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Persons in the News

Shri P M Prasad took the charge as Chairman and Managing Director, CCL (Central Coalfields Limited). Prior to this Shri Prasad was working as CMD, BCCL. A mining engineer with M.Tech in opencast mining from IIT (ISM). He has vast and varied experience of 36 years in different subsidiaries of Coal India Limited and NTPC. Shri Prasad began his career as an executive trainee with Western Coalfields Limited (WCL), a subsidiary of Coal India Limited (CIL) in 1984. He exhibited dedication, hard work, sincerity and dynamic leadership as he progressed through different roles in the company and became General Manager If Lingaraj area in Mahanadi Coalfields Limited (MCL). In 1994-95, he was instrumental in reopening of DRC mines which was affected by the underground fire during his posting in WCL. For this remarkable job, he was awarded as 'Best Mines Manager' from Secretary Coal, Ministry of Coal (MoC) and Chairman, Coal India Limited in 1995. During his successful stint as General Manager at MCL, he was responsible for successful opening and operations of 'Kaniha Opencast Project' from March, 2020. He also credited for diversion of nallah at Hingula Opencast Area to unlock coal reserve of 26.00 MT in the year 2014-15 and commencement of New Railway Siding No.9 at Talcher Coalfields. He has a special penchant for safety and the projects with which he was associated have won various prizes at different competitions including hat-trick for two projects i.e. Padmapur Opencast, WCL between 1996 and 1998 and Nandira UG Mine, MCL between 2004 and 2006. In May, 2015 he joined NTPC as Executive Director (Coal mining). He was acknowledged for expediting the process of award of MDO projects and awarded pakribarwadih coal block (NTPC's first project) and floated NITs for remaining coal blocks. In March 2016, he took charge as Executive Director cum Head of the Project, Hazaribagh, Jharkhand. During his tenure, he led the commencement of coal mining operation at Pakribarwadih mines, Hazaribagh. During his term in

2016 Pakribarwadih was bestowed with the first prize in 'Swarn Shakti Awards'.

In February, 2018 he joined Northern Coalfields Limited (NCL) as Director Technical (P&P) where he was responsible for operations of five areas of the company along with key departments like Corporate Planning, Civil Engineering, Railway Siding, Environment & Forest etc. Under his leadership, NCL was awarded at the World Environmental Conference in June 2018 for outstanding work in environment conservation. He took over the challenging conditions, he led from the front with commitment, vigor, and dedication. He spearcheaded the comany's fight against the COVID-19 pandemic and was instrumental in various initiatives to transform the overall performance of the company.

Shri Ujjwal Kanti Bhattacharya presently Executive Director, NTPC Limited, has taken charge the post of Director (Projects), NTPC Limited. Prior to his appointment as Director (Projects), Bhattacharya has also worked as ED (International Business Development) and ED (Projects), NTPC. Shri Bhattacharya joined NTPC in the year 1984 as Ninth Batch of Engineering Executive Trainees and was initially posted at NTPC Korba which was then situated in Madhya Pradesh. He is an Electrical Engineering Graduate from Jadavpur University, Kolkata. He has also completed his PG Diploma in Management from MDI, Gurgaon.

Shri Pradosh Kumar Basu presently Chief Financial Officer, ONGC Petro Additions Limited, has been appointed for the post of Director (Finance), National Aluminium Company Limited (NACL). Shri Basu has joined ONGC Petro additionss Limited (OPaL) as Vice President - Finance on 1st January, 2018. He is a Certified Management Accountant (CMA) from (The Institue of Cost & Works Accounts of India - ICWAI) 1990 batch. In addition to this he is also a Certified Public Accountant (CPA) from American Institute of Certified Public Accountants. USA. Shri Basu has a rich experience of around 29 years in the field of Business Finance Controlling, Strategy, Fund Management, Risk Management, Commercial and Business Planning, Performance reporting, Audit Management in Oil, Gas and petrochemical organizations. prior to joining OPaL he was working with Qatar Petroleum as Head of Business Finance & International Operations.

Shri Somnath Nandi presently Executive Director, Steel Authority of India Ltd (SAIL), has been appointed for the post of Director (Technical), NMDC Limited.

Smt. Soma Mondal presently Director (Commercial) Steel Authority of India Ltd (SAIL), has been appointed for the post of Chairman, Steel Authority of India Ltd (SAIL). Prior to this, she was Director (Commercial), NALCO, Bhubaneswar. She graduated in Electrical Engineering from National Institute of Technology, Rourkela in 1984. Starting her career as a Graduate Engineer Trainee in NALCO. Shr had been instrumental in devising marketing strategies of different products for NALCO in the Domestic & Overseas market and had also been actively involved in launch of various new products by the Company. Under her guidance several systemic improvement initiatives were implemented in Marketing and Materials Management functions at NALCO.

Shri R Rajesh Kumar presently General Manager, Uranium Corporation of India Limited, has been appointed for the post of Director (Technical), Uranium Corporation of India Ltd. (UCIL).

COAL NEWS

CIL TO INVEST OVER RS 1.22 LAKH CR BY 2023-24 : COAL MINISTER

CIL will pump in over Rs 1.22 lakh crore on projects related to coal evacuation, exploration and clean coal technologies by 2023-24, to achieve 1 billion tonnes of fuel output target, Coal Minister Pralhad Joshi said. Out of the proposed spend of over 1.22 lakh crore, Coal India Ltd (CIL) has planned to invest Rs 32,696 crore on coal evacuation, Rs 25,117 crore on mine infrastructure and Rs 29,461 crore on project development by 2023-24, the minister said while addressing a stakeholders' meet organised by the PSU through video conferencing. He added that the state-owned company will also invest Rs 32,199 on diversification and clean coal technologies, Rs 1,495 crore on social infrastructure and Rs 1,893 crore on exploration works.

The investment of Rs 1.22 lakh crore will be utilised to fund a total of 500 projects, Joshi added. The company is eyeing 1 billion tonnes of coal output by 2023-24, he said. "Engagement and involvement of all concerned stakeholders in the company's affairs will reduce and uncover the project risks. Such two-way interactions help pave way for mutually beneficial newer ideas, improvement areas and project-related expectations," the minister said. The minister said avenues for business opportunities with Coal India are huge. The company would invest around Rs 14,200 crore by 2023-24, in two phases, for its 49 first-mile connectivity projects, he added.

First-mile connectivity is the transportation of coal from pitheads to dispatch points. This is being done to bring in improved efficiency in coal transport and computer-aided loading, replacing the existing road transport between the two points. Similarly, to raise coal output and reduce import dependency of coal, CIL has identified a total of 15 greenfield (new) projects to operate through the mine developer and operator (MDO) mode. It would entail a total investment plan of about Rs 34,600 crore, of which likely investment ending 2023-24 pegged at about Rs 17,000 crore.

Evacuation infrastructure is another major area where Coal India will infuse large amount of money into economy. Investments in rail logistics like developing major railways (about Rs 13,000 crore), railway sidings (about Rs 3,100 crore) and procurement of own wagons (Rs 675 crore) would total up to over Rs 16,500 crore by 2023-24. "Coal India and its subsidiaries are engaged in procurement of various types of goods, works and services amounting to approximately Rs 30,000 crore per year. This is where the role and importance of stakeholder step in," the minister said. Coal Secretary Anil Kumar Jain, CIL Chairman and Managing Director Pramod Agarwal, and other senior officials from the coal ministry and the company attended the meet.

COAL INDIA TO RESTART CLOSED UNDERGROUND MINES

Coal India is readying a strategy to retrieve production from underground mines where mining was discontinued due to several challenges. The company has identified 12 such mines with provisional mineable reserves of around 1,060 million tonnes (MTs). Of these 12 mines, eight belong to Eastern Coalfields Ltd (ECL) and the remaining four fall under Bharat Coking Coal Limited (BCCL), spread over the states of West Bengal and Jharkhand.

“The project is on the drawing board but CIL aims to start the process soon to bring these mines back to active production. This is in effort to increase production through indigenous sources” a senior company executive said. CIL is keen to fast track the issue once Central Mine Planning and Design Institute (CMPDI), its mine consultancy arm, which has been entrusted to prepare a data dossier submits its report on the feasibility.

These mines were discontinued because of difficult geo-mining conditions, economic unviability and non-availability of suitable methods to extract deep-seated reserves at the time. While the eight mines of ECL have projected reserves of around 596 MTs, the four mines belonging to BCCL add up to 464 MTs. ECL mines have coal of varying grades between G3 and G7 with one mine having coking coal, which is used in steel making. All four mines of BCCL are coking coal reserves which are scarce in the country.

The Ranchi-based CMPDI shall prepare the study on sufficiency of extractable reserves in consultation with the concerned subsidiary coal companies to prepare a detailed list for revisiting the discontinued mines for production. Subsequently, coal companies will float tenders as per their requirement to engage suitable Mine Developer and Operators and others having requisite technical knowhow to pursue the operations on their behalf. The mines were discontinued in different years in the past, some dating back to more than 20 years. “With the advancement of technologies in the coal mining sector it is possible to extract the locked in coal reserves of these mines and this prompted us to explore the option," the executive said.

MINING NEWS

HINDALCO SIGNS MOU WITH ULTRATECH CEMENT TO DELIVER BAUXITE RESIDUE

Hindalco Industries, a global leader in aluminium and copper, on Thursday said it has signed an MoU with UltraTech Cement to deliver 1.2 million metric tonne of bauxite residue annually to the cement company's 14 plants located across seven states. Hindalco claims to be the world's first company to achieve 100 percent red mud (bauxite residue) utilisation, across three of its refineries.

"Hindalco...is going to find value from this bauxite residue waste. So this announcement is about 1.2 million tonnes of bauxite residue which is going to one company UltraTech Cement which is India's largest cement producer," Hindalco's Managing Director Satish Pai told PTI.

Red mud generated in the alumina manufacturing process is rich in iron oxides, along with alumina, silica and alkali. The cement industry has developed the capability to process red mud as a replacement for mined minerals such as laterite and lithomarge in its process.

Hindalco is supplying red mud to UltraTech Cement plants where it has been proved to be an effective substitute for mined materials, successfully replacing up to three per cent of clinker raw mix volume, a company statement said.

Hindalco's alumina refineries are currently supplying 250,000 metric tonne of bauxite residue to cement companies every month, making Hindalco the world's first company to have enabled such large scale commercial application of bauxite residue, it said. Hindalco has been working with cement companies to develop high-grade inputs for the construction industry. It has built a strong customer base and supplies red mud to over 40 cement plants every month, Pai said.

"We have achieved 100 per cent red mud utilisation at three of our refineries and our vision is to achieve zero-waste alumina production across our operations. Hindalco's actions underscore our commitment to embracing solutions that have the potential to deliver long-term sustainability impact and transform the future," Pai said.

In the current year, Hindalco aims to achieve 2.5 million metric tonnes of bauxite residue utilisation. Globally, 160 million metric tonnes of red mud is produced annually and stored in large tracts of land which is a serious industry challenge.

To find a sustainable solution, Hindalco has invested in infrastructure and collaborated with cement companies, with UltraTech Cement being a key partner, the statement said. "UltraTech has been among the early adopters in India on the use of alternative raw materials and fuels in manufacturing and invested to build storage, handling and processing facilities. Use of waste like red mud as an alternative raw material for manufacturing cement requires infrastructure and process modification to ensure a win-win for both business and the environment," UltraTech Cement Managing Director K C Jhanwar said.

Last year, UltraTech consumed about 15.73 million metric tonnes of industrial waste as alternate raw material and about 300,000 metric tonnes as alternative fuel in its kilns. "With an annual supply of 1.2 million metric tonne of red mud from Hindalco, we expect to conserve more than 1 million metric tonnes of mined natural resources like laterite in our manufacturing process. Enhancing our contribution to the circular economy by strategically increasing the use of waste as raw material and fuel in the cement manufacturing process, is in line with our aim to achieve our long-term sustainability goals," Jhanwar said.

The Memorandum of Understanding (MoU) represents a significant sustainability initiative for both Hindalco and UltraTech. Waste of one industry being used as an input material in another is more than an example of a circular economy, it exemplifies Hindalco's sustainability-first approach to business, the statement said.

TALCHER FERTILIZERS TO EXPEDITE PROJECT

Coal Minister Pralhad Joshi reviewed the progress made in operational activities of Talcher Fertilizers Ltd and asked it to expedite the coal gasification project. Talcher Fertilizers Ltd is a joint venture between GAIL India Ltd, Coal India Ltd, Rachtriya Chemicals and Fertilizers Ltd and Fertilizer Corporation of India Ltd (FCIL). Took stock of progress made in operation activities, by Talcher Fertilizer Limited Advised them to expedite coal gasification project and assured them of support from the ministry Joshi said in a tweet. The coal gasification based ammonia-urea project, a first of its kine in the country, would have a design capacity of 2200 tonnes per day of ammonia and 3,850 tonnes per day of urea, the government had earlier said. The state-of-the-art plant at Odisha will produce 100 tonne per day of sulphur flakes as a saleable by project.

The plant will produce 2.38 million tonne cubic metres per day of natural gas equivalent synthesis gas from coal, the government had said. Earlier owned by FCIL, the plant stopped production in March 1999. Now, Talcher Fertilizers Ltd is reviving its operations. TFL's promoters have so far committed ₹8,000 crore on various awarded contracts, the government had earlier said. The project will have an output of 1.27 million metric tonne per annum (MMTPA) of 'Neem'-coated urea using of blend of indigenous coal and pet coke as feedstock. Up to 10,000 people are expected to be employed during the construction period under over 4,000 direct and indirect employment opportunities will open up once the plant begins operations.

FINANCIAL RESULTS OF NLCIL FOR THE QUARTER ENDED 30.06.2020

The total income of the Company for the quarter ended 30.06.2020 is ₹2386.86 crore as against ₹1904.03 crore in the corresponding period of the previous year, registering a growth of 25.36%. During the quarter, the Company recognised as an Exceptional item, the one-time Rebate of ₹42.09 crore to DISCOMs on account of COVID-19 pandemic based on guudelines issued by Ministry of Power, Govt. of India.

Profit Before Tax for the quarter is ₹455.42 crore as against ₹429.12 crore in the corresponding period of the previous year, registering a growth of 6.12%. Profit after tax for the quarter ended 30.06.2020 is ₹292.54 crore as against ₹323.04 crore in the corresponding period of the previous year. Power generation during the quarter ended 30.06.2020 is 5698.60 MU as against 5059.11 MU in the corresponding period of the previous year, registering a grwoth of 12.64% mainly on account of commissioning of Unit-I of NNTPS (2x500 MW) and of 709 MW Solar Project in Previous 3rd quarter of previous year.

Power export during the quarter ended 30.06.2020 is 4962.67 MU as against 4305.88 MU in the corresponding period of the previous year, registering a growth of 15.25%. The EBIDTA (excluding exceptional item) for the quarter ended 30.06.2020 is ₹1075.48 crore as against ₹755.55 crore, registering gwoth of 42.34%.

For the consolidated financial statement:- The total income of the Group during the quarter and year ended 30.06.2020 is ₹3065.80 crore as against ₹2330.69 crore in the corresponding period of the previous year, registering a growth of 31.54%. During the quarter, the group has recognised as an Exceptional Item, the one-time Rebate of ₹85.43 crore to DISCOMs on account of COVID-19 pandemic based on guidelines issued by Ministry of Power, Govt. of India. Profit Before Tax for the quarter ended 30.06.2020 is ₹531.55 crore as against ₹368.79 crore in the corresponding period of the previous year and registered a growth of 44.13%. Profit after tax for the quarter ended 30.06.2020 is ₹343.48 crore as against ₹283.77 in the corresponding period of the previous year and registering a growth of 21.04%. The EBIDTA (excluding exceptional item) for the quarter ended 30.06.2020 is ₹1380.18 crore as against ₹883.99 crore in the corresponding period of the previous year and registering a growth of 56.13%.

