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Prof.(Dr.) S. Jayanthu

Persons in the News

Shri Dilip Kumar Mohanty presently Chief General Manager, NMDC Limited has been selected for the post of Director (Production), NMDC Limited recommended by PESB. As Director (Production) of NMDC, Shri Mohanty will be a member of the Board of Directors and will report to the Chairman and Managing Director (CMD). He also will be overall in charge of various operating mining and other units of the corporation. He will be responsible for achieving the targeted production of each unit.

Shri T Saminathan presently Director (Commercial), KIOCL Limited, has been selected to post of Chairman and Managing Director, KIOCL Limited. He holds Degree in Mechanical Engineering and Post Graduate Diploma in Business Management and has more than 3 decades of experience in KIOCL Ltd in the iron ore Mining, Beneficiation, Palletization and Pig iron making since joining in the year 1986 as Graduate Engineer. During initial period, he served in Kudremukh mine Beneficiation Plantand later moved to Corporate Office, Technical Services Department, Bangalore in 1992 and executed projects viz: Crusher III installation, Relocation of Crusher I and installation of additional Ball Mills. Served in CMD's Secretariat as Technical Officer to CMD for shorter period and moved on to materials department in the year 2009. Prior to assuming charge as Director (Commercial), he was GM (Material) heading both the Materials & Commercial Divisions. He is instrumental in bringing tolling concept which has resulted in increased Capacity utilization of Pellet Plant. He is also put in system improvement in supply chain and logistics which has resulted in reduced transit and handling losses of iron ore fines, brought down inventory holding level, framed and implemented risk management across the organization, introduced e-procurement through service provider MSTC and started GeM procurement. He is a life time member in Indian Institute of Materials management (IIMM) and Indian Institute of Mineral Engineers (IIME).

Shri Manoj Kumar presently General Manager, Central Mine Planning & Design Institute Ltd (CMPDIL), has been selected to the post of Chairman & Managing Director, Central Mine Planning & Design Institute Ltd (CMPDIL) recommended by PESB. Shri Kumar is a Mining Engineer with distinction from the Indian School of Mines, Dhanbad 1985 batch. He obtained First Class Mine Manager's Certificate of Competency in the year 1989. He also did M.Tech in Rock Excavation Engineering from WCL/SECL. He has been serving the coal industry for more than three decades. During that period served in WCL, SECL & ECL in various capacities. He is known for his expertise in difficult underground mining methods and Continuous Miner Technology. With his vast practical experience of underground and opencast coal mining, enriched with the experience of planning and contract management. He has been instrumental in growth and sustainability of production at the places he has worked. He has keen interest in taking new initiatives. He has travelled to USA, South Africa, Australia and Geneva for participating in various programs on project Management and Coal Mining.

Shri Ranjit Rath presently Chairman-cum-Managing Director, Mineral Exploration Corporation Limited, has been selected to the post of Chairman and Managing Director, Bharat Coking Coal Ltd recommended by Public Enterprises Selection Board (PESB). Dr. Ranjit Rath is an alumni of IIT Bombay, IIT Kharagpur and Utkal University. Prior to this he was the General Manager with Engineers India Limited, New Delhi and was posted with Indian Strategic Petroleum Reserves Ltd., New Delhi, a SPV under the Ministry of Petroleum & Natural Gas. He has portfolio of multifarious roles spanning from strategy formulation, business development, upstream asset management and application of geosciences & exploration geology in several important projects including creation of Strategic Petroleum Reserves (SPRs) a first of its kind initiative in India entailin underground rock caverns for strategic storage of crude oil - An intervention towards energy security.

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COAL NEWS

COAL INDIA LTD FORGES AHEAD TOWARDS ENERGY EFFICIENCY

In a bid to reduce carbon footprint in its operational area, Coal India Ltd (CIL) has put special thrust on energy efficiency measures and is forging ahead with a series of measures to offset carbon emission in mining operation in all its coal producing companies. Apart from taking immediate action for efficient use of energyh, CIL has also drawn an ambitious 5-year plan of carbon offset in different fields of its operation.

Coal companies has several areas for implementing energy efficiency measures such as colonies, buildings, offices, industrial establishments, etc. apart from efficient Power Supply Management. However the major reduction in carbon emissin comes from various mining activities like Heavy Earth Moving Machines (HEMM), Transport, Ventilation, Pumping etc. With the help of its subsidiaries, CIL had been taking various energy conservation and efficiency measures over the years and is now moving ahead with emphasis on activities responsibile for more environment pollution. The major thrust is on replacing the huge fleet of HEMM equipment running eigher by CIL departmentally or contractually on diesel consumption with LNG. This will be a major breakthrough in not only cutting down cost, but will also reduce carbon emission. CIL has taken initiatives to go for Pilot Project in collaboration with GAIL in some mine sites of CIL before starting bulk use of LNG. GAIL will establish LNG storage & dispensing system, arrange transport of LNG from terminal to mine site & will arrange KIT and retrofitting. BEML will provide all technical assistance. The performance of Dumber and engine will be monitoring and studied during the entire pilot period in collaboration with Cummins. One of the Pilot Project at Bharatpur Opencast Mine of Mahanadi Coalfields Ltd. in Odisha will completed by the end of this year. A comprehensive model is being devised to convert maximum heavy vehicles on LNG in the coming years.

Another important addition will be the introduction of around 1500 E-Vehicle in all mining areas of CIL over a period of next five years. Around 200 E-Vehicle alone will be put in operation by the end of this year. Pumping of water in both opencast & underground mines is done on a large scale through orthodox equipment which results in more energy consumption. CIL will be introducing around 1700 energy efficient motors for pumps in all its mining operations. In its various establishments, CIL will be replacing around 5000 conventional ACs and other appliances by energy efficient Star rated appliances. Similarly, around 2.5 lakh LED lights wil be introduced in place of conventional lights to save energy. More than 1 lakh energy efficient super fans will be used in offices by replacing old ones. In colonies, around 2200 street lights will be put on auto timer to save energy. On implementation of aforementioned energy efficiency measures, CIL has envisaged to create a carbon offset of around 2.5 lakh tonnes in next five years. With active implementation on all the above fronts, CIL is committed to achieve a carbon offset of more than 60000 tonnes by end of this year which will be a major breakthrough.

CIL INKS PACT FOR PURCHASE OF 11 RUSSIAN ROPE SHOVELS FOR NEARLY RS 1,462 CR

CIL NSE said it has inked a pact for purchase of 11 Russian rope shovels for nearly Rs 1,462 crore. Electric rope shovels play a vital role in opencast mines for loading of material. "In an ongoing process of modernising its ageing heavy earth moving machinery fleet, Coal India Ltd (CIL) closed a deal valued at nearly Rs 1,462 crore for purchase of 11 20-cubic metre electric rope shovels," the PSU said in a statement. CIL tied up a contract with Iz-Kartex named after P.G.Korbokov Ltd, a Russian shovel manufacturing company for installation and commissioning of the shovels after it bagged the bid through participation in global competitive tender involving reverse auction. Contract has been concluded considering life cycle cost of equipment with likely consumables and spares for a period of eight years.

"This is the first major equipment procurement finalised in the ongoing fiscal so far. We are fast tracking our procurement process in a bid to strengthen our mining equipment and replace the aging machines," CIL said. The delivery of all the electric rope shovels would be concluded by September 2023. All the newly contracted eleven rope shovels would be pressed into use in the opencast (OC) projects of CIL arm Northern Coalfields Ltd (NCL). While three each of the machines would be put into operation in Nigahi, Dudhichua and Jayant one each would be used in Khadia and Amlorhi. With already nine such shovels operational in NCL the latest acquisition would swell their number to 20. "Each of the 20 Cu.M electric shovel is priced close to Rs 133 crore including the landed value of the equipment, spares and consumables for eight years," the statement said. The first machine will roll out in NCL in June next year and thereafter at least one each every 45 days. The complete delivery is scheduled by September 2023 as per the contract.

MINING NEWS

VEDANTA SAYS TOTAL PRODUCTION AT ZINC INTERNATIONAL RISES 62% IN THE FIRST QUARTER

Vedanta Ltd said that total production at Zinc International rose 62 per cent to 61,000 tonnes in the first quarter of the ongoing fiscal. "Total production for Q1 FY22 was 61,000 tonnes, higher by 62 per cent as compared to Q1 FY21 mainly due to higher Gamsberg production due to ramp up and COVID lockdown restrictions which were in place in Q1 FY21," Vedanta said. The company said that the cast metal aluminium production (including trial run) at its smelters in Jharsuguda and BALCO increased by 17 per cent to 5,49,000 tonnes in Q1 FY'22, over the year-ago period mainly due to ramp-up of pots. With regard to iron ore business it said that there was no production at Goa due to suspension of mining operations. "We continue to engage with the Government for resumption of mining operations," it said.

