SOUVENIR

NATIONAL SEMINAR
ON
UNDERGROUND COAL MINING

" THE FUTURE OF OVERGROUND LIES BELOWGROUND "

28 August 2010 at Hotel Golconda, Hyderabad

Moulana SCCL

Jointly organised by

The Directorate General of Mines Safety
The Singareni Collieries Company Limited

NATIONAL SEMINAR
ON
UNDERGROUND COAL MINING

Organised by

The Directorate General of Mines Safety
The Singareni Collieries Company Limited

Foreword

Coal shall continue to be the prime source of energy in the Global energy scenario meeting about 60% of the requirement. Major coal producing countries – United States, China and India would be increasing their production levels further but would still end up importing coal to some extent to bridge their demand – supply gaps. In Indian scenario, dependence on coal as prime source of energy shall continue for the next few decades. With rapidly improving living standards, the per capita electric power consumption is increasing at an equally rapid rate. The gap between demand and supply is increasing more heavily than planned, with the planned capacity addition of power generation lagging behind and the coal production from captive coal blocks allotted under NCDP delaying by years.

The scenario in SCCL is not much different. Ironically, the scenario is further worse with capacity addition hindrances due to more share of coal production from UG mines, mining at deeper horizons in existing UG & opencast mines and non availability of opencastable deposits leftover in SCCL leasehold area. Against the national average of 15% production from underground coalmines, SCCL is producing about 22% from its UG coalmines surpassing the Australian average of 20% coal production from UG mines. Further more, all the opencastable coal blocks have been opened up or projectised and about 61% of the reserves in left over coal blocks are in the depth range of 300m to 600m and beyond. All the existing UG mines are getting deeper day by day and all the opencast mines are operating at higher strip ratios, nearly 4 times the national average strip ratio of OC mines. As a result the core activity of coal mining in SCCL is less remunerative in the prevailing cost –price scenario. Moreover about 75% of the coal produced is of power grade and is linked to Government/PSU power sector utilities, the prices of which are indirectly regulated by the energy sector.

In this backdrop, to sustain in the complex business scenario, SCCL is aiming at introduction of bulk production technologies in some of the suitable UG coalmines. UG bulk production is the only key to sustainability in the prevailing conditions. The role of DGMS in permitting and regulating entry of suitable mining machinery for deployment in Indian UG mines is commendable. The Indian coal Mining Industry is keeping pace with the global majors in introduction of various technologies.

UG mining is fraught with dangers and mining of deep-seated coal blocks is associated with dangers of greater intensity in strata behaviour, ventilation, long travel distances, long haul distances, ergonomics, coal bumps, gas and coal out-bursts, structural problems/discontinuities, increased pumping requirements, increased face temperatures, increased heat addition due to face machinery and associated safety risks. The mechanization programs of UG mines shall address all these issues in detail, still ensuring that coal is produced at a competitive price.

I wish that this National Seminar on UG mining shall address all the related issues for the benefit of the Indian Coal Mining Industry.

(K J AMARNATH)
Organising Secretary &
CGM (HR & BD)

GOVERNMENT OF INDIA

SRI PRAKASH JAISWAL

Minister of State (Independent charge) for Coal & SPI

MESSAGE

I am pleased to know that the Singareni Collieries Company Ltd. jointly with the Directorate General of Mines Safety, Ministry of Labour, Government of India will be organizing a National Seminar titled "The Future of Over Ground Lies Below Ground" on 28 August 2010 at Hyderabad.

The topic chosen for this Seminar is highly relevant in the present context. Coal is the driving force behind the phenomenal growth that our country has achieved over the years. The demand for coal is rising and it has been imperative that we meet the coal production target for our country to meet its targeted growth rate. To achieve this goal, we have to implement the latest technologies, modern labour practices and strategies, streamline our policies and practices. Available resources have to be exploited in a scientific manner to achieve prosperity.

I am sure the Seminar would throw up many useful tips for the coal industry for the benefit of our nation. I take this opportunity to wish the National Seminar a great success.

(SRI PRAKASH JAISWAL)

GOVERNMENT OF INDIA

C. BALAKRISHNAN
Secretary, Ministry of Coal

MESSAGE

It gives me immense pleasure to note that 'The Singareni Collieries Company Limited' and 'Directorate General of Mines Safety' are jointly organizing a National Seminar on Underground Coal Mining with the theme "The Future of Overground Lies Belowground" on 28th August 2010 at Hyderabad.

While it is a fact that the present trend in coal production in the country is more tilted towards open cast mining, it is however important to focus on underground mining as well, particularly in the context of the reserves position of companies like SCCL. Long gestation periods, economics of scale, technology, production, productivity and safety are the major challenges in the development of underground mines. SCCL has been taken lead in the country in developing mechanized underground mines adopting the state of the art technologies.

Organising such seminars would provide an opportunity for exchange of knowledge as also a scope for benchmarking. I am sure that the deliberations in the seminar would result in evolving best practices in promoting production, productivity and safety through underground operations.

I wish the event all success.

(C. BALAKRISHNAN)

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भारत सरकार
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Ministry of Labour & Employment
खान सुरक्षा महानिदेशालय
Directorate-General of Mines Safety

S J Sibal
Director General of Mines Safety

MESSAGE

I am pleased to be associated with the National Seminar on Underground Coal Mining titled **"The Future of Underground Lies belowground"** being organized jointly by The Directorate General of Mines Safety, Ministry of Labour and Employment and the Singareni Collieries Company Limited, at Hyderabad.

Safety of men and machinery and Conservation of coal are two major concerns in exploitation of the available coal reserves of the Country. DGMS has been supporting the initiatives of Indian Coal Mining Industry ensuring safety and conservation. As a responsible Government Coal Mining Company, SCCL has shown its commitment towards Safety & conservation measures in its purview of coal mining operations. SCCL has implemented several new initiatives in its long journey of 120 years. It is expected that SCCL shall lead the coal mining industry initiatives for introduction of bulk production technology in deep-seated coal blocks, which would ultimately benefit the entire Indian Coal mining industry.

I sincerely hope that the National Seminar would be the first step towards economic exploitation of deep-seated coal blocks.

I wish the Seminar a grand success

16/8

(S J Sibal)

Government of Andhra Pradesh
Energy Department

Sutirtha Bhattacharya, I.A.S.,
Principal Secretary to Government

MESSAGE

I am pleased to note that The Directorate General of Mines Safety and The Singareni Collieries Company Limited are jointly organizing a National Seminar on Underground Coal Mining titled "The Future of Overground Lies Belowground", at Hyderabad.

This Seminar comes at a time when the Energy needs of the Nation are growing at a faster pace than ever and the shallow coal deposits amenable for highly mechanized Opencast mining are nearing exhaustion. The future of coal mining is truly in the expeditious implementation of bulk production technologies for exploitation of deep-seated coal reserves. It is heartening to note that SCCL is taking concrete measures in furtherance of UG mining.

I am quite hopeful that the joint initiative of The DGMS and The SCCL shall be a smart beginning in ensuring energy security.

I wish the Seminar a grand success.

(Sutirtha Bhattacharya)

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खान सुरक्षा महानिदेशालय
Directorate-General of Mines Safety
South Central Zone, Hyderabad.

S.I. Hussain
Dy. Director General of Mines Safety

MESSAGE

I am immensely happy to be part of the National Seminar on Underground Coal Mining titled **"The Future of Overground Lies Belowground"** jointly organized by The Directorate General of Mines Safety, South Central Zone and The SCCL at Golconda Hotel, Hyderabad.

The energy demand is growing day by day. The need of the hour is to increase the production from all resources so as to meet the demand. The largest coal producing countries like China, USA and Australia are producing coal from underground at 95, 33 and 20% respectively, whereas India produces about 15% coal from underground mines.

The coal reserves amenable for opencast mining are depleting fast. There is a need for a quantum jump in production, productivity and high degree of safety from underground mining operations. Bulk production from deep-seated underground coal seams is the future of coal mining in India. The time for such seminar is apt and need of the hour.

I wish the National Seminar a grand success and convey my best wishes to all the participants and the organizing committee.

(S I Hussain)

The Singareni Collieries Company Limited

(A Government Company)

S. NARSING RAO, I.A.S

Chairman & Managing Director

MESSAGE

It gives me immense pleasure to be associated with The National Seminar on Underground Coal Mining jointly organized by The Singareni Collieries Company Limited and The Directorate General of Mines Safety - titled **"The Future of Overground Lies Belowground".**

SCCL has always been leading the Indian Coal Mining Industry in absorbing suitable technologies for ensuring safe, environment - friendly and viable Coal Mining operations. SCCL is presently at a crucial stage where the operations need to undertake a paradigmatic shift towards introduction of productive Underground bulk production technologies. The current production levels are difficult to be sustained in the near future given the adverse geological conditions of the yet to be projectised coal blocks left over in its leasehold area. SCCL has initiated induction of Underground bulk production package. Company is also planning PPP (Public Private Partnership) as a business model in other Underground project for introduction of bulk production technology.

This National Seminar is coming at most appropriate time and I wish that this Seminar would signify start of a new era in the Indian Coal Mining Industry.

(S. Narsing Rao)

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The Singareni Collieries Company Limited

(A Government Company)

J V DATTATREYULU

Director (Operations)

MESSAGE

I am pleased to state that The Singareni Collieries Company Limited and The Directorate General of Mines Safety are jointly organizing a National Seminar on Underground Coal Mining, aptly titled **"The Future of Overground Lies Belowground"**

This National Seminar comes at a time when the shallow coal deposits are under active exploitation stage and are nearing exhaustion. All the Opencast mines of SCCL are already operating at strip ratios of about 4 times the national average strip ratios. The underground mines are getting deeper and deeper. Almost all the unexploited coal blocks are beyond the economically exploitable depths. In this context, to have a rosy future, it is imperative that economic exploitation of the deep-seated coal blocks with Bulk Production Technologies is the only alternative. The efforts of DGMS in guiding and permitting introduction of suitable Mining Technology and Machinery for the same are commendable.

It can be emphatically said that "The Future of Overground Lies Belowground" and it is high time for the Indian Coal Mining Industry to invest in UG coal mining for a sustained future. SCCL has been in the forefront of Indian Coal Mining Industry in implementation of newer technologies and implements. SCCL is the first Indian Coal Mining Company to implement Enterprise Resource Planning (ERP) to ensure optimal utilization of resources. I am confident that SCCL would also lead the introduction of bulk technology for exploitation of deep-seated coal blocks.

I wish the National Seminar a grand success for the benefit of Indian Coal Mining Industry.

(J V Dattatreyulu)

The Singareni Collieries Company Limited

(A Government Company)

D L R Prasad

Director (Planning & Projects)

MESSAGE

It gives me immense pleasure and pride that The Singareni Collieries Company Limited and The Directorate General of Mines Safety are jointly organizing a National Seminar at Hyderabad on Underground Coal Mining titled "The Future of Overground Lies Belowground".

Due to increasing depth of Underground coalmines and higher stripping ratio of Opencast mines in the lease hold area, SCCL is on the verge of a viability crunch. Though the physical performance indicators like production, productivity, Annual Turnover of the Company are continually rising, profitability of Coal Mining Operations is not commensurate with the improvement. In view of the above and due to fast depletion of opencastable reserves the only way out is introduction of bulk production technologies in Underground coalmines to enhance the production levels and ensure viability of the operations.

This is the most opportune time for the conduct of the National Seminar and I wish the National Seminar all the success.

(D L R PRASAD)

The Singareni Collieries Company Limited

(A Government Company)

I V N PRASADA RAO

Director (E&M)

MESSAGE

It gives me immense pleasure that The Singareni Collieries Company Limited and The Directorate General of Mines Safety are jointly organizing a National Seminar on Underground Coal Mining titled **"The Future of Overground Lies Belowground",** at Hyderabad.

The Singareni Collieries Company Limited is known for its professional approach in technology absorption both in coal mining and in implementation of ITES in coal mining. The successful implementation of highly mechanized coal mining operations calls for equally high standard of equipment maintenance to ensure uninterrupted operation. The new generation bulk production technologies suitable for deep-seated coal blocks involve application of ITES in equipment operation, maintenance and performance monitoring. SCCL has the required knowledge base to gear up to the necessity and ensure safe, uninterrupted and highly productive face operations from its deep-seated coal blocks.

In this context, organizing a National Seminar on Underground Coal Mining is quite timely and a welcome move to address various issues involved in absorption of the technologies. I am hopeful that the National Seminar addresses all the related issues and I wish the National Seminar a grand success.

(I V N Prasada Rao)

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Sri **J V Dattatreyulu**
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Sri **D L R Prasad**
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ADDRESS

I am extremely happy to participate in the National Seminar on **"The future of coal mining lies below ground"** and thank the organizers for giving me this opportunity to share some thoughts with the distinguished participants on under ground coal mining.

Coal has been the world's fastest growing fuel and coal use is expected to grow faster than any other fuel far into the future. In an effort to meet the demands of a developing nation, the Indian energy sector has witnessed a rapid growth. However, resource augmentation and growth in energy supply have failed to meet the ever-increasing demands exerted by the multiplying population, rapid urbanization and progressing economy. Hence, serious energy shortages continue to plague India, forcing it to rely heavily on imports. The development of core infrastructure sectors like power, steel, and cement are dependent on coal.

Planning Commission has noted that energy demand is growing at 7% per year. As per the Expert Committee on Road Map for Coal Sector Reforms, a shortfall of 100 Million tonnes of thermal coal is expected in the country by the end of FY12. The coal reserves of India up to the depth of l200 m have been estimated by the Geological Survey of India at 276.8 billion tonnes as on April 2010 of which 108 billion tonnes are proven. To meet this demand-supply gap, the Government is looking at various alternatives e,g, FDI, acquisition of overseas coal blocks, captive mining, faster project approvals, better technology etc. With the increase in coal demand and growing awareness towards sustainable development; the coal industry has drawn a consensus over the need for increased production from underground coalmines.

The largest coal producing countries like China, USA and Australia are producing coal from underground mining at 95 per cent. 33 per cent and 20 per cent, respectively. With just 15 per cent share of coal production from UG mines in India, there is a need for a quantum jump in production and productivity from such mines as there are more opportunities in productivity improvement and cost benefits in underground mining. From the current share of 15 per cent, the industry aims to reach a total coal production of 30 per cent from underground UG mines by 2030 after realizing that the reserves that could be mined through the opencast method will get exhausted in the next 15 to 20 years and hurdles in surface land acquisition in future.

Emphasis on UG mining

Currently mining is done predominantly by opencast methods to exploit the proven reserves situated within a depth of 300 m. At present, multiple clearances are required from the government for commencement of new opencast projects like site clearances for mining lease, forestry clearance and environment clearance. The process would be much simpler for UG mining as the forest land and environment clearances in respect of underground mines are relatively uncomplicated.

India is a global player in coal mining with third place in total production and 5th in underground production. But still have low level of mechanization and there is massive scope for improvement from 0.5 ton per man-year to 5 tons per man-year in underground coalmines by introducing mass production technologies like longwall mining in the immediate near future. India has huge untapped potential for underground mining with extractable reserves upto a depth of 600 m. Size of mining operation and introduction of appropriate technology is key to the success of underground mining.

Bulk of the total underground coal production in India comes from board and pillar mining. The contribution from mechanized Longwall or from special methods like blasting gallery has remained at low level. Phased replacement of small un-economic mines with larger mines using modern technologies coupled with improvement in underground mine management practices is absolutely necessary, if underground operation are to be made Profitable and competitive.

This calls for increasing the level of mechanization, introduction of state-of-the-art machines and ensuring their optimal utilization as per international standards. This includes introduction of mass production technology at suitable locales, replacement of manual loading by deployment of SDL/LHD and reorganization of transport system, enhancement of evacuation capacity by driving additional shafts and inclines/drifts and deployment of additional coal winning equipment and starting new projects.

The Mass production technologies which have been established as main underground coal winning technologies in major coal producing countries are longwall, highwall, Punch longwall, longwall top coal caving and continuous miner/bolter miner for room and pillar mining and development of longwall gate roadways.

Longwall Mining

Longwall being a mass production technology well proven around the world in all conditions like steep and gassy seams with geological disturbed or strong roof conditions.

In India, though the first mechanized longwall was introduced in 1979 at Moonidih, the method could not be established as major production technology as easier options like opencast mining for achieving is available for extracting shallow depth deposits. It is the need of the hour to make longwall a successful technology by using the lessons learnt during last thirty years of longwall experience.

International longwall trends

Longwall production increased from 1000T/day in 1980's to 35000T/day in 2010. Longwalls can be introduced with minimum proved extractable reserve of 100MT, a minimum Life of the mine of 25-30 years deploying high-speed development systems using Bolter Miners/CM/RH for continuity of longwall operations & longer panels. Essential Requirements for longwall success include system approach for selection of equipment, detailed ventilation studies for providing effective ventilation including air cooling arrangement, scientific assessment of support requirement & strata behavior, modern roadway support systems, developing and adopting world class operating and maintenance practices, quality training of the longwall team, and modern transport system for speedy transport of men and material as well as for the equipment transfer. Mines are to be planned like Adriyala Longwall of M/s. Singareni Collieries Company Limited with state-of-the art technology to achieve 3 to 5MT of output, wherever favorable reserves are available.

In USA, Australia and China, longwalls are being operated with production ranging from 2MT to 10MT with a face width ranging from 150m to 400m. Average production from each Longwall face is more than 3MT/ year. Trend is towards wider faces of around 400mtrs and longer panels of around 4000m with only one longwall face per mine, two gate roadway system deploying continuous miners with shuttle cars and bolters, height of extraction upto 4.8mtrs and a depth of upto 600mtrs.

Support capacity ranging from 700T to 1700T with 2 legged - 1.75m and 2m width, Shearer capacity ranging from 600KW to 3000KW, AFC Capacity ranging from 1500T/hour to 5000T/hour AFC power ranging from 2x500KW to 3x1200KW, Coal clearance system of 6000T/h in mains and 3500T/h in longwall with conveyor widths of 1800mm and 1500mm respectively with a speed of 4.0mtrs/sec are the need of the day.

Trends in power distribution

A 1000KVA power center was commonly found for the Longwall section in 1980's. Today, it has increased to more than 11000KVA. Similarly, 1000V face equipment was exclusively used in 1980's, today most Longwalls employ 2400V/3300V or 4160V/6600V to deliver high power to the power centres, and subsequently to the face equipment.

To reduce voltage drop during power transmission, high voltages power is used which will in turn reduces the size of cable required. Normally, 24/33-138KV/132KV power supplied to the mine can be reduced to 12-14KV/11KV using transformer at mine substation, which is then delivered to the power centres at Longwall Section. Transformers at the power centre reduce the voltage to 4160V/6600V or less for the face equipment.

Punch longwall mining.

The aim of this method is to mine coal from the highwall of an open cut operation, in which the stripping ratio far outweighs the production cost of coal mined. The system requires no transport, conveyor drifts, shafts, complex ventilation systems or main headings as in conventional underground mining methods, hence this benefit provides cheaper, faster, simpler access and commencement of longwall mining. Gaining knowledge about mining, geological, and other information is quickly achieved at an early stage. This method is flexible as the infrastructure can be easily relocated and requires less manpower. The development of gate roads on future panels is separate from the current longwall panel due to the use of barrier pillars.

Continuous miner/Bolter miner

Second high capacity system with proven success in South Africa producing more than 90% of UG output and around 50% output in USA. Wide variety of cut sequences can be employed to achieve annual production of 0.3MT to 8.0MT from each continuous miner with a district OMS of around 13T.

Continuous miner system is the most popular method for room and pillar mining and Longwall development operations. In underground coalmines about 2000 units are in operation in over 50 countries. Continuous miner with rubber tyred shuttle cars and mobile bolting equipment can work to extract a seam thickness of 0.9m to 6.0m.

Longwall top coal caving

The best method for extraction of thick seams with increased resource recovery of about 80%. In China production from longwall top coal caving is more than 50% of the total production from longwalls. Longwall top coal caving gives better face control with low face working heights, improved control of spontaneous combustion, more efficient with improved production consistency and involves less gate road development.

High wall mining

Many of Indian opencast mines are reaching their pit limits. Existence of surface dwellings in many places limits the expansion of currently running opencast mines. Also, in many cases the overburden becomes so high that coal extraction becomes uneconomical. But with the use of highwall machines, a cutter is placed on the top of a continuous miner kind of machine and taken through a conveyor inside the seam, which is almost 500-600 m deep inside. That was not possible till now, and large amounts remained untapped owing to limited means and high cost of mining of that seam.

Highwall mining is a new technology, which can extend the life of opencast mines without disturbing the surface dwellings, and maintaining economy and productivity. This technology is in use in United States and Australia and to be introduced in coalfields at Ramagundam Opencast Project-II of M/s The Singareni Collieries Company Ltd (SCCL).

Introduction of technologies like CBM and UCG for Recovery and commercial extraction from deep-seated seams shall be explored. Appropriate technology available can be adapted to suite site specific conditions like planning short Longwall faces of 100m to 150m unlike 250m to 200m face lengths in US, Australia and Germany.

SCCL being one of the major coal producing company in India has understood the need of the mass production technologies and introduced continuous miner technology at GDK 11 Incline and VK 7 Incline and proposed high productive longwall panels at Adriyala Longwall Project with targeted production of 3Mt per annum, Shortwall mining at RK New tech Mine and High Wall mining at RG OC II and MOCP.

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Environment

The increased working temperatures will require the introduction of expensive methods like chilled water-cooling or refrigeration. Unfortunately all mechanized operations of winning coal and transporting will involve production of large quantities of dust. Hence in addition to use of water other dust suppression methods need to be considered at an early stage of planning itself. With increased depth the present non-gassy seams may become gassy. A systematic programme of investigations must be initiated to determine the gas content of seams at depth and gas migration and emission rates in workings, which should lead to the design of suitable ventilation schemes. Large deep mines require main mechanical ventilators of large capacity and pressures so that it will run at reasonably high efficiency over the major portion of the life of the mine. Underground booster fans are now to be included as an integral part of the ventilation network. Ventilation network analysis and simulation software can be made use to forecast the introduction of ventilation devises, driving of new roadways etc.

As routine measurements of environmental parameters by hand held instruments are found to be inadequate, feasibility of remote monitoring and control systems as integral part of any mechanization programme are to be explored to maintain safe and comfortable climatic conditions.

Strata control

Thick and strong roof layers, hardness and strength of most coal seams in India require design of proper Longwall shield supports for roof control and shearers of proper cutting technology for acceptable reliability and service life.

Inherent difficulties in Indian geo- mining conditions are due to presence of hard roof over coal seams, which can be overcome by proper studies of strata behaviour and loading pattern on supports systems.

For achieving improved safety, conservation, higher level performance while working deeper areas with adverse roof condition and high in-situ stresses, pre-determination of detailed geo-technical and Geo-engineering parameters like

In-situ stress and permeability tests,
- PMP tests
- Caving index
- Under ground geo-technical mapping
- In-situ strength of coal, Piezometric studies
- Geo-physical logging (neutron, gamma, resistivity and density, modelling
- Micro logging
- Core photography and
- Core profiler

shall be taken up prior to the introduction of the technology.

For conducting above studies, the guidance of internationally reputed scientific institutes like CSIRO, Australia and RMT, UK along with Indian scientific agencies shall be taken.

Training

Success of any technology depends on people, process and technology. People factor stands at the forefront as efficient process can only be managed by trained, skilled and highly motivated employees to sustain good working practices, safety standards, consistency and availability. For developing skilled and motivated workforce with proper training in technology, radical change in life style, environmental conditions at workplaces and at home and also more involvement in decision-making should be envisaged. This would help in change of attitude among people engaged in hi-tech resulting in better teamwork.

Extensive training is required for the Longwall team to operate modern longwall face. Key areas of training modules are longwall management systems, operational systems, maintenance systems, salvage and relocation systems, specialized equipment and general mine operations and equipment management systems.

Safety

Considering the safety scenario of the last decade, in spite of exercising utmost vigil by way of supervision and inspections in underground mine faces, 38.76% the accidents occurred on account of roof and side fall of which 58.50% accidents occurred at in-bye ends. Which indirectly point outs the mechanisation at the face and thereby making less number of men exposed to such situations.

Introduction of face mechanization to minimize multifarious activities at faces. Adopting best operating, maintenance and face transfer practices includes preparation of risk management plans (RMP) and preparation of TARP (trigger action response plan) and hazard plans.

With the standardization of roof bolting activity in all underground mines, the roof fall accidents reduced considerably. Supporting the goaf edges in depillaring panels with breaker line supports to control the goaf-overriding into the working areas, hydraulic open-circuit props/powered supports matching the strata control needs of the Blasting Gallery (BG) and Longwall (LW) technologies.

By phasing out of manual loading in active working sites, exposure of work persons to potentially dangerous areas is reduced,

The most desired impact that of reduced mine accidents can be a reality as seen from the experience of M/s SCCL wherein, a 50 % reduction was established in the fatalities post introduction of face mechanization.

Out-bye Mechanization

While formulating the strategies for face mechanization in underground workings, it is to be ensured that back up facilities like coal evacuation, support system, ventilation arrangements etc. are compatible with face mechanization

To attain full utilization of the machine mining technology, introduction of man riding systems or other modes of men transport for easy and comfortable access from and to the working areas from surface, design and provision of good out-bye coal evacuation system by belt conveyors and provision of strata bunkers instead of the conventional track haulage systems would be required, tele monitoring of mine gases in faces and other parts of the mine including the main return airways in mechanized depillaring panels.

The challenges in underground mechanization for the increased production and productivity with safety could be met if the projection planning was guided by a realistic approach considering all important components like suitable, productive and safe methods, increased machine utilization, inventory management, reduction in cost due to accidents through improved health and safety standards, improved work culture, and discipline through efficient management. Training of workforce for underground mechanization to enable increased production would be an essential input. The application of research and development for scientific exploitation is also another input in meeting the challenges in increased mechanization for higher productivity with profitability. Policy guidelines may also be drawn for replicating the Chinese model of developing suitable technologies for higher percentage of extraction under our geo-mining conditions.

At the end, it is everybody's concern to prove that the above mass production technologies will successfully cater to the needs of the nation for the survival growth of the economy which needs a well-defined policy for adoption of mass production technology including longwall technology, developing efficient indigenous vendors for the longwall equipment and spares, tailor-made equipment suitable for particular geo-mining conditions in the mines, proper training facilities to generate required skill, policy to develop proper cadre scheme suitable for high mechanization, proper planning of place of application , proper infrastructure facility and establishing proper R&D facility to deal with strata control problems.

To sum up, I would once again like to emphasize the NEED FOR MAKING THE UNDER GROUND MINING A VIABLE AND RELIABLE TECHNOLOGY TO MEET THE SOARING ENERGY NEEDS OF THE COUNTRY. I would like to welcome the participants to explore the possibilities of extracting deep-seated coal reserves by introducing suitable mass production technologies with safety.

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Exploitation of deep-seated coal deposits-Challenges

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SYNOPSIS

It is well understood that coal continues to play a predominant role in the development of the nation till another more efficient alternative source is discovered. Coal will be in the centre stage for meeting the ever-increasing demand for power generation.

Over the years, coal reserves available at shallow depth were extensively exploited by opencast mining or large number of small conventional, manual under ground mines. The time has come that, there is no alternative but to mine coal from deeper horizons. There are only few methods for extraction of coal from depth and Longwall is popular among them.

This paper deals with likely problems, which are to be addressed for safe and efficient working at deeper horizons.

1.0 INTRODUCTION

The minerals and other natural resources are essential for economic and industrial growth. The search and exploitation of metals and minerals need to be continued to improve the economy and standard of human life. It is inevitable and indispensable that this industry continues to flourish and develop.

Behind every act of sophistication / modernization there is absolute presence of metal, non-metal or fuel based product mined from the mother earth, highlighting a close relationship between advance of nation and mining. The growth rate of mineral produce needs to be enhanced to keep pace with envisaged GDP growth rate.

Coal takes care of about 63% of country's energy needs. Commercial energy consumption in India has grown from a level of about 26% to 68% in the last four and a half decades. The current per capita primary energy consumption is 243Kgoe/year, which is well below that of developed countries. Driven by the rising population, expanding economy and quest for improved quality of life, energy usage in India is expected to rise to around 450 kgoe/year by 2010. Considering the limited reserve potentiality of petroleum & natural gas, problems like social reluctance and limitations of Hydel projects and geo-political perceptions of nuclear power, coal will continue to occupy center-stage of India's energy scenario.

India's installed capacity for power generation has tripled over the last 20 years and now exceeds 101,000 MW. However, the total demand is expected to increase by another 3.5 times in the next two decades.

The total coal demand will nearly double, and both oil and gas demand will triple, as shown in Table-1. There seems to be no alternative to coal for meeting the energy needs of the country in the foreseeable future.

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Table-1

Year	Coal (Million tonnes)	Oil(Million tonnes)	Gas(Billion Cub mts)
1997	311	83	21.5
2020	688	245	70.8

Source: Planning Commission's India Vision 2020

The demand for coal is fast increasing and is estimated to be about 500 Million Tonnes (2010-11).

Fuel wise break-up of the primary energy consumption is as under

Consumption by Fuel	India (%)	World (%)
Oil	32	37
Natural Gas	8	24
Coal	54	27
Nuclear Energy	1	6
Hydro-Electric	5	6
Total	100	100

(Source: BP Statistical Review of World Energy 2005)

Total annual hard coal production in India is about 500 million tonnes (m.t) (2009-10) out of which nearly 80% is from Opencast Mines. Coal India produces about 91% of total Indian coal production and SCCL's share is about 9%. The expected demand for coal by 2011-12 is about 731 MT, whereas coal production would be around 550 MT, leaving a gap of about 181 MT, which needs to be met by imports/captive mining.

2.0 COAL RESERVES:

India is the third largest coal producer in the world, with hard coal reserves of around 248 billion tonnes, out of which 93 billion tonnes are proven (3). India holds around 10.2% of the world's proved hard coal and lignite reserves and produces around 7% of total world's production. The depth wise coal reserves of India are as follows:

(in Billion Tonnes)

DEPTH(m)	PROVED	INDICATED	INFERRED	TOTAL(In Bt)	(%)
0-300	71	66.5	15	152.5	61.5
300-600	6.5	39.5	17	63	25
0-600 (Jharia)	14	0.5	-	14.5	6
600-1200	1.5	10.5	6	18	7.5
0-1200	93	117	38	248	100

(Source: GSI Report, January 2005)

2.1 Depth – Wise coal reserves of Andhra Pradesh (Godavari Valley Coal Fields) as on 01.01.2005 in million tonnes is as follows:

DEPTH(m)	PROVED	INDICATED	INFERRED	TOTAL
0-300	5467	2229	102	7798
300-600	2796	2832	553	6181
600-1200	—	1018	1929	2947
0-1200	8263	6079	2584	16926

Both the tables clearly indicate that the reserves in Andhra Pradesh are at greater depth than that of average all India figures. At present most of the existing mines and present projects are for extraction of deposits with in the depth range of 0-300 metres. To have sustained production, projects have to be formulated for extraction of coal reserves locked up within the depth range of 300-600 metres.

2.2 Production

In World's hard coal production scenario, 70 percent of coal comes from underground mining. Out of the total underground production, 70% is contributed by mechanized longwall constituting about 50% of the total hard coal production. However, the Scenario in India is not the same.

In Indian Coal Mining the present proportion of OC to UG in our country is about 80:20. In future, this may have to go up to 60:40, which means that the UG mines will have to produce not only in bulk safely but also with improved economics. Till date, mines are being operated at shallow depth, for working of mines at deeper horizon, the challenges are going to be different and solutions need to be different. This requires a paradigm shift in overall outlook of all stakeholders. This paper deals with the requirements, challenges that are likely to be faced and solution for meeting the challenges.

As of now the shallow reserves are being extensively exploited by open cast methods. The coal reserves amenable for opencast mining are fast depleting and hence the future coal has to be won from deeper horizons. Excepting some patches, the reserves available for meeting the future demand occur between 300 and 600 meters depth.

Over the years, shallower coal reserves were exploited with conventional Bord and Pillar methods with certain degree of mechanization. Mechanization is mostly confined to few areas having gradients flatter than 1 in10.

All the above mentioned technologies are suitable up to a particular depth i.e., 450mtrs. At deeper horizons, high capacity Longwalls look to be the only alternative.

2.3 DEPOSITS

More than 98% of our coal reserves occur in 8 states, with Jharkhand-20.1%, U.P-9%, Orissa-24.3%, Chhattisgarh 17.1%, West Bengal-11.1%, Madhya Pradesh 7.8%, Andhra Pradesh 6.9% and Maharashtra 3.6%.

Depth of the ore body: Nearly 61% of total coal reserves are estimated within 300m depth cover, distributed in all coalfields from Godavari Valley to Upper Assam. The prime quality coking coal of Jharia is available mainly in upper horizons while the superior quality non-coking coal of Ranigunj is available in lower coal horizons. The quality of coal of Central India to Maharashtra is also available mainly in seams in this depth range. As a result all these mines worked such seams extensively, primarily developing on pillars and depillaring with sand stowing. With unfavorable economics of sand stowing and non-availability of virgin patches for further development, most of the mines have been working by splitting or slicing the pillars, winning roof or floor coal manually or with SDLs conveyor combinations.

State wise coal resources estimate as on 1-1-2007.

STATE	0-300m	300-600m	600-1200m	Total reserve
A.P	7922	6514	3024	17461
Chattisgarh	32167	8614	669	41450
U.P & Jharkand	36998	14601	3285	54884
Jharia	14213		5217	19430
Maharastra	6789	2698	183	9670
M.P	12902	6727	148	19777
Orissa	44636	16139	1224	61999
W.B	12361	10975	4999	28335
Grand Total	155785	80636	18749	255170
% Share	61.24	31.46	7.35	100

3.1 Exploration:

New techniques required to explore deeper deposits include use Geophysics for interpretation of Geology and for in-seam seismic survey, Estimation & Recording borehole information and deviations, if any, derive information with minimum borehole density, delineation of faults of throw as less as 2m, Geological hazard mapping, Estimation of caving and support requirement, particularly at points of hazard identified above. Incorporation of 3D Geological hazard map shall be minimum statutory requirement.

3.2 Planning:

The planning of the project shall include long term and short term planning to assess all requirements of the projects. Piece meal arrangement shall not be allowed for planning /developing blocks. No Bord & Pillar development below 350m depth, operation of opencast mines up to a depth of 350m, Working from dip side of property, etc., shall be salient features. Regulations need modification to include “strategic planning”.

3.3 Development:

At present, development of seams is done according to Regulation 99 of CMR1957 in which pillars and galleries are formed. These pillars and galleries are expected to offer long-term stability and withstand till they are extracted. However, some times at greater depths of more than 250m it was observed that spalling of coal takes place and pillars do fail. Collapses take place in parting/galleries thereby making extraction of coal seams difficult. Sometimes some seams are lost forever. Further, if development is carried out at a depth beyond 360m and upto 600m, these developed pillars have to offer long-term stability. This can be achieved only if the pillars are designed according to the geological conditions i.e., formation of seams, presence of cleavage planes, stresses being encountered etc. Design of pillars with the help of numerical modeling will ensure required stability. Regulations need modification to include development with restrictions. Shaft sinking / man winding beyond a depth of 400m & compulsory return airshafts at closer interval of 1000m of incline distance shall be made compulsory. The dimensions of roads are to be increased to minimum of 5.5m x 4.0m to accommodate higher capacity conveyors and men transport system. Return roadways shall be planned in stone only.

3.4 Supports:

Earlier the workings were kept supported by conventional supports like props and cogs etc. From 80's onwards, steel supports/bolts were introduced in a big way. The 6th and 7th National conferences on safety in mines brought large-scale improvement in the use of steel supports/bolts. This support system is offering medium term stability. However, if the workings extend beyond 300m depth, the support system needs a paradigm shift. These supports should have a longer life period. Therefore, depending on the life of workings, the permanent supports shall be selected with the help of proper scientific study. The development if carried out in hard stone will withstand for longer periods and this may be considered as an alternative option comparing galleries made in coal seams.

3.5 Bumps:

Due to greater depth of workings, high pressures act on the pillars and galleries resulting in bumps. Adequate steps shall be taken to reduce stresses and measure the forewarning in order to take steps to prevent dangers arising due to bumps.

3.6 SSR:

SSR to be framed with more scientific methods using numeral modeling. Dimensions of galleries shall be as large as possible, Monitoring of roadways with proper scientific instruments, Underground mapping of critical areas, Rock bumps monitoring, posting strata control officer for each mine shall be made mandatory Reduced barrier thicknesses shall be thought of in design of longwall panel layout.

3.7 Ventilation:

In underground mines, ventilation plays a vital role while working. The workings have to be kept in dry and cool conditions. The humidity shall be kept at optimum level to provide comfortable conditions. However, increase of depth by each metre results in additional strata temperature. If depth goes beyond 300m at least 10 ^{o}C temperature is added to the existing air. Further, if heavy machinery is introduced like shearer/ continuous miners and shuttle cars etc., with diesel engines, lot of heat is generated which further deteriorates the environmental conditions. In order to provide comfortable conditions, high speed, and high water gauge fans with air conditioning is the only answer. Even spot air conditioning needs to be looked into.

3.8 Men Transport

Transport of men and materials into the farthest and dip most workings safely is one of the major challenges in deep mines. Proper and effective transport system saves lot of time and improves efficiency. The present transport systems used like man riding chair car/chair lift systems can work to some extent. But we need mass rapid transport system with full safety. This can be achieved by providing vertical shafts into the mine workings and high-speed elevators. Some alternatives in transport systems are, use of high speed chairlift & chair car, use of belt riding, use of self propelling diesel cars, trackless haulage system & use of steep winding.

3.9 Gas

Majority of the deep seams are associated high degree of emission of gases. This poses major problem in carrying faster development and extraction. Deep seams have to be first degasified by methane drainage system or CBM method. This also provides early recovery of investment as well as ensures safety during extraction with green field environment. Continuous tele monitoring is one more answer to the problem of detection for effective dilution of foul/poisonous gases.

3.10 Dust

Exploitation of deep seams calls for high degree mechanization like use of continuous miner technology or long wall method of work. High production capacity of faces is bound to generate lot of dust. Apart of creating health hazard, dust also creates dangers causing explosions. To mitigate this problem, high precision dust measurement systems, dust suppressors and dust extractors including dust evacuation systems shall be put in place.

3.11 Water

In deep seams where work is carried out with high level of mechanization, consumption of water may be heavy which is likely to pose problem. High level of water management system shall be provided to mitigate water dangers.

3.12 Fire

Apart from coal fires/spontaneous heating, the machines will generate lot of heat and also fires may result in their use. The equipment like motors, cables, belts, fuel oils and other material shall be fireproof.

3.13 Evacuation of persons

Deep workings post major problem of evacuation of persons safely if need arises. Work persons shall be thoroughly trained in use of protective equipment. Reliable protective equipment shall be provided. Emergency response system shall be so designed and put in place that all emergencies are handled with ease. Emergency refuge chambers shall be created and persons shall reach those chambers and from there to surface safely. The other safety systems shall be Automated fire fighting systems, compulsory / mandatory/ Escape roadways with fastest means of escape, Fire alarms and smoke detectors & CO2/Nitrogen plant to handle spot fires.

3.14 Available technologies

The available technological options at greater depths are limited. Though Blasting Gallery technology was used in underground mining for thick seams, it has inherent limitation at depths beyond 300 meters especially with regard to strata control and spontaneous heating.

3.15 Coal Bed Methane (CBM)

CBM is a remarkably eco friendly clean gas, when burnt. If tapped from coal beds economically and burnt properly as fuel it is an important source of energy with additional benefits viz., reduction in green house effect and reduction in mining hazards. The extraction of CBM in our country is in experimental stage and once established, this method will be a viable answer for fulfilling energy requirement.

This leaves, “Longwall” the proven technology for production and productivity all over the World to work with deeper deposits. Longwall mining in the world is moving towards increased face dimensions, least cost per tonne, higher productivity and lesser face transfer periods. The production per face is ranging from 1.0 million tonnes per annum (MTPA) to 4.0 MTPA, though there are certain extremes of 8 MTPA. The various variants of longwall such as single pass longwall, multi section longwall (as being practiced in Park-Teknik, Turkey) and sub level caving (as practiced as Longwall Top Coal Caving, in China) are to be critically examined for adopting successfully in India under similar conditions.

For depths beyond 300m, Longwall is likely to be the main method for bulk production though continuous miners will also be used wherever conditions permit. Unfortunately no serious efforts have been made in respect of R&D for liquidating standing pillars at a depth beyond 300m, which account for huge locked up reserves. Maintaining these workings itself involves high cost in addition to losses due to deterioration, fires and safety problems. Present method of extraction of these reserves particularly in multi-seam workings by stowing is a slow process and the availability of sand is not assured in many coal-mining areas. There is an urgent need for planning liquidation of these reserves by mechanized methods. Coal India Limited is in the process of bringing some positive results in this direction with their plans of extraction of standing pillars by mechanized longwall mining.

4.0 Conclusion and Recommendations

Huge investments are required for extraction of coal from deeper deposits (more than 300m). Detailed exploration, sinking of shafts, development of infrastructure for introduction of Longwall technology requires advance planning, as the gestation periods are long. But all these have to be treated as an investment for future. It is suggested that special funds may be generated by imposing cess on current coal production.

The fund so collected could be utilized for the development of Longwall blocks beyond 300m including exploration, shaft sinking, tunnel drivage, trunk roads etc. A separate wing/ department could be formed to undertake exclusively Longwall infrastructure developmental activities. These blocks may be planned to last for at least 10 years and could be given to coal companies on risk/gain share basis, for working high performance long wall faces. Only then it could be expected that the long walls perform to the international standards. If required in these deep blocks infrastructure is to be developed and the same are to be offered on contract / joint venture / partnership mining to private coal companies. This will not only pave way for development but will also infuse latest technologies and competition among the coal companies.

Concerted efforts are required by the policy makers, Coal companies and manufacturers to translate the ideas into concrete action and reap the benefits of technology in the years to come. I consider this conference to be one of the most critical and important one in this direction and hope that the deliberations and conclusions of this conference will go a long way in formulating what is required for the sustained exploitation of deep coal seams.

5.0 Acknowledgements:

The authors are grateful to Sri S.I.Hussain, Dy.D.G.M.S, South Central Zone, Hyderabad, for permitting to publish this paper. Thanks are due to other officers and all others who have worked with us in mechanization including frontline officers, supervisors, technicians and workmen. The views expressed by the authors in this article are of their own and not necessarily of the organizations to which they belong.

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Underground coal mining in India – Technological options and challenges ahead

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1. Introduction

World Coal Institute estimates coal as the major contributor for energy generation to the tune of 60% and the balance shall be from gas, diesel, nuclear, wind and hydel. In India, 75% coal is consumed by power sector. The demand tends to outstrip domestic supply. The power sector continues to report capacity losses from coal shortages. The pace of power capacity addition has hardly been commensurate with the need. Less than 30 GW of the planned 40 GW for 2002-07 could have been materialized, as reported by The Energy and Research Institute of India (TERI). The Government's recent effort to build several 4000 MW power plants under ultra mega power scheme would require coal blocks with reserves of about 600-700MT. The projected coal demand at the end of 15th Five year plan (2031-32) is 1900MT which is three times the existing coal production. Hence the present 6-8% growth in coal production would not be sufficient.

The country has nearly 110 BT proven and about 60 BT extractable coal reserves. The production of coal in India is shared by CIL (81%), SCCL (9.5%), others & captive mines (9.5%). As per the Coal Mines Amendment Bill, Government of India has identified captive coal blocks and as on 31-03-2010, 214 Coal blocks having geological reserves of 50889.3 MT were allotted to Private and Public sector utilities to augment coal production. But this is only transitory solution for the deficit. Most of the coal production comes from open pit mining and it is nearly contributing to over 89% of absolute production in the country. Open pit mining has its own limitations due to depth and environment pollution issues, whereas huge reserves of coal is locked up in underground as standing pillars, in thick seams and in depths beyond 300m, the economic exploitation of which requires suitable technology. This not only shows lack of resource management but also leaves a great technological void to compensate opencast coal production with proper exploitation of existing underground resources.

There is an urgent need for development and implementation of of bulk production technologies for deep-seated deposits in the depth range of 300m – 600m. Coal production at higher rates from underground, particularly at depths more than 300m, is possible with "Longwall Mining Technology", which is a proven technology worldwide. Continuous Miner technology is also being used wherever the reserves are not suitable for longwall technology in countries like US, Australia, South Africa and China. Besides, nearly 40% of the proven coal reserves are in thick seams posing technological challenge for long time. The conventional underground method of pillar extraction in multi stages was the only proven technology so far for thick coal seam extraction in the country. The percentage of extraction in this method is well known to be less than

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50%. The other mining methods such as widestall, longwall with increased height of extraction are having their own draw backs. The Blasting Gallery method of winning thick seams introduced in SCCL in 1989 proved to be of great success. On the other hand, the coal pillars in underground both in CIL and SCCL due to various complex mining conditions need to be rightly exploited to satisfy the country's present coal requirement.

This paper introspects the challenges for bulk production from underground mines as the production from open pits is getting slowed down due to uneconomical stripping ratio and explores the possibility of sustainable winning of underground resources with viable technological options.

2. Resources in Indian coal mines

The third largest coal producer in the world, India has an age old history in coal mining sector. Coal mining in India dates back to the 18th century. However, the regulatory framework for this industry was conceived as late as in 1923. In 1972-73, the Indian government nationalised the coal industry, primarily to develop the sector, since it was considered of strategic importance for rapid industrial development. India has the fourth largest reserves of coal in the world (approx. 276.8 billion tonnes). Coal India Ltd (CIL) and SCCL are the two major coal producing Public Sector Companies in the country. Coal deposits in India occur mostly in thick seams and at shallow depths. Non-coking coal reserves aggregate at 244.0 billion tonnes (84 per cent) while coking coal reserves are 32.0 billion tonnes. Indian coal has high ash content (15-45%) and low calorific value. Coal in India occurs in two geological time periods, Gondwana and Tertiary. Gondwana coalfield occurs with sedimentary rock of lower Gondwana age, which contributes 99.5% and rest is Tertiary. Gondwana coal is distributed in the valleys of Damodar, Son, the Mahanadi, the Godavari and Wardha whereas the tertiary coal is spread over extra peninsular areas. When compared to black coal, the lignite reserves are relatively modest.

3. A look into future and its challenges

India's coal demand is expected to increase manifold within the next 5 to 10 years due to the completion of ongoing coal based power projects and demand from metallurgical & other industries. Demand for coal has been rising at an annual rate of 6 per cent since 1992-93 and the Indian coal companies are unable to meet the projected demand. The investment needed to bridge the gap of around 400 million tonnes, between the level of production in the public sector (290 million tonnes in 1995-96) and the projected demand of 731.10MT (Working Group on Coal & Lignite) at the end of 11th Five year plan (2011-12) is estimated to be US$ 18 billion. The public sector is expected to increase its production accordingly, subjected to an additional investment of US$ 8-10 billion. The balance requirement of 150 million tonnes will have to be met by imports in the short run and by new investments in the long run. As per the new economic reforms, government relaxed controls on pricing and distribution of coal and this new coal policy is encouraging private sector participation in captive coal mining. Government of India has identified captive coal blocks and 214 blocks with Geological reserves of about 50.89 Billion Tonnes were allotted to private and public sector end users to augment the coal production. But this is only a transitory solution for the deficit.

Hence the real challenge lies ahead on how the existing and future underground resources are managed for bulk coal production. However, developments in exploration, detailed geo technical studies, ventilation solutions for deeper mines, hazard mapping, support techniques for complex strata conditions and the men/material transport are the solutions for sustainable exploitation of future mining blocks.

4. Underground coal mining in India and technological option for future

Underground mining in India is mainly conventional Bord and Pillar method with manual loading which is an age-old mining system, accounts for about 20% of coal production. This was major limiting factor in 80s. Scraper loaders were introduced in late 1960's, which were mounted on rails and load coal onto tubs. But it had little scope due to its limitations. Steel bolts such as point anchor bolts and wedge bolts were introduced in place of wooden supports have significantly increased safety and productivity in coalmines. Belt conveyors replaced series of haulers and lengthy tramming circuits in underground for coal transport in 80's. The semi-mechanized methods using SDLs and LHDs have become popular only during the last decade. Some specialized mining like yield pillar method was so designed to withstand the abutment loads and the critically sized pillars to yield nonviolently. SCCL has introduced this method in one of its mines 'VK-7 incline' to extract pillars safely with continuous miner where the sand stone roof is very strong and difficult to cave. However, the percentage of coal recovery falls below 40% in these methods. Longwall retreat with caving introduced three decades ago, has proved to be successful in few mines only due to the limitations in the method and its applicability in Indian conditions.

4.1. Long wall mining

4.1.1. A brief review of Longwall mining in India

As a global phenomenon, the pace of technological change had been especially rapid in the second half of the last century and the mechanization of unit operations led to the development of Longwall technology with the concept of mass production in coal mining industry. It was also aimed at reducing the drudgery, monotony and dangers to work persons engaged in underground mining operations. The development of mass production technology including Longwall equipment, Continuous miners, ploughs and shearers have been accompanied by a series of incremental and innovative developments in roof supporting practices. India also has followed the world trend in 1975. 'Project Black Diamond' envisaged introduction of 130 Power Support Longwall (PSLW) faces by the year 2000. Initially, the first fully mechanized self- advancing PSLW face was introduced in Moonidih mine in Jharia Coalfield in 1978. Subsequently more mines were planned with PSLW in the eighties, namely, East Katras (BCCL), Seetalpur, Dhemo-Main, Jhanjra, Khottadih (ECL), Patharkhera (WCL) and Churcha (SECL) and first long wall in SCCL was introduced at GDK 7 incline in 1983 followed by a few other mines in the Company. In the process about 30 PSLW sets had been imported from different sources in different countries like UK, Poland, Russia, Germany, France and China. Barring a few exceptions, the Power Support Longwall faces gained moderate success. Most of the Longwall faces were far from the desired level of production and productivity on sustainable basis. In addition, largescale introduction of longwall technology received severe setbacks due to its successive failures at Churcha (SECL) and Khottadih (ECL) mines. At present, longwall mining accounts for a meager production of about 4% of the total underground production.

4.1.2. Factors affecting the Longwall performance in Indian mines

4.1.2.1. No Policy for Introduction of Mass-Production Technology

Even after nationalization, the Government of India was not firm on policy for mass production technology, like longwall and continuous miners. Because of that no private/government company has come forward for manufacture of underground mining equipment for mass production technology.

4.1.2.2. Standardization of Longwall equipment

There was no standardization of longwall equipment in the country. As such, longwall equipment purchased from various sources were unique in specifications with no possibility of inter-changeability. As a result, no indigenous manufacturer was motivated to manufacture Longwall spare parts for which demand was small. Delay in procurement of spares affected production from Longwall panels. As the number of operating faces is less, the suppliers were not able to provide either manufacturing facilities or spares depots in India.

4.1.2.3. Wrong place of Application

The study of few cases in the country revealed that the Longwall technology was introduced in extremely critical conditions such as difficult geo-mining conditions, steep and thin seams, at deeper horizons with very high ambient temperature, Degree-III gassiness and mines where coal evacuation system was extremely circuitous with a series of conveyors. These factors proved a serious bottleneck in improving productivity from Longwall faces at its very budding stage and gave a wrong signal as if the technology is not suitable to Indian mining conditions.

4.1.2.4. Face geometry

Longwall face width was designed from 60m-165m, the length varying between 500m to 1200m and operational depths of 30m to 350m so far. In these conditions, very few mines recorded good results such as VK-7 and GDK-10A mines of SCCL with regard to production consistency. Non-availability of longer panels due to geological disturbances, or due to surface features to be protected and presence of standing pillars in an upper seam resulted in frequent shifting of equipment and increase in non-productive work in Indian coal mines, whereas, the coal seams in countries such as China, Australia and the US have more favorable conditions for longwall mining and allowed longer and wider panels.

4.1.2.5. Lack of Infrastructure Facility

Introduction of longwall technology in already existing mines which were not having sufficient infrastructure to match the desired level of production resulted in de-rating of the projects. Provision of matching infrastructure was either delayed or never came up in most of the cases.

4.1.2.6. Geo-technical studies and R&D facility

In most of the cases, inadequate geological information and geo technical knowledge due to inadequate borehole density have become major causes for failure which often led to wrong planning (including wrong selection of powered roof supports and wrong orientation of panels with respect to horizontal stress direction). Further it led to too many geological surprises such as projections of faults, thinning of seams, intrusions and variation in strength of immediate roof rocks during longwall extraction. In addition, the poor knowledge on hydro-geological conditions led to high water ingress problems at the face and continuous water percolation in the strata led to strata control problems. The most glaring example in this regard is failure of powered supports at Churcha (SECL) and Khottadih (ECL). In both the cases the supports collapsed and failed to withstand the load exerted by superincumbent strata during periodic weighting due to underrated supports. These two incidents gave severe jolt to the programme of large scale introduction of longwall technology in other Indian mines.

4.1.2.7. Technical lapses

There were a number of other technical lapses pertaining to longwall face operations such as: the gate road development rates with older version Road headers like AM-50 and Dosco were not matching with longwall retreat rates; longwall units were introduced in inferior quality top and upper seams which significantly affected longwall mining economics; lack of man riding facilities in underground resulted in workmen reaching the face very late causing delays and interruptions in the face operations. The conventional face transfer system including equipment withdrawal from one face and shifting to other face took 3 to 6 months, which also contributed to lower productivity from longwall mines.

4.1.3. Making Longwall Technology successful

4.1.3.1. Things to be learnt from China

China introduced longwall mining in the late seventies and early eighties as in India, but within 20 years it has not only emerged as the world leader in coal production, but has established itself as the largest user of longwall technology in underground mines and has created for itself an international market for export of the technology, expertise and equipment. From the very beginning, it adopted wholesome approach for large-scale longwall mechanization in their UG mines. The approach was very methodical and it took into account their own social and economical conditions. Instead of instantaneously jumping into hi-tech mechanization, only in some isolated mines, they introduced the technology stage by stage with incremental development. China has developed tailor made equipments suitable to their conditions. For this they have first generated skilled workforce of engineers, operators, designers, research personnel and manufacturers. They gave greater emphasis to applied R&D for product design and quality improvement. China has developed huge infrastructure at unit levels as well as central levels. It has constructed a number of new highly productive and efficient mines with different capacities based on seam/geological conditions by identifying suitable coal blocks in advance. It has improved its metallurgy for indigenous manufacture of powered supports with higher support resistance, more powerful shearer, AFC and belt conveyor and started achieving 6-10mt coal from a longwall face per annum.

4.1.3.2. Suitable blocks for wide and lengthy longwall faces

It is extremely important to choose the proper place of application of this mechanized longwall technology, which is capital intensive and involves a lot of time and manpower in installation, salvaging and shifting of equipment. The existing underground mines in CIL and SCCL have got limited scope for this technology as far as the infrastructure is concerned. Hence, suitable virgin blocks should be identified. As far as practicable, no other technology shall be combined with longwall. The expansion of existing mines is possible but only beyond 300m depth where it is required to explore success of longwall face at deeper horizons. The existing facilities like man riding, ventilation and coal conveyance can be utilised during development till permanent set up is made. The minimum proved resources should be 100Mt so that the projects can be sustained for 25-30 years with one particular set up or infrastructure. Today the world trend is to provide longer and wider panels to minimize the number of longwall face shifting operations.

4.1.3.3. Proper equipment for specific geo-mining conditions

It is required to do advance studies, numerical modeling and preparation of adequate data related to the specific geo-mining conditions of the mine, to make longwall equipment tailor made to the site specific geo-mining conditions. More over, one set of equipment can be used with only minimum modifications. More particularly, the powered roof supports, which are available in the market shall be carefully selected with respect to their load resistance, load expected from overlying strata and seam gradient.

4.1.3.4. Indigenous capacity of equipment manufacturing at Low cost

The mixed results of longwall technology during the last 30 years could not usher in any appreciable change in the economics of any such project. The landing cost of the equipment is one of the reasons. No indigenous manufacturers have turned-up for manufacturing LW equipment set so far. Few firms started manufacturing LW sub-assemblies like power support legs and hydraulics etc. It may take another 10 years to develop the indigenous vendors to get technical expertise. The scope can be improved only when the number of operating faces is more. A developing country like India is not in a position to bear any economic fall outs due to failure of longwall faces to produce at its rated capacity. Success does not come easily on its way, but only out of sustained and hard effort. Sufficient effort was put in and R&D was done all these days. Further, longwall faces in the country have produced a huge number of experienced mining engineers and experts. But the ultimate challenge is to reduce equipment cost and operating cost with the help of indigenous technology.

4.1.3.5. Both CIL and SCCL have to launch LW technology

The indigenous technological expertise comes only if much more number of longwall faces, atleast 30 to50 Nos. with more face length are introduced both in SCCL and CIL. Most of the coal seams in the northern part of the country are found at shallow depth with stripping ratio as low as 0.5, which neither posed any coal scarcity nor warranted large-scale underground mechanization in the last 30 years. But the situation is topsy-turvy now and it is necessary to meet the coal demand from underground mines. The Central Government and Planning Commission assessed the ground situation and have taken proactive decision to decentralize the mining industry and allocated 214 coal blocks to private parties for captive consumption.. Experts anticipate only mixed results out of this. A real improvement and next generation mining can be achieved only if CIL which is the largest mining operator in the country comes forward to introduce longwall faces for bulk underground production.

4.1.3.6. Bolter miners for Roadway development

One of the reasons that the longwall faces struggle in the country is the current low gateroad development rates. Low capacity Alpine miners and Doscos are being used for panel development in India, whereas these machines were modified as per their needs in US, Australia and China. High power cutter motors; robust cutter head and traction system in the latest version machines improves machine stability, ability to work in seam gradients upto 10-15^0 and ensures faster drivage. The onboard bolting facility further improved utilization hours and development rates by 400-500m per month. However, the capacity of these machines, restricted faster drivages for high capacity longwall faces. Hence, these machines were also replaced by continuous miners in US and Australia. Continuous miners had been dominant in development with twin gate roadways two decades ago. But the continuous miners are assisted by separate bolters for roof and rib bolting with ‘place change’ operation. Whereas, the bolter miners, technically the continuous miners with on board bolting facility in the machine itself are becoming dominant in the recent years which can further boost up the rate of drivage to match with much sophisticated 6-10 Mt producing longwall faces. Thus bulk output from longwall face cannot be achieved without bolting facilitated miners or Bolter miners. There are varieties of machines available in the market to choose the best fit to seam and mining conditions and economy

4.2. Continuous miners

Continuous miners are being used in the coal blocks which are not suitable for bulk longwall output in the order of 2-6 Mt with longer and wider faces and do not have project life for atleast 25 years, particularly in US, South Africa, Australia and Chinese mines. Hence, apart from longwall technology, bulk production is being achieved with continuous miners all around the world. The excavation and mining equipment group of RWTH Aachen University, Germany has identified that as many as 1400 Continuous miners and 200 Bolter miners are in operation across the world during 2008.

Moreover continuous miners are a suitable option for liquidating standing pillars with bulk production in our country. The first fully mechanized room and pillar system in India, using continuous miner technology, started its operations in May 2002 at Chirimiri Anjan Hill Mine, South Eastern Coalfields Limited (SECL) on risk/gain approach. The complete system, supplied by Joy Mining Machinery Ltd, included a 12CM15 continuous miner, two shuttle cars, a feeder breaker, a mobile roof bolting machine and electrical distribution system. Since startup, the system has averaged over 40,000 tonnes per month on the development of a five entry room and pillar system and has now achieved over 50,000 tonnes in a month by de-pillaring. Except Chirimiri and Tandsi, the other CM faces performed moderately. Now, with considerable awareness and training it is possible to produce 4 to 6 LTPA in Indian mining conditions. There is a wide range of products available in the market to suit varied mining conditions. But the concern is landing cost of equipment imported. However the day is not far away when the indigenous miners at low price may dominate the market in the coming years.

Presently miners belonging to JOY and Bucyrus are working in Anjan Hill Mine, Chirimiri (SECL) commissioned in May 2002, Tandsi Mine (WCL-June 2003), VK No.7 Incline (SCCL-Aug, 2006), Jhanjra Under ground Mine (ECL-June, 2007) and GDK 11A Incline (SCCL-Dec, 2008). SCCL, apart from its presently working two CM, is planning to introduce some more in the near future.

4.3. Extraction of Thick seams-BG

A huge amount of coal reserves are locked up in thick seams in the country. Both CIL and SCCL are having huge reserves of such kind. The conventional underground method of Bord and Pillar development and depillaring in multistage with or without stowing is the only available and proven technology all these days. The percentage of extraction in this method is well known to be less than 50%. Wide-stall method and sub level caving are having their own drawbacks due to either less percentage of extraction or newer technology, which is not yet practised in the country. SCCL is having thick seam reserves of about 40% out of its proved coal reserves of 9435.78 Mt. The current mining methods and designs for thick coal seams in underground mines are inefficient and result in huge losses of valuable coal resources.