MORE INDUSTRY-FRIENDLY REFORMS IN MINING SECTOR VERY SHORTLY: PRALHAD JOSHI

Mines Minister Shri Pralhad Joshi on a FICCI Webinar on 11th August said the government will come out with more industry-friendly reforms in the mining sector very shortly. "More industry-friendly, productive friendly reforms will be brought to the mining sector very shortly," Joshi said during a webinar on "Indian Mining Industry: Contribution Towards Aatmanirbhar Bharat". "At this juncture I would also like to urge the industry stalwarts and stakeholders to share their insights as to how collectively we can collaborate and innovate to make this sector self reliant," he said.

The minister also invited investors, explorers and miners to come and explore the huge opportunities that the Indian mining sector offers. The minister said that other issues like illegal mining, environment clearance and forest clearance will be deliberated and suitable action as per the law will be taken in the due course of time. The minister further said that 500 mining blocks would be offered through the open and transparent auction process. Mining as a sector creates wealth and employment and strengthens the nation from within, Joshi said.

The sector, he said, contributed Rs 4.1 lakh crore to India's GDP in the last financial year by employing about 1.1 crore people. Yearly, 5.5 crore people depend upon the sector for their livelihood. India is a mineral rich country producing 95 different minerals, including metallic and non-metallic and minor, he said adding the mineral sector therefore is the backbone of the country's economy. Stating that commercial coal mining is the biggest reform in the coal sector the country has ever seen, Joshi said in coming times the reform will boost the production by introducing competition, transparency and private sector participation.

CAT® HYDRAULIC MINING SHOVEL BUCKET WITH REPLACEABLE BASKET

Caterpillar now offers an innovative 2-piece bucket for Cat® hydraulic mining shovels. The design reduces downtime by limiting refurbishment to the area of the bucket subjected to most of the wear—the basket. The replaceable basket enables faster, easier and safer rebuilds compared to traditional buckets. In addition, the basket design can evolve with mine site conditions to further reduce downtime and optimize capacity over the life of the bucket.

The durable upper structure of a bucket will host several baskets during its long service life, thus the need for optimizing basket replacement. Also, the 2-piece bucket is lighter than conventional buckets, yet it features high wear resistance. The basket is a single piece of structural steel with no liner or wear plates, and the floor and sideplate thickness are optimized for bucket size and anticipated wear rate. The basket is retrofittable onto legacy buckets used in compatible digging conditions. The 2-piece bucket enhances both safety and serviceability. Replacing just the basket requires less gouging, welding, and grinding than buckets protected with wear plates. The single-piece basket design also reduces potential hazards caused by stored energy. After the initial design is completed for the application, replaceable baskets can be ordered in advance and stocked on site. For more information about Cat 2-piece buckets for hydraulic mining shovels, contact the local Cat dealer.

MOIL WORKING ON NEW PROJECTS WORTH RS 581 CRORE AT MINES IN MP, MAHARASHTRA

Manganese ore mining firm MOIL Ltd is working on multiple new projects worth cumulatively Rs 581 crore at its mines in Madhya Pradesh and Maharashtra, according to its annual report. The company is aiming to complete these projects by August 2021, the miner said in its Annual Report 2019-20. At Munsar mine in Maharashtra, the company is setting up a new vertical shaft at a depth of 160 metres at a capital cost of Rs 51.32 crore.

The scheduled completion of the work, it said, was in April 2020. However, the work is in progress and the completion of the project shall be in November 2020, the report said. Another project of Rs 77.15 crore for setting up a sinking vertical shaft at a depth of 324 metres is going on at the company's Ukwa mine in Madhya Pradesh. At the site, shaft sinking and lining up to 200 metres has been completed. The project is expected to be completed in August 2021, the PSU said. A Rs 194-crore project of sinking a large diameter high-speed vertical shaft of 330-metre depth at Gumgaon mine Maharashtra would be completed by January 2021, the report said adding that shaft sinking and lining up to 180-metre depth at site is completed.

At Balaghat mine in Madhya Pradesh, work for sinking a large diameter high-speed vertical shaft of 750-metre depth is undergoing. The shaft sinking and lining up to 480-metre depth at Rs 259-crore project site is completed and the overall project is scheduled to be completed in July 2021, it said. In the report, MOIL also informed about two projects worth Rs 418.82 crore, for which its board has already given approval. The company plans 50,000 MTPA (metric tonnes per annum) ferro alloys plant at Balaghat mine with an investment of Rs 263.82 crore, and 25,000 MTPA ferro alloys plant at Gumgaon mine with an investment of Rs 155 crore. However, the company did not share any further details with respect to the planned projects but said "these projects have been approved by the board subject to JV or offtake agreement with prospective customers. Entering into offtake agreements is now being explored and discussions are underway". MOIL, under the Ministry of Steel, is the largest producer of manganese ore in the country and operates 11 mines in the states of Maharashtra and Madhya Pradesh.

NMDC'S BOARD APPROVES DEMERGER OF IRON AND STEEL PLANT IN CHHATTISGARH

NMDC Ltd, has approved the proposal to demerge its 3 million tonne Iron & Steel Plant in Nagarnar, Chhattisgarh. "The Board of Directors of the Company at their meeting held on Thursday the 27th August 2020, inter-alia, have accorded in-principle approval to the proposal to demerge its NMDC Iron & Steel Plant (NISP), Nagarnar, Chhattisgar," the company said. NMDC's Nagarnar steel plant was under-construction at a cost of over Rs 20,000 crore, being completely funded by NMDC. The company had been raising non-convertible debentures for completing the steel project. After the demerger, all incremental capital expenditure for the steel plant can be self-funded by the demerged entity. Analysts estimate that the in-principle approval by the board of NMDC to demerge the steel plant, i.e creating a separate listed company eventually with a shareholding akin to NMDC will be value accretive to the minority shareholders."If pursued in a time bound manner, this can lead to separate avenues of fund raising for the government of India, allowing free cash flow yield and correspondingly the dividend yield of NMDC to increase substantially," said ICICI Securities in a report. This comes at a time when the company's profits were severely hit by the viral pandemic and it reported a 55% decline in net profit at Rs 532.90 crore during the first quarter of the financial year 2021, as against a profit of Rs 1,179.28 crore in the same period last year. "The COVID-19 had an impact on the operations of the company during the June quarter. There has been a loss of around 18.23 lakh tonnes of production and 23.94 lakh tonnes of sales, this has resulted in a loss in sales revenue of around Rs. 737 crore the current reported period." the company said in its notes to accounts. After the announcement, the company's shares jumped 12.5% to trade at Rs 108 apiece. "The demerger will improve return ratios of the mining entity substantially and allow investors a better pureplay mining opportunity. We see execution as the key risk," ICICI Securities report said.

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Recent Practices and Advancement in Mineral Industry

P. K. Satpathy*

India is a country blessed with abundant mineral resources which play an important role not only in the development of the nation but also in offering competitive edge to the Indian Industries. In addition to these benefits, skilled manpower and rising demand of ferrous and non-ferrous metals further support the idea of value addition in the country.

Now, coming to the theme of seminar, **"Recent Practices and Advancement in Mineral Industry,"** since civilization began, people have used mining techniques to access minerals in the surface of the Earth. In the earliest days, mining was slow-going and dangerous. However, as time progressed, society has developed safer and more accurate methods of locating and uncovering substances found in the earth.

In the beginning, miners used primitive tools for digging. Mining shafts were dug out by hand or using stone tools, making the entire process very lengthy. Mining technology leaped forward again in the late Middle Ages when miners started using explosives to break up large rocks. Black powder was used for breaking rock and was eventually replaced with dynamite in the mid-19th century. At the same time, advancements were being made in motorized mining tools, such as drills, lifts and steam-powered pumps.

The Industrial Revolution spurred improvements in explosives and mining equipment. Mechanical drills powered by pistons, compressed air and Hydraulics significantly increased the capability and efficiency of mining hard rock. Improvements in other mining processes occurred too. Handpowered loading and hauling were replaced by electric conveyors, mine cars, and vehicles.Mechanization and new technology.

sparked dramatic improvements in mining techniques.

The life cycle of mining begins with exploration, continues through production, and ends with closure and postmining land use. The three major components of mining (exploration, mining, and processing) overlap somewhat.

Modern mineral exploration has been driven largely by technology. Many mineral discoveries since the 1950s can be attributed to geophysical and geochemical technologies.

* Director (Production) NMDC Ltd.

India is intending to complete data generation to levels comparable to those of Australia and targeting to:

- Provide digital geological maps in public domain
- Provide already acquired analog/ digital aeromagnetic data to exploration agencies
- Complete National Geo-Chemical Mapping (NGCM) and National Airborne Geophysical Mapping (NGPM) data acquisition for the entire OGP area on priority followed by integration of the entire data set and providing the same to the public in digital form as part of baseline geoscience data.
- Low altitude, close spaced aero geophysical (magnetic, Electro-magnetic (EM), radiometric, gravity) data.

NMDC as an exploration and mining company, has utilized Multidisciplinary Exploration Techniques involving Space technology in the form of Remote Sensing Studies,Airborne Magnetic Survey (in association with NGRI, Hyderabad), GIS Studies, Geological, Geochemical & Geophysical Surveys etc for various prospects allotted to NMDC.

Technology in the Mining and Processing refers to physical hardware, operational procedures, information systems, and management practices. Mining and processing technology include both fixed and mobile machinery and equipment (e.g. drilling, blasting, loading and hauling equipment, crushers, conveyors and mills) as well as supporting technologies such as monitoring, control, and communications systems, planning and design tools and other support services.

The mining industry experienced the innovations in the past such as in open pit mining, block caving, long wall mining, draglines, use of belt conveyor for bulk material transportation, sulphide flotation, and metal leaching are some notable examples of breakthroughs which improved the productivity and reduced operating costs. Additionally, most productivity or cost efficiencies in recent decades have also been driven by the incremental improvement of existing technology such as larger, longer lived, and more efficient shovels, haul trucks, LHD's, larger crushers, grinding mills, flotation cells etc. The economic extraction of previously uneconomic mineral deposits has been made possible as a result of innovations and improvements in mining techniques and processing technologies.

As near-surface mineral deposits are depleted and environmental and social awareness grows, mining companies move to greater depths, pit slopes are getting higher, and modern technologies are used to excavate rocks at a much faster pace than ever before. There is certainly a great challenge in designing of excavation in rock masses whether at surface or at underground and it requires good understanding of ground condition. **Considering the seriousness of issue, DGMS Vide its Circular no.02 of 2020 dated 09.01.2020**, has suggested guidelines for systematic Monitoring of slopes in Opencast Coal and Metalliferous Mines, where Monitoring Methodology, Recording and analysis of data and organisation for slope monitoring has been clearly spelt out.

One of the most popular mining advancements that you can expect to see more of is the power of data on surrounding ecosystems and communities. With data-driven decisions helping companies to drive transformation faster, companies can expect efficiency through automation, reduced costs and improved responsiveness in all operations. Digital is not just about incorporating a gamut of technologies but is an approach to run business processes more effectively and increase value. Mining Industry are moving beyond the mass production periods, and are entering a customised production era. **Industry 4.0** aims to enhance the capability of a company to cater to the different needs of its customers by using various disruptive technologies. These technologies include the Internet of Things, smart manufacturing, artificial intelligence, big data, and machine learning, among others.

On-going digitalization of mine and mining operation provides enormous capabilities for the sector to collect vast amount of data and information (i.e. Industrial Big Data), from the assets in operation. This real time data driven approach to operate mining systems is expected to transform the way mine is operated and maintained ensuring high level of productivity, increased reliability and quality at reduced life cycle costs for the organization. There is significant value at stake in the mining industry from the implementation of new technologies that support the enhanced profitability and sustainability of mines. However, in order to realise this value, new technology must be implemented in a way that is both effective and sustainable. In this context, PSU’s like NMDC continuously strive to improve sustainability performance and focuses on following key topics:

- Competitiveness, profitability and growth
- Efficient mining and state of art technology deployment in mining
- Lean ore utilization and tailings management
- Protecting water resources
- Land management and Biodiversity preservation
- Being committed to health and safety of employees, contract labours and communities
- Attract, develop and retain people
- Valuing human rights
- Engaging and supporting our communities
- Being trustworthy and transparent
- Maintaining good governance

Dear Friends, National Steel Policy-2017 envisages that the industry will be steered in creating an environment for promoting domestic steel and thereby ensuring a scenario where production meets the anticipated pace of growth in consumption, through a technologically advanced and globally competitive steel industry. National Mineral Policy 2019 emphasis on the Grant of clearances for commencement of mining operations streamlined with simpler and time bound procedures facilitated through an on-line public portal with provision for generating triggers at higher level in the event of delay, Creation of dedicated funding for boosting exploration activities without additional burden on miners, Maintaining resource inventory registry of the country in accordance with a globally accepted public reporting standard on a web-based system for public viewing integrated with GIS etc.

For the above target to achieve, Technology is a key foundation and enabler of the Mine of the future initiative. Technology must play a role in the following:

- Restoring agility and flexibility in the value chain
- Shifting from a cost reduction mindset to one of value creation
- Increasing production and productivity
- Improving recovery rates and eliminating waste
- Reducing the need for people, especially at remote sites and underground
- Improving ore body knowledge and the planning process
- Aligning the organization around strategic and tactical goals
- Increasing the robustness of business and industry intelligence.

With the above positive note, I thank you for giving me this opportunity to share my views on this platform.

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Selection of Rock Excavation Machinery Based on Rock Toughness, Hardness, Deformation and Physico-Mechanical Properties

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ABSTRACT

This paper describes the selection of rock excavation machinery properties based on rock toughness, hardness, deformation and physico-mechanical properties of rock. Rock fracture toughness have important contributions to make in achieving improved confidence in designing rock structures, forming excavation in rocks and promoting improved efficiency in rock fragmentation process. The paper also suggests indirect methods which are less time consuming and ...to direct method for determining rock fracture. A statistical analysis shows good correlation between hardness, strength and rock detonatability with the fracture toughness. These are useful, apart from the other applications for the assessment of rock drilling and cutting equipment. This value facilitates in the selection of rock excavation, handling and processing equipment.

***Keywords:** Rock fracture, rock toughness, rock hardness, rock deformation, rock physico-mechanical properties*

INTRODUCTION

There are three factors whichlargely determines the selection of excavating equipment. These are;

(i) Geo-mechanical factors of the material to be excavated
(ii) Performance factors
(iii) Design factors

Geo-mechanical factors of the material is the first and most important in the selection and this cannot be over emphasised. Parameters such as strength (uniaxial compressive strength) tensile strength, shear stength and modulus for rapture), elastic properties (Young's Modulus and Poisson's ratio). Specific gravity, visco elastic properties, stress field and other factors, for instance, porosity, permeability and moisture content etc.

Rating for underground equipment is always difficult and the choice is more restricted. There is very little information on underground equipment. It is always advisable to consult manufucturers. Design rlateds directly to machine productivity and includes digging range, bucket capacity, travel speed and reliability. The design factors provide level of technology and the control and power available. Support factors availability of servicing and maintenance facility. The cost factor is probably one of the most qualitative which cannot be undermined.