At Karnataka, production volume in Q1 FY'22 was 1.4 million tonnes, higher by 53 per cent as compared to Q1 FY'21 and 24 per cent sequentially. Last year Q1 had impact of nationwide COVID 19 lockdown. Pig iron production was at 2,02,000 tonnes in Q1 FY'22, higher by 85 per cent as compared to Q1 FY'21 and 29 percent sequentially, it said. Last year, the first quarter had impact of nationwide COVID 19 lockdown. One of the major furnaces, whose relining activity was completed in Q4 FY'21, is running stable. With regard to steel segment it said that total saleable production for Q1 FY'22 was 2,89,000 tonnes, higher by 8 per cent as compared to Q1 FY'21, Vedanta said.

NTPC TO SET UP INDIA'S SINGLE LARGEST SOLAR PARK AT RANN OF KUTCH

NTPC Renewable Energy Ltd, a 100% subsidiary of NTPC, has received the go-ahead from Ministry of New and Renewable Energy (MNRE) to set up 4750 MW renewable energy park at Rann of Kutch in Khavada, Gujarat. This will be India's largest solar park to be built by the largest power producer of the country. NTPC Renewable Energy Ltd (NTPC REL), has been given the go-ahead by MNRE on 12th July 2021 under Mode 8 (Ultra Mega Renewable Energy Power Park) of Solar Park Scheme. NTPC REL has plans to generate green hydrogen on a commercial scale from this park.

As a part of its green portfolio augmentation, NTPC Ltd, India's largest energy integrated company aims to build 60 GW Renewable Energy Capacity by 2032. Currently, the state owned power major has an installed capacity of 66 GW across 70 power projects with an additional 18 GW under construction. Recently NTPC has also commissioned India's largest Floating Solar of 10 MW (ac) on the reservoir of Simhadri Thermal Power Plant, Andhra Pradesh. An additional 15MW (ac) would be commissioned by August 2021. Further, a 100 MW Floating Solar Project on the reservoir of Ramagundam Thermal Power Plant, Telangana is in the advanced stage of implementation. Additionally, NTPC RE Ltd. has recently signed an MoU with UT, Ladakh and Ladakh Autonomous Hill Development Council (LAHDC) for the generation of green hydrogen and deployment on FCEV buses. The signing of the MoU was also market with the inauguration of NTPC's first solar installations in Leh in form of solar trees and a solar car port.

NALCO NET PROFIT AT 1300 CR IN FY21 COMPARED TO 138 CR IN FY20

According to the audited financial results, taken on record in the Board of Directors meeting held on June 28th, 2021, NALCO's Net Turnover has improved to Rs. 8869.29 crore in FY21 against Rs. 8425.75 crore in previous, while the Net Profit for FY21 has jumped by 840% to Rs. 1299.53 crore compared to Rs. 138 crore in FY20. The results were driven by strategic decisions on procurement, sales & marketing, favorable LME prices and augmented by strong operational performance by units despite restricted manpower deployment due to COVID guidelines. During the year 2020-21, NALCO has achieved the highest ever production of bauxite at 73.65 lakh tonnes. Similarly, the Company also achieved the highest-ever Aluminium metal export of 1.92 lakh tonnes, surpassing the decade old record of 1.46 lakh tonnes achieved in 2009-10. Further, the Company also achieved producton of 20.85 lakh tonnes of alumina hydrate in Refinery in Damanjodi and 4.18 lakh tonnes of Aluminium metal from smelter plant in Angul, Odisha. Shri Alok Tandon, Secretary to Govt. of India, Ministry of Mines has congratulated NALCO collective and Board of Directors for the impressive results. Appreciating the NALCO Management under the leadership of Shri Sridhar Patra, CMD, he also urged to continue the growth momentum in coming years.

TATA STEEL ARM SIGNS MOU WITH JINDAL STAINLESS FOR UTILISING CHROME ORE IN SUKINDA

Tata Steel Mining Limited (TSML) and Jindal Stainless Limited (JSL) signed a memorandum of understanding (MoU) to jointly utilise chrome ore locked up in the boundary between their mines located in Sukinda of Jajpur district, Odisha. “This is a very unique collaboration where JSL & TSML will derive maximum value from a joint mining effort. This effort will enhance the availability of ore in the region without any adverse environmental impact, as it's an already explored area," said Abhyuday Jindal, Managing Director, Jindal Stainless Limited. This would help the conservation of chromite ore which otherwise would have been left unmined forever, the companies said in a joint statement.

Both the companies would now initiate steps to get necessary statutory approvals from concerned authorities before jointly starting mining operations. "We are committed to sustainable mining and such a joint initiative will set examples for organizations especially in the mining industry to collaborate in the larger interest of mineral conservation and sustainability," said MC Thomas, Managing Director, Tata Steel Mining. The MoU was signed at Bhubaneswar by Mr M C Thomas, Managing Director, Tata Steel Mining Limited, and Mr Shashibhushan Upadhyay, Vice President (Projects), Jindal Stainless Limited. Mr Ratan Jindal, Chairman, Jindal Stainless Limited, Mr Abhyuday Jindal, Managing Director, Jindal Stainless Limited and other senior officials from both companies had joined virtually for this special occasion.

JSW STEEL TO INVEST RS 750 CRORE IN JSW PAINTS OVER THE NEXT THREE YEARS

JSW Steel plans to invest around Rs 750 crore in JSW Paints in tranches over the next three years. “In the first tranche of the strategic investment, the company will invest around Rs 300 crore and subscribe to equity shares equivalent to approximately 6.88% of the issued and paid-up equity capital of JSW Paints during Q2 of FY 22,” JSW Steel said while announcing its June quarter earnings. JSW Steel has been investing and expanding capacities in its coated business both organically as well as inorganically. Additional colour coating lines are being commissioned at Vasind, Kalmeshwar, Vijayanagar and Srinagar.

“The paint companies in India have limited expansion plans in coil coatings that are consumed by the company’s colour coating business. It is important for JSW Steel to strategically secure coil coating supplies for colour coated steel, which is a profitable downstream value-added product,” the company said. Many of the paint retailers can be potential retailers for JSW Steel coated products enhancing the retail footprint for steel products, the company said. “JSW Paints approached the company for an equity investment…Overall, this investment will be a very good strategic fit for JSW Steel - from jointly innovating, securing supplies, to having a strong competitive advantage,” said JSW Steel in a statement.

JSW Steel announced a CAPEX plan of Rs 25,115 crore for the next three years and it recently acquired Asian Colour Coated Ispat in October 2020 for Rs 1,550 crore. ”…The CAPEX will help us set up a state-of-the-art colour-coated facility in Jammu & Kashmir to support local demand and development in the state," said the group's chairman Sajjan Jindal in the company's latest annual report. JSW Paints, located in western India, has set up an R&D centre at Vasind and has been able to work closely with the JSW coated team to develop and introduce new and innovative products.

SHREE CEMENT PUNE PLANT TO COMMISSION IN SEPTEMBER

The western Indian foray of Shree Cement had been delayed due to COVID-19 disruptions but the company expects to commence commercial production from September, officials said. The completion of a clinker grinding unit of 3 million tonne per annum (MTPA) at Patas in Pune district of Maharashtra got delayed by a year because of COVID-19 and right of way issues. Investment in the plant, spread across 65.7 acres, was over Rs 600 crore and will get clinker from its group plant in Karnataka, they said. However, during the year 2020-21, the company had commissioned commercial operations of a clinker grinding unit having capacity of 3.0 MTPA at Athagarh Tehsil in Cuttack District of Odisha.

The company has about 43 million tonne capacity from four integrated plants and nine grinding units in a total of nine states. "We have able to commence Odisha project despite absence of plant OEM supplier due to disruptions but Maharashtra project got delayed. We expect to commence production in September," sources told. The company is setting-up up to 12000 Ton Per Day (TPD) brownfield clinkerisation unit at village Khapradih in Baloda Bazar district of Chhattisgarh. The project activities are running on track and the project is likely to be completed in the first half of FY 2022-23. The cement major was eyeing for 80 million tonne capacity by 2030. Company officials remained optimistic for the current fiscal with the GDP growth for FY 2021-22 projected to be in the higher single digit, the cement industry is also expected to achieve healthy growth.

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Assessment of Waste Dump Stability through Slope Monitoring at a Lead - Zinc Opencast Mine

A. G.Sangode* S. Kumbhakar* C. P.Verma* J. C.Jhanwar*

ABSTRACT

The assessment of the stability of waste dump at large lead- zinc opencast mine in the state of Rajasthan was carried out through slope monitoring. The mine has only external waste dump, which is very big in size spreading over an area of around 300 Ha. The maximum height of waste dump is 140 m with 7 benches each of 20 m height. With a view to assess any significant movements in the waste dump and its overall stability, slope monitoring was conducted with the help of Total Station and 3D Terrestrial Laser Scanner (TLS). From the analysis of monitoring data, changes in horizontal distance & elevation across most of the monitoring stations located on different sides/benches of the waste dump have mainly varied in the range of 0.0 - 1.0 cm & 0.0 - 2.5 cm respectively. This paper briefly presents the details of the study carried & the results of slope monitoring. The analysis of movement observations & visual observations of the waste dump made during the course of this study does not indicate any significant instability in different sides of the waste dump. The waste dump appeared to be stable from on an overall stability basis. However, some recommendations/ suggestions were made further improve the stability and to ensure the waste dump stability in future.

