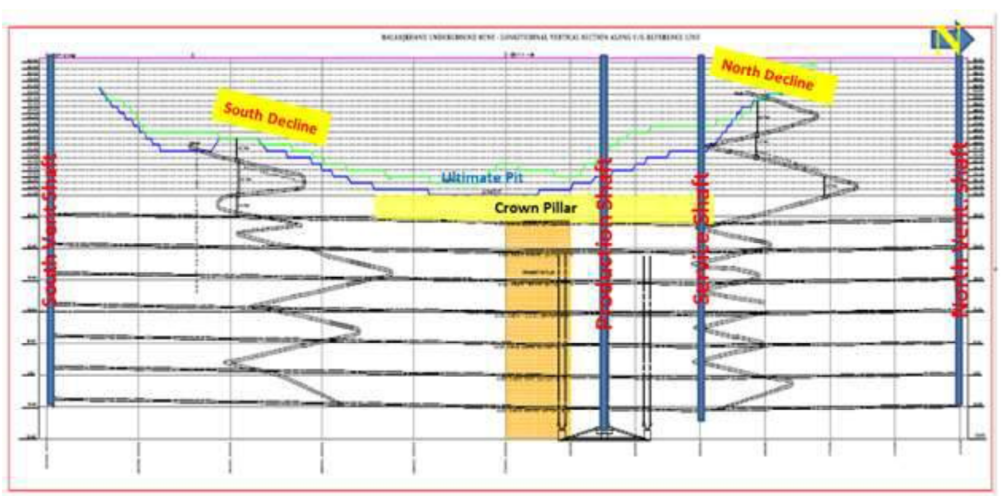


Figure 6: Longitudinal section of proposed underground mine

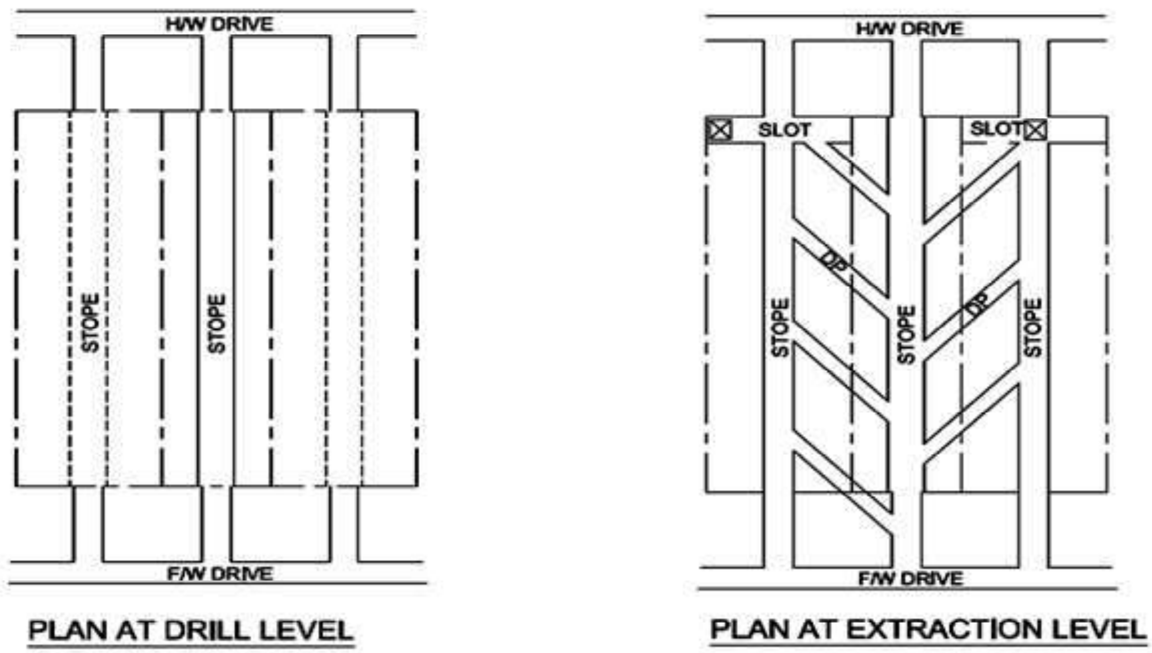


Figure 7: Stope design for proposed underground mine

SAFETY ASPECTS OF UNDERGROUND MINE

There are various safe aspects of underground mining like roof support, presence of gases, water ingress, blast vibrations, fire, pillar stability, stope stability etc. Although all safety issues are needed to be addressed but during transitioning from open pit to underground mine; blast vibrations from open pit, roof support, stope stability and water ingress from the open pit become significant.