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Traditionally, uniaxial compressive strength has been the sole index for predicting the role of penetration (Williamson, 1970). More recently, a better correlation is being suggested between penetration rate and the critical energy release rate of the rock (i.e. deermined by a fracture toughness test).Abrasion hardnes is another important rock property relocated to the penetration rate. Equipment manufucturers are constantly researching with the object of achieving faster rate of penetration through a greater variety of harder and more abrasive rocks and with reduced wear on catters and other components.

PRINCIPAL FACTORS INFLUENCING ROCK FACTOR PROCES

What is a fracture ? It is the formation of planes or separation in the rock material. It involves the breaking of bounds t form a new surface. It is not synonymous with failure or peak strength.There are various factors which can influence the fracturing process in rocks. There are:

(i) Heterogenity, the variation in crystal structure and strength localy ahead of an extending rock can affect the stability and continuity of crack growth.
(ii) Discontinuity: Since rock is discontinuous, the pre-existing discont...dies in rocks can affect the local stress distribution and crack propagation behaviour,

(iii) Anisotropy which is variation of fracture parameters such as the work of fracture, critical strain energy release rate of fracture toughness as a function of fracture propagation orientation.
(iv) In-situ stress field can significantly influence the fracture process in the rock mass and
(v) Environmental conditions which can substantially affect the fracture behaviour of a rock. These are continuing pressure, temperature, ...pressure, differential stress and strain rate.

Crack inition and its propagation is a complex phenomena and it needs an advanced technique for prediction. However, rock behaviour under high stress has resulted in hazardous situations in deep underground mines and has promoted considerable attention to be focussed on rock fracture mechanics and their appliction to improve control and the achievement of greater ...in such situations.

MECHANICAL EXCAVATORS

About 30% of the earth's crust consists of shale and mudstone which can be excavated by backhoe front-end loader (FEM) or an earth excavator. Weak weathered igneous rock and closely jointed schists can be excavated by FEM. The choice of the excavating machine depends on the type of material to be excavated, output required, capital available and maintenance cast.

Kirsten (1982) suggested a classification system to predict how easily rocks can be excavated using digger, ripper or blasting. Abullatif and Crude (1983) suggested three other systems:
(i) Fracture of .rock in relation to the quarry and performance of rock construction materials (1974).
(ii) The Norwegian Q and the
(iii) South African RMR systems, all of which are based on block size and strength of the rock to be excavated.

The field tests have shown the RMR values of upto 30 could be dug and up to 60 could be ripped, where rock masses having an RMR 60 and above required to be blasted. Uniaxial compressive strength is quite useful to be determined for massive and weak rocks, whereas sonic velocty gives a good indication of rippability in strong rock masses. The ratio of sonic velocity measured in the laboratory to that determined in the field indicates whether ripping of ink will be possible.

The mechanical properties of the material comprising the deposit and country rock (and soil if overburdened) are the factors considered in selecting the equipment in surface and underground mines. These are:
(i) Elastic properties (young's modulus and Poisson's ratio)
(ii) Plastic or viscoelastic properties (flow or creep)
(iii) State of stess (original or modified by mining activities) and ,
(iv) Consolidated compaction and competence (ability of opening to stand unsupported)
(v) Other physical properties specific gravity porosity, permeability and moisture content.

FRACTURE TOUGHNESS TESTS

The fracture toughness tests determines the energy required to propagate a single crack. It is designed to first initiate the crack at a prefixed location and then two, to propgate it in a manner so that when the stress intensity decreass as the fracture length increases. Fracture toughness tests are required for studies at rock cutting, hydrafracturing and explosive fracturing.

Several test configurations Figure 1, such as core disk with a radial notch or a short core with anaxial v v-shapd or a longer rock core in bending with a central notch...(sentence incomplete). In the disk and short rock core tests, the notch is forced to open circles by applying opposing tensile forces to the notch end or through aluminium pieces cemented to the rock.

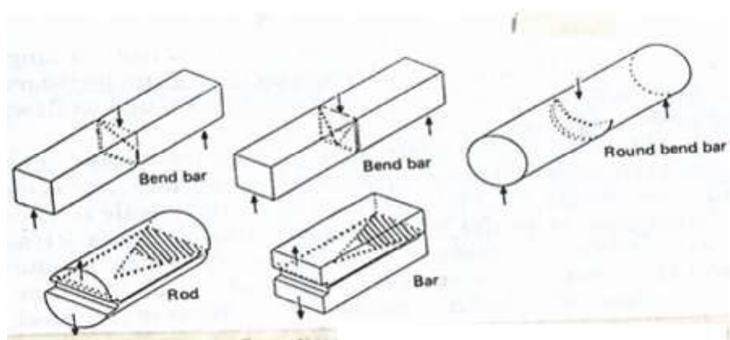

Figure 1: Various confugarations of fracture toughness test with chevronnotched specimens (afterKarfakis et al,1986)

Fracture toughness can also be determined as a function of axial and confining pressure. An internally prenotched specimen is subjected to interval pressure until it bursts. Fracture toughness in a measure of critical stress intensity

K_{IC}, at the crack tip required to initiate and propgate the fracture. It is a function of applied load and stress concentration, which is related to poisson's ration and geometry.

Fracture toughness can also be expressed as critical energy release rate G_{IC} the elastic modulus, and poisson's ratio as given in Equation 1 below:

$$G_{IC} = \frac{K_{IC}^2 (1-\nu^2)}{L} \quad [1]$$

This indicates the rock cutting perfrmance of the disk ont he tunnel (or rockway) boring machine.

DEFORMABILITY PROPERTY

Deformation is defined as change in shape, either expansion, contract or other forms of distortionss. It is caused due to ...and load or stress. It may also result lfrom a change in temperature such as thermal expansion or contraction. Even contact of rocks in water can cuase deformation in the form of swelling or shinkage.
Deformability property describes the ease with which a rock can be deformed. Deformability of a rock mainly depends on the porosity and the degreee of jointing of the rock. Pores and joints are the weakest deformable parameters in the rock. Deformation is a dimensionless and emperically, it is the change in length (which is a very small value in microns $\left(1/10^6\right)$metre

HARDNESS OF ROCK

Hardness loosely applied to rocks is synonyms to strength as we say soft rocks or hard rocks but hardness is more strictly defined as a property of rock forming minerals. There are various ways in which hardness of rocks can be determined. For instance, by scratch method (Mho's scale)...test using National Coal Board (NCB), UK, cone indentor,Figure 2, impqact and rebontest using shore scleroscopeFigure 3, and schmidt hammer test (in-situ testing). Abrasion hardness and impact hardness are useful apart from other applications for the assessment of rock drilling and cutting equipment. This value facilitaes in the selection of rock excavating, handling and processing equipment.

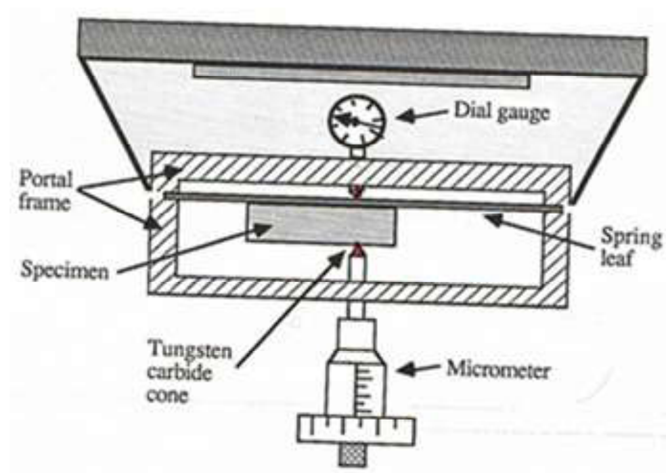

Figure 2: Diagrammatical illustration of the NCB cone indenter

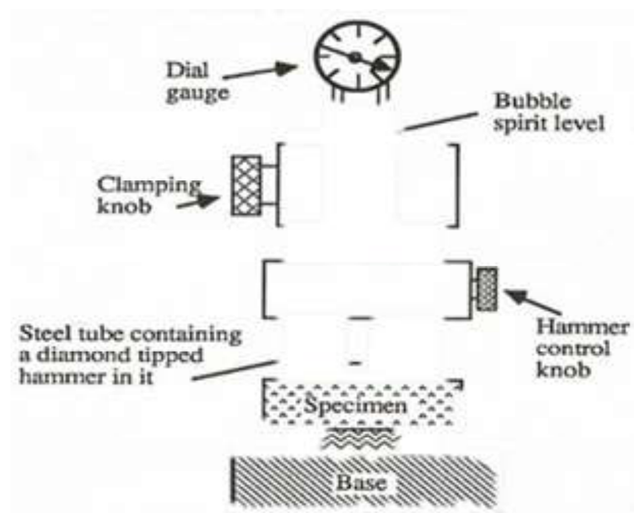

Figure 3: Diagrammatical illustration of Shore Sclerascope

In this context, mentioning an interesting equipment, sandblast test for abrasion resistance may not be out of place. The interrelationship of rock hardness to rock fracture toughness suggested by Whittaker...(1991) are given in Equations 2 and 3 below:

$$K_{IC} = 0.237 + 0.155 \times H_{CI} \quad [2]$$
$$K_{IC} = 0.277 + 0.165 \times H_{CI} \quad [3]$$

Where;

K_{IC} = mode I fracture toughness (MPa
K_{IIC} = Mode II fracture toughness
H_{CI} = The NCB can indicate hardness index

Correlation fracture toughness with physico-mechanical propertiesFigures 4 and 5 , are given bellow:

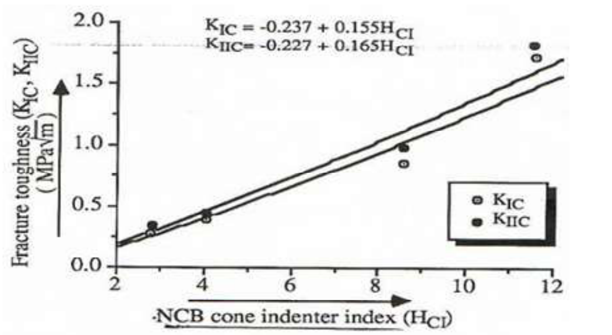

Figure 4: Diagrammatical illustration of Shore scleroscope

Physico-mechanical properties considered here are uniaxial compressive strength, tensile strength, print load strength, elastic constraints (Young's modulus and Poisson's ratio) and the velocity of accoustic waves. In corelating these parameters, an average value of the calculated strengths and deformation parameters of rock tested should be obtained.

Table 1: Correlation of Fracture toughness with Physico-mechanical properties(after Whittaker, 1991)

No	Description	Parameter
1	Frcture toughness versus tensile strength	K_{IC} = 0.27 + 0.107 K_{IIC} = 0.057 + 0.86
2	Fracture toughness versus uniaxial Compressive strength	K_{IC} = 0.708 + 0.006 K_{IIC} = 0.114 + 0.005
3	Fracture toughness versus point load strengthwhere K_{IC} =1.331 + 0.074 I where K_{IC} is in **MPa$\sqrt{m}$** and I is in MPa R = 0.55	K_{IC} = 1.33 + 1.074 I
4	Fracture toughness versus flexure rigidity where K_{IC} is in **MPa$\sqrt{m}$** and σ_{fr} is in MPa	K_{IC} = -0.042 + 0.042σ_{fr}
i5	Fracture toughness versus Young'sModulus where E is Young's Modulus (EPa)	K_{IC} = 0.336 + 0.026E K_{IIC} = 0.251 + 0.018
6	Fracture toughness versus Poisson's ratio where V = Poisson's ratio	K_{IC} = 0.991 + 1.653 V K_{IIC} = 1.249 + 7.814
7	Fracture toughness versus accoustic Wave velocity where Vp is the velocity of the accoustic wave (km/s)	K_{IC} = 1.68 + 0.65Vp K_{IIC} = -1.15 + 0.45Vp

CONCLUSION

A statistical analysis based on laboratory test for a wide range of rocks has shown a close relationship between fracture toughness and hardness index and physico-mechanical properties. The hardness and physico-mechanical property tests are much less extensive and time consuming than the fracture parameter tests for deriving K_{IC} or KrIC. These conditions with hardness and physico-mechanical property are being used as a basis for indirectly evaluating for rock fracture toughness value or nay one of the physico-mechanical

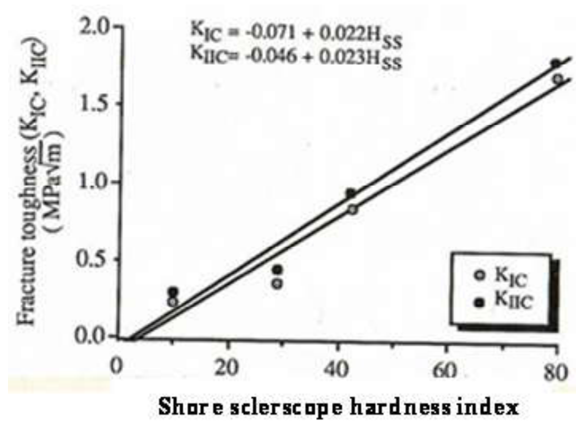

Figure 5: Relationship of mode I and mode II fracture toughness to Shore scleroscope hardness index (after Whittaker, 1992)

properties. Such a method of study and predictin of the fracture behaviour of rocks has given an improved understanding of the effect of rock fragmentation on wear ...and excavating machines. This is generally helpful in selecting rock excavating machinery for better efficiency and economy.

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Ergonomic Assessment of Whole Body Vibration Exposure Monitoring on Heavy Earth Moving Machinery Operators' in Open Cast Limestone Mine of South India

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ABSTRACT

Heavy Earth Moving Machineries (HEMM) operation in open cast limestone mine, leads to whole body vibration (WBV) exposure and development of musculoskeletal disorders among the operators. WBV occurs in HEMM in vertical direction, z axis, front and back direction, x axis and from left to right vice versa direction, y axis. The WBV characteristics in HEMM evaluate the nature of health risk of an operator in comparison to functions of individual HEMM. The objective was to measure and analyze the magnitude of vibration in x, y and z axis, observe the functional work practices of HEMM machine, to evaluate the health risk to the operator and to formulate necessary control measures for mitigation of the same. The frequency weighted Root Mean Square acceleration data was collected as per ISO 2631-1:1997 guidelines by using human vibration meter HVM100. In the present study WBV exposure was evaluated for 16 (Sixteen) HEMM Operators' in an open cast Limestone mine of South India for assessing the health risk using RMS acceleration value and Vibration Dose Value (VDV) in relation to daily duration of work exposure. Among the 16 machines, the dominant axis of vibration was x axis for four (25%) machines, z axis for twelve (75%) machines. While evaluating all I6 equipment, it was observed that three (3), 18.75% showed minimal health risk, eight (8), 50% indicated moderate health risk and the remaining five (5), (31.25%) showed high health risk due to whole body vibration exposure for respective operators.

Key Words: HEMM, Whole body vibration, RMS acceleration, VDV.