Keywords— waste dump, stability assessment, slope monitoring, total station, 3D laser scanner

INTRODUCTION

The main objective of this study is to assess the stability of waste dump at a large Lead- Zinc opencast mine situated in the state of Rajasthan and to recommend appropriate waste dumps stabilization measures. Waste dump slope monitoring forms an integral part of safety management in opencast mines. It provides information for detection of potential unstable ground and also helps in the assessment of the performance of design & stabilisation measures, which involves identifying any slope instability and/or failure mechanisms that develops with mining activity & progressive dumping. If the failure mechanisms are understood and the slopes are properly monitored, the risk of slope movement and the subsequent consequences can be considerably reduced. This allows for optimal mining conditions that are safe for mine personnel as well as working equipment. In order to achieve this, one has to find the most adequate monitoring solution that meets all the necessary requirements, which is often a challenge. In this mine, the stability of an external waste dump was monitored with the help of Total Station and scanning of waste dump area with 3D Terrestrial Laser Scanner. Only external waste dump of 140 m height spreading in an area of around 300 Ha was monitored along three sides i.e. south, west and north sides with nearly 25 monitoring stations/prisms on quarterly basis with the survey team of mine.

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GEOMINING DETAILS OF MINE & CHARECTERISTICS OF WASTE DUMP

A. The Location of Mine

The mine is located 15 km southeast of Gulabpura in Bhilwara District, Rajasthan. It forms a part of pre-Aravalli Banded Gneissic Complex consisting of gneisses, schists and intrusions of acidic and basic igneous rocks, which occupy predominantly the south-eastern plain of Ajmer and Bhilwara. It can be located in the Survey of India topo-sheet no. 45 K/9 & 45 K/13 and is bounded by Latitude - N 25° 50' 00" & Longitude - E 74° 44' 15". The mine is accessible by road from Bhilwara, which is the nearest major town on National Highway (NH) No. 79 approximately 70 km of the mine. A satellite view of the mine is shown in Fig. 1. The mine has external waste dump only.

Fig. 1: A satellite view of the lead-zinc mine along with waste dump (Source: Google map)

B. General Details of Waste Dump

The waste dump consists of the waste rocks excavated from the lead-zinc mine and mainly consists of Garnet-Biotite Sillimanite-Gneiss (GBSG), Pegmatite and Amphibolite. It is situated on the base rocks of GBSG. The bulk density, cohesion and the angle of internal friction of the waste dump spoil material are 19.4 KN/m3, 53 KPa and 23 degree respectively as shown in Table 1(CIMFR Final Report, 2012). The mine has only external waste dump, which is very big in size spreading over an area of around 300 Ha. The maximum height of waste dump is 140 m with 7 benches each of 20 m height. Typical view of the waste dump is shown in Fig. 2. The different cross-sections and a surface plan of the waste dump indicating various monitoring stations/prisms are shown in Fig. 3 & 4 respectively.

Table 1: Geotechnical parameters of dump material

Strength Parameters	Dump mass (drained condition)	Dump foundation (GBSG)
Cohesion (kPa)	53	245
Angle of internal friction (degree)	23	30
Bulk density (kN/m3)	19.4	27.7

Fig. 2 (a & b): A typical view of the Waste Dump

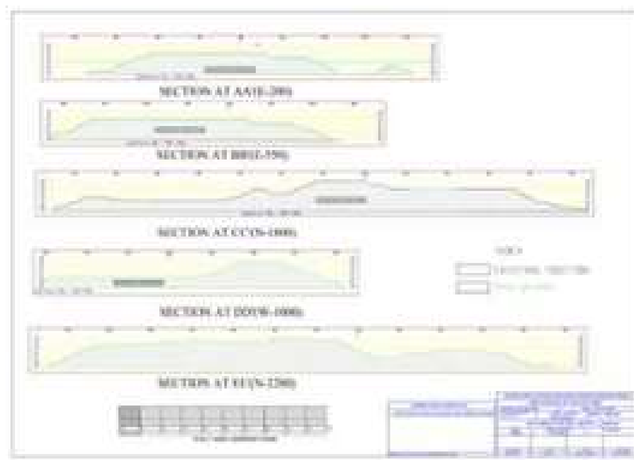

Fig. 3: Cross-section of waste dump (E-200, 550, 1800, 1000)

MONITORING OF STABILITY

The stability of waste dump was monitored mainly with the help of Total Station based monitoring. The survey team of the mine conducted the monitoring in the presence of CIMFR scientists on quarterly basis. For this purpose, reflector prisms were installed on alternate benches at an interval of around 200 m in the south, west & north-west sides of the waste dump.

Initially, the monitoring stations were located in south side only but later on more monitoring stations were added on other sides as well. One instrument station was located on the hangwall side of the pit to monitor the south side and two instrument stations were later installed on the North & North-West side of the waste dump to monitor the other sides of waste dump. The horizontal distance and elevation of each monitoring station/target was compared with the base/first observations of the respective stations to derive amount of change in the horizontal distance & elevation. The changes in horizontal distance & elevation of different monitoring stations as observed on different points at the year-end are shown in Tables 2 and depicted in Graph vide Figs. 5 & 6.

The changes in horizontal distance and elevation across most of the monitoring stations located on the different sides/benches of the waste dump have mainly varied from 0.0 to 1.0 cm & from 0.0 to 2.5 cm respectively (CIMFR Final Report, 2019).

Table 2: Results of final monitoring in the South, West and North sides of waste dump

Monitoring Stations	Change in Elevation(cm)			Change in Horizontal Distance(cm)		
	South Side	West side	North side	South Side	West side	North side
1	1.25	-0.01	0.0	-0.02	0.00	0.00
2	-3.78	1.46	0.0	0.56	-0.49	0.00
3	0.00	2.36	0.0	0.00	-0.71	0.00
4	1.87	2.53	0.0	0.36	-0.72	0.00
5	1.87	2.92	0.0	0.52	-0.17	0.00
6	-2.34	11.53	0.0	0.36	0.40	0.00
7	1.96	0.00	0.0	0.04	0.00	0.00
8	-2.99	0.00	-0.7	0.38	0.00	0.00
9	-0.14	0.00	0.0	-0.01	0.00	-0.03
10	-0.14	0.00	0.0	0.23	0.00	0.00
11	-0.51	0.00	0.0	-0.15	0.00	0.00
12	0.20	0.00	0.0	0.05	0.00	0.00
13	-1.36	0.69	0.0	-0.31	-0.49	0.00
14	-0.43	1.95	-0.6	0.02	-0.65	0.00
15	0.00	2.42	-0.6	0.00	-0.76	-0.04
16	0.55	1.23	-2.7	0.21	-1.57	-0.02
17	0.00	0.00	-2.5	0.00	0.00	-2.14
18	0.00	0.00	-3.5	0.00	0.00	-1.17
19	-2.99	0.00	-2.7	0.22	0.00	-1.69
20	3.11	0.00	-0.8	-0.03	0.00	-1.59
21	-4.77	0.00	-1.4	0.18	0.00	-2.29
22	-6.42	0.00	-0.5	-0.59	0.00	-1.11
23	-4.43	0.00	0.0	0.34	0.00	-1.20
24	-2.44	0.00	0.0	-0.01	0.00	0.00
25	-0.58	0.00	0.0	-0.93	0.00	0.07

Fig. 4: A surface plan of the waste dump indicating monitoring stations

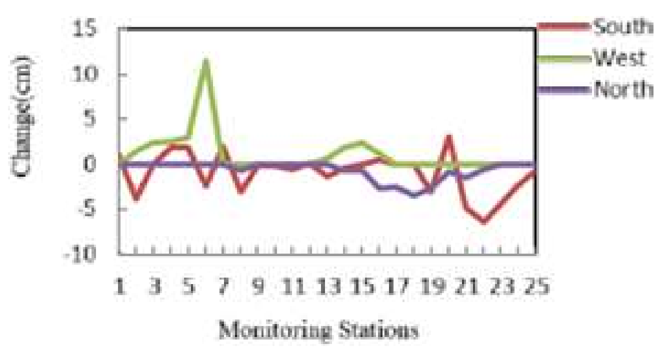

Fig. 5: Change in elevation of different points in south, west and north sides of waste dump

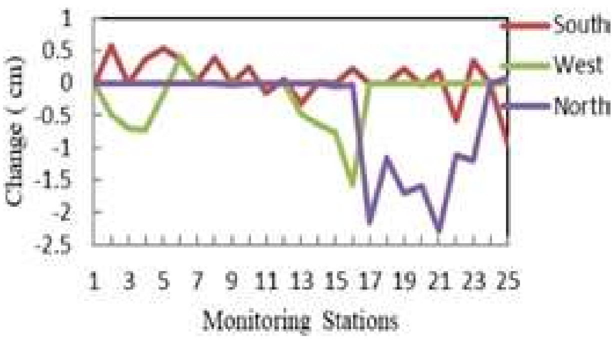

Fig. 6: Change in horizontal distance of different points in south, west and north sides of waste dump

The analysis of movement observations and visual observations of the waste dump made during the course of this study does not indicate any significant instability in different sides of the waste dump and indicate an overall stability of the waste dump. The dump slope monitoring is carried out with the help of Total Station & Terrestrial Laser Scanner as shown in Fig.7.Three-dimensional (3D) Laser scanner data were analysed for change detection by ATLAScan software as shown in Fig.8. It shows insignificant change in slope profile.