4.3.1. Blasting Gallery- a success venture in SCCL

The Blasting Gallery method of thick seam extraction was introduced in SCCL during 1989 with the technical collaboration of Charbonnages de France (CdF), France. Based on its success, the method was introduced in five mines of the company in VK-7, 21 incline, Gdk 10 incline, Gdk 8 incline and Gdk 11A in phases in the last two decades. Over this period, the Blasting gallery method is established as an economically viable method for bulk production. Evidently, this method is so proved to be safer due to its inherent mechanization of drilling, loading, transporting and supporting. The percentage of coal recovery would be higher than any other method existing for thick seams. In the later stage, it was focused to adopt the same technology to extract coal from standing pillars. Though this method appears to be conceptually easier and operationally dangerous in initial days, the simple mechanization and the face operation without much complication are the key factors that made people to be well conversant to the applicability of the system with respect to their local mining conditions. Hydraulic supports with canopy specially designed for the purpose of having clearance for LHD to ply can replace existing manual installation of steel bars supported on open circuit props. Walking breaker line supports in the junctions could reduce human drudgery and are much safer and productive too.

4.3.1.1. Strata control problems

The experience in SCCL reveals that caving is not a problem in the coal seams with overlying strata having compressive strength varying between 100-300 Kg/cm^2 and of easy to moderate caving roof. The technique of induced blasting incorporated in this method had given better results in bringing down the immediate roof at desirable intervals. The regular falls of immediate 3-5m layers of overlying sandstone strata allows the upper and massive layers to readily cave in. Every periodic fall and induced fall had minimum impact on the gallery supports and roof & sides. While working over the goaved out panels of bottom seam and simultaneous working of lower and upper seams at GDK-8 incline revealed that the strata has significantly fractured and caved regularly.

4.3.1.2. Fire control in BG

Spontaneous heating is one of the major problems being faced in BG. The occurrence of spontaneous heating in working panels, not only threat the general safety but also forces to close down the panels losing huge quantity of natural resources. It often ended up in sealing a large section of mine affecting the mine economics adversely. The BG panels are being successfully mined in SCCL with the following preventive measures:

1. Floor coal and curtain coal is meticulously removed during extraction and descensional ventilation system is followed to contain the gases inside the goaf and to restrict goaf ventilation.

2. Induced blasting is done at an interval of 5m and up to 9 to 10m height in roof to reduce strata control problem as well as fill the goaf regularly avoiding air pockets inside.

3. Proactive inertization is achieved by continuous injection of CO_2 and N_2 into active goaf. A storage tanker with a capacity of 30 metric tonnes of liquid CO_2 ensures its constant availability through pipelines. The combination of CO_2 and N_2 creates identical density of goaf gases, which is advantageous as they can spread over the entire sealed off area within a short period. CO_2 has an added advantage that it reacts endo-thermally consuming heat of 40.8 kcal/mole of CO_2. Besides, the adjacent sealed off goaf is also inertized.

4.4. Extraction of thick seams-LTCC (Longwall Top Coal Caving)

The LTCC method is based on the 'Soutirage' longwall caving method originally developed in the French coal mining industry. Then China has further developed the LTCC technology and started using LTCC for thick seam mining. It basically involves an additional AFC behind the longwall chocks to transport top coal caving behind the Shields. When compared to other thick seam mining techniques, it ensures a high recovery rate and productivity. With the experience of LTCC operators; the coal recovery percentage is increasing year by year. As an equipment innovation, the recent Chinese developments have relocated the top coal draw points to the rear of the Longwall supports, rather than bringing coal through the roof canopy of the shield onto a conveyor within the shield structure. The Chinese equipment has a pivoting supplementary goaf or tail canopy behind the support. With the rear AFC extended and the rear canopy lowered/retracted, caved top coal can be loaded onto the rear AFC. The Chinese industry had reported averages of 15,000 to 20,000 tpd from an LTCC face; up to 75% recovery of plus 8m thick seams using a 3m operating height Longwall and plus 5 MTPA face production. There are now well over 100 LTCC faces in China. A new semi-automated 300m long LTCC face was installed at the Xinglongzhuang Colliery of the Yankuang Group, in Shandong Province, in August 2001, with production capacities of at least 7MTPA. The consistent caveability of the top coal in an LTCC operation is crucial to its travelling along the rear conveyor. Even greater problem is if the coal hangs up, even only or a short time, such that it caves but beyond the reach of the rear AFC. The main geo-technical components affecting coal cavability are uniaxial compressive strength (UCS); cleat, bedding and other discontinuities and vertical stress on the coal. Chinese experience is understood to be that compressive strength ranging from 15 MPa to 25 MPa is well suited for good caving conditions. Horizontal stress too has lot of influence. The best-suited blocks for LTCC in India are available in CIL. With much longwall experience and R&D works done for last 20 years, CIL must take appropriate initiative to commission first LTCC face in the country.

5. Challenges for bulk production from underground

5.1. Exploration and detailed geo-technical studies

Recently, SCCL has entered into MoU with CSIRO, Australia for technical support for implementation of first ever high capacity longwall technology for which the detailed studies have been conducted which broadly includes increase in borehole density to 20 / Sq Km, study of overlying strata behaviour upto the height of 100 to 150m over the longwall panels. The existing practice of study levels depends on the requirements of the projects. Complete and detailed studies of entire block are not done before implementing the new projects as done in US and Australian mines. Besides, in most of the cases the mining projections are made depending on the existing geological data. As far as practicable, coring needs to be done for each borehole, preserved in core library for analysis and photographed too. The data from non-cored boreholes can be generated with Geo–physical logging (neutron, gamma, resistivity and density). In-situ stress and permeability measurements must be conducted in the boreholes equally spreaded over the proposed panels. The permeability tests shall be conducted in different depth horizons to have most representing result ranging from barren measure rock upto geological domain rocks including interburden. Apart from the above, PMP tests, Caving index, In-situ strength of coal, Piezometric studies, Core profiler and Micro logging shall be done to formulate most realistic mine planning. Minex modeling is the one software launched in India and found its success to delineate the coal/ore structure.

5.2. Ventilation solution for deeper underground mines and introduction of air cooling system in underground

The first Air Shaft for coal mine, only 27m deep was sunk in the year 1851 at Eagra near Damalia in Raniganj coalfield. Whereas, a number of shafts of greater than 1000m depth were sunk in 1890s and 1910s. Airshaft at Champion Reef- gold mine in KGF reached a depth of 3211m, which is one of the deepest mines in the world. Whereas, the coal mining operations have crossed 300m depth and are extending beyond 400m in the country and facing complex climatic conditions with high dry bulb temperatures due to strata temperature, mechanisation and humidity. Hence, it is the need of the hour to formulate efficient ventilation in underground to create comfortable conditions. Deep shafts are inevitable to bring cool air at the deepest point. Higher capacity fans upto 400 m3/s operating upto 250 mm water gauge are to be planned to work mechanised faces in deep-seated reserves. Except in few metalliferous mines, air cooling/ refrigeration was not practised in coalmines so far. But the present situation demands underground cooling system to reduce ambient temperature of intake air. SCCL is installing its first refrigeration plant in underground (500RT chiller with 45000CMH air handling unit working at 40 mm water gauge) at VK-7 Joy miner face and is also planning to install in two more mines. CIL is also planning to introduce AC plants in underground. The cost of refrigeration per tonne of coal is highly insignificant against the losses that accrue out of inefficient ventilation.

5.3. Strata control problems in deep seams

As the workings are going deeper, the in-situ stress domain changes and becomes complex. Any slight change in the magnitude of horizontal stress may cause heavy roof damages such as roof guttering. The roof geology and stability may vary vastly. The response time of unsupported roof may still get reduced. There must be improvement in roof bolting system with the required performance and rapid installation system. Hence, the existing manual roof bolting system with cement grout medium will not at all work for better roof control. Hence, it is crucial, to switch over to mechanised bolting system with resin grout medium. SCCL has already started working on these lines. There are varieties of bolting solutions in the global market. SCCL may shortly introduce mobile bolters.

A policy document is under preparation at SCCL, which envisages mechanised bolting solution and the use of resin grout medium replacing existing cement grout medium completely as a long-term policy. Hence the requirement of resin becomes huge and the same will be met with, by setting up resin manufacturing plant of its own or tie up with the existing manufacturers to install a plant for SCCL.

6. Conclusion

India is the third largest coal producer in the world and is producing nearly 85% of coal from opencast mining presently. Opencast mining has its own limitations due to depth and environment pollution. Hence it is required to get bulk output from underground mines. Bulk production is possible by opening new coal blocks suitable for sophisticated mechanisation to work beyond 300m depth and managing existing coal resources in underground mines optimally.

The Country needs to focus on longwall mining and ought to revive its earlier policy of 1975 ‘BLACK DIAMOND’ to introduce powered support longwall faces in both CIL and SCCL in feasible blocks having good quality of coal. If longwall faces are planned abundantly, it creates competition amongst equipment manufacturers from abroad and develops indigenous market too which would bring down cost of production. Different models like Mine Developer ‘cum’ Operator (MDO), Technology Provider ‘cum’ Operator (TPO) and risk/ gain sharing can be worked out with foreign participants.

Hence, CIL, SCCL and the private operators who are allotted coal blocks for underground coal mining must plan to introduce as many longwall faces as possible in the blocks which are feasible for bulk production.

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MEN TRANSPORTATION IN UNDERGROUND MINES

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1. INTRODUCTION

Over a period of time underground mines have become extensive. The time spent by workmen in traveling miles together from surface to work place and back increased. Considerable time and energy spent on travelling made management to think for speedy, effortless and safe man riding systems to reduce the unproductive time and manual effort.

Towards the above, Man Riding systems are introduced to reduce this unproductive time and thereby to increase the available time for productive work. The Man Riding system also reduces the energy spent by the workmen in traveling. The reduction in fatigue is directly related to the gradient and distance of the walking place. The time and energy saved because of introduction of Man Riding System could be utilized by the workmen for increasing production and productivity.

RECOMMENDATIONS

The Committee on Safety in Mines (Report published by Dept. of Coal in August, 1979) recommended that "Man Riding facilities should be introduced by 1985 wherever feasible".

The 8th Conference on Safety in Mines held in May' 1993 had recommended suitable action in this regard.

Further in 9th Conference on Safety in mines, it was also recommended that "in mines where long and arduous travel is involved arrangement for transport of men should be made".

Most of the SCCL Mines belong to the second category i.e., having arduous travel due to adverse gradient.

HISTORY.

For deep shaft and vertical transportation winding engines are in use world over from the steam age and subsequently been converted to electrical winders.

But for incline mines the man riding systems are developed in the recent past in 70's.

In India 1st such system (Chair lift system) is introduced in CHINIACURI mine of SECL, Coal India.

The latest system of men transportation is by free steered vehicles which are widely used in Australian Mines and this technology is yet to be adopted in India.

Keeping in view the welfare and well being of men and towards effective utilsation of manual effort on productive works SCCL started introducing these modern and efficient men transporting systems in various mines since 1990.As on date 15 chair car & 23 chair lift systems are in use in 27 Mines and 9 new systems are under various stages of implementation.

2. BENEFITS OF MAN RIDING SYSTEM:

There are several intangible benefits that can accrue by the introduction of Man Riding System but their quantification in terms of tonnage or economics is difficult.

These can be summarized as below:

a) The energy saved in traveling will leave the workmen relatively fresh at the face, which is expected to improve industrial relations as well as reduce accident rate.

b) The reduction in fatigue may result in reduced absenteeism.

c) The resultant saving energy and time will contribute to higher productivity levels which will get quantified only on long run in a given mine.

The installation of Man Riding System thus has be to considered safety and welfare measure initially.

MAN RIDING CHAIR CAR SYSTEM

Man Riding Chair Car System is similar to Rail Locomotive except the Engine being stationary in this system and Anchor car and Man rider similar to Bogies.

The Man Riding Chair Car System mainly comprises of the following:

1) Direct Haulage built up / suitably modified for Man Riding application.

2) Man Rider Train comprising of one Rope Anchor and two Chair Cars. (as per requirement)

3) Signaling and Communication System.

4) Electrical System.

Newly built 150 HP/87 HP Hauler or the existing 150 HP/87 HP haulers are suitably modified to incorporate the following features for man riding purpose.

a) Caliper Brake :

The foot operated caliper brakes are replaced by hydraulically operated caliper brakes. The brakes are applied by the disc springs and released by hydraulic system.

b) Hydraulic power pack:

The hydraulic power pack comprises of 5 HP electric motors driving 30 LPM, 45 bar gear type hydraulic gear type pumps which feed 2Nos. of 450 mm hydraulic cylinders. The power pack is so designed that one motor and gear pump set is always standby.

c) Thruster Brake:

The first motion shaft of gear- box is replaced with an extended shaft. An emergency electro hydraulic thruster brake with drum is mounted on this shaft. This brake is in addition to the hydraulically operated caliper brake

d) Speed Indicator :

An electronic speed sensing and display device is provided, which also incorporate over speed tripping facility. The speed sensing unit is mechanically driven from the main haulage drum. The display device is mounted on control desk in front of the haulage operator. Provision is made to check the speed sensing unit after decoupling it from the drum.

e) Distance Indicator :

A distance indicator driven mechanically from the haulage drum indicates the distance travelled. This indicator is located in front of the operator. The drive is through worm gear box, sprockets and chains. The dial of the indicator is calibrated to indicate the various levels with reference to the location of the haulage.

f) Under / Over wind:

A screw limit switch is provided to signal over travel and under travel of the Man Rider Cars. The drive to screw limit switch is tapped mechanically through sprocket and chains and worm gear box. The limits are so set that when the Man Rider Car reaches either of the extreme ends, the screw limit switch sets off alarm signal and the haulage is stopped.

g) Dead man’s handle:

A dead man’s handle with dead man switch is provided in the hauler control drum to enable effective operation of the haulage. If the operator loses control over the dead man switch the haulage power is cutoff. All these safety features are electrically so interlocked that when any field trip condition (like over/under travel) occurs then the supply power is cut-off and the haulage is brought to stop.

In case the haulage operator is incapacitated and loses control of the dead mans lever, the haulage motor power supply is cut-off and both the brakes are actuated and the system is brought to stop.

150 hp Hauler

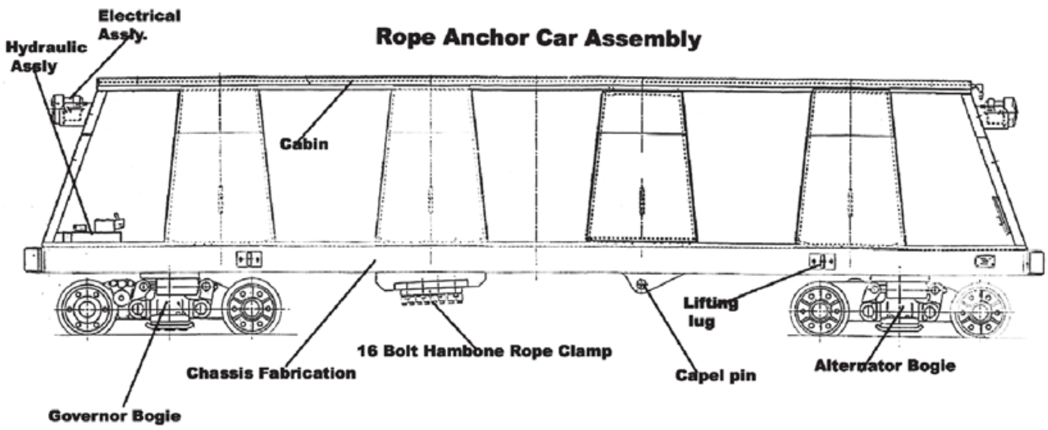
Under wind / over wind screw limit switch

Disc springs and Hydraulic cylinders Thruster brake unit

Man riding car system mainly consists of Rope anchor car and chair car man rider with following features.

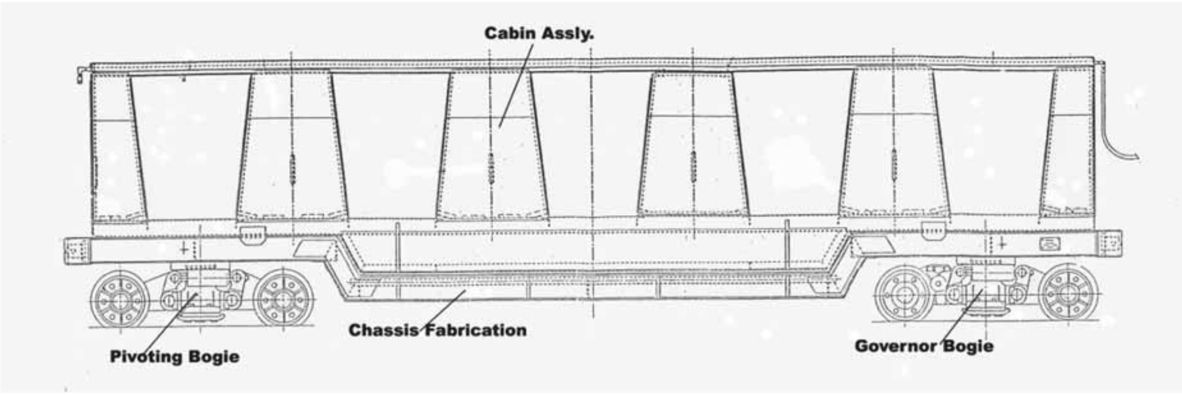
ROPE ANCHOR CAR :

Tare Weight	:	2.54 Tonnes
Rail Gauge	:	610 mm
Running Speed	:	8 KMPH
Trip Speed	:	8.9 KMPH
Trip	:	Set B
Brake Shoe Material	:	Tungsten Carbide
Seating Capacity	:	24 men
Rope Clamp	:	16 Bolt Multi Clamp



CHAIR CAR MAN RIDER

Tare Weight	:	2.9 Tonnes
Rail Gauge	:	610 mm
Running Speed	:	8 KMPH
Trip Speed	:	8.9 KMPH
Governor Gears	:	Set B
Brake Shoe Material	:	Tungsten Carbide
Maximum Load	:	15 Tonnes
Seating Capacity	:	30 Men
Rope Clamp	:	2 Single Screws



The important design parameters

Rope Anchor Car:

Chassis:

The chassis is manufactured from structural steel sections, and with a thick floor plate. Each end of the chassis is provided with 1.5 % Manganese steel safety chains, and couplers and the chassis is mounted on 'Railer' brake bogies.

The chassis is fitted/provided with the following.

a) Pressure gauge.

b) Hydraulic Tank, Hand Pump and all associated hydraulic valves to allow operation of each vehicle individually.

c) 16 bolt Hambone Rope Clamp to which the haulage rope is clamped and positioned before the white metal winding rope cappel connection on the underside of the deck.

Canopies:

The Man Riding canopies are fabricated around a substantial mild steel frame work with mild steel side, roof and end panels, and capable of transporting 24 men in a 3 abreast configuration.

Provision is made for

a) adequate visibility with laminated glass wind screen at both ends

b) head/ rear light.

c) hinged side panel to allow emergency stretcher access.

d) emergency brake handles linked to the hydraulic braking system.

Governor Bogie: One Governor Bogie with an Over speed governor will be a heavy duty four wheeled articulating bogie incorporating independent hydraulic suspension units on each wheel reducing the risk of derailment on curves or changes in gradient and set for 610mm rail gauge. A pair of hydraulic brake units is mounted at each end of the bogie which connects the running wheel support arms to the main frame. By pressuring the hydraulic fluid on the rear side of the brake cylinder the wheels are brought together which in turn lifts the chassis causing the brake shoes to lift clear of the rail by 25mm. The pads will be Tungsten Carbide.

When the hydraulic system is exhausted i.e. by manual operation of emergency hand valve lever or in the event of governor trip, the brakes are lowered onto the rail and the weight of the car is transferred through the top brake pad.

The centrifugal Over Speed Governor is driven through a gear train from one of the running wheels. The trip speed of the governor will be set 20% above the normal running speed of the haulage. The running wheels will be 305mm diameter and manufactured from manganese steel complete with adequately sized taper roller bearings.

The end bogie is fitted with a rope guide which captures the rope and the guide is used to open and close the trapping pulley units and Suspension mounts are mounted between the turntable bridge and cross axle to give a dampened suspension.

Alternator Bogie : Alternator bogie will be heavy duty four wheeled articulating bogies incorporating independent hydraulic suspension units on each wheel reducing the risk of derailment on curves or changes in gradient and set for 610mm rail gauge. The bogie arrangement shall have a pivoting, turntable bridge to cater for cross track misalignments of up to 50mm with all other features as similar to the Governor bogie. An FLP alternator is mounted on one of the side arms and is driven via a chain from one of the bogie running wheels. The alternator is self regulating unit and can be run off load with no damage.

Hydraulic system: Shall Consist of i) Oil Storage Tank ii) Filler Breather iii) Pump iv) Relief Valve v) Pressure Gauge vi) Brake Cylinders vii) Governor Valve viii) Emergency Brake Valve:

The hydraulic system is designed to release the car brakes and hold them in readiness for instant use in the event of an emergency. The pressure is maintained at a set pressure (2500 PSI),If the emergency isolator is open (or alternatively the governor over speed valve is operated) then oil pressure is lost in the brake pilot circuit, which will dump oil from the brake cylinders back to tank, thus lowering the top brake shoes onto the rail. For connecting any man riding car to the rope anchor car, should have hoses attached to the rope anchor car hydraulic system.

Electric Circuit: The electric circuit comprises the following components: **Head Light / Rear Light, Change over Switch** & **Alternator.**

MAN RIDING CHAIR LIFT SYSTEM

The system is similar to Aerial Rope way working over mountains (Tourist Spot) or as an Endless rope in under ground mines having endless rope driven by Electro-Hydraulic System.

2.0 ELECTRO-HYDRAULIC CHAIR LIFT SYSTEM:

2.1 The Chair lift system for men transport is an endless haulage system driven by Electro- Hydraulic power pack incorporating complete safety devices as necessary for transporting men in Under Ground mines.

2.2 The system shall consist of a drive unit arrangement, a return station, rope guiding pulleys with fittings and Electricals.

2.3 The drive unit arrangement comprises of an Electro- Hydraulic power pack and a hydrostatic high torque hydraulic motor directly connected with the driving pulley.

2.4 The device is equipped with built in servo controlled automatic brake system.

2.5 The speed of the rope can be adjusted from 0 to approximately 3 M/sec. at maximum.

2.6 Directional control valve device is provided to maintain the set speed by regulating the flow.

2.7 The return end installation comprises of a roof suspended mono rail fitted with return pulley and counter weight.

2.8 Detachable chairs shall be provided which can be easily engaged with and disengaged from the wire rope at the embarking and disembarking station. Arrangement of the chairs is capable of negotiating up to 18 deg. inclination.

2.9 The embarking station is specially designed taking in to consideration all safety precautions. At the starting point the chair shall be engaged on an inclined rail and when a lever mechanism is operated the chair along with person will slowly glide to catch the running rope. At the time of disembarking the chair carrying the person will smoothly leave the rope and glide over inclined rail slowly and there by comes to stand still position. Provision is made to prevent running back of the chair to the rope and guard is provided from over running.

2.10 The rope is properly guided and its tension correctly controlled with the help of different types and sizes of pulleys and installed at intervals over the entire length of the system and counter weight at the end.

2.11 The Man- Riding Chair lift system is monitored by an operator at the driving station. The system is such that it can be switched off by an emergency stop switch situated in the push button station at the driving station. Further, there are No. of pull cord switches along the entire length of installation and by using any one of these switches the system can be stopped. For additional safety measure 2 switches are also provided in the guide path of the counter weight in order to stop the system when ever the counter weight crosses the top or bottom limits.

A telephone system is also provided for better communication and co-ordination control between the drive station and return area.

2.11 The operating brake for the drive unit is built from complete hydraulic system consisting of the high torque radial piston motor and swash plate type pump. When the pump is in zero position, unbalanced system loads actuated by chair lift create a hydraulic pressure; even then, the drive sheave movement is locked because of hydrostatic condition of hydraulic circuit. The park and emergency brake is built from a spring loaded disc brake which is hydraulically released (fail safe type). In case of hydraulic failure the springs will actuate the brake and stop the drive sheave. The disc brake is modifiable for clock wise or anti clock wise revolution of the drive sheave. The changeable brake pads are adjustable.

CONCLUSION

The winders and man riding systems working presently in the mines are with old technology, slow in speed and are not adequate for deeper shaft. With the availability of new technology, the winders and man riding systems also requires modification or replacement. A thought is required to be given for use of high- speed winders and man riding systems with latest technology for transportation of persons to underground mines for effective utilization of work force for productive work. The speed of winders at present is kept as 5.0 m/ sec (max) while the latest winders are working with speed of 10 m/sec for material winding. The same winders can be modified to incorporate additional features for use of men transportation. This may also require modifications in Coal Mines Regulation, 1957 and the conditions governing use of man riding systems in underground mines regarding permissible speed, increase in slow banking zone to maintain low acceleration rate, safety gadgets etc. In addition to this for the present installations relentless & uncompromised maintenance practices and training is required, that only will make these systems reliable, safe, and convenient for use in underground mines.

CHALLENGES ENCOUNTERED WHILE WORKING WITH CONTINUOUS MINER AT GDK-11 INCLINE / RAMAGUNDAM- A CASE STUDY

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**V. Rama Mohan Rao
***K. Venkateswarlu
****G. Srinivasa Rao

Abstract

Continuous Miner (CM) Technology has been introduced in conjunction with diesel operated Ram cars for the first time in India to improve production, productivity, safety and conservation at GDK 11 Incline. Longwall technology was tried in the mine from 1991 to 1996. Subsequently development and depillaring was taken up with semi-mechanization (LHD). During 2008, CM with Diesel operated Ram cars was introduced in the mine. Development of B1 & B2 panels was started in December 2008 with CM. Localized depositional features became a major impediment for mining operations leading to unstable roof conditions. During development of Panel B1, adverse strata problems were encountered associated with roof falls in a cut out distance of even 4-5m and the progress was minimal. To address the problem, a Scientific study was conducted which recommended development of a trial road way offset by 300 to the present direction of the dip galleries in South-easterly direction, which would orient the dip galleries closer to the mapped minimum horizontal stress direction, thus reducing the risk of stress induced failure in areas of disturbed roof lithology. As a result, stable roof was observed, no roof falls occurred, which enabled a maximum cut out distance of upto 12m. After completion of the development of B2 panel with noticeable improvement in strata conditions, B3 panel was developed based on the experience gained during the drivage of trial roadway with re-orientation of dip galleries. At present B2 panel is being depillared without any strata problems.

This paper deals with the problems experienced during development stage of working with Continuous Miner.

GENERAL

The GDK 11 Incline mine is located in the north central part of Ramagundam area, between north latitudes 180 41’ 30” & 180 41’ 10” and east longitudes 790 32’58” & 790 34’54”. The full dip of the seams is 1 in 8 to 1 in 10 in the direction of N 600 E. The block is bound by three faults on the south-west, north-east and southern side. In all, 15 faults were interpreted from the exploratory boreholes and from the underground mine workings.

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GDK –11 mine block covers an area of about 8.20 sq.km. A total of 7 seams are present in this block and out of that four extractable coal seams are under exploitation.

STATUS OF MINING

Initially I seam is exploited with conventional method of Bord and Pillar mining. Later Long wall mining was introduced in this seam. Thickness of I seam ranges from 4.0 to 6.5m and is being extensively exploited in top portion with sandstone roof and leaving part of the seam in the floor. Subsequently, middle portion and bottom portion were exploited. To deploy Load Haul Dumpers (LHD) in I seam, Bottom portion of the seam was selected with sandstone floor leaving about 3.60m of seam portion in the roof. Presently, Continuous Miner is introduced for development and depillaring of virgin area in the dip side of the block in the top portion of the seam (Figure1).

Details of the Seams

Seam	Parting (m)	Thickness (m)	Usual Thickness (m)	RMR Value	Geological reserves (MT)	Method of working
1 Seam	-	3.97 to 6.0	5.0	44.5 to 47	40.50	Depillaring with CM Technology
2 Seam	15.28 to 22.64	1.36 to 3.96	2.60	41	24.26	Developmen t with LHD's
3 Seam	49.71 to 71.25	4.57 to11.37	8.60	48.92	65.69	B.G. Method
4 Seam	8.15 to 13.17	1.80 to 4.27	2.50	51.75	22.66	Developmen t with LHD's

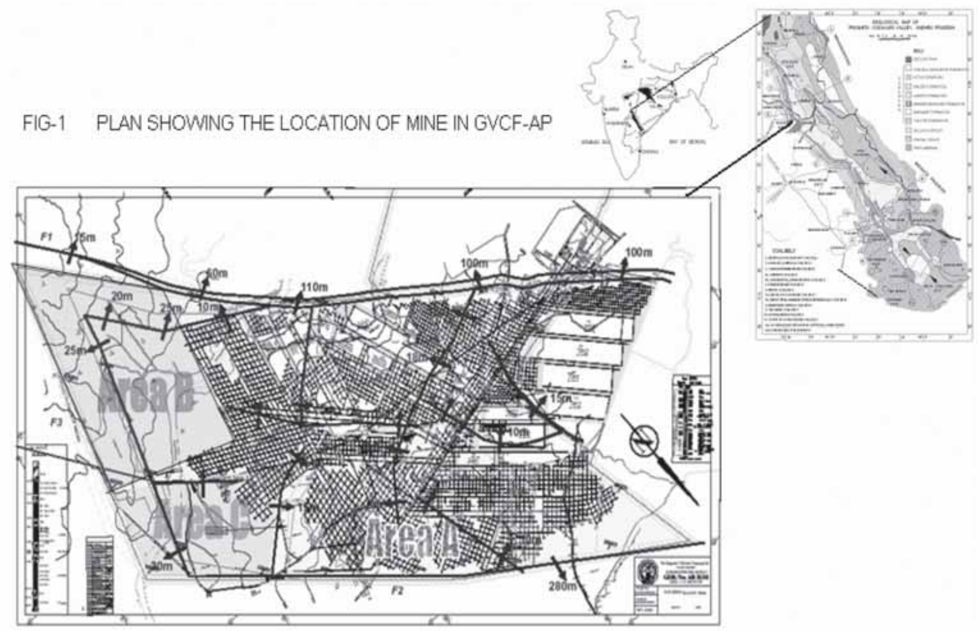


FIG-1 PLAN SHOWING THE LOCATION OF MINE IN GVCF-AP

DEVELOPMENT OF B1 & B2 PANELS

While working with Continuous Miner in Panel B1, two unexpected faults were intersected and subsequently it was shifted to Panel B2.

PROBLEMS IN B1 PANEL

- Two unexpected down throw Faults were encountered during the drivage of galleries at 25D & 26D/ 85L & at 84LS/29D, which deteriorated the roof condition.
- Due to geological disturbances 5 no's of roof falls took place at 27AD/84L & 29D/84L after cutting.
- Initial teething troubles of project implementation
- Bogging down of Ram cars & Continuous Miner in floor.
- Because of the above problems a decision was taken to shift the operations from B1 to B2 panel.
- Accordingly equipment was shifted to B2 panel and started working from 04.02.2009. The production in B1 panel from 02.01.2009 to 22.01.2009 is 4279 Tonnes only at an average of 183 Tonnes / day.

Due to the adverse mining conditions experienced in the dip drivages, geotechnical mapping of the B2 panel was taken up to assess the cause of the roof falls. The reported falls in the dips are generally found to be localized and occurred during the cutting sequence and before roof bolting. On closer examination these falls are found typically in the areas with disturbed roof lithology of the drivages.

It is therefore proposed to develop a trial road way offset by 300 to the present direction of the dip galleries in a south easterly direction as shown in the plan. (Figure-2). This would orient the dip galleries closer to the mapped minimum horizontal stress direction, thus reducing the risk of stress-induced failure in areas of disturbed roof lithology.

However, by reorienting the dips by 300 will change the pillar geometry from square to parallelogram. This changed geometry effectively reduces the original 46m square pillar to an equivalent 40m square pillar. It also reduced the calculated pillar safety factor from 3.4 to 2.6. Even with this effective reduction in pillar size, the factor of safety is still more than the minimum recommended safety factor of 2 (for pillars that are designed for subsequent pillar extraction).

Safety factor for two different shape and size of pillars (for B2 panel)

W_e (m)	B (m)	H (m)	h (m)	C (Mpa)	Strength (Mpa)	Load (Mpa)	Safety Factor
46 (Rectangular)	6	325	3.6	20.01	30.50	10.38	2.94
40 (Rhombus)	6	325	3.6	20.01	26.66	10.75	2.48

Where,
We – effective width, B -width of the gallery,
H -depth of cover, h -height of extraction &
C – uni-axial compressive strength of coal.

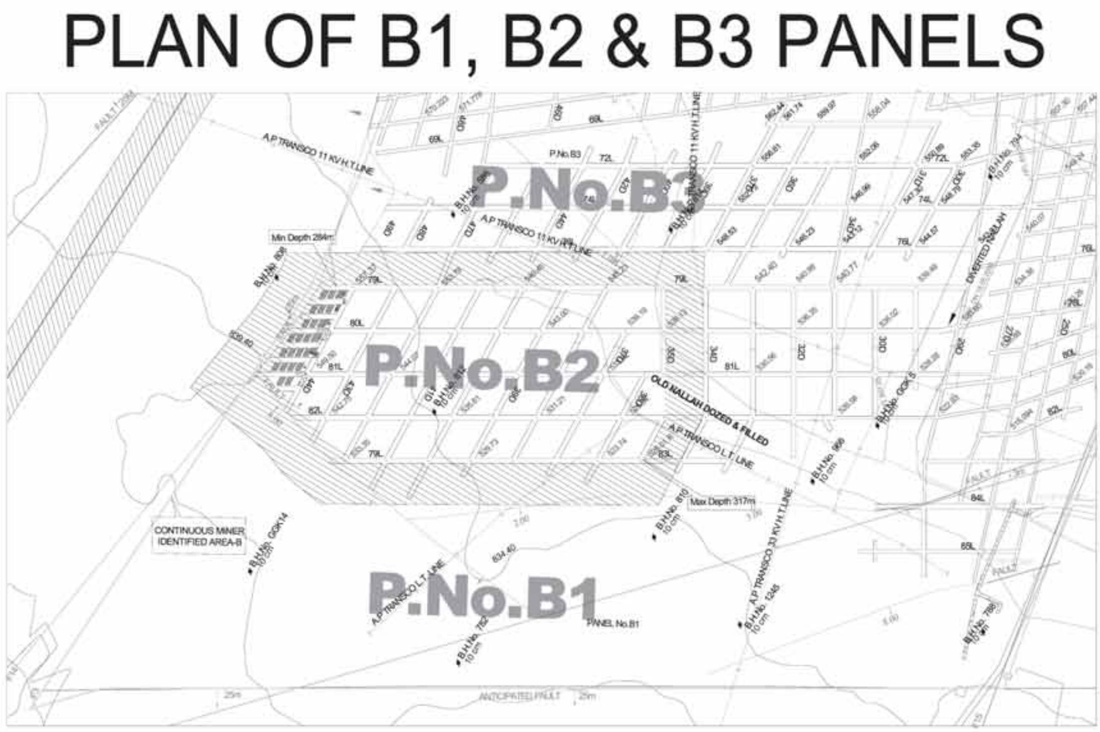
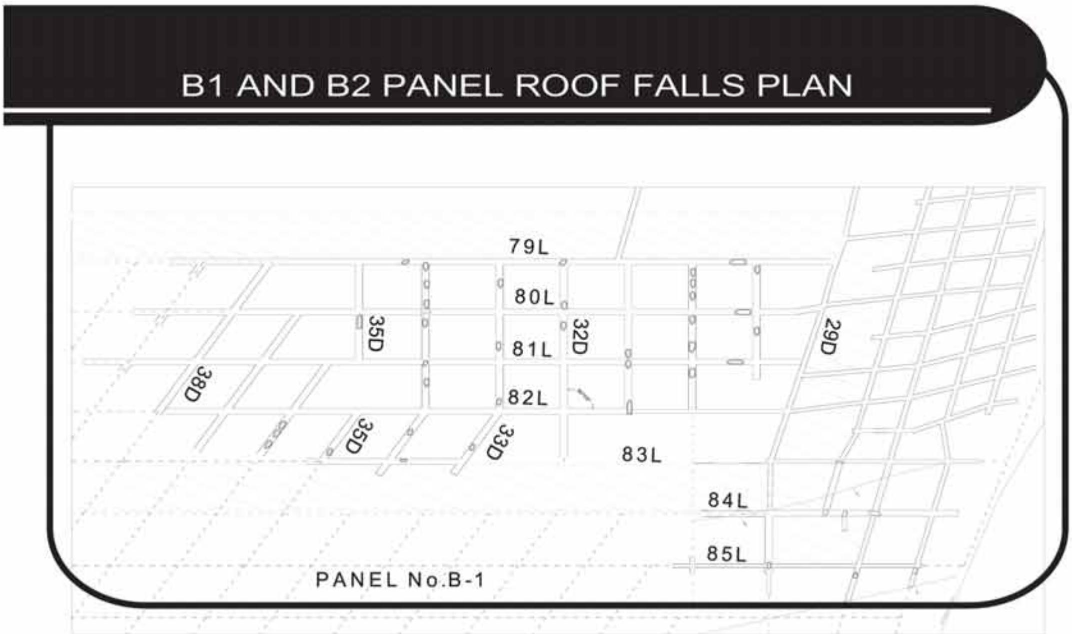

PLAN OF B1, B2 & B3 PANELS
P.No.B3
P.No.B2
P.No.B1
A.P.TRANSCO 11 KV.H.T.LINE
Min Depth 284m
Max Depth 317m
OLD NALLAH DOZED & FILLED
A.P.TRANSCO L.T. LINE
CONTINUOUS MINER IDENTIFIED AREA-B
DIVERTED NALLAH
PANEL No.B1
ANTICIPATED FAULT

Figure-2

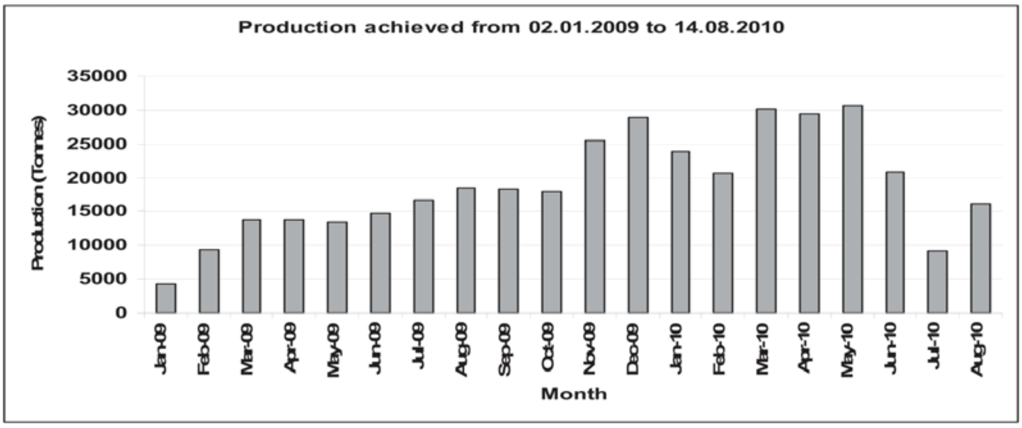

B1 AND B2 PANEL ROOF FALLS PLAN
79L
80L
81L
82L
83L
84L
85L
35D
32D
29D
38D
35D
33D
PANEL No.B-1

SUMMARY OF OTHER PROBLEMS & PRACTICAL SOLUTIONS IMPLEMENTED WHICH RESULTED IN HIGHER PRODUCTION FROM B2 PANEL

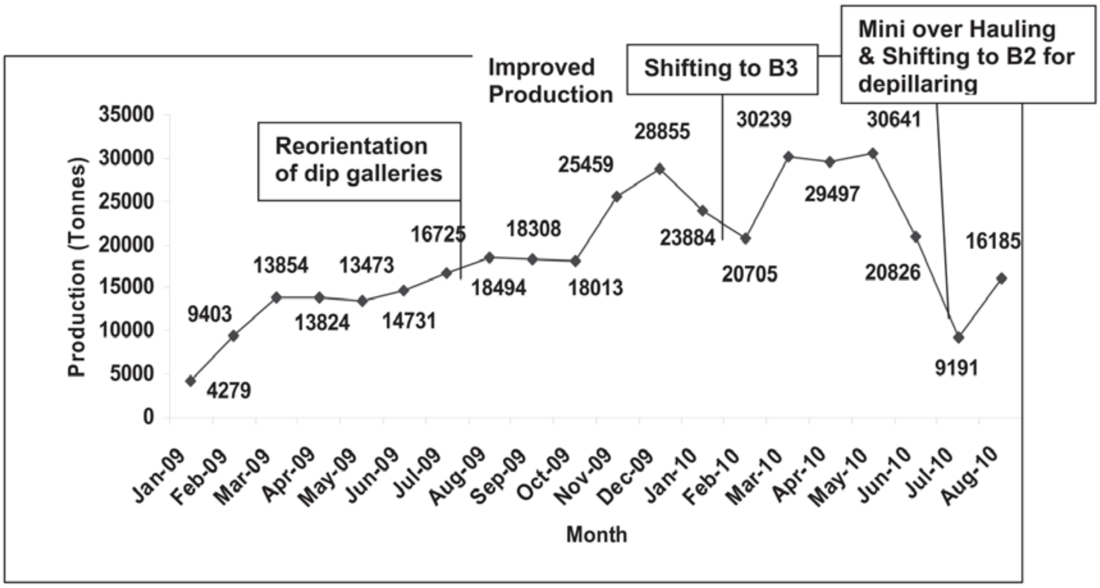
Sl. No.	Problem	Solution
1	**Water problem at the face.** While working with Continuous Miner and Roof Bolter, appox. 30 GPM of water is consumed, which is damaging the floor causing slush and resulting in skidding and jamming of the machinery at junctions.	Ditches made at every junction and water is diverted into that ditches. Bucket pumps installed to pump out the water.
2	Soft coal floor getting broken away due to heavy weight of machinery CM : 72 T Roof Bolter : 30.513 T Ram Car : 25 T (without load) Ram Car : 40 T (with load)	Found a hard coal layer at 2.7m to 3.6m height from roof and maintained the same horizon. Instead of air fill tyres foam filled tyres were introduced and also applied chains to the tyres.
3	Ram cars / Continuous Miner jamming in slush, sometimes causing more delay.	Installed the Feeder Breaker at the junction due to which the Ram cars can unload from three directions. This arrangement successfully prevented bogging down of the Ram cars at the junctions.
4	Roof falls in B1 panel	Roof falls were observed in B1 panel at 27D/84L and 29D/85L. Cut out distance was reduced to 3 to 4m.
5	Roof falls in B2 panel	a) The problems are almost the same as B1 Panel (roof & floor problems). b) Most of the falls have occurred only in dip galleries. c) Due to the above, it was decided to re orient the dip galleries since the level galleries were found to be stable. d) Accordingly DGMS permitted to drive few dips experimentally with 60 degrees instead of 90 degrees. e) After reorientation of dip galleries, the roof was stable and the cut out distance could be increased from 4m to about 12m. f) At present the strata problems are reduced.
6	Mis-Match of CM and Roof bolter	The bottom row of side bolting is being done manually after supporting the top row with roof bolter.

CONTINUOUS MINER PERFORMANCE

- The production in B1 panel from 02.01.2009 to 22.01.2009 is 4279 Tonnes only at an average of 183 Tonnes / day.
- The production in the Continuous Miner district has increased from 9000 tonnes to 31000 tonnes / month with an average daily production 1100 tonnes.
- The Continuous Miner was idle many times for want of supported roof.
- Mis – match of Continuous Miner and Dual Boom roof bolter during development. (CM idle at least 6 hours in a day).



Production details from January – 09 to August (up to 14th) - 2010



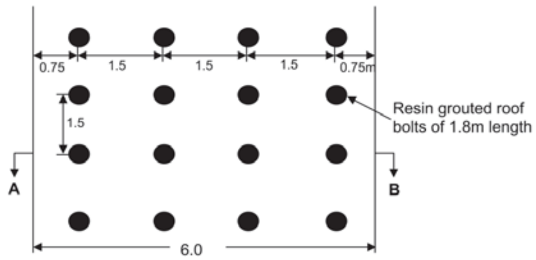
Cost Analysis

During the year 2010 – 2011, 81,341 tonnes of production was achieved against the targeted 1, 04,000 tonnes.

Up to June 2010 Rs. 13.80 Crores Capital expenditure has been incurred on Continuous Miner Technology. The details of different cost components and profit earned are as follows:-

DESCRIPTION	Amount in Rs. Lakhs
Wages	373.85
Stores	172.98
Power	45.14
Other Expenses	537.82
Depreciation	163.97
OPERATIONAL COST	1293.77
Work shop	18.46
Area over heads	67.02
TOTAL COST OF PRODUCTION	1379.25
SALES REALIZATION	1404.09
PROFIT / LOSS	24.84

SYSTEMATIC SUPPORT RULES DURING DEVELOPMENT & DEPILLARING



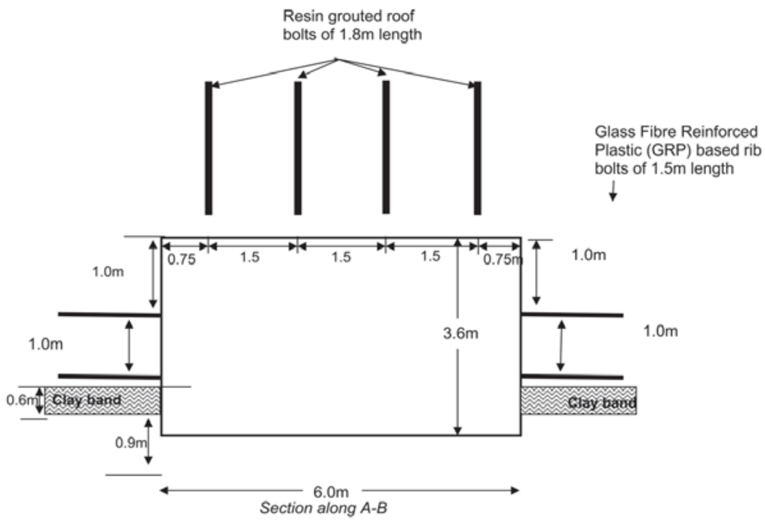


Figure: Support system in developed and split galleries and side pillars

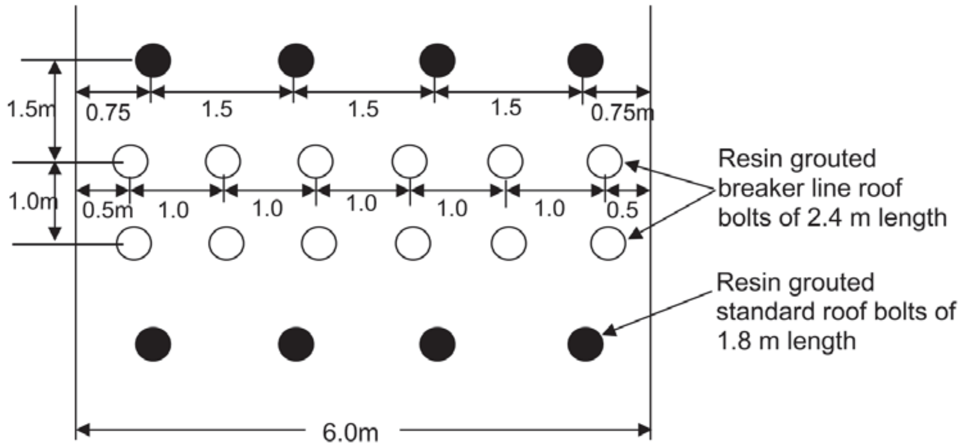


Figure: Proposed breaker line support system in depillaring galleries

Proposed support system at junction is shown in the Figure given below.

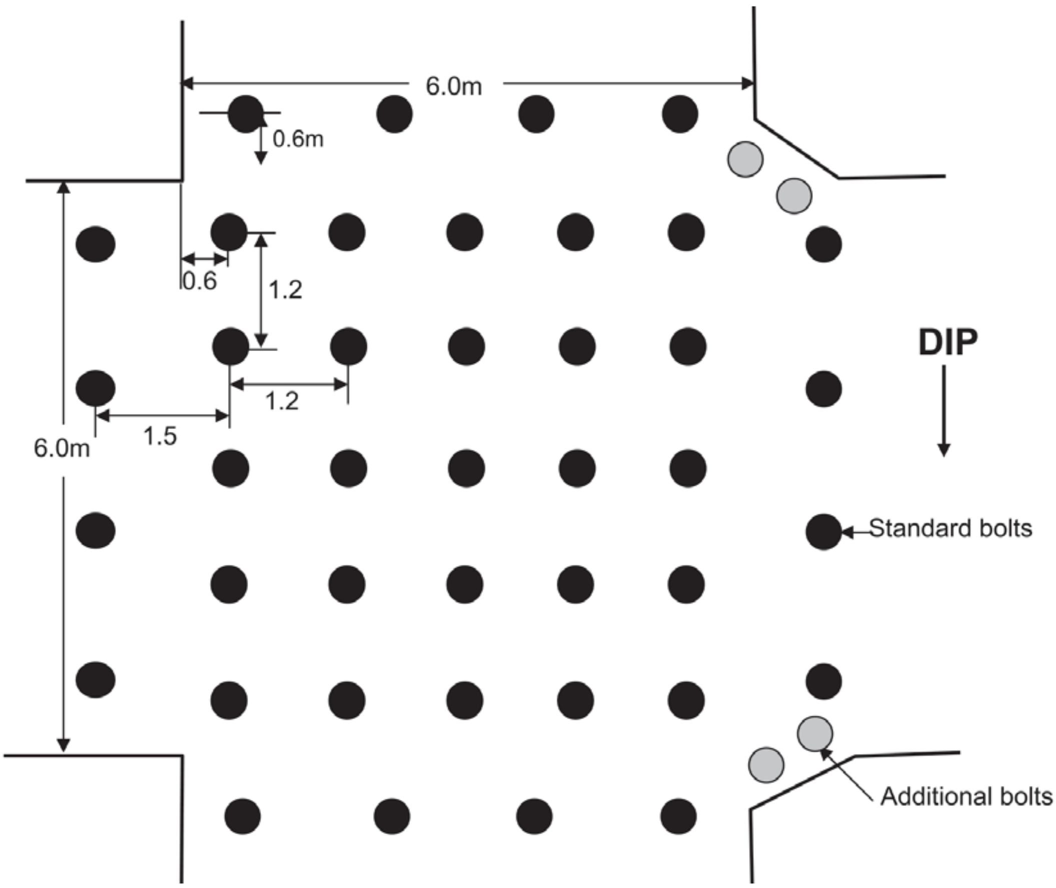


Figure: Proposed support system at junctions

STRATA MONITORING:

Rock Quality Designation (RQD (BHNO. R1245)

The RQD for immediate two layers of roof strata of I seam are with values of 31% and 58% respectively.

Classification range of these, fall under Poor to Fair, designating the roof as not strong enough.

Rock Mass Rating (RMR)

Rock mass classification system have become an integral part of empirical mine designing to provide guidelines for roof stability and to select appropriate support design. The Rock Mass Rating (RMR) of roof strata is accordingly tested in this mine to classify the strata.

Rock mass rating (RMR) and the Norwegian Q rating (Hoek and Brown, 1980) provides comprehensive classification of joints, adding scores for different parameters to give guidance on tunnel support.

- RMR of 80–100 indicates sound rock; support is not usually needed in tunnels
- RMR of <20 indicates poor rock; support is required in tunnels.

The data on five parameters is collected layer-wise to assess the RMR on the drill samples at 81L-N / 28AR & 30D of I seam (Top section) in GDK-11 Incline. The data is processed with CIMFR software to arrive at the layer-wise RMR and weighted RMR.

The details of RMR are listed in the below given table.

Rock Mass Rating Location: 81L-N / 28AR AND 30D of I seam in GDK-11A Incline								
Layer		**Layer-1**	**Layer-2**	**Layer-3**	**Layer-4**	**Layer-5**	**Layer-6**	**Layer-7**
Lithology		Mg Sst*	Mcg Sst	Mg Sst	Mcg Sst	Mcg Sst	Mg Sst	Mcg Sst
Density (t/m^3)		2.5	2.22	2.25	2.18	2.28	2.17	2.16
Thick-ness	cm	6	6	12	16	17.5	104.5	38
	Ratin	*11*	*11*	*16*	*19*	*20*	*30*	*25*
Structrl. features	Index	11	11	11	11	11	11	11
	Ratin	*12*	*12*	*12*	*12*	*12*	*12*	*12*
Weathe-rability	Valu	97	94	90	91	91	82.6	82
	Ratin	*15*	*12*	*11*	*11*	*11*	*8*	*8*
UCS (Mpa)	Valu	27.5	25.5	23	14.5	17.1	12.6	14.45
	Rating	*7*	*7*	*6*	*4*	*5*	*4*	*4*
Water seepage	Value	0	0	0	0	0	0	0
	Rating	*10*	*10*	*10*	*10*	*10*	*10*	*10*
RMR Value		**44**	**33**	**44**	**44**	**44**	**44**	**44**
Class		**III**	**IV**	**III**	**III**	**III**	**III**	**III**
Description of Rock		**FAIR**	**POOR**	**FAIR**	**FAIR**	**FAIR**	**FAIR**	**FAIR**

Weighted RMR - 48 – FAIR ROCK

* Mg – Medium grain Sst – Sand Stone Mcg – Medium - coarse grain

The weighted RMR is 48, which classify the roof strata strength as 'Fair Rock". However, presence of various sedimentary features in the panel area of B1 and B2 have affected the stability of the rock, thus warranting the necessity to study the local depositional conditions to arrive at a calculated decision on roof strength. Evidences to assess such features are limited in small borehole samples, obtained at the Exploration stage. Hence in-mine geotechnical mapping need to be carried out to map the ground realities.

The following Strata Monitoring Instruments are installed in B2 panel

1) Telescopic convergence Indicators
2) Dual height Tell Tale Extensometers
3) 4 Wire rib extensometers
4) Magnesonic bore hole extensometers
5) Strain gauged roof bolts (Instrumented bolts)

Dual Height Tell Tale Extensometers

About 65 Nos dual height tell tale extensometers were installed before reorientation of the dip galleries.

From the above, 16 nos. of Dual height tell tale extensometers shown readings ranging from 1mm to 15mm and where the bed dilation is more than 5mm, additional 2.4m roof bolts / cable bolts were grouted.

While developing the reoriented dip galleries, additionally 77 nos of Dual height tell tale extensometers were installed. There was no significant movement / load observed in Telescopic convergence Indicators, Magnesonic borehole extensometers and Strain gauged roof bolts (Instrumented bolts). It is also remarkable that no roof falls occurred in the panel after reorientation except one fall each at 35D / 82L and 38D / 82L which were due to unsupported roof because of breakdown of the Roof Bolter.

4 - Wire Rib extensometers

The details of movement of strata in pillar in horizontal direction (through rib extensometer) is given in the following table:

Location	Movement of strata in pillar in horizontal direction				Date of installation	Date of observation	Remarks
	Below 1.2m	Between 1.2 and 2.5m	Between 2.5 and 5m	Between 5 and 7.5m			
81L/32-33D (Rise side)	16	5	1	2	14/05/09	23/06/09	After 23/06/09 there was no movement of strata in pillar in horizontal direction
81L/32-33D (Dip side)	3	0	0	0	17/05/09	23/06/09	

There was no significant movement / load observed in Telescopic convergence Indicators, Magnesonic borehole extensometers and Strain gauged roof bolts (Instrumented bolts).

Development of B3 panel

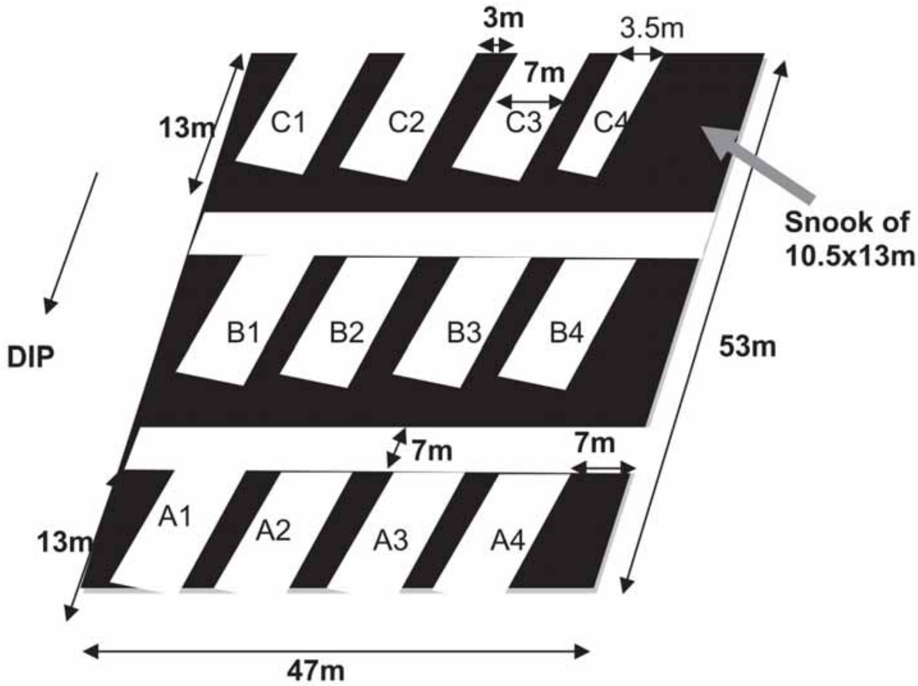
- After completion of development of B2 panel and the Permission for depillaring of B2 panel was delayed, mean while development of B3 panel was started on 04.02.2010.
- B3 panel is also developed with re-oriented dip galleries.
- In B3 panel 111 Nos of Dual Height Tell – Tales were installed. No bed dilation was observed in the above instruments.
- No roof falls occurred in the B3 panel.

Depillaring of B2 panel

- Depillaring of B2 panel started on = 20.07.2010.
- Production achieved from 20.07.2010 to 14.08.2010 = 25,376 Tonnes
- So far 3 pillars were extracted (6100 m2) and 4th pillar is under splitting.

Method of Depillaring:

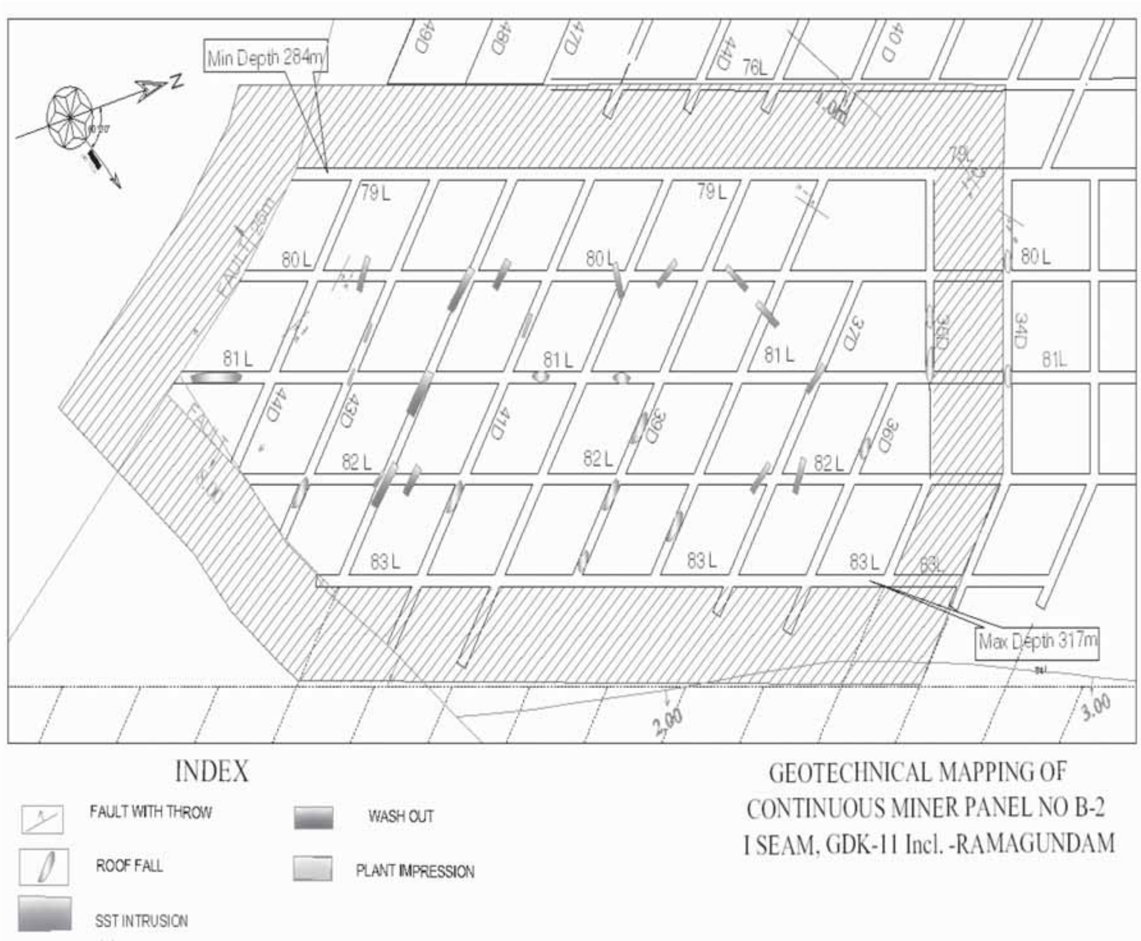
Extraction of pillar during depillaring suggested by the Rock Mechanics Technology (RMT, U.K) Double Split - three equal fenders (Double Split – Equal Fenders - Splits Fendered off Dip Sides Only).