INTRODUCTION

The whole body vibration (WBV) is an oscillatory motion which changes velocity by constantly accelerating, from one direction to other. The oscillatory motion is a simple harmonic sine wave or a multiple wave complex differing in frequency, amplitude and acceleration or it may be random non repeating series of complex waves[9, 11,12,]. WBV is a Vibration transmitted to the body through the supporting surfaces such as feet, buttocks or back. The WBV in mining equipment is transmitted through the seat and the feet of the operator. The seat transmitted WBV occurs in dozers, wheel-loaders, dumpers, trippers, shovels, backhoes, drill machines, draglines, bucket wheel excavators, re-claimers, spreaders, load-haul dump vehicles (LHD), graders, crushing plant and belt conveyor drive head operator's room etc. The body part most likely affected for WBV exposure depends on direction and distribution of motion within the body, magnitude of vibration, body posture during work, vibration frequency and duration of vibration exposure[9,11,12,].

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In 1977 the International Labor Organization (ILO) stated vibration as an occupational hazard and recommended the following: "Measures have to be taken to protect employees from vibration, the responsible authorities have to establish criteria to determine the danger; when necessary, and the exposure limits must be defined by means of these criteria. Supervision of employees exposed to occupational hazard as a result of vibration at their work places must also include a medical examination before the beginning of this particular job, as well as regular check-ups later on"[9, 10, 11, 12,].

Epidemiological evidences reveals occupational exposure to WBV is associated with increased risk of low back pain (LBP), lumbar inter-vertebral disc disorders, sciatic pain, and degenerative changes in the vertebral column. WBV exposure is directly related to sick leave, absenteeism, chronic pain, disability and loss of working man days[9, 10]. NIMH conducted two studies to reveal the percentage mining employees exposed to WBV while operating HEMM. The said study reveals an average of 18 % employees were exposed to WBV at work (Mandal & Srivastava, 2006)[11,12].

An epidemiological study on dumper operators reveals the prevalence of musculoskeletal disorders (MSD) related to WBV exposure. The LBP was significantly higher (85%)

in the exposed population as compared to controls (20%). Similarly, pain in the ankle (37.83%), shoulder (30 %) and neck (37.5%) were higher among exposed as compared to unexposed population (5%, 0% and 15% respectively). It showed significant degradation of lifestyle among the exposed workers (Mandal & Srivastava, 2010)[10].

In India, the Directorate General of Mines Safety (DGMS), recommended adoption of appropriate steps for ensuring desirable degree of comfort and protection against WBV. There is no specific vibration exposure limiting values[8]. The 10th Conference on Mines Safety Recommends that vibration monitoring of HEMM & other machineries are necessary as per ISO Standards before its introduction in mines [8]. MSD and workplace factor investigators of NIOSH indicated strong evidence of positive correlation between exposure to WBV and low back disorders[9, 10]. The current article aims to characterize the vibration emanating from HEMM in an open cast limestone mine.

METHODOLOGY

The WBV exposure was eva1uated among sixteen (16) HEMM operators in an open cast limestone mine of South India. The WBV exposure magnitudes were measured with WBV meter HVM 100, make Larson Davis human vibration analyzer, in accordance with ISO 8041:2005 & ISO 2631 -I: 1997 guidelines[6, 7]. The Tri-axial seat pad accelerometer SEN 027 was placed on the HEMM operator's seat and the operator was asked to sit on the said seat pad. The seat pad was aligned to the basi-centric or right-handed orthogonal coordinate system related to the contact surface depicted in Fig 1[6]. The signal transmission cable was routed accordingly to avoid interference of equipment control. The operators were briefed about WBV measurement and it was ensured that the measurement do not hinder their work. The magnitude of vibration was measured in terms of root mean square (RMS) values of frequency weighted acceleration (Aeq m/s^2).

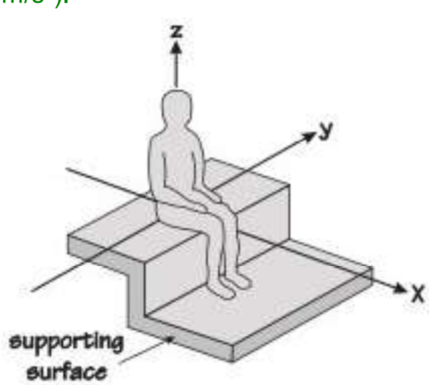

Fig 1: Basicentric axes of the human body considered for evaluation of Whole body vibration

The measurement periods varied between 10 to 60 minutes during normal operation of HEMM. The measurement duration represents the operation cycle of equipment. The operators were interviewed to find the average number of cycles or trips he performed or completed in a day for cyclic operation like tippers. In case of non-cyclic type operation like back-hoe, shovel, dozer, ripper dozer, wheel dozer, loader, grader, drill machine, the duration of exposure was quantified by collecting duration of work at stretch from operator & management.

The prediction of health risk exposure to WBV primarily depends upon two factors i.e. vibration magnitude along the dominant axis & duration of exposure in a day.

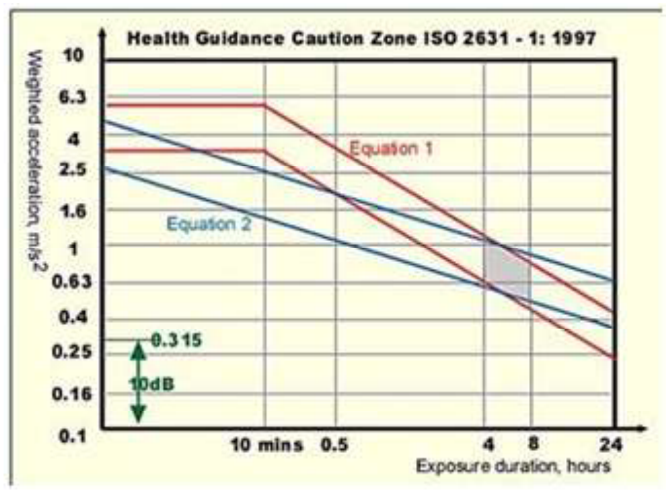

Figure 2: Health Guidance Caution Zone (HGCZ)

The graphical representation of Health Guidance Caution Zone (HGCZ) in Fig 2 of ISO 2631-1:1997 was referred for evaluation of exposure to health risk[6]. HGCZ is the area between a set of two parallel lines corresponding to lower and upper limits. There are two such sets in this graph. The first one uses the duration of exposure and acceleration magnitude in RMS values (Aeq m/s^2) in x and y coordinates respectively to determine the severity of exposure. Evaluation of a point P (*x, y*) plotted according to duration (*x* axis) and magnitude (*y* axis) of an exposure was carried out using the criteria summarized below:

- Exposure below the zone, the health effects are not clearly indicated [marked as "minimal"][6, 9, 10].
- Inside the zone the health risk is indicated [marked as "moderate"] i.e. there is a probability of vibration induced injury to occur[6, 9, 10].
- And above the zone, the health risk is quite likely [marked as "high'"][6, 9, 10].

The second set of parallel lines uses Vibration Dose Values (VDV), for those readings where the Crest Factor (CF) was above nine in linear scale. Here an additional evaluation of WBV was done by using VDV which was considered for risk assessment in blue in the HGCZ Graph. The zones represented by two different methods coincide for durations of about 4 to 8 hr, and the standard warns against using the zones for shorter durations[6, 9, 10].

The exposure durations between 5 and 30 min, may exceed the limits of the zone according to one method and not to reach the zone for the other. A doubling of RMS acceleration magnitude results in a reduction of exposure time by a factor of 16 for one of the methods and a reduction of exposure time by a factor of 4 for the other. For assessments according to VDV, the health guidance caution zone has upper and lower limit bounds at 8.5 and 17 $m/s^{1.75}$, respectively[6].

RESULT AND DISCUSSION

Shocks of various intensities are often the part of vibration history when any equipment is in operation. If the peak values are more than nine times the corresponding RMS acceleration values, in such cases, ISO 2631-1:1997 recommends use of Vibration Dose Value (VDV) to evaluate WBV[6]. Results of risk assessment using RMS acceleration values have been shown in Table 1. Similarly, results of risk assessment using VDV are shown in Table 2.

Figure 3: Accelerometer setting on HEMM operator's seat

Table 1: Risk assessment for whole body vibration exposure of HEMM operators using RMS acceleration values in a South Indian Limestone mine (n = 16)

Sr. No.	Equipment, Operator, Date, sample ID No.	Axis	A_{eq} (m/s^2)	Adjustment by scaling factor K^*	Duration of exposure (hrs)	Health Risk (by HGCZ)**
1.	Ripper Dozer RD3, Komatsu D375A, Mr. S. Sengamuthu, ML3A Old Ramp Haul road, V_1	x	0.95	1.33	**6**	High
		y	1.07	1.50		
		z	**2.40**	**2.40**		
2.	Back Hoe, L&T Komatsu PC 300LC Mr. Thangarasu, ML2 4th bench, V_2	**x**	**0.26**	**0.36**	6	Minimal
		y	0.12	0.17		
		z	0.25	0.25		
3.	Dozer No. A12, BEML 080 A12, Mr. Saikat Ali, ML2 4th Bench, V_3	x	0.40	0.56	6	Moderate
		y	0.35	0.50		
		z	**0.57**	**0.57**		
4.	Back Hoe 2, Tata Hitachi Zaxis 310 LCH, Mr. Mahanad Wahav ML2 N 3rd bench, V_4	x	0.27	0.37	6	Moderate
		y	0.30	0.42		
		z	**0.50**	**0.50**		
5.	Vibro Ripper, Kobalco SK350, Mr. Gopalan, ML1 1st bench, V_5	x	0.38	0.53	6	Moderate
		y	0.37	0.52		
		z	**0.69**	**0.69**		
6.	Rock Breaker 1, L&T Komatsu PC300 Mr. Kolanch, Location ML1 old office area, Sengamuthu, V_6	x	0.37	0.52	6	Moderate
		y	0.30	0.42		
		z	**0.88**	**0.88**		
7.	Tipper TN32 P2244 20T MAN CLA 25.280, Mr. Manikanandan N., ML1 old office area to OB dumpyard, V_7	x	0.56	0.78	6	High
		y	0.59	0.97		
		z	**1.65**	**1.65**		
8.	Ripper Dozer RD2, Komatsu D375A Mr. Mahendra Kumar, ML3 B Pit, V_8	**x**	**0.70**	**0.97**	8	High
		y	0.48	0.67		
		z	0.44	0.44		

9.	Motor Grader Komatsu GD405A Mr. G. Nagabuna Rao, ML3A Pit Haul Road, $\mathbf{V_9}$	*x*	0.46	0.65	6	High
		y	0.53	0.74		
		z	**1.06**	**1.06**		
10.	Backhoe Kobelco SK210LC Mr. J. Prabhakaran, ML4 Top bench, $\mathbf{V_{10}}$	***x***	**0.26**	**0.36**	6	Minimal
		y	0.15	0.22		
		z	0.25	0.25		
11.	Rock Breaker L&T Komatsu PC 200 LC, Mr. Settu Kumar ML9 RL32 NE 3rd Bench, $\mathbf{V_{11}}$	*x*	0.35	0.49	6	Moderate
		y	0.22	0.30		
		z	0.57	0.57		
12.	Back Hoe Tata Hitachi Zaxis 210CH Mr. M. Rajani, ML9 W 3rd Bench, $\mathbf{V_{12}}$	*x*	0.19	0.27	6	Moderate
		y	0.15	0.21		
		z	0.55	0.55		
13.	Rock Breaker Kobalco SK380HD Mr. S. Parthivan ML9 W 3rd Bench $\mathbf{V_{13}}$	*x*	0.50	0.70	6	Moderate
		y	0.29	0.40		
		z	0.74	0.74		
14.	Dozer BEML BD50 Mr. P. Murgesh, ML9 RL37, $\mathbf{V_{14}}$	*x*	0.46	0.65	6	Moderate
		y	0.43	0.60		
		z	0.41	0.41		
15.	Back Hoe Tata Hitachi Zaxis 210CH Mr. Satish Kumar, ML9 RL37 W $\mathbf{V_{15}}$	*x*	0.22	0.31	6	Minimal
		y	0.22	0.30		
		z	0.35	0.35		
16.	Tipper TN61 B2377 MAN CLA25. 280 20T Mr. P. Govindraj ML9 to OB dumpyard $\mathbf{V_{16}}$	*x*	0.39	0.54	8	High
		y	0.50	0.69		
		z	0.92	0.92		

* Where k_x= 1.4, k_y=1.4, k_z=1.0

* Minimal, Moderate and high refers to Not Indicated, Indicated and Likely for health risks assessment as per ISO Standard 2631-I:1997[6]

Table 2: Assessment of health risk using VDV_T for equipments whose CF_{Linear}> 9 along the respective dominant axis (n=9) in South Indian Limestone mine.

Sr. No.	Equipment and Operator	Dominant axis	Measured VDV ($ms^{-1.75}$)	Measured period (Sec)	VDV_T ($ms^{-1.75}$)	Duration of exposure (hrs.)	Health Risk calculated by VDV_T
1.	Ripper Dozer RD3, D375A, $\mathbf{V_1}$	*z*	25.20	988	54.49	6	High
2.	Back Hoe 2 Zaxis 310 LCH $\mathbf{V_4}$	*z*	5.71	774	13.12	6	Moderate
3.	Vibro Ripper, SK350, $\mathbf{V_5}$	*z*	6.27	746	14.54	6	Moderate
4.	Rock Breaker 1, PC300 $\mathbf{V_6}$	*z*	7.57	563	18.84	6	High
5.	Ripper Dozer RD2, D375A $\mathbf{V_8}$	*x*	6.09	404	17.7	8	High
6.	Motor Grader GD405A $\mathbf{V_9}$	*z*	9.22	749	21.33	6	High
7.	Back Hoe Zaxis 210CH, $\mathbf{V_2}$	*z*	6.81	535	17.17	6	High
8.	Rock Breaker SK380 HD, $\mathbf{V_3}$	*z*	6.46	987	15.01	6	Moderate
9.	Back Hoe Zaxis 210CH, $\mathbf{V_5}$	*z*	1.78	549	4.43	6	Moderate

* Minimal, Moderate and High refers to Not Indicated, Indicated and Likely for health risks assessment as per ISO Standard 2631-I:1997[6].

Among 16 machines studied for WBV the dominant axis of vibration was *x* axis for four machines and *z* axis for twelve machines.

➢ **Backhoe** - In five backhoes, two backhoes showed *x* axis and four backhoes showed *z* axis as the dominant axis of vibration. Two backhoes indicated moderate health risk and three indicated minimal health risk to its respective operator.

Figure 4: Pneumatic Seat of a back hoe for reduction of vibration at source

- **Ripper Dozer-** The two Ripper Dozers showed *x* and *z* axis as the dominant axis of vibration and both indicated high health risk to its respective operators.
- **Dozer** - The two dozers, showed *z* and *x* axis as the dominant axis of vibration and both dozers indicated moderate health risk to its operators'.
- **Vibro Ripper** - The vibro ripper mounted on the boom of backhoe Kobalco SK350, showed *z* axis as the dominant axis of vibration and it indicated moderate health risk to its operator.

Figure 5: WBV study on Vibro Ripper

- **Motor Grader** - The dominant axis of vibration was z axis and it showed high health risk to its operator. The motor grader had massive type of seat without any cabin suspension.

Figure 6: WBV study on Road Grader operator

- **Rock Breaker** - The three rock breakers showed *z* axis as the dominant axis of vibration and all three indicated moderate health risk to its operators'.
- **Tippers** -The two 20 Tonner capacity tippers, make MAN CLA25.280, recorded *z* axis as the dominant axis of vibration and both indicated high health risk for its operators'.