Fig. 7: Monitoring observations with Total Station &3D Terrestrial Laser Scanner

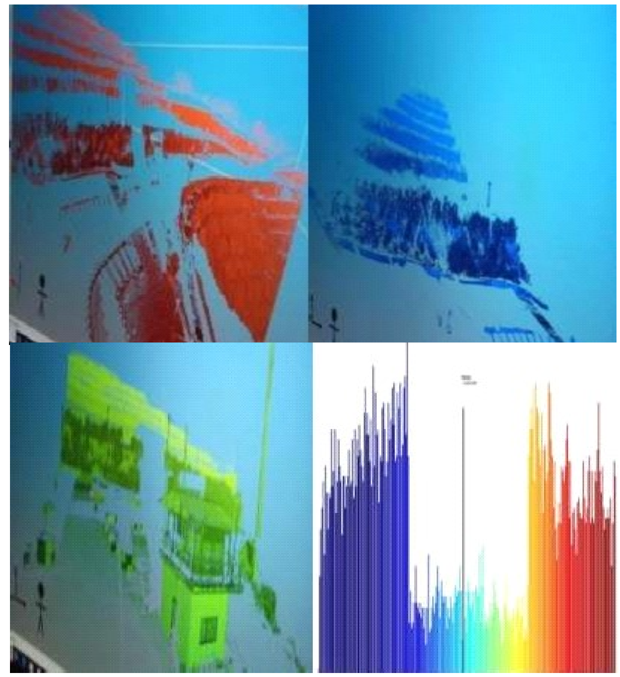

Fig. 8: Processed scanned images and inspection report

SUGGESTIONS/RECOMMENDATIONS

It is suggested that systematic slope monitoring be implemented for all the sides of waste dump and accordingly, monitoring stations at an interval of around 200-300 m be installed on alternate benches on a staggered pattern on East, North-East & SE sides also.

The application of geotextiles or any other suitable means be implemented to establish vegetation cover on waste dump bench slope surfaces to protect dump slopes against erosion due to wind & water and to improve its stability. Water should not be allowed to accumulate on the bench floors & on top of the dump. Appropriate drainage measures be put in place in the form of drains on every bench connecting to main garland drain at the bottom level. It is essential that these drains be kept clear of silt and debris.

It was suggested that gullies/voids formed, if any due to water induced erosion be repaired through proper dozing of waste material. Additional heap of waste material should not be left on the benches. It should be cleaned and the gradient of the bench should be maintained so as to ensure smooth flow of rain water to lower level in a planned way.

The systematic monitoring of waste dump stability should be continued and the movement observations be scientifically analyzed to evaluate any potential signs of instability & to implement appropriate corrective measures. It was also suggested that the waste dump be thoroughly inspected on a regular basis especially during the monsoon & post monsoon period to identify any indications of instability including the development of tension cracks anywhere on the waste dump surface. In the case of tension crack, it must be properly filled with waste material and should be monitoring for its further progression.

CONCLUSION

The external waste dump is very big in size spreading in an area of around 300 Ha. It has a maximum height of 140 m with 7 benches each of 20 m height. It mainly consists of Garnet- Biotite sillimanite-Gneiss (GBSG), Pegmatite and Amphibolite & is situated on the base rocks of GBSG. The stability of this waste dump was monitored with the help of a Total Station& 3D Laser Scanner. The monitoring observations of Total station were analysed on quarterly basis & also on collective basis at the end of fourth quarter. The changes in horizontal distance & elevation across most of the monitoring stations located on different sides/benches of the waste dump have mainly varied in the range of 0.0 - 1.0 & 0.0 - 2.5 cm respectively. The analysis of movement observations & visual observations of the waste dump made during the course of this study does not indicate any significant instability in different sides of the waste dump. The waste dump appeared to be stable from on an overall stability basis. However, some recommendations/suggestions were made to improve the drainage, to control the water & wind induced erosion with a view to further improve the stability and to ensure the waste dump stability in future. Further, it was suggested that systematic monitoring of waste dump be continued for all the sides of waste dump and the movement observations be scientifically analyzed to evaluate any potential signs of instability & to implement appropriate corrective measures.

ACKNOWLEDGEMENT

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Model Development to Study the Impact of Tunnelling Near Coal Mining Areas

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ABSTRACT

Most of the coal mine areas near the cities are under-utilized because of ongoing extraction of coal. With the detailed study of ground behaviour, this space can also be utilized for transportation purposes such as roadways, railways etc. In urban areas, mostly partial extraction methods are used to extract the coal avoiding the trough and sinkhole subsidence. For this, the detailed modeling is to be done before and after the excavation of the tunnel near the working coal mine areas. The prepared model is analyzed for the stresses which will exceed their elastic state. The location of the stresses is noted and sufficient control measures are to be adopted. The main problems which are encountered in the tunnel are discontinuities, underground water and gas emissions from the coal mines. This paper emphasizes on the numerical modeling of the tunnel and coal seam which is extracted partially.

Keywords—Partial Extraction Method, Numerical Modeling

INTRODUCTION

Due to increase in the population in urban areas, there is a need to increase the transportation of people and goods. For this, underground tunnel is the best option in urban areas. When the area belongs to Coal mining, then there is a need to study the performance of the ground surface and surroundings of the coal seam. The soil or rocks are in equilibrium state at rest. When the excavation or underground opening is made, the equilibrium of the surrounding rock mass is disturbed causing the stresses to redistribute around the opening. In urban areas, mostly partial extraction methods are used to extract the coal because the structure will be more stable and there will be less settlement on the surface when compared with the full face excavation methods of coal and therefore avoiding the trough and sinkhole subsidence. The partial extraction methods are Non-effective width (NEW), Chess Board, Goaf Pillar, wide and stall, splitting of pillar with stowing, splitting of pillar with side bolting and Harmonic Mining (Lokhande et al., 2005).

The depth between the tunnel and the working coal seam also plays a prominent role in the stabilization of structure. If the distance is less, it may result in sinkhole subsidence. The minimum distance should be 3 times the diameter of the tunnel. After the construction of the tunnel, when the coal seam is extracted completely using partial extraction methods, the performance of the ground needs to be monitored otherwise the tunnel may collapse into the coal seam whenever there is a stress redistribution or heavy water inflow into the tunnel. The parameters such as geological discontinuities, underground water and gas emissions plays a major role in deciding the whether the rock will withhold the tunnel or not. This paper emphasizes on the numerical modeling of the tunnel and coal seam on the basis of geometrical and geological data. This paper also presents the difference of ground reaction before and after the modeling of the tunnel.

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GEOTECHNICAL AND GEOLOGICAL PROBLEMS

For designing the tunnel, the main parameters which create the problems for the stability of the structure are geological discontinuities, underground water, gas emissions and others.

A. Geological Discontinuities

Mostly design the structure such that there should not be any major geological discontinuities otherwise, the stability of the structure will deteriorate. If there are any discontinuities within the designed structure, then there is a need to study the effect of the discontinuities in the surrounding strata. Here geological discontinuities are joints, faults, fractures etc. Generally these are due to the release of tensile stresses of the surrounding rock. In this paper, continuum modeling is considered (assuming no major geological discontinuities) avoiding the minor geological discontinuities.

B. Underground Water

The groundwater is the biggest problem while designing the underground structure. If there is a heavy ground water inrush, then the pore water pressure increases resulting in breaking the bonds of the soil or rock which ultimately leads to the crack development and causing instability to the designed structure. When the groundwater encounters geological discontinuities, the water tends to widen the discontinuity because of high pressure and causing the structure to collapse. The groundwater becomes problematic during construction of the tunnel. The only way to escape this situation is to drain the water using drain holes, if it becomes the difficult task to do breakage of the bonds of the soil or rock so, then grout the surrounding rock mass of 5-10 times the diameter of the tunnel using the water repellent material.

The selection of the grout depends on the quantity of water in rush into the tunnel.

C. Gas Emissions

Mine gases may be explosive (methane), toxic (Carbon Monoxide and hydrogen sulphide) or asphyixiant (blackdamp; which is oxygen depleted air). The migration pathways for gases are permeable rock formations, faults, joints, fractures, manmade cuttings, excavations, boreholes, adits, shaft. Mine gas emission may be a significant issue during the construction because they are normally inflammable and explosive. Therefore imposes a high risk to the people working on the site (Tong et al., 2013).

D. Others

Blasting also instigates cracks during their operation and it enhances the joints, fractures and faults to an extent. Residual voids such as galleries, shafts, adit, storage platforms with and without fill (gas, water and other materials) is a great danger to the tunnel structure.