Method of Pillar Extraction during Depillaring

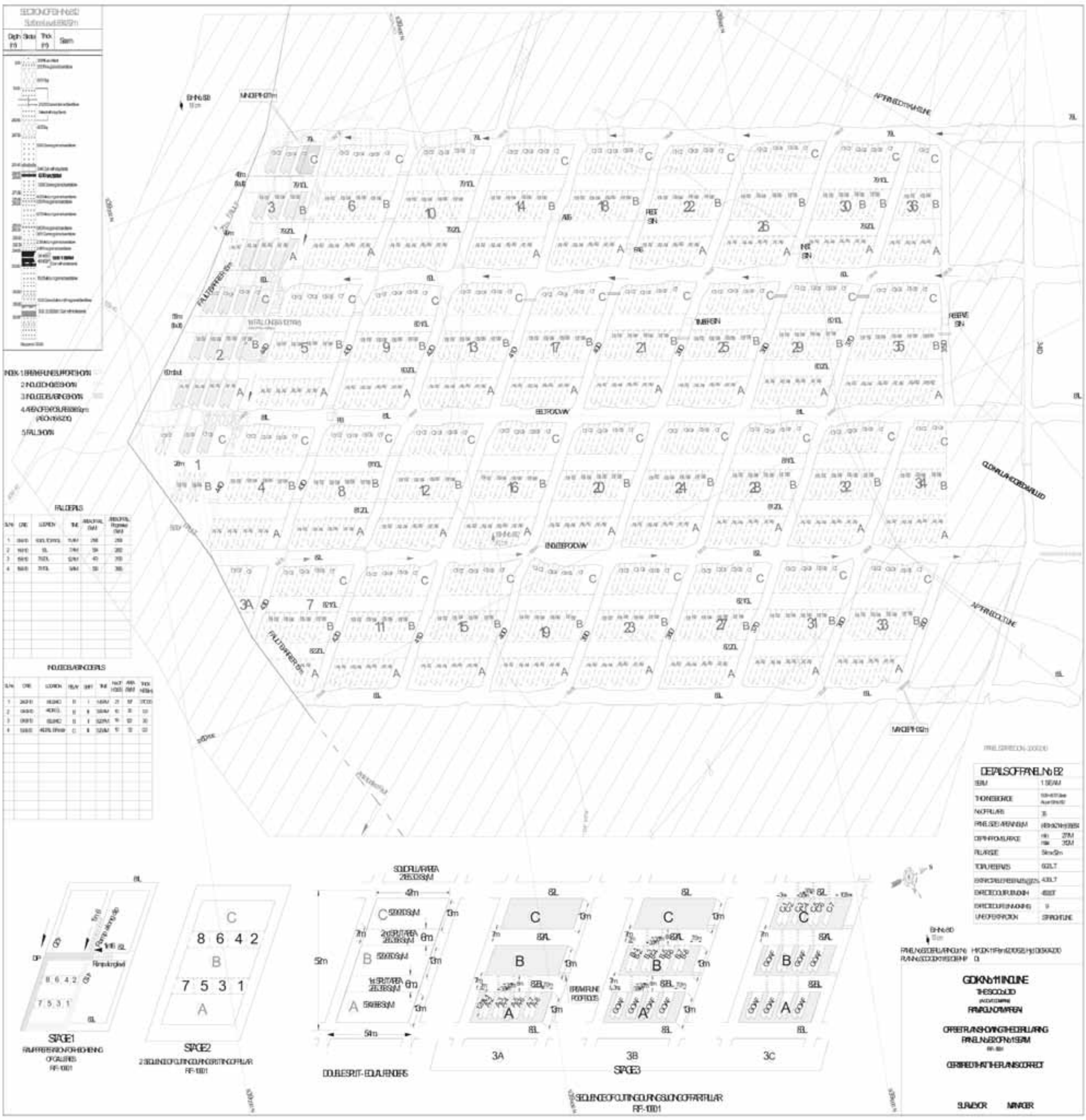
Roof Fall Details

S.No	Date	Location	Shift / Time	No. of holes	Thickness of fall (m)	Area of fall (m2)	Remarks
1	28.07.2010	81LS / 44D	1st / 01:45PM	21	3 TO 3.5	197	Induced Fall
2	04.08.2010	44D/801/3L	3rd / 03:00AM	10	0.3	35	Induced Fall
3	06.08.2010	80 1/3 L TO 81 1/3 L	Pre / 11:00AM	-	4	2108	Natural Fall
4	08.08.2010	80 LS / 44D	2nd / 08:20PM	19	3	123	Induced Fall
5	13.08.2010	44D/79L B fender	3rd / 05:20AM	10	0.3	52	Induced Fall
6	14.08.2010	80L	Pre / 07:00AM	-	4	554	Natural Fall
7	15.08.2010	79 2/3L	1st / 12:00PM	-	4	473	Natural Fall
8	16.08.2010	79 1/3L	Pre / 09:00AM	-	4	530	Natural Fall



GEOTECHNICAL MAPPING OF CONTINUOUS MINER PANEL NO B-2 I SEAM, GDK-11 Incl. -RAMAGUNDAM

DEPILLARING PANEL No.B2



Strata Monitoring Instruments installed during depillaring

Name of instruments	Parameters measured
Auto warning Tell - Tale Extensometer	Bed separation, Anchor at 10m
Rotary Tell-Tale Extensometer	Bed separation, Anchor at 8m
Dual Height Tell-Tale Extensometer	Bed separation, Anchor at 1.5m & 5m
2 / 4 Wire Roof Extensometer	Strata Separation in the roof
2 / 4 Wire Rib Extensometer	Strata Separation in the pillar
Strain gauged roof bolts (Instrumented roof bolt)	Load distribution along the roof bolts
Stress Cells	Stress over Pillar

There was no significant movement / load / stress observed in all the Strata Monitoring Instruments.

CONCLUSIONS

- It is observed that roof of I Seam is uneven in deposition. This type of undulations in the roof was experienced in this mine during Longwall mining also.
- The weighted RMR though classify the roof strata as ‘Fair Rock”, the presence of above such depositional features in the panel area of B1 and B2 have affected the stability of the rock.
- After reorientation of dip galleries closer to the mapped minimum horizontal stress direction, no bed dilation was observed in the roof strata of the dip galleries and a cut out distance of 12m could be maintained. No roof falls were observed after reorientation of the dip galleries.
- The experience gained in working the three panels – B1, B2 & B3, would be very useful in future, in successful extraction of about 10 Million tonnes of coal from the mine with CM technology.
- After reorientation of dip galleries there is an increasing trend in production.
- With the experience gained, it is felt that the 3 nos diesel operated Ram Cars & 2 nos Dual Boom Roof Bolters are recommended for continuous production.
- Bigger pillars are resulting in more lead, which substantially affects the production and productivity. Smaller pillars can be considered during development.

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Role of Information Technology in Coal Mining Industry

Sankar Krishnan & Rohit Vyas,
L&T Infotech

Abstract

Coal mining industry needs to adapt an integrated mine management system for development planning, production, operational control, compliance management and business decision-making. Global Mining Industry experience shows that data within most organizations are managed in a disjointed manner. Low level of computerization had restricted the penetration of Information Technology in core business process across the coal mining value chain. This paper emphasizes on the need of various information systems and available solutions which can address key business requirements of the Coal Mining Industry.

1. INTRODUCTION

Global energy demand is showing an upward trend with increased activity in Steel and Power sector. These sectors will continue to depend heavily on coal as prime source of energy as alternative sources are marred with environment and Geo political concerns. Coal mining companies had responded to demand supply gap and adopted measures to increase the overall production of coal. Capacity expansion, increased capital expenditure and optimization of resources for increased productivity were the key areas of focus in coal mining. Coal mining industry is facing the following business challenges across the globe:

a) Capital project execution and management

b) Supply Chain Management (SCM): Effectiveness and Capital Utilization

c) Local Compliance, Environment Health Safety (EHS) and Sustainability

d) Acquisition of New Assets and Management

e) Industry wide Consolidation and Divestment

These challenges are being met globally with adoption of advance mining process and information technology (IT) to yield effective project management and high level of productivity.

2. PRESENT IT SCENARIO IN INDIAN COAL MINES

Coal mining industry had widely acknowledged the benefits of information systems and adopted point solutions to optimize its core business functions only. Most common applications across the industry are geological solutions for Mining and ERP for business operation. Mining industry is yet to utilize the IT for complete mining value chain. Low level of computerization restricted the penetration of Information Systems and processes are managed manually. Wherever computerization has taken place, information is stored in a number of different application systems with varying data formats and also with varying technologies with limited integration. Islands of technology and information silos with little or no integration or interfaces are in use and it is apparent that important strategic decisions are made based on incomplete and/or outdated information. Common disadvantages faced by industry are data duplication, loss of human efforts, production realization, and productivity, dependency on manual processes and operational risks arising out due to lack of information.

3. MINING BUSINESS MAP

Coal mining is complex, regarded as capital and asset intensive. It involves closely knit work groups sharing cross-functional information across the value chain. A typical high level business information flow chart in mining is depicted below:

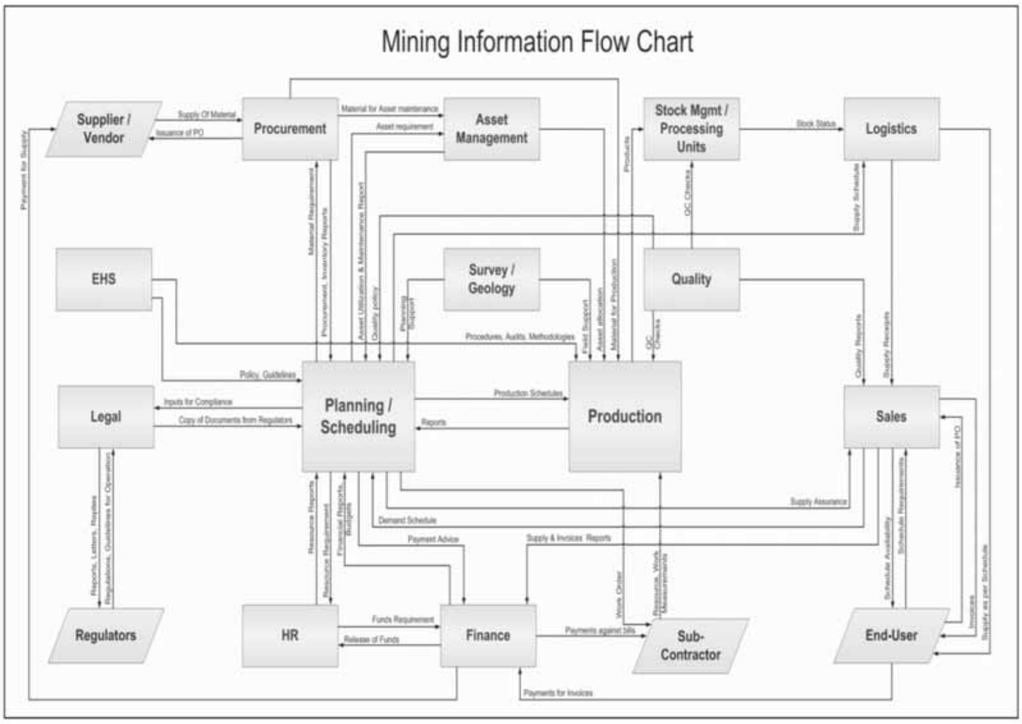

Figure 1 Mining Information Flow

Core information flows from production sites & planning/ management team to various business functions to support the uninterrupted production of mineral. Numerous data is generated and flowed down to respective work group. Individual work group own activity specific data in multiple applications and synergy between these applications are nonexistent. In real time operation information flows several times back and forth between these workgroup in multiple form of communication and existing IT systems in industry serves limited purpose. This scenario can be overhauled by interfacing real time monitoring applications with ERP and other tools to complete the information circuit.

4. BUSINESS VALUE CHAIN

Mining value chain includes the following key components:

a) Project Management
b) Production
c) Mineral Beneficiation
d) Transportation
e) Sales / Pricing and Trading

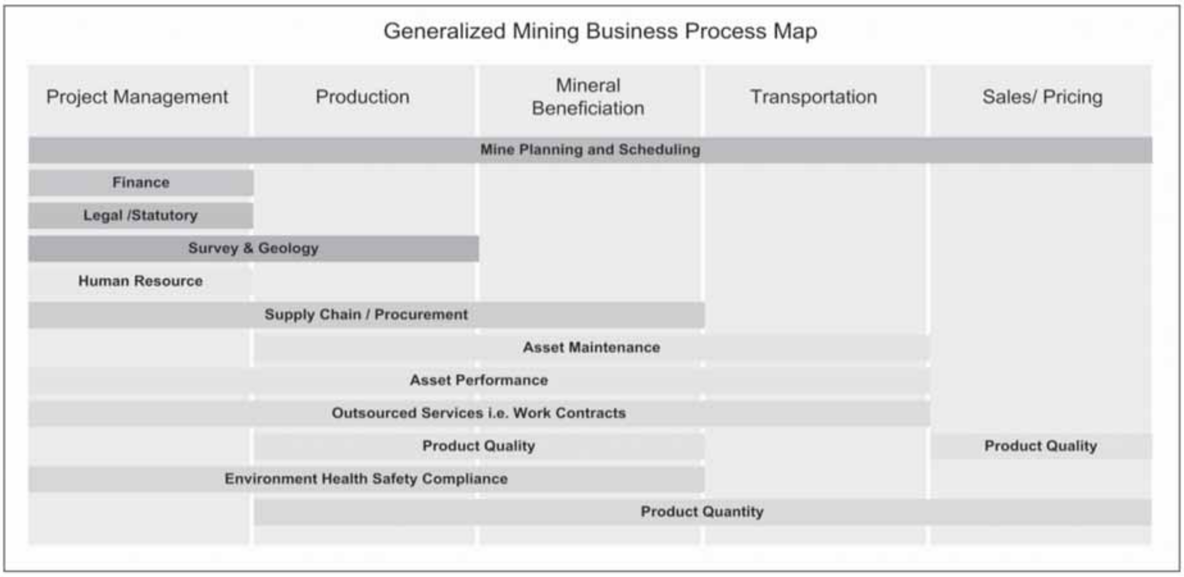

Figure 2 Mining Business process map and its component are depicted above in a generalized form

Mine project management involves various activities which are mostly managed through ERP solutions where data from Finance, Human Resource, Asset management and Supply Chain are thoroughly captured. Present ERP had limited or no integration with the mine planning, compliance management i.e. Legal & EHS. Integrated frameworks are required for catering all these business need or customized applications with interfaces can be a fit. Each value component receives and shares the information from various work groups as indicated in above figure and completes defined business activities in value chain.

Present Information systems are loosely coupled and cater to the prime business requirement neglecting the other areas, which are vital for project execution. Industry now needs to focus on these areas to utilize the Information Technology to optimize their operational process and integrate requirements of enterprise-level decision-making processes. This will provide the enterprise a seamless coverage of key business and production functions and provides a coherent flow of information at all critical interfaces of the extended supply chain of the organization. The solutions should be designed and deployed in a modular and scalable fashion with the flexibility to reconfigure existing applications and integrate new applications in a cost-effective manner.

Following are the areas which are yet to be explored but are critical in terms of Information Management in Coal Mining Industry:

a) Document Control & Management: Coal Mining has complex business documentation & regulatory requirement for project monitoring and progress. Pool of raw data is processed on daily basis for generation of documents. Individual unit/projects generate large number of these documents that are scattered. Disadvantages of existing systems are dependence on individual system to fetch the documents, time-consuming process & duplication of work. Solution lies in IT enabled centralized repository of documents with workflows and access control ensuring the confidentiality of the information/documents.

b) Greenfield Project Management: New coal asset development includes a series of activities involving various stakeholders. Effective and timely coordination is key to minimize the gestation periods in coalmine development. Industry today needs to capture pre development and approval activities like Geological Interpretations & Reporting, Financial Closures, Environment Clearance, Land Acquisition and Mining Lease process in IT application to monitor the progress and informed decision making for each activity.

c) Sub Contract Management: Sub contracting the works and Mine Development and Operation (MDO) contracts is common to today's coal mining. Key information on Assets, Personnel, Production, Dispatch, Payment, Sub Contract performance evaluation etc. are managed under designated departments in scattered form. It is imperative to create and utilize IT applications and interfaces which can pool out required details automatically and provide key users with significant information for effective management of various activities.

d) EHS Management: Statutory and social compliance are integral to coal mining. Varied reporting and documentation requirement are maintained manually across the coalmines with considerable efforts. Non-compliance can result in undesired consequences, structured and stringent management framework is prime need of mine management. Cost-effective and flexible IT system / products can help the management in EHS Management, Compliance and Reporting, Risk and Hazard Management with adoption of best practices

5. INTEGRATED MINE MANAGEMENT SYSTEM (IMMS)

Coal mining companies should take holistic approach and implement Integrated mine management system to optimize the resources and maximize the return.

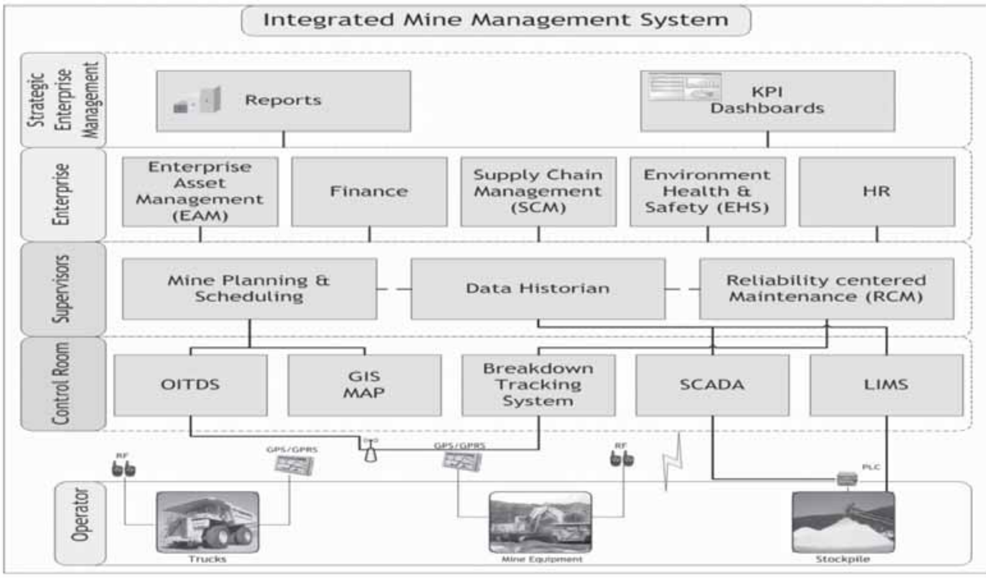

Figure 3 Integrated Mine Management System

Integrated mine management system utilizes function specific IT tools and applications with required interfaces to provide insights for Strategic Enterprise Management. First layer of IMMS will capture the data at operational level through various technologies and platforms like OITDS, SCADA. Supervisory level utilizes this data for short term and long term planning and decision-making, which includes data historian which provides vital information for equipment health and inputs for RCM process.

At enterprise level all the data are accumulated for business functions like finance, HR, SCM etc. these modules clubbed with customized ERP application and interfaces fetch relevant data to enterprise level decision making and reporting. Seamless integration of software application reduces the data duplication and reduction in effort for reporting.

6. CONCLUSIONS

IT systems will play key role for transformation of business process in Coal Mining Industry with integrated information flow. Information Technology had assisted the mining fraternity in resource optimization in its core process and coal mining industry need to look beyond to that by integrating information system across the mining value chain for maximum benefits. It is indispensable for mining companies to focus on the following to meet the business challenges.

a) Evaluation of existing information management and business requirement
b) Reengineering of business processes with focus on adoption of best practices
c) Formulate long term Information Strategy for the organization
d) Identify the right fit IT solutions
e) Innovative technologies

Coal mining industry should recognize the benefits being offered by Information Technology and create an environment where Information systems have a bigger role to play in their operations and management.

7. ABOUT AUTHORS

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Underground Mine Mechanisation – Enhanced Productivity and Safety

Subhasis Das
Vice President – Underground Mining
Sandvik Mining and Construction

69% of India's energy balance is dependent on coal fired power plants. India has a current installed power capacity of 170 GW . Even if we consider a long term projected growth at 8% GDP , to meet the demand growth India has no other alternative, but to increase installed power capacity to 300 GW, by 2020.

Out of 250 Billion Tonnes of total reserves only 80 Billion Tonnes can be effectively mined by open cast mines with the current acceptable stripping ratio . Moreover ,getting environment clearance and land acquisition is a lengthy procedure.

So to meet the target of UGM coal production of 125 Million Tonnes , by 2025 the only option that is left with Coal Mining Industry in India is to introduce Mass Production Technology at a very fast pace .

What are the essential desirables for introduction of Underground mass Production Technology ?

1. Continuous mass operation.
2. High production capacity
3. Higher man productivity per shift
4. Increased safety for miners
5. Higher recovery of coal
6. Better Return on investment
8. High reliability of production
9. Efficient strata control
10. Better protection to our environment

To achieve optimum Productivity and Safety in underground mining, the correct selection of equipment presents a challenging task.

This paper describes the interaction of the various pieces of equipment in underground room and pillar mining, as well as guidelines for machinery selection for better productivity and safer operation.

What could be possible reasons for slow mechanisation of Under Ground Coal Mines in India ?

One of the many answers is that products were introduced in a quest for increasing productivity and reducing costs, but these equipment did not always fully meet all the requirements as stated above. Many mines wanted to install (and still do so) the latest state-of-the-art machinery however many times the requirements have been limited to standard product offering of machine manufacturers and not aligned to meet the exact requirement of the user.

It requires considerable know-how and experience to be able to run this selection process successfully. This applies both to the mine officials as well as to the equipment suppliers. Especially the complex mining processes and the interaction between the various pieces of equipment and the environmental constraints as well as the skill level of operators need to be deeply understood!

Fig. 1: Sandvik Bolter Miner and Shuttle Car underground in Action

Expertise

Well-educated and experienced engineers are necessary to understand these interactions, both for a mining company as well as an equipment manufacturer; however, these are not always easily available.

Sandvik Mining and Construction, for instance, has identified a need to increase the knowledge about mining processes among its employees. A post-graduate academic education programme called the "Sandvik International Mining School" has been created together with the mining university of Leoben, Austria and several other international mining universities such as the University of Witwatersrand (South Africa), the Colorado School of Mines (USA), the University of New South Wales (Australia), the Technical University of Helsinki (Finland) and the Camborne School of Mines (England).

During a two-year course the students are receiving an intensive training on applications and processes in all aspects of mining.

The aim of this training programme is to enable Sandvik's sales engineers to act as true partners for their customers. They are partners who understand the needs of their customers because they understand the business of their customers.

Safety First

Apart from productivity, Safety plays a more and more important role in every aspect of mine planning and selection processes.It is also the top priority in the design and manufacture of Sandvik's machines.

A great number of technical improvements promote the operational safety of the machines.

Some examples shall illustrate these statements:

The operating concept of Sandvik's Bolter Miners is centred around ergonomic and safe operations of bolting rigs and cutting at the same time. Ergonomic platforms and rails make the life of the operators safe and easy.

The control of the bolting rigs via solenoid valves gives the added benefit of being able to collect roof strata data and assists the mine's roof control engineers in planning the support.

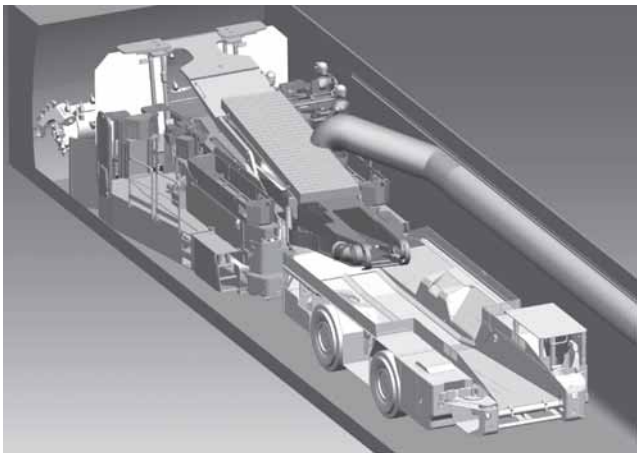

Fig. 2: Bolter Miner and Shuttle Car

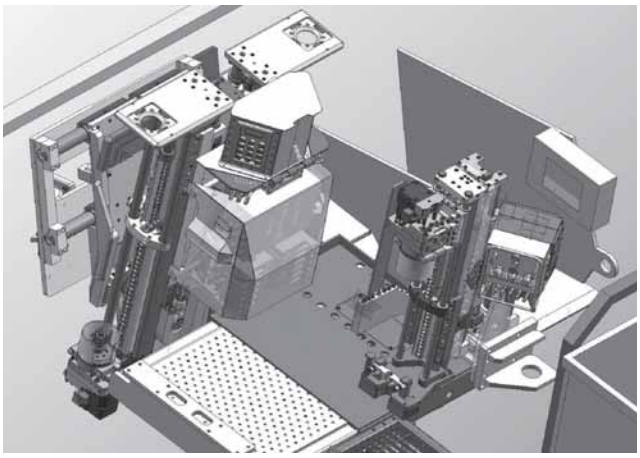

Fig. 3: Push-Button controls on a Bolter Miner

Modern Flameproof Diesel Engines meet the latest requirements for low emission and low energy consumption. These engines are available on Sandvik's Coal Loaders and Scoops and are fully ATEX and MSHA certified.

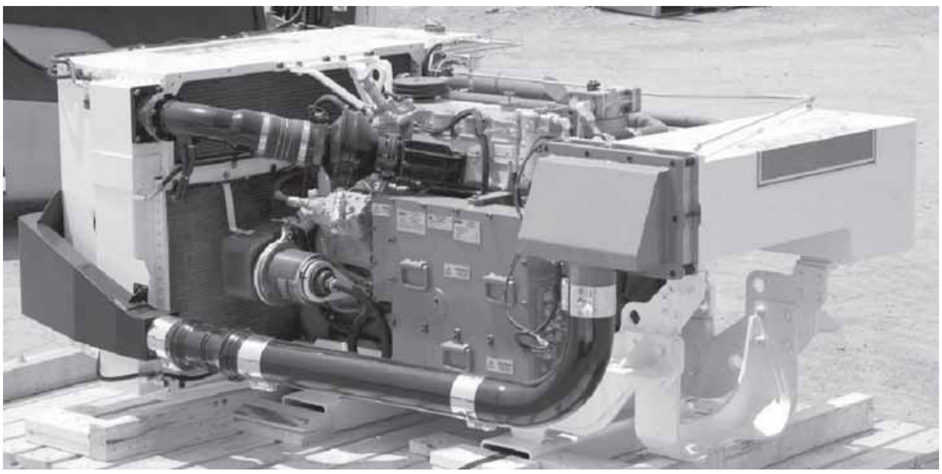

Fig. 4: ATEX approved Diesel engine

Ergonomic roof bolting machines, such as the Mobile Bolters of the DM100, DM200 and DM300 series, offer highly powerful bolting machines arranged on compact chassis and featuring high safety standards.

Other safety features on Sandvik machines include

- High-pressure water sprays on cutter elements of roadheaders and continuous miners, for optimum dust suppression and cooling of picks, as well as certified spray systems for methane dilution (ignition prevention);
- Methane detection equipment, linked to the cutter motor of a roadheader / continuous miner to further limit the risk of ignitions;
- On-board dust ductings and collectors (scrubbers) with up to 10 m3/sec capacity to eliminate dust, generated during cutting, from the mine environment;
- ROPS and FOPS certified cabins on coal loaders and some roadheaders

Equipment selection

The correct choice of mining equipment has a great influence in the total mining costs.
Typically, the average underground mining machine's share of the total mining costs is only approx. 3%. The optimum machine, however, is able to contribute to productivity by 40%.
In other words, a small amount of investment, carefully selected, can have a great impact in the productivity of any mining operation.

Roadway development for longwall mining

Roadheaders

Roadheaders excavate the rock by means of a cutter boom. The cutter boom can be independently moved in horizontal and vertical direction. This makes roadheaders adaptive to any shape of section. Roadheaders can cope with a wide variation of operating conditions and are well suited for selective excavation.

A roadheader in standard design covers the following functions:

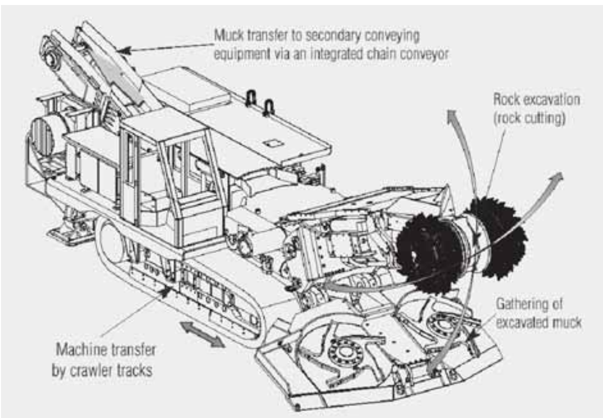

Fig. 5: Roadheader functionality

This sequential process of excavation serves for the versatility of roadheaders with regard to shape and size of the cross section and enables selective mining.

The Fig. below shows some typical cross sections excavated with roadheaders.

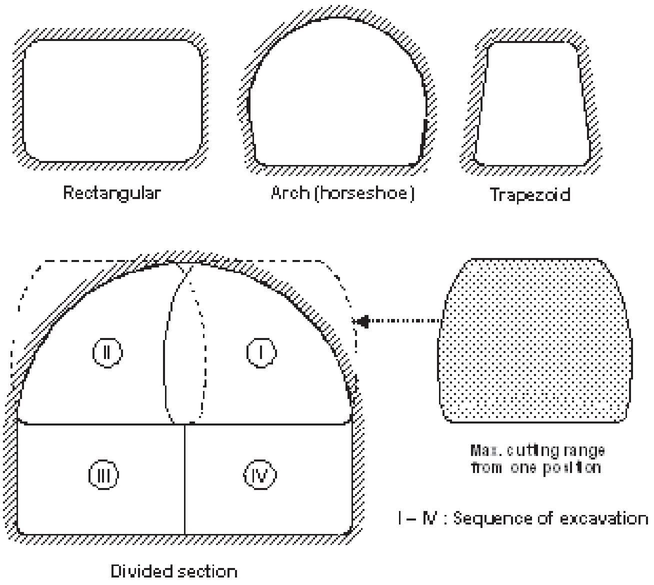

Fig. 6: Typical cross sections for roadheader excavation

In room-and pillar mining the consecutive excavation of a wider section in two parallel steps forms a common method - if the roof conditions admit the resulting wider span.

Gathering of the excavated muck is effected by means of the gathering arms or spinners on the loading table. To its greatest extent the loading process can be effected simultaneously with excavation.

Sandvik's large roadheaders can be equipped with a hard-rock cutting package. This "ICUTROC" facility allows the machines to cut hard rock (100 – 160 MPa) economically.

Apart from Longwall gate road developments many Sandvik Roadheaders are deployed in South Africa in Bord & Pillar Mining operation producing 30,000 to 50,000 tonnes of coal per month.

Continuous Miners

Continuous miners are double pass excavation machines used in Bord & Pillar operation. Their main field of application are seam-like deposits. The great majority of such machines are used in coal mining. These machines are mostly used as production machines in Room and Pillar (Board and Pillar) mining.

Due to their compact design, the Sandvik Continuous Miners MC250 has been successfully demonstrated performance in South Eastern Coalfield Limited touching highest productivity of 18,000 tonnes in a month.

This is an effective cost economic solution that can be adopted by Indian Coal Industry . This machine does not require sophisticated evacuation and expensive service backup as is demanded by the standard continuous miner projects currently running in India.

Clearly MC250 is the solution to the increased demand on mid size mechanisation catapulted by increased EMS & wage cost.

Fig. 7: Continuous Miner MC250 during customer training

The MC250, pictured above, is very flexible and manoeuvrable due to its small cutter width of only 2.7 (2.9) metres. Even very narrow roadways can be excavated.

Standard continuous miner MC350 & 370 can be used to extract coal upto 3.6 mt Coal Seam height . The worlds largest continuous miner and MC450 & 470 can excavate upto 5 mt height but it has to be supported by matching belt evacuation system.

Mobile Bolters

Sandvik has a great range of mobile bolting machines available. All of these feature a high level of safety for the bolter operators, as these can always work under supported roof. The low-height machines of the DM100 series are only 990 mm high and can install roof bolts in roadway sections between 1.3 and 3.1 metres height. The small and compact machine can work even in undulated seam conditions.

Fig. 8: Mobile bolter DM130 with two bolter operators

The larger Mobile Bolters of the DM300 series are equipped with four roof and two rib bolters and are designed for very high bolting density requirements.

Fig. 9: Mobile bolter DM300 with four roof and two rib bolters

Bolter Miners

The BOLTER MINERs integrate a bolting system into a continuous miner. This allows simultaneous cutting and roof/rib support.
The machines are mostly used in high-speed roadway development, but can also be successfully operated in room and pillar operations, where roof support is a safety hazard.

Drill rigs for roof bolting and rib bolting (option) are integrated parts of the machine.
A canopy or independent hydraulic props are linked to frame and crawler tracks and provide a fixed position for bolting, while the excavation unit (cutter drum, cutter boom) and muck discharge facilities (loading table, chain conveyor) are arranged on a longitudinally sliding frame.

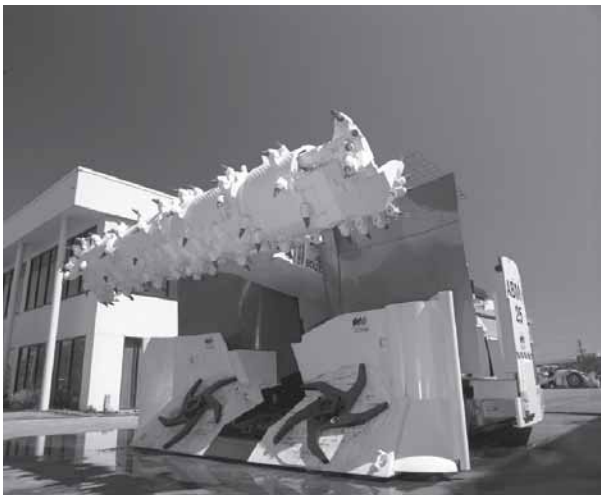

Fig. 10: Bolter Miner

The following individual functions are executed

1. Machine transfer by the crawler tracks
2. Setting of canopy, temporary roof support
3. Cutting
4. Loading of excavated material
5. Conveying
6. Roof and side bolting

There are more than 250 bolter miners of Sandvik which is operating in South Africa , Australia , US , China and several other countries in Longwal gate road development and Bord & Pillar coal production.

Sandvik Bolter Miner has produced more than 1.2 million tonnes of coal repeatedly in South Africa and was awarded the best Capital Equipment in 2009, by a leading organisation.

In China Sandvik Bolter Miner has been consistently driving more than 50 mts / day as average in coal longwall drivage . In Australia this machine has been consistently making far higher advances than what is achieved even in China .
On-board Bolters for Roadheaders

The bolting rigs used on Sandvik's BOLTER MINERs can also successfully be added to roadheaders, to increase the advance rate in single roadways. The power and flexibility of these bolting units also guarantees a high level of quality and safety for the bolt installation.

Fig. 11 Sandvik bolting rig on roadheader MR620

Shuttle Cars

Shuttle Cars play an important role in roadway development, when more than one heading are advanced at the same time. They are used to bridge the transport gap between the cutting machine and the main belt conveyor.

Sandvik's TC790 Shuttle Car, for instance, can carry 18 tonnes of coal in one load, equal to the advance of one metre in a small roadway section of e.g. 4.9 m width and 2.6 m height

Sandvik has placed the operator safety and comfort as top priority in the design of its shuttle car. Single-wheel suspension and optimised visibility are the main benefits for the personnel.

Fig. 12: Shuttle Car TC790 in operation with Bolter Miner

Continuous Haulage systems

The ideal material discharge system for a high-speed roadway development system is continuous haulage. This can either be:

- continuously advancing belt conveyor, for instance in combination with Sandvik's Self Advancing Conveyor Head, as can be seen in the following illustration:

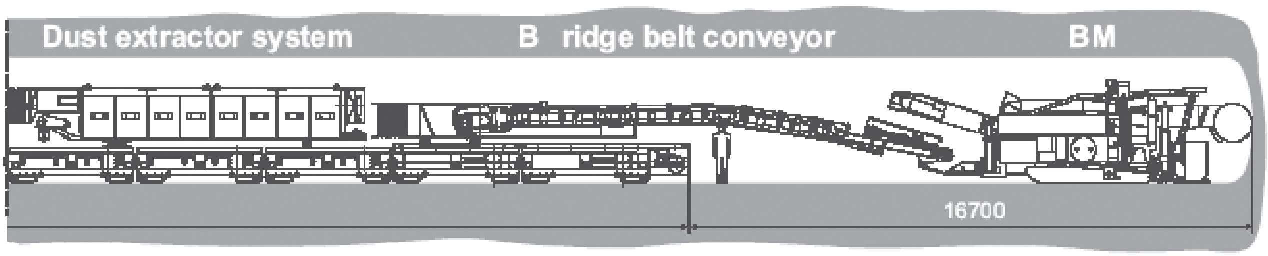

Fig. 13: Roadway development system: Bolter Miner+ Self-Advancing Conveyor Head of main conveyor

- or a periodically advanced belt conveyor in combination with a continuous haulage system. This system allows you also to follow the advance around corners and into side-roads.

An example of these systems is Sandvik's CHS500 system:

A belt conveyor is mounted on monorails and forms a tear-drop like pouch in which the cut material is transported.

Fig. 14: Cross section of Sandvik's Continuous Haulage system CHS500

Applications - Room and Pillar mining

The classical room and pillar mining method includes a series of five to seven headings per section, like this:

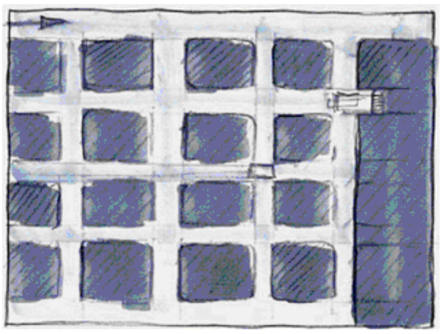

Fig. 15: Typical layout of five-road room and pillar system

It is equipped with the following machinery

Qty.	Description	Action
1	MB670/ MC350 or MC250	cutting
2	Mobile Bolter DM130	drilling and bolting (not with MB670)
2	Shuttle Car TC790	transport coal to belt conveyor
1	Feeder Breaker	receives coal from shuttle car + feeds onto belt
1	Belt Conveyor	coal transport
1	Rail transport	men and material transport

1	Utility scoop	stone dusting + re-locating equipment (electrics, fan, …)
	Ventilation brattices	to direct the air flow
1	booster fan	to assist air flow to continuous miner

The picture below shows a typical high-performance room and pillar mining layout (from South Africa), designed for rapid advance and easy conveying. The equipment used includes:

Qty.	**Description**	**Action**
1	Bolter Miner MB750 (MB370)	cutting and roof support
1	Continuous Haulage system	material discharge to the main conveyor
1	Utility vehicles	transport, stone dusting + re-locating equipment (electrics, fan, …)
	Ventilation brattices	to direct the air flow
1	booster fan	to assist air flow to continuous miner

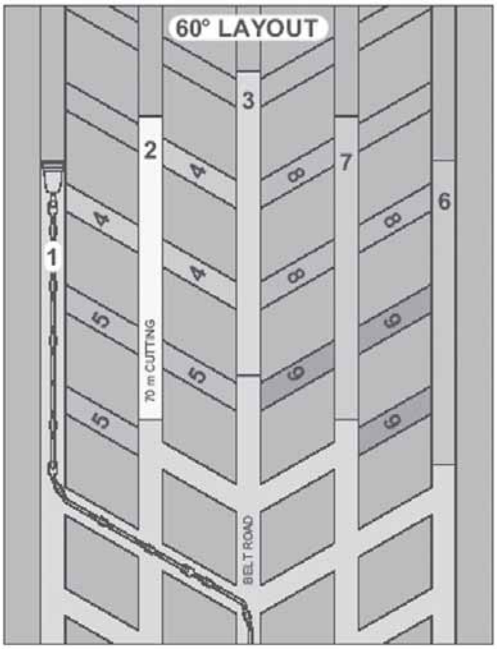

Fig. 16: Typical layout of five – road room and pillar system for continuous haulage

Sandvik Mining and Construction is able to provide all the equipment needed for such operations, and has the expertise available to propose the most suitable combination, based on over 40 years of experience with the design and manufacture of coal mining equipment.

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CHALLENGES IN DEEP SEAM MINING VIS-À-VIS STRATA CONTROL AND COAL BUMPS

* Dr S Jayanthu, **R.Srinivas,
*** Snehendra Singh and **** V Laxminarayana

1. INTRODUCTION

Over many years, declining production rate and increasing production cost from Indian underground coalmines posed a stern challenge to mining engineers. In view of complex geo-mining situations compelling the closure of many underground mines, deep seated and complex coal deposits require special attention at this juncture, although it is late to realize the importance of it. Due to depletion of reserves amenable for surface mining with time, India has to gear up for large underground production within next three to four decades. The involvement of industrial houses and those of leading global players should be encouraged for State of Art resource input and managerial support.

Over 61% of the total coal resource of the country is estimated within 0-300m depth cover, nearly 32% within 300-600m depth cover and small share (7%) below 1200m depth cover Table.1. Coal below 600m depth cover is invariably of superior grade and is available in East Bokaro, Jharia, Raniganj, Godavari valley & small share in South Karanpura, Talcher and Sohagpur. The coal reserve within 300-600m is available in all the prominent coalfields including power grade coals in Rajmahal, Talcher, Singrauli, Mand-Raigarh, Ib valley and Korba. Mining of complex deposits often worked with sand stowing has failed to meet the production target, productivity and economics. Methane drainage from the seams under mining should be done to ensure better working environment, safety of the workers and the workings.

State	Resource estimate as on 1.1.07 under depth			Total Reserve (Mt)
	0-300m	300-600m	600-1200m	
A P	7922	6514	3024	17461
Chhattisgarh	32167	8614	669	41450
Jharkhand	36998	14601	3285	54884**
**Jharia	-------14213---------------		5217	19430
Maharashtra	6789	2698	183	9670
M.P	12902	6727	148	19777
Orissa	44636	16139	1224	61999
W Bengal	12361	10975	4999	28335
Grand Total	155785	80636	18749	255170
% share	61.24	31.66	7.35	100

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** Research Scholar,
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**** Director of Mines Safety, DGMS,

Table 1: Depth wise Gondwana coal resources of India (Singh, 2007)

Innovative steps are required to ensure success in the areas of shaft sinking technology to develop access to deeper seams. Processing and dispatch system should be compatible to the mass production technology. Equipment supply and spares availability should be ensured for efficient full life performance. Man power preparation including training and on face operational skill should be developed on priority. Work culture should be improved in respect of devotion, commitment and adaptation of modern technology with efficiency; Program should have support of the nation for continuity and financial back up. Sudden change is not possible. But a change is possible and sustainable with proper planning sufficiently in advance, we should not make it too late to act and hence our preparedness for meeting the challenges of mass exploitation of deep seated and complex coal deposits deserve attention of all the concerned at this moment. Similar impetus has been observed in the thrust areas identified by various coal companies in India.

2. STRATA CONTROL IN COAL MINES

The progress of the technology in many branches of engineering is quite rapid in recent years. However, in case of underground coal mining, the progress is not as expected. It remained a lot with traditional systems and only a few attempts were made to adopt/absorb recent trends, such as resin bolting, mobile roof supports, truss supports and cuttable bolts.

With the advent of modern coal mining techniques, it has become imperative to adopt roof bolting as a primary means of support in place of the traditional supports. About 2500 million tons of coal has been locked in pillars of which only about 1000 million tons is amenable to opencast mining, about 1500 million tons is to be extracted by underground mining. Strata management is one of the major reasons for losing of pillars. Although technology has improved now-a-days with the introduction of Blasting Gallery method, Integrated Caving method and Hydraulic Mining, some of them are unsuccessful with the loss of trials at Churcha, Kottadih, etc., and many more due to lack of suitable strata control techniques. Salient features that led to typical problems in underground coal mining include;

- Steeply dipping, faulted, folded, highly gassy beds under aquifers and protected land have remained virgin.
- Developed pillars under fires, surface features sterilized because of acute shortage of sand.
- Development has been in multi sections.
- Highly stressed zones have been created due to barriers/stooks causing difficulty of mining of the underlying seams.

The future of mining industry demands more emphasis on caveability studies, support design and modification to the existing guidelines through obervational approaches for cost effective and safe mining operations. Research organizations like CIMFR and NIRM initiated many studies to help coal industry for better, efficient and safe extraction of coal through

i) analytical analysis and mathematical models

ii) empirical analysis and models and

iii) numerical modeling with computerization.

Some of the rock mechanics analyses were aimed at

i) support design in complex mining conditions

ii) partial extraction under water bodies/townships through wide stall method and

iii) mechanized depillaring etc.

The methods were site specific and were designed for intermediate level of mechanization and techno-economically viable in terms of production and productivity. Still there is a scope for rock mechanics application in the following areas:

- Development of scientific methods for maximum recovery under surface structures
- Exploitation of thick and multiple seams for shallow depth covers
- Utilisation of crushed overburden material for stowing
- Support designs for deep mining of coal seams

Technically, observational approaches for strata control have been widely thought over but limited attempts were made due to need of additional instruments for the purpose of monitoring roof behaviour. Various instruments visually showing bed separation etc, are used in UK, USA etc, to evaluate the effectiveness of the support/stability of roof. Modifications in the support systems were made based on the data from these instruments. Continuous monitoring of strata behaviour in terms of convergence of openings in advance on either side of the extraction line, and stress levels over pillars, stooks in advance of the extraction and ribs in the goaf was recorded through remote monitoring instruments for understanding the strata mechanics at critical conditions of roof falls. Continuous monitoring of support pressures was attempted to investigate the rock mass response to mechanised pillar extraction (Follington IL and Huchinson, 1993).

Integrated Seismic System **(ISS)** has been introduced by NIRM on an experimental trial at Rajendra mine, SECL, for prediction of strata movement during coal extraction by longwall mining (NIRM, 1998, 1999, 2000). The system developed by South Africa works on the principle of monitoring micro-seismic activities through geophones. The concept of tele monitoring or online monitoring is yet to be established to improve the safety aspects in underground coal mining. The use of Borehole TV Camera for caveability studies is the need of the hour for detailed analysis of strata behaviour during mining.

There is no radical departure from methods used in the past except for solid blasting, face mechanization, powered supports, shields etc. The expertise developed in some of the trials especially in central India has been allowed to be frittered away instead of their consolidation and extension. Development of thick seams without ascertaining the method of final extraction shall be discouraged in the interest of conservation of coal.

Awareness on the importance of recent trends of geotechnical instrumentation/investigations to the frontline supervisors/officials needs highest priority at present. Proper understanding of the limitation of the available strata control techniques may lead to formulation of reliable guidelines suitable for typical geo-mining conditions across the country. Well established "**Strata Control Cell**" can address the strata control issues by proper monitoring of strata and taking adequate control measures in time. NIT-Rourkela is in the quest of developing some reliable guidelines for some of the above-mentioned issues through application of suitable strata control techniques. Keeping this requirement in view, short term courses on "**Strata Control Techniques And Instrumentation For Enhancing Safety In Coal Mines"** at the Mining Engg Dept of National Institute of Technology, Rourkela were organized during 19-21 Nov, 2009. Workshop technology exchange programmes, Training programmes were also conducted at NIT-Rourkela, in coalfield areas such as Nagpur WCL, Orient area MCL, Bilaspur SECL, Ramagundam SCCL During 2008-2010

3. COAL BUMPS

Underground coal mining has been considered a high-risk activity worldwide. Innumerable accidents have occurred throughout history in coalmines of this kind, leading to the loss of human lives in many cases. However, if accident statistics are analyzed in more detail (seriousness, frequency, material and financial losses etc.), it is apparent that the major problems are found in deep coalmines. This is so due to the high mechanical stresses existing at great depths and to their possible interaction with the rock bursts in the coal pillars. Therefore Underground collieries have since long, experienced sudden, usually unexpected, rock burst and gas burst occurring away from the freshly exposed working faces at more depths, due to presence of heavy vertical loads acting on the rocks and high pressure gasses present in the cavities of rocks. This was true for rock bursts also. A rock burst is an "'explosion-like" fracture which usually occurs at the edge of a seam or in a pillar. Highly stressed rock disintegrates suddenly in a violent & dynamic manner. Fragments of fractured rock acquire velocities of more than 10 m/s, sufficient to cause injury and even death to miners, damage to equipment and openings and substantial disruption and economic loss to mining operations. The advance prediction of rock burst at any depth of the mine can be simulated and analysed by Numerical modeling Fig.1.

Coal bump is defined as a sudden release of geologic strain energy that can expel large amounts of coal and rock into the face area due to mining at deeper horizons resulting in fatalities and injuries to underground workers. It has been recognized as a sudden catastrophic failure of coal and caused serious problems to underground coal mining worldwide in the past 100 years. Great attempts have been made to understand the mechanisms of coal bumps and methodologies were developed and proposed to predict the hazard based on the analysis of Numerical modeling.

A coal and/or gas outburst is a complex mechanical process in which the fracture splitting and ejection of coals in gassy coal seam are to a large extent dependent on the gas pressure, in-situ stress and physico-mechanical properties of coal and surrounding rock. Therefore, it is of great importance to investigate the mechanism of coal and gas outbursts based on the stress field in the rock roof, floor and coal seam. The instantaneous outburst of coal and gas away from the working face during coal mining or drilling is a complex phenomenon.

It is generally agreed that at least one of the following five conditions is necessary for the coal bumps to occur:

(1) The depth of cover exceeding 300 m,

(2) The overlying strata are relatively strong and stiff,

(3) The coal is structurally strong,

(4) The floor does not heave readily, and

(5) The mining method produces high stresses over a large area of the seam.

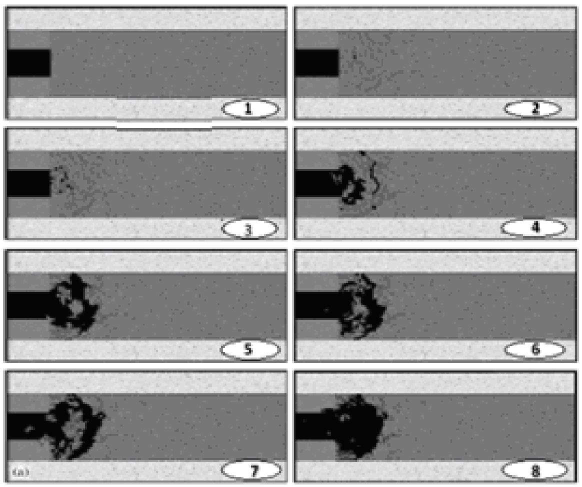

Fig 1: Failure criteria of rock burst in the coal pillars through Numerical modeling (Xua et al, 2006)

The successful reproduction of the experimentally and in-situ observed outburst failure phenomena with a numerical method implies that our understanding of the mechanisms of coal and gas outbursts has reached a more reasonable level which, in turn, will help us to make further progress in better understanding of the mechanism of instantaneous outbursts and controlling and preventing their occurrence as induced by underground mining. The Fig.1 shows the numerical simulation of coal burst in deep mine operation.

4. SOME MINING PRACTICES IN HIGH STRESS CONDITIONS

Horizontal stresses affect a number of coalmines (Jayanthu S, Gupta, R, N. Sibbal S., and Mozumdar. TK, 2000, Jayanthu et al, 2000). To address the effects of the stress field and to control its potentially damaging effects, a number of control strategies have been developed, such as reorientation of the retreat direction, stress shadowing of the key openings, and altering the mining cut sequence. However, many of these techniques are direction dependent, and to be effective, they require precise determination of the major (maximum) principal horizontal stress direction.

In-situ stress measurement by hydro-fracturing is generally adopted for coalmine areas such as Tandsi mine, WCL, and Shantikhani mine, SCCL etc. As this method is costly, some laboratory methods were also applied for some case studies in Indian projects, mostly tunneling and hydroelectric projects. In-situ stress estimated by laboratory method, was compared with the in-situ values determined by Hydro fracturing method (Jayanthu et al, 2009). The data from eight sites was compared, and there was a good agreement between the two methods. An analysis of the results indicated that the laboratory method of determining the in-situ stress of rock mass by 'Kaiser effect' is a promising technique. Advanced method of signal analysis will help in identifying the Kaiser effect accurately. However, more studies are required to standardize the procedure for estimation of in-situ stress by Kaiser method.

Roof slotting is one tactic to stress shadow the adjacent workings. This was tried at Northern West Virginia, where a 15 cm wide slot closed to 7.5 cm within 2 days after cutting. In Illinois coal mine a 15 cm wide slot closed to 7.5 cm within 7 days (Frank, et al., 1999).

The studies by the National Institute for Occupational Safety and Health (NIOSH) and the Mine Safety and Health Administration (MSHA) at Sargent Hollow Mine, in Wise County, VA, indicated that the weak floor strata was being subjected to and damaged by high horizontal stresses. After the 'advance and relieve mining method' was implemented, the overall mining conditions at the mine improved, and the roof control plan was approved for further use. Primary support in the galleries was 1.8 m tensioned rebar bolts, while 2.4 m long tensioned rebar bolts were also used. Based on stress mapping, the maximum horizontal stress direction was determined to be ENE, which is in agreement with the regional stress field. Mobile roof supports (MRS) were employed to extract the pillars while advancing the second panel. With first panel syndrome, extremely adverse ground conditions were experienced while developing and retreating the first panel in a new reserve. However, at many of these operations, favorable ground conditions were experienced in subsequent panels. The significant findings of MSHA include:

- Difficult mining conditions occur at depths greater than 280 m. It is probable that vertical stress also contributed to poor ground conditions.
- Barrier and single pillar extraction may have been beneficial in improving the ground conditions. It is not evident whether the favorable mining conditions experienced in areas where the advance and relieve mining method was used, were due solely to stress relief.

Need of change in the traditional legislation has been emphasized by many investigators in view of the recent advancements in support strategies (Metchel and Wing, 1998; Ghose 1999).

5. CONCLUSIONS

Instantaneous Bumps and Gas bursts in underground coalmines under **deep depths** continue to pose a hazard to safe & productive extraction of coal. The problem results from a combination of the effects of stress, gas content and physico-mechanical properties of the coal. In addition, numerical simulated results not only trace the initiation, propagation and coalescence of cracks in coals, but also present the associated evolution of the stress field in the coal seam and the roof and floor of the rock strata, i.e., the stress redistribution in the coal seam and rock roof and floor at every stage.

Stress measurement, whilst now possible, remains expensive and difficult. A particularly promising area in this regard is a technique known as Stress Determination through Measurement of Acoustic Emissions or “the Kaiser Effect”. An analysis of the results indicated that the laboratory method of determining the in-situ stress of rock mass by Kaiser effect is a promising technique. Advanced method of signal analysis will help in identifying the Kaiser effect accurately. However, more studies are required to standardize the procedure for estimation of in-situ stress by Kaiser method.

Numerical modeling still has a long way to go and enormous potential for the future. This will help to model such things as rock burst events, like the one which led to a fatality in France last year, and the design of support systems at junctions and face ends, where a majority of roof falls still tend to occur. We also need to be able to investigate the effect of increasing the spacing between rows of rock bolts along a roadway much more accurately. The work on **reinforcement testing** also needs further development. The tools have now been developed to improve our understanding of how rock bolts work. What is now needed is to apply these tools systematically to gain that improved understanding and to extend the tools to cable bolts and flexible bolts.

Finally, it is important to continue to improve the **instrumentation,** which allows all this to happen safely. It needs to be cheaper, more reliable and easier to use. Well established “**Strata Control Cell**” can address the strata control issues by proper monitoring of strata and taking adequate control measures in time.

6. ACKNOWLEDGEMENTS

The Author is thankful to Dr T N Singh, Former Director of CMRI, Prof D P Singh, former Vice-Chancellor of Lucknow University and Prof S P Mathur, Former CMD of CMPDI & ECL, and former Advisor of Ministry of Coal, Government of India for their consistent inspiration in perusing various studies in coalmines. Prof. R,N.Gupta, Former Director, Dr V Venkateswarlu, Head of Mine design division, National Institute of Rock Mechanics (NIRM)

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Improvised Coal Exploration for High Capital Intensive Technologies

* Y.S. Babu Rao

Abstract: Coal has been recognized for centuries as a major source of energy. The total proved reserves in Godavari Valley Coalfield are 9436 m.t. (as on 31.03.2010). The coal mining in India including in Singareni Collieries Company Limited (SCCL) is mostly confined to shallow depths. To pace with modern technologies, exploration techniques also need to be reoriented keeping in view the higher cost involvement. Well planned and executed exploration programmes of both time and cost effective nature will ensure taking well informed decisions on the basis of data generated by these advanced exploration techniques, minimizing the risks. Advanced high capital intensive technologies/techniques are being implemented in Coal exploration in SCCL with multi disciplinary approach, which includes Geology, Drilling, Geophysics, Hydrogeology, Geo-engineering, and Geo-informatics etc.

Introduction

Coal has been recognized for centuries as a major source of energy. It was an important stimulant to industrialization, both in India and elsewhere, and it currently contributes around 28% of the world primary energy usage next only to oil and natural gas i.e. hydrocarbons.

The Godavari valley coal field, the only coal bearing area in South India, covers area of 17000 sq.km. having a strike length of about 350 Km lying mostly in the state of Andhra Pradesh. An area of 1700 sq.km is found to be potential for regional exploration. A total area of 596 sq.km (excluding old abandoned mines) has been covered by Detailed Exploration in Godavari valley coalfield, by the company.

A total of 3.5 lakh metre of detailed exploration is planned in Godavari Valley Coalfield during the XI plan period to prove additionally 895 m.t. of coal reserves. The company is planning to produce about 52 million tonnes by the end of XI plan (March, 2012), by adopting state of the art Exploration techniques to generate adequate geo-technical data to cope up with planning for high production mines. SCCL is operating a total of 50 mines with the current production level of 50.4 million tones during 2009-10. The coal extracted so far by SCCL is about 929 million tonnes by adopting different mining technologies.

In India, out of total coal production of 532m.t. during 2009-10, only 11% is contributed from the underground coalmines. The rest i.e. 89% is from opencast mines. With the fast depletion of shallow deposits, the future of coal mining industry lies in deposits located in depth.

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Proved Coal Resources

The total proved reserves in Godavari Valley Coalfield are 9436 m.t. (as on 31.03.2010).
The depth wise reserves are as follows:

				(in million tones)
Depth (m)	Proved	Indicated	Inferred	Total
0-300	6060.68	3561.05	147.28	9769.01
300-600	3370.71	4721.16	653.91	8745.78
600-1200	4.39	1448.16	2228.17	3680.72
TOTAL (0-1200)	9435.78	9730.37	3029.36	22195.5

Out of 9436m.t of proved reserves, about 3325 m.t of geological reserves are in the blocks covered by working UG and OC mines. About 1000 m.t of reserves are in the abandoned/ closed mines. Thus a balance of 5111 m.t of geological reserves are available for future from which some of the explored blocks are projectised for taking up for mining. A total of 3117 m.t of proved geological reserves are available from the depth ranges from 300-600m and beyond.