Vibration Dose Values – In some cases where the linear crest factor i.e. ratio of Peak acceleration and RMS acceleration were greater than 9, the analysis of WBV was done on as per VDV. Here nine (9) machines comprising of three backhoes, one motor grader, two rock breakers, two ripper dozers and one vibro ripper had linear Crest Factors above 9 so WBV was further evaluated as per VDV values. The VDV values of two ripper dozers, one rock breaker, one motor grader and one backhoe showed high health risk to its operator due to WBV exposure. The two backhoes, one vibro ripper and one rock breaker showed moderate health risk on the basis of VDV values.

Among all sixteen equipment, three (3)(18.75%) showed minimal health risk, eight (8) (50%) indicated moderate health risk and the rest five (5) (31.25%) showed high health risk due to WBV exposure evaluated through RMS acceleration value and daily duration of exposure.

CONCLUSION AND RECOMMENDATION

Mechanical vibration has multi-factorial origin which includes road condition, speed, seat condition, maintenance of the machine. Mining is a continuous changing process of mine topography so all machines requires periodical vibration monitoring. The operator's seats should be pneumatic suspension seats in all HEMM. The focus of WBV reduction should be in *x*-axis along with dampening vibration in z axis. Translational vibration in *x* axis is in front & rear and WBV in rear direction may be attenuated by lumber supported back rest. An ergonomical seat should be developed to absorb vibration in *x*-axis. As WBV hazard is mainly emanating from *x* axis, the operators may be safeguarded from vibration by using seat belts.

SPECIFIC RECOMMENDATION

1. Ripper Dozer (RD) - Ripper dozer Operation requires two alternate phases of activity i.e. ripping and dozing. Ripping operation converts plane surface into an uneven operating zone. During ripping and dozing operation the RD has to move front and back while the operator is required to turn back repeatedly for seeing the ripping operation. This increases the postural discomfort of the operator as he works in twisted torso of his spinal cord, especially in the thoracic lumber region and lumbo sacral region. This aggravates WBV exposure due to shearing stress. Moreover the operator sometimes tries to get up from seat in half standing posture with his head turned back while resting his back on the seat rest during ripping operation. Even though the two ripper dozers are crawler mounted yet the vibration intensity was found to be high in both machines in all the three axes. The seat adjustment as per body weight and height of respective operators may improve the overall performance of WBV reduction at source. Slow optimum speed in operation of two ripper dozers can further reduce the WBV at source. Use of video camera on the back side with a monitor in the cabin may be explored to avoid twisting of torso & half standing posture of the respective operators especially during ripping operation. Periodic rotation of jobs to lesser vibrating machines such as backhoe or shovel is suggested to reduce the rate of WBV exposure of both operators.

2. Dozer - Dozer Operation requires alternate forward and backward movement. During this operation the operator is required to turn back, especially during backward movement of dozer. This increases his postural discomfort as he works in twisted torso of his spinal cord especially in the thoracic lumber region and lumbo sacral region. The two dozer machines are crawler mounted without a pneumatic seat and separate cabin suspension. The two operators of respective dozers were operating their machines at slow optimum speed. The operator's seat in both dozers may be replaced with a pneumatic type seat to reduce vibration at source. The cabin of both dozers may be fitted with AC and a video camera on the back side with LCD monitor in the cabin control panel, to avoid twisting of torso especially during rear movement of dozer. Periodic rotation of jobs to lesser vibrating machines such as backhoe, shovel or drill is suggested to reduce the rate of WBV exposure of respective operators'.

3. Vibro Ripper - The Vibro Ripper is mounted on the boom of a backhoe with a pointed ripping plate. The ripping plate penetrates the ore body with harmonic vibratory force and loosens the earth material of the ore body by cutting through it. The harmonic vibratory force is dampened by fitting the boom with pneumatic spring so that minimum vibration may be transmitted via the boom in operator's cabin and seat in *z* and *x* axis. The operators may be instructed to adjust the seat factor as per his body weight and height before operating the machine. This vibro ripper backhoe may be fitted with cabin suspensors to reduce WBV, transmitted through boom, at source. The operators may be further instructed to park the vibro ripper fitted backhoe on a stable surface/ground before starting the ripping operation of the ore body. There should be minimum play of backhoe crawlers on the surface during vibro ripping operation. The operators may be given specialized training in operation of vibro ripper for giving minimum actuating operational force at optimum harmonic vibration frequency.

4. Backhoe - Among four backhoes, two has recorded moderate health risk due to WBV. The major reason for this is the mode of operation backhoe. The respective backhoe operators' having moderate health risk exposure may be sent for periodic refresher trainings for better handling of the equipment. The operators should be instructed to adjust the body weight & height parameter of the seat as per his body weight & height before starting the work. The backhoe crawlers should be parked on a haulage leveled surface in horizontal plane for reduction of play and structural vibration at source. Inclined parking of backhoe crawlers may be avoided during backhoe operation. All the backhoes should be fitted with ergonomically designed pneumatic type of seat to reduce WBV at source.

5. Rock Breaker (RB)- The hammer vibration of three rock breakers are not transmitted to the seat through the boom. The boom vibration is transmitted to the operator's cabin & seat due to placing the rock breaker on uneven surface. It also depends on mode of rock breaker operation. All three RBs should be fitted with pneumatic type seat to reduce WBV at source. The RB operators are sent for periodic refresher trainings for better handling of the equipment.

6. Tippers: The two tippers were fitted with massive type seats without any seat adjustment facility. Both tippers were not having any cabin suspension thereby causing significant amount of WBV exposure to its operators. All these condition along with uneven haul road have lead to high level of WBV exposure to its operator. The operators should operate the tippers at an optimum speed especially during turns, bends and climbing on inclined haul roads. The existing seats should be replaced with ergonomically designed pneumatic suspension type seats. The pneumatic pressure of the tyres in both tippers should be maintained as per the standards and the old worn out tyres may be replaced periodically with proper grid tyres. The Tipper operators may be sent for periodic refresher trainings. Rotation of job is also recommended for mine tipper operators.

7. Motor Grader (MG) - The motor grader has massive type of seat, without any seat adjustment facility. This MG should be provided with pneumatic adjustable seat. There is no cabin suspension in MG and the tyres are worn out without any grips. It is recommended to replace the MD tyres with proper grips.

The WBV is an Occupational hazard in metalliferous/non-metalliferous open cast and underground mines of India. Presently there is no strict regulation or legislative control of WBV hazard exposure for operation of HEMM and other mining equipment in India. One circular was made under Metalliferous Mines Regulation (MMR), 1964, by Directorate General of Mine Safety (DGMS) in the seventies[8]. As per DGMS legislation & circular of seventies the vibration limits, states that there should be adequate steps which will ensure desirable degree of comfort and protection necessary for vibrating tools, affecting Hand arm vibration (HAV)[8]. Secondly the said circular further states that there should be adequate measures to ensure the desirable degree of protection and comfort necessary for transmission of WBV through supporting surface like operators' seat in HEMM and other auxiliary mining equipment to the operator's buttocks, back and vertebral column[8]. The said circular does not mention anything regarding the foot transmitted structural vibration from crushing and screening plant crusher, screen work & walk area, belt conveyor side walk bridge area.

There is no specific HAV and WBV exposure limit value in DGMS circulars till date. In the current scenario a stringent DGMS circular is necessary to control WBV at source, at the medium and at personal protective level[8]. In developed countries like USA, UK, Canada & Australia, mining statutory authorities gave specific circulars for control of workplace vibration depending on some standards stated below.

USA follows ACGIH - WBV Standard, WBV: ANSI S3 18, NIOSH # 89-106 for Whole body vibration, HAV: ANSI S3 34 & ACGIH – HAV[4].

UK follows European Union Directive 2002/44/EC for HAV & WBV[1].

Canada follows ACGIH, ANSI & ISO standard[13].

Australia follows Australian standard AS2670 for WBV & AS 2763 1988 for HAV[6].

In India the Bureau of Indian standard (BIS) has followed the ISO 2631:1997 for WBV & ISO 5349:1986 for HAV monitoring[5,6]. Presently metalliferous and non-metalliferous mining companies in India do not have the awareness regarding whole body & hand arm vibration exposure. DGMS 10th safety conference held on 26th & 27th November, 2007 at New Delhi, states in clause 1.6, the forthwith implementation of DGMS (Tech) Circular No.18 of 1975, for protection of worker against noise and vibration in working environment[2]. Further in DGMS 11th safety conference held on 4th & 5th July, 2013 at New Delhi states in clause 4.2 that vibration studies of various mining machineries before their introduction in mining operation should be done as per ISO standards[3].

Unfortunately most of the mining companies in India have not followed the recommendation of DGMS 10th & 11th safety conference recommendation till date. It recommended that WBV & HAV monitoring should be conducted in all HEMM and other auxiliary mining equipment once in every year for all open cast and underground metalliferous and non-metalliferous mines. DGMS should make WBV & HAV mandatory for all semi- mechanised and mechanised open cast and underground mines.

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Indian Non-Coal Mining Industry- Future Agenda through NMP 2019

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ABSTRACT

Minerals are essential inputs for the economic and social development of a nation. India is endowed with variety of mineral resources. India's non-coal mineral sector which includes, ferrous minerals, non-ferrous minerals, base metals, fertilizers, refractory and many other industrial minerals catering to the various core and non-core mineral based industries and contributing significantly for the economic growth of the nation. In 1991, India initiated wide-ranging programme of economic reforms. In tune with this, a new era was ushered in when the National Mineral Policy was pronounced in March 1993 and the mining sector was opened up for private initiative and investment. To give further boost to the mineral sector of India, the National Mineral Policy 2008 (NMP 2008) came into effect. However, the country's vast geographical areas are still to be explored to the desired levels. Detailed exploration to understand and uncover this potential is crucial for the growth of Indian economy. Therefore, the National Mineral Exploration Policy (NMEP) for non-fuel and non-coal minerals was spelt out in 2016 to have strategy and outline the action plan that would be adopted to ensure comprehensive exploration of country's mineral resources. Recently, the new National Mineral Policy 2019 replacing the extant National Mineral Policy 2008 was pronounced in February 2019 to have a more effective, meaningful and implementable policy that brings in further transparency, better regulation and enforcement, balanced social and economic growth as well as sustainable mining practices. Cascading reforms in the form of Mines & Minerals (Development & Regulation) Act 1957 and Rules made thereunder are made from time to time to give effect to the policy directives. At the same time large number of mining leases are on the verge of expiry in March 2020 which will be put on auction to grant fresh mining leases. Thus, presently, Indian mineral sector is on the threshold of major structural reforms. The present paper deals with the status of non-coal mining sector, major policy initiatives and future agenda for the non-coal mineral sector.

Keywords—Son-coal mining, national mineral policy, amendments, NMEP.

INTRODUCTION

Mining sector is an important segment of the Indian economy. Since independence there has been a pronounced growth in the mineral production both in terms of quantity and value. As on now, India produces as many as 95 minerals, which include 4 fuels, 10 metallic, 23 non-metallic, 3 atomic and 55 minor minerals (including building stones and other materials) (Anon et al (GOI)).

Immediately after independence in 1947 and with the adoption of Industrial Policy Resolution, the search for minerals particularly for those essential to industrial development was intensified. Ambitious programmes were launched in successive 'Five Years Plans' to increase the production of minerals to meet the growing demand of the core industries like steel, cement, power, nonferrous metals, fertilizer, etc. and also in view of higher exports for much needed foreign exchange. Government of India initiated major economic reforms in 1991 aimed at deregulation and de-licensing of the existing regime. In tune with this, a new era was ushered in when the National Mineral Policy was pronounced in March 1993 and the mining sector was opened up for private initiative and investment. To give further fillip, the new National Mineral Policy 2008 replacing the 1993 mineral policy came into force in March 2008. The National Mineral Exploration Policy (NMEP) for non-fuel and non-coal minerals was spelt out in 2016 to have strategy and outline the action plan that would be adopted to ensure comprehensive exploration of country's mineral resources. Recently, the new National Mineral Policy 2019 replacing the extant National Mineral Policy 2008 was pronounced in February 2019 to have a more effective, meaningful and implementable policy that brings in further transparency, better regulation and enforcement, balanced social and economic growth as well as sustainable mining practices.

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Cascading reforms in the form of Mines & Minerals

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OVERVIEW OF INDIAN NON-COAL MINERAL SECTOR

The wide availability of the minerals in the form of abundant rich reserves made it very conducive for the growth and development of the mining sector in India especially the noncoal mineral sector.

A. Mineral Resources

Concerted exploration carried out in the post-independence period both in known as well as in virgin areas, has established large resources of minerals. Indian Mineral industry has a well-established exploration structure. Geological Survey of India and Mineral Exploration Corporation Ltd. are the main exploratory agencies supplemented by the various State Directorate's of Geology and Mining has carried out extensive exploration. Off late many private entrepreneurs are entered in the mineral exploration sector which yielding positive results. As a result, the mineral base has increased from 34 to 95 minerals.

B. Number of Mining Leases

India is well-endowed with a wide variety of naturally occurring minerals. India has a total geographical area of 328.73 million hectares. Of this, the mining lease area, except for fuel, atomic minerals and all minor minerals, constitutes around 0.10%. The position of mining leases as on 31.3.2018 reveals that there are as many as 3,834 mining leases (excluding coal, lignite, petroleum, natural gas, atomic minerals and minor minerals) granted in the country by the State Governments covering 42 minerals with a total lease area of about 325876.20 hectares and spread over 24 States (Anon (IBM))

C. Mineral Production & value

The total value of mineral production (excluding atomic & fuel minerals) during 2018-19 has been estimated at Rs.1,24,020 crore, which shows an increase of about 10.11% over that of the previous year. During 2018-19, estimated value for metallic minerals is Rs. 61,009 crore or 49.19% of the total value and non-metallic minerals including minor minerals is Rs. 63,011 crore or 50.81% of the total value (Anon et al (GOI)). India's ranking in 2016 as compared to world production was 3rd in steel (crude), 4th in chromite, iron ore, aluminium (primary) & zinc (slab), 5th in bauxite and 6th in manganese ore and copper (refined) (Anon et al (GOI)).

D. Self-Reliance in Minerals & Mineral-Based Products

India continued to be wholly or largely selfsufficient in minerals which constitute primary mineral raw materials that are supplied to industries, such as, thermal power generation, iron & steel, aluminium, cement, refractories, etc. India is, by and large, self-sufficient in coal (with the exception of very low ash coking coal required by the steel plants), lignite, bauxite, chromite, iron, limestone, etc. India is deficient in kyanite, magnesite, sillimanite, rock phosphate, manganese ore, etc. which were imported to meet the demand. Despite high degree of self-sufficiency, some quantities of various minerals/ores are imported due to economic consideration or requirement of specific grade to meet the demand for either blending with locally available mineral raw materials and/or for manufacturing special qualities of mineral based products. To meet the increasing demand of uncut diamonds, emerald and other precious & semi-precious stones by the domestic Cutting and Polishing Industry, India is dependent on imports of raw uncut stones for their value-added re-exports.