PREPARATION OF THE MODEL

A. Model before excavating the tunnel

A Model is Prepared in RS2 9.0. This model consists of different layers which are soil, Sandy mudstone, Siltstone, Medium mudstone, Quartz sandstone, Coal, Argillaceous siltstone, Medium Sandstone, Silty fine sand rock. The material properties are given in Table.1. In this model, partial extraction method used for extracting the coal is wide and stall method. The Bore hole section of the model is given below:

Fig. 1: Borehole section

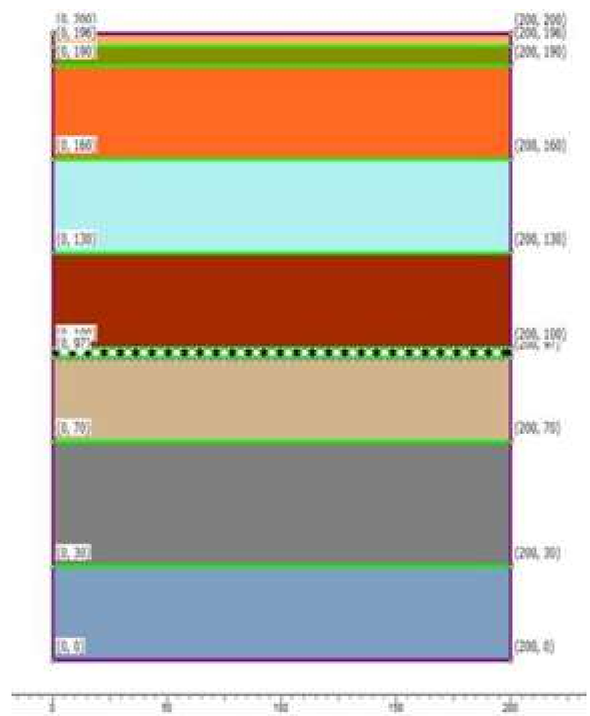

Fig. 3: Model before excavating the tunnel

B. Model after excavating the tunnel

The tunnel is located at 15 m from the ground surface. It is a horseshoe tunnel with radius of 3.125 m and tunnel width of 6.25 m. The area of the tunnel is approxiamtely 32 m^2.

Table 1: Material properties

Material Name	Unit Weight (MN/m^3)	Poisson's Ratio	Young's Modulus (MPa)	Material Type	Peak Tensile Strength (MPa)	Peak Friction Angle	Peak Cohesion (MPa)	Residual Tensile Strength (MPa)	Residual Friction Angle (°)	Residual Cohesion (MPa)	Porosity Value
Soil	0.0196	0.29	1500	Plastic	0.05	24	0.074	0	24	0.074	0.5
Sandy Mudstone	0.024	0.22	2000	Plastic	1.6	33	2.5	1.6	33	2.5	0.4
Siltstone	0.0252	0.25	1600	Plastic	1.6	28	4.5	1.6	28	4.5	0.3
Medium Mudstone	0.025	0.23	3100	Plastic	5.03	37	10.1	5.03	37	10.1	0.35
Quartz Sandstone	0.0267	0.24	3730	Plastic	2.3	41	11	2.3	41	11	0.2
Coal	0.0137	0.23	1200	Plastic	1.1	20	0.8	1.1	20	0.8	0.25
Argillaceous Siltstone	0.0245	0.16	2500	Plastic	1.8	30	5.66	1.8	30	5.66	0.25
Medium Sandstone	0.0254	0.134	2200	Plastic	5.14	40	8.5	5.14	40	8.5	0.15
Silty Fine Sand Rock	0.025	0.14	1500	Plastic	3.12	33	5.5	3.12	33	5.5	0.25

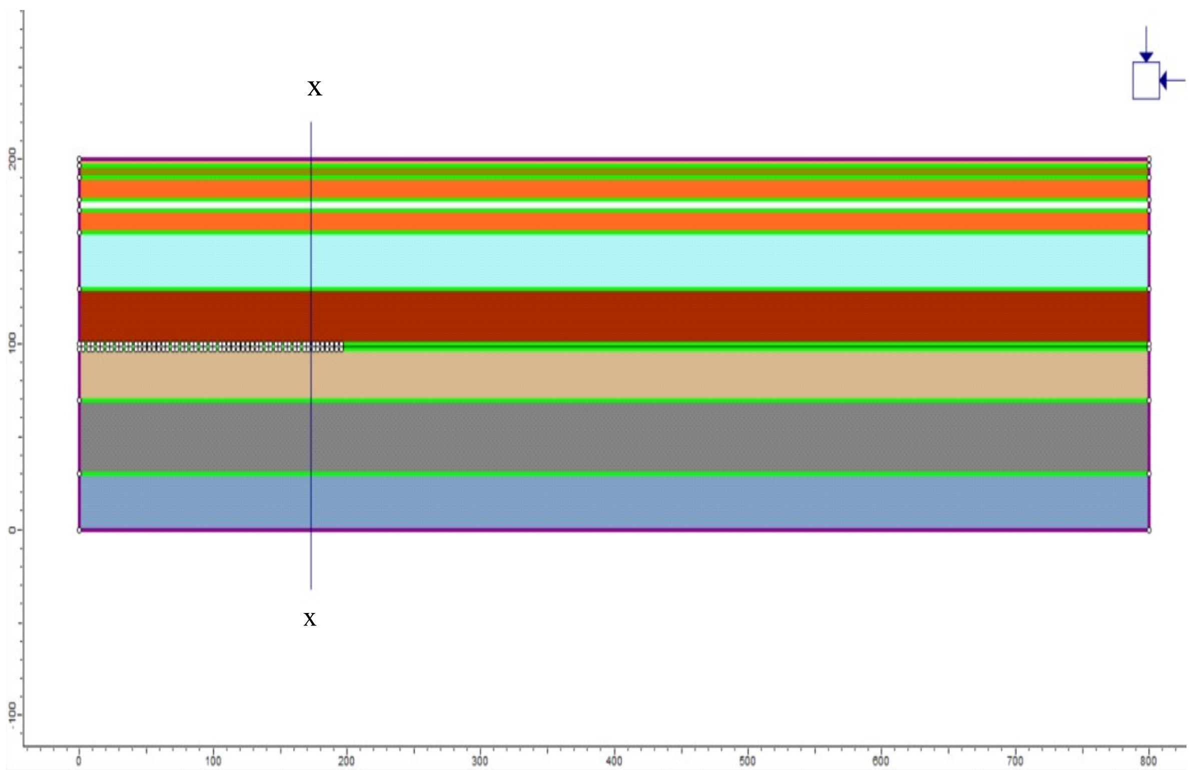

Fig. 2: Model in Longitudinal direction

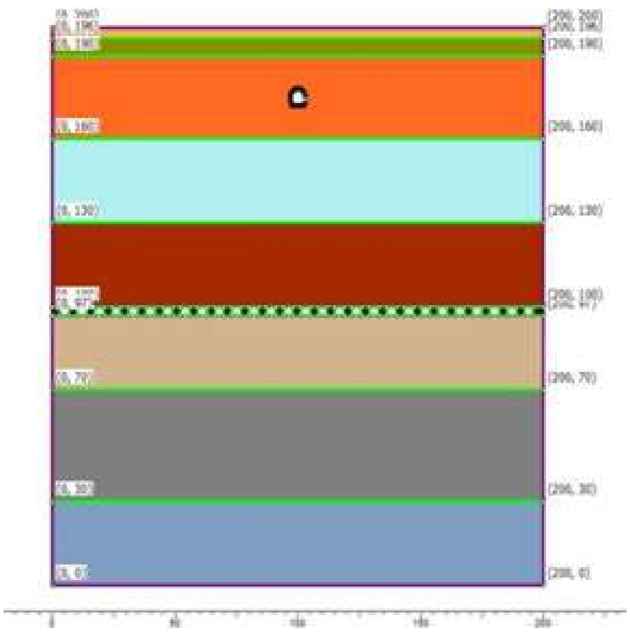

Fig. 4: Model after excavating the tunnel

RESULTS

The main Problem near the coal mines is redistribution of stresses. Due to this, settlement or subsidence on the surface, volumetric strains, stresses etc will change. This paper emphasizes on vertical displacement and stresses.