Present Scenario

The coal mining in India including in SCCL is mostly confined to shallow depths (<300m) i.e. up to 200m depth in case of opencast mines and upto around 300m depth in case of underground mines due to difficult geo-mining conditions and also techno-economic reasons. This has resulted in exhaustion of shallow deposits and necessity for planning extraction of deeper deposits with appropriate technology with due consideration for safety, conservation etc.

The current mining methods and designs for thick coal seams in underground mines in India are labour intensive and less productive with a typical annual coal production ranging from 0.3 to 0.5 million tonnes only. Keeping in view safety and technological limitations, the current methods also result in huge loss of valuable coal resources with an average coal recovery rate of around 50%. There is an urgent need for a comprehensive investigation of various options for thick seam mining and development of optimum extraction technologies and designs for improving production and coal recovery from thick seams, to meet the increased coal consumption needs in India. In addition, as the coal resources and mines are getting deeper, there is a greater urgency for development of optimum and efficient underground extraction technologies for all the seams in general and for thick seams, in particular.

To pace with modern technologies, exploration techniques also need to be reoriented keeping in view the higher cost involved. The following advanced high capital intensive technologies/techniques are being implemented in Coal exploration in SCCL with multi disciplinary approach, which includes Geology, Drilling, Geophysics, Hydrogeology, Geo-engineering, Geo-informatics etc.

Exploratory Drilling coupled with Geophysical logging

It is a regular practice in coal exploration that boreholes are drilled at 400m grid interval as per ISP norms. For opencast and longwall identified blocks, the boreholes will be drilled in close spaced grids, say 200m. At present, the general ratio of coring and non-coring is 60:40 in shallow blocks and 40:60 in deeper blocks. With the available new technologies coupled with geophysical logging, it is now observed that, drilling with an overall ratio of coring to non-coring at 25:75 would suffice and all these open holes have to be invariably geophysically logged to obtain the desired geological data.

Core photography

Digital core photographs are taken for all drill core samples with high resolution digital camera.

Fig- 1. Digital photographs of core samples.

These photographs are used extensively for identification of samples for geo-technical tests. The Core profiler software developed by Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia is helpful in preparing the Composite logs of cored boreholes, depicting every information available for the borehole viz. Geological, Geophysical, Geo-Engineering, Core photos, etc.,

Geo-technical Rock Testing

The Geo-technical data, such as Density, Porosity, UCS, Tensile strength, Seismic Wave Velocity (P&S wave), Young's Modulus, Poisson's Ratio, Triaxial strength (Cohesion and Friction) Shear Strength, Rock permeability etc, are generated from borehole cores with adequate number of laboratory tests covering the entire lithology carried out to quantify the rock mass strength and deformation parameters. Selection of cores for geo-technical testing is carried out on the basis of litho logical grouping. Photographs are taken for the samples both before and after testing (Fig-2a-b).

Fig-2a Before testing

Fig-2b After testing

Geophysical Logging by sophisticated probes

Three new digital geophysical loggers mounted on vehicles with latest digital multi probes like neutron, sonic, gamma, acoustic, caliper etc., are procured to generate various additional parameters from boreholes. The functions of various probes and log responses are described hereunder.

(Table-1 & Fig.3).

Table.1. Functions of Geophysical probes

Sl. No.	Purpose	GP Logging probes	Recording /Response
1	Geological correlation, Determination of Lithology, Identification of thin beds permeable zones	Resistance/ Resistivity Self Potential	Electrical Resistance, Resistivity of the strata Spontaneous potential of the strata
2	Geological correlation, estimation of shale content, Detection of radio active zones	Natural Gamma	Low gamma emission (cps)
3	Determination of bulk density, Porosity, Identification of coal seams	Density logging	Induced gamma emission (cps)
4	Lithological studies, Geological correlation	Neutron logging	Induced Thermal Neutron emission
5	Borehole diameter and caving zone	Caliper logging	Borehole diameter
6	Produces accurate formation conductivity even in dry or open wells	Induction logging	Formation Conductivity
7	Lithology identification, Porosity, Rock strength and elasticity	Full wave Sonic logging	Formation (Sonic) velocity
8	Fracture interpretation and borehole deviation, bedding planes	Acoustic Tele viewer with deviation	Imaging

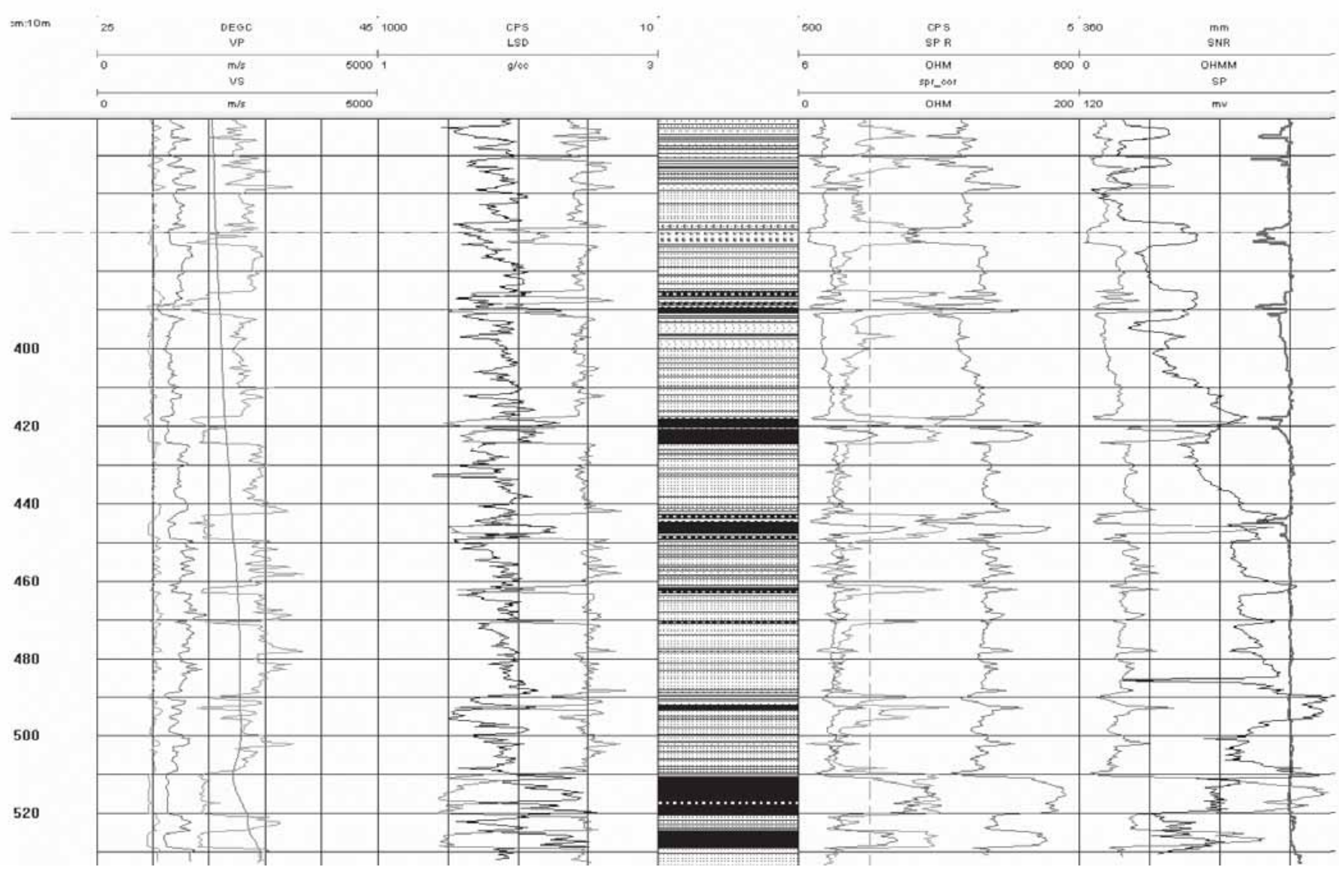


Fig .3 Geophysical Log responses

The P wave velocities are now used to empirically derive the UCS of sandstones with appreciable accuracy. Attempts are also being made to define strength of the rock formations from the combination of geophysical logs mainly using sonic, density, neutron-neutron and natural gamma logs. The concepts of 'Geophysical Strata Rating' are also under trial to assess the strength of rocks without resorting to the core data.

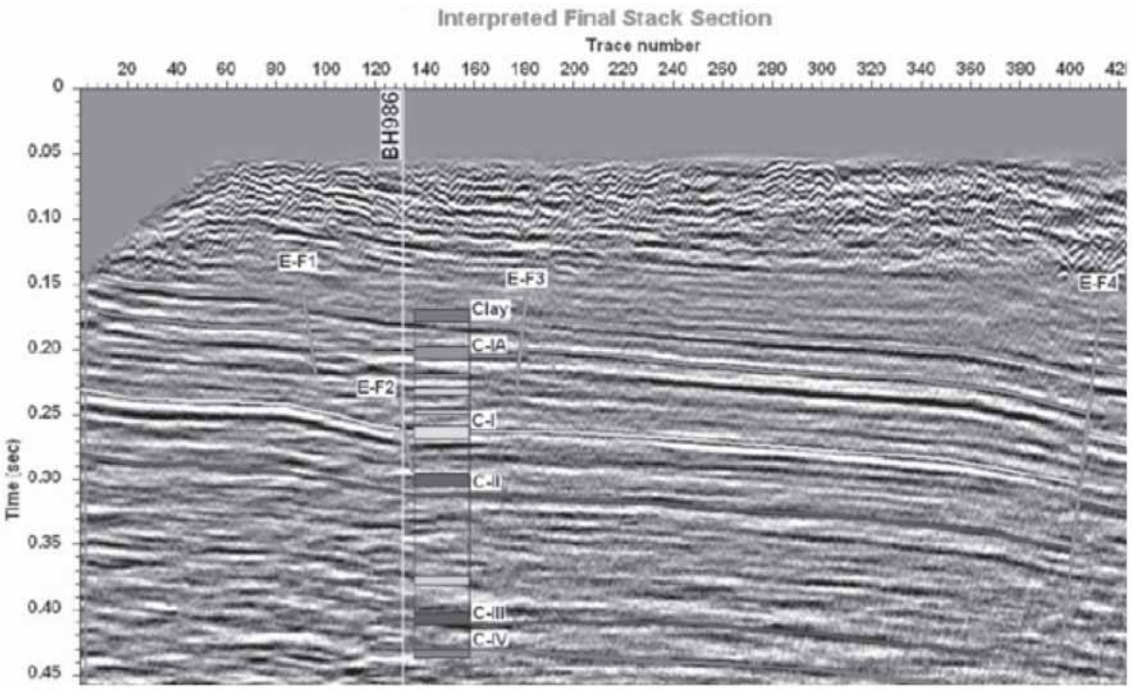
The data of acoustic image logs is used to interpret the breakouts to determine the stress directions. The image data is also used to delineate the bedding planes, fractures and assess the strength of the rock units. Studies are also being carried out to determine the ash content of coal seams estimated from geophysical logs to arrive at the quality of coal seams.

2D/3D seismic studies

In order to rule out the structural disturbances such as minor faults in the High productive Longwall Panels and to increase the level of confidence in achieving the targeted production from the LW panels, involving huge cost investment, it is proposed to carry out 2D/3D seismic surveys in the proposed longwall blocks.

NGRI, Hyderabad carried out 2D seismic studies in the already explored blocks on experimental basis and the data is largely in line with the geological data already interpreted. (Fig. 4)

Fig. 4. Seismic section line with geological interpretation



Insitu Stress Studies

The Insitu Stress and permeability studies are required to understand the magnitude and direction of the in situ stress field and aquifer-wise permeability, to enable mine planners to orient the LW panels. The insitu stresses, if not taken care during the initial stages may adversely affect planning of any underground drivages. The schematic view of the wire line packer testing system is shown in Fig.5.

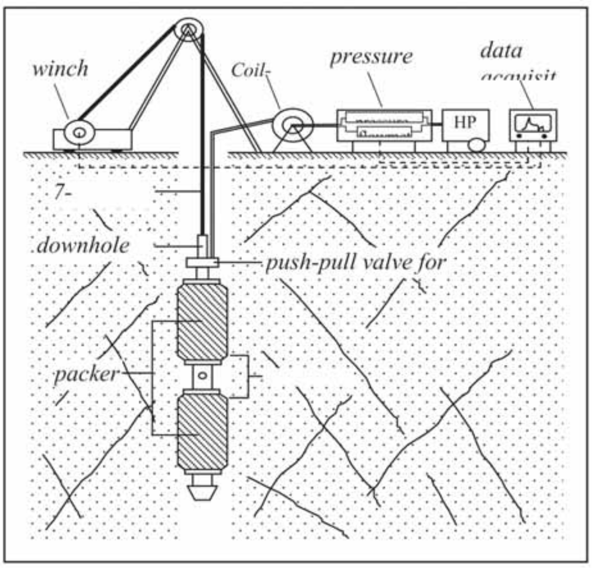


Fig. 5. Schematic view of the wire-line packer testing system

Initially, in-situ stress measurements by hydro fracturing were conducted through a surface borehole drilled in GDK-8A Inc., area. It was the first time to conduct such tests through a surface borehole in coal mining industry. M/s Mesy (India) Pvt Ltd, a joint venture company with Mesy Gmbh, Germany is carrying out insitu stress and permeability tests in deeper boreholes in India. One of such studies was carried out in a deep borehole (531m depth) in the Adriyala shaft block of Ramagundam of Andhra Pradesh. Subsequently, in-situ stress studies were undertaken in the KTK LW block (Warangal District, AP) and Shanthikhani LW block (Adilabad District, AP). Altogether, SCCL has spent about Rs 1.4 crores for carrying out the studies successfully in the above blocks.

The in-situ stress data thus generated serves as a vital input for numerical modeling to carry various simulation studies.

Hydro-geological investigations

The Hydro-geological studies in the coalfield areas are aimed at assessing the probable inflow of water when the mine is opened up, and also to assess the cause of seepage of water into the mines, so as to recommend appropriate control measures by evaluating hydraulic parameters and estimating the probable inflow of water into the proposed mine workings. This requires drilling and construction of pumping and observation wells, development of wells, conducting Aquifer Performance Tests and Groundwater modeling. Alternatively SCCL is installing Vibrating wire Piezometers in different aquifers in a borehole at various locations in and around the block to assess the impact of mining on ground water regime.

All the above pre-mining studies were conducted to acquire information on embedded strata of coal seams, which certainly help in designing suitable layouts for longwall panels.

Geo-modeling

The Horizon module of Minex is an extremely useful software for the creation of Geological 3D Model of a coal deposit. Magnitude of Geo-model work is directly proportionate with increase in number of stratigraphic layers, faults and structural complexity in a block.

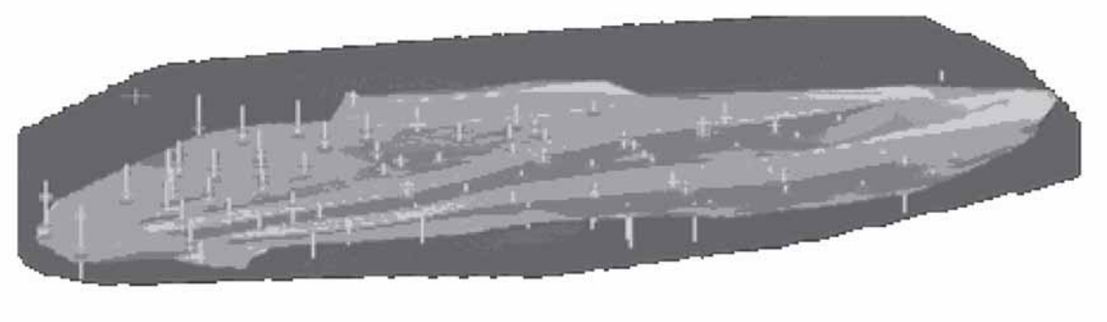


Fig. 6. 3D Geological model of Sattupalli Block-I

Good understanding of the structural set-up viz. fault disposition, their effects on seam and their displacement etc., and customized way of using various options and menus of Horizon will help in creation of a realistic 3D geological model of a coal deposit in a faster way (Fig. 6). Thus, the 3D geological model data also helps in preparing mine layout plans at a faster rate.

High capital intensive drilling

At present SCCL exploration average targeted meterage is about 330m per month per drill. To meet the additional drilling requirement for generating required geo-technical data as well as to delineate the geological structure in more detail to suit to various mining technologies in deeper blocks, it is proposed to procure High Capacity Hydrostatic deeper Rigs. Additionally, the exploration in the deeper parts of identified blocks can also be taken up facilitating deciphering of structure as well as proving reserves at a faster rate.

It is also being proposed to take up directional drilling to establish the continuity of the seams as well as to confirm the geological structure further at deeper depths of identified shaft blocks. Directional drilling will also be planned to prove continuation of seams / for conformation of structure in the areas covered by hills, forest, other surface constraints etc., adjoining to mining blocks in collaboration with external drilling agencies.

Conclusions

Exploitation of mineral resources is a key factor for the economic growth of a country. The role of exploration geo-scientists is to look for unknown manifestations of the deposit parameters and ensure minimizing the risks during its extraction. Well planned and executed exploration programmes of both time and cost effective nature will ensure taking well informed decisions on the basis of data generated by these advanced exploration techniques, minimizing the risks. In the interest of safeguarding huge investments in the mining industry, it is imperative that pre-mining exploration and geological services at the active stage of mine development are mandatory. Expenditure on exploration in acquisition of comprehensive database is negligible when compared to the huge investment likely to follow during the course of mining.

Acknowledgements

The author is thankful to the Management of The Singareni Collieries Co Ltd for kindly according permission to submit the paper to the Seminar. The views expressed in this paper are those of the author and need not be of the organization he belongs to.

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PENTADYNE-HP

An Innovative Technology on the Indian Horizon to Facilitate Acceleration of Coal Production in Underground Coal Mines

P-5 EXPLOSIVE HAVING HIGHER AIR GAP SENSITIVITY (AGS) OF 15 cm FOR USE WITH SPACERS IN BLASTING OFF-THE-SOLID FOR HIGHER PULL AND MORE COAL OUTPUT

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Introduction

In Bord and Pillar method of underground coal mining, galleries or roadways of approx 3 m height and 4.0 m width are developed in the coal seam, perpendicular to each other, leaving solid pillars of coal between the galleries to support the roof of the coal seam for safe working. In seams, which are less than 3 m thick, the height of gallery is limited to seam thickness.

The development of galleries is normally carried out using explosives and two methods are in vogue:

a) Blasting against a machine cut face – in this method, a Coal Cutting Machine (CCM) is used to mechanically excavate a slice (cut) in the coal seam of approx 15-20 cm height and 1.2 to 1.5 m deep. Coal cutting machines are designed to provide a bottom cut or mid cut or top cut. Normally 2 rows of shotholes are drilled in the solid coal above or below the cut and the depth of shotholes is 15 cm less than cut depth. All shotholes in a row are blasted instantaneously using permitted category Instantaneous Electric Detonators and permitted explosives commensurate to the degree (gassiness). It is common to fire the blast in two rounds. The machine cut acts a free face for the shotholes to fire into, thus preventing blown out shots. Blasting with cut face yields more lump / round coal.

b) Blasting coal off-the-solid (Solid Blasting) – in this method shotholes are drilled in a pattern in the coal face, charged with permitted P-5 category explosive and blasted sequentially using permitted category millisecond delay detonators. This method is called as Blasting off-The-Solid due to absence of free face. The initial free face is created by blasting set of shotholes drilled in a wedge or fan form (cut holes) with an optional stab hole. The cut area is initiated first using detonator of lower delay number and then enlarged to the gallery size by firing more shotholes in a desired sequence using detonators of higher delay number. In mines of degree I, II & III gassiness, blasting off-the-solid is allowed only with P-5 explosives and electric millisecond delay detonators. The delay between two consecutive shots should not exceed 60 milliseconds and the total duration of the blast should not exceed 150 milliseconds in case of degree I & II mines and 100 milliseconds in degree III mines.

Figures 1 and 2 gives the shothole patterns for cut face and solid blasting respectively (Ref: 4)

Degree of gassiness	Blasting with machine cut face - explosive category and charge per shothole (grams)	Blasting Off-The-Solid using P-5 category - explosive charge per shothole (grams)
Degree I	800 with P1 category explosive	1000
Degree II	1000 with P3 category explosive	565
Degree III	1000 with P5 category explosive	565

Since gallery width is more or less fixed, the output of coal in a blast is dependant on the seam thickness or height of operating gallery. Powder factors (average) achieved with the two types of blasting are as under:

Type of Blasting	No. of Shotholes	Shothole depth (m)	Powder Factor (t/kg)
Solid Blasting	12	1.2 – 1.4 m	2.0 to 2.8
Blasting with Cut face	8	1.2 – 1.4 m	5.0 to 7.0

Blasting coal off-the-solid (Solid Blasting) using permitted category P-5 explosives and millisecond delay detonators with the explosive cartridges loaded end-to-end is being practiced for last few decades in Indian underground collieries. In Degree-I underground coalmines, maximum explosive charge allowed is 1000 grams, which occupies a charge column length of approximately 1.0 – 1.05 meters. In a shothole of 1.4 meters length, pull between 1.0 to 1.2 meters is achieved yielding blasted coal of 10-16 MT commensurate to face dimensions and seam thickness (height).

Use of Load Haul Dumpers (LHD) in underground coal mines require minimum 35 – 40 MT of blasted coal in the faces for their optimum utilization. This paper describes the results achieved with new product PENTADYNE-HP, a P-5 category permitted explosive having high Air Gap Sensitivity (AGS) and spacers, for carrying out blasting off-the-solid in degree-I mines.

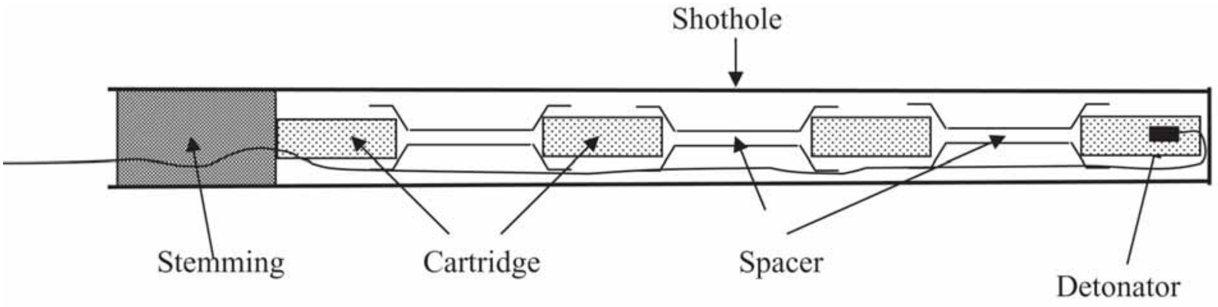
The Innovation

PENTADYNE-HP is a permitted P-5 explosive, having high air gap sensitivity (AGS) of 16-18 cm in open and 20 cm in PVC pipe confinement. This was developed by the R&D Department of Explosives Division - Gulf Oil Corporation Limited, Hyderabad for Coal S&T Project of Central Institute of Mining & Fuel Research (CIMFR) titled “A Method Of Solid Blasting In Underground Coal Mines For Improvement Of Pull In Development Faces Using Air-Decked Cartridges” (Patent filed by CMRI No. 1538 DEL 2005: Author - Sanjay Kumar Roy).

PENTADYNE-HP enables carrying out blasting using air decks within a shothole in underground coalmines. The air gaps are provided by using hollow thin-walled PVC spacers suitably shaped to accommodate a 32 mm diameter cartridge on either end (see photo and sketch below). The spacers are designed to provide an effective air gap of 15 cm between the explosive cartridges. The higher air gap sensitivity ensures continuity of detonation of the explosive cartridges separated by spacers inside the shothole, unlike gallery blasting where the cartridges separated by spacers are set-off using permitted detonating cord. For small diameter permitted and non-permitted Class-2 explosives, the Bureau of Indian Standards (Draft) specifies AGS of not less than 2 cm only.

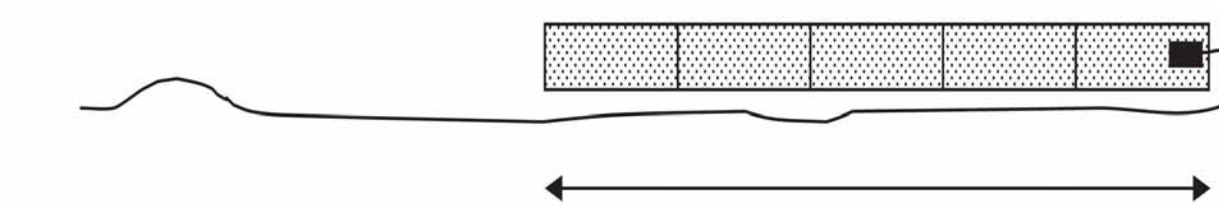
In the context of using an air deck, blasting-off-the-solid (BOS) is carried out using Pentadyne-HP and Coal Delay Detonator in the conventional manner, except that the explosive cartridges are separated by spacers described above. For the same number of explosive cartridges in a shothole, use of spacer results in increased charge column length, which enables increasing the depth of shotholes drilled in coal face, resulting in increased pull and higher output of coal. Increased coal output results in higher powder factor (t/kg) and detonator factor (t/detonator) (Ref:1).

Sketch below gives the configuration of primer cartridge (reverse initiation), explosive cartridges separated in spacers and stemming inside a shothole.

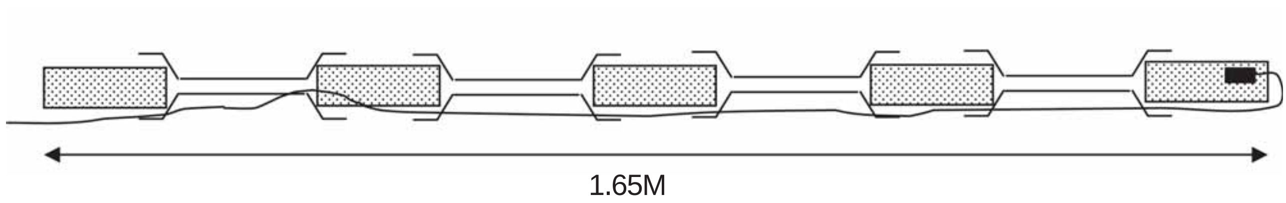


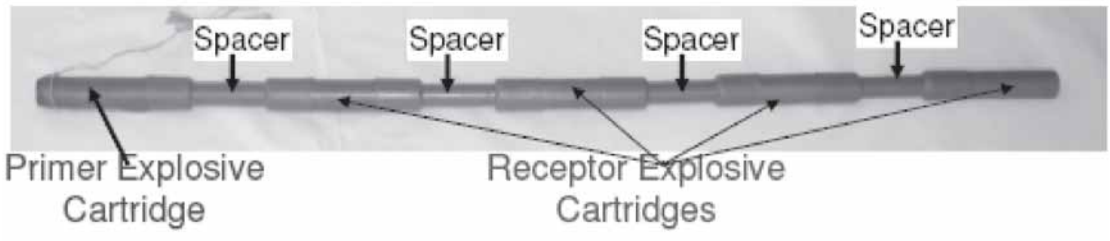
(Sketch NOT to scale)

5 explosive cartridges of 200 grams each (viz 1000 grams) when charged ‘end-to-end’ occupy a charge length of 1000 mm to 1050 mm (1.0 to1.05 meter) in a shothole. When charged in a shothole of 2.4 m depth, 1.35 m remains empty.



For achieving 35 - 40 MT of coal per blast for LHD to operate optimally, minimum pull (advance) required is 2.2 m for a face dimension of 3.5m x 3.5m or 1.9m for a face dimension of 3.5m x 4.00m. The depth of shothole should be around 2.4 m. 1000 grams per shothole charged with 5 cartridges placed between 4 spacers effectively increases the charge column length to approx 1.65 m, thus bringing down the uncharged length to 0.75 m.





(Photo: Courtesy Dr Sanjay Roy, Explosives & Explosion Lab, CIMFR Dhanbad- Ref: 2)

Details of trials and results achieved with Pentadyne-HP

Field trials have been carried out successfully without a single misfire of explosive cartridge at Singareni Collieries Company Limited and Monnet Ispat Energy Limited.

Normal shothole depths with hand held electric drilling machines is 1.4 – 1.5 m. With extra effort, the drillers are able to drill upto 1.8 meters manually. During trials, drillers co-operated and manually drilled shotholes upto 2.4 m depth. GDK-5 Incline, Ramagundam Area-I of Singareni Collieries Co Ltd have acquired Universal Drilling Machine (UDM) which has been deployed in de-pillaring faces for drilling shotholes of 2.4 – 2.6 m depth. With this machine, dependency on manual drilling for deep shotholes has been eliminated.

GOCL Engineers in close association with scientists of CIMFR's Explosives & Explosion Laboratory carried out more than 100 blasts at GDK-5 Incline of SCCL and Milupara Mine of Monnet Ispat Energy Limited during 2008-09 in both Development and Depillaring Districts using variants of parallel hole patterns. At SCCL, coal output of 35 to 45 MT was achieved in gallery dimension of 4.0-4.4 m x 3.6 – 3.8 m with pull (advance) between 2.0-2.2 m. At Monnet Ispat's Milupara underground coalmine, 20 – 22.5 MT of coal was obtained in coal faces of dimension 4.5 m x 2.5 m using shothole depth of 2.0 m. (Ref: 5).

CIMFR's Blasting Department also carried out independent consultancy project with SCCL for achieving longer pull (advance). Modified Parallel Shothole cut and Modified Angled cut (wide V-cut) were used in both development and de-pillaring faces Modified Parallel Hole pattern yielded upto 28.5 MT in development and upto 45 MT of coal in depillaring faces with average pull between 2.0 – 2.1 m. With Modified V-cut, upto 35 MT in development and upto 50 MT of coal in depillaring faces was achieved with pull between 2.0 – 2.2 m. Average depth of shothole was 2.4 m and charge per shothole was 1000 gm in cut holes, 800 gm in side holes and 600 gm in top holes. Gallery width in development faces was 3.2-3.8 m and height varied from

2.5-2.8m, while in depillaring faces, gallery width was 4.0-4.2 m and height 3.8-4.0 m. CIMFR also recorded the ground vibrations in the roof. Peak Particle velocity (PPV) recorded was 3.62 mm/sec at a distance of 52 m and 106 mm/sec at a distance of 15 m. Maximum charge per delay during experimental blasts varied between 3.2 and 7.8 kg. The full details of work done by CIMFR's Explosives & Explosion Laboratory and Blasting Department are available in References: 2 and 3.

Figures 3 and 4 give an idea of parallel hole patterns used during trials.

Trials have also been completed in underground coalmines of Coal India Limited (CIL) in the presence of Officials of Central Mine Planning & Design Institute (CMPDIL), for inclusion of Pentadyne-HP in list of products approved for use in CIL mines.

It may not be out of context to mention that the explosive met DGMS stipulated limits of Carbon Monoxide (50 PPM) and Nitrogen Oxides (5 PPM) in the after blast fumes. In view of higher pull obtained with Pentadyne-HP, the extent of unsupported roof increases after the blast and mine has to ensure providing adequate support to the increased area of exposed roof.

Conclusions

1. PENTADYNE-HP is ideally suited for achieving high 'advance' (pull) amongst permitted explosives in India, in view of its high Air Gap Sensitivity (AGS) which enables use of spacers between explosive cartridges to extend charge column. Only PENTADYNE-HP has been approved by DGMS for carrying out Solid Blasting using spacers (presently in Degree-I mines).

2. In view of high air gap sensitivity, PENTADYNE-HP does NOT require the use of detonating cord (as used in gallery Blasting) to initiate explosive cartridges placed between spacers.

3. Maximum charge per shothole allowed by DGMS in Degree-I mines for Blasting Off-The-Solid (B-O-S) is 1000 grams (I Kg). Use of spacers between explosive cartridges increases charge column length for same charge weight in a shothole and assists in higher pull (advance).

4. Achieving a pull (advance) of 2.0 to 2.2 meters with shothole depths of 2.4 – 2.6 meters to obtain a yield of 35 to 45 tonnes of blasted coal in a single blast has been demonstrated successfully.

5. Use of Pentadyne-HP would facilitate increasing the productivity and OMS of the underground coal mine without high cost investments and using available resources. Mines have to invest in UDM (Universal Drilling Machines) and low cost spacers made with same material as used in Gallery Blasting.

6. Use of shotholes of 2.4 to 2.6 m depth would require electric delay detonators with 3.5 – 4.0 m long leadwires for easy and proper series connections.

7. Use of full series of millisecond delay detonators viz delay numbers 0 & 1-6 in a blasting round is recommended for achieving longer pull.

8. Since longer pull results in higher extent of roof exposure, adequate precautions need to be taken in terms of support immediately after the blast.

9. As per DGMS permission, spacers for use with Pentadyne-HP should be of the quality used in BG panels and the average weight of spacer should not exceed 21 grams. Air deck length between two cartridges of Pentadyne-HP should not exceed 15 cm.

Acknowledgement

The authors thank the Management of Gulf Oil Corporation Ltd for according permission to present this paper. The comments are of the authors and not necessarily of the organization they represent. Authors thank Dr S K Roy & Mr. R R Singh, Scientists of Explosives & Explosion Lab and Dr P Pal Roy & Dr C Sawmliana of Blasting Department of CIMFR, Dhanbad. Authors also thank the Managements of Singareni Collieries Co Ltd and Monnet Ispat Energy Limited for all help and co-operation rendered for carrying out trials with Pentadyne-HP reported in this paper.

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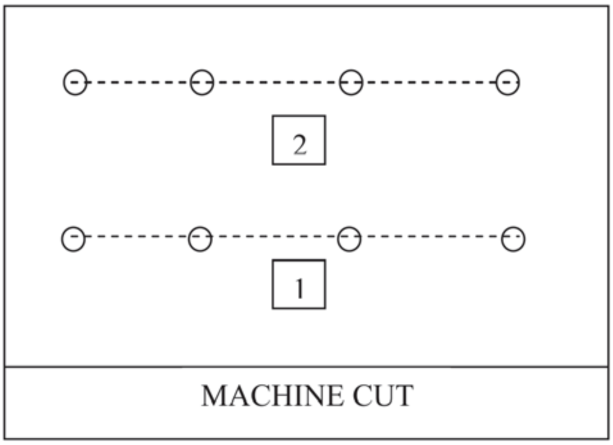
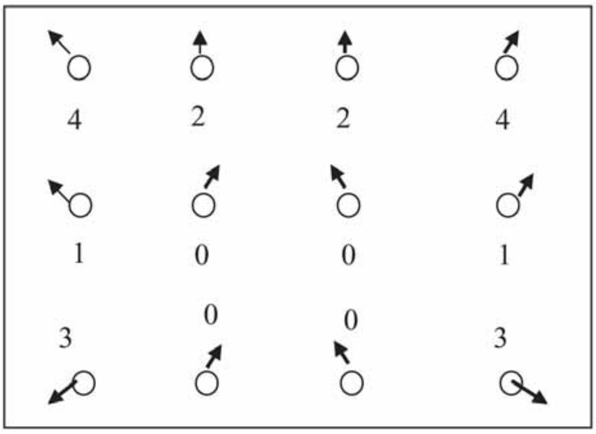


Machine cut showing Under - Cut.

Two rows of shotholes drilled and the shotholes are fired instantaneously, preferably in two rounds. The numbers indicate sequence of firing the shotholes.

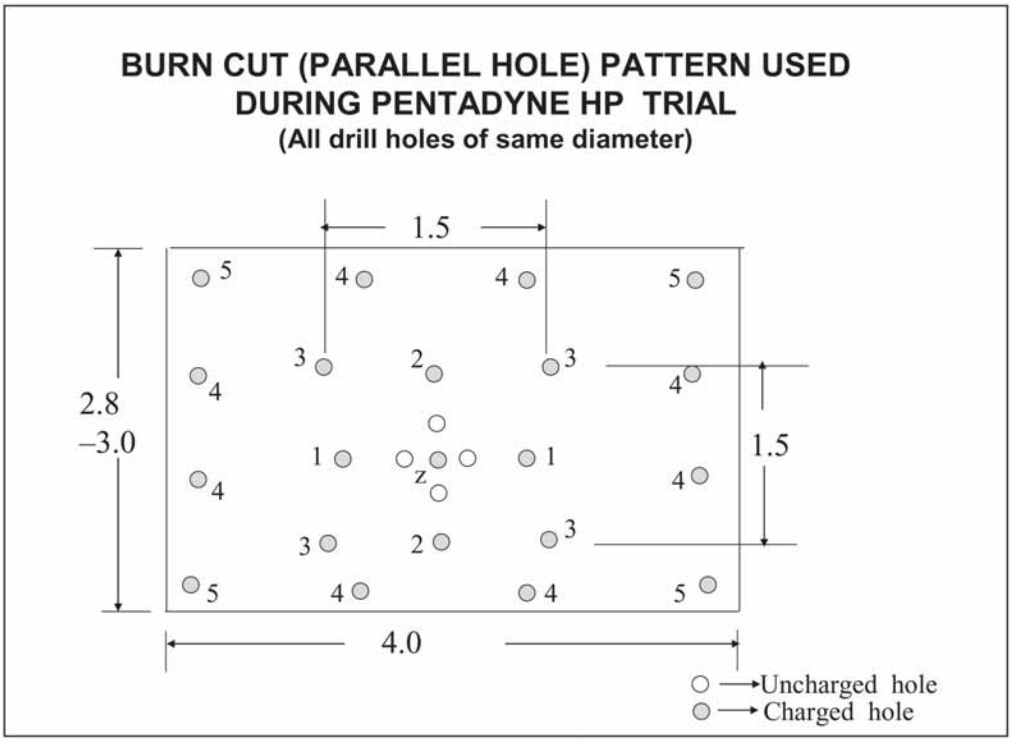
Figure-1



Blasting off-The-Solid

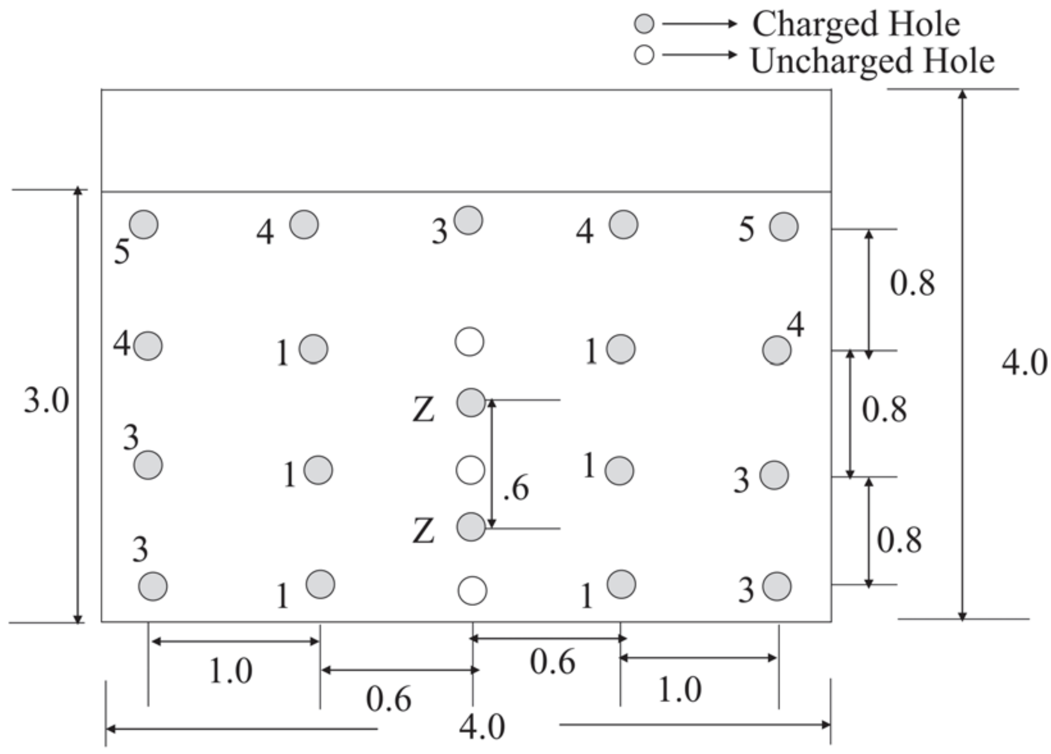
Shotholes are drilled in a pattern, charged with P-5 category permitted explosives initiated with millisecond permitted delay detonators. The numbers indicate delay detonator number.

Figure -2



(Dimensions in metres – not to scale)

PARALLEL HOLE PATTERN USED DURING PENTADYNE HP TRIAL(All drill holes of same diameter)



(Dimensions in metres – not to scale)

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HOW SAFE ARE OUR MINES?

** Suresh,*

Concern for man and his fate must always form the chief interest of all technical endeavors. Never forget this in the midst of your diagrams and equations.

- Albert Einstein

COAL SCENARIO

- Coal is the prime source of energy
- Coal production from opencast - 85%
- Coal production from underground -15%
- Expected demand gap by FY 2012 will be 100 Million tonnes.
  Mineable reserves from opencast fast depleting.
- Most of the reserves lie in areas covered by forests, dwellings
- Constraints in obtaining environment clearances.
- Land acquisition problems-reluctance, delays in surrendering.
- Only option is to produce coal from under ground mines at competitive price.
- Over the years underground mining has been manpower intensive.
- Production was directly proportional to strength of manpower.
- Enhancement in production was only incremental.
- Introduction of mechanization was tentative and slow.
- Multiple activities and concentration of men at face exposed them to dynamic roof conditions.

NEED OF THE HOUR

- Make a turn-around by enhancing safety production and productivity.
- Reduce the exposure of men for improving safety.
- Introduce appropriate technologies for mass production.
- Mechanize the coal getting operations, supporting systems and transport.
- Pay attention towards the men, methods (processes) and machinery for achieving success.

THE CHALLENGES

- Most of the men are illiterate or semi-literate.
- We have to deploy the employees who were hitherto working as manual loader on machines.
- Development of skills requires sometime and cannot be achieved over-night.
- Correction of mis-matches between existing and proposed infrastructure facilities.

CGM (Mktg & Mvmt), SCCL.

TRAINING

- People factor is of prime importance for a successful process.
- Training shall be based on identified needs.
- Train the brains to evoke a positive, proper response at an appropriate time.
- Special attention shall be paid to team building, as the employees have to take care of each other in-group activities.
- A reserve pool of multi skilled employees shall be available to press them into service in case need arises.

ENVIRONMENT

- Mechanization along with its advantages brought some challenges in the form of higher emission of heat, generation of high volumes of air borne dust.
- Simulation of ventilation networks and advance action regarding provision of proper environment to serve the life of the mine are a must.
- Working in deeper mines necessitates special methods to deal with gas, dust.
- Application of cooling mine air to improve environment will be the order of the day.
- Suitable methods for drainage of methane shall be adopted.
- Special clothing to give protection from heat & humid atmosphere shall be provided to the employees
- Sample study shall be conducted regarding health of the persons exposed to abnormal environmental conditions.

TRANSPORT

- Mechanization of underground mines requires transport of large quantities of material, handling of heavy equipment/machinery.
- For an optimum utilization of equipment men are expected to reach the spot in time.
- To reduce the fatigue in travel and operations, men have to be provided a speedy and safe transport facility to the nearest possible point from the work spot.
- Special and safe methods have to be evolved to handle the heavy materials.
- Mass production from the mines demands installation of heavy-duty conveyors, intermediate storage systems.
- Sequential operation system shall be utilized to avoid interruptions in transport.
- Installation of Koepe winding system shall be thought of for faster evacuation of coal from deeper deposits.

STRATA CONTROL

- Studies of strata behavior to overcome difficulties in managing overlying hard roof layers.
- Pre-determine details of geo-mining conditions, geo-engineering parameters.
- Guidance of reputed Indian and international institutes must me utilized for introduction of appropriate mechanization.
- Special studies shall be undertaken for extraction of coal beneath built up areas.
- Pre-determination of the bump/rock burst prone areas must be done to take timely safety precautions.

EQUIPMENT

- Select equipment most suitable for the present and proposed future sites
- Evolve and adopt best safe operating and maintenance practices.
- Advance action shall be taken to keep an inventory for uninterrupted supply of spares.

CONCLUSIONS & RECOMMENDATIONS

- For a safe productive and successful mine management we shall have passion for excellence and compassion towards our hard working miners.
- Initiate steps for creating a healthy environment at home and at work place.
- Motivate the people by providing avenues for elevation.
- Involve people in decisions pertaining to safety and work related issues.
- Efforts shall be made to bring in attitudinal changes.
- Selection of person and his training shall be given an equal importance as that of the machine.
- Preparation, updating of risk management plans shall be done religiously.
- Set benchmarks in safety standards and never compromise on them.

Ultimately we can conclude that our mines are as safe as we think, because we are the people who set the standards.

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Strata Monitoring in SCCL Mines – Some Experiences

Dr. K. Srinivas & Dr. K.V. Shanker**, Mr. P. Balamadeswaran[$]*

ABSTRACT

Shallow coal deposits are exhausting with time in India and hence the future of coal mining in this country lies with Underground mining of deep-seated deposits. The problems to be faced in these deep underground mines would be many and one of the important, from the safety point of view, is strata control. The efficacy control can be ascertained by proper monitoring and analysis of various parameters of strata like convergence, rate of convergence, C_1 / C_2 ratio, deformation of different immediate roof layers, load on the supports, stress on the pillars including the barriers vis-à-vis the roof falls (strata movement), distance up to which front abutments extend, etc.

The Department of Mining Engineering, Anna University has carried out number of strata monitoring investigations in the underground mines of SCCL in variety of situations, namely, extraction by Longwall, Bord and Pillar by caving and stowing, development of retreat longwall gate roadways under goaf, etc.

These investigations provided interesting and useful information relating to the maximum convergences and rates of convergence different strata can tolerate without collapsing, height up to which roof layers have deformed, stresses in the pillars and the barriers, maximum load on the supports during different weighting periods, behaviour of the chock shield supports during the loading cycles, etc. A variety of instruments from different manufacturers have been used and certain difficulties were encountered in using them.

This paper deals with important findings of the said strata monitoring investigations, which will be useful in designing the mining parameters and support systems in future. Certain remedial measures for the optimum utilisation of the instruments for improving the effectiveness of strata monitoring have also been proposed.

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Information Technology Applications in Mining Industry - Experiences in SCCL

*B. Bhaskara Rao,

Next to industrial revolution, the internet and information technology has shown highest impact on the society. The IT revolutionized every walk of life whether it be manufacturing be business, be art or be social life. The mining industry can be no exception. However the mining industry lag the rest of the activities in adopting the latest trends due to its complexicity. The objective of the paper is to bring out the experiences of the Singereni Colleries Company Limited in harnessing information technology.

The key activities in pre-mining stage are Exploration and geological modeling, Mine planning including Environment management plan, Project clearance till commissioning of the project. During operation phase short term planning & scheduling, machine maintenance & operations and production, coal quality management , safety are the critical components. The key components are essentially to be supported by allied activities like manpower management, material management, logistic support and management. The results of all these activities converge into Finance.

The successful IT adoption is influenced or limited by data acquisition systems which include systems like SCADA , communication channels and at the end converging into logical analysis of the data. In the following sections , the status of IT applications in SCCL in various fronts is discussed.

PROJECT CONSTRUCTION

Exploration and geological modeling is the foundation of the mining activity. The data acquisition and interpretation is complex. SCCL has modernized the exploration techniques. Minex software is procured during 2004 itself for geological modeling.

Mine planning , similar to the geological modeling , has greater component of interpretation of the data. The packaged software supplement the human effort and accelerate the project preparation. SCCL has all its plans in digital mode on autocad platform and autocad is extensively used in mine planning. Minex is also used in mine planning. Now as more user friendly and less expensive software are available and it is planned to procure the for mine planning.

In summary it is to mention that the mining project planning is highly specialized activity with high degree of integration with geo spatial data. Hence only a suitable specialized packaged software can meet the requirement.

*General Manager, Adriyala Area

The interpretation of geospatial data for various purposes like Land use pattern and environment monitoring is carried out through external expert agencies. ERDAS and other specialized software are used to meet the above requirements.

Once project is approved , the execution of the project is monitored. This activity is common to any 'project management system'. Monitoring execution of key activities , time and cost over runs are best fit into any standard system. As such SCCL is seriously considering to utilize the PROJECT SYSTEM module in SAP in the immediate future.

SCCL has initiated various steps to harness Information technology in these aspects. In coming years it is contemplated to expand the usage of the specialized mine planning software.

PROJECT OPERATIONS

Short term scheduling and planning be in OC mines or in UG mines is now facilitated by autocad plans. SCCL has all its statutory and non statutory plans in digitized format. Hence the plans with desired features and desired scale are generated with ease and accuracy. This enhanced better planning of mines for safety or for normal operations.

Mine Survey - In addition to the mine plans SCCL has modernized the survey instruments with early introduction of Total Station Instruments, GPS bases survey instruments and Laser scanners.

Mine Management System (MMS) - Day to day operations in operating mines include manpower allocation and utilization as well as Machine maintenance and production performance. These activities are similar to any industrial operations and can be supported by standard ERP. But considering their integration with geospatial data like mine plans and allied systems like safety and quality SCCL has strategically adopted to develop a customized package which will have greater flexibility in initial phases. Two variants of **the Mine Management System (MMS)** – UGMMS for UG mines and OCMMS for OC mines is implemented in all mines of SCCL. The scope covers all basic activities at the mine. Salient features include :

- Attendance booking of the workmen directly into the system which generates the data for wage payment. The attendance to payroll process is totally paperless process.
- the allocation of manpower , the machine availability and deployment and capturing the operating performance production. The shift end production reports are generated from the system.

OITDS - Operator independence truck dispatch system is introduced at one pilot opencast project for real time monitoring of HEMM (Shovels & Dumpers) to maximize their utilisation. With evolving new technologies like RFID, video analytic and the availability of multiple wireless communication methods and standards, the possibilities of low cost options are under examination by SCCL.

Safety of the men , machinery and mine is the single most critical component of the mine operations. Enhanced mine safety is essentially possible only by harnessing the information technology whether by process controls are by data analysis and administrative controls.

- ***Ventilation net work analysis*** : SCCL has acquired software and developed skill sets to analyze the ventilation networks of any mine internally and take up improvements. The software 'VENTNET' is in use.
- ***strata control***: Numerical modeling software flag 2D or 3D are widely customized to the Indian context and various scientific institutes are providing support for conducting studies at various sites and situations . These studies are facilitating for successful introduction of new methods of mining. SCCL is considering the procurement of the above software and building internal capability for strata monitoring more scientifically.
- ***On line gas monitoring***: SCCL has introduced sensor based tele-monitoring of gases in BG panels and other such specific locations. However difficulties are encountered in maintaining them due to non availability of spares and non availability of the expertise locally.

Accident analysis is a standard statistical management tool for accident prevention. SCCL has developed web based in house software where the occurrence of accident is recorded at the mine, injury and treatment details at the hospitals. The occurrence of serious accident is intimated to the connected senior officers by automated sms. The system generates all statutory reports and accident analysis reports.

Statutory trainings at VTC and fitness in Periodical Medical Examination (PME) is mandatory for every workmen deployed in underground. The details are now captured into central database. The automated validation of the statutory compliance is contemplated once the past 5 years data is updated.

Technologies are evolving for monitoring of various parameters on line and disastrous management system. Deployment of such technologies was limited due to high costs involved and due to the large number of manpower and locations to be monitored in the conventional hand section mining. With increased mechanization and concentration of extraction areas it shall be possible to adopt such technologies. SCCL is closely examining the S&T projects in development of sensors and UG communication to adopt them on commercial scale.

Enterprise Wide Resource Planning (ERP)

Mining activity can be safe and efficient only if all the supporting functions are effective. Material Management, Human Resource management and Sales and Distribution are the most important which directly influence the mine operations. All these activities and mine operations converge finally as Financial Performance.

SCCL had number of in-house software to support various processes in these functions. But these applications were not integrated and were on local servers. This was leading to the inconsistency in the data and delayed information to the top management.

These activities are not industry specific but are mostly similar across the industries. Hence SCCL took the bold initiative of implementing highly integrated packaged ERP solution for the first time in Indian coal mining.

SAP is implemented during the year 2008. The initial scope is inclusive of MM (Material Management), SD (Sales and Distribution), HR (Human Resources) and FICO modules.

Salient features and benefits derived are

- The implementation has brought visibility of the inventory across the company.
- The coal dispatches are integrated to the digitisers at the weigh bridges and billing is on line.
- The customer and vendor settlements are accelerated.
- The system is driving financial discipline and operational efficiency into the industry.

The scope of ERP is to be expanded to on stabilization of the existing scope.

Allied activities

SCCL has a strong in house software development team. The team provides the customized solutions for various auxiliary requirements.

Some of the solutions provided are as below:

- Daily production reports.
- Capturing suggestions on mine safety from employees
- Grievances redressal system
- Monitoring internal transportation of coal to CSP and Washeries.
- Monitoring of Oxygen percentage in sealed off Areas and face temperatures monitoring.
- Repair activities at Area workshops and monitoring status of repairs of sub assemblies.
- CMPF management of contract labour.
- Bills preparation in civil activities.

It is to summarise that SCCL has adopted Information technology in all its operations. ERP-SAP is adapted to the standard business activities. Various mining specific packages are adapted for the specific purposes like geological modeling, ventilation. The core operations are supported by customized software Mine Management System. Various auxiliary operations are provided with in-house software.

Future Plans

- Though MMS system is meeting the operational requirements at the mine, the lack of its integration with finance and SAP limits the integrated on line report generation. Hence there is need to migrate the production planning and machine maintenance functionalities to SAP.
- Mining operations are depended on geospatial data. At present the business data and the plan data are independently available. It is essential immediate need to provide integrated information system on GIS platform. Steps are already initiated in the direction.
- The communication infrastructure (both data and voice) over ground is established and the

central server is accessible at every 'office' on surface. But the connectivity to below ground and to the active mining areas in opencast mines is yet to be done. This limits both the data acquisition as well as data utilization. On line monitoring of various parameters will be possible if the communication channels are established. There are no appropriate proven and approved systems for mining environment. Development of such systems is to be done in collaboration with potential vendors.

- Various new technologies are popular now. RFID, Video analytics, GPS are some of the emerged technologies which can have a major role in mining industry. However identification of the need and development can occur only if the mining and electronic industries work coherently. Further these applications need to be integrated with ERP.
- Various specific purpose software like ventilation network analysis, numerical modeling software are not integrated with the geospatial data or ERP. It is necessary to bring such silos of information on to an integrated platform.

Critical Success Factors:

The key factors determine the success of IT implementations are:

- The IT implementations are nota simple introductions of new technologies. They are personnel oriented. Integration of people and change management are the factors which determine the success.
- The support and involvement of the top management is the most critical and essential factor for the success.
- The IT projects are to be lead by the functional leaders who can orient the business need to the implementation. The technology shall play a supportive role.
- Most IT projects fail due to improper scope management. While the big pictures shall always be defined first, the implementation shall be carefully scheduled duly considering the people factors. The standard approach of THINK BIG, START SMALL and SCALE UP FAST is suitable for successful projects.
- While designing the scope the infrastructure limitations are to be duly factored.
- As IT implementations are mostly people oriented, training on regular mode is necessary till it is totally absorbed by the people.

Conclusion:

Information technology like any other field has great potentiality to impact safe and sustainable mining. However mining industry need to understand the evolving technologies and how each can find a place in mining. With active industry involvement and coherent working of all agencies involved the 'ART of mining' shall emerge as 'SCEINTIFIC mining'.

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EXTRACTION OF DEVELOPED PILLARS BY YIELD PILLAR NON-CAVING METHOD WITH CONTINUOUS MINER TECHNOLOGY AT VK 7 INCLINE, SCCL – A CASE STUDY

Ch. Vijaya Rao, General Manager, Kgm

H.Veeraswamy, Agent, UG Mines, Kgm.

1. Introduction

Venkatesh Khani No.7 Incline (VK 7 Incline) was started on 15.08.1954. The Mine is situated at about 10 km from Kothagudem in Khammam District, AP. It is 297 km away from state capital Hyderabad. The mine take area is 748 Ha with 155 Ha Non-forest land and 593 Ha forest land.

The mine is having 4 seams, viz. Queen Seam, Index Seam, King Seam and Bottom Seam. The average gradient of the seams is 1 in 7. The details of the seams are given below.

Seam	Thickness in m	Parting	Depth	
			Min	Max
Top seam (Queen Seam)	9 - 11		62	357
		15		
Index	1.2		112	141
		25		
King Seam	5.5 – 10.5		125	425
		5 – 6		
Bottom Seam	3 - 6		149	298

There are 5 openings to this mine – two inclines and three shafts (two return air shafts and one intake cum man winding shaft). Man winding shaft was established in 1974.

Top seam

Top seam was developed up to 98 Level and further development was stopped due to inferior quality of coal. Longwall Technology was introduced in the year 1985 in this seam. A total of 19 longwall panels were extracted with powered roof supports in this mine. At present, Panel No. T-17 is under extraction by depillaring with caving using Load Haul Dumpers.

King seam

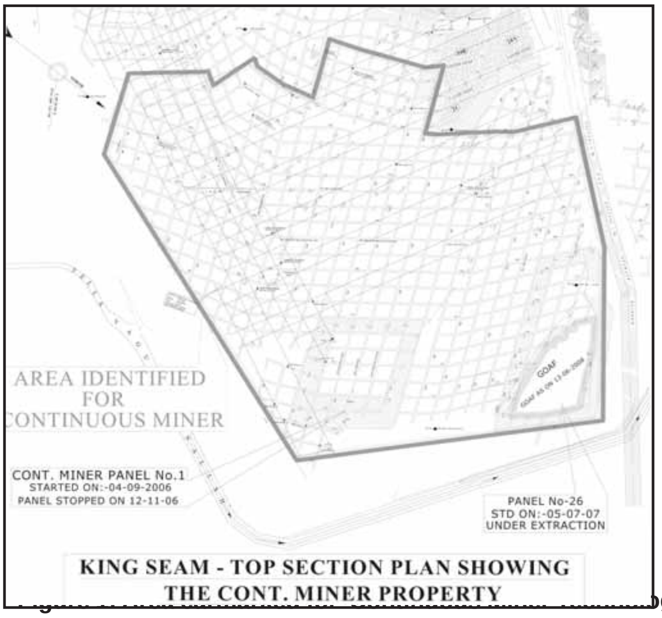
In King seam development was completed along roof up to the proposed boundary. So far five BG panels were extracted with full seam height and 19 panels were extracted with conventional depillaring.

Bottom seam

Bottom seam is developed up to 31 Level in North side boundary and 42L in the South side boundary. Dip side development could not be done due to thinning out of the seam i.e. less than 1.0 m. So far five panels were depillared with hydraulic sand stowing.

The age of the King Seam developed workings is more than 20 years and extended up to a depth of 325-425m. About 7 million tonnes of coal is locked up in developed pillars below 250m depth line. The property above 250m depth line was earmarked for opencast mining. For faster rate of liquidation of standing pillars in King Seam it was planned to extract the dip side property by Continuous Miner Technology. The area identified for Continuous Miner Technology is shown in Figure-1. Accordingly, Continuous Miner Technology was introduced in King Seam in 2006 in CMP-1 Panel with caving method. CMP-1 panel was started in August 2006. By November 2006, 4 pillars were extracted and a roof fall accident occurred on 12.11.2006. The extraction was stopped. Later a detailed study was made to suggest alternative methods and it was recommended by M/s Joy / RMT, UK to extract the standing pillars by Yield Pillar Non-Caving method with Continuous Miner and Shuttle Car combination, keeping in view the specific geological conditions in King Seam.

One panel i.e. CMP-2 was extracted by this method. In this paper the experience of Yield Pillar non-caving method at VK 7 Incline is elucidated.



...ogy

2. Details of CMP-2 Panel

Seam	:	King seam
Panel dimensions:		Length-225m, Width – 175 m
Minimum Depth cover	:	367.86 m
Maximum Depth cover	:	403.5 m
Area of the panel	:	39375 m^2.
Average size of pillars	:	45m x 45 m
No of pillars	:	20
Total coal extractable in one pillar	:	6987 tonnes
Total coal available in the panel	:	262752 tonnes (with 4.6m ht of extraction)

Coal extracted	:	194320 tonnes
Percentage of extraction	:	74.0 (including development)
Gradient	:	1 in 8
Grade of coal	:	D
Gassiness	:	Degree I
RMR	:	62

3. Design of Yield Pillar Non-caving method:

This method involves leaving of remnant pillars systematically (with width to height ratio of 5) in the goaf that will yield over a period of time. Their safety factor will ultimately be below 1 and pillar crushing is expected over a period of time but not near the extraction / mining area. It is the gradual mode of failure that is critical in producing safer and, better control of risks than the full caving method. The pillar strength calculations are given below.