E. Foreign Trade

India exports a large number of minerals and mineral based products. It is the largest exporters of sheet mica to the world market. It is also a leading exporter of iron ore, manganese ore, chromite and granite. Although lacking indigenous resources, India has emerged as a leading centre for cutting, polishing and export of diamond in the valueadded form. The important items of export include cut & polished diamonds, precious stones, iron ore, chromite, manganese ore, rough & polished granite, barytes, steatite, alumina and metals like aluminium, iron & steel etc. The total value of exports of ores & minerals from India during 2017-18 was of the order of Rs.1,99,120 crore. On the other hand, rough diamond, gold, coking coal, copper, lead, zinc, nickel, tin, tungsten, rock phosphate, asbestos, potash, petroleum etc, are some of the important minerals and metal, which are being imported. The import bill of all ores & minerals during the corresponding period accounted for about Rs.10,28,501 crore (Anon et al (GOI)). This picture indicates a marked imbalance between exports & imports and highlights the need to explore and exploit such minerals with emphasis on value addition and price competitiveness.

NATIONAL MINERAL POLICY 2019

Against the backdrop of a long phase of policy gaps and judicial interventions across the mineral and resources sector, the National Mineral Policy, 2019 (NMP 2019) has been introduced in February 2019 to bring about changes making India's mineral and resources sector globally competitive and moving closer towards resource security. The National Mineral Policy 2019 includes provisions which will give boost to mining sector such as3,4:

a) Introduction of Right of First Refusal for RP/PL holders
b) Encouraging the private sector to take up exploration.
c) Auctioning in virgin areas for composite RP cum PL cum ML on revenue share basis
d) Encouragement of merger and acquisition of mining entities
e) Transfer of mining leases and creation of dedicated mineral corridors to boost private sector mining areas.
f) To grant status of industry to mining activity to boost financing of mining for private sector and for acquisitions of mineral assets in other countries by private sector.
g) It also mentions that Long-term importexport policy for mineral will help private sector in better planning and stability in business.
h) Rationalize reserved areas given to PSUs which have not been used and to put these areas to auction, which will give more opportunity to private sector for participation.
i) The Policy also mentions to make efforts to harmonize taxes, levies & royalty with world benchmarks to help private sector.

Among the changes introduced in the National Mineral Policy, 2019 include the focus on make in India initiative and gender sensitivity in terms of the vision. In so far as the regulation in Minerals is concerned, EGovernance, IT enabled systems, awareness and Information campaigns have been incorporated. Regarding the role of state in mineral development online public portal with provision for generating triggers at higher level in the event of delay of clearances has been put in place. NMP 2019 aims to attract private investment through incentives while the efforts would be made to maintain a database of mineral resources and tenements under mining tenement systems. The new policy focusses on use coastal waterways and inland shipping for evacuation and transportation of minerals and encourages dedicated mineral corridors to facilitate the transportation of minerals. The utilization of the district mineral fund for equitable development of project affected persons and areas. NMP 2019 proposes a longterm export-import policy for the mineral sector to provide stability and as an incentive for investing in large scale commercial mining activity. The 2019 Policy also introduces the concept of inter-generational equity that deals with the well-being not only of the present generation but also of the generations to come and also proposes to constitute an interministerial body to institutionalize the mechanism for ensuring sustainable development in mining.

Some of the commercial implications of NMP 2019 are described here (Anon (IMEU)):

A. Exploration incentives

The policy proposes simpler, more transparent and time-bound procedures for obtaining clearances, incentives for the use of state-of-the-art technologies in exploration of minerals, the right of first refusal at the time of auction and seamless transition from reconnaissance permit to prospecting license to mining lease or auctioning of a composite reconnaissance permit cum prospecting license cum mining lease in virgin areas on a revenue sharing basis, or any other appropriate incentive in accordance with international practices. It also proposes tax incentives for risk capital and industry status to the mining sector.

B. Security of tenure

The policy proposes assured security of tenure to the concessionaire and an increase in the trust levels in the process by way of inclusive policies, increased responsiveness, better regulation, transparency, openness and fairness.

C. No-go areas

Ecologically fragile areas will be declared as "inviolate or no-go areas" out of bounds for mining and exclusive mining zones will be created with prior in-principle statutory clearances demarcated for the mineralized belt. This will give clarity to all stakeholders and will avoid conflict of interest and curtail delays in starting mining operations.

D. District mineral foundation

The policy proposes a district mineral foundation that will be guided by the provisions of the Prime Minister's Mineral Area Development Plan for the inclusive and equitable development of people and areas affected by mining.

E. Inter-generational equity

The policy notes that the state has to ensure that future generations will receive the benefits of inheritance and, therefore, it has to receive the full value of the extracted minerals. Further, the policy proposes that intergenerational equity should be assessed using a disaggregated approach and be adopted considering the reserves or resources and their potential for reuse through recycling.

F. Exclusive regulatory authority

The policy proposes to establish a national level unified authority, as an inter-ministerial body under the Ministry of Mines, to ensure the fulfilment of policy objectives. The authority will comprise members from the Ministry of Coal, Ministry of Earth Sciences, Ministry of Tribal Affairs, Ministry of Rural Development, Ministry of Panchayati Raj, Ministry of Steel, and state governments.

G. Pricing of mining commodities

Enabling investment through foreign direct investment will be key to making mineralbased materials available to domestic users at a reasonable price. This implies lesser government influence, which would make mining more attractive to investors.

H. Resolving environmental issues

The policy provides a two-fold approach for the resolution of environmental issues pertaining to the mining industry. It highlights prevention and mitigation as the means to achieve sustainable development and to resolve environmental issues.

I. Geological information

The policy lays down various guidelines to facilitate geological exploration by providing greater clarity on issues such as access to information. It proposes open dissemination of information in a digitized format with automated updates on the concession lifecycle with respect to baseline and mineral exploration data, national inventory of mineral resources, and the mining tenement system. The policy attempts to integrate the country's overall strategy on economic development and guide the exploration, extraction and management of minerals. The new regulatory environment is likely to provide a fillip to ease of doing business. The policy focuses on the promotion of domestic industry, the reduction of dependence on imports, the provision of an efficient regulatory mechanism, high penetration of e-governance systems, employment generation and the requirement for a unified authority. The policy seeks to make mining a stand-alone industry in India, thus giving impetus to attract further industryspecific investment, which is coupled with the introduction of the long-term export-import policy for the mining sector.

ACTION INITIATED

A. Amendments in Statue

As outlined in the NMP 2008 and NMP 2019, already various measures have been initiated. The "Mines & Minerals (Development & Regulation) Act, 1957" which governs the mineral sector, was overhauled by amendment in 2015, to bring in greater transparency, remove discretion and infuse greater ease of doing business. The "Mines & Minerals (Development & Regulation) Amendment Act, 2015" designed to put in place mechanism for:

a) Improved transparency in the allocation of mineral resources;
b) Obtaining for the government its fair share of the value of such resources;
c) Attracting private investment and the latest technology;
d) Eliminating delay in administration, so as to enable expeditious and optimum development of the mineral resources of the country.

By new dispensation, e-Auctions mandated for the grant of mineral concession to ensure transparent process of allotment of mineral blocks. At the same all new lease would be granted for 50 years and need of renewals and prior approvals removed for ease of doing business and removing discretions. Provision has been for establishment of District Mineral Foundation (DMF) for welfare of mining affected areas/people, through contribution from the mining lease holders established. In the said amendments penal provisions made extremely stringent to deter illegal mining activities. Further, provision for constitution of special courts by the State Govt. for fast-track trial of cases of illegal mining has been made. Provision has been made for the creation of the National Mineral Exploration Trust (NMET) by putting 2% cess on the royalty. All requisite subordinate Rules for implementation of amendment formulated and notified.

B. National Mineral Exploration Policy 2016

National Mineral Exploration Policy 2016 (NMEP) (For Non-

Fuel and Non-Coal) has been brought out by the Government in 2016 to give further momentum to exploration efforts (Anon NMEP). The policy purports to permit the engagements of private agencies to carry out exploration work in identified block/areas with right to certain share in the revenue accruing to State Government throughout the lease period, with transferable rights. The Policy states that this percentage/amount will be paid by the successful bidders to the concerned exploring agency and will be determined when mineral blocks on the basis of successful exploration are put on e-auction. The policy moves towards working out normative cost of exploration for different kinds of minerals so that the exploration agencies could be compensated, in case they do not discover any mineable reserves in their respective areas.

C. Substantial Development Framework

As envisaged in the National Mineral Policy 2008, all mining activities are required to undertake within the parameters of Framework of Sustainable Development (SDF). As part of roll out of SDF, the Ministry of Mines through Indian Bureau of Mines has brought out a concept of Star Rating Evaluation of mines. Under the Star Rating Scheme, a credible system of evaluation of mining footprints and to take up mining activity, encompassing inclusive growth, without adversely affecting the social, economic and environmental well bring has been developed. It has been instituted as a two tier system providing self-evaluation templates to be filled in by the mine operator in online system developed through IBM portal followed by validation through IBM. As per Rule 35(2) of Mineral Conservation and Development Rules 2017 every holder of a mining lease has to monitor mining & allied activities as per IBM notified templates from time to time and shall require to submit online self -assessment report before 1st July every year for previous financial year along with soft copy of high resolution satellite images obtained from CARTOSAT-2 satellite LISS-IV sensor on the scale of cadastral map for that financial year, covering the mining lease and an area of two kilometers from the lease boundary. Subsequently IBM carries out validation of the star rating.

D. District Mineral Foundation

District Mineral Foundation (DMF) is meant to address the long-standing demand of the local people in mining areas for inclusive growth. The funds for DMF are being met from additional contributions of 30 % of royalty by existing miners and 10% by miners granted mines after the MMDR Amendment w.e.f. 12.1.2015. The Annual budget of DMFs for major mineral States would be about 6,000 crore (Anon et al (GOI)). The Government has formulated Pradhan Mantri Khanij Kshetra Kalyan Yojana (PMKKKY) to be implemented by the DMFs of the respective districts. Directives has been issued under Section 20A of the Act by the Central Government on 16.09.2015. The PMKKKY has mandated 60% of the funds to be utilized for High Priority Areas, such as Drinking water / Environment preservation and pollution control / Health care / Education / Skill development / Welfare of women, children, aged and disabled people / Sanitation and balance 40% of the funds can be utilized for Infrastructure - Roads & physical infrastructure / Irrigation / Watershed development. The projects implemented under PMKKKY will help create a congenial mining environment, ameliorate the condition of the affected persons and create a win-win situation for the stakeholders. More than Rs. 34,098 crore have been collected as cumulative accrual so far under DMF. During the year 2019-20, so far more that 7790 crores have been accrued for all the States. Projects of nearly 23, 000 crore have been sanctioned for various projects (Anon data).

E. Mining Surveillance System

The Ministry of Mines, through Indian Bureau of Mines, has developed the Mining Surveillance System (MSS), in collaboration with Ministry of Electronics and Information Technology (MeitY) and Bhaskaracharya Institute for Space Applications and Geoinformatics (BISAG), Gandhinagar, to use space technology for facilitating State Governments in curbing illegal mining activities in the country.8 MSS is a satellitebased monitoring system which aims to establish a regime of responsive mineral administration, through public participation, by facilitating State Governments in curbing instances of illegal mining. Any unusual land use change activity observed on satellite imagery in a zone up to 500m from the boundary of mining lease area is captured and flagged off as Triggers, which may also include illegal mining. The wider use of Satellite Remote Sensing Technology together with Information Technology will offer quick, transparent and periodic monitoring of mining leases including easy access to remote areas. The MSS also includes user-friendly mobileapp for use of mining officials which will receive alerts, do field verification and submit inspection reports. This mobile app also aims to establish a participative monitoring system where the citizens also can use this app and report unusual mining activity which will be generated as a trigger. The site verification of the trigger would be done by officials of mining departments of concerned States, who will also take appropriate action in cases of illegal mining.

FUTURE AGENDA AND CHALLENGES

A. Exploration Priorities in India

With vast resources lying unexplored, survey and exploration is the first step towards developing domestically available minerals for internal utilisation. Globally economies with large mining base or potential resources have projected significant spends for exploration. However, Indian Exploration budgets are still limited. In India most of current exploration is on coal, iron ore, and surficial mineral. By contrast the largest proposal of global exploration spends are in gold, base metals and diamonds. Given its geological make up, India is highly prospective for all these minerals (Vijay kumar) In order to enhance spending and expedite mineral exploration, the Government has set up National Mineral Exploration Trust (NMET).

The Trust supports regional and detailed mineral exploration in the country and other activities approved by the Governing Body, to achieve its objects. They include-special studies and projects to identify, explore, extract, beneficiate and refine deep seated and concealed mineral deposits, studies on mineral development, sustainable mining, mineral extraction and metallurgy adopting advanced scientific and technological practices, detailed and regional exploration for strategic and critical minerals, upgradation of mineral exploration status in an area from G3 to G2/G1 level, exploration leading to grant of mineral concessions, aerial and ground geophysical surveys, geochemical surveys, capacity building of personnel engaged in mineral exploration, etc. So far 188 explorations projects have been undertaken/under implementation through NMET fund worth of more than Rs. 890 crores (Anon data 2020).

B. Mining Leases Expiring in March 2020

As per the new dispensation, the lease period of merchant mines extended under the Section 8A (6) of the MMDR Amendment Act 2015, would expire on 31.03.2020.

The State Governments and the Central Government have laid emphasis from the beginning to enable the auction of these mines expiring in 2020 and their transition so as to have the continuity of production.

The State Government and IBM have together identified about 334 Mining Leases which would expire on 31.03.2020. Out of these, 49 working mining leases have significant contribution in the production of iron ore, manganese ore and chromite ore in the country (Rajeshwar Rao).

Most of the production of these expiring mines is from Odisha. The seamless operationalization of these mining leases is important to ensure that there is no disruption in production of minerals in the country. These mines have to be put on auction in a time bound manner for smooth transition from old lessees to new lessees which would emerge from the auction process. For this purpose, the Central Government has brought out Mineral Laws Amendment Ordinance 2020 by which the successful bidder through auctioning of the mining leases which are expiring shall deemed to have acquired all valid rights, approvals, clearances, licences that were vested with previous lessee for a period of two years (Anon Mineral laws).

C. Mining Tenement System

The Mining Tenement System (MTS) is a Digital Repository of entire Life Cycle analysis of each Mining Concession granted for major Minerals excluding Coal, Fuel and minor minerals. This includes automation of all the processes and approvals at various levels of governance thereby mapping all the activities from identification of potential mineral bearing areas to even post closure of mining activity thereby enabling real-time transfer of electronic data and files, with Geographical Information System (GIS) interface. The system has been primarily conceptualized to transform the functioning of Indian Bureau of Mines for efficient, effective and transparent delivery with a provision to bring on-board the State Mining Departments of States all across the country as per the option exercised by them.

This online computerized system will provide information in visual graphic form in GIS and textual form known as Registry component. The information data base to be maintained in the project includes duration of concessions, security of tenure, criteria for grant of mineral concession, transferability of PL, reservation of areas, details of grant of mineral concessions, disputes, forest details, MOEF clearance, infrastructure, taxation, illegal mining, captive mines, exports-imports, etc. The project is already started execution by IBM. The projects involve development and operation of modules such as Registration and Online Returns, Mobile App for Daily Return, Mining Plan, PMKKY and Ore Accounting System under Phase-1. In the Phase-

2, modules such as Grant of Concessions, Concession management & inspections, Transformation of IBM databases, GIS platform, Revision and Star Rating of Mines would be developed.13 Three modules of MTS Project viz. PMKKKY, Registration and Daily Returns are already developed and made operational.