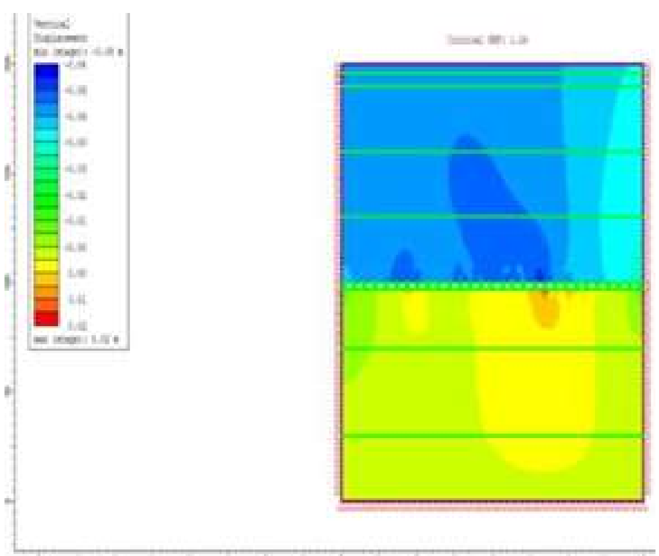

Fig. 5: Vertical displacement of the model before excavating the tunnel

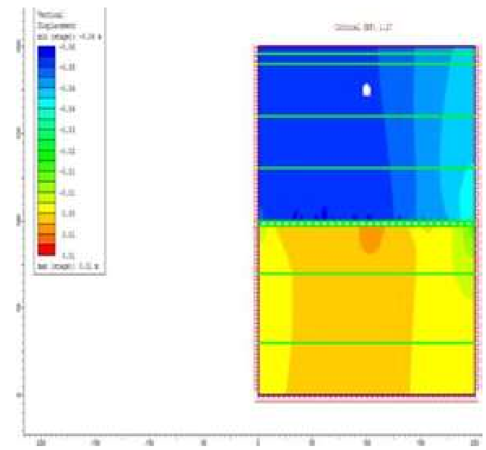

Fig. 6: Vertical displacement of the model after excavating the tunnel

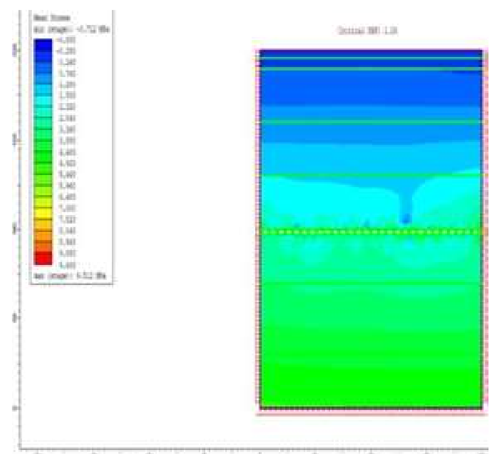

Fig. 7: Mean stresses before excavating the tunnel

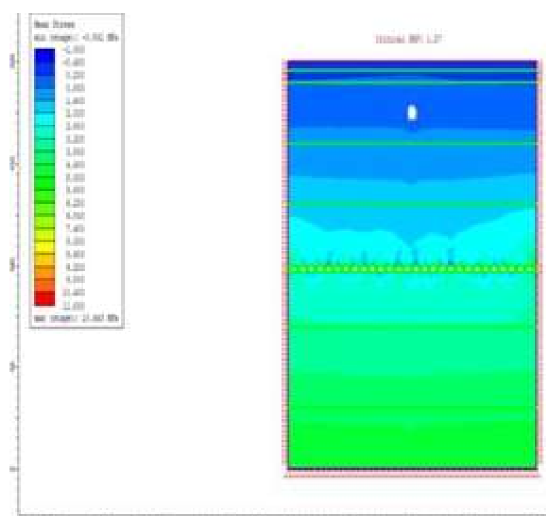

Fig. 8: Mean stresses after excavating the tunnel

The settlement and mean stresses are slightly increased after excavating the tunnel when compared with before. Here there are trivial changes in the settlement and mean stresses. Even the strength reduction factor remains almost similar. So, the structure may not have any specific problems but however when working in real situations some problems may arise because the ground strata is unpredictable (not same) even at small distances. If any problem encounters, then the following control measures are to be followed:

CONTROL MEASURES

A. If groundwater is the problem then,

- ☞ De-watering or controlled Pre-drainage.
- ☞ Waterproof grouting should be done in the surroundings of the tunnel.
- ☞ Drain Holes and Curtain grouting from the tunnel face is to be employed.

B. If Voids, joints are the problem then,

- ☞ Foam grouting.
- ☞ Lining should be reinforced by increasing reinforcement percentage.

C. If soft strata is problem then,

- ☞ Forepoling should be done.

D. If subsidence is the problem then,

- ☞ Backing filling with the help of sand or other waste materials in the partially extracted areas. Curtain grouting is commonly required to prevent the potential sinkhole development.

CONCLUSIONS

To construct a tunnel near the working coal mine areas, the complete data of lithology and geometry of the extracted and extracting coal seams, goaf areas, ground water table, discontinuities, gas emissions and others should be available in detail. It becomes expensive and difficult to construct a tunnel above the working coal seams because of geo-technical and geological problems. Here the distance is too large between the tunnel and the working coal seam, hence there are trivial changes in settlement and stresses. The monitoring instruments are to be installed in the extracted coal seam, inside the tunnel and at working face, to keep a check on ground or strata behaviour.

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Assessment of Energy Use at Underground Coal Mine – A Case Study

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ABSTRACT

In this paper, energy consumption pattern has been analysed for building of a benchmarking system for coal production with maximum energy efficiency and minimum specific energy consumption (energy consumption per unit of coal production) in Tandsi underground mine. In preliminary energy audit, comparison of specific energy consumption (kWH/Te), month wise energy consumption (kWH), annual average power factor & maximum demand (kVA) has been carried out for last three financial year 2016-17, 2017-18 & 2018-19 respectively. In methodology of audit, a power balance chart of different equipment used in Tandsi UG mine has been prepared as per the working hours of equipment and demand factor of different equipment considering productivity norms for Financial Year 2018-19 to analyse the share of energy consumption by different areas.
Keywords—Electrical Energy Audit, Preliminary Audit and Energy Bill

INTRODUCTION

Energy audit is a medium to assess energy consumption analysis in a specific organization or plant or industry. During energy audit, data is accumulated, colligated and explored the opportunities to reduce energy consumption per unit of product output and to minimize energy cost without affecting production and quality. Studies that performed energy audit and energy consumption pattern for different industries have been presented [Ibrik et al]. Realization of energy efficiency growth and minimize energy cost could be obtained through energy audit in large consuming industries such as pulp and paper mills, steel works, or iron foundry [Larsson et al, Klugman et al, Thollander et al]. Hence, energy audit can decrease the adverse effects due to enhanced energy prices and build the energy efficient system [Thollander et al].

Spain described that end-user group can be audited to find out the following facilities to save energy cost:

a) To cognize energy use of each type over a period of time.
b) To calculate energy cost.
c) To find out usage of energy.
d) explore theexist opportunities for reducing energy usage and / or cost.

Auditing is classified in to three types by Spain:

a) Preliminary Energy Auditing (PEA)
b) Energy Auditing (EA)
c) Technical Energy Audits (TA)

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Preliminary Energy Auditing (PEA) is to collect information about types of energy and its usage and to know the layout of the plant to see how all the procedures operate in organization or plant. During the Energy Auditing (EA), load profiles and flow of energy through system are investigated in elaborated manner to search out certain points, in which electrical energy can be conserved and also calculated electricity cost per unit product.

Technical issues such as metering, data systems, and SCADA (Supervisory Control and Data Acquisition) etc. are included during technical energy audits (TA). After completion of above three types of audits, all the suggestions, ideas, data and information are added together to find out the areas where problem arises or where the optimum result can be achieved with the minimum effort.

This paper is structured around four main axes detailed according to the following parts:

The first part defines the energy audit and its types & methodology. The second part is devoted to the preliminary electrical energy audit analysis of Tandsi underground coal mine. The third part will focus on assessing the energy performance of the most energy-consuming equipment.

ELECTRICAL ENERGY AUDIT: TYPES AND METHODOLOGY

As per the Energy Conservation Act, 2001, Energy Audit is defined as “the verification, monitoring and analysis of use of energy including submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce energy consumption [BEE - GOI]".

A. Type of Energy Audit

The type of Energy Audit to be performed depends on [BEE - GOI]:

- Function and type of industry
- Depth to which final audit is needed, and
- Potential and magnitude of cost reduction desired

Thus Energy Audit can be classified into the following two types.

1. Preliminary Audit
2. Detailed Audit

B. Benefits of Audit in Industrial Facilities

1. Financial benefits which contribute to reduction in operating costs or an increase in the profits of organization.
2. Operational benefits that assist the management of industrial site improve the comfort, safety and productivity.
3. Environmental benefits like reduction in CO_2 concentrations or other greenhouse gases and emissions [Report by European commission, director general of employment and social affairs].

C. Preliminary Energy Audit Methodology

The preliminary audit (alternatively called a simple audit, screening audit or walk-through audit) is the simplest and quickest type of audit. It involves minimal interviews with site- operating personnel, a brief review of facility utility bills and other operating data, and a walk-through of facility to become familiar with the building operation and to identify any glaring areas of energy waste or inefficiency.

The preliminary analysis helps the energy auditor to better understand the plant by providing a general picture of the plant energy use, operation, and energy losses. This effort provides enough information to undertake any necessary changes in the audit plan [Ali et al].

Preliminary energy audit is a relatively quick exercise to [BEE - GOI]:

- Establish energy consumption in the organization
- Estimate the scope for saving
- Identify the most likely (and the easiest areas for attention
- Identify immediate (especially no-/low- cost) improvements/ savings
- Set a 'reference point'
- Identify areas for more detailed study/ measurement
- Preliminary energy audit uses existing, or easily obtained data

CASE STUDY OF TANDSI UNDERGROUND COAL MINE

The preliminary electrical energy audit was carried out at Tandsi Underground Coal Mine where first author (Manoj Kumar) is working as Assistant Manager (Electrical & Mechanical). The Tandsi UG mine is located in the western part of the Pench-Kanhan valley coalfields. The mine is under administrative control of Western Coalfields Limited Kanhan Area.

A. Data Analysis

On field study of Tandsi UG mine, a set of historical data was received regarding coal production, energy consumption, power factor and maximum demand. We know that energy consumption should directly relate with coal production. Knowing this, we have calculated Specific Energy Consumption (SEC), which is Energy consumption per unit of production. The following results were presented based on data received from mine office.