As per Salmons formula for squat pillar, the strength for pillars with a w/h ratio greater than 5 is as follows

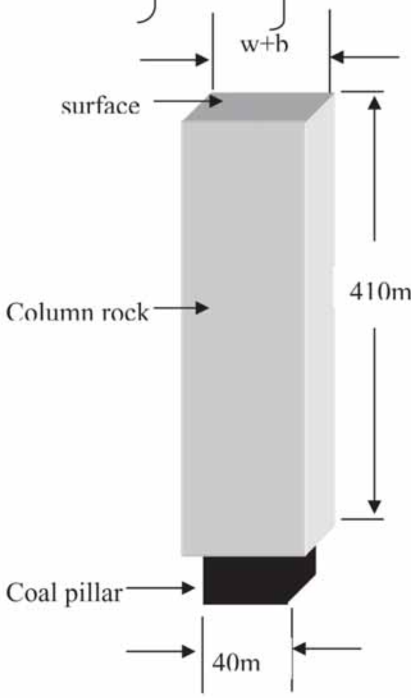
$$\text{Pillar strength} = \frac{19.05}{40^{0.133}\, h^{0.066}} \left\{ 0.237 \left[\left(\frac{40}{5 \times h} \right)^{2.5} - 1 \right] + 1 \right\}$$

Where w = pillar width and h = pillar height.

At VK7 in CMP-2 panel, w = 40m, roadway width is 4.5m, mining height is 2.5m and depth is about 400m, width to height ratio is 15.70.

$$\text{Pillar strength} = \frac{19.05}{40^{0.133}\, 2.5^{0.066}} \left\{ 0.237 \left[\left(\frac{40}{5 \times 2.5} \right)^{2.5} - 1 \right] + 1 \right\}$$

= 57.1 MPa



Pillar Load:

Pillar load is calculated using Tributary Area Theory:
Simply assumes that equal size pillars in a regular pattern carry equal loads and that the load is that of a column of rock lying over the pillar

Load = 400 x (w+b)2 ρxg

= 400 x 452 x 2500 x10

= 20250000000

Over the area of the pillar = 20250000000/40^2

= 12.7MPa

Pillar Safety Factor = Strength/Load

= 57.1/12.7= 4.6 (good for long term stability)

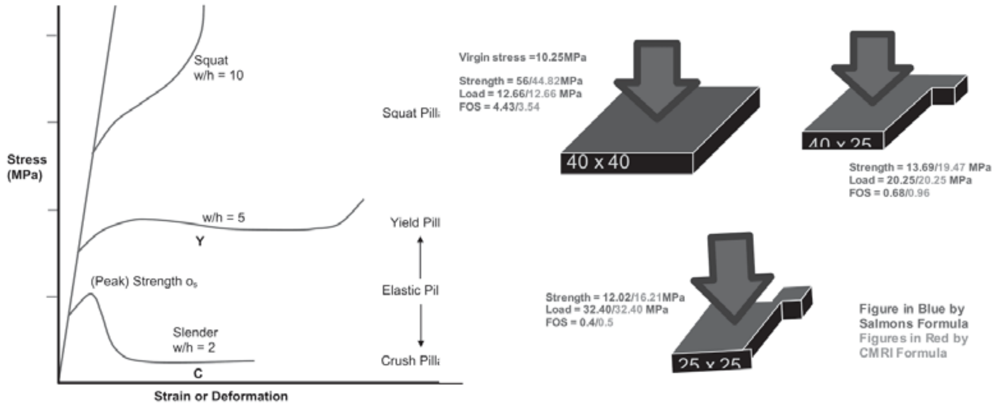


Figure 2: Load deformation curve (left) and safety factor of remnant/yield pillars (right)

As per the load deformation curve (Figure-2), the yield Pillars (Remnant Pillars) with w/h ratio of 5 will gradually yield on the increase of stress and once they are crushed by 30-40%, they begin to carry load again and hence **there is no scope of sudden failure of remnant pillars.**

4. Method of extraction

The existing galleries are developed conventionally with 2.5 m height and 4.2 m width. Remotely operated Continuous Miner cuts the coal and load on the shuttle car. The shuttle car of 9 tonnes capacity transports the coal from face to feeder breaker and from there coal is transported to surface through a system of belt conveyors. In order to facilitate maneuverability of shuttle cars, it is permitted to widen all the galleries in the panel up to a maximum width of 6.5m / 7.5m and height of 3.0m by supporting the roof and sides as per the approved Systematic Support Rules. The widening and heightening operations were commenced on 10.6.2009 and completed on 29.9.2009.

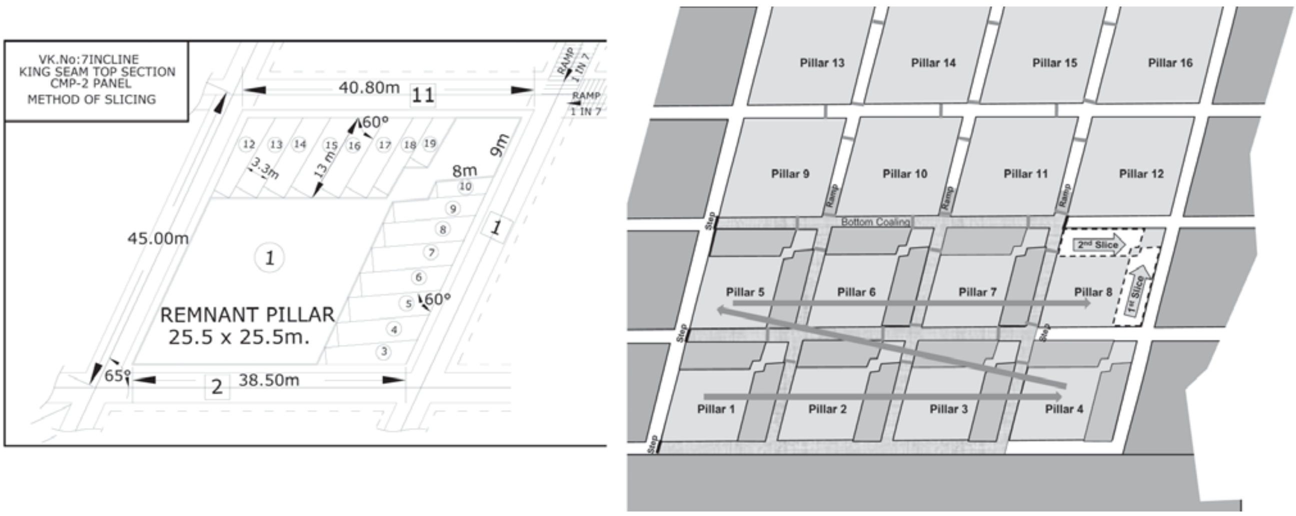


Figure 3: Method of slicing and sequence of slicing.

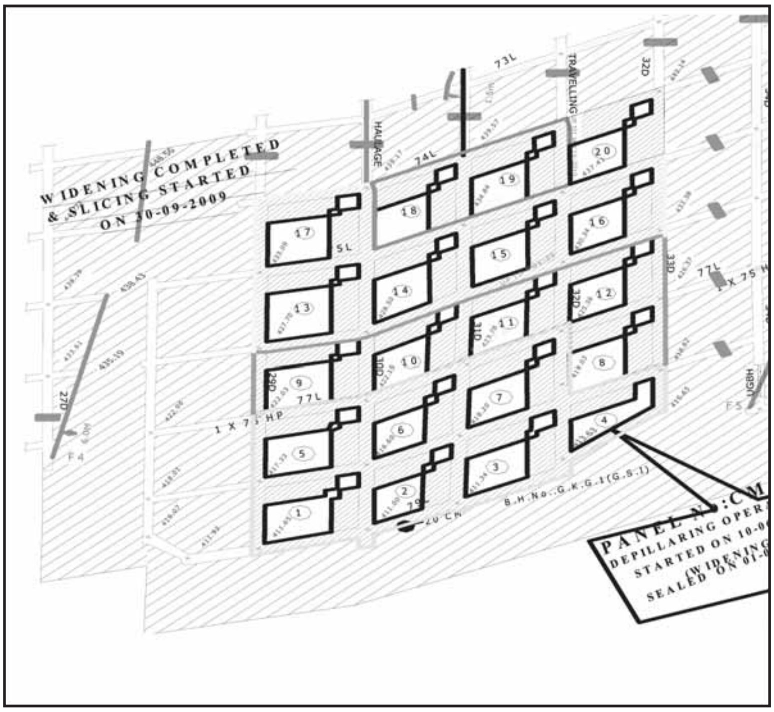


Figure 4: Remnant Pillars left after completion of CMP 2 panel.

The manner of extraction and sequence of extraction is shown in Figure 3.

- Before extraction of pillar, a ramp not less than 1 in 7 shall be made for smooth maneuverability of continuous miner and shuttle car for heightening of the gallery by floor dinting.
- The original galleries of the pillar under extraction shall be heightened upto 4.6m by dinting floor coal up to dip most level.
- Each pillar so formed would then be extracted by driving level slices of length not more than 15.0m at an angle of about 60^{o} with respect to centre line of the gallery.
- The width and height of the slice shall not exceed 3.3m and 4.6m respectively.
- The First slice of the pillar would commence from the dip side corner of the pillar.
- Similar such slices shall be made from dip to rise of the pillar upto 6/7 number of slices.
- The last slice shall not be more than 8.0m.in length. In the same manner pillars along the level shall be reduced by dip slices from the corner of the pillar.
- After the competition of slicing of the pillar, the resultant left out yield pillar shall not be less than 25.5m X 25.5m.
- Only straight line of extraction would be followed as shown in Figure3.

After widening and heightening, the extraction of 20 pillars in CMP 2 panel was started on 30.9.2009 and completed on 21.1.2010. The remnant pillars left after completion of the panel is shown in the Figure 4.

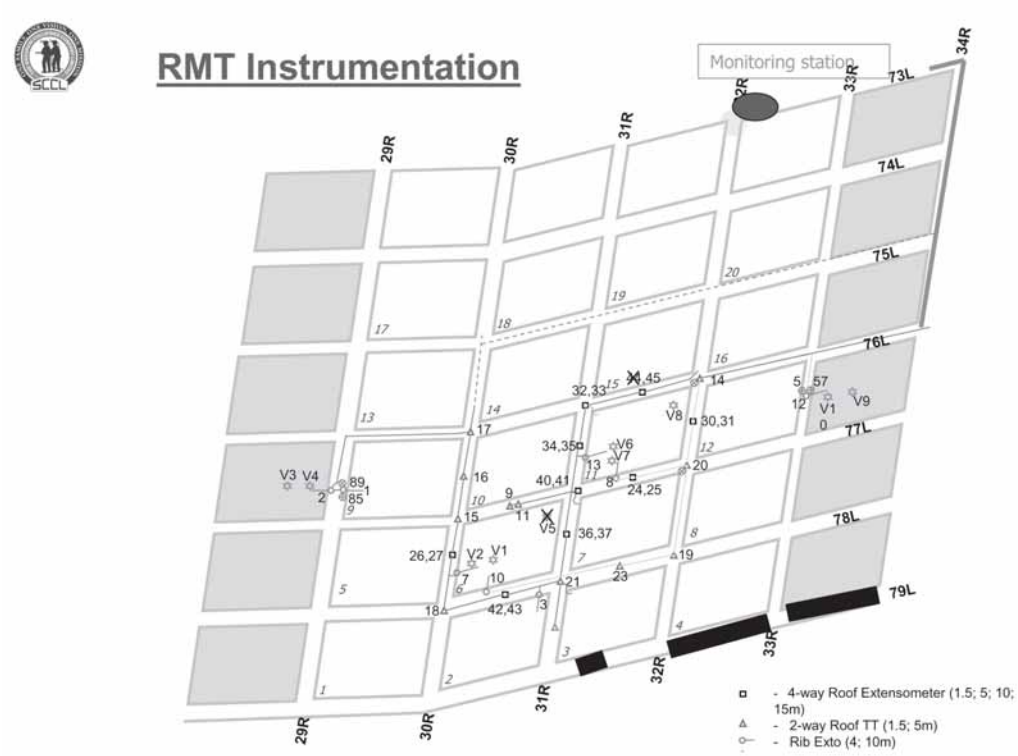
5. Strata Monitoring in CMP-2 panel

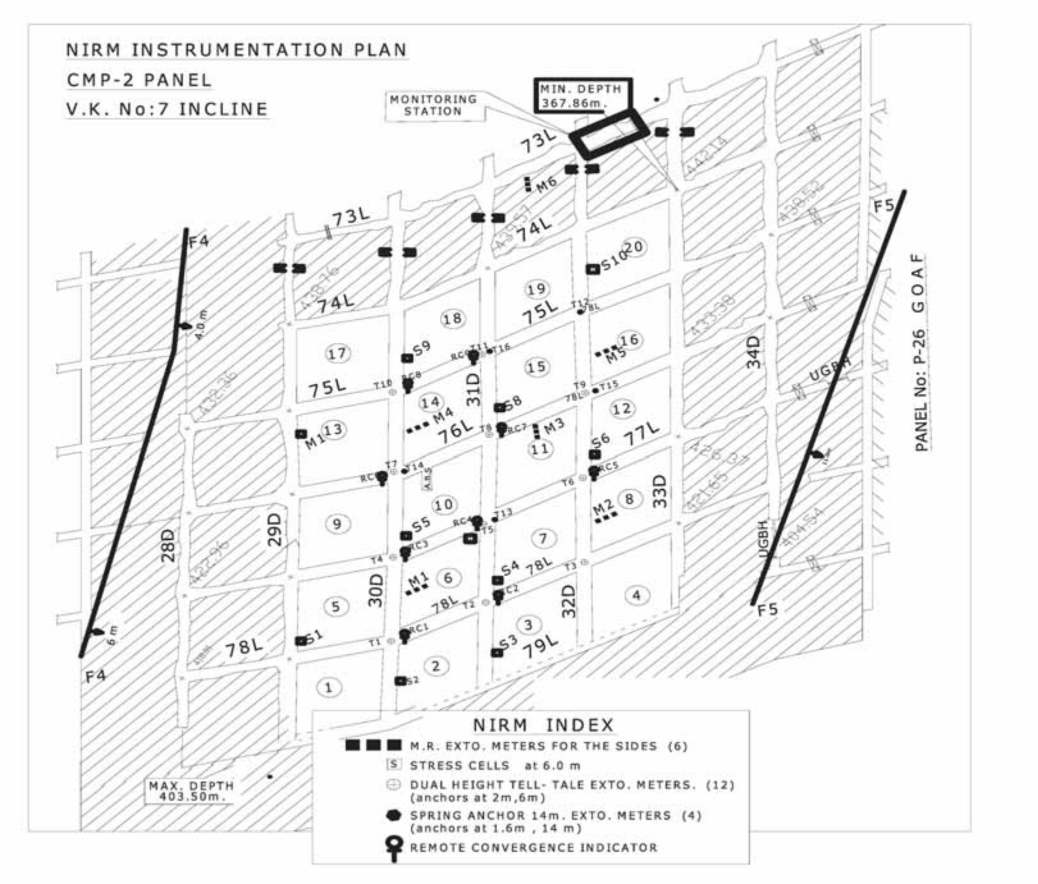
As per the DGMS permission, scientific agencies RMT, UK and NIRM, India have monitored strata behaviour in CMP 2 panel. The instrumentation plan and details of instruments of RMT and NIRM are given below. All the instruments of RMT and stress cells & Roof to floor convergence indicators of NIRM were remote monitoring type and were monitored from a station located out side the panel round the clock. From the caveability index of roof rock, it is observed that a weak layer exists at 13 to 14m horizon in roof. To monitor the bed separation beyond the weak layer, the roof exto are anchored at 15m in to the roof.

Type and number of instruments installed by RMT and NIRM.

Instrument	To measure	RMT	NIRM
Remote reading VW stress cells	Stress on pillars	10	14
4 way remote roof extos	Bed separation	10	--
2 way remote roof extos		10	16
2 way remote rib extos	Pillar Dilation	8	--
Remote convergence indicators	Roof to floor Convergence	8	9
Pillar strain metres	Pillar dilation	4	--
Magnetic Ring Exto	Pillar Dilation	--	5

- **All RMT instruments are remote type. Stress cells and RCIs of NIRM are remote type.**





6. Strata behavior observed by instrumentation

The strata behavior revealed by various instruments is discussed below.

Stresses: the maximum change in stress over pillar No 3 is 3110kPa, change in stress over pillar No 6 is 4865kPa, and over remnant pillar No 11 is **9161kPa**. The maximum stress recorded over barrier pillar at 33D/77L is **18482.5 kPa**.

Bed separation in the goaf: The maximum bed separation upto 15m in the roof is 14.6mm at 77L/30-31D (in the goaf). The maximum bed separation found between 5-10mm roof is 8.7mm at 32D/76-77L. In the centre of the panel, bed separation up to 15 m in roof was 17.6 mm at 31D/77L-78L. Bed separation up to 6.6 mm was recorded in 1.5 – 5 m zone and in 10 – 15 m zone.

Bed separation in the workings ahead of extraction: About 1.5 to 2.5 mm of roof movements were recorded in the workings ahead of pillar under extraction by extos.

Roof to floor convergence: Maximum roof to floor convergence of 106.2mm was recorded at 31D/77L Jn (in the goaf). Maximum of 278mm bed separation was observed at 32D/77L.

Rib Dilation: Maximum rib dilation of 148mm was recorded in Pillar No 6.

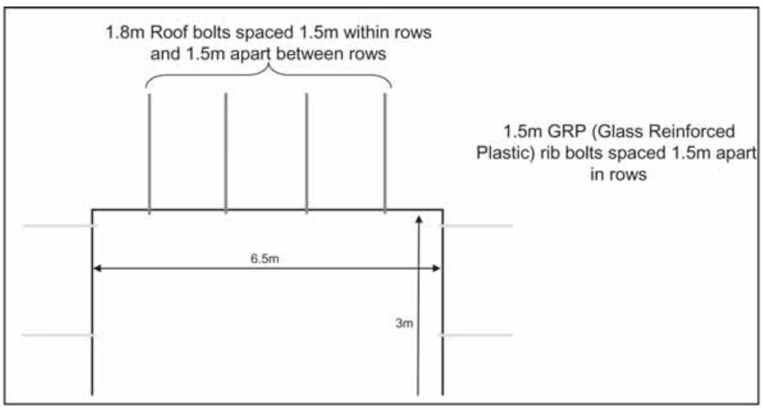
Physical observations

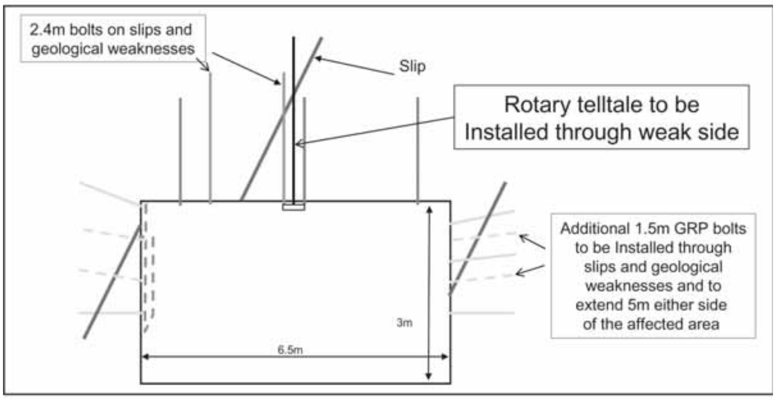
The readings indicated by instruments in terms of stress, bed separation, roof to floor convergence revealed that the remnant pillars are yielding and the same has been observed physically. The salient physical observations are given below:

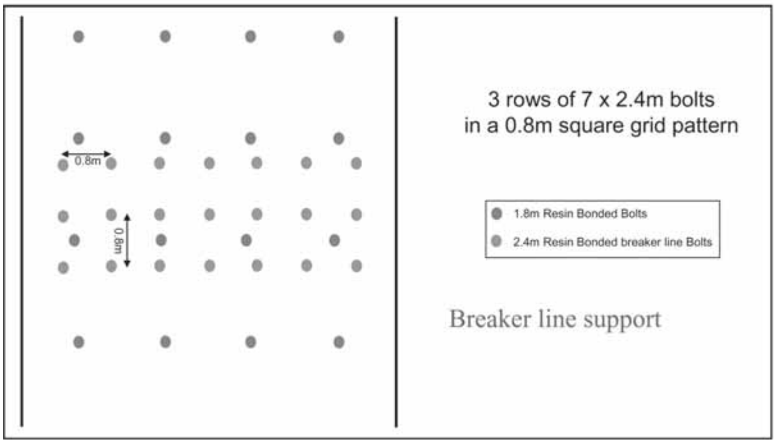
- Bending of indicator props in the goaf. Floor heaving was observed in all the levels in the vicinity of pillar under extraction and also up to one pillar ahead.
- Side spalling along the dip and along the rise in the levels.
- Pillars are taking load while slicing but are deforming in a slow and controlled manner as they deform.
- The roof is very stable in the extraction zone and only exceeds the 5mm action level when well inside the goaf area.
- Tensile cracks were observed in all the levels except 74L; most of the indicator props in the goaf along 32Dip got completely bent.
- There was no yielding or failure of any of the pillars or snooks during the working of the panel; but the pillars are under high stress as indicated by the stress cell readings, sounds from the pillars and heavy side spalling in all the pillars.
- There was no fall of roof in the working areas during the extraction; minor falls in the goaf were indicated from time to time. However, high roof-to-floor convergence was observed in the junctions, as indicated by the RCI and the bent indicator props.

7.0 Systematic Support Rules:

Supporting with resin grouted roof bolting is permitted in this panel. Support design in the galleries, at geologically disturbed areas and at goaf edges (breaker line) applicable to CMP 2 panel are illustrated in the following sketches. Side bolting is done with GRP bolts & plastic mesh.







8.0. Production comparison:

(Caving & non-caving by Continuous Miner and caving (conventional) by LHDs).

The production details of CMP2 panel comparative to LHDs with caving (P-26 panel) and Continouis Miner with Caving (CMP 1 panel) are given below:

panel no.	no. of pillars	seam thickness m.	coal available in the panel with 4.6m ht. (t.)	height of extraction m.	coal extracted during development with 2.8m ht	coal extracted during depillaring	total dev + dep	% of extraction
P-26 (LHD Caving)	29 (45 x 45)	4.6	3,29,084	4.0	67,600	180146	2,47,746	75.28
CMP-1 (Caving)	4 (45 x 45)	4.6	59,570	4.6	9631	38,288	47,919	80.4
CMP-2(Yield pillar Non-caving)	20 (45 x 45)	4.6	2,62,752	4.6	42,529	1,51,791	1,94,320	74.0

The percentage of extraction for same pillar dimensions of 45 x 45m when compared between (i) caving with LHDs (4.0m height of extraction), (ii) Yield Pillar Method with Continuous Miner (4.6m height of extraction) and (iii) Caving with CM technology is as follows:

- % with LHDs(Caving Panel) : 75.28%
- % with CM Technology with Caving : 80.40%
- % with CM Technology with Non-Caving : 74.00%

9. 0: The merits and demerits with Yield Pillar Non-Caving method are given below:

Merits	Demerits
1. Safe method as there is no danger of roof falls in the working area and no extension of goaf falls into the working area.	1. More side spalling which was addressed by tensile plastic mesh and 1.5/2.0m long GRP bolts.
2. No danger of airblast/wind blast.	2. Floor heaving.
3. Low goaf edge load.	3. As the depth increases recovery will be less due leaving of large size remnant pillars.
4. Continuous production	4. Strict operational controls are required to ensure leaving specified size of remnant pillars and snooks.
5. More productivity and production.	
6. Recovery 65-75%.	

Conclusion

Based on the experience gained in Yield Pillar Non-caving Method, it can be concluded that the method is suitable for prevailing geo-mining conditions in King Seam at VK 7 Incline. It is proved to be a safe and productive system of working with no local falls occurring within the working area during extraction in CMP-2 panel. The front abutment pressures are found to be very low.

Acknowledgement:

The authors are grateful to SCCL management for permitting to present and publish this paper in this seminar. The views expressed in this paper are those of the author and not necessary of the organization to which they belong.

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Physiological workload of underground coal miners in India – An Ergonomic Approach

*Dr. N. C. Dey , **S. Pal

Introduction

A large number of factors play significant role in ergonomics, which include body posture and movement (sitting, standing, lifting, pulling and pushing) and environmental factors (noise, vibration, illumination, chemical substances). These factors determine to a large extent safety, health, comfort and efficient performance at work in everyday life. Ergonomics is the science concerned with the "fight" between people and their work. It puts people first, taking account of their capabilities and limitations. It aims to make sure that tasks, equipment, information and the environment suit each worker. Ergonomics helps in designing equipment; work processes vis-à-vis work environments in terms of tasks and activities of the people. At the workplace, the application of ergonomics aims to promote health, efficiency and well being of workpersons. It focuses on *people* in order that they can work safely and efficiently.

In mining, as in other industries, the exposure of workers to very hot conditions is unhealthy and unproductive. Persons working in hot & humid work sites tend to be inefficient and quite often workers prefer to stay away from work or ignore unsafe working situations.

Physical load in occupational settings

Physical work requires exertion of force through dynamic and static muscular contractions. In occupational settings, muscular activity may be categorized as follows: heavy dynamic muscular work (mainly moving of own body weight), manual materials handling (moving external loads), static postural muscular work, and repetitive muscular work. Heavy dynamic muscular work primarily increases energy expenditure and causes cardio respiratory (overall) strain responses. Manual materials handling is a combination of dynamic and static muscular work, for which strain responses are both cardio respiratory and musculoskeletal (i.e., local) in nature. The physical load associated with static postural or repetitive muscular work primarily generates musculoskeletal strain responses. Despite rapid technological developments, heavy dynamic muscular work and manual materials handling will continue to be required for execution of tasks associated with various occupations and mining industry especially underground mining. Furthermore, muscular overexertion, lifting and carrying, static postural work, repetitive movements and sudden peak loads may lead to physical distress, injury or disease and therefore constitute as risk factors associated with work disability.

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** Research Scholar, BESUS

Criteria for selection of categories

The ***priority based criteria*** that have been used to select the categories of miners as ***subject of this study*** are mentioned below:

- Those who are supposed to stay inside the ground against adverse conditions of mine.
- Those who devote maximum time in their allocated faces / place of work and as such extremely important in terms of coal output of the company.
- Whose jobs are quantitative in nature and whose wages are related with the tonne of coal raised or number of holes drilled or number of faces dressed.
- Whose jobs are supposed to be physically demanding.

Keeping the above mentioned dominant criteria in view, the Drillers and Carriers have been selected as the subjects in this study.

Physiological parameters (Direct & Derived)

Weight, Height, BMI

Weights of the subjects are measured in kilograms by a sensitive human weighing machine and heights are measured in centimeters using an anthropometric rod. Body mass index is expressed in $kg.m^2$.

Resting heart rate (HR_{res})

The subjects are allowed to sit comfortably in a reclining position for at least 30 minutes at the surface prior to their work before going down to mine. During this time heart rates are measured by stethoscope. The minimum heart rate recorded during this period is considered as the resting heart rate and expressed beats per min.

Working heart rate (WHR)

It is accomplished both by using Mobile heart rate monitor and placing the stethoscope at the apex of the heart and the time counted for 10 beats by the stopwatch, which is then expressed in beats/min (Astrand 1986, Anderson 1978).

Working Oxygen consumption: (W_{VO2})

Oxygen consumption during activity is obtained from Oxylog II machine by fitting the mask on the workers face and the portable instrument is fitted to their back. The value is directly collected as visible on the liquid crystal display of the machine at least 5-10 minutes after the beginning of work for a considerable period of time.

Recovery Heart Rate (RHR)

At the end of work, the recovery heart rates are measured for three minutes by counting heart rate at regular intervals for the last thirty seconds in each minute of the recovery period (Brouha 1967). The study is extended up to the 5^{th} minute (for all subjects chosen for finding the recovery status) to find out the pattern of recovery of the workers.

Summary of Brouha's fatigue assessment techniques

Condition	Criteria
Normal state	P_1 - P_3 = 10 bpm and $P_{1,}$ $P_{2,}$ P_3 = 90 bpm
No – recovery state	P_1 - P_3 < 10 bpm and P_3 > 90 bpm
Inverse recovery state	P_3 > 90 bpm and P_1 - P_3 = -10 bpm
No increasing cardiac strain	P_1 = 110 bpm and P_1 - P_3 > 10 bpm

- Phase 1: P_1 = heart rate during the last 30s of the first minute
- Phase 2: P_2 = heart rate during the last 30s of the second minute
- Phase 3: P_3 = heart rate during the last 30s of the third minute

Where $P_{1,}$ $P_{2,}$ P_3 are respectively called the first, second and third recovery heart rate.

Derived Parameters

Net cardiac cost (NCC)

NCC, the derived parameter is obtained as the difference of working and resting heart rate of the subjects and expressed in beats/min. **NCC = WHR-RHR.**

Relative cardiac cost (RCC)

This is the derived parameter obtained by expressing the heart rate at a given workload as the percentage of heart rate reserve (HRR) of a particular individual (heart rate reserve is the difference between maximal and resting heart rate) to depict the relative intensity of workload. It is calculated as**: RCC= NCC / HRR* 100.**

Energy Expenditure (EE)

This is obtained by multiplying the working oxygen consumption by five as one litre of oxygen yields nearly five kilocalorie of energy.

Cardiac strain indices and the recommended limits of physical strain during a job

Indices	**Proposed by**	**Recommended limits**
Net Cardiac Cost (NCC)	(Lablanch Combier &Ley)	30 beats. min-1
Relative Cardiac Cost(RCC)	(Lablanch Combier &Ley)	30%HRR

Workload determination of Carriers

The physiological responses during carrying coal are presented below in table 1, which shows the average working heart rates less than 40 years of age is below 130 beats min^{-1} and therefore seems to be a heavy job for them whereas above 40 years of age it appears to be as very heavy job (Astrand 1986). Therefore the average working heart rate response showed the task to be heavy to very heavy in nature (Fig 1). The mean net cardiac cost is found to be within a range of 61-66 beats min^{-1} in all carriers and is observed to be quite above the recommended limits (Chamoux et al 1985).

Table 1: A comparison of cardiac strain, metabolic cost, duration of work and lead distances (LD) amongst different age group of carriers

Variables	Age groups (Years)			
	20-29 (n=6)	30-39 (n=6)	40-49 (n=7)	50-59 (n=6)
WHR (bpm)	124 ± 4.8 (117-129)	128 ± 5.12 (121-136)	133 ± 6.92 (124-142)	130 ± 5.32 (122-138)
NCC (bpm)	63 ± 5.96 (55-69)	66 ±5.2 (57-72)	65 ± 10.47 (50-78)	61 ± 9.62 (57-76)
RCC (%)	48 ± 3.58 (43.3-52.3)	53 ± 4.07 (45.6-57.6)	60 ± 7.6 (49-70.4)	61 ±7.15 (50.5-72.4)
EE (Kcal/min)	5.61 ± 0.54 (4.9-6.1)	6.14 ± 0.57 (5.3-7.0)	6.61 ± 0.78 (5.65-7.7)	6.33 ± 0.6 (5.42-7.2)
Duration (min)	52.5 ± 8.89 (43-65)	52.33 ± 5.88 (46-63)	52.4± 8.63 (40-67)	47.16±4.4 (40-52)
LD (Meter)	18.8± 7.29 (10.2-29.5)	24.33± 5.5 (18.4-32)	28.18± 13.1 (12.2-48)	21.6± 4.1(15.6-27.8)

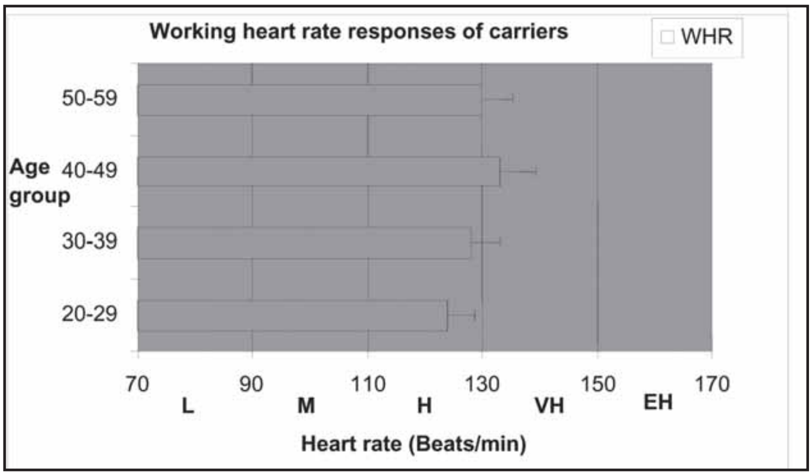

Figure-1

The metabolic cost (EE) however found to be lowest in younger group (5.61 Kcal min^{-1}) in comparison with the highest value observed in 40-49 age group of carriers (6.61 Kcal min^{-1}) .The cost incurred so far during carrying load showed that the activity is heavy to very heavy in nature (Ramanathan 1967) and is shown in the Figure 2.

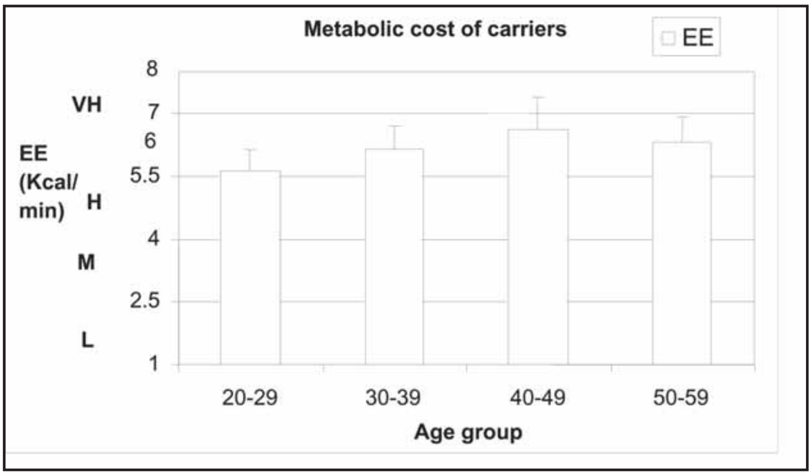

Figure 2

The recovery pattern indicates the heaviness of their job in respect of each category of miners. In figures 3 and 4, recovery pattern of carriers (20-29 years) and (50-59 years) are shown. As per Brouha's assessment all carriers experiences no recovery state within the present state of conditions.

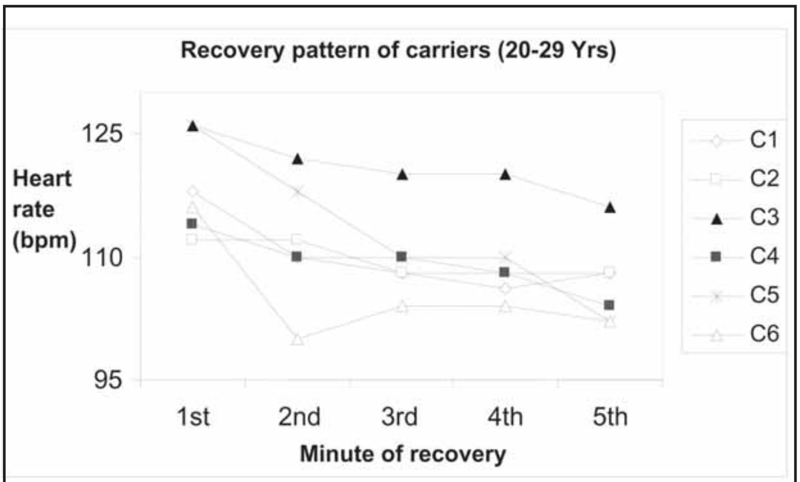

Figure 3

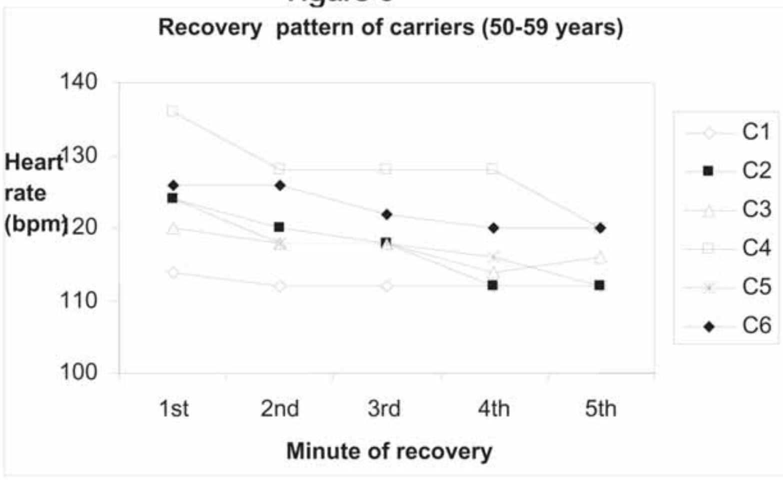

Figure 4

Workload determination of Drillers

Noise is a stress that not only damages hearing but also elevates heart rates and affects other physiological parameters which in turn reduces physical performance (Text Book of Astrand, page 504). The mean working heart rates in first phase are found to be ranging between 125-129.8 beats min^{-1} in all drillers where the mean values of drillers above 40 years of age indicates that the task appears **just marginal to be very heavy** (130 beats min^{-1}) for them. In contrast to that the average heart rates in the second phase is observed to be ranging from 130-132 beats min^{-1} for all the drillers and thereby confirms the phase II activity as a **Very Heavy** category of work. The mean net cardiac costs are found to be varying within a range of 59-62 beats min^{-1} and 57.8-64 beats min^{-1} among different age group of drillers. These are found to be quite above the recommended limits (Lablanch & Ley).

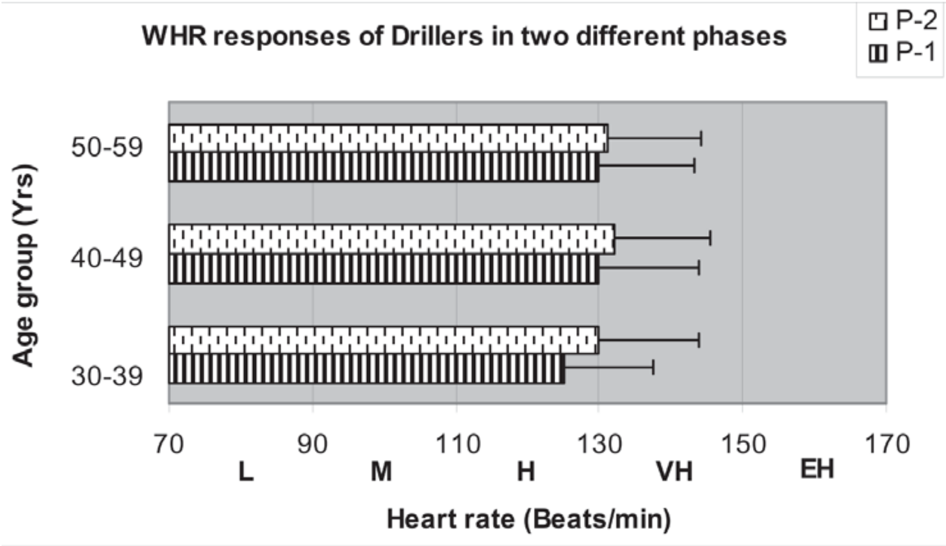

Figure 5

The mean relative cardiac costs are found to be in the range of 49.6%-60.6% and 53.8%-62.4% respectively in first and second phase and are reported to be elevated as the age increases in both the phases of work. The mean metabolic costs of the younger group are found to be lower in both the phases (6.1 and 6.4 Kcal min^{-1}) of drilling as compared to drillers more than 40 years of age. The mean metabolic costs in Phase I & II (6.32 and 6.49 Kcal min^{-1}) however designate the task to be heavy in nature for the subjects working in this study. The recovery patterns of few drillers having less than 40 years age are in normal state while drillers more than 40 years age are facing no recovery state (Figures 6 and 7).

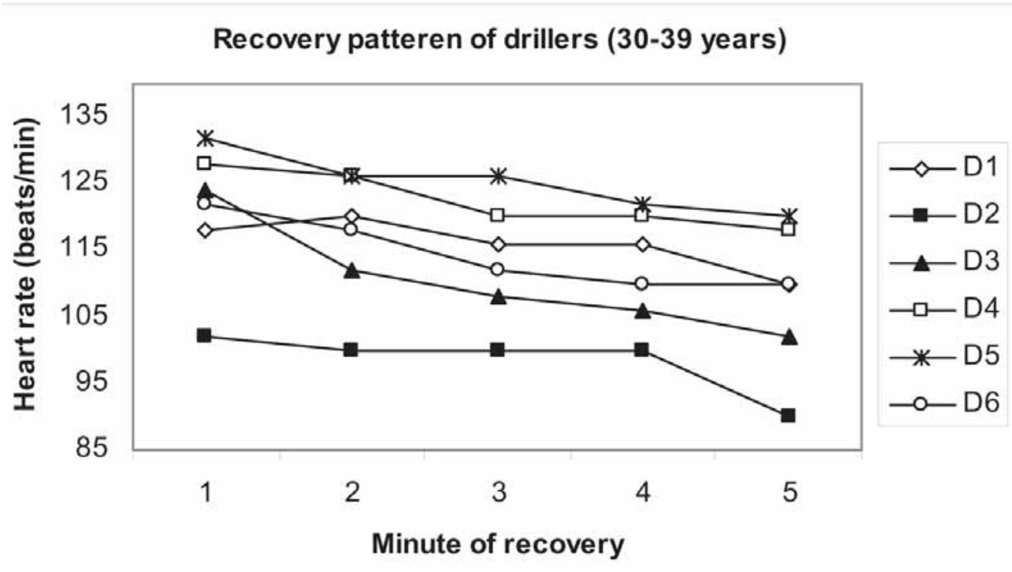

Figure 6

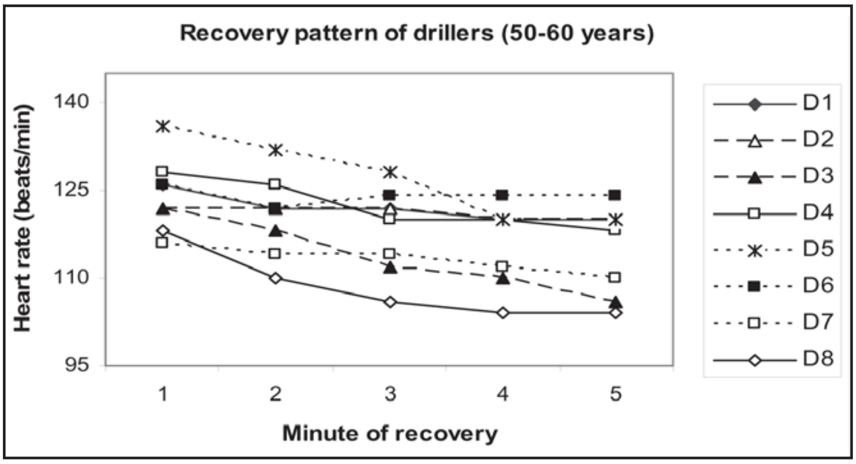

Figure 7

Conclusion

The recovery heart rate during rest periods following a work cycle in a hot environment is a measure that can be used to understand workload and to monitor heat stress. Work/rest regimens give the body an opportunity to eliminate excess heat and lessen the production of internal body heat. A good work/rest schedule should result in significant recovery of heart rate during rest period. One known fact is that people are poor judges of when they require rest. Usually by the time a person feels tired, an inordinately long rest will be required for recovery. Suitable rest break period in respect of all categories of miners are to be ergonomically determined.

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UP-GRADATION STRATEGIES FOR VENTILATION IN UNDERGROUND MINES OF THE SCCL

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**** G. Venkateshwarlu*

ABSTRACT

Coal mining by underground operations is intensive in SCCL and it is planned to increase the production capacity from the currently operating underground mines for utilizing full potential. To enhance the production capacity, up- gradation of various facilities has to be taken care of. This includes mine ventilation, which is of paramount importance for improving safety and operational productivity.

In this paper the diversity of geo-thermal conditions and need for special attention required by the underground coal mines of SCCL compared to other parts of the globe are outlined. Various possibilities are explored and presented for up-gradation of ventilation in existing mines and strategies are presented for depths upto and beyond 600m.

1. Introduction

Underground coal mining operations in SCCL are currently at a maximum depth of about 420m, with most of the workings concentrated between 200m-300m depth. In SCCL, after 1990 the average depth of the mines and the average production from production districts/mines have taken a giant leap, necessitating drastic changes in ventilation requirements. With extensive introduction of fully mechanized and semi-mechanized working methodologies, the ventilation requirements have undergone a drastic change necessitating increased quantity requirements in all those mines. Heat from two critical components i.e., geothermal and machinery is demanding increased ventilation requirements for safe and comfortable operating conditions.

It is imperative to plan for enhancing the production capacity from the existing mines. Increase in the production capacity in existing mines by further increase of mechanized production units at deeper workings is possible in some of the mines, whereas, it is associated with restrictions in many of the mines due to inherent limitations in the existing Mine ventilation arrangements.

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Underground mining at greater depths at 300m-600m with intense mechanization calls for critical planning for safe, comfortable and productive operations for sustenance. Underground coal mining conditions in India and specifically in SCCL are found to be different in both geo-mining and geo-thermal conditions compared to many parts of the world and need special attention to address the challenges likely to be faced in near future.

2. The diversity of geo-thermal conditions:

The environmental conditions in Indian underground coal mines specifically in SCCL are different when compared to the conditions in other parts of the country and the world. Annual average temperature in SCCL areas is observed to be high compared to many parts of the world as given in the following table:

Country / Region	Annual average surface temperature	Approximate Virgin Rock Temperature (VRT) at 400m depth
India / SCCL	28^0 C	38^0 C
India / BCCL	26^0 C	36^0 C
Australia	19^0 C	27^0 C
China	17^0 C	25^0 C
Poland	-	25 ^{0}C
UK	11^0 C	22^0 C
Germany	11^0 C	19^0 C
Canada	8^0 C	12^0 C

Table 1: Annual average temperature and VRT in various countries

It is evident from the above table that the thermal environment in underground mines of SCCL is hotter compared to other parts of the country and severely hot when compared to some of the other parts of the world.

Due to high level of VRT in SCCL underground mines, creating comfortable conditions at workplace by increasing quantity and even cooling of mine air by artificial means is also proposed in some of the mines.

3. Current ventilation systems in SCCL:

Presently 36 underground mines are in operation, where technology of mining is semi-mechanization with LHD & SDL, Blasting Gallery, Road headers, Longwall, Continuous Miners and conventional hand-section mining in some of the mines. Production from these mines is about 12 MT, which is about 24% of total production of SCCL.

The following table gives the capacity of Main Mechanical Ventilators in operation at various mines

Sl No	Mine	Capacity (kW)	Quantity (m^3/min)	Pressure (mm of wg)	Equivalent Orifice (m^2)
1	PVK 5 Inc	225	7400	84	8.5
		150	3900	56	
2	VK 7 Inc	250	7600	68	8.7
		150	3800	70	
3	21 Inc	225	7800	76	5.7
4	PK 1	225	7270	55	6.2
5	Kondapuram	225 (proposed)	-	-	-
6	Goleti 1&1A	250	11260	62	9.1
7	Kasipet	150	7000	74	5.2
8	Shantikhani	250	7490	72	5.6
9	RK 1A	225	7590	66	5.9
10	KK 1	150	5990	47	5.5
11	KK 2	150	5810	25	7.4
12	KK 5	150	5560	26	6.9
		150	4520	36	4.8
13	RK 5	225	10250	68	7.9
14	RK 6	225	10300	45	9.7
15	RK 7	250	13360	42	13.1
16	RK NT	250	9100	41	9
17	RK 8	150	4350	44	4.1
18	SRP 1	150	5600	54	4.8
19	SRP 3	225	8730	30	10.1
20	IK 1A	225	7040	76	5.1
21	GDK 1&3	225	8500	71	6.4
		75	2830	45	2.7
22	GDK 2&2A	150	5200	53	4.5
		150	6400	52	5.6
23	GDK 5	225	10080	63	8
24	GDK 7 LEP	150	7000	29	8.2
25	GDK 11	250	6650	74	9.9
		225	6650	74	
26	GDK 8	225	8700	63	6.9
27	GDK 8A	150	5600	50	5

Sl No	Mine	Capacity	Quantity	Pressure	Equivalent
28	VKPL	250	7570	64	6
29	GDK 10	250	9100	56	7.7
30	GDK 10A	250	8200	89	5.5
31	Adriyala	500 (proposed)	-	-	-
32	KTK 1	250	11700	72	8.7
33	KTK 2&2A	75	3220	26	4
		150	6150	38	6.3
34	KTK 5&5A	250	10050	32	11.2
35	KTK LW	150	6600	36	7
36	KTK 6	150	5230	50	4.7

Table 2: Capacity and operating parameters of Main Mechanical Ventilators

Equivalent Orifice (EO)		Air quantity circulated in mines		Capacity of Fans	
EO (m^2)	No of mines	Air quantity (m^3/min)	No of mines	Fan capacity	No of mines
4.0-6.0	15	4000-6000	6	150 kW	9
6.0-8.0	10	6000-8000	9	225-300kW	22
8.0-10.0	8	8000-10000	6	375-475kW	3
10.0-12.0	2	10000-12000	11	-	-
12.0-14.0	1	12000-14000	2	-	-

Table 3: No of mines with respect to EO, Air quantity and Fan capacity

It can be observed from the above table that, as far as the aerodynamic resistance is concerned, most of the mines in SCCL fall in medium and low category thus permitting to ventilate with high air circulation at low pressure.

4. Various schemes for up-gradation of ventilation systems in SCCL

It is proposed to increase the production capacity from various existing underground mines by utilizing the available infrastructure in an efficient manner and by providing additional infrastructure wherever needed.

In some of the mines capacity addition is proposed within the existing mine boundaries in a depth range of upto 360m, and in some of the mines extension of boundary on dip side upto a depth of about 550m is also proposed. In few mines development is in progress and in most of the mines, shallow reserves are exhausted and further extraction has to be taken up on dip-side of de-coaled areas. In all the options, mine resistance increases and concurrently, ventilation requirement increases.

Ventilation up-gradation systems to meet the proposed requirements are observed to be site-specific for improving existing environmental conditions and for the proposed enhancement of production capacity.

The following schemes for up-gradation can be considered for improving ventilation and to meet the capacity addition requirements:

- Effective utilization of existing entries
- Re-organization of existing ventilation systems
- Effective/optimum utilization of existing capacity of Main Fans
- Installation of High Capacity Main Fans
- Provision of additional new entries
- Introduction of artificial air-cooling systems

5. The up-gradation potential for ventilation:

The potential for up-gradation of ventilation in existing mines is governed by the following major factors:

- Size of entries suitable for the projected ventilation requirements projected needs
- Sustenance of existing sealed off de-coaled areas
- Possibility of pillar heating with increase in Main Fan pressure
- Increase of temperature due to increase in depth

Size of entries of existing mines:

- Tunnels size varying from 7.0m^2 – 14.0m^2
- Length of tunnels varying from 60m – 1130m
- Shaft size varying from 4.8m – 6.5m diameter
- Depth of shafts varying from 15m - 290m

In most of the mines, cross section of entries has been the limiting factor for increasing air quantity and also contributing to major part of the mine resistance.

Ventilation pressure requirements: All the Main Fans in SCCL are presently operating below 90 mm of wg (0.9kPa). To meet the future requirements, Main Fans are required to be operated at a pressure of about 150 mm of wg (1.5kPa) in some of the existing mines.

As far as possible, heat in workings is to be minimized by increased air circulation and diversion of heat generated by various sources directly to return airways, planning multiple intake & return road ways of sufficient cross-section and sectionalisation of un-used workings. Based on requirement, artificial air-cooling systems are also to be provided wherever justified.

The following table gives the various aspects for the up-gradation of ventilation:

6. Future strategies for underground mining beyond 600m depth:

Sl No	Mine	Proposed re-arrangements and limitations in ventilation system
1	PVK 5	➢ Conversion and isolation of entries and shafts ➢ Re-arrangements in ventilation system ➢ Air-cooling arrangements ➢ Isolated / de-coaled areas around the shafts ➢ Fan is expected to operate at 90mmwg to produce
2	Kasipet	➢ Provision of additional entry as intake ➢ Re-arrangements in ventilation system ➢ Installation of 225kW Fan. ➢ Air quantity can be increased from 7000m^3/min to about 10000m^3 min, fan is expected to operate at 80mmwg
3	SK	➢ Air quantity can be increased from 7490m^3/min to 8400m^3/min by increasing 250kW Fan blade angle, pressure increases from 72mmwg to 90mmwg
4	RK 5	➢ Re-arrangements in ventilation system ➢ Air quantity can be increased from 10250m^3/min to 12000m^3/min by increasing 225kW Fan blade angle, pressure increases from 68mmwg to 93mmwg
5	RK 6	➢ Re-arrangements in ventilation system ➢ Operation of two 150kW Fans in parallel mode instead of existing 225kW Fan ➢ Air quantity can be increased from 10300m^3/min to 13800m^3/min pressure increases from 45mmwg to 81mmwg

Sl No	Mine	Proposed re-arrangements and limitations in ventilation system
6	RK NT	➢ Re-arrangements in ventilation system ➢ Air quantity can be increased from 9100m³/min to 12000m³/min by increasing 250kW Fan blade angle, pressure increases from 41mmwg to 70mmwg
7	SRP 3	➢ Re-arrangements in ventilation system ➢ Air quantity can be increased from 8730m³/min to 12000m³/min by increasing 225kW Fan blade angle, pressure increases from 30mmwg to 57mmwg ➢ Further increase of air quantity is possible by operation of 2 x 150kW Fans in parallel mode. Air quantity delivered can be increased to about 14400m³/min at 82mmwg
8	IK 1A	➢ Re-arrangements in ventilation system ➢ Provision of additional entry as intake ➢ Conversion of second tunnel as return ➢ Air quantity can be increased from 7000m³/min to 10000m³/min by increasing 225kW Fan blade angle
9	GDK 5	➢ Re-arrangements in ventilation system ➢ Air quantity can be increased from 10080m³/min to 12000m³/min by increasing 225kW Fan blade angle, pressure increases from 63mmwg to 89mmwg ➢ Further increase of air quantity upto 15000m³/min can be attained by installing 550kW Fan operating at 140mmwg
10	GDK 11	➢ Re-arrangements in ventilation system ➢ Air quantity can be increased from 13300m³/min to 15000m³/min by increasing 250 & 225kW Fan blade angle, pressure increases from 74mmwg to 92mmwg ➢ Further increase of air quantity upto 18000m³/min can be attained by installing 650kW Fan operating at 135mmwg
11	VKPL	➢ Re-arrangements in ventilation system ➢ Improving aerodynamics of conveyor installed in Main Tunnel ➢ Air quantity can be increased from 7570m³/min to 9600m³/min by increasing 250kW Fan blade angle, pressure increases from 64mmwg to 90mmwg

Sl No	Mine	Proposed re-arrangements and limitations in ventilation system
12	GDK 10	➢ Re-arrangements in ventilation system ➢ Air quantity can be increased from 9100m³/min to 10800m³/min by increasing 250kW Fan blade angle, pressure increases from 56mmwg to 77mmwg
13	KTK 1	➢ Re-arrangements in ventilation system ➢ Air quantity can be increased from 11700m³/min to 12200m³/min by increasing 250kW Fan blade angle, pressure increases from 72mmwg to 90mmwg ➢ Further increase of air quantity upto 16000m³/min can be attained by installing 500kW Fan operating at 130mmwg
14	KTK 5&5A	➢ Re-arrangements in ventilation system ➢ Air quantity can be increased from 10050m³/min to 12000m³/min by increasing 250kW Fan blade angle, pressure increases from 32mmwg to 46mmwg ➢ Further increase of air quantity is possible by operation of 2 x 225kW Fans in parallel mode. Air quantity delivered can be increased to about 18000m³/min at 90mmwg
15	KTK 6	➢ Re-arrangements in ventilation system ➢ Air quantity can be increased from 5230m³/min to 6600m³/min by increasing 150kW Fan blade angle, pressure increases from 50mmwg to 78mmwg

Underground coal mining at about 600m depth needs critical consideration of various parameters as detailed below:

Entries

- ➢ One downcast (DC) shaft and one up cast (UC) shaft of 8m-12m diameter connecting all the seams
- ➢ Man-winding in DC shaft
- ➢ Up cast shaft with high capacity Koepe Winder for coal transport and transportation of machinery and for emergency Man-winding
- ➢ Wherever possible, transportation may be provided from extension of incline roadways of existing
- ➢ Development of long gate-roadways for Longwall are to be done by simultaneous drivage of twin-roadway with interconnections at every 200/400m

- One roadway is to be used as intake and the other as return.
- Auxiliary ventilation by forcing is to be provided with auxiliary fans of required capacity installed at LVC (Last ventilation connection) with blower ducting of suitable diameter.
- Suitable dust extractor and dust control measures are to be adopted for better comfort conditions.

Main Fans

- Direct-driven Axial / Centrifugal-flow high efficiency fans
- Capacity requirement would be 300 – 500 m^3 / s (18,000 - 30,000 m^3/min) 1.5 - 4.0 kPa (150 – 400 mm of wg)
- Prime Mover capacity about 0.6 MW to 3 MW

Air-cooling requirements

- Air-cooling arrangements may be required to be provided in multiple stages, i.e., cooling at mid-way or at the end of trunks in first stage and further cooling at the entrance of district/face
- Cooling at multiple stages will optimize the positional efficiency and also leads to energy conservation
- Capacity of the cooling system would be about 1/3 of the capacity of face machinery and strata heat which would be about 1000-3000 Rt (refrigeration tonnes) for entire operations

Spontaneous heating

- Inertisation of strategic locations of caved Longwall caved goaf with optimization by CFD (Computational Fluid Dynamics) modeling
- Continuous on-line monitoring of working panels and all other strategic locations of the mine right from entrance to exit of the mine air
- All sorts of preventive measures are to be scrupulously implemented to avoid all other types of mine fires

Scientific investigations

- Scientific studies such as Numerical Modeling are required to be taken up for design of large size entries and trunk roadways for long term stability
- Optimization studies are to be taken up for Ventilation Networks, design of Air-cooling systems and Inertization modeling using CFD

- Optimization of mining technology based on conservation and economy
- R&D shall continue for Indigenous development and manufacture of Longwall, Continuous Miner & Bolter Miner equipment

Conclusions

Expensive entries like large diameter & deeper airshafts, large cross-section tunnels that may be required for up-gradation of ventilation should be effectively utilised to increase the production capacities. To increase ventilation capacity of any mine, justification is to be arrived between the factors such as possibility of reduction of mine resistance and expenses involved as well as increase of fan capacity / pressure.

Increase of intensity of airflow is considered as a pre-requisite to improve environmental conditions at workplace in most of the underground mines. In existing mines having risk of spontaneous heating and which are required to be operated at deeper horizons, artificial air-cooling requirements are to be justified based on limitation of increase of air quantity which is associated with high ventilating pressure.

As it is planned to install high capacity Main Fans in near future, similar capacity fans which are required to be operated at about 1.5 kPa (150 mm of wg) can be installed in needy mines such as GDK-5, GDK-11 and KTK-1 to gain experience of operating such fans safely in various mining conditions.

The future entries and infrastructure is to be utilised in most capital efficient manner. Techno-economic optimization studies are needed for future deep projects for optimum shaft size model involving shaft sinking cost, depth of the shaft, life of the mine, air quantity, aerodynamic resistance factor and energy.

Acknowledgements

The authors are very much thankful to the management of The Singareni Collieries Company Limited for permitting to publish this paper. The views expressed in the paper are of the authors and not necessarily of the organization to which they belong.

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Simultaneous extraction of No. 3 seam by BG Method and No. 4 seam with Hydraulic sand stowing at GDKNo.8 Incline

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Kondameedi Ravinder, SOM
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Abstract

In Indian coalmines, Blasting Gallery method of extraction is the most successful method of extraction for thick seams with higher percentage of extraction. In most of the mines of SCCL, the thick No. 3 Seam is underlain by No. 4 Seam of 3 to 4 meters thickness. The extraction of thick seam by BG method is damaging the No. 4 Seam and huge reserves of better quality coal in No. 4seam is lost forever.

To avoid the damage to the (3 m thick) No. 4 Seam, which lies beneath the (9-10 m) thick No. 3 Seam, a study has been conducted for the simultaneous extraction of No. 3 Seam & No. 4 Seams (in conjunction with sand stowing in No. 4 Seam) with the association of CIMFR for firming up of sequence of extraction.