D. Use of Enhanced Space Technology

Indian Bureau of Mines, has entered into a MoU with National Remote Sensing Centre (NRSC), for a pilot project "Sudoor Drushti" to demonstrate the feasibility of using High Resolution Satellite Imagery and Digital Elevation Model (DEM) in monitoring mining activities / changes over selected group of mines. Regarding setting up of Remote Sensing Laboratories, NRSC has guided IBM in finalizing the technical specification of software, hardware and procurement procedures. IBM has procured all the necessary software and hardware for the lab. The remote sensing labs at Nagpur and other at Hyderabad is under development. As a part of pilot project in Tandur area Andhra Pradesh, volume changes in a cluster of mines (6) studied for 2007- 2015 period and observed that overall volume change is +10 to 11% only.1 This technology would enable to facilitate to monitor periodic changes of the mining areas within the mining lease boundary for a time period.

CONCLUSIONS

Indian mineral industry has come a long way. With the passage of time, many reforms suitable to the contemporary needs have been undertaken. However, in spite of this, the share of mining industry to the national GDP is not significant. By effecting the major reforms in the form of MMDR 2015 amendments, with the adoption of NMEP 2016 and NMP 2019 coupled with several initiatives already executed and contemplated projects, it is expected that Indian mineral industry can compete with global leaders.

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Application of AI in Mining- A Case Study

S. Singh*

ABSTRACT

Longwall Mining is the most productive and mechanization friendly coal mining method for deep seated coal deposits. Looking at the current coal requirements and quickly depleting opencast mines in the country, longwall is the future of coal mining industry in India. In order to understand the behaviour of a longwall roof, the leg pressure data of all 146 shields in Adriyala longwall panel-1 of SCCL mine were analyzed. A program was developed to detect mining cycles and determine the parameters of it from the shield pressure data. Another program in combination with the previous program was developed for visualization of periodic weighting as well as the roof loading across the panel. An artificially intelligent tool was developed using artificial neural networks and k-means to learn the roof behaviour patterns from the mining cycle parameters. The program generated reports can be helpful for the mine management to take decisions regarding the roof control as well as the operations of the longwall on daily basis. Putting all the programs together this project has the potential to aid the longwall automation for greater success in terms of safety as well as high production rate requirements.
Keywords— Longwall mining, artificial intelligence, mining cycle, artificial neural network.

INTRODUCTION

The longwall mining is a mining method with higher output rate and continuous production. The method is suited for high mechanization as well as automation thus giving better opportunity for including advanced technologies and techniques like Artificial Intelligence for analyzing and improving the production.

According to the father of Artificial Intelligence John McCarthy 1956, it is" the science and engineering of making intelligent machines, especially intelligent computer programs". It is a way of making a computer, a computer con- trolled robot or a program that can think intelligently. The philosophy behind the artificial intelligence is" can a ma- chine think or behave like humans?" Thus, the development of AI started with the intention of creating similar intelligence in machines that we and regard high in humans.

Many researchers have worked on artificial intelligence techniques and developed various methods and tools for bet- ter analysis of the data resource. Some of the most common methods and tools used are neural network, support vector machines, Bayesian classifiers, regression techniques and clustering methods. Today artificial intelligence is the most used technology in the fields of engineering, bio medical, maths, neuroscience, philosophy and sociology.

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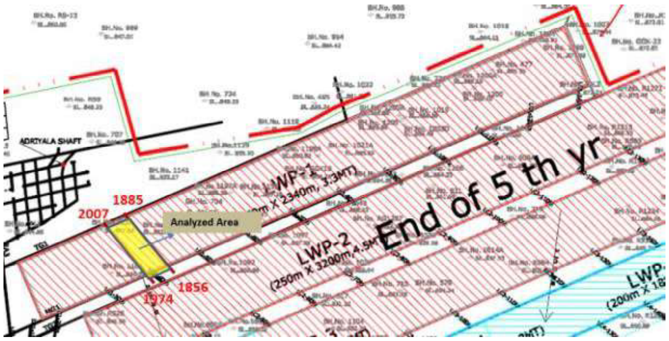
ADRIYALA LONGWALL PANEL-1 DESCRIPTION

Adriyala longwall project (ALP) is an integral part of GDK-10 Incline mine,SCCL. First time in India, high capacity longwall mine with 3.0 MTPA is planned with a panel length of 2350m and face length of 250m. Adriyala long- wall project is having 4 no of seams with thickness is ranging from 4.5m to 11m. Initially the development and ex- traction of the longwall panel is planned in No 1 seam. The thickness of No1 seam between 6 to 7m and having 2 clay bands. The middle clay thickness is varying between 0.2m to 0.4m and top clay which is located just below the sandstone roof having the thickness between 0.6m to 0.8m. The existence of middle clay is present in all along no 1 seam but the top clay existence is varying i.e. at some places the top clay exists and at some places it does not exist. The both clay bands are playing major role in the roof behaviour. The clay bands are separated with coal and shaly layers of about 2.2m thickness.

DATA COLLECTION

The roof is supported by a sequence of 146 power supports with 2 hydraulic legs across the face length of the panel. Each hydraulic leg is equipped with a sensor that reads the roof pressure at every 10 second interval. The data obtained from the mine for analysis is of June,2016. Advancement in this duration for Main Gate is from 1856m to 1974m and for Tail Gate from 1885 to 2007m from the start of panel. The map of area is shown in the figure1 There are three types of data collected from the mine which are 1)Borehole data 2)Shearer position data 3)Shield pressure data. The position of shearer is taken as the shield number in front of which the shearer is present.



MINING CYCLE

The resistance of the shield and leg closure are results of the interaction between roof, support and floor. Based on an earlier study (Islavath et al. 2016), it was shown that there are four distinctive periods that define a mining cycle. The four periods of a mining cycle are shown in the figure 2.

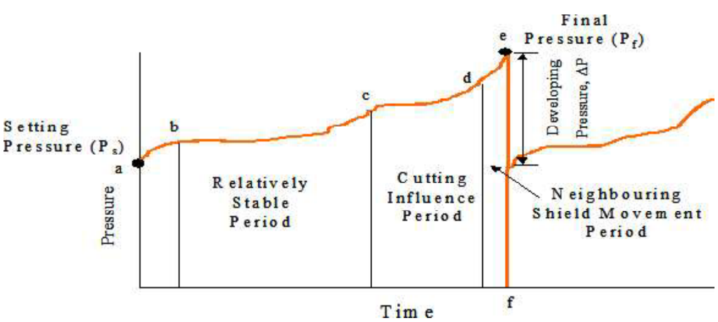


Fig. 2: Mining Cycle

ESTIMATING MINING CYCLE FROM REAL TIME DATA

To detect the mining cycle effectively first the shearer cycles are detected because the number of mining cycles are same as number of shearer cycles in case of unidirectional cut. A simple algorithm was developed to detect the number of shearer cycles. In this algorithm a flag variable is set to positive when shearer is moving from main gate to tail gate and set to negative in the opposite case and based on the number of flag changes we determine the number of shearer cycles. Another algorithm was developed to detect the number of shield cycle from the pressure data of shields. The shield cycle detection is based on the pressure values read by the sensors on hydraulic legs of the support. The basis of the algorithm is that when a support is advanced there is no contact between the roof and the canopy of support and hence the reading will be zero. The algorithm locates the steep falls in the pressure values and check whether that was a cycle or not. The checking part is important because sometimes the shields are lowered due to some operational problems and are not advanced. After applying the algorithm on the shield pressure data the results obtained are shown in the figure 3. The black line shows the number of shearer cycles of actual mining cycles.

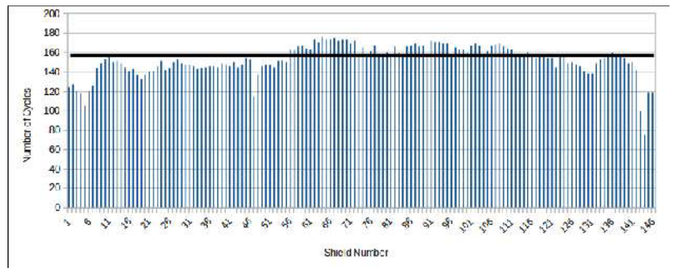


Fig. 3: Shield Number vs Number of Cycles after Mining Cycle Detection Algorithm

The function of this algorithm is to make all the shield cycles (detected by the previous algorithm) equal to the actual number of cycles without losing the feel of the phenomenon that is occurring. We have found out that inspite of detecting most of the cycles in the previous algorithm some of the cycles are not detected and some of the shields show more than the actual number of cycles, but to go for further analysis all the detected cycles must be equal to shearer cycles. Hence this is a very important as well crucial algorithm. In this algorithm we are adding and deleting some cycles from the shields judiciously, so that at the end all the shields show same number of cycles as that of shearer.

ANALYSIS OF ROOF USING MINING CYCLE DATA

Since the periodic weighting is an important phenomenon to understand the behaviour of roof, it becomes essential to visualize the phenomenon in a convenient way. We have shown two ways to visualize periodic weighting.

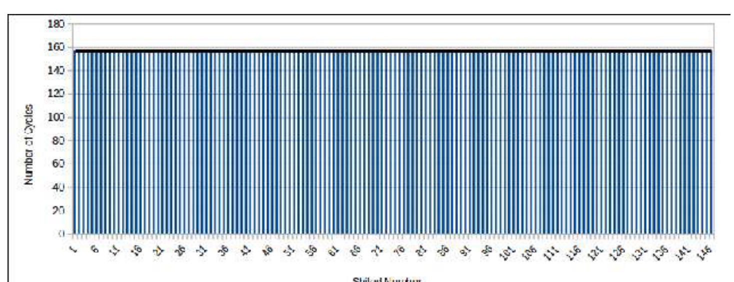


Fig. 4: Shield Number vs Number of Cycles after Mining Cycle Detection Algorithm

A. Color Plot

Figure 5 shows a color plot of the pressure distribution along the panel. The X axis shows the mean setting time for every mining cycle and the Y axis depicts the shield number. Each colored box in the figure shows the pressure range during that mining cycle. Since the time for every mining cycle is different from one another it becomes difficult to visualize the periodic weighting interval in this plot.

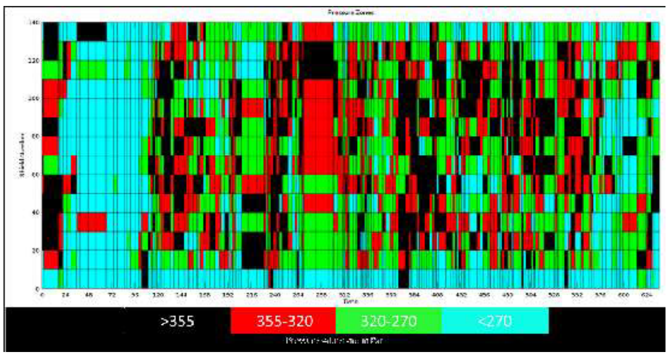


Fig. 5: Final pressure distribution with shield setting time for June, 2016

However, if the pressure zones are plotted with respect to face advancement then the visualization of periodic weighting becomes easier because for every mining cycle the face advancement is more or less same which is 0.7 meters in our case. The figure 6 shows the color plot of pressure distribution along the panel with respect to face advancement. The blue boxes in the plot are the reported periodic weighting intervals by the mine officials and it can be seen that the plot also shows high pressure zones within blue boxes.

B. Profile Plot

The profile plot is basically a plot of section of the color plot along the X axis.

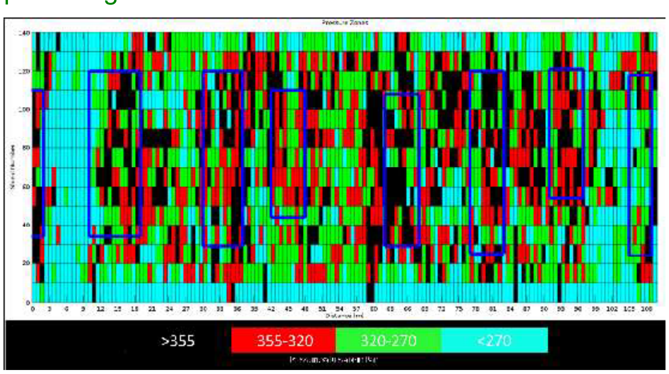


Fig. 6: Shield Number vs Number of Cycles after Mining Cycle Detection Algorithm

If we consider a particular shield group and plot the average pressure values against the distance, we get a pressure profile for that group of shields. Figure 7 shows a pressure profile of 60 shields' group (41 to 100). From the figure the high and low pressures can be seen easily which shows that how the roof is behaving. When the pressure is building up that means the length of beam is growing and the pressure decrements shows that roof has fallen/falling. Since this profile is of a group of middle 60 shields which means that it is indicative of overall roof behaviour of the panel.

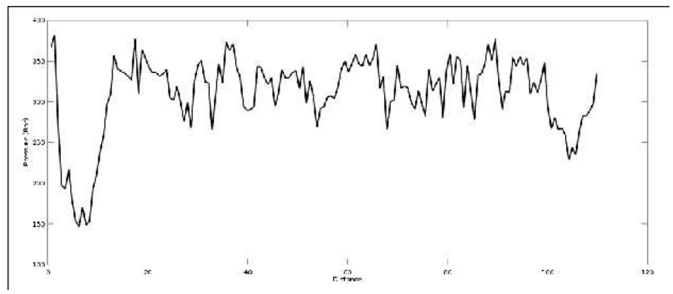


Fig. 7: Pressure profile generated by taking average pressure of shield number 41 to 100

The small fluctuation in the profile is due to the immediate roof fall or some roof falls in small zones. To remove these small fluctuation 2 point moving average is used so that the global main roof behaviour can be analyzed. Figure 8 shows the pressure profile after 2 point moving average. The profile can be visualised as a sequence of bumps as shown in the figure 9, where each bump indicates a periodic weighting.

These bumps can be learned using modern artificial intelligence techniques and with the help of bump parameters we can learn the type and behaviour of the main roof. Artificial Neural Network is used to learn the bumps in our case.

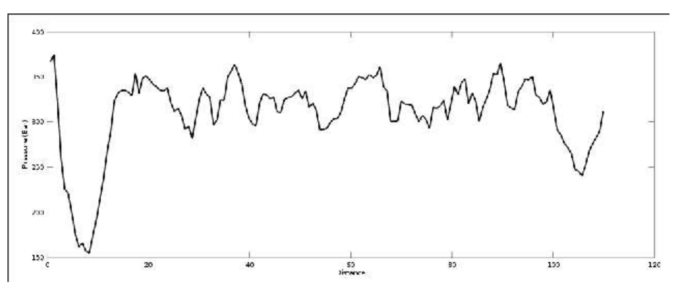


Fig. 8: Pressure profile generated after taking 2 point moving average

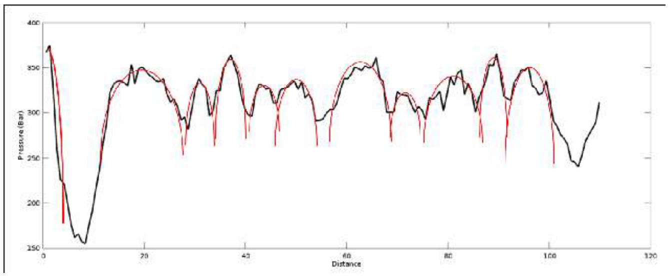


Fig. 9: Pressure profile visualization using sequence of bumps

BUMP ANALYSIS USING ARTIFICIAL NEURAL NETWORK

A bump has two parameters, width and intensity/Height (figure10). Our aim is to learn these two parameters using artificial neural network. The generalized neural network can surely fit the pressure data with very low mean square error, but in that case we won't be able to learn the geological conditions causing the roof fall.