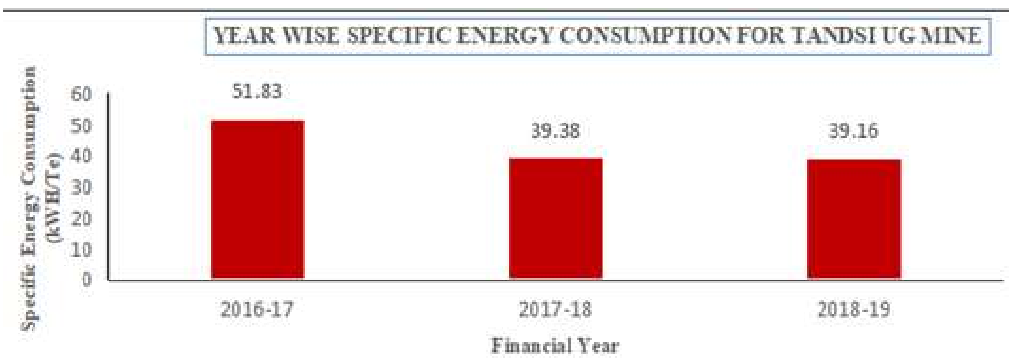

Fig. 1: Comparison of Specific Energy Consumption for last three financial years

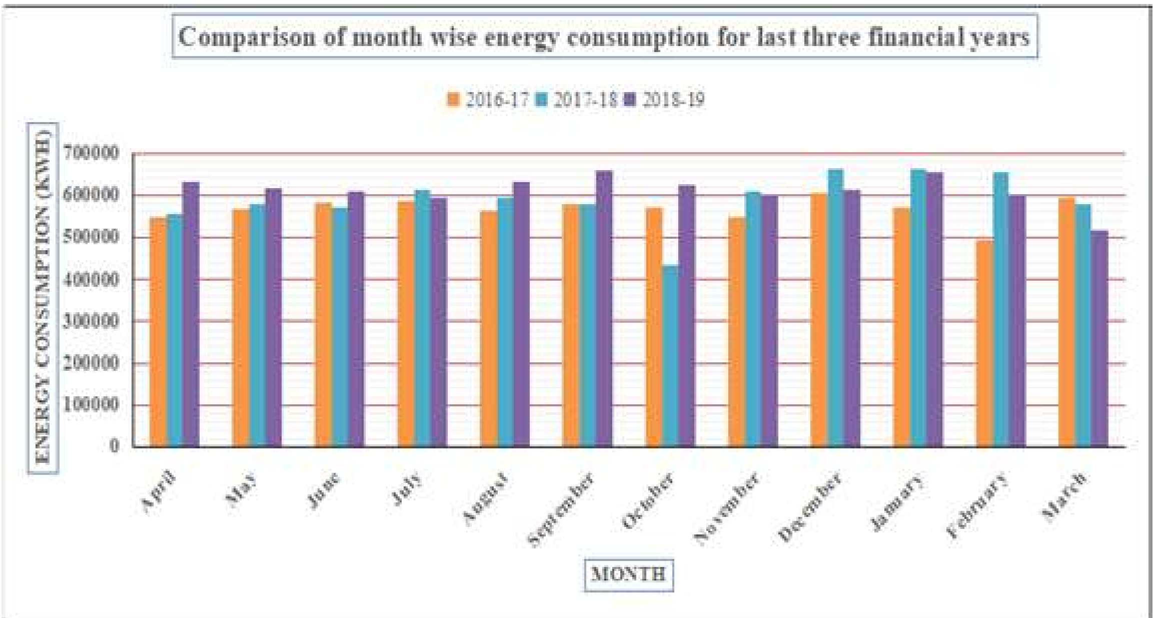

Fig. 2: Comparison of month wise energy consumption for last three financial years

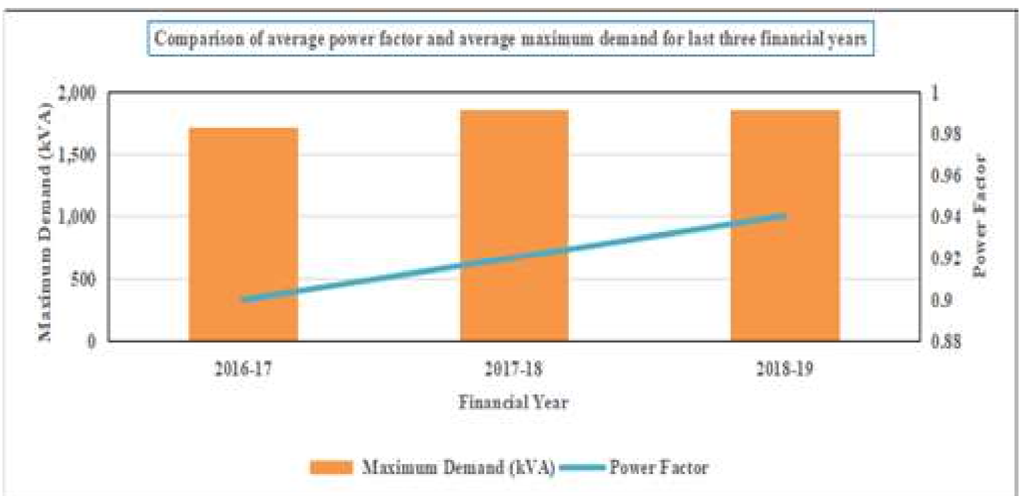

Fig. 3: Comparison of average power factor and average maximum demand for last three financial years

Industrial Feeder consists following sections:

- Ventilation Fan
- Face Equipment (LHD, Hydraulic Roof Bolting Machines and Drill Machines)
- Belt Conveyors for transportation of coal
- Man Riding Chair Car System for transportation of Man and Haulages for transportation of underground material
- Underground Pumping
- CHP
- Unit Workshop, Unit Store, Mine administrative office and Illumination (Surface & UG)

Non-industrial Feeder consists following Sections:

- Township
- Water Supply for township and Filter Plant

B. Different Areas of Energy Use

Tandsi UG mine like other coal project has different areas of energy uses. Major areas of energy uses are Ventilation Fan, Face Equipment, Coal transport, Pumping etc. besides mine administrative office, unit workshop, unit store and illumination (Surface & UG) are other areas of energy consumption.

To analyse share of energy consumption by different areas, a power balance chart of different equipment has been prepared as per the working hours of equipment and demand factor of different equipment considering productivity norms for Financial Year 2018-19. The major energy consuming centers and their share of energy consumption based on power balance chart is estimated as under:

CRITICAL ANALYSIS AND MAJOR FINDINGS

On the basis of data analysis, some of electrical results were drawn out and major findings during preliminary electrical energy audit were discussed with Tandsi underground coal mine. Those are –

A. Analysis of pumping consumption

1. One pump having high head loss causing high capacity motor power.
2. Motor of drive with suitable ratings has not been provided.
3. Old Motors need to be check for efficiency.
4. No inlet and outlet gauges provided.
5. To avoid stage pumping for reduction in energy consumption.

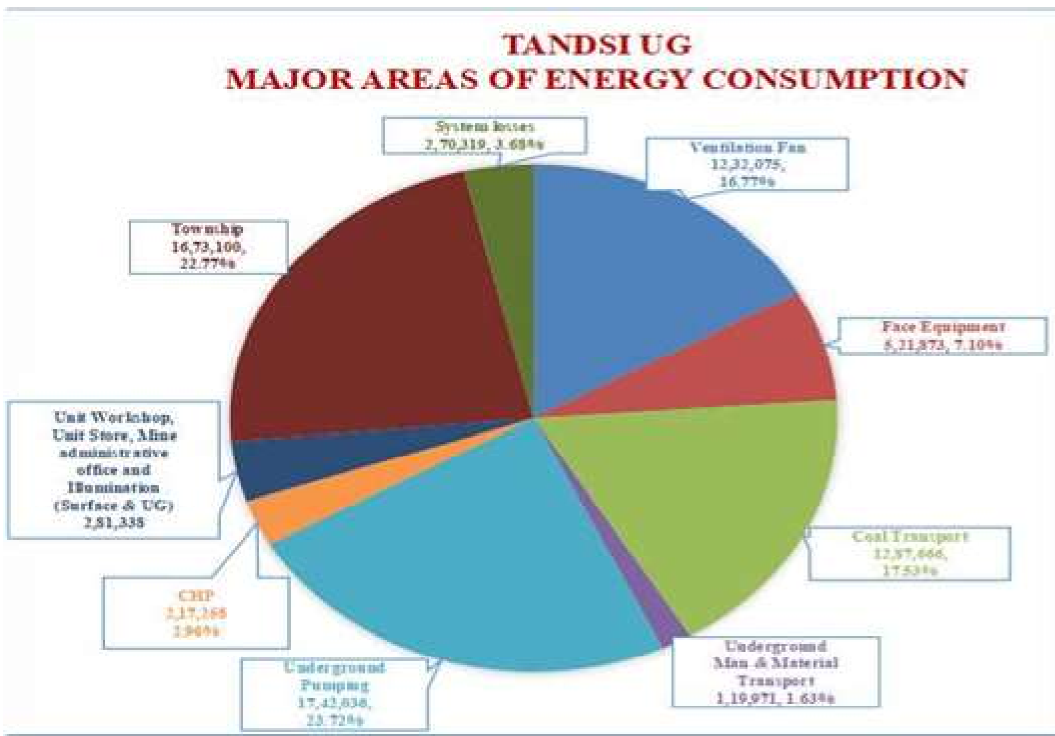

Fig. 4: A Pie-diagram showing percentage share of different areas on the basis of power balance chart

6. To dewater more quantity with same capacity for minimum utilization of energy
7. To install digital energy meters on every individual pumps

B. Analysis of Township consumption

1. To segregate of industrial (mine) and domestic (township) feeders
2. To install energy meters on every individual employee's quarter. Energy meters proposed shall be of digital type and suitable for recording energy consumption data as per TOD.