This paper attempts and discusses various observations and scheme of Strata Monitoring done for effective ground control in successful extraction of coal in 3&4 seams, conservation and safety in the depillaring panels of GDK 8 Incline mine of The Singareni Collieries Company Limited.

Objective

The principal objective of this paper is to present different steps in the process of evolving a suitable method of extraction of No. 3 Seam & No. 4 Seam with an objective to conserve available “B Grade” coal of No. 4 Seam. Extensive strata monitoring was done in No. 3 Seam and No. 4 Seam. The critical values of roof convergence and floor deformation of No. 3 Seam vis-à-vis convergence in No. 4 Seam were analyzed for firming up of sequence of extraction of No. 3 Seam & No. 4 Seam

In the process of firming up of sequence of extraction the parameters that were paid utmost attention were

1) BG Panel Design & No. 4 Seam panel design
2) Strata management in No. 3 Seam & No. 4 Seam
3) Fire management in No. 3 Seam

Introduction

Godavarikhani No.8 Incline exists in the southern extension of South Godavari Mining Lease. It falls in Ramagundam taluk of Karimnagar District of Andhra Pradesh State.

No. 3 SEAM: In the mine, thickness of No.3 seam varies from 9.0 m to 10.5 m. The Quality of coal is "D" Grade. At certain places it is developed in two sections i.e. top and bottom & at certain places only bottom section is developed. In 3 seam depillaring is carried out by Blasting Gallery method. At present top section of 3 seam is not being developed to facilitate depillaring by BG.

No. 4 SEAM: In the mine, thickness of No.4 seam varies from 3 m to 3.96 m. The Total workable reserves are about 11.8 MT and the Grade of coal is 'B'. The seam is fully developed by board and pillar method. Extraction of the pillars is being done by sand stowing. The parting between the 3&4 seams is 9-10 m

Background of Study Area

At this mine No.4 seam below the No. 3 seam is extensively developed and is standing on pillars. The blasting gallery (BG) method of extraction was carried out in the over lying No.3 seam. After a period of 5 to 6 years allowing for settlement of goaf in No.3 seam, the extraction of No. 4 seam was started with hydraulic sand stowing below the goaved out part of No. 3 seam.

The following are the observations:

1) Extensive roof damage & falls at most of the junctions extending up to 3 m depth in many places prior to the commencement of panels in lower seam

2) Spalling of sides was prominent, to the extent of more than 2 m, which was not common while working the lower seam alone.

3) Extensive advance roof bolting and other vertical supporting was done, while working the lower seam with sand stowing, but still, roof damage was noticed and some pillars had to be left without extracting, due to bad roof conditions. Due to the above reasons, the percentage of extraction was poor with a maximum of 68 % in the lower seam stowing panel against the regular extraction of around 90 %

   This was mainly due to BG Method in Upper seam and parting of only 9-10m between No. 3 seam & No.4 seam.

   Keeping in view the above difficulties, the situation was reviewed and discussed with inspectorate on the whole issue of depillaring of No.3 Seam and No.4 seam and decided to experiment the two alternatives as mentioned below.

   1) Depillaring the underlying No. 4 Seam by sand stowing as soon as main fall takes place in the overlying No. 3 Seam or

   2) Depillaring the underlying No. 4 Seam by sand stowing first under the virgin No. 3 Seam and then extracting No. 3 Seam by BG Method, keeping a lag of 80 m.

Alternative-1: Depillaring the underlying No. 4 Seam by sand stowing as soon as main fall takes place in the overlying No. 3 Seam

As per the First alternative, overlying BG-II/6 panel was started first in No.3 seam in August-2007. The No.4 seam was extensively supported with roof bolting (1.8m) and vertical supports at junctions.

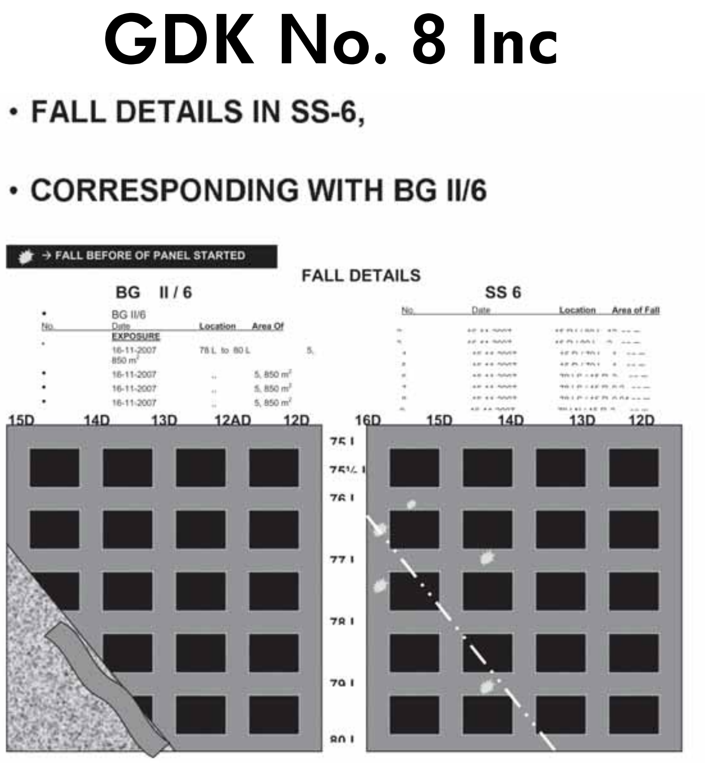
Despite extensive roof bolting and vertical support in the lower seam, the following points were observed:

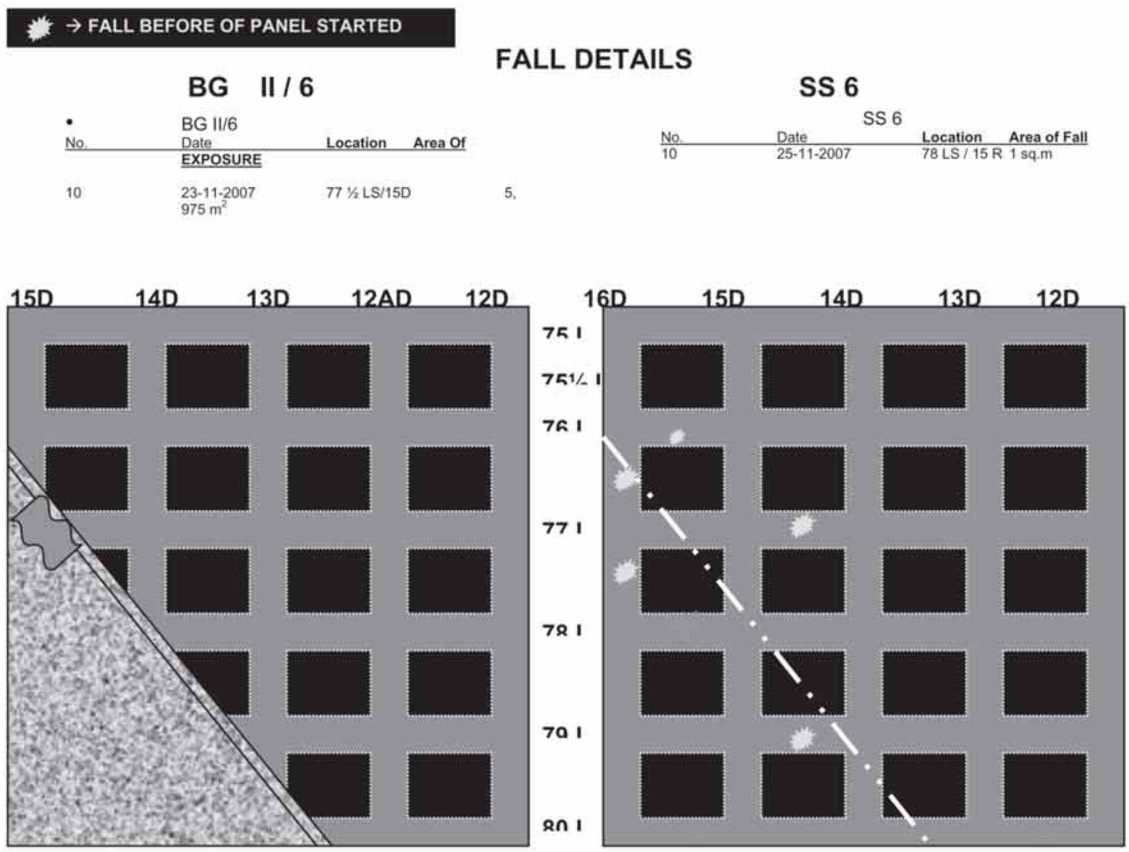
1) Heavy roof falls extending up to 3 meters, after extraction of 5,850 m^2 area (Before main fall) in the overlying BG Panel)
2) Extensive roof damage was observed due to dynamic loading associated with the falling stone in caved BG goaf
3) In addition to the dynamic loading, back abutment pressures had contributed to a greater extent for damage of roof and sides
4) Crushing and sides spalling of the pillars had taken place due to front abutment pressures
5) Maximum cumulative convergence of 6 mm was observed in 1.5 m anchor at 79 LS / 14 D

Due to the above unsafe conditions in No.4 seam, extraction could not be taken up immediately after main fall in upper seam (No. 3 seam)

Observation

After the study it was concluded that the damage due to front abutment pressures were confined to 40 m ahead of line of extraction in overlying No. 3 seam

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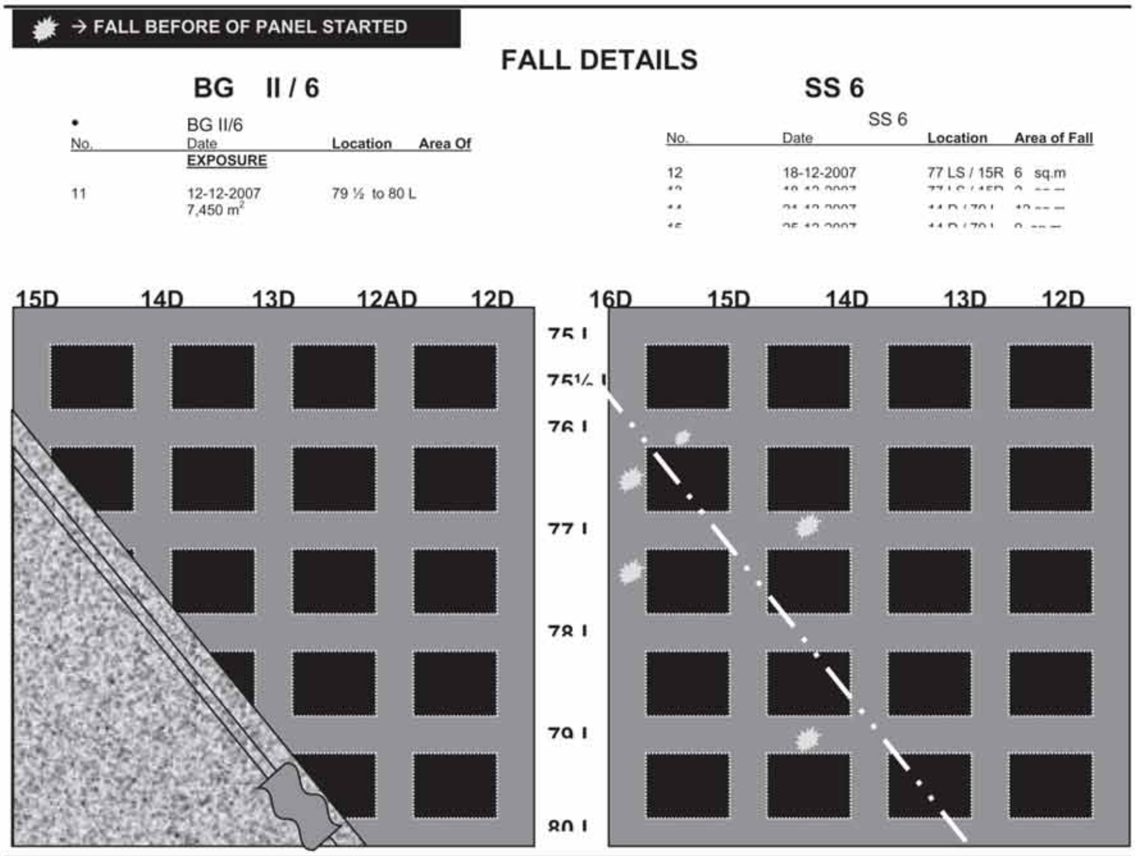
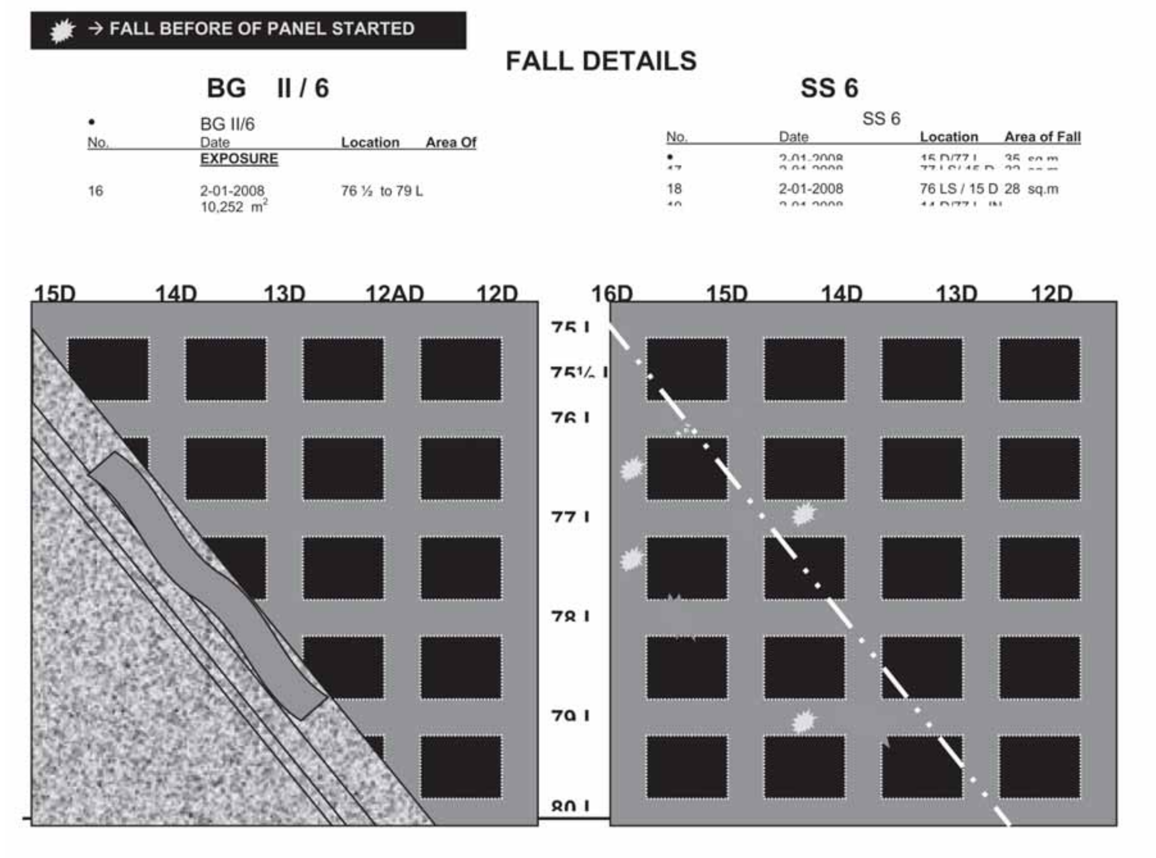
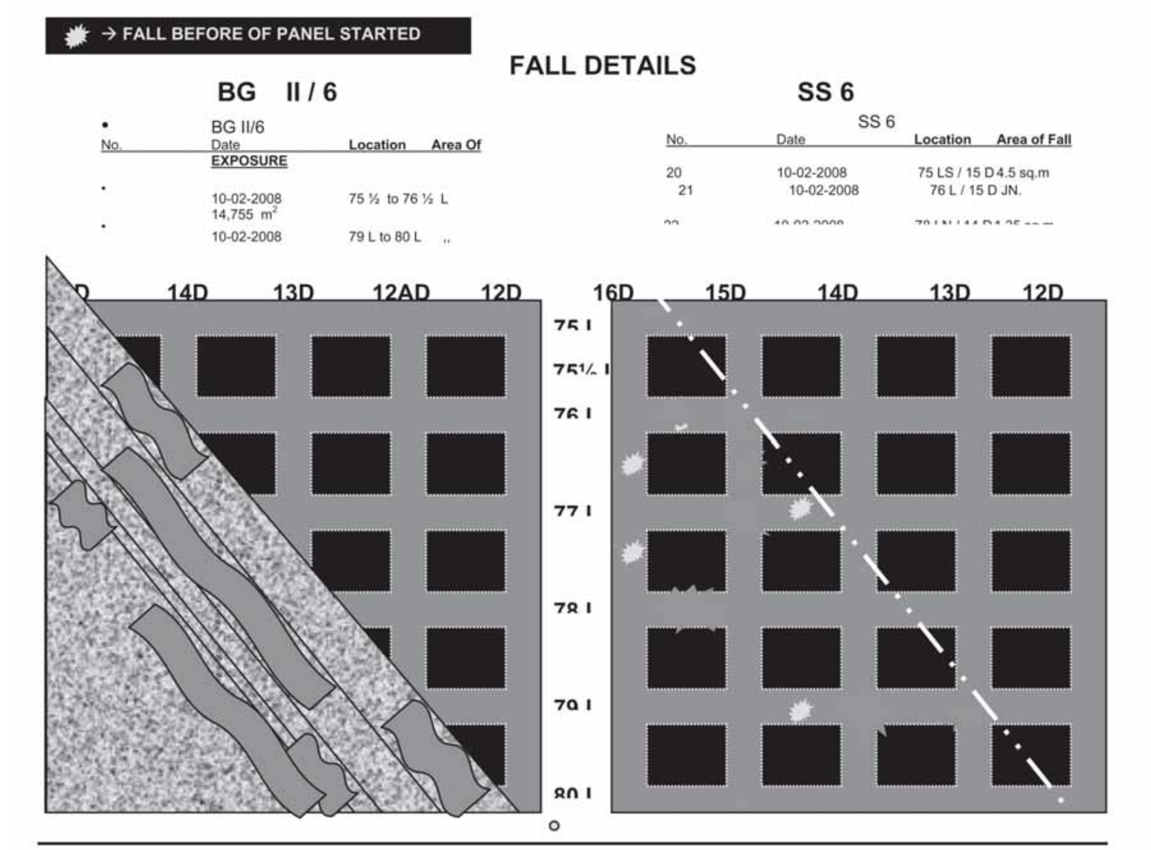
FALL DETAILS
BG II / 6
BG II/6
No. Date Location Area Of EXPOSURE
10 23-11-2007 77 ½ LS/15D 5,975 m²
SS 6
SS 6
No. Date Location Area of Fall
10 25-11-2007 78 LS / 15 R 1 sq.m
15D 14D 13D 12AD 12D
16D 15D 14D 13D 12D


→ FALL BEFORE OF PANEL STARTED
FALL DETAILS
BG II / 6
BG II/6
No. Date Location Area Of EXPOSURE
11 12-12-2007 79 ½ to 80 L 7,450 m²
SS 6
SS 6
No. Date Location Area of Fall
12 18-12-2007 77 LS / 15R 6 sq.m
15D 14D 13D 12AD 12D
16D 15D 14D 13D 12D


→ FALL BEFORE OF PANEL STARTED
FALL DETAILS
BG II / 6
BG II/6
No. Date Location Area Of
EXPOSURE
16 2-01-2008 76 ½ to 79 L
10,252 m2
SS 6
SS 6
No. Date Location Area of Fall
18 2-01-2008 76 LS / 15 D 28 sq.m
15D 14D 13D 12AD 12D
16D 15D 14D 13D 12D


→ FALL BEFORE OF PANEL STARTED
FALL DETAILS
BG II / 6
BG II/6
No. Date Location Area Of
EXPOSURE
10-02-2008 75 ½ to 76 ½ L
14,755 m2
10-02-2008 79 L to 80 L ,,
SS 6
SS 6
No. Date Location Area of Fall
20 10-02-2008 75 LS / 15 D 4.5 sq.m
21 10-02-2008 76 L / 15 D JN.
14D 13D 12AD 12D
16D 15D 14D 13D 12D

Alternative -2: Depillaring the underlying No. 4 Seam by sand stowing first under the virgin No. 3 Seam and then extracting No. 3 Seam by BG Method, keeping a lag of 80 m.

Extraction was started in 4S/SS-7 panel which is below the BG – II/7 panels. The inspectorate has permitted the extraction in No. 3 Seam after No. 4 Seam had advanced 80 meters and advised to maintain a lag of 80 m between the No. 4 Seam & No. 3 Seam workings

The line of extraction is diagonal with an angle of 55^0 from horizontal in No.3 Seam, whereas it is straight line of extraction in No. 4 Seam. So in order to maintain a lag of 80 m in the lower levels the upper levels of No. 4 Seam had to be advanced to 120 m with respect to upper workings of No. 3 Seam and also it was noticed that during the course of extraction cracks were observed in upper level of No. 3 Seam floor at a distance of 100 m behind the No. 4 Seam workings.

Maximum subsidence observed was 113mm in the floor of the No.3 seam

In view of the damage to the floor of No. 3 Seam, DGMS was requested to alter the straight line of extraction in No. 4 Seam with a step straight line extraction, so as to have 80 m lag at the upper levels and forming a step at a distance of ¾ form the bottom most levels. Even with this combination also the roof deterioration was noticed at a distance of 80 m from BG line of extraction

From the above it is observed that

i) **The front abutments of 3 seam BG are acting ahead of 40 m from the line of extraction of BG**

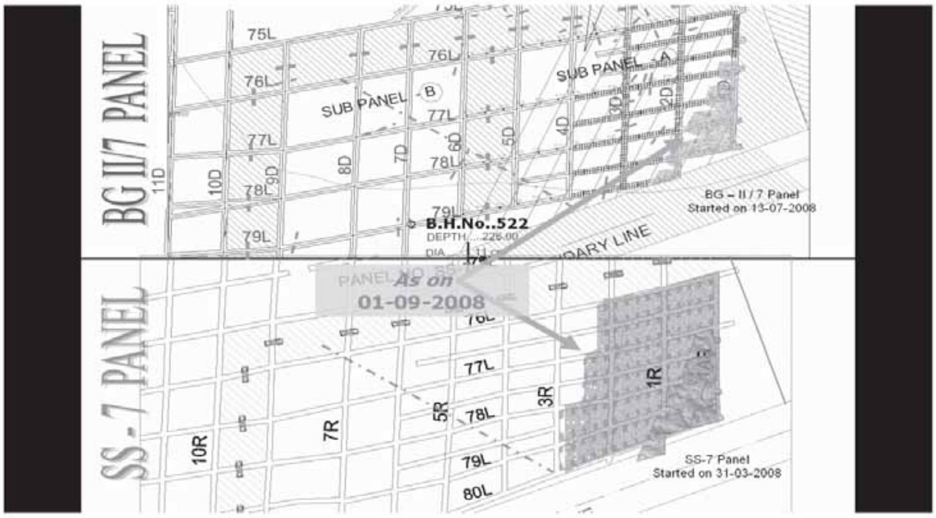
ii) **The rear abutment pressures of No. 4 seam are acting behind 80 m from the line of extraction of No. 4 seam**

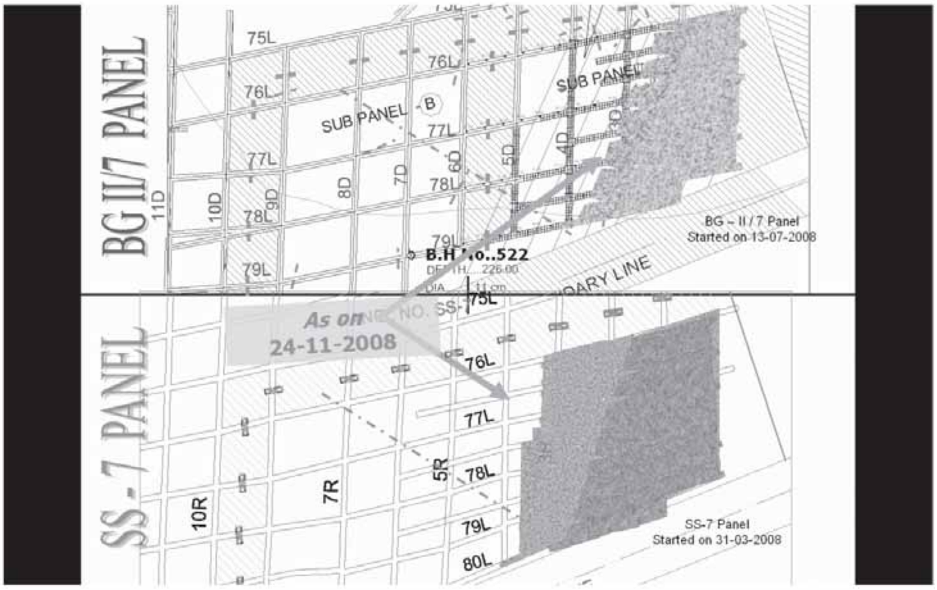
With the above experience ‘‘***the sequence of extraction is so planned that the rear abutment pressures of No. 4 Seam are in the goaf of No.3 seam and the front abutment pressures of No.3 seam are in the goaf of No.4 seam***.” Accordingly the panels were formed and approached DGMS for diagonal line extraction in both No. 3 Seam and No. 4 Seam with a minimum lag of 40 meters and maximum of 60 meters

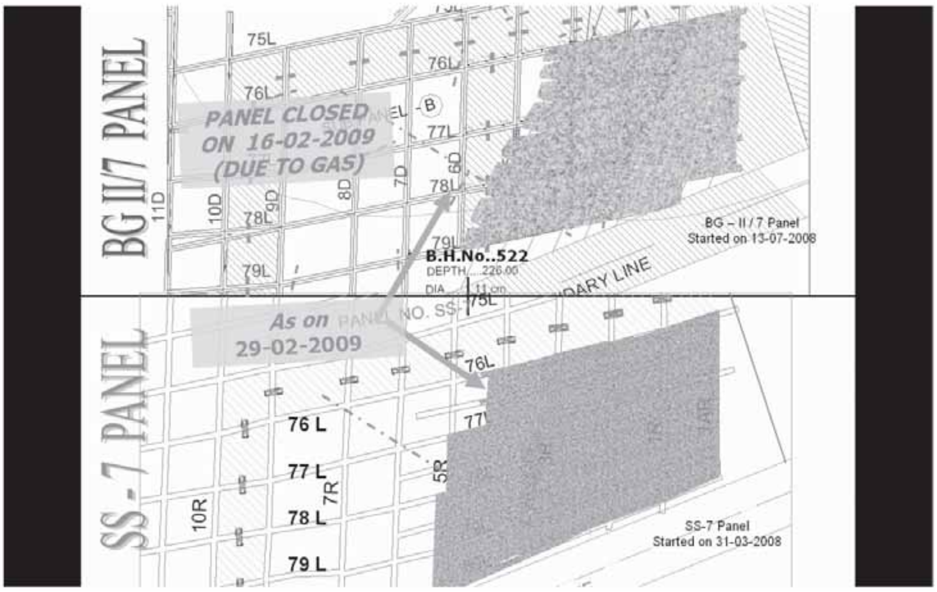
Presently BG-II/8 & SS-8 South panels are being extracted without any major strata problems while ensuring the safety and conservation of coal in both the seams

Blasting Gallery Panel

Proper design of BG panels, considering all connected problems like strata problem, fire and goaf management etc. plays a vital role in successful extraction of both the seams.


BG II/7 PANEL
SS - 7 PANEL
SUB PANEL - B
SUB PANEL - A
B.H.No..522
As on
01-09-2008
BG – II / 7 Panel
Started on 13-07-2008
SS-7 Panel
Started on 31-03-2008


BG II/7 PANEL
SS - 7 PANEL
SUB PANEL - B
As on
24-11-2008
BG – II / 7 Panel
Started on 13-07-2008
SS-7 Panel
Started on 31-03-2008


BG II/7 PANEL
SS - 7 PANEL
PANEL CLOSED
ON 16-02-2009
(DUE TO GAS)
B.H.No..522
As on
29-02-2009
BG – II / 7 Panel
Started on 13-07-2008
SS-7 Panel
Started on 31-03-2008

The following parameters shall be taken into consideration in the planning stage for safe & successful extraction of BG panels

1) Panel design
2) Strata Management
3) Fire Management

1) Panel Design parameters:

a. Area of the panel:

   i. Panel size should be such that extraction should be completed within 7 months. From the past experience at GDK 8 Incline mine, the area of the panel should be around 23,000 m^2.

b. Length of the maximum diagonal line:

   i. The optimum length of the diagonal line should not exceed 200 m at maximum span for better strata control and for achieving goaf line velocity of 1 m per day.

c. Pillar size:

   i. 40 m X 40 m size of the pillar is considered suitable from the blasting point of view and loading of the coal from the goaf.

   ii. After splitting of the pillar into two halves the resultant rib shall not be more than 16 m.

   iii. While extracting the rib, the left over curtain coal shall be removed to the possible extent from the goaf, to avoid further problem with the spontaneous heating.

   iv. Room & goaf type ventilation is found to be good.

d. Superimposition of No. 3 seam & No. 4 seam galleries wherever practicable.

2) Strata Management

i) Maximum diagonal line length should not exceed 200 m to avoid over riding of pillars

ii) Supporting up to 40 m length with 200 mm X 200 mm I-section girders in place of 150 mm X 150 mm girders for better strata control.

iii) Cable bolting shall be practiced at the junctions soon after the formation of the junctions during the development.

iv) Maintaining goaf line velocity of not less 1 m per day.

v) Induced blasting should be done regularly whenever area of un-collapsed goaf exceeds 100 m^2.

vi) Instrumentation

The strata monitoring in the panel is done with the following instrumentation.

   i) Convergence recording (0.5 m, 2.5 m and 8.5 m)

   ii) Load cells

iii) Stress capsules

iv) Multi point borehole extensometer (MPBX)

As the No. 4 seam is being extracted with stowing the No. 4 seam workings are about 40 m in advance to the BG line of extraction. The floor of the BG panel is being monitored by installing points at floor level in all the levels.

vii) As per permission conditions, strata is being monitored in each shift and being recorded. The data is being sent to the CMFRI scientist from time to time for analysis, and to give suggestions to mine authorities for safe workings of the BG panels. Quarterly strata monitoring review meetings are being held at the office of the DMS, Region – I, Hyderabad with inspectorate along with scientists of CMFRI and SCCL officers.

The fall of roof is correlated with convergence in 8.5 m rod as follows: (experiences drawn from the previous panels)

1) 8.5 m point anchored convergence point:

- In a shift, convergence recorded is as much as 2 mm, at two convergence stations located out bye of the goaf edge (i.e. 5 m to 15 m) for three successive shifts in three consecutive levels. Then roof caving has taken place in the goaf area of the above said levels.
- In a shift, convergence recorded is less than 2 mm/shift (i.e. 1 mm to 2 mm), side spalling and sounds in goaf were observed. As a precautionary measure extra supports (OC props) are fixed up to 10 m from the goaf edge.
- In our observation, 8.5 m convergence roof bolt has given appropriate indication of an impending roof fall.

2) 0.5 m & 2.5 m point anchored convergence point:

- In a shift, whenever 2.5 m point anchored convergence point convergence exceeded 2 mm, in the same room for at least two consecutive shifts, immediate roof coal layers get crumbled. Hence, tightening and strengthening of the laggings above the girders is done.

viii) Goaf Management:

Based on the cavability studies of roof of No. 3 seam at GDK 8 Inc through Geo Mechanical properties, maximum cavability index of roof is about 1424 for the 3.6 m thick bed immediately above the No. 3 seam and cavability index of roof is about 1977 for 4.7 m thick bed located at 30 m above roof level of No. 3 seam

So, the roof is classified as easily caveable because the cavability index has not exceeded 2000 for any of the beds above No. 3 seam.

However, to avoid excessive buildup of pressure on the pillars induced blasting is done whenever the hanging roof in any level is 100 m^2.

3) Fire Management

i) Regular monitoring of goaf atmosphere in all the THREE shifts apart from the Tele-monitoring System.

ii) Ventilation of the panel: Air quantity should be not less than 2000 m^3/min.

iii) Flushing of CO_2 into the goaf from the bore holes driven from the surface at critical points (@ 5 T / day).

iv) Goaf samples are collected form ¾ inch pipe laid down in the barrier pillars. This is to ensure the efficacy of CO_2 spreading in the goaf and depleting of O_2 in the goaf area.

v) Round the clock flushing of N_2 into adjoining sealed off panels shall be carried out to prevent the migration of fire.

Conclusion

After study it was concluded to extract No. 3 Seam with BG method and No. 4 Seam with hydraulic sand stowing with a minimum lag of 40 meters and maximum lag of 60 m between No. 4 Seam and No. 3 Seam

This method is proposed to be implemented in the neighboring mines also, GDK 11 Incline & VKP Mine of SCCL.

Acknowledgement

Our sincere thanks to Sri. DLR Prasad Director (P&P), SCCL, who has guided us for successful completion and implementation of the project.

Our sincere thanks to Sri S J Sibal, DGMS, Sri. P. RANGANATHEESWAR, DMS, REGION-I and SRI R. SUBRAMANIAN, DY. DMS, for their encouragement, association, permission and guidance. Our sincere thanks are due to the management of Singareni Collieries Company Limited for permitting to publish this paper.

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Swimming the turbulent water – Various business models for development and operation of Coal blocks

*M. Shalem Raju, ** Chilka. Srinivas

1.0 Introduction

Technology absorption has been the way of life at SCCL. Starting from the introduction of Electric coal drills in Underground mines of SCCL in 1937 to implementation of Enterprise Resource Planning (ERP) for better utilization of resources in the year 2009, SCCL has led the Indian Coal Mining Industry as a torch bearer in its long history of 120 years of coal mining in India. Various other technologies, which have been implemented in coalmines across the Country, have also been quickly adopted by SCCL to suit its needs.

SCCL is operating 36 UG mines and 14 OC mines producing more than 50 mtpa hard coal, with a manpower of about 68,000 in Godavari Valley Coalfield (GVCF) from a proven reserve base of 9436 MT of coal reserves distributed in 17,000 Sq. Km dispersed in 4 Districts of Andhra Pradesh namely Adilabad, Karimnagar, Warangal and Khammam. The density of coal reserves in the SCCL leasehold area is sparse at about 5.55 Million Tonnes per Sq. Km.

The proved coal reserves in SCCL lease hold area as on 31-03-2010 are 9436 MT. Since inception about 1000 MT of coal reserves have been exhausted and about 3325 MT of coal reserves are in the coal blocks covered by working OC (Opencast) & UG (Underground) mines, which are predominantly in a depth range of 0-300 m. All the present operating mines are getting deeper and deeper. Coal occurring in SCCL leasehold area is predominantly poor grade suitable for power generation and 71% of the coal production is linked to Government Power Utilities. The price of coal produced by SCCL is indirectly controlled by the Energy Sector and as such the market realization of the power grade coal from the Government Power Utilities is less remunerative in the current cost - price scenario. This is resulting in very less operating margins from the core activity of coal production. The Profit After Tax (PAT) realized from the operations of the Company even while operating at this depth range of about 30m, is not even sufficient to meet the short-term capital requirements of the Company. In the present cost – price scenario, once the operations extend to the depth range of 300-600m the economic viability of the coal mining operations of the company will be at question.

The future of SCCL lies in economic exploitation of the deep-seated coal blocks with proved coal reserves of 3117 MT in the depth range of 300-600m and beyond, aggregating to a whopping 61% of the balance 5111 Mt of proved coal reserves available for future exploitation. All opencastable coal blocks have already been projectised and the future coal production shall be invariably from deep-seated coal blocks. It is an understood

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fact that swimming this turbulent water with the present business model of departmental operations and part out-sourcing would not prove effective. Hence, various business models have been analyzed for their suitability to SCCL operations in this paper, in relevance to the current business scenario.

2.0 Various Business Models

The development and operation of coal blocks is planned by the block allottees suiting to their needs with a view to start coal mining operations at the earliest, so as to meet their specific end-use requirements. Out of the 210 coal blocks, which stand allotted as on 31.03.2010, 14 coal blocks have been advertised in the Mine Developer-cum Operator (MDO) route and the first contract in this business model is yet to start commercial mining operations. Some of the initiatives are stalled due to legal, forest / R&R (Rehabilitation & Resettlement) and environment issues.

To cope with the fast increasing demand for coal from the energy sector, it is required to start coal production from these coal blocks immediately, in the interest of the nation, or else the gap should be bridged with importing coal at higher prices involving transport and viability concerns. Similarly, the Public sector coal companies are also planning to increase their production capacities by expanding the existing mines and/or opening up new/virgin/abandoned coal blocks/mines. These initiatives are either in MDO/JV (Joint Venture) business models. Various Business models are being tried by CIL, SAIL & SCCL in development and operation of UG Mines. In this backdrop a critical analysis would be required to customize suitable business model for specific needs.

A. Straight Contracts

Straight Contracts are generally limited period contracts with limited scope of work to the contractor in the entire coal mining activity.

Contractors' role is limited to production and transfer of coal or handling of OB in a part of the mine, the contractor identified on the basis of an open/limited tender enquiry.

- All the statutory clearances and permissions are obtained by the Owner.
- Owner holds the Mining lease of the coal block.
- Owner prepares his own Mining Plan and obtains permission from MoC. All environmental clearances are also obtained by the Owner.
- Dispatch infrastructure and arrangements are either owned and operated by the Owner or separately outsourced.
- Mine Planning and supervision of operations including safety aspects shall be the responsibility of the Owner.
- Contractor's role is limited to procurement of the required machinery, its operation and execution of his scope of work, which is basically a limited scope in a fixed boundary.

- Subsidiaries of CIL (Coal India Limited) are planning few of their UG coalmines with straight contracts for operation & maintenance, purchasing the required equipment through the contractor.

Advantages of the Model

- Skilled contractors with Mine Planning & safety, supervision experience are not required.
- A number of contractors can be engaged in different sectors of the Project for various activities thereby dependence on an external agency for meeting Owners requirements is avoided.
- Competitive prices can be expected due to no unforeseen/hidden risks involved in the contracts and availability of comparatively large vendor base.
- Owner can concentrate on technical, safety and marketing part.
- Contractor can work focused on his core activity.
- Capital requirement of the Owner is reduced for procurement of the required mining machinery.
- Revenue expenditure on account of consumables, spares and planning/purchase of spares is reduced.
- For Government Companies, instead of initiating separate purchase actions for capital equipment, revenue expenditure – POL (Petroleum Oil & Lubricants), spares, service, maintenance contracts etc., one single contract will avoid time and cost overruns, for each such part activity.
- Spares management, inventory control and maintenance management issues are under the scope of the Contractor and hence better utilization of resources is ensured.
- Owners' equipment getting obsolete or idle is avoided.
- Due to competitiveness, efficiency of operations is assured and the benefit is accrued indirectly to the Owner.
- Access to a large pool of experienced contractors.

Limitations

- Litigations arising out of contractual obligations.
- Labour unrest/disputes.
- Contract workpersons are not protected under Labour laws and are some times/often exploited by the Contractors. Owner should enforce diligence as Principal Employer and ensure enforcement of labour laws through the contractor by making required provisions in contractual obligations to avert the risk.
- Inefficiency of the contractor affects the owners' revenues, increasing production cost.
- Cartelisation may result in huge losses.

B. MDO Contracts

MDO Contracts are basically bundled contracts with scope of work of the contractor starting from land acquisition, detailed exploration, mine planning, obtaining permissions & clearances, creating infrastructure, actual Mining operations, Operation & maintenance of machinery, safety, supervision and environment aspects extending upto transfer of coal to a fixed transfer point. Some MDO contracts are specifying identification of suitable coal blocks also and extending upto coal handling and dispatch upto the end use plant by rail/road/ conveyor etc. In such contracts the role of Owner is very limited with absolutely no control over the operations and contractors except through enforcement of contractual obligations. SAIL has advertised NIT for development & operation of two of its UG coal blocks in the MDO route. Subsidiaries of CIL are planning introduction of Mass-production technologies in their mines in the MDO route.

Advantages of the Model

- Owner need not have any experience in Mining Operations.
- No capital investment
- No owners' manpower is required for execution of the project.
- No safety risk to the owner.

Limitations

- In India there are no big Contract Mining Companies, which have the required expertise and capable of sourcing the required capital inputs.
- Contract Mining Companies in India mostly execute straight contracts executing part OB removal, coal extraction or tunneling contracts etc. They don't have the required Mine Planning, Mine Safety and supervision experience to take up big MDO contracts.
- Hidden risks in various operations are factored by the contractors resulting in high prices.
- With less competition, price quotes are not competitive.
- Indian Contract Mining Sector is not so matured with well-designed risk sharing mechanism in place.
- Lot of ground still remains uncovered in specifying the roles and responsibilities and the consequent risk-gain sharing mechanism between Mine Owners & MDO Contractors.
- In many cases, more particularly Govt./PSU MDO contracts, all risks are loaded on Contractors.
- Even legal, statutory and political risks are shifted to the scope of MDO.
- Legal and regulatory frame works are certain critical uncertainties affecting survival of Contract Mining business apart from Contractual risks.

- Fund raising for the MDO contractors is also a matter of concern, more particularly in the prevailing market conditions/recession. Funding of Mining Projects may be even more difficult with high contractual risks of land acquisition, development and safety matters included in the contractor's scope of work.

To absorb all the risks, the MDO contracts are planned for longer terms so that all the costs are factored over a long term. Not many contractors are ready to absorb contractual risks for longer terms due to the associated hidden financial risks. Even if all the hidden risks are also factored by the contractors, the cost becomes so high that the market price of coal indicates a huge financial loss to the Owner.

C. JV mode Contracts for shared risk or Open Book system

- A different business model with risk and gain sharing between the Owner and the Contractor can be JV mode where the ownership of the coal block is shared between the parties and risks & returns are also shared between the parties. With no hidden costs involved both the parties operate in a win-win business environment.
- Shared risk system can start from pre-feasibility phase to execution of the project for its life without undue losses/profits to any party.
- The scope of work of each party is clearly defined and each party executes its role with transparency without any undue loss or profit to any party since the books are open for inspection of the other party.
- JV Partner alone or Owner and JV Partner or Owner alone takes action for getting clearances & permissions and finances the project as per their understanding.
- JV Company delivers coal to the Owner at a price fixed in the tendering process with appropriate provision for escalation.
- Mining lease can also be transferred to the JV Company.
- But Block allottee/owner should hold atleast 26% equity in the JV.
- The JV Partner is selected in a transparent competitive bidding process

<u>Advantages of the Model</u>

- Beneficial to both the parties with risk and gain properly shared.
- No hidden costs and risks
- Execution of projects with no cost or time over runs.
- Reduced cost of operations.

Limitations

- It can be successful only if the responsibilities and risks & roles of each party are clearly defined.
- If a particular activity, like LA / R&R are jointly handled, it may result in buck – passing.
- Problems are expected in sequential responsibilities – one party stalled in execution of a preceding activity may hinder the execution of another sequential activity, which necessarily precedes the subsequent activity of other party.
- No Coal Mining contract is yet executed in this model, as yet.
- Availability of suitable JV partner with the required technical and financial strengths in Indian market is a question. Associated with it is the risk of high costs to the owner.

3.0 Experience of SCCL in these Business models

a. Straight Contracts

- SCCL is awarding numerous straight contracts for OB removal, coal extraction, Infrastructure, Transport contracts etc, which are generally short term contracts with limited responsibility and risk involvement.
- Cost benefit is accrued to SCCL.
- Wide vendor base is available and the cost benefit of high competition is transferred to SCCL.
- Assured Mining schedules and certainty of product delivery schedules.
- Timelines are aligned with project aspirations.
- No hidden costs to SCCL or risks to the contractor.
- Reduced capital investment for SCCL.
- Assured cash flow from operations to Contractors.
- SCCL has not awarded any straight contracts in UG mining.

b. MDO Contracts

- This model is of much disadvantage to a technically sound owner who can manage the hidden risks involved in development and operation of coal blocks. So SCCL is not awarding any MDO contract.
- SCCL as a technically sound Company is participating in various MDO tenders floated by coal block allottees.
- SCCL is planning for straight contracts of part activities (sub-contracting) in case the MDO contract is awarded to SCCL.
- Dual advantage of less competition in MDO arena and more competition in down stream straight contracts is possible in this business model. The cost benefit is ultimately extended to the coal block allottees/owners.

- SCCL is yet to enter into / conclude a contract in this business model.
- Though 210 coal blocks stand allotted as of now and about 14 coal blocks have been advertised in MDO route, the first MDO contract is yet to be awarded in Indian Coal Mining industry.
- SCCL is planning introduction of high capacity new-generation longwall equipment in one of its existing UG mines, which has been planned for such mechanization. The role of the contractor is to design suitable equipment, procure the same, take care of operation & maintenance, produce and transfer coal to SCCL at a designated transfer point on surface at a stipulated production level on cost per tonne basis. SCCL shall take care of safety, supervision, ventilation & pumping. Due to the responsibility matrix involved between the parties, the contractor is termed as "Technology Provider – cum – Operator" (TPO).

c. JV Route/Risk Gain sharing model

- Though SCCL is yet to conclude an agreement in this business model it is engaged in active talks with four Government coal block allottees for development and operation of four coal blocks. SCCL has entered into an MoU with M/s. APGENCO for development and operation of Tadicherla-I coal block in this business model.
- With no hidden costs and risks involved, both SCCL and the Owners shall be at advantage.
- The expertise of SCCL can add value to the activity in professional coal mining operations and SCCL is also benefited with assured returns on its costs incurred. Block Owners are also at advantage with reduced costs and assured coal production.
- Further, SCCL is planning to operate some of its presently unviable UG coal blocks in this business model, expecting good response from the vendor base with a stipulation in place to extend coal sharing to the JV partner selected in a transparent competitive bidding process to his end use projects. Required clearances and permissions are awaited.

4.0 Conclusions

a. Complex technical and commercial issues involved in extraction of deep-seated coal reserves call for dynamic business models suitable for and tailor-made for the application.

b. It can be emphatically concluded that SCCL is pursuing different business models to its definite advantage, duly considering the advantages and disadvantages.

c. In pursuing these business models, the following elements are given due attention, so that no disputes arise in execution of the contracts. NIT (Notice Inviting Tender) and Agreements should address all these issues in sufficient detail.

   - Scope of work of coal party.
   - Responsibilities of coal party.
   - Measurement and reporting methodology of Key performance indicators.

- Payment terms.
- Price variation methodology.
- Guarantees and Penalties.
- Dispute resolution mechanism.
- Standards and Specifications.
- Schedules and time frames for deliverables.
- Events of default and termination clauses.
- Recover in case of default and payment on termination.
- Term of contract and provision of extension.
- Disclaimers

d. Coal block allottees with no experience in coal mining operations have to opt for MDO business model, where there is less competition.

e. Experienced operators may be selected by such coal block allottees to execute their coal blocks in JV / shared risk route, for avoiding huge financial risks.

f. A critical analysis of a particular requirement is to be done before taking a decision to delegate the development & operation of coal blocks.

g. A well-planned and calculated approach for selection of suitable business model is most important to successfully execute mining contracts.

5.0 Acknowledgements

The authors are thankful to the Management of SCCL for permitting presentation of this paper in the National Seminar on Underground Mining. The views expressed by the authors in the paper are their personal and not necessarily of SCCL.

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Role of Some Critical Parameters on the Performance of Quick Setting Cement Installation with Roof Bolt in Underground coal Mine

G. C. Roy* and N. C. Dey**

Abstract

With the advancement of underground coal mining technology, roof bolting becomes the prime means of supporting system. It can be used in solid blasting face and has got flexibility to adopt in mechanized mines too. Moreover it gives opportunity to avoid deforestation. As a result of that it is replacing the traditional system of timber support rapidly. Presently available quick-setting cement (QSC) is not very conducive to adapt in underground coalmines in India. In this paper an attempt has been made to identify the key parameters, which are responsible for change in performance of roof bolting in coal mines.

Key words

Ordinary Portland cement (OPC), Quick Setting cement (QSC), High Alumina Cement (HAC), Setting time, Pull load, etc.

Introduction

Roof support is a fundamental requirement for strata control in underground mining practice both in metal and coal. Roof control is a major problem affecting safety and productivity in underground mines. Roof fall itself accounts for nearly 44% of the underground fatal accidents[1]. In coalmines freshly exposed roof in development faces are supported to resist bed separation of overlying roof strata to avoid accidents due to roof fall. Timber support was the primary method of support system, which was used to support immediate roof and still continues to be an effective system for ground support, due to its availability, flexibility, and ease of installation.

Timber supports suffer from lots of setbacks, such as higher material cost and labour cost associated with its labour-intensive installation, involvement of huge deforestation, provide restriction on transportation of materials, increase cost of mine ventilation, etc. Timber supports are replaced to a large extent by roof bolting. Presently with the advancement of underground coal mining technology, roof bolting becomes the prime means of supporting system. It can be used in solid blasting face and has got flexibility to adopt it in mechanized mines too. Moreover it gives opportunity to avoid deforestation. As a result of that it is replacing the traditional system of timber support rapidly.

However, roof falls still occur frequently in the roof bolted entries. The two possible reasons are: the lack of knowledge of and technology to detect the roof geological conditions and lack of roof bolting design criteria and its quality (as prescribed in DGMS Circular) for modern roof bolting systems[2].

Various ingredients of QSC play an important role on its setting behaviour as well as strength characteristics.

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** Professor Department of mining Engineering, Bengal Engineering and science University, Shibpur, Howrah-03.

Composition of OPC, QSC and HAC

Chemical analysis of cement in laboratory is basically very time consuming and cumbersome job. Moreover the result obtained through these processes is highly erroneous. Scanning Electron Microscope/Energy Dispersive Using X-Ray (SEM-EDX) can efficiently count the atomic percentage and weight percentage of the different elements in the composition (as shown on figure 1). Spectrums of different elements in a sample are analyzed and the atomic percentage and weight percentage of elements are obtained from it. Figure 2 shows the spectrum of ACC cement. After obtaining the atomic percentage of different elements a logical analysis is done to obtain the percentage of oxides of different metals through balancing of oxygen to get the absolutely correct chemical composition of the cement samples

Figure 1: SEM – EDX

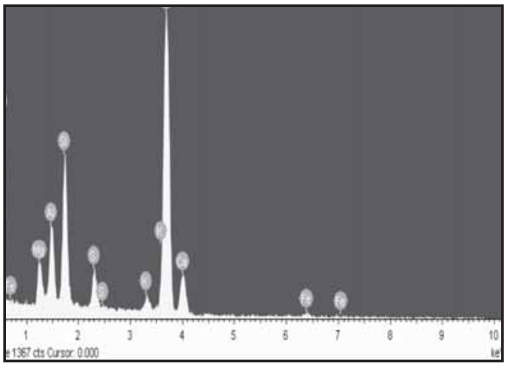

Figure 2: Spectrum of a cement sample

The raw materials used for the manufacture of cement consist mainly of lime, silica, alumina and iron oxide[3]. These oxides interact with one another in the kiln at high temperatures to form more complex compounds. The relative proportions of these oxide compositions are responsible for influencing the various properties of cement; in addition to rate of cooling and fineness of grinding. Ordinary Portland cement (OPC), Quick Setting Cement (QSC) and High Alumina Cement (HAC) samples have been collected from the commercial market and chemical analyses of those samples have been carried out in laboratory. Table 1 shows the approximate oxide composition limits of OPC, QSC and HAC.

Oxides	OPC	QSC	HAC
Al_2O_3	6.7	4.2	34.7
SiO_2	24.4	23.0	11.6
CaO	58.7	18.5	44.4
MgO	5.2	6.8	1.9
$CaSO_4$	3.8	44.6	0.0
Fe_3O_4	0.5	0.2	1.4
K_2O	0.5	0.0	0.0
MnO	0.2	0.0	0.0
K_2SO_4	0.0	0.3	0.0
Na2SO4	0.0	0.1	0.0
TiO_2	0.0	0.0	6.1

Table: 1 approximate oxide composition limits of OPC, QSC and HAC

Chemical analysis shows that the OPC and HAC have high percentage of calcium oxide where as QSC has very high percentage of Calcium Sulphate. HAC contains extraordinary percentage of alumina and oxides of titanium metal. Difference in rest of other ingredients is not significant in all three types of cements.

Significant Parameters in QSC

Initial setting of OPC varies from 180 minutes to 330 minutes. Initial setting times of different OPC available in the market are being carried by Auto Vicat Apparatus as shown in figure 3. Addition of calcium sulphate hemihydrate (CaSO4. ½ H2O) reduces the setting time of OPC rapidly and it brings down to few minutes. The influence of calcium sulphate hemihydrate on initial setting of OPC is shown on figure 4 and the characteristics can be expressed as per the following relation:

$y = a+bx+cx^2+dx^3$

Values of co-efficient;

a = 1.30

b = -2.84

c = 1.96

d = -4.25

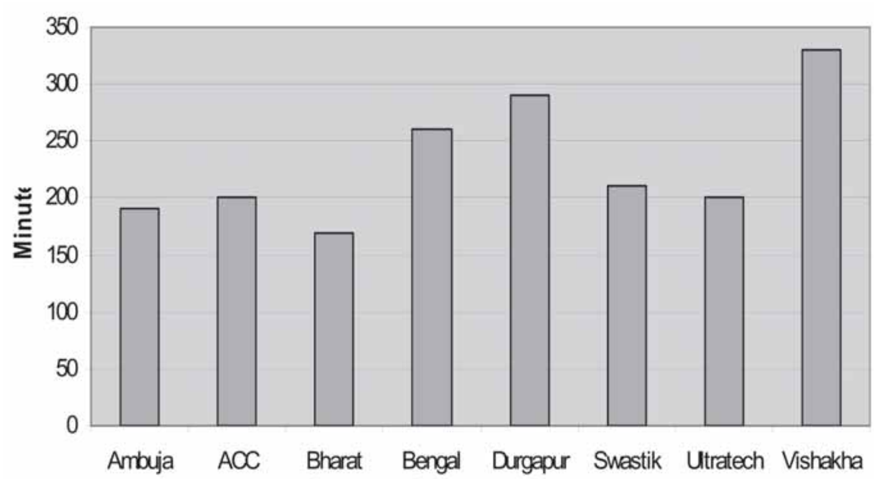

Figure 3: Initial setting time of OPC

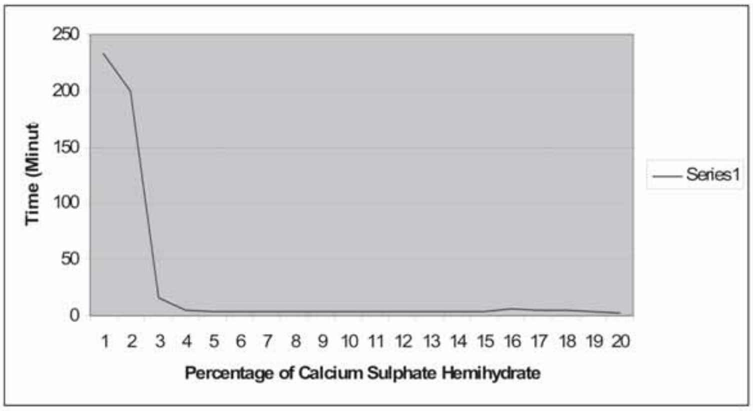

Figure 4: Initial setting time of OPC with different percentage of $CaSO_4$.1/2 H_2O

Addition of CaSO4. ½ H2O in OPC reduces its initial setting time but it does not carry any impact on its strength. The anchorage loads in different time interval are shown with increasing percentage of CaSO4. ½ H_2O in table 3. It is observed that the initial anchorage load both in half an hour as well as in two hour is very poor. Though these compositions are quick setting in nature even then it cannot be recommended to use in underground coalmines as anchorage material for the purpose of roof bolting.

Table 2: Anchorage Load of Roof Bolt with different percentage of CaSO4. ½ H_2O

Serial No.	CaSO4. ½ H_2O percentage	Anchorage Load of 1.5m full column grouted roof bolt		
		½ Hour (Ton)	2 Hours (Ton	24 Hours (Ton)
1	5	0.8	1.1	10.4
2	8	1.1	1.3	11.7
3	11	1.3	1.4	8.6
4	14	1.1	1.3	9.7
5	17	1.0	1.3	9.1
6	20	1.1	1.3	10.8

Laboratory experiments shows that High Alumina Cement (HAC) has a great influence on gaining early strength of composite mixture of OPC and CaSO4. ½ H_2O up to a certain range. Early strength reduces sharply when the percentage of HAC increases above 40% of the total mixture. Experimentation is carried out in laboratory to estimate the ultimate pull load of full column grouted roof bolt of 1.5m. Results of the same are shown on table3.

Table 3: Ultimate Pull Load roof bolt with different percentage of HAC

Serial No.	OPC (%)	HAC (%)	$CaSO_4$.1/2 H_2O (%)	Anchorage Load of 1.5m full column grouted roof bolt (Ton)
1	70	10	20	0.6
2	60	20	20	1.3
3	50	30	20	1.9
4	40	40	20	4.0
5	30	50	20	1.5
6	20	60	20	1.3
7	10	70	20	1.5

From the above table it has been observed that 40% OPC, 40% HAC along with 20% $CaSO_4$.1/2 H_2O yields early high anchorage load to 1.5m full column grouted roof bolt. The performance is satisfactory. So, it can be tested in mines prior to make recommendation for supporting freshly exposed roof in underground coalmines as anchorage material.

Field-trial report

Cement samples prepared as per serial no.4 of table 4 in the laboratory of mining engineering department of Bengal Engineering and Science University of Shibpur. Prepared sample, which is of quick-setting nature has been tested in 12th rise above 23 level of RVI seam of Main Industrial Complex unit of Jhanjra Project mine of ECL. Table no 3 shows the field trial report.

Table 3: Ultimate Pull Load roof bolt observed in freshly exposed roof

Serial No.	½ Hour	2 Hour	24 Hour
1	2.5 (failed)	4.5 (failed)	13 (not failed)
2	3.0 (failed)	4.5 (failed)	13 (not failed)

Conclusion

Calcium Sulphate Hemihydrate reduces initial setting time of OPC rapidly. So, it is a very important ingredient of quick-setting cement. But it alone along with OPC cannot be used as quick-setting cement in mines. Addition of proper proportionate of high alumina cement with the mixture of OPC and Calcium Sulphate Hemihydrate can certainly develop qualitative and cost-effective QSC for application in roof bolting in underground coalmines.

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NUMERICAL MODELLING
- AN EFFECTIVE TOOL FOR STRATA CONTROL IN COAL MINES

*B. Ramesh Kumar, **Debasis Deb,
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ABSTRACT

Proper understanding of complex behavior of rock mass has always been difficult for reliable design and safe operation of mining structures. Numerical modelling has emerged as a popular tool solving the static as well as the dynamic processes assisting in proper design and operation of the structures. This paper introduces the basics of different numerical modelling approaches, various applications of numerical modelling techniques for strata management in mines and various numerical modelling codes that are being used elsewhere in the world in the field of mining. A practical example of shield strata interaction in longwall panel using ANSYS finite element code is also illustrated.

INTRODUCTION

Understanding the behaviour of rock in general and the jointed rock mass, in particular, has always been difficult for mining engineers involved in reliable planning & design and safe operation of mining projects under complex and difficult conditions. Although there exist a number of analytical techniques that can be used in engineering design, the simplicity of these models and the complexity of the real world often force the engineer to search for alternative methods of analysis. Numerical modelling techniques require far more computational power than analytical techniques, but they are well suited in addressing complex geometries and material behaviour.

A model is a simplification of reality rather than an imitation of reality. It is an intellectual tool that has to be designed or chosen for a specific task1. Most of the numerical modelling undertaken in the process of mine planning and design involves using linear elastic, static, and boundary element programs.

The speed, memory efficiency and ease of use of these codes render them well suited to quick design analysis. It is sometimes necessary, however, to incorporate non-linearties, such as brittle failure or joint slip, and also to solve problems involving dynamic stresses, plastic displacements, thermal properties and heat transfer, time dependent behaviour, etc., into particular analysis.

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Numerical models can represent complex geometries with a high degree of accuracy. The approach adopted in all numerical methods is to “divide the problem into small physical and mathematical components and then sum the influence of the components to approximate the behaviour of the whole system”. The series of complete mathematical equations formed in this process are then solved approximately. By definition, the computational solutions are always approximations of the exact solution.

A numerical model code is simply capable of: (1) solving the equations of equilibrium, (2) satisfying the strain compatibility equations, and (3) following certain constitutive equations - when prescribed boundary conditions are set forth.