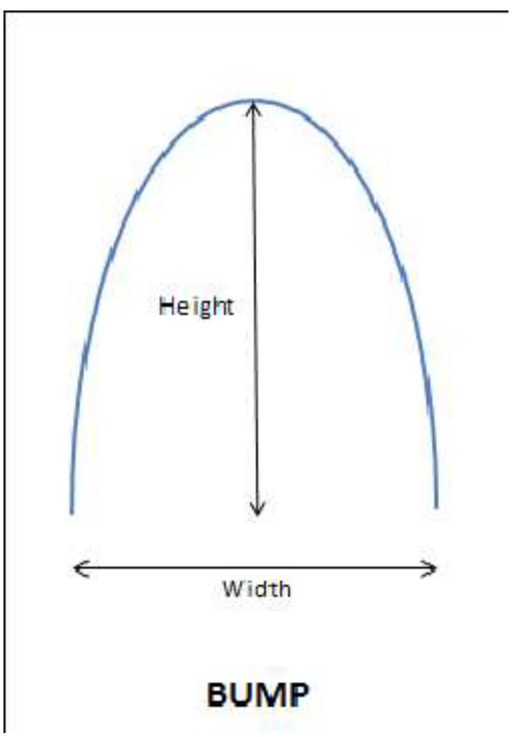


Fig. 10: Bump

To learn the geological conditions of the roof there is a need of a different neural network architecture that can take the periodic weighting parameters into account and fits the data with low error as well.

A. The Bump Function generation

The pressure variation in a longwall panel is a one variable function estimation problem i.e. pressure vs face advancement. According to Muller (1991), a pressure peak can be described by a "bump" function, B(x) as:

$$B(x) = \frac{a}{2}[F(x - a) - F(x - c)] \qquad (1)$$

Where c > b > 0, ± represents the amplitude or the intensity of the bump and F(x) is the activation function. The activation function used in this case is Sigmoid function given by:

$$F(x) = \frac{1 - e^{-2x}}{1 + e^{-2x}} \qquad (2)$$

Figures 11 and 12 shows the generation of bump function by subtracting two activation functions F1(x-a) and F1(x-c) respectively. The width of the bump is given by (c-a) and the height of the bump is ± which is at the location (b+a)/2.

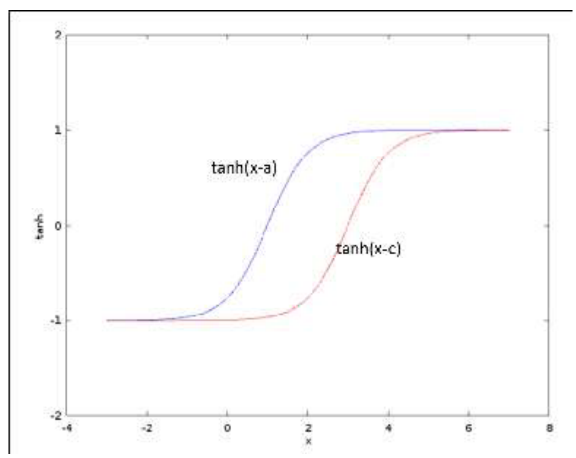


Fig. 11: tanh with x shift

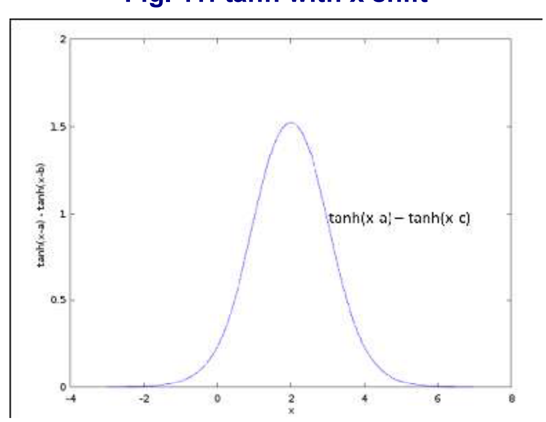


Fig. 12: Bump function after subtraction

NEURAL NETWORK ARCHITECTURE DESIGN TO LEARN BUMP FUNCTION

A special neural network architecture was constructed for the detection of loading peaks of the pressure cycle. The architecture is shown in the figure 13 . The network consists of three layers, i.e. input layer, hidden layer, output layer. The input layer contains two nodes one of them provides a constant value - 1 as bias and the other node gives advancement of face as input "x". The hidden layer consists of pair of nodes each pair is used to learn a bump. The number of pairs required in the hidden layer depends on the number of pressure peaks present in the pressure profile. The output layer contains only one node which gives the pressure peak, P, as a result.

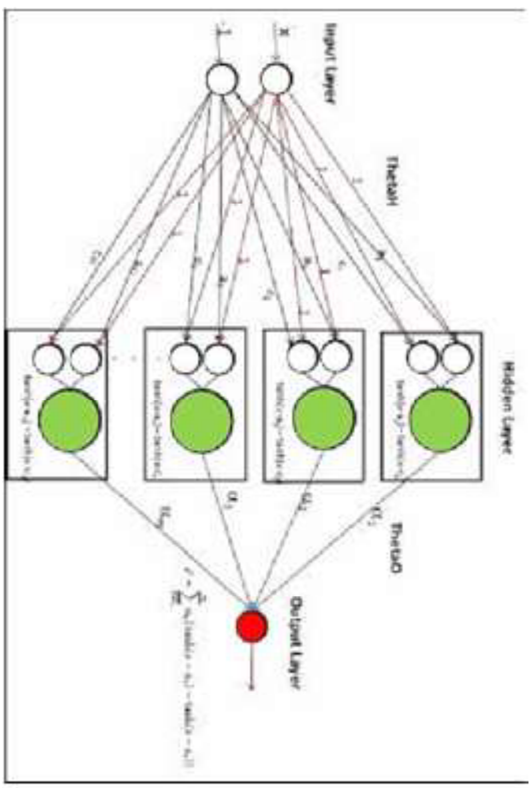


Fig. 13: Figure showing the architecture of neural network designed for roof analysis

All the inputs and out values are stored in the form of a matrix. The input matrix is named $[INP]_{mX2}$. where m is the total number of patterns available for training. The actual output matrix is named $[OP]_{m\times 1}$. The Weights between in- put layer and hidden layer is given by $[ThetaH]_{2X2b}$. where b is the number of bumps. The weights between hidden and output layer is given by $[ThetaO]_{1\times b}$.

A. Results Obtained after applying ANN

The ANN given above is applied for three different conditions to understand the roof behaviour. In first case the neural network is applied for the central 10 shields of the panel which covers a width of 17 meters.

This case is considered to learn the roof behaviour locally. The results for this case are shown in figure 14. Number of bumps used for this case are 20. In second case 30 central shields' average is taken and ANN is run on that. This covers a width of 50 meters. The results are shown in figure 15. Number of bumps used for this case are 18.

The last case takes the central 60 shields' average profile. This case is taken to understand the global behaviour of the roof above the panel. The results for this case are shown in figure 16. Number of bumps used for this case are 14. It can be seen that the number of bumps are reduced to learn the roof as we move from 10shields to 60 shields' average. This is because in case of 10 shields' average the effect of immediate roof will also be there and hence we found more number of bumps with less intensity. As we move to the higher range of shields we can find that the lower intensity bumps are not present because for greater width of the panel the effect of immediate roof is negligible.

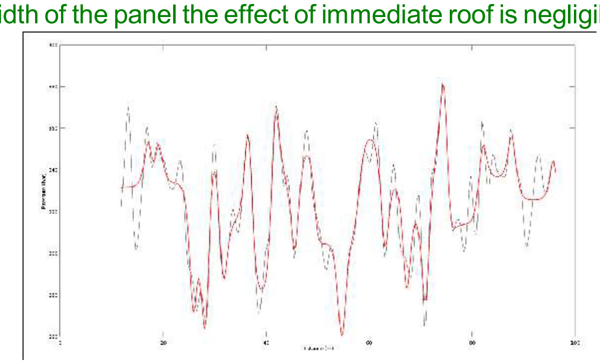


Fig. 14: Figure showing pressure profile fitted by neural network on 10 shield averagE

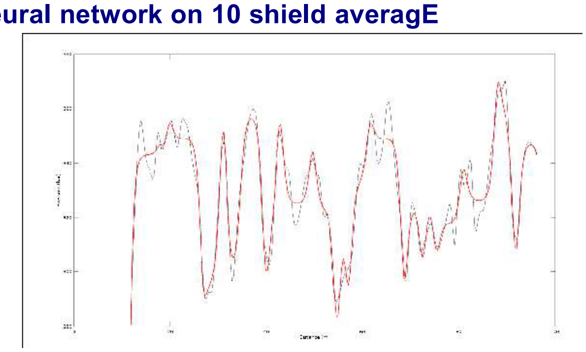


Fig. 15: Figure showing pressure profile fitted by neural network on 30 shield average

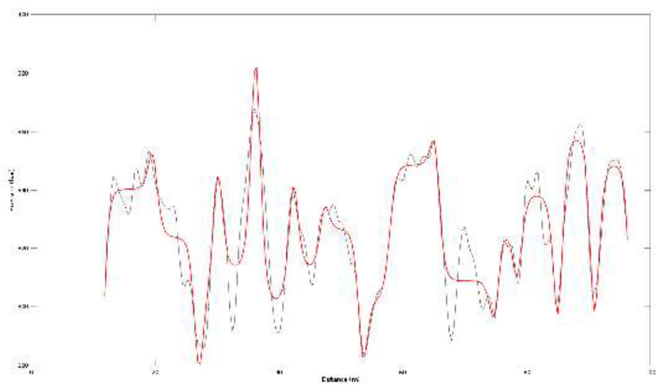


Fig. 16: Figure showing pressure profile fitted by neural network on 60 shield average

CLASSIFICATION OF ROOF ABOVE THE SEAM

The classification of longwall roof can be done using Tree Classification method (Jiyang et al. 1998). In this case study k-means classification technique is used to classify the long- wall roof. The neural network learns various bumps as shown in previous section. If we see the bumps learned by the network, we can see that there are various types of bumps in terms of their intensities and width. In this case k-mean clustering algorithm is used with value of k=3 (number of clusters).

Results Obtained After applying k-means algorithm the classified bumps for 10 shield average, 30 shield average and 60 shield average are shown in figures 17, 18 and 19 respectively.

10 Shields' Profile (17-meter Panel Width)	
Bump Type	Average Interval(m)
Blue Bump	20
Red Bump	25
Black Bump	9.09

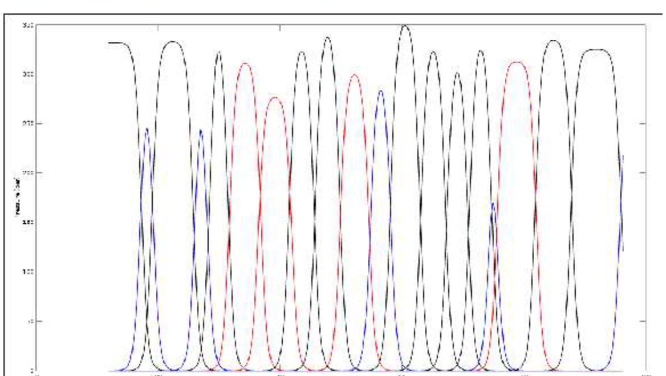


Fig. 17: Figure showing classified bumps in three groups for 10 shield average

30 Shields' Profile (50-meter Panel Width	
Bump Type	Average Interval(m)
Blue Bump	25
Red Bump	14.28
Black Bump	14.28

60 Shields' Profile (100-meter Panel Width	
Bump Type	Average Interval(m)
Blue Bump	25
Red Bump	20
Black Bump	20

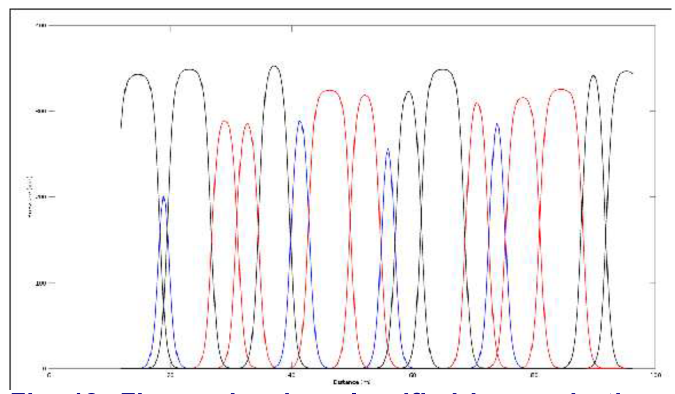


Fig. 18: Figure showing classified bumps in three groups for 30 shield average

CONCLUSION

Longwall mining is the most effective underground coal mining method, but there are a lot of ground control problems which can cause injuries, failures and interruption in coal production.

Hence, there is a requirement of judicious analysis of the longwall roof which can be helpful in overcoming the above-mentioned problems.

The current technologies of sophisticated sensors had made it possible to collect the pressure data at every 10 second interval and the artificial intelligence techniques has given tools to analyze the obtained data for better understanding of the roof/strata.

A program is developed for analyzing the obtained data which can generate daily reports and can be used for making crucial decisions regarding roof control, panel advancement rate, supports and induced caving.

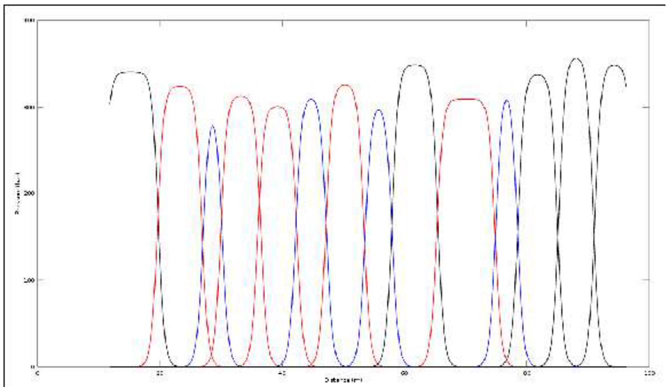


Fig. 19: Figure showing classified bumps in three groups for 60 shield average

The developed program was not only used for analyzing the collected data but it can also be used to learn about the roof behaviour using the modern artificial intelligence technique. The artificial intelligence is used to train the roof data and learn the periodic weighting parameters, interval and intensity of weighting, with a high precision. The k-means classification technique classifies the roof based on the parameters of periodic weighting. In our case the classification was done in three groups. the classification of roof can be done using fuzzy logic technology as well (Razani et al. 2016; Deb, D. 2003).

In case of 10 shields it can be seen that the intensity of low intensity bumps are lower than 30 shield and 60 shield cases. This happens because it takes only 10 shields' average and the width for that across the panel is only 17 meters, which means that the parting is unable to hold itself for small span. while in case of 30 shields and 60 shields the intensities of low intensity bumps (blue bumps) are higher as well as the width of these bumps are more as compared to 10 shields case. This happens because the width considered for these cases are much higher, 50 m and 100 m respectively, which increases the intensity in global sense.

The availability of borehole data at all the points is not possible because of the economic constraints, but with help of classification technique it can be identified that the longwall is passing through what kind of geology. Thus, this study provides a great tool to easily understand the behaviour of the roof through which the longwall is passing that too with the help of only shield pressure data obtained in real time.

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