The PPV values (@400m,700kg/delay, PPV Transverse - 2.16 m/s) obtained from the surface blast are within the permissible limits (USBM RI8507 and OSMRE) and pose no serious threat to the old and modern buildings nearby. The rock mass in the north mine is competent to withstand ground vibrations due to blasting. However, it is recommended to provide necessary artificial support such as rock bolt and cable bolt in areas prone to weathering and discontinuities. If such condition arises, proper support system will be designed and installed.It is recommended to provide artificial support such as rock bolting and cable bolting in the crosscuts and drill drives to reduce the tensile zone. Rock bolting of 1.8 – 2.4m and 22 mm diameter with resin grout will be necessary at the drill level, extraction crosscut, extraction level and also in footwall and hangwall drive.

Backfilling is absolutely necessary as soon as stope is mined out.Since, the jointed rock condition in the south side is weaker as compared to north side.Filling operation will be critical in south mine. MCP tailing is suitable for hydraulic backfilling as far as the tailing characteristics are concerned.IIT has recommended using MCP tailings with 8% cement by weight.

For open pit operation rainwater is the major determinant of mine pumping capacity. The catchment area for open pit is 1.68 sq. km and rainfall is 1000 – 1200mm. After the open pit operation ceases, only dewatering will continue to prevent excessive accumulation of water in the pit. To ensure minimum seepage of water from open pit to underground workings a crown pillar of 40m thickness is left as barrier between open pit and underground mine. Besides this, a separate dewatering arrangement for underground mine is made. Underground mine drainage is proposed for collection on each sub-level passes to local sumps and then via boreholes or drainage lines to main pump station sited near the service shaft.The high free silica content of the quartz reef and granite means that respirable dust in mine air must be minimized mainly through ventilation and adequate air flows.Two specific areas of dust control are,Crusher stations, andConveyor loading and discharge points adjacent to the Hoisting Shaft.

CONCLUSIONS

The safety consideration for open pit mining operation and underground mining operation needs to be designed simultaneously. The dewatering operation for open pit mining operation needs to continue to for safe working in underground mine.

Systematic support rule-SSR (as required under Regulation 112 of MMR 1961) shall be followed for all the drives and opening in underground. After each round of blasting, the sides and back shall be thoroughly dressed for loose rock while developing drives and crosscuts.

It is recommended to properly monitor and study the stability of the remnant pillar at the time of operation. Based on the monitoring data and rock mass conditions, stoping parameters or blast design may be relooked if necessary.

ACKNOWLEDGEMENT

The study is a part of the M.Tech (Mining) thesis work, and in partial fulfilment of the M.Tech(Mining) course work being pursued at AKS University, Satna. Thanks are due to management of HCL for giving permission to pursue M.Tech on Part Time mode. The views expressed are of the author and not of the organisation. Thanks are also due to Dr G.K.Pradhan, for his guidance.

SELECTED REFERENCES

1. Carter, T. (2000) An Update on the Scaled Span Concept for Dimensioning Surface Crown Pillars for New or Abandoned Mine Workings. in 4th North American Rock Mechanics Symposium: American Rock Mechanics Association.
2. Chen, J., Gu, D. and Li, J. (2003) Optimization principle of combined surface and underground mining and its applications. Journal of Central South University of Technology (English Edition), 10(3), pp. 222-225.
3. MCP Mine Plan 2013-17, Modification of Scheme of Mining (2012-13) and Mining Plan (2013-17) & Progressive Mine Closure Plan (2013-17): 23rd August 2012.
4. Nilsson, D. S. (1981) Optimization of Underground Mine Development - Introduction. AIME Annual Meeting,(81-52).
5. Pradhan, G.K. (2020) Introduction to Mining Technology, Vol. I, An AKS University Initiative, Published by Mintech Publications, Bhubaneswar, p. 425.
5. Unpublished report titled: "Stope Design and Stability, Production Planning and Paste Backfilling to Produce 5 Million Tonne per Annum", Department of Mining Engineering, IIT Kharagpur.


Organised by
THE INDIAN MINING & ENGINEERING JOURNAL
CELEBRATING 60 YEARS The Indian Mining & Engineering Journal
National Seminar
on
SDMiNER
Sustainable Development of Mineral Resources
and
Annual Awards Function
27-28 November 2021
Khajuraho
Chairman of Organising Committee :
Prof. S. Jayanthu
NIT Rourkela & Editor-in-Chief, The IME Journal
Convenor :
Dr. G.K. Pradhan
AKS University, Satna
gkpradhan58@gmail.com
www.imejournal.com
Knowledge Partner
AKS University
Satna (M.P.)
The Khajuraho temple complex,
a designated UNESCO World Heritage site,
is a series of beautifully built structures