The main sources of the input data for the numerical model are, site investigations, and laboratory and field tests. Numerical methods will give approximate solution, but not the exact solution of the problem. The numerical modelling technique seems to be a valid tool for mine design, if it is properly used.

NUMERICAL MODELLING APPROACHES

Various numerical modelling techniques have been developed and are currently being used by engineers and scientists world over. The methods are categorized as Continuum, Discontinuum and Hybrid Continuum/ Discontinuum.

The continuum assumption implies that at all points in a problem region; the materials cannot be torn open or broken into pieces. All material points originally in the neighbourhood of a certain point in the problem region remain in the same neighbourhood throughout the deformation or transport process.

1. **Continuum methods**
   - Finite Difference Method (FDM),
   - Finite Element Method (FEM),
   - Boundary Element Method (BEM).
2. **Discontinuum methods**
   - Discrete Element Method (DEM),
   - Discrete Fracture Network (DFN) methods.
3. **Hybrid Continuum / Discontinuum methods**
   - Hybrid FEM/BEM,
   - Hybrid DEM/BEM,
   - Hybrid FEM/DEM, and
   - Other hybrid models.

BOUNDARY ELEMENT METHOD (BEM)

This method derives its name from the fact that the user 'discretizes', or divides into elements, only boundaries of the problem geometry (i.e., excavation surfaces, the free surface for shallow problems, joint surfaces and material interfaces), thus reducing the problem dimensions by one and greatly simplifying the input requirements. In this method the conditions on a surface could be related to the state at all points throughout the remaining medium, even to infinity. The information required in the solution domain is separately calculated from the information on the boundary, which is obtained by solution of boundary integral equation. Boundary element methods (BEM) are simpler and faster, but usually not powerful enough to accommodate complex geometry and excessive variations in rock mass properties.

Finite Element Method (FEM) and Finite Difference Method (FDM)

In practice finite element method is usually indistinguishable from the finite difference method. In these methods, relate the conditions at few points with in the medium (nodal points) to the state within a finite closed region formed by these points (element). The physical problem is being modeled numerically by discretizing (i.e. dividing into zones or elements) the problem region.

The FDM is a direct approximation of the governing partial differential equations (PDEs) by replacing partial derivatives with differences at regular or irregular grids imposed over problem domains, transferring the original PDEs into a system of algebraic equations in terms of unknowns at grid points. The solution of the system equation is obtained after imposing necessary initial and boundary conditions. This method is the oldest member in the family of numerical methods, one that is widely applied.

In FEM, trial functions, usually polynomial, are used to approximate the behaviour of PDEs at the element level and generate the local algebraic equations representing the behaviour of the elements. The local elemental equations are then assembled, according to the topologic relations between the nodes and elements, into a global system of algebraic equations whose solution then produces the required information in the solution region, after imposing the properly defined initial and boundary conditions.

Finite Differential techniques (FDM) are far more powerful and versatile. Complicated problems involving complex geo-mining and stress environments, as often found in actual mining complexes, can be studied and solved in much more elaborate and realistic fashions in these methods. "FDM results into conditionally stable solution. That is, the convergence of the solution at different stages of iteration to a true solution depends on the size of elements and size of the load steps. It has also got the advantage of time-stepping which allows a better understanding of the trend and mode of a failure".

FEM is perhaps the most versatile of all methods and capable of yielding the most realistic results even in complex geo-mining conditions. Complexity in problem formulation and requirements of long computer time and large memory space seem to be its major shortcomings. As his requires more memory, it may not able to accommodate layer problems.

Discrete Element Method (DEM)

The DEM for modeling a Discontinuum is relatively different compared with BEM, FEM and FDM, and focuses mainly on applications in the fields of fractured or particulate geological media. The essence of DEM is to represent the fractured medium as assemblages of blocks formed by connected fractures in the problem region, and solve the equations of motion of these blocks through continuous detection and treatment of contacts between the blocks. The blocks can be rigid or be deformable with FDM or FEM discretizations.

Hybrid approaches

To make use of the merits of the above methods, a few hybrid simulation procedures coupling more than one method have also been evolved. The main types of hybrid models are the hybrid BEM/FEM, DEM/BEM models. The hybrid models of DEM/FEM are also developed. The BEM is most commonly used for simulating far-field rocks as an equivalent elastic continuum, and FEM and DEM for the non-linear or fractured near-field where explicit representation of fractures or no-linear mechanical behaviour, such as plasticity, is needed. Various numerical approaches to model an excavation and the representation of fractured rockmass are as shown in figures1 and 2 respectively.

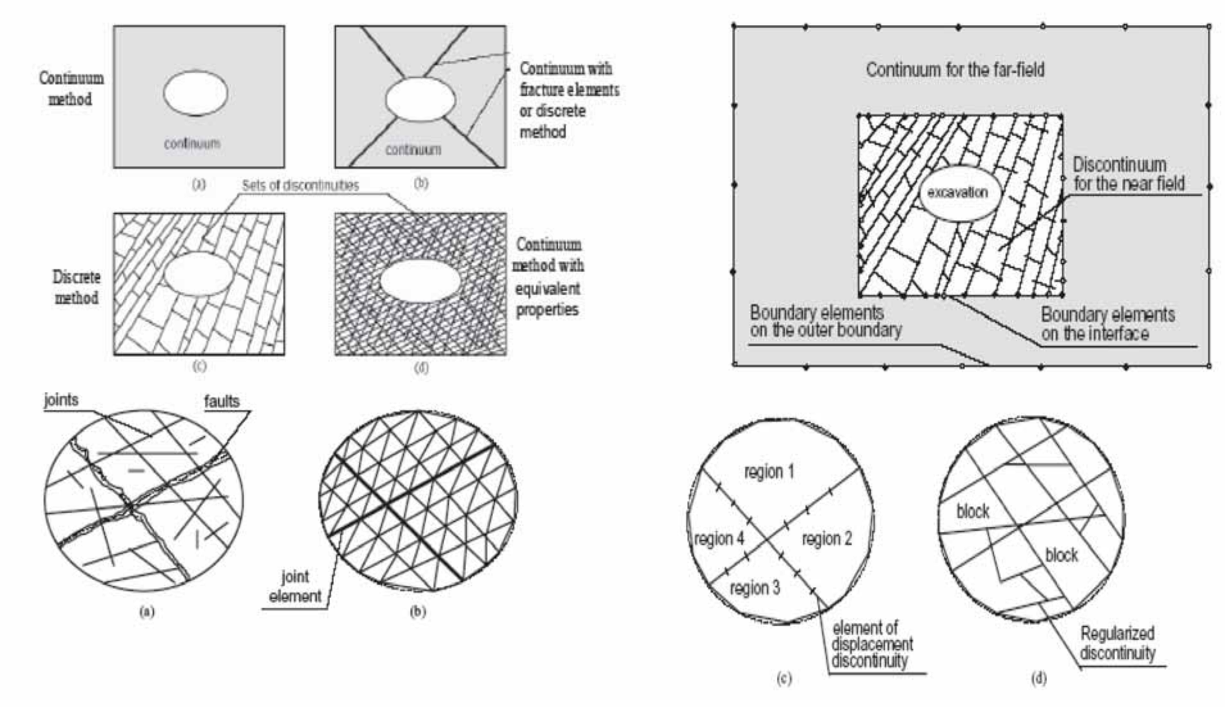


Fig.1 (a) and (b) Numerical approaches to model an excavation in a rock mass[2]

Fig.2 Representation of a fractured rock mass showed in (a), by FDM or FEM shown in (b), BEM shown in (c), and DEM shown in (d) [2]

Applications

The various applications of numerical modelling programs in the field of mining are as follows;

1. Design of Openings, and Pillars.
2. Design of Supports for Bord and Pillar and Longwall workings.
3. Design of pit slopes and dumps and estimating their stability in case of opencast mines.
4. Prediction of Main and periodic weightings in Bord & Pillar and Longwall workings.
5. Analysis of shield support interaction in case of Longwalls.
6. Analysis of long term stability of permanent mine excavations.
7. Prediction of surface subsidence over mine excavations., and
8. Simulating effects of blasting on stability of mine workings in Underground as well as in opencast mines.

Being totally computer based, numerical modelling techniques have a special touch of glamour and sophistication compared to other approaches in rock mechanics and ground control studies. The results of the modern software packages are presented in attractive and convincing fashions.
In short, to-day's numerical modelling software programs have such interesting and charming features with make believe style of presentations of their results, that very commonly their users and sometimes the experts as well, get carried away by the impression that these methods are far superior to all other conventional approaches. It is strongly believed by many that these techniques are capable to provide answers to all the questions regarding ground control in little time; their results and subsequent predictions cannot go wrong and no other studies, whether observational, empirical or analytical, are required to support or supplement them.

Model Calibration

Any numerical modelling exercise on rock excavations, without proper calibration and validation is incomplete and should not be fully relieved upon. Of course, un calibrated models may be used to have a preliminary idea for the likely situation that may be encountered in and around a rock excavation, or for arbitrary case studies, provided the input parameters are realistic.

It is a wrong concept that precise numerical simulation of a real mining problem needs much less time than other alternatives. Initial task of calibration and validation of a model is perhaps a long and more complicated process than other methods. But, this technique reveals much more information and once validated, more reliable and accurate predictions are possible from a model. The information required for calibrating a numerical model is shown in Figure.3.

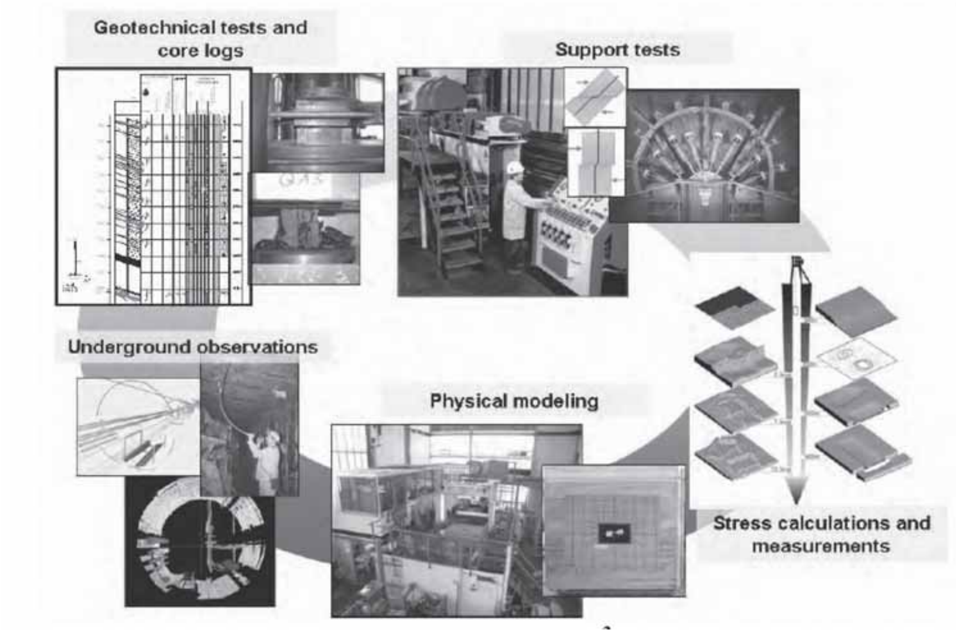


Fig.3. information required to calibrate a model[3]

The various numerical modeling softwares available and are being used in the field of mining are as given in the below Table 1. The complexity rating from easiest to most difficult to use is: simple, mediocre, advanced, complex, specialist.

Code	Source	Type	Use	Complexity
BESOL	Mining Stress Systems	2D/3D BEM	Common	Simple
EXAMINE	Roc Science Inc	2D/3D BEM	Rare	Mediocre
MAP 3D	Mine Modelling Ltd	3D BEM	Moderate	Mediocre
LaMODEL	--	3D BEM	Moderate	Simple
MUSLIM/NL	USBM	3D BEM	Moderate	Mediocre
FLAC	Itasca Consultancy Ltd	2D/3D FDM	Common	Advanced/Complex
COSFLOW	CSIRO	3D FEM	Rare	Advanced
Phase2	Roc Science Inc	2D FEM	Moderate	Simple
ANSYS	ANSYS, Inc	2D/3D FEM	Moderate	Advanced
ABAQUS	Dassault Systems Simulia Corp	FEM	Moderate	Advanced
PFC	Itasca Consultancy Ltd	2D/3D DEM	Rare	Complex
3DEC	Itasca Consultancy Ltd	3D DEM	Rare	Complex
UDEC	Itasca Consultancy Ltd	2D DEM	Moderate	Advanced
BEFE	--	2D/3D FE &BEM	Rare	Complex
ELFEN	Rockfield Software Ltd	2D/3D FE &DEM	Rare	Complex

Table 1: Comparison of various Numerical modeling Softwares

Application of finite element method in Longwall mining

Finite-element method has found wide application in ground control study of longwall mining. This widespread use is related to their ability to model the irregular structure, non-linear, non-homogeneous, and anisotropic nature of rock strata.

Generally, rock strata, such as sandstone, limestone, shale, clays, and other intermixed sediments that occur with coal seams, do not behave elastically in actual engineering problems. They may go into plastic state (or change in material property due to load) after the load on them exceeds a certain limit, which is called elastic-to-plastic state (Cook et. al., 2001). Thus, in the case of analyzing inelastic and nonlinear behavior of strata related coal mining, the nonlinear material model should be employed.

Peng, 1980 applied three-dimensional finite element analysis to determine the major controlling factors in the design of an advancing longwall panel and its support systems. In the same manner, Peng et. al., 1980 again employed a three-dimensional finite element model to analyze a retreating longwall panel. Szwedzicki, 1981 simulated a longwall entry model using the result of stress distribution around underground openings that had a fracture zone. The fracture zone was modeled by either changing the elastic constants of rock mass or using Goodman's joint element. This study emphasized that fracturing of rock around working face caused a distressing of the rock mass around the underground opening. Qian et. al., 1983 carried out a study using finite element modeling based on data from field observations of rock pressures in two faces under different conditions and movement of the overlaying strata and stress distribution. He studied the effects of support resistance on face convergence. Wu, 1985 analyzed the horizontal supporting force of powered support on longwall faces for ground control. Park and Ash, 1985 and Park and Gall, 1989 analyzed a progressive-failure of longwall coal and used in finite element analysis by applying different failure criterion such as Mohr-Coulomb criterion, Hoek-Brown criterion, and Griffith's criterion. Park and Saab, 1990 attempted to simulate the interaction between face supports and overburden strata under various mining conditions using three-dimensional finite-element models. They also simulated the fault effects on the face by simply employing weak material elements for faults in the numerical model. Lee, 1993 simulated the interaction between shields and surrounding strata, and main roof behavior and its effect on shields. Detailed simulations of the interactions were performed by developing a small scale longwall model equipped with exact dimension of shield structures and applying the non-linear elastic behavior of shield legs.

Finite Element Analysis of Longwall Panel - A case study from Panel No.1. of Adriyala Longwall Project

However, in India, it was planned to deploy a 2 leg shied having a capacity of 1150 tonnes in Adriyala Longwall project, SCCL This high capacity value is incorporated into the study keeping in view of the future prospects of longwall mining in deeper seams which is of paramount importance for future coal mining in India in general and to SCCL in particular.

E (Gpa)	Poisons ratio	Cohesion (Pa)	Friction angle	Dilation angle
2.2	0.35	6.00E+06	30	15
2.3	0.35	6.00E+06	30	15
4	0.35	6.00E+06	30	15
2	0.28	7.00E+06	30	15
3.7	0.28	7.00E+06	30	15
2.3	0.28	7.00E+06	30	15
4.9	0.28	7.00E+06	30	15
3.2	0.28	6.00E+06	30	15
3.2	0.28	9.00E+06	30	15
2.6	0.28	5.50E+06	30	15
7.5	0.28	6.50E+06	30	15
2.7	0.15	8.00E+06	30	15
2	0.27	4.00E+06	30	15
2	0.27	4.50E+06	30	15
0.8	0.35	5.00E+06	30	15
2.7	0.28	7.50E+06	30	15
2.7	0.19	7.50E+06	30	15
4.9	0.19	7.50E+06	30	15
2.8	0.27	5.50E+06	30	15
5.4	0.29	5.50E+06	30	15
2.3	0.29	5.50E+06	30	15
2.3	0.29	7.00E+06	30	15
6.9	0.29	7.00E+06	30	15
2.8	0.12	1.40E+06	30	15
4.3	0.02	1.50E+06	30	15

Table 2. Various parameters used for finite element modeling (Ref BHNO.R 1203)

Parameters considered for giving input data to LW Panel No.1 modeling are listed in the table below. Apart from the above density of the different layers is the additional input to the modeling. Assumed friction angle of the rock layers as 30 degrees and dilation angle as half of the frictional values in our modeling, Shield capacity of 2x 1152 T of double telescopic type and various layers were prepared and material properties were assigned as above for the simulation of original LW panel condition and finally the boundaries were fixed by giving boundary conditions.

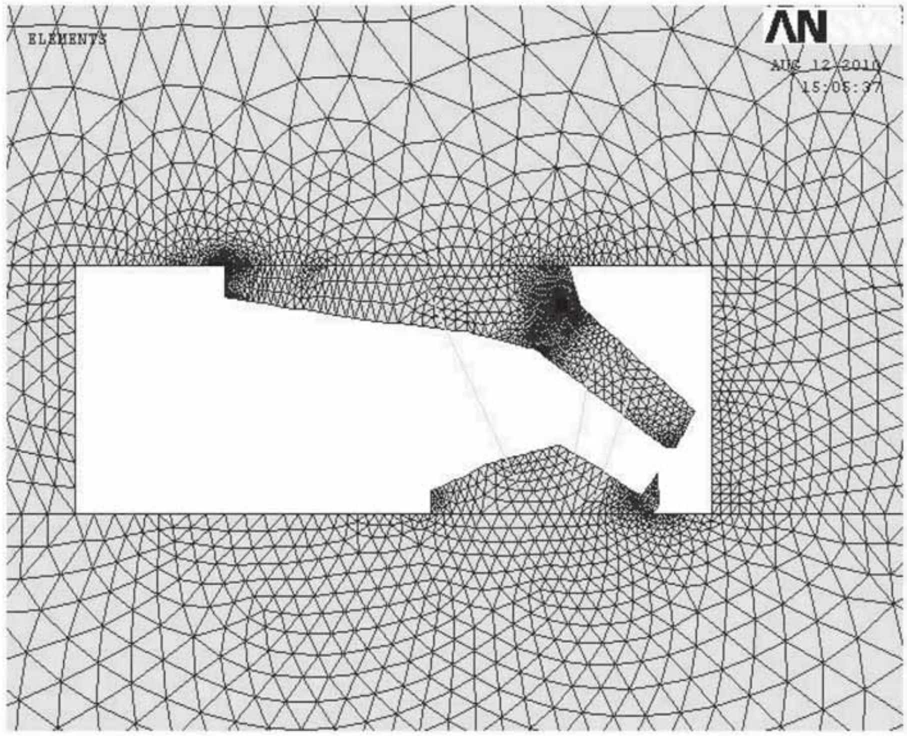
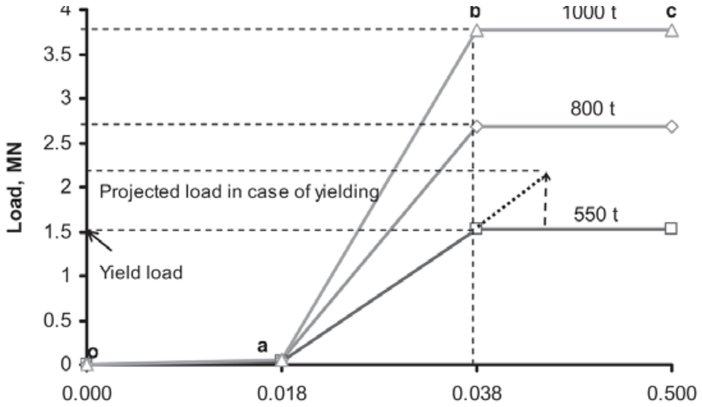


Fig 4. Inserted shield into the model

A general purpose software called ANSYS 10.0 (USA based) was used to run the model and to know the interaction between shield and surrounding strata and also load coming on to the actual shield legs. All finite element models are analyzed with non-linear material behavior using Drucker-Prager yield criterion. Rock layers, coal seam and powered support structure except hydraulic legs and lemniscate links are modeled with 6-noded quadratic triangular elements by this software. Two noded bar elements are used for shield legs and lemniscate links. The finite element model of longwall panel represents the vertical cross-section along the middle of the longwall panel and hence plane strain constitutive material behavior is assumed(4)&(5).

Behaviour of Shield legs

Hydraulic legs are assumed to behave as elastic-perfectly plastic material based on their load-deformation characteristics as shown in figure 5. In case of yielding, total strain increment of hydraulic leg is divided into elastic and plastic strain. The elastic strain increment contributes to stress (or load) increment of the leg. The plastic strain increment changes the shape and size of the yield surface. Hence, in finite element analysis, the load on the hydraulic leg does not exceed the yield load. However, the total strain of yielded leg varies with the capacity of powered supports and other geo mining conditions. As a result, for statistical and neural network analysis, it is necessary to incorporate the total load based on the total strain of the hydraulic leg assuming its behavior as a linear spring with unlimited capacity (dotted line in figure 5)4.



convergence of the leg, m

Figure 5. Load convergence characteristics of hydraulic leg (Ref after Deb.et.a[l]) Figure 5. shows three different phases of loading (oa, ab, and bc) on the shield leg for different capacity of chock-shield supports. In the initial phase (oa), the shield does not respond to the roof convergence because the deflection of the roof, is caused during the advancement and prior to setting up with the roof. In this case, an average 18 mm of initial convergence is taken based on the field observations at various longwall faces. In the second phase (ab), operating phase, an equivalent elastic modulus of shield leg is applied to simulate roof loading and finally last phase (bc) simulate the yielding of chock-shield support. Calculated 52 Mpa as yield stress and assumed shield is in full contact with the immediate roof and floor.

Analysis and results

From the analysis one can understand different kinds of stresses coming on to the shield from all directions and the plastic & elastic zones surrounding the shied area. The peak stresses observed on the legs after cutting the face is about 48 Mpa, which is slightly less than the yield value of the shield.

Result of axial stress on the shield leg for a linear model and resulted linear strain values observed are as follows

SAXL=-0.24879E+08 (MPa) EPELAXL=-0.004013(M)

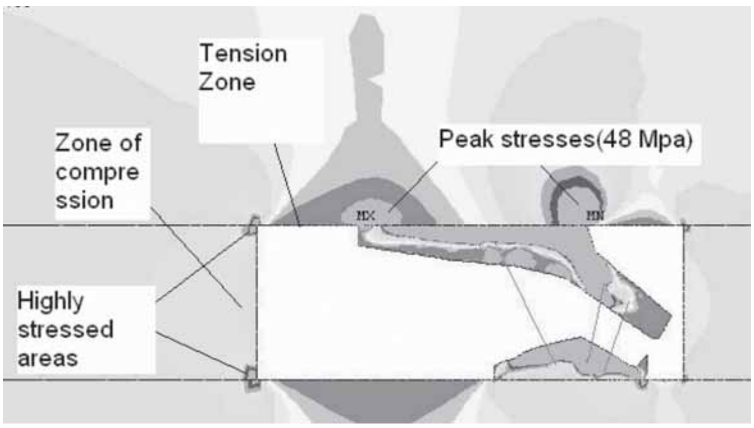


Fig 6. Interaction of shield support with surrounding strata

Conclusions

1. Numerical modelling is a very promising and effective tool in understanding the rock mass response subjected to complex loading conditions. Efficient use of this tool for reliable design and fixing of strata management problems requires a thorough knowledge of the modelling theory, scope and limitations.
2. Using numerical models, shield, rock strata, coal seam and goaf interactions can be modeled effectively for different in-situ loading conditions.
3. Proper analysis of model response is very important which requires the basic understanding of the mechanisms involved in the physical process being modeled and the requirement for its numerical simulation.
4. Result of axial stress on the shield leg for a linear model and resulted linear strain values observed from this model respectively are SAXL=-0.24879E+08 (MPa) EPELAXL=-0.004013(M)
5. Results from numerical simulation should be compared with field measurements for back calculations and improved input data.
6. More experiences are needed in comparative study between numerical simulations and other analytical methods for precise numerical simulation.

One point worth remembering about the mathematical mystery, in which strata control is so often shrouded, is that the rock was there first. The science was derived from what people saw the rock do. The mathematics is really only a handy form of short hand to generalize descriptions of the behaviour of the rock. Nobody should allow math's to get in the way of strata control. If there is a dispute, the rock is always right. - Dr. J Nielen Van Der Merwe

Acknowledgments

The authors are thankful to the management of SCCL and Director General Of Mines Safety for their co-operation and encouragement for this work. The views expressed in this paper are opinion of the authors and not necessarily of the organization they serve.

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ROOF BOLTING PRACTICE IN UNDERGROUND MINES -Needs a review and a corporate policy

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1. INTRODUCTION

Roof support is one of the crucial issues to be addressed in the mechanised faces. It consumes lot of time and affects cycle time of the machinery. Inefficient bolting system needs secondary supports which is always uneconomical and increases risk factor of men involving in a repeated activity. Hence, failure of support is one of the major problems that affects safety and productivity in the underground mines. The fall of roof and sides is the predominant cause of accidents in complied accidents statistics in Indian underground coal mines. There were n-number of support systems using wood and steel developed and practiced over a period in the country. But the tale of roof fall accidents continues to be major threat in under ground mines.

In 1988, the DGMS constituted 'Paul Committee' to draw up support plan for underground mines properly and more scientifically. The committee accepted the geomechanics classification approach developed by CMRI & ISM and brought out roof classification and support design based on Rock Mass Rating (RMR). Their report in 1990, insisted upon roof bolting as inevitable support system in Indian coal mines. The Eighth Conference of Mines Safety emphasised upon Paul committee report and adoption of roof bolting as vital method of support. Coal Mines Regulatory body implemented the above and demanded roof bolting as an active support system in the mines. It has issued various circulars regarding method of installation, quality control and monitoring. Assimilation of this state of art of support technique in underground coalmines successfully practiced. Initially roof bolts were fixed with cement grout. The cement grout bolts in watery strata started failing. The load bearing capacity of the cement grout bolts is attained only after its setting time is elapsed making the miners to expose to that unsupported areas for longer period. By that time the bolts are loaded by active stresses resulting in dilation of roof. The resin grout is the major reward for mining engineers for their continuous effort in the field of R&D and it is capable of developing quickest and highest anchorage strength and proactive stiffness to the strata. The resin bolting system with pneumatic bolters is being introduced in a phased manner in SCCL which addresses the complex geo-mining conditions. It improved production and productivity, but at the same time there are some lapses in the applicability of resins bolting system.

Hence, a review of the existing support system and a corporate policy is required at this juncture with regard to support plan, grout medium, drilling medium, standards of consumables and quality control.

2. THE NEED FOR REVIEW OF ROOF BOLTING PRACTICE.

Despite the fact that the roof bolting is one of the most primary and active supports used for ground control, falls of ground still remain the single major cause of fatalities and injuries in the year 2009. Majority of the roof falls occurred during the process of bolting/under the supported ground before attaining expected load. These indicate that there is a fundamental problem in the use of correct roof bolting in different geotechnical environments. Various parameters involving the quality control, design and operational lapses were contributed in hindering the success of roof bolting. An understanding of the fundamentals of roof and support behavior, as well as the uncertainties in bolting consumables will improve the effectiveness of roof bolts installed.

2.1. Existing bolting system

Roof bolting in SCCL is being done using handheld electric drill machines using quick setting cement capsules as the grout medium. There is a wide range of bolting consumables are being used in mines. Roof bolts of 1.5mx20mm, 1.5mx22mm, 1.8mx20mm, 1.8mx22mm, 2.4mx20mm, 2.4mx22mm are used. Cement capsules of diameter 20mm, 25mm, 32mm for the hole diameter 27mm, 35mm and 43mm are being used. Roof bolting with resin grout is being practiced in few mines where the resin capsules with diameter 20mm, 24mm with varying lengths from 280 to 800mm are being used in conjunction with pneumatic roof bolters, electric drill machines and new generation bolting machines. The roof bolts are mostly not being tested for their physical, mechanical and chemical properties. They are supplied with machine cutting threads instead of rolled threads which is failing merely for 9-12T pull load. Cement capsules of different manufacturers were tested by R&D once in a year. When the drilling is being done manually, the perpendicularity of the hole is merely depending on the skill of the workmen. In the increased semi- mechanization in vogue, the immediate support of Freshly Exposed Roof (FER) in stone roof has become problematic. In transformed life style of the work force, manual drilling creates human drudgery and doesn't match with the targeted production.

2.2. Review of grout medium

The load bearing of the cement grouted bolts starts only after its setting time is elapsed (i.e. after 30min/ 2hrs). Still such time the miners are exposed to unsupported areas for long durations. It is proved that the cement grouted bolts in watery and weathered strata got failed. It is further observed that the full column grouted bolts left with a column of 40-70cm void without grouting which gives scope for roof dilation. The increased semi mechanisation demands roof support by tensile bolting to allow free passage of trackless mining equipment in the production areas.

2.3. Lapses in bolting design

As the support design is prepared by individual mine managers which carries weightage of the experience and knowledge of those individuals and in turn is being followed by succeeding managers. The bolting design, once prepared may not hold good in all the conditions. As mine is progressing, the depth increases as well as the stress pattern. Any slight change in the horizontal stress domain at deeper mining areas influence the roadway greatly resulting in roof guttering. Under this sort of mining conditions also, one need to excel and achieve the production and safety targets for the existence and growth of the company.

2.4. Lapses in resin-bolting application

There are few lapses in application of resin bolting system which need to be reviewed at this juncture. The experience in some of the mines shows that our crews' expertise is not adequate to use dual speed resins system. In most of the cases, the premature setting/ fast setting of upper most resin capsule prevents further entry of the bolts into the hole and such bolts were protruding outward which will not deliver any useful application. The very purpose of resin grout is to apply pretension and to create a proactive stiffness in the strata but its understanding is poor amongst the crew and there is no uniformity in the standards of resin application and its consumables.

3. ADVANTAGES OF RESIN BOLTING

3.1. Importance of resin bolting

Resin is basically a hydrocarbon derived from plants and the synthetic resin is the materials with similar properties to natural resins which is a viscous liquid capable of hardening. The polyester resin is derived by unsaturated polymerization-polyaddition or polycondensation reactions. The capsules for mining applications are manufactured with the composition of this polyester resin (28.5%), crushed limestone (66%), resin catalyst organic peroxide (5%) and the accelerator. This composition adds improved hardness and shelf life to the resin. Resin bolting is widely accepted support system currently being used throughout the major coal mining areas in the world. The USA uses approximately 100 million bolts per year and South Africa uses 5 million bolts with 90% being full column. Australia uses 4 million full column grouted bolts per year. Russia, China and Europe are major expansion areas at this moment as per the source 'Minova guide to resin grouted bolts'. As per the analysis of experts all over the world, the number of roof falls drastically reduced after converting to resin support. Resin bolting is more effective as an active support method, utilizing the rock to support itself by applying internal reinforcing stresses. Resin bolted gallery can provide an unobstructed opening with minimum maintenance.

3.2. Resin is superior over cement grout

The resin bolting system when proper consumables are used and effective pre-tension is given, generate a compressive strength of more than 80 MPa after setting which provides a safe working environment. The risk of exposing persons to unsafe area is reduced from 2 hours to few minutes. It exerts anchorage strength of 20-25 Te which provides a mechanism to resist changing roof stresses along the entire length of the fully grouted bolt, thereby assuring stabilisation of strata for long period of time. The anchorage is independent of strata type and a strong anchoring strata is not required. Also it develops increased resistance to blasting vibration and prevents both vertical and horizontal strata movements. The fully grouted bolts completely seal wet holes and exclude air, thus reducing corrosion of the bolt assembly and weathering of rock. Resin does not shrink, in fact it expands slightly on chemical reaction which ensures full column grouting without any voids inside the hole as faced in cement grouted bolts. The resin grouting is best suited for geologically disturbed, fractured and moist roof. Resin grouted bolts are used as both primary and permanent support and does not restrict mechanisation. Resin provides opportunity for pre-tension at higher axial load in shorter time.

4. IMPORTANT CONCEPTS IN RESIN BOLTING

4.1. Annular space

Annular space is an important parameter in resin bolt system. Annular space is difference between radius of drill hole and roof bolt ie, gap available in the hole after bolt is inserted. Increase in hole diameter will result in poor confinement of the resin, leading to a reduction in the shear strength of the bond and reduced load transfer capability. The smaller the annulus, the more efficient is the mixing of the resin as well as shredding of the plastic casing of cartridge. Further the smaller the thickness of the resin, the stiffer the bond between the bolt and the rock. The pneumatic and hydraulic bolters can drill holes with 27mm diameter. But for the optimum anchorage of the resin capsules the annular space shall be between 3 to 7 mm.

4.2. Roof Response Time (RRT)

The Roof Response Time (RRT) is, 'The duration of time elapsed between the exposure of roof and the first indication of dilation of roof layers due to redistribution of stress both vertical and horizontal'. It varies with geological and geotechnical factors. It varies from seam to seam and mine to mine. This is one of the critical measures for selection of bolting system and drilling medium. The bolting system and the drilling equipment should have the capability of drilling and grouting the bolts within the roof response time. Mines in US, Australia and South Africa use this parameter as a vital component in strata management which is always system inbuilt.

4.3. Torque nut or conical seat

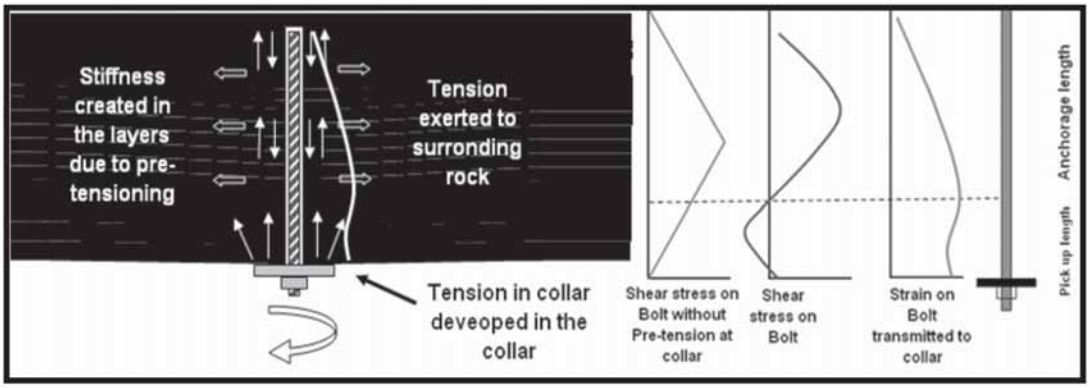
The torque nut is designed to ensure that it does not rotate relative to the bolt during the bolt installation through the resin to the back of the hole. But is tightened by the drill machine once the resin has set to a sufficient strength. The curvature portion of the nut takes care of full contact to the bearing plate or conical washer when bolt is installed in angle. So for angled bolts, it is mandatory to use torque nuts.

4.4. Dome washer

DGMS insisted on the use of flat bearing plates of dimension 150x150x6mm in the initial stage when used with cement capsules. For the use with resin bolting, the normal flat bearing plates are replaced by dome washers of dimension 150x150x8mm. Dome washer is flat bearing plate dome shaped at the center. It has a compatible central hole of required size and an angled side to accommodate conical seat and nut. On application of 150KN torque, it must get flattened. The action of pretension simultaneously induces stiffness in the bolt and flattens the dome washer. By flattening of the dome washer, a proactive tensile stress is developed around the collar of the bolt. The collar failure is the one, frequently occurs in the cement grouted bolt as the system generally fails to develop stiffness in the bolt column. Therefore the stresses get transferred to collar of the bolt.

4.5. Pre-tensioning

Pre-tensioning is application of an axial tensile stress into the roof bolt shortly after its setting. When an axial thrust or torque is given, a small pull load is applied in the bolt. With the effective resin anchorage, it generates stiffness in the bolt, grout and adjacent strata. This stiffness in the bolt, grout and adjacent strata induces compressive and tensile stress in the adjacent rock beds. To achieve this, a torque of nearly 150KN is applied to tighten the bolt with pneumatic bolters. The high setting torque (300KN-400KN) is practice in mines abroad. The pre-tensioned bolts clamp the thinly laminated roof beds into a thick beam which is more resistant to bending. A stronger beam can be built with the same bolt by applying larger installed load. Pre-tensioned bolts are more effective when the immediate roof layers are weak. Moreover, the act of pretension ensures the plate is very tight against the immediate roof.



4.6. Short Encapsulation Pull Test (SEPT)

The resin grout provides anchorage of 80 MPa which is higher than the tensile strength of steel bolt that steel bolt fails prior to resin. For this reason a specially installed bolt with a short length of resin encapsulation is required in order to measure the anchorage properties of the resin system rather than the strength of the roof bolt. This is known as the Short Encapsulation Pull Test (SEPT) and is an internationally recognised method of measuring the performance of roof bolt, resin, rock anchorage and bond system.

5. DRILLING MEDIUM

Before introduction of the pneumatic bolters, the roof bolting and the face drilling was carried out with electric drill machines. When the same drills were used to drill holes in moist sandstone roof, the overload protections of the machines were frequently disturbed. More number of drill bits and drill rods were consumed. Face blasting was delayed due to break down of drill machines and production was badly affected. Technically resin bolting was not possible with electric drill machines. Hence, SCCL has purchased 138 pneumatic roof bolters with compressors to address the above problems and also to fulfill the recommendations of 10th national conference of safety in mines.

5.1. Improvements after introduction of bolters

After introduction of the pneumatic bolters, faces could be bolted with resin grout medium resulting in quicker supporting and safer environment. More importantly the human drudgery was eliminated to a great extent. The number of bolts fixed per shift has increased and the consumption of the drill bits and drill rods was decreased. Damage to drill machines decreased and in turn the availability of drill machines to coal cutters for face drilling and blasting has increased.

5.2. Draw backs in the existing bolters- need to be addressed

The O-rings, seals of the control assembly, leg assembly and water hubs are getting damaged frequently. The failure of O-rings and seals result in leakage of water and air and in turn sluggish operation. The round portion of the drill shank of Alminco and Rana machines are different, a common drill rod can't be used. The length of controlling arm is not sufficient while bolter is being lifted when drilling. Oil consumption is more that the number of holes per litre is not matching with the standard as the firms suggested. The water leakage damages the gear box bearing and clutch bearing and air motor pinion. The components should be replaced in time after their shelf life by awarding rate contract to those firms. A Centralised repairing shed will reduce blocking of the spares in each mine. Dry drilling will reduce the weight of the water hose and water problems in the face. The Rana roof bolters are provided with 'O' ring on drill shank to arrest water. In Alminco Roof Bolter seal is provided in the chuck which is resulting jamming the drill rod. Unless the seal is removed drill rod is not inserting resulting in water leakage. To facilitate pretension, it can develop torque of 160-200 Nm and even 400Nm also can be achieved. But practically, it is not possible to apply that much torque to the bolt as the drill mast gets twisted and the persons can't hold it.

6. A POLICY ON 'ROOF BOLTING'

A review of roof bolting issues is inevitable at this juncture keeping in view of the present scenario and future underground deep mining. The review of resin bolting system, a scientific understanding of its applicability and the requirements of statute emerges an integrated policy to be prepared and put into action to bring our mines to next generation mining.

6.1. Support design

Generally, bolting pattern and specifications of bolting (bolt spacing, row spacing, and bolt angle) is designed by mine managers and safety officers with the help of RMR and rock load calculations. This is varying widely mine to mine, seam to seam and area to area. Hence, the existing bolting pattern of all the UG mines must be verified and better bolting pattern must be suggested. A data-base for all UG mines including rock load calculations as per Paul committee recommendations and DGMS circulars shall be generated. Support pattern and design shall be done more scientifically using numerical modeling for all the mines, if required the necessary software shall be purchased and sufficient number of officers shall be trained in numerical modeling.

6.2. Drilling medium

The best drilling medium has to be selected for immediate and long term requirement. It must suit to the geomining conditions of SCCL. Further, it shall ensure proper drilling for roof bolting in all types of roof strata. Machines shall be capable of being operated from a distance or be provided with suitable canopy to protect the supporting personnel during bolting operations. It should give immediate reinforcement in poor roof and watery strata. The dimensions of different existing pneumatic bolters and their accessories such as shank, chuck, 'O' rings, hoses and adopters should have similarities so that the consumable can be interchanged. The required spares as per the OEM recommendation, irrespective of the individual mine requisitions shall be procured to make them available in the SCCL stores. A separate organisation both at mine level and at corporate level must be set up for maintenance and monitoring of roof bolters and bolting activity. As these pneumatic bolters have few drawbacks including the inability to develop effective pretension to bolts, SCCL must work out for introduction of mobile bolters or mechanised drill machines in a phased manner.

6.3. Grouting medium

Deeper mining, complex ground conditions, weaker roof and watery roof conditions ultimately demands the use of resin grout. Cement grout system shall be completely eradicated. Switching over to resin bolting will address most of the strata problems encountered during mining process in all kinds of strata in SCCL. Procurement of resin capsules from the existing suppliers shall be continued after incorporating the required modifications in NIT. For meeting the future demand, effective Quality control and cost reduction, a resin plant shall be established by the company. of its own or on TPO concept. Since the correct storage (>25^0) is required to ensure effective performance of resins, they should be stored at dry places. For this purpose, separate rooms with 'Air conditioners' shall be provided in each mine for storing the resins.

6.4. Bolting consumables

When planning for the better grout medium with improved anchorage strength, the quality and standards of the roof bolts assembly also gained importance, which necessitated a policy on the bolting consumables. There shall be uniformity in sizes of bolting consumables for all the mines ie., bolt diameter (20mm), bit diameter (27mm) and drill rod diameter, (26/27mm). The necessity of TMT rebars yet to be decided upon. But the MS grade Fe-500, Fe-650 or above would work for the requirement. Roof bolt nuts shall be cold rolled compatible to 20mm bolts confirming to DGMS circular No.11 of 2009. Length of the bolt can vary depending on local strata conditions. Procurement action should be continued by incorporating the above required changes as per the latest DGMS circulars in the existing NIT. A manufacturing unit shall be established by SCCL at centralised location to minimise the costs and to ensure quality.

6.5. Reinforcement

The supply of W-straps and its length & hole spacing are not matching to requirement of the bolting pattern of individual mines. Often, some alteration is being done at work site with gas cutting and welding. An attempt by this policy to arrive at a common pattern (atleast hole spacing) will ensure uniform lengths and hole spacing of W-straps. A standard size of re-inforcement such as W-straps, taking different gallery widths into mind shall be arrived at so that there may not be a necessity of further alteration at mine site. Bearing plates must comply the specification of DGMS circulars 150x150x8 mm but the place of application must be specified to have optimum utilisation. The use of bearing plates (flat), domed washers, conical seat must be defined and differentiated clearly.

6.6. Quality control and Monitoring

The required quality checks at the area and mine level by providing the required test facilities. Special laboratory or the area's available laboratory can be so established to have required facility to conduct quality checks for roof bolts, resin capsules. The facility required for quality control checks is given the DGMS circular No.10 of 2009. Proper set up for Short Encapsulation Pull Test (SEPT) must be established. The necessary equipment shall be purchased. A monitoring body at corporate level, area level and unit level in both the disciplines mining and E&M shall be established for effective monitoring of the bolting system. A special drive should be initiated in implementation of this policy.

6.7. Responsibilities and Instructions

A wide range of individuals would be involved in implementation of the bolting systems. It is a natural tendency to attribute performance difficulties to some deficit in the bolting system. Hence the policy must define 'Roles and Responsibilities' of various personnel from corporate level to end user. Still, there are some confusion and contradiction in the application of the resin bolting system. Hence the policy document should also include technical part of resin bolting system, code of procedures and some specific instruction like Do's and Don'ts.

7. CONCLUSION

The resin grout maintains its superiority over cement due its, high, effective anchorage capacity in shortest time creating a safe environment in coal face. The resin enables pretension of bolts with high setting load. The anchorage provided by the resin bolts is independent of strata type and addresses to the complex geomining conditions. The increased semi mechanisation demands roof support by resin bolting system to allow free passage of trackless mining equipment and for faster drivage. Since the resin bolted roof can provide an unobstructed opening with minimum maintenance, the production and productivity will be improved. The best drilling medium has to be selected for immediate and long term requirement. It must suit to the geomining conditions of SCCL and it shall ensure proper drilling for roof bolting in all types of roof strata. But there are few lapses in application of resin bolting system which need to be reviewed at this juncture.

Hence, it is need of hour to have a better understanding of resin bolting system and to have a corporate 'Policy on bolting system' at this changed scenario of mechanisation in underground mines for sustaining improvements.

Acknowledgements

The authors are very much thankful to the management of The Singareni Collieries Company Limited for permitting to publish this paper. The views expressed in the paper are of the authors and doesn't necessarily of the organization to which they belong.

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Under ground coal gasification – ONLY solution of future DEEP SEATED coal deposits

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ABSTRACT:

Worldwide coal reserves are vast over 10 trillion tonnes. Mining coal is hazardous work. Many coal reserves are too deep or too low in quality to be mined economically. Today, less than one sixth of the world's coal is economically accessible. Coal has ash within it which has to be discarded. Mining and subsequent burning of coal generally leaves environmental foot prints like pollution, and climate change. However for India, abundance of coal coupled with scarcity of other sources of energy, the mining and use of coal is critical. But cleaner and cheaper ways can be found to convert coal to gas or liquid fuels, to replace oil and natural gas.

There is a renewed interest worldwide to make maximum percentage of coal reserves economically viable by using technologies like underground coal gasification which converts coal to a combustible gas underground. Every country is trying to produce secured safe and clean energy from its own reserves like coal, lignite etc. By applying underground coal gasification (UCG) technology, the coals reserves of low grade coals, deep and thin seams that can't be mined economically can also be utilized. Further the UCG process is safer and cleaner and associated with less emissions and environmental effects. This paper deals with the methodology of under ground coal gasification, drilling pattern and different techniques involved in ignition processes with advantages.

INTRODUCTION

The idea of gasifying coal underground belongs to Sir William Siemens, who suggested gasifying coal in situ. The next mention of underground coal gasification belongs to Dimitri I. Mendeleev – the famous Russian chemist who invented the periodic table of elements. In 1910, three patents (American, Canadian and British were granted to American engineer Anson G. Betts for inventing a method of utilizing un-mined coal. In 1912, famous chemist Sir William Ramsay – the first Briton to win the Nobel prize in chemistry – spoke, Ramsay said that there is a way to abolish this smoke nuisance. Instead of burning coal, it can be gasified underground by drilling a borehole, firing coal, supplying air and extracting hydrogen and carbon monoxide. The produced gas then can be used to generate electricity. His statements created an international surge of interest in UCG.

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Location	Coal type thickness	Dates	Gas Produced in 1963 (Cub.m X 10000)	Remarks
podmoskonaya	Lignite 0.8 to 4.6 m	1946-1963	-	Coal exhausted in 1963
Lisichanskaya	Bituminous 0.4 to 0.8 m	-	220	Discontinued due to thin seam
Yuzhni-Abhinskaya	Bituminous (1.3 to 3.9 m)	1955 to current	290	Used for heating
Shatskaya	Lignite 0.3 m to 2.7 m	1963-1966	-	Abandoned due to technical problems
Anronskaya	Lignite 4-20 m	1957(current)	860	Used for power generation (100 KW)
USA pilot trials	Various	1973-1988	10(estimated)	

Table 1: past ucg work

2. UNDER GROUND COAL GASIFICATION

Conversion of in-situ coal into synthesis gas is called underground coal gasification, this gasification occur through the same chemical reaction that occur in surface gasifier. The key gasification reaction is Partial heat of combustion in which coal is converted to synthesis gas at increased temperature .

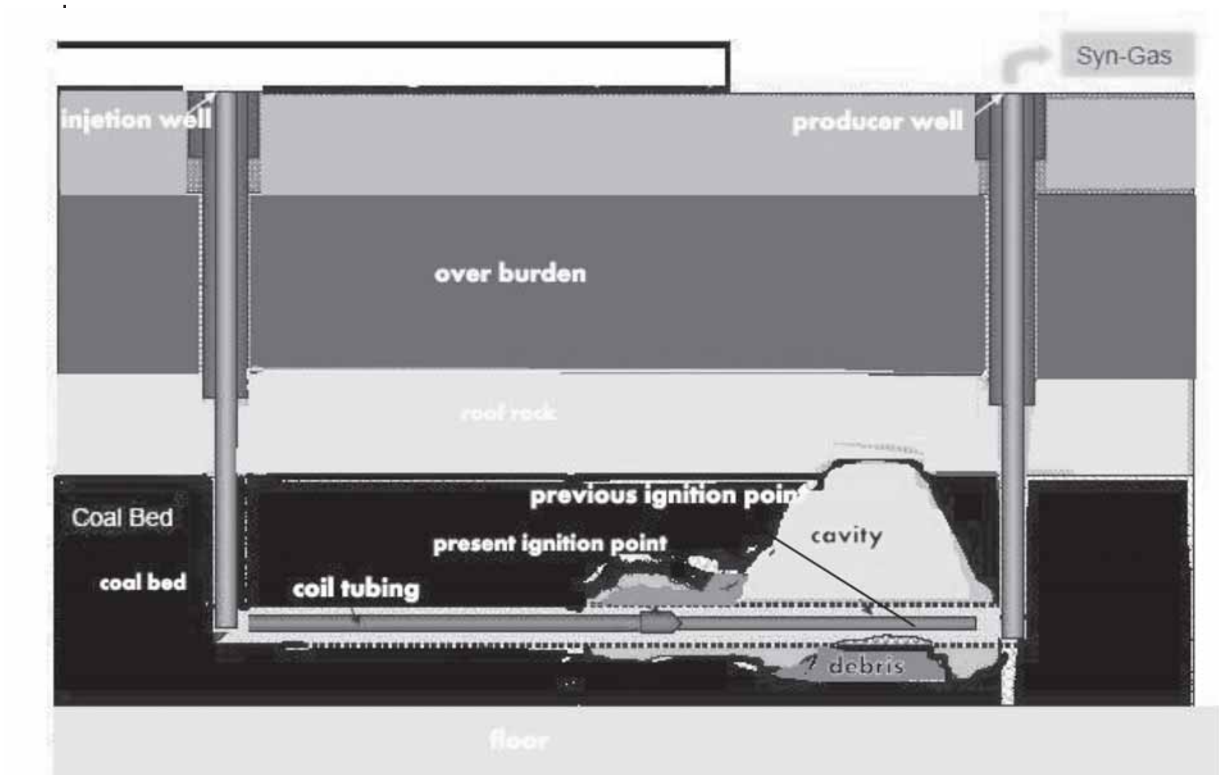

Fig 1. UCG technique

During underground coal gasification gas is extracted from deep coal seams. Wells are drilled to inject air or steam which are used in the process of combustion and gasification. Underground coal gasification process involves mainly:

1) Selection of site
2) Drilling techniques
3) Ignition and gasification
4) Surface arrangements

3. SELECTION OF SITE CRITERIA FOR UCG SITE SELECTION

The determination of selection criteria for UCG locations is an important problem. The criteria for underground mining, including technological and land-use restrictions, are well known, but in some cases, the criteria for UCG are expected to be different. For example, the UCG process has specific requirements for the depth and thickness of coal seams that differ from those applicable to mining.

3.1.Thickness of Coal Seam. The available information on the minimum seam thickness for UCG is somewhat contradictory. Ergo Energy states that UCG can be used in coal seams as thin as 0.5 m.47 As mentioned above, UCG work in the FSU showed that the heating value of the produced gas decreases significantly with decreasing coal thickness below 2 m (see Figure 1), so this value might be considered a desirable lower limit.

3.2.Depth of Coal Seam. The depth of coal seams is not a critical parameter. The LLNL experts indicate that the minimum depth should be 12 m.1 On the other hand, relatively shallow coal seams are generally used for surface mining. Sixty meters is the typically applied limit to the depth of surface mining and is therefore considered a bounding limit in this analysis. To decrease the risk of subsidence, Burton et al.1 recommend operational depths of >200 m. Depths of more than 300 m require more complicated and expensive drilling technologies, but they also have advantages such as minimized risk of subsidence and the possibility of conducting the UCG process at higher pressure, which increases the heating value of the produced gas. Also, deeper seams are less likely to be hydrologically linked with potable aquifers, thus avoiding drinkable water contamination problems.

3.3.Coal Rank and Other Properties. With the present state of knowledge, low-rank, high-volatility, non caking bituminous coals are preferable. UCG might work better on lower rank coals because such coals tend to shrink upon heating, enhancing permeability and connectivity between injection and production wells. 1 Also, the impurities in lower-rank coals might improve the kinetics of gasification by acting as catalysts for the burn process. For coals of the same rank, the heating value of the UCG gas increases with increasing heating value of the coal. The values of porosity and permeability within the coal seam might also be important factors, but it is difficult to use them as criteria at this point because of the scarcity of such data. Better cleated and more permeable seams allow for more effective connection between the injection and production wells, leading to faster transport of reactants and a higher rate of gasification. On the other hand, higher porosity and permeability increase the influx of water and increase product gas losses.

3.4. Dip of Coal Seam. Shallow dipping coal seams are preferable. Such seams facilitate drainage and the maintenance of hydrostatic balance within the gasifier; they also minimize potential damage to the down dip production well from material that is moved in association with the UCG process. A report by GasTech5 recommends dip angles of 0-20°. However, UCG has been successfully carried out in steeply dipping seams;8 thus, dip is not a critical constraining factor for selecting and operating UCG sites.

3.5.Groundwater. Water is an essential component of the UCG process, and thus its availability either from within a coal seam or from a source adjoining the seam is an important characteristic. The adjoining rocks must contain saline water (>10000 ppm total dissolved solids, as per U.S. Environmental Protection Agency regulations) and have a significant deliverable volume. In many cases, the coal itself serves as the principle aquifer within the strata graphic section and is bounded by impermeable shales and low-density rock. In some cases, permeable sandstones form the roof rock and therefore are in hydrological connectivity with strata outside the coal seam. aquifers within a distance of 25 times the seam height is generally recommended, have been successfully carried out in seams in closer proximity to potable underground aquifers, but the potential risk of contamination increases in such a setting.

3.6. Amount of Coal. Gas produced by the underground gasification process can potentially be used in several applications. These applications range from supplying mobile units that could provide gas in agricultural areas to supporting large power and chemical plants producing hundreds to thousands of megawatts of electrical energy and vast amounts of hydrocarbon based products. For this reason, the evaluation of potentially productive sites must include the determination of the amount of coal available in a gasification project in conjunction with a consideration of the potential applications of the produced gas. Additionally, for each potential site, the productive lifetime of the site must be determined as a function of required gas yield. For illustration, for 20-year continuous operation of a 300 MW UCG-based combined-cycle power plant (efficiency, 50%), it is necessary to produce 75.6 × 109 Nm3 of syngas with a heating value of 5 MJ/m3. Based on the Chinchilla experimental data (see section 2.6), 33 × 106 metric tons needs to be gasified for this purpose. Note that this amount can be decreased by a factor of 2 by using oxygen and steam as injection gases, which, however, increases the cost.

3.7. Land-Use Restrictions.

There is no indication in the literature that UCG should be farther from towns, roads, and other objects than underground mines, assuming that the process design and environmental monitoring eliminate water contamination and air pollution. Thus, the land-use restrictions for underground mining can be applied to potential UCG sites.

Various considerations are taken into account while selecting the site for underground coal gasification plant establishment. Some of the basic requirements and important considerations are as follows:-

- Seam thickness should be greater than 2m.
- Seams with variable thickness and having variable partings are avoided.
- Avoid seams with overlying coal within 15m seams thicker than workable thickness (1.5m which can be mined in future).
- Minimum reserve of coal should be 3.5Mt and Minimum overburden of 100m.
- Minimum distance of 1.6 km from populated areas, rivers, lakes and abandoned mines.
- Minimum distance of 0.8km from major faults, folds, highways and railway lines.
- Minimum distance of 3.2 km from active mines.
- Roof and floor conditions should be competent against leakage of gasses.
- The seam should be below water table zone and far from major aquifers.

3.8. Coal Characteristics

The characteristics of coal/coal seams that determine the suitability for UCG applications are:

- Carbon content, ash content, calorific value, Porosity and permeability of coal surrounding rocks and Gradient of seam.

4.0. DRILLING TECHNOLOGY

Deep, high pressure UCG will rely on guided drilling technology to initiate a well at the surface which will intercept and follow a coal seam, probably for 400m or more, and to establish a link between injection and production wells. Guided drilling technologies have been used successfully for many years within the oil and gas industry. Advances in down-hole measurement and communications technology, coupled with the location of guidance sensors directly behind the drill bit, has resulted in the development of a new generation of guided drilling equipment capable of providing greater accuracy, increased drilling speeds and cleaner hole completions The measurement of position co-ordinates and formation characteristics close to the bit, together with the ability to transmit the information to the surface, allows the engineer to steer the borehole accurately, particularly when combined with steerable drilling systems that can be operated remotely from the surface. As with any drilling operation, problems can be experienced in controlling the borehole within a target horizon depending on the geological conditions.

Recent technological developments include:

- Range of geophysical sensors to facilitate continual evaluation of formation Characteristics and 3-D modeling at the surface.
- Sensors close to drilling assembly to ensure steering accuracy.
- Real-time down-hole to surface, and surface to down-hole, data transmission for remote monitoring and steering control.
- Rotary steerable systems controlled at the surface and with higher drilling rates than? down-hole-motor (DHM) systems.

  There are different types of methods in drilling these holes single horizontal and vertical wells, paired horizontal wells, paired vertical wells, and more complex well geometries (e.g., herringbone).

4.1. DRILLING TECHNIQUES

Drilling is the most important and expensive work in UCG which influence the success of the project. The salient features of UCG drilling are:

- It gives the access to coal seams.
- It provides reliable channel for gasification processes.
- The drilling has to follow the lower part of seam for efficient gasification.
- The injection well should accurately intersect with production well.
- Near horizontal drilling required.
- Near bit position sensing required as much accurately as possible.
- Down assembly should be highly steerable and controllable.
- It is desired to have ability to sense coal boundaries.

Horizontal drilling is divided into different types based on radius for its purpose

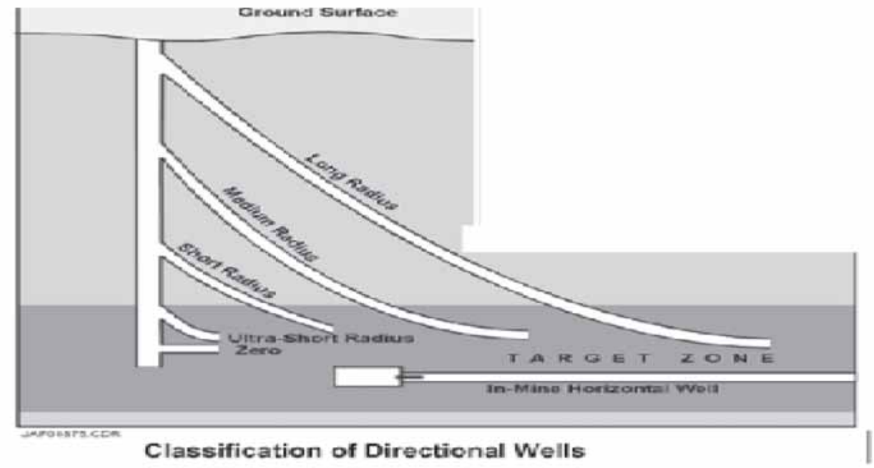

Figure No.2. Horizontal drilling pattern

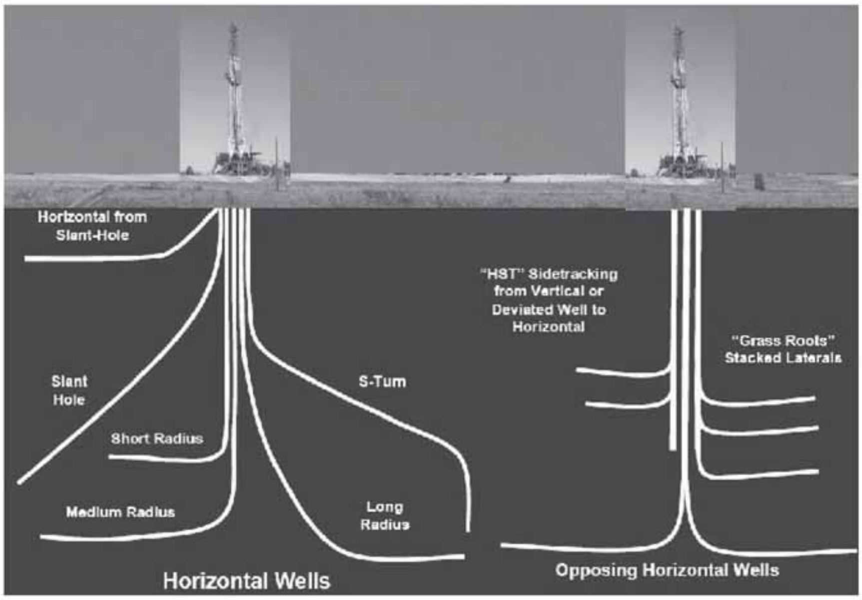

Fig 3. Snapshot of horizontal drilling

Sl. No.	Type of curve	Approx. angle made(deg)
1	long	2-06
2	medium	06-40
3	short	40-70
4	Ultra short	70- 150
5	Zero	< 5

Table 2. Curve build rates of drill holes

5.0.IGNITION AND GASIFICATION

There are several methods for igniting the gasifier as given below.

- Controlled retractable injection point (CRIP) method
- Blind hole electric ignition
- Lateral extension reactor
- Each method has its own importance and application, but presently CRIP technology is widely used.

5.1.CRIP technology:

The CRIP process involves the use of a burner attached to coil tubing, the devices is used to burn through bore hole casing and ignite coal. Thus ignition system can be moved from one point to another point depending on the size of cavity formed. This technique also enables a new reactor to be started at any chosen upstream location after a declining reactor has been abandoned. Ignition of gasifier will start from the end of production well by introducing a pyrophoric compounds tri-ethyl borane to ignite a methane burner located at the end of coiled tubing. Once the line is burnt gasification agents are introduced and the product gas is then generated, because the surrounding coal will be gasified creating a caved zone which postpone investigations indicates extension of at least 5 times the seam thickness. The temperature of the reaction zone and rate and the product gas quality rate are affected by loss of gas to the surrounding strata and uncontrolled water ingress.

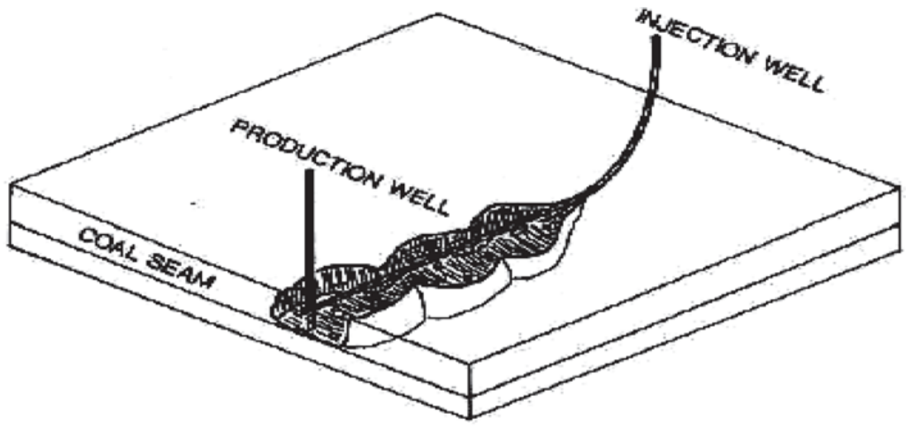

Figure 3. A schematic of the CRIP reactor

5.2. Cavity behavior and growth model

Installation of injection and production wells is costly and therefore it is desirable to gasify maximum volume of coal between them. As the gasification proceeds cavity formation occurs and extend until roof collapses. This roof collapse is important as it aids the lateral growth of the gasifier, in this gasification zone.

1. Gasification growth leads to a less uniform distribution of flow in the system where cavity is formed.
2. An increase in separation between injection and recovery wells during cavity growth (assisted by CRIP) could increase the duration of reactant coal content and hence improve gasifier performance thus improving the efficiency of the plant.

6.0. Chemical reaction during gasification

The basic features of the UCG process are the utilization of low aliphatic alcohol such as methanol (CH_3 CH_20H) along with steam to supply a highly reactive form of hydrogen for coal gasification. Oxygen may be supplied to help initiate the reaction. However if once the process starts and reaches a optimum level there is no need for supply of oxygen because heat required for endothermic reaction is supplied by exothermic reactions. Fundamental reactions involved in coal gasification are:-

a. Heterogeneous water-gas shift reaction
   $C + H_2O$ $H_2 + CO$

b. Shift conversion
   $CO + H_2O$ $H_{2\,+} CO_2$

c. Methanisation
   $CO + 3\ H_2$ $CH_4 + H_2O$

d. Hydroginating gasification
   $C + 2\ H_2$ CH_4

e. Partial oxidation
   $C + ½\ O_2$ CO

f. Oxidation
   $C + O_2$ CO_{2+}

g. Boundary reaction
   $C + CO_2$ $2CO$

7.0. Environmental Benefits of UCG

Surface production and combustion of coal can create environmental problems. These include atmospheric pollutants such as SOx, NOx, and mercury, solid wastes such as fly ash or slags, and direct environmental concerns such as surface mining, mountaintop removal mining, and acid-mine drainage. UCG faces none of these issues.

- No Sox is produced: Sulfur in the coals is converted to H2S or COS, which are
- Easily guttered and converted to solid form.
- relatively low temperatures, so no NOx is generated
- No ash is produced: All ash remains underground
- Reduced mercury and particulate streams: roughly ½ the equivalent flux reaches the surface, and are readily managed there using conventional approaches.
- Reduced plant footprint: The lack of ash management, coal storage, and surface
- Gasifiers reduce plant size and operational complexity.
- Reduced environmental footprint: The only surface expression of syngas production is well heads and connecting pipelines. There is no surface mining. These advantages provide the opportunities for lower capital cost, improved regulatory compliance, substantial emissions reduction of criteria pollutants, and reduced surface footprint and legacy.

- No mining; no surface ash management.
- Smaller footprint for surface facilities.
- Fewer particulates, NOx, Sox.
- Good coincidence between sites for carbon storage and UCG.

7.1. Environmental Issues In UCG

- Migration of VOCs in vapor phase into potable groundwater.
- Organic compounds derived from coal and solidified metals from minerals contaminating coal seam groundwater.
- Upward migration of contaminated groundwater to potable aquifers due to thermally-driven flow away from burn chamber.
- Buoyancy effects from fluid density gradients resulting from changes in dissolved solids and temperature.
- Changes in permeability of reservoir rock due to UCG.

8.0. Conclusion:

UCG is potentially the most important clean coal technology of future with worldwide application even for deep coal beds. Experience indicates that yet some important technical considerations in designing a commercial gas production scheme are required to make project successful like the flow pattern inside the UCG cavity which is a complex thing to comprehend.

Considering the future coal blocks which are deep and directly lying under forest areas, under ground coal gasification seems to be the better alternative both in terms of productivity as well as sustainability of our environment.

9.0. Acknowledgements:

The authors express their deep gratitude to the SCCL management and particularly HRD department for conducting the National seminar in Under ground mining and giving this invaluable opportunity. The views expressed by the authors are their own and do not necessarily represent their employers'.

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EXTRACTION OF STEEP SEAMS WITH SIDE DISCHARGE LOADERS

* P.Ranganatheeswar, ** B.Papa Rao,
*** B.Kishan Rao, *** P.Sathaiah

1.0 INTRODUCTION

Huge coal reserves exist in steep seams and suitable technologies for extraction are in development stage. At present coal from these seams is extracted mostly by Bord & Pillar mining with manual loading. About 30%of the total underground production is from Manual Bord & Pillar mining. The extraction of steep reserves requires suitable mining methods to maximize resource recovery in an economically viable manner.

There is need for Mining of steep seams (steeper than 13 deg) with improved production performance and extraction percentage with customised mining technology because most of these seams hold better quality coal. In SCCL, 65% of the underground mines are steeper than 13degrees, rendering mechanization difficult. Recommendations of the 10th National Conference on Safety in Mines emphasized the introduction of mechanization even in steep seams to phase out manual loading for improving the safety standards and also to offset human drudgery.

To phase out manual loading in SCCL, introduction of semi mechanization has been completed in all the mines which are flat or slightly inclined (Flatter than 1 in 5) with the introduction of SDLS and LHDs. In 40% of the Underground (UG) mines of SCCL, manual loading is still continuing due to non-suitability of the mines for introduction of semi-mechanization. In these mines considerable reserves are locked up in developed pillars which are to be extracted. Manual method of mining needs to be continued in these underground mines unless technically feasible mechanized methods of mining are adopted. With the adoption of appropriate technology and equipment in these mines, productivity can be enhanced significantly simultaneously avoiding human drudgery.

Use of the Semi-Mechanised Bord and Pillar system with introduction of Side Discharge Loaders (SDLs) was thought of for their applicability in extraction of pillars in steep seams. With the keen interest shown by the senior management of SCCL and Mines Inspectorate of SC Zone, Hyderabad, SDLs were proposed to extract pillars in SS-1/3S panel/ No. 3 Seam at KTK No. 5 Incline mine of Bhupalpalli Area, where the gradient of seam is 1 in 2.5. Apparent Dip slicing method was adopted and a new method of operation was formulated for the extraction of pillars with SDLs. As per the new method, SDLs were deployed in steep seams from February 2009. Involvement of the regulatory bodies and higher authorities at every stage of

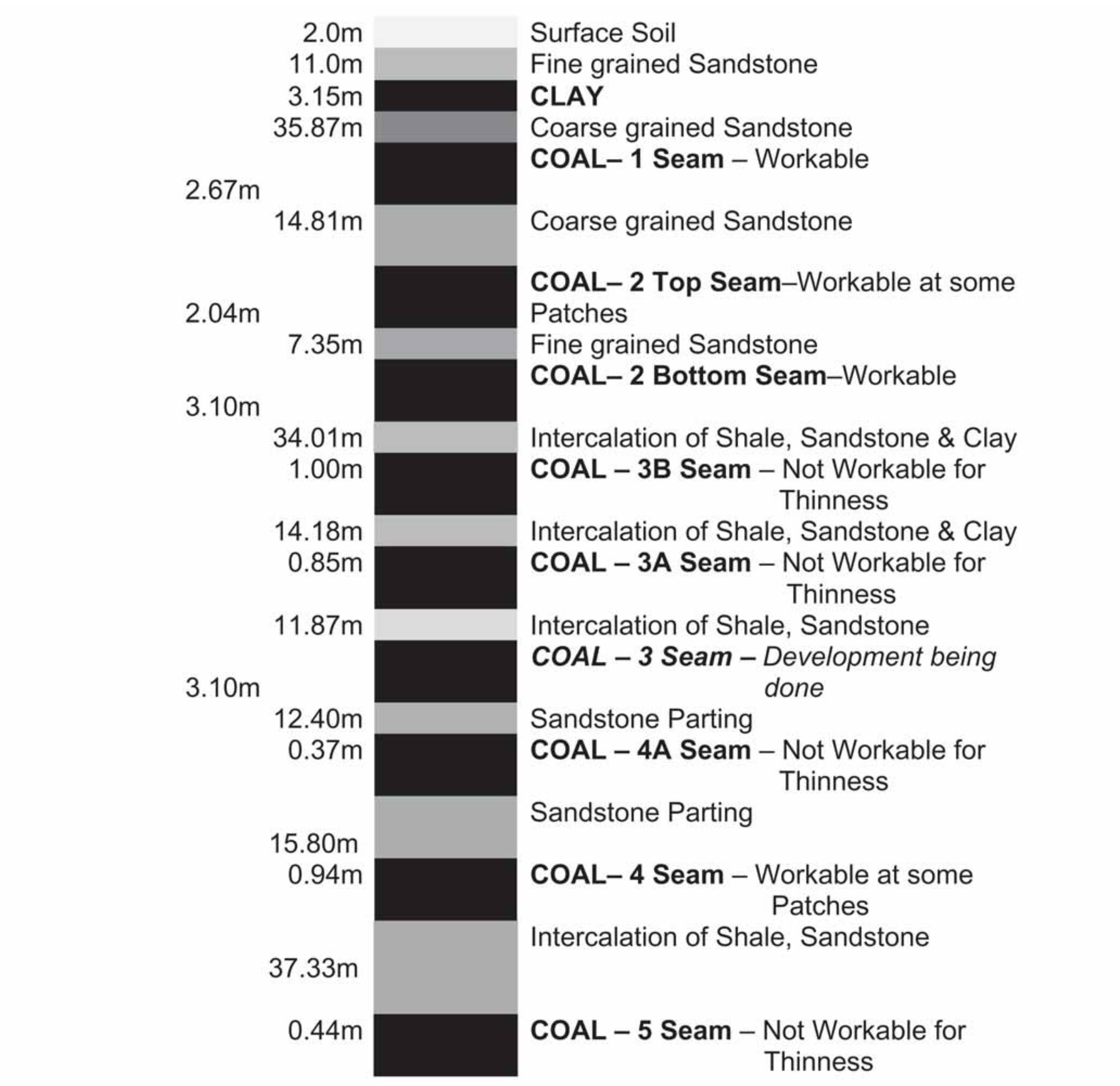
1. Director of Mines Safety, Reg.No.1, Hyderabad Region no.1
2. Deputy Director of Mines Safety, Hyderabad Region No.1
3. General Manager, Bhupalpalli area, M/s SCCL,
4. Additional General Manager, KTK-5 Inc, M/s SCCL.

2.2 Details of the workings of Seam No.3 of 3SS-1 panel are tabulated below

Width of the Gallery (m)			Height of the Gallery (m)			Depth of cover in 3SS-1 PANEL (m)		Working Panel Size (Sq. m)
Min	Max	Avg	Min	Max	Avg	Min	Max	535m x 165m
3.6	4.2	4.0	3.0	3.0	3.0	144	242	

2.3 Bore Hole Section

Borehole No. 357



3.0 EXISTING METHOD OF MINING

Development was done by Bord and Pillar mining with conventional drilling and blasting and loading of coal into mine tubs manually. Transport of tubs to surface is along a network of direct and endless haulers. Development was done along true dip of the seam (i.e 1 in 2.5 to 3.0 gradient). Presently extraction of pillars is being done by hydraulic sand stowing.

Problems with this system:

i). Manual loading – persons not willing to work in steep seams due to drudgery

ii). Low rate of extraction and productivity

iii). Safety –more work persons are exposed at the active faces.

- Roof management at more number of junctions.

To improve the system, and in compliance with the recommendations of the 10th National Conference on Safety in Mines, which emphasized the introduction of mechanization even in steep seams to phase out manual loading, the mine and senior managements of SCCL thought of exploring the possibility of mechanizing the loading operations in steep seams.

A method has been devised to split the pillars along the strike direction and slicing to be carried out along the apparent dip with an angle of 44^0 between full dip and apparent dip thereby making the workings comparatively flatter i.e. at 1 in 4 gradient, which allows the maneuverability of SDLs.

The following Parameters were considered before opting for apparent dip slicing with SDLs in conjunction with hydraulic sand stowing:

a) **Geological disturbances** - The roof overlying seam is traversed by some hidden slips, faults and the rock was highly jointed at places.

b) **Cavability of the strata** – Cavability Index of the seam was calculated using the CIMFR formula

$$CI = S\, L^{n}\, t^{0.5} /5$$

Wherein

S = compressive strength of the roof rock

L = Average length of the core

n = a factor depending on the RQD

t = thickness of the strong bed

With the above the feasibility of caving of the roof strata was studied. It was found that the nature of roof was difficult to cave (cavability index > 4100). Hence option of caving was eliminated and a decision was taken to liquidate the property in conjunction with hydraulic sand stowing which not only improves the safety but also protects upper seams.

c) **Past experience** - Depillaring by caving was done in two panels in the same seam, in which lot of difficulties were experienced in regular caving of roof because of the hard and massive sand stone layers lying in immediate roof. This phenomena posed great difficulty in regular caving of the roof, forcing the premature closure of a panel.

d) **Rate of extraction** – The pillars were developed along full dip with 1 in 2.5 to 3.0 gradient and depillaring of the panels was carried out with conventional mining, with which the desired rate of progress and production levels could not be achieved.

4.0 NEW METHOD OF OPERATIONS

The following issues were considered:

i) **Marching of SDL from Surface:** It is proposed to transport the SDL on GMT trolley in main incline as this ensures utmost safety in transportation on steep gradients. Thereafter, marching of SDL can be taken up with its electric power along the level galleries.

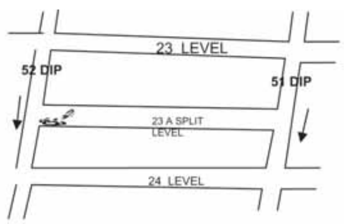
ii) **Splitting from dip (1 in 3):** To drive split galleries in level directions and blast the floor to offset the cross gradient as level floor is required for SDL. If the problem of opening of the split gallery along haulage dip originates alternatively it shall be done by driving the central advance slice in the immediate part pillar.

iii) **Working the slices**: It is proposed to drive the slices at a gradient of 1 in 4 to facilitate maneuverability of SDL. The proposed width of the slice is 3.6mtrs with a rib of not less than 2.0mtrs, thick against the stowed goaf. The rib shall be judiciously extracted.

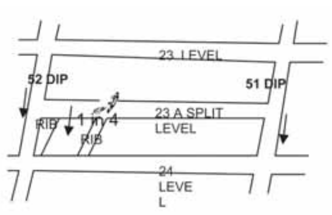
iv) **Marching of SDL from one level to other level**: It is proposed to march SDL from one split to the other by driving an advance central slice at a gradient of 1 in 4.0 in the center of the half pillar lying one pillar ahead of the pillar under extraction, restricting to one such slice in every pillar (Fig. 2B).

5.0 METHOD OF EXTRACTION:

The Central splitting of pillar with SDL was done at 23AL and slicing operations along apparent dip of 1in 4 with 3.6m width leaving 2m rib was completed in 9 shifts (figure 1A & 1B). The supporting pattern was changed from conventional props and cogs to 1.5m grid resin bolting, to facilitate the movement of SDL. However, the cogs were strategically placed at the entrance of all junctions considering the maneuverability of SDL.



1A. Splitting Operation

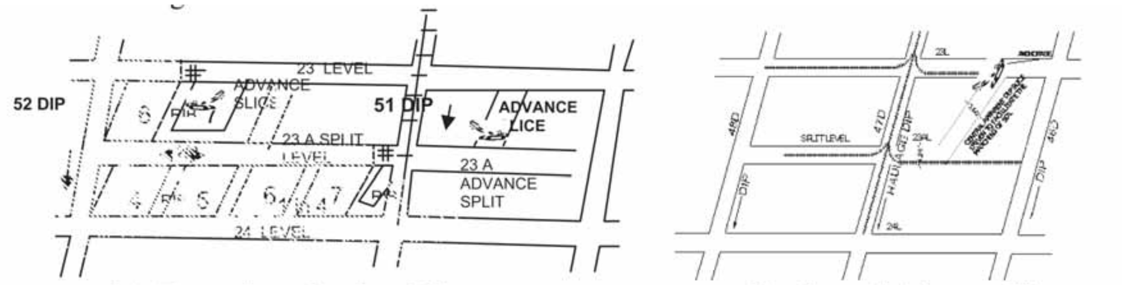


1B. Slicing Operation

5.1 Marching of SDL from one level to another level along Central Advance Slice dip

A Central advance slice in 1 in 4 gradient was driven for easy marching of SDL. The width of the advance slice was restricted to 3.0mtrs and the acute corners so formed were stitched with wire ropes and the roof is supported as being done in the slices.

Not more than one such central apparent dip slice in every pillar, within two pillars of splitting, to facilitate the marching of SDL between one level to another level.



2A. Extraction of outbye Rib 2B. Central Advance Slice

All such central apparent dip slices so formed shall be kept supported with two rows of cogs at an interval of 2.4 m and these cogs are removed when marching of SDL is done.

All such central apparent dip slices are stowed fully before commencement of extraction in preceding slices.

5.2 Extraction of Outbye Rib :-

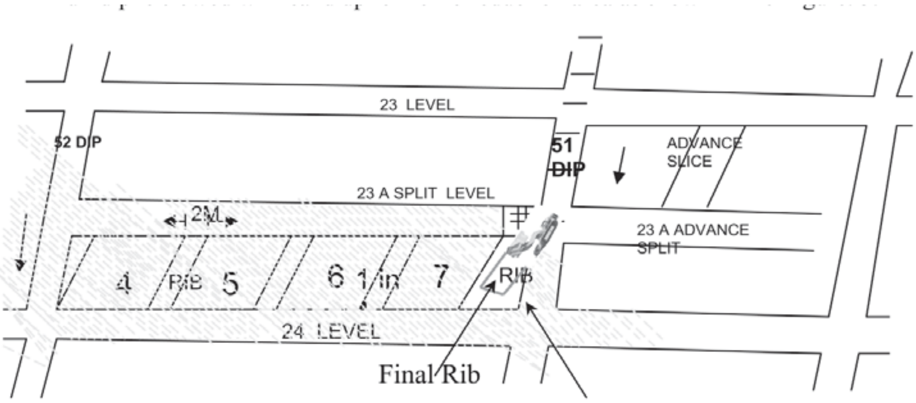
The original dip gallery was pre-stowed before extracting the outbye rib for the following reasons

a) to prevent SDL from skidding/toppling along the original dip while moving across the dip gallery during extraction of outbye rib.

b) to reduce the exposure of roof after extraction of outbye rib and to extract the rib safely

c) to facilitate the SDL maneuverability for 100% extraction of outbye rib coal.

Full dip is stowed with sand up to the rib reduction area as shown in the figure. 3.



6.0 OBSERVATIONS

- Faster rate of extraction is achieved.
- The exposure of work persons in the active stress zone is reduced.
- The production and productivity increased. Frequent marching of SDL avoided and thus availability of SDL for production increased.
- This method is economic, safe and approved.

7.0 CONCLUSIONS

This method has undoubtedly provided an answer for mechanized loading operations in the areas where development has already taken place along full dip in steep seams. Earlier the only available option for extraction of pillars was conventional manual loading. Thus, this method paved the way for semi-mechanization in steep seams.

This experience has revealed that a) the rate of extraction of coal in steep seams in the panel is much faster in the mechanized method, b) reduces human exposure in the active working areas and c) eliminates the drudgery of manual loading as suggested by 10th National Conference on Safety in Mines.

8.0 Acknowledgements

The authors are extremely thankful to Shri S.J.Sibal – DGMS, Shri S.I.Hussain-Dy,DGMS (SCZ),Hyderabad for permitting this paper to be published, Shri Satish Puri–Dy,DGMS, HQ (the then, Dy. DGMS, SC Zone, Hyderabad) for extending his valuable suggestions, technical support and approval for adopting this method.

Last but not least the authors are also thankful to the work persons, supervisors and officers of KTK No. 5 Incline for their commitment and dedication in the successful implementation of the method.

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Ventilation Design of RG-I Area Coal Mines

Iqbal Ahmed & Ramakrishna.Morla***

ABSTRACT

The main objectives of ventilation planning is providing adequate air quantities in all workings, reducing heat and humidity in deep underground mines, improving VEQ (Ventilation Efficiency Quotient), reducing over all resistance of the mine & selection of optimum size of MMV (Main Mechanical Ventilator) or combination of fans for proposed ventilation system of the mine so that required air flow rates are achieved with minimum air power consumption.

In the present study an effort has been made to simplify Ventilation planning of the mines so as to obtain effective results. One of the main objectives of the present study is to provide required air quantities into the fixed flow branches of the network, without using booster fans.

1. Introduction

The ventilation design of a mine should ensure adequate air quantities to all the working places and all other important stations in the mine. The fan(s) selected to ventilate the mine should be able to deliver the designed quantities. The main objective of this work is reducing the main fan pressure and increasing overall quantity of mine air. The following table shows the ventilation details of RG-I Area mines.

Table1: RG-1 Area mines and ventilation Parameters

Mine	Fan Make , capacity	Quantity m^3/min	Pressure mm of wg	Resistance Ns^2/m^8	Area of equivalent orifice (m^2)
GDK-1 Incline	Voltas , 300HP	8500	71	0.0347	6.38
GDK-2 Incline	Sulzer, 200HP	5,200	33	0.0431	5.73
GDK-2A Incline	SIWAX, 200HP	6,400	52	0.0448	5.62
GDK-3 Incline	Joy, 100HP	3000	12	0.0470	5.48
GDK-5 Incline	MMM, 300HP	10,500	60	0.0192	8.58
GDK-7LEP	Voltas, 200HP	7,000	29	0.0209	8.23
GDK-11 Incline	Voltas ,300HP(2fans)	13,500	74	0.0143	9.93

In RG-I Area GDK 11 Incline has very low resistance and area of the equivalent orifice is also very high. GDK-2, GDK-2A and 7LEP mines have only two intakes each but since GDK-7LEP mine has multiple intake and return roadways for the working districts, the mine resistance is low. GDK-5 inline has 5 intakes and GDK-11 Incline has four intakes due to which these two mines also have low resistance.

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2. Steps taken to improve ventilation

2.1. Reduction of the resistance of the mines.

In GDK-2 Incline mine, No.3 Seam return air flows through a single narrow gallery (from 22L/23D to 18L/13D) and No.4 Seam return air also flows through a narrow gallery (from 22L/23D to 17L/19D). After widening and cleaning of these two narrow return airways, the main fan pressure was reduced by 3 mm of wg. In the following figure (part of simplified ventilation network diagram of GDK-2 Incline), the bold line shows the widened gallery.

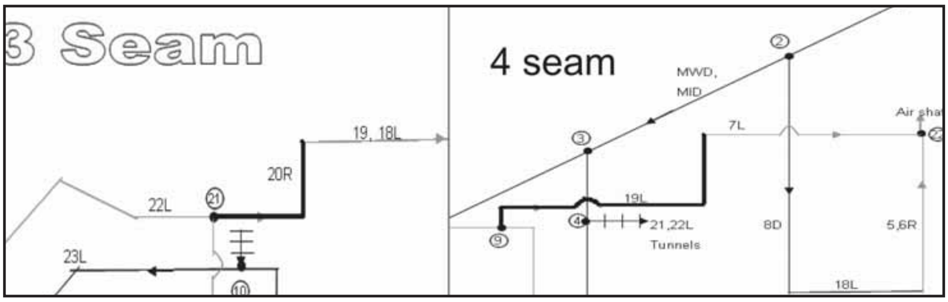

Figure 1: Widening or cleaning of returns in GDK-2 Incline at
22L/23D to 18L/13D in 3 Seam and 22L/23D to 17L/19D in 4 Seam.

In GDK-5 Incline Mine No.4 Seam north and development districts' return air flows through a restricted single air crossing at 2L/MWD. After increasing the cross-sectional area of the air crossing from 10.5m^2 area to 13.5m^2, water gauge of main fan was reduced by 2mm. After establishing parallel returns for 4 seam south and development districts and widening of 2L air crossing, resistance of the mine was reduced from 0.025Ns^2/m^8 to 0.019 Ns^2/m^8 and water gauge has dropped from 64 mm to 60 mm.

2.2 Optimum size of fan

When a branch is simulated as fixed quantity branch, airflow in that branch remains constant. To achieve fixed quantity, airflow should be balanced in all other branches and simulation of the network with fan characteristic curves should be done.

The following table shows the Characteristic curves of RG-1 Area Mines.

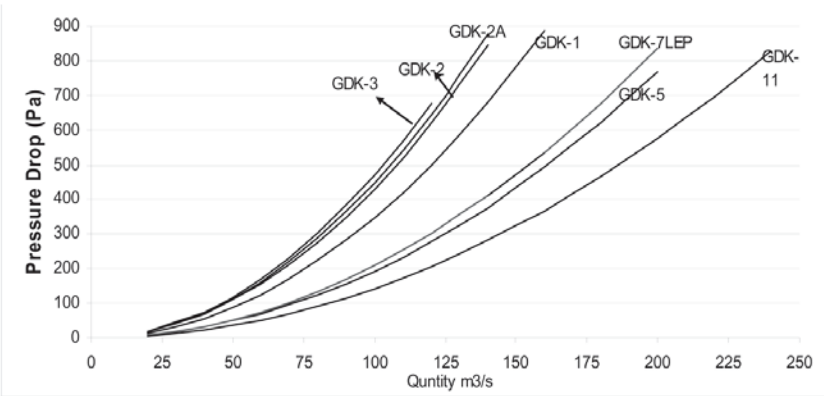

Figure 2: RG-I Area Mines Characteristic curves.

With the help of existing and proposed mine characteristic curves and Fan characteristic curves the operating points of the mines should be found out. Basing on the operating points selected, the optimum size of main fan, with various blade angles should be simulated. If required we may go for installation of new fan(s). At GDK 11 Incline, for ventilating Continuous miner, BG, Development and Depillaring districts, more than 13,500 m^3/min quantity is required. It is difficult to send such huge quantity with a single 300HP fan. For addressing this difficulty, two 300HP parallel fans are deployed at same blade angle. At present total quantity of the mine is 13500 m^3/min at 74mm of water gauge.

Future workings of GDK-2 incline will have two development districts at about 400m depth, which require 15,000 m^3/min air quantity. At present the mine is having only one 200HP fan. Caved goaf panels are present near the return airshaft and air velocity of two intakes is close to the statutory limit. For addressing this problem different simulation studies were conducted and a solution was found i.e., to drive a new tunnel from surface to No.4 seam, deepen the air shaft from No. 1 seam to No.4 seam, to connect a 300HP fan to this shaft and to convert present return air shaft into Intake airshaft. After doing these jobs, the mine will get 15000m^3/min quantity of air at 82 mm of water gauge.

2.3. Power Consumption

The air power requirement of a fan is the product of the fan pressure and air quantity.

Table 2: RG-I area mines Power Consumption

Mine	Total Air Power KWH per year	Current (amp)	Electrical Power Consumption KWh per year	Efficiency Of main mechanical ventilator (%)	Power cost@ Rs.3.39KWh (Rs)
DGK-1 Incline	8,64,368.9	38	16,17,265	53.4	54,82,528
GDK-2 Incline	2,45,775.8	20	8,51,192.1	28.8	28,85,541
GDK-2A Incline	4,76,656.1	26	11,06,550	43.0	37,51,204
GDK-3 Incline	51,561.36	45	2,55,357.6	20.1	8,65,662.4
GDK-5 Incline	9,02,323.8	54	22,98,219	39.2	77,90,961
GDK-7LEP	2,90,748.8	19	8,08,632.5	35.9	27,41,264
GDK-11 Incline	14,30,828	44(2)	37,45,245	38.2	1,26,96,382

GDK- 11 Incline is consuming more power than other mines, because two fans are running in parallel. GDK-1 Incline main fan efficiency is high. Consuming one Ampere of power costs Rs.1, 44,277. Similarly, power cost for every one mm of water gauge is Rs.92, 234.

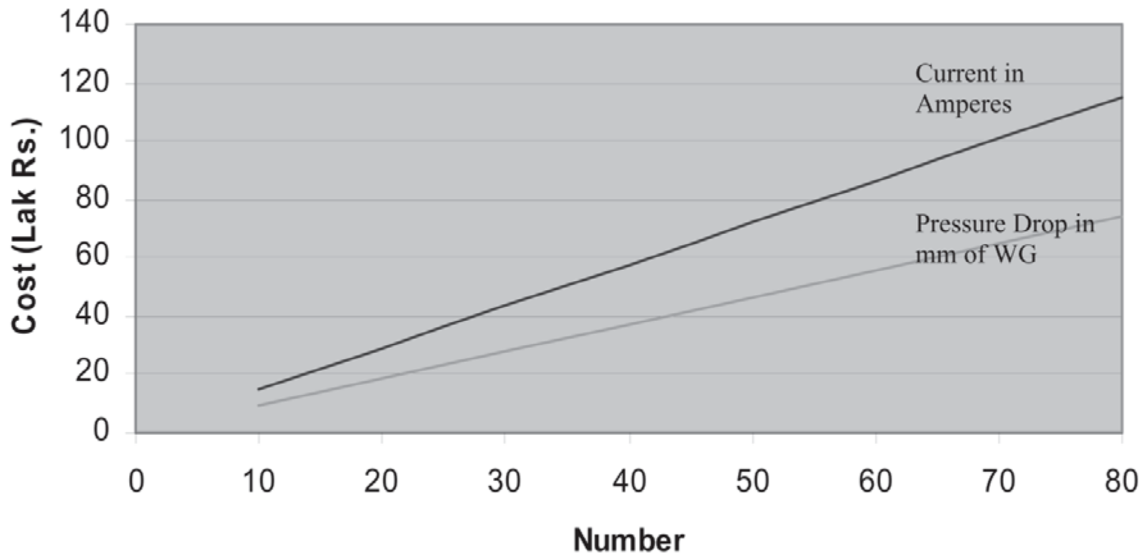

Figure 3: Relation between power cost with pressure and Current

2.4. Descensional system of ventilation in BG panel

At GDK-11 Incline, in Blasting Gallery Panel, descensional system of ventilation (Figure 4) is adopted. Here the airflow is uniform and comparatively brisk throughout the goaf (at the same lower section of goaf AB, substantial air quantity is passing across this area and it is about 2000 m^3/min which is entering through number of rooms at higher horizon). Workplace (rooms) comfort is also comparatively better in this system of ventilation due to uniform airflow in all the rooms. Compared to the ascensional system of ventilation chances of fire are also less.

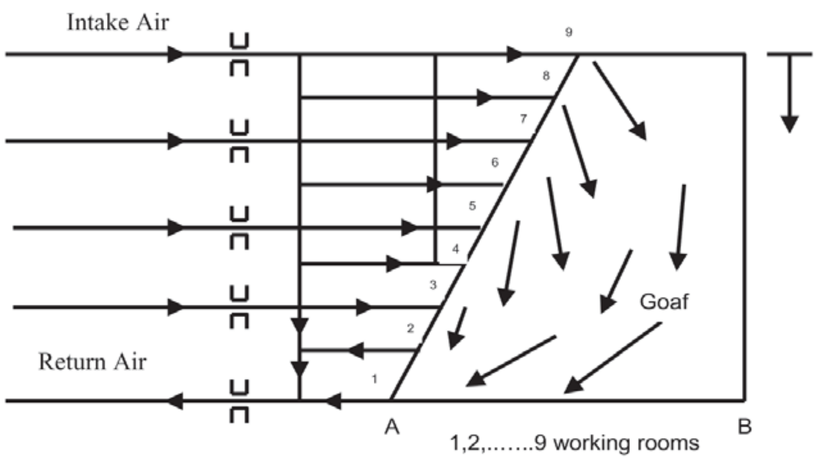

Figure 4: Airflow pattern in descensional system of ventilation in BG panel

3. Conclusions

The present study clearly reveals that the method of ventilation design in the mines of RG-I Area, Mine resistance plays a major role on quantity and fan pressure. Fan selection for the given situation involves simulating the ventilation network with different fan characteristic curves and selecting the most suitable fan. Power cost is directly proportional to the wg/fan pressure. With increase of every one mm of wg, power cost proportionately increases by Rs. 92,234. Descensional system of ventilation in BG panels has given good results.

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Using Integration to Enhance Agility and Innovation

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Using Integration to Enhance
Agility and Innovation

Presentation
on
SCCL ERP – Project

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AGENDA

1. About SCCL
2. ERP What it is & Why in SCCL
3. Project Details
4. Success Factors
6. Benefits
7. Future Road Map
8. Q &A

COMPANY PROFILE

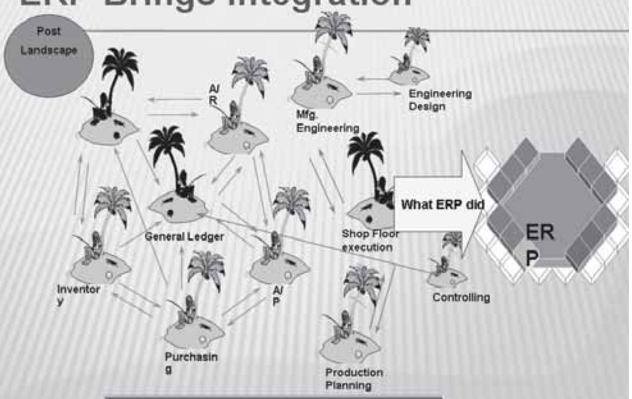
- SCCL is coal mining company owned by GoAP & GOI. Produces 50 million tons of coal p.a., with over 6000 crores turnover
- Operates 50 mines spread over in 4 districts in AP
- For administrative convenience the mines are grouped and operations are divided into 11 areas
- Supporting departments like Purchase, stores, F&A, Marketing workshops etc are there at each area & Corporate
- Deals with around 3000 customers & equal number of vendors
- Maintains inventory of over a One Lakh varieties of items
- Manpower of around 70,000 employees
- Diversifying to power generation also
- The company is pioneer in adapting new technologies

WHAT IS ERP ?

ERP- Enterprise Resources Planning

An ERP solution is essentially single software comprising of very tightly coupled modules (application programs) that can perform all electronic data processing that was traditionally being done by the fragmented systems.

ERP Brings Integration



ERP - WHAT IS IT?

- Process view of business vs. functional “silos”
- Integration of systems, one database
- Supports most of company’s info needs
- Transaction oriented systems (OLTP)
- Accounting, payroll, invoicing, supply chain optimization, sales force automation, customer service …
- Leads to improved performance, better decision making, competitive advantage
- Lays foundation for electronic commerce
- Replaces a multiplicity of different systems and databases
- One integrated system

CAUTION IN ERP

- Less flexibility in process flow changes
- Dependence on available standard packages and their frequent upgradations / versions
- High initial investments in Software, Hardware & Training
- Enterprise wise networking is a must before implementation
- Tough in implementation - possible through implementers which is costly
- Change Management
- Discontinuing of legacy systems which are already developed / Implemented
- Integration of legacy system with standard package

BUSINESS DRIVERS FOR ERP SOLUTION

- Distributed databases-need for central database & central server architecture
- One integrated application in place of multiple applications
- Current Applications are not scalable for portal based features
- BPR
- Provide integrated view of operations at various locations
- Need for a real-time data capture and processing for supply-chain functions
- Improve inventory visibility
- Reduce paperwork and manual processing

ERP PACKAGES

- Basically of 2 types- Custom built or Standard Packages
- Custom built are specific to an Industry/Process and not easy to develop covering all functions.It is costly and risky
- Standard Packages are available across the shelf are developed based on processes / best practices by established software companies
- Some standard packages are
  - SAP
  - Oracle /People soft
  - Axapta
  - Ramco

ERP Solution Opted

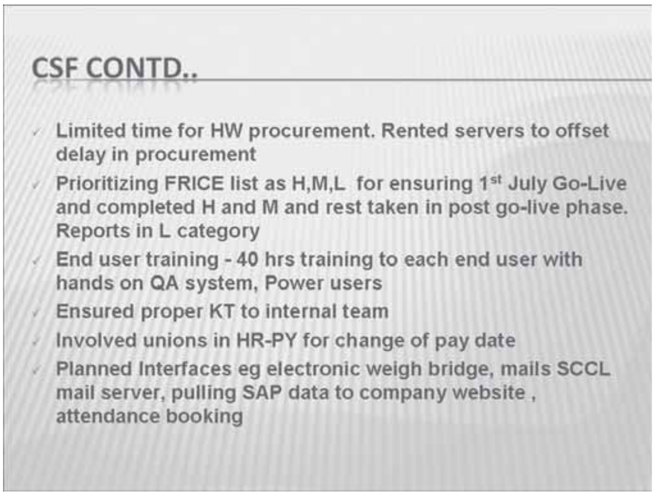
- ✓ A carefully planned/thought decision, took 2 years time (2005-2007) to arrive at the appropriate ERP package
- ✓ Considered various ERP products, and evaluated
- ✓ Experiences of other organizations (PSUs) have been considered before making a choice
- ✓ Had wide ranging consultations with various stake holders
- ✓ SCCL has chosen SAP-ERP product for meeting the business requirements pertaining to functions Marketing & Sales, Procurement & Inventory, Finance & Costing, HCM, QM, BI/BW, ESS
- ✓ SAP because
  - ✓ Mining-focused functionality
  - ✓ Market leadership in enterprise software
  - ✓ Broad experience, Strong references from comparable public sector enterprises in India
  - ✓ Global presence and support infrastructure

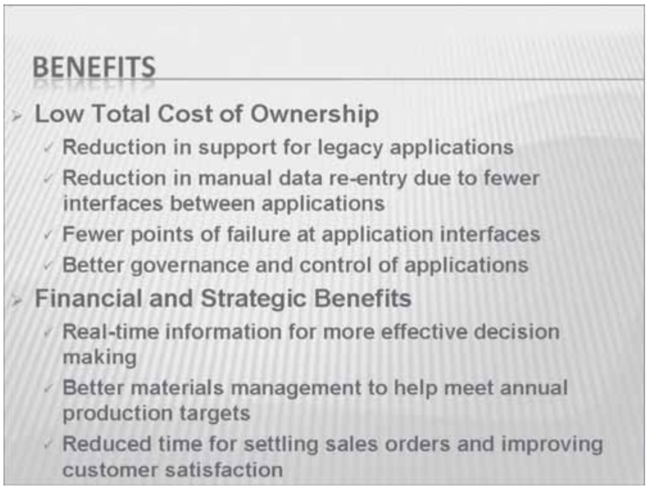
PROJECT TIME LINES

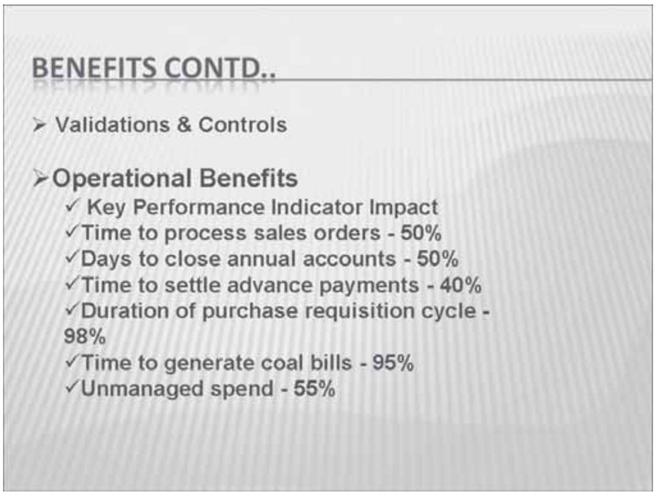
- Combination of Big bang & pilot approach
- Followed the universally accepted methodology for implementation
- Project Kickoff on 03/12/07
- BBP completed end of Feb 2008
- Realization end of May 2008
- Final Preparation end of June 2008
- Go-Live 1st July FICO, MM pilot in 2 areas & SD big bang
- HR PY on 1st Aug 2008 big bang
- Rollout of MM & FICO to all the 11 areas completed on 02/03/2009 and successfully generated FS in SAP for the FY 2008-09 in SAP
- Starting with FY 2009-10 all the business transactions are

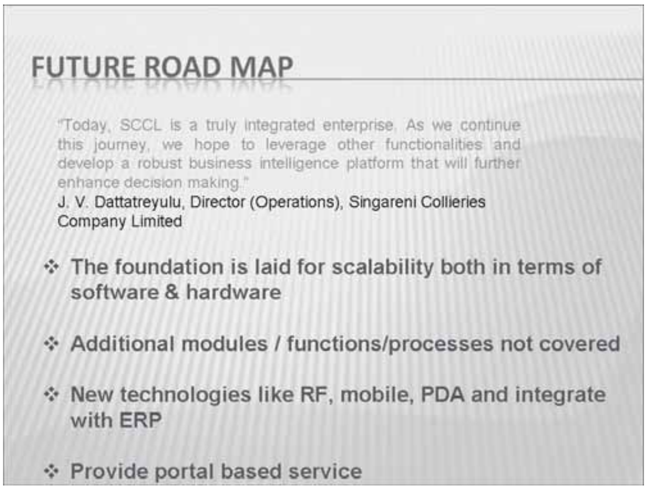
CRITICAL SUCCESS FACTORS

- No time or cost overrun
- Periodical monitoring of the project by the CEO
- Director (Operations) , one of the functional Director of the SCCL is the Project Sponsor
- Constituted core team with around 35 members both functional & technical headed By Proj manager to work on full time basis, matching number of consultants from SAP were deployed to complete the implementation.
- Ensured proper KT to the SCCL team
- All HODs members of SCOM with minimum monthly reviews
- Quarterly review by Board
- Core team given Level 1 training for 45 days & IDES installed immdtly
- Core team handled the roll out and also PGL issues
- Adopted standard SAP functionality


CSF CONTD..
Limited time for HW procurement. Rented servers to offset delay in procurement
Prioritizing FRICE list as H,M,L for ensuring 1st July Go-Live and completed H and M and rest taken in post go-live phase. Reports in L category
End user training - 40 hrs training to each end user with hands on QA system, Power users
Ensured proper KT to internal team
Involved unions in HR-PY for change of pay date
Planned Interfaces eg electronic weigh bridge, mails SCCL mail server, pulling SAP data to company website , attendance booking


BENEFITS
Low Total Cost of Ownership
Reduction in support for legacy applications
Reduction in manual data re-entry due to fewer interfaces between applications
Fewer points of failure at application interfaces
Better governance and control of applications
Financial and Strategic Benefits
Real-time information for more effective decision making
Better materials management to help meet annual production targets
Reduced time for settling sales orders and improving customer satisfaction


BENEFITS CONTD..
Validations & Controls
Operational Benefits
✓ Key Performance Indicator Impact
✓Time to process sales orders - 50%
✓Days to close annual accounts - 50%
✓Time to settle advance payments - 40%
✓Duration of purchase requisition cycle - 98%
✓Time to generate coal bills - 95%
✓Unmanaged spend - 55%


FUTURE ROAD MAP
"Today, SCCL is a truly integrated enterprise. As we continue this journey, we hope to leverage other functionalities and develop a robust business intelligence platform that will further enhance decision making."
J. V. Dattatreyulu, Director (Operations), Singareni Collieries Company Limited
The foundation is laid for scalability both in terms of software & hardware
Additional modules / functions/processes not covered
New technologies like RF, mobile, PDA and integrate with ERP
Provide portal based service

❖ ❖ ❖ ❖

MODERN LONGWALL TECHNOLOGIES – CONTRIBUTION TO SAFETY AND PRODUCTIVITY

* Reiner Schuster, Director, Bucyrus

Mine Engineering

- Geo-Mechanical Studies
- Longwall and Environment
- Infrastructure
- Risk Management

State of the art Longwall technology

- Major components
- Safety aspects

Longwall operations

- Organisation
- Management
- HR Skills

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IMPROVING GROWTH AND OPERATIONAL PERFORMANCE THROUGH NEW PRODUCT DEVELOPMENT AND OPERATIONAL EXCELLENCE

** Dean Thornewell, Director, JMML, UK*

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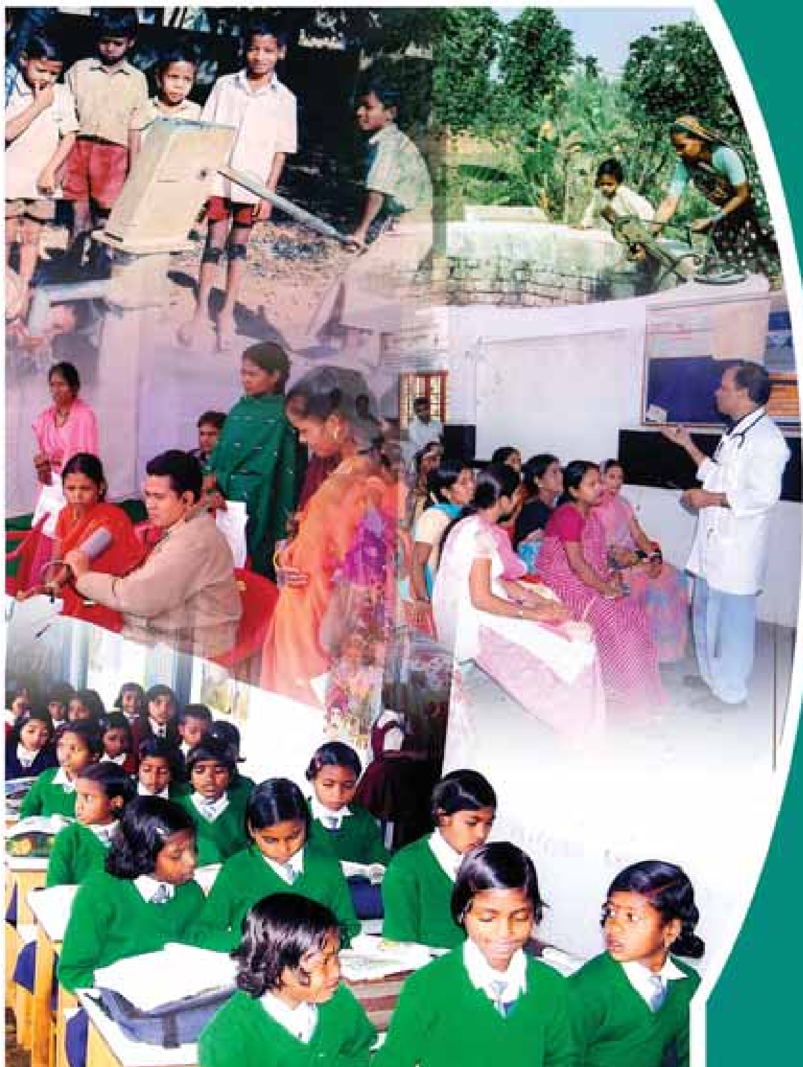
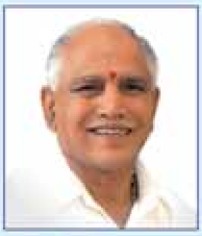


साऊथ ईस्टर्न कोलफील्ड्स लिमिटेड
मिनी रत्न कम्पनी
(कोल इंडिया लिमिटेड की सहायक कम्पनी)



Shri B.S. Yeddyurappa
Hon'ble Chief Minister, Govt. of Karnataka &
Chairman, KPCL

Dr. S.M. Jaamdar, IAS
Managing Director, KPCL

GAS, THERMAL, WIND, HYDRO AND SOLAR
POWERING KARNATAKA

KARNATAKA's pride, India's asset - KPCL, a commanding presence in the national power sector

Karnataka Power Corporation Ltd. was established on 20th July, 1970 to implement power projects and meet the energy requirements of Karnataka. In its decades of existence, it has diversified into a multi-energy generation utility with hydel, thermal, solar and wind power generation projects. Its present installed capacity of about 6000 MW comprises 3637 MW of hydel, 2220 MW of coal-based thermal, 128 MW of diesel 6 mw of solar and 4.55 MW of wind. It has been a path breaker and has created several benchmarks in the construction, operation & maintenance of power projects in the country.

The Karnataka Power Corporation Ltd. (KPCL), has been a prime mover and catalyst behind key power sector reforms in the State.

A bouquet of powerful projects

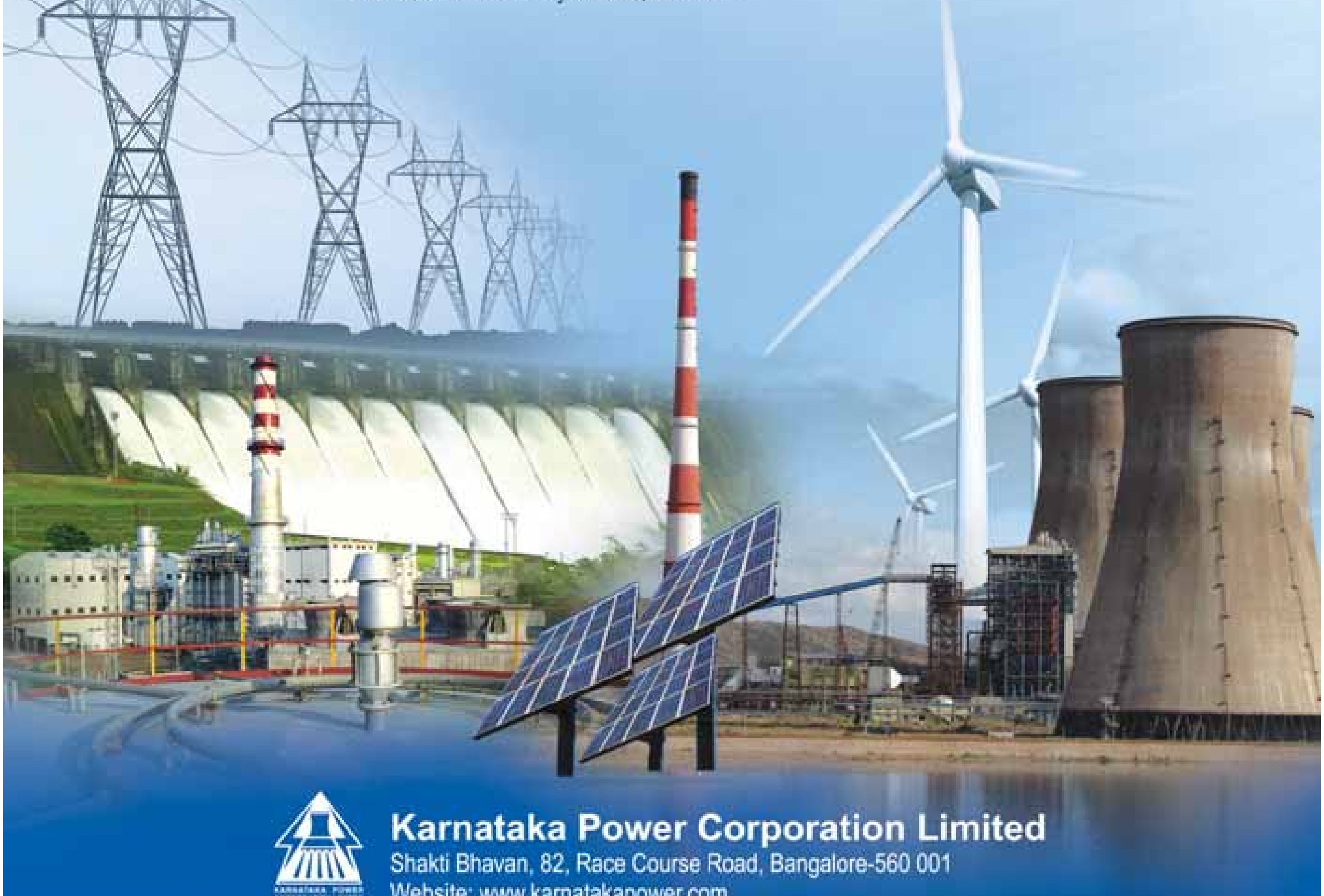
As on date, KPCL meets around 60% of the electricity consumed in the state. With demand growing exponentially, it has been entrusted with the task of adding 9000 MW capacity with a total financial outlay of Rs. 40,481 crores.

The break-up of New Projects is as below:

Project	Capacity in MW
Coal-based Thermal	4700
Hydro	775
Wind Farm	39.75
Gas-based Thermal Plant	3500
Total	**9014.75**

KPCL is already implementing the following projects which are under advanced stages of completion:

Project	Capacity in MW
BTPS Unit II	500
Solar PV Plant in Raichur	3
Up gradation of NPH Units 4&6	30
Total	**533**



Karnataka Power Corporation Limited
Shakti Bhavan, 82, Race Course Road, Bangalore-560 001
Website: www.karnatakapower.com

KPCL's Aim - Abundant Power Production, Prosperous Karnataka

SERVICES OFFERED

BUSINESS DEVELOPMENT

THE SINGARENI COLLIERIES COMPANY LIMITED

(A Government Company)

ACKNOWLEDGEMENTS

We are privileged to place on record our heart-felt thanks to Sri. **Sri Prakash Jaiswal**, Minister of State (Independent charge) for Coal & SPI, Sri. **C Balakrishnan** IAS, Secretary, Ministry of Coal, Government of India, Sri **S J Sibal**, Director General of Mines Safety, Ministry of Labour & Employment, Government of India, Sri **Sutirtha Bhattacharya** IAS, Principal Secretary, Energy Department, Government of Andhra Pradesh, Sri **S Narsing Rao** IAS, Chairman & Managing Director, SCCL, Sri **S I Hussain,** Dy DGMS, South Central Zone, Sri **J V Dattatreyulu,** Director (Operations) & Director (Personnel, Administration & Welfare), SCCL, Sri **D L R Prasad,** Director (Planning & Projects) & Director (Finance), SCCL and Sri **I V N Prasada Rao,** Director (E&M), SCCL for their valuable messages wishing success and for their unstinted support and guidance in the conduct of the National Seminar.

Our sincere gratitude is owed to the authors for contributing valuable technical papers for the Souvenir from all corners of the country.

We express our thanks to various firms for the support extended by them through issue of advertisements in the Souvenir.

We place on record with gratitude the endeavor of the Patrons & Seminar organizing committee members for their untired efforts in the conduct of the Seminar and to the Souvenir committee for planning, publishing and bringing out this memorable Souvenir.

We express our sincere thanks to M/s. Taher Graphics, Kothagudem for bringing shape to the Souvenir, in time.


Expertise in action
Mechanical coal cutting expertise
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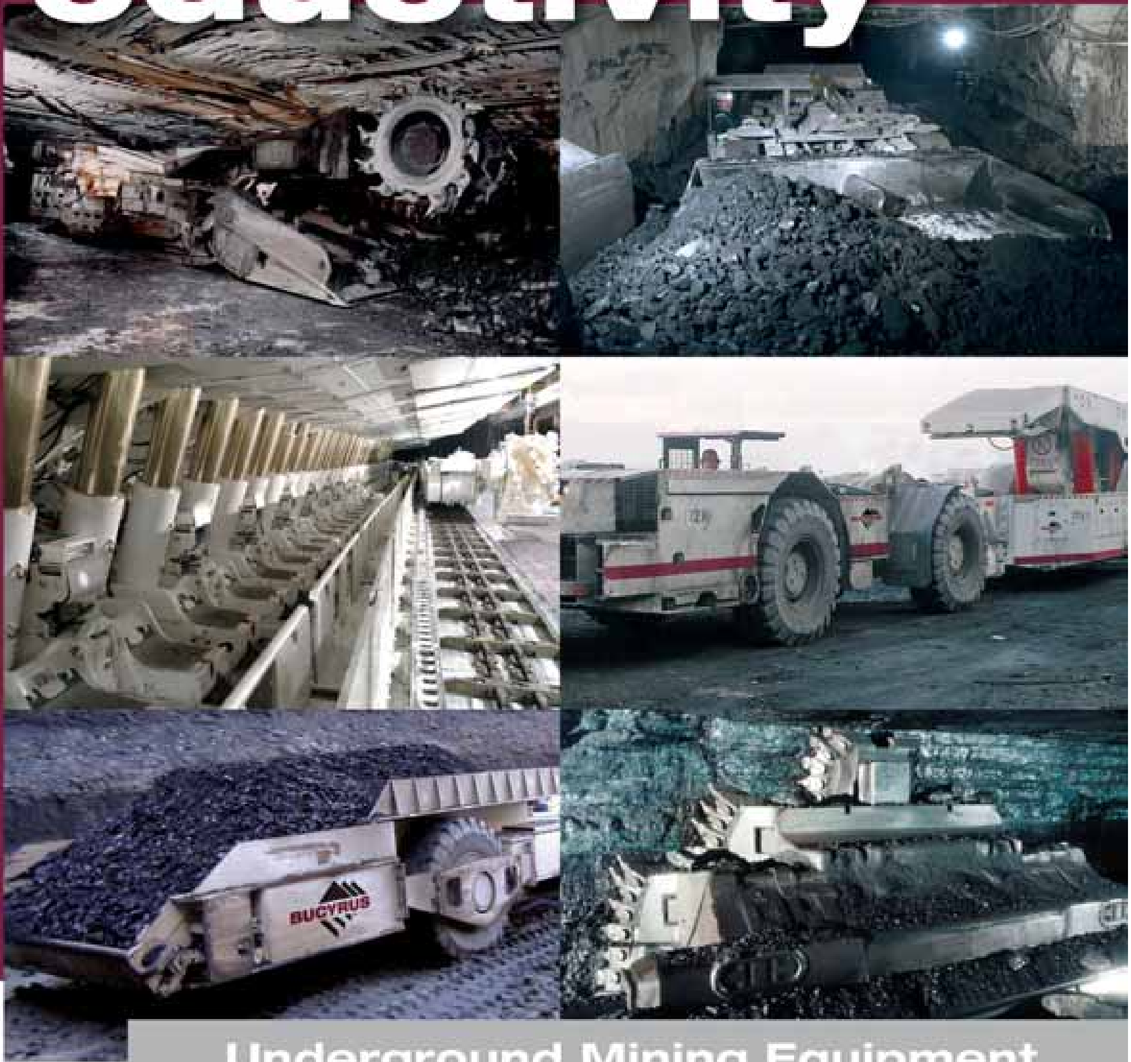

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