C. Analysis of energy consumption for coal transport

1. FLP Squirrel Cage induction motors are of older one, need to be changed with high energy efficient motors.
2. The drive of conveyor belt can be reduced from 90 kW to 55 kW/37 kW, 55 kW to 22 kW rating FLP motors.
3. Variable frequency drives can be used for belt conveyors

D. Energy Consumption for Ventilation Fan

1. Variable frequency drives can be used for speed control of ventilation fan during between Shift Time for 2 Hours.

2. Optimization techniques can be used for speed control of ventilation fan according to air flow, pressure and velocity.

3. To control the speed of induction motor drive ventilation fan through Mine Environment Condition (Humidity & Temperature of UG Tandsi Mine)

E. Energy Consumption for Unit Workshop, Unit Store, Mine administrative office and Illumination (Surface & UG)

1. To install energy digital energy meters at 415 V at following locations to measure lighting (illumination at surface) other office load:

i. Unit workshop, Unit Store etc.

ii. Mine Administrative Office

iii. Inclined Pit Office

2. To replace existing light sources from LED light sources

i. 45 W CFL should be replaced by 25-30 W LED bulbs

ii. 40 W tube lights should be replaced by 18 W tube lights

iii. 23 W CFL should be replaced by 5-8 W LED bulbs

iv. Rest of all the CFL, tube light, Flood light and incandescent bulbs (HPSV) should be replace with equivalent lumen output LED

F. General Analysis

1. Starting Matter of slip ring induction motor drive with resistance cut method for Man Riding Chair Car System transportation of man from surface to underground.

2. Reactive Power Compensation – Capacitor banks are using in main substation 33kV/3.3kV for improvement of power factor.

3. Cable losses not carried out at all.

4. Load factor is less than 50%

CONCLUSIONS

Present assessment regarding consumption of electrical energy was done at Tandsi underground coal mine as per standards provided by bureau of energy efficiency and data was critically analyzed to benchmark major power consuming sections within industry. Now detailed electrical energy audit is necessary to examine what is happening in existing electrical system of industry and what is to be done in order to improve system so that efficiency in each section of electrical operations can be achieved to conserve electrical energy.

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Study of Various Approaches Used for the Selection of Underground Stoping Methods in Hard Rock Mines

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ABSTRACT

Selection of the underground mining method in hard rock mines is one of the most important decisions that should beamed by mining professional. To carry out extraction from mineral body, selecting a proper underground stoping method is especially vital in terms of the techno-economic parameters. Many approaches do not include safety and the production efficiency. Over the years, a number of works have been carried out by various researchers to build up a systematic approach to help the engineers to make this selection. The approaches used include MCDM, AHP, FAHP, Nicholas Technique, etc. But, these approaches are mainly based on available databases and fail in inserting the intuitive feeling and engineering judgments of experienced engineers to the selection process. A study of different approaches has been presented in this paper.

Keywords—mining method selection, ahp, fahp, nicholas technique

INTRODUCTION

Underground methods for exploitation of mineral deposits are employed when the depth of the deposit, the stripping ratio of overburden to ore (or coal or stone), or both become prohibiting for surface exploitation. Once economic analysis points to underground methods, the choice of a proper mining method is very critical in underground hard rock mines as it directly affects the ore recovery and dilution and amount of development needed. The mining methods also decide the level of technology required and in turn affect the type of equipment required, cycle time and chronological succession of operations, production (tonnes per year) and the risks (financial and operational) involved.

Generally two or more feasible methods may be available as options for a mine planning engineer for a given deposit.

SIGNIFICANCE OF THE UNDERGROUND MINING METHOD SELECTION (MMS)

Proper method selection incorporates the flexibility to respond to changes significance of the underground mining method selection (MMS) in both internal and external conditions. Internal conditions are those that are dictated by the deposit itself, whereas external conditions are determined by outside considerations such as business or market requirements (Krantz and Scott, 1992).

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Earlier, selection of an extraction method was generally based on operating experience at a similar type of mine or on methods already in use in other parts of the deposit. This approach though may work satisfactorily in some cases; it cannot be followed for selection of optimal stoping methods for all situations.

TRADITIONAL APPROACHES DEVELOPED TOWARDS MINING METHOD SELECTION

Mining Method Selection (MMS) problem is one of the most critical and vital steps in designing an ore extraction system. The MMS problem has been widely studied in recent years. The approach to MMS problem can be classified into three divisions: qualitative methods such as Boshkov and Wright (1973), numerical ranking methods such as Nicholas (1993) and decision making methods. A comprehensive survey of literature on the first two groups can be found in Namin et al(2009).

The Established and conventional approaches for the selection of underground hard rock mining methods, several MMS/UMMS tools are developed through the years.

APPLICATION OF MULTI CRITERIA DECISION MAKING APPROACH TO THE PROBLEM OF MINING METHOD SELECTION

The traditional selection of method approaches used criteria's as the primarily, the physical parameters and rock strength characteristics. Therefore sometimes many mining methods may appear to be equally feasible. In order to further determine which methods are better suitable considering other important techno-economic factors many new and unconventional approaches were considered for the given problem. The approaches used for selection of mining method by researchers, academicians, practicing mining engineers includes

- AHP
- MCDA
- Fuzzy Logic including application of fuzzy sets and fuzzy numbers
- Fuzzy AHP
- Decision theory and operations research applications
- Nicholas theory
- Combination of two or more approaches

The process of solving MMS problem by decision making models can be divided into two stages:
Stage 1: Determining relative weight associated with each criterion.
Stage 2: Selecting the most suitable mining method with respect to all criteria.

Considering the above mentioned literature, realized that researchers have faced two difficulties in process of solving MMS problem: (i) calculation of relative weight associated with each criterion in the first stage,
(ii) uncertainty in judgment for decision makers in both stages.

LIMITATIONS OF THE PREVIOUS RESEARCH WORK

The power of the AHP approach lies in its ability to hierarchically structure a complex, multi-attribute problem into a comprehensive structure representing the decision maker's perception of the decision problem. This is emphasized in the application of AHP. Although AHP lends itself very well for the computer application, unless handled by a proficient person, it will be tedious and time consuming. Also the possibility of a rank reversal in AHP has not been examined by any of the authors. Due to the nature of comparisons for rankings, the addition of alternatives at the end of the process could cause the final rankings to flip or reverse.

The TOPSIS method is also implemented in one of the studies. The major weaknesses of the TOPSIS are not providing for weight elicitation, and consistency checking for judgments. However, AHP's employment has been significantly restrained by the human capacity for information processing, and thus the number seven plus or minus two would be the upper limit in comparison. From this viewpoint, TOPSIS alleviates the requirement of paired comparisons and the capacity limitation might not significantly dominate the process. Hence, it would be suitable for cases with a large number of attributes and alternatives, and especially handy for objective or quantitative data given.

The PROMETHEE method has some power in comparison with AHP method, such as: the PROMETHEE does not aggregate good scores on some criteria and bad scores on other criteria, it has less pair wise comparisons and it does not have the artificial limitation of the use of the 9-point scale for evaluation (Macharis, Springael, Berucker, Verbeke 2004). Very often the PROMETHEE method leads only to a partial classification of the alternatives which requires a modified version of the method which is not discussed in this study.

Nicholas technique is a simple decision making tool which is only used in order to select the mining method. This technique enjoys a simple weighting system, so the way of its application is not complicated. In addition, in order to assign the scores to mining alternatives, it uses a small range of crisp numbers. There are many reasons indicating that Nicholas technique is not able to select the most suitable alternative correctly. One of these reasons is the way of defining criteria and sub-criteria in Nicholas technique. Another reason indicating the inability of Nicholas technique in selecting the suitable mining alternative is that a change in the state of criteria accounts for a huge difference between their scores. Even in the modified version of Nicholas, in spite of using weighting factor, the deficiency use of an improper weighting system and the lack of determination of a weight for each criterion have not been completely eliminated. In the proposed approach, by the use of AHP and the control of inconsistency ratio of judgments, weighting process has been modified in comparison to Nicholas technique and problem such as obtaining equal final weights for each alternative has therefore been eliminated.

There is no single appropriate mining method for a deposit. Usually, two or more feasible methods are possible. Each method entails some inherent problems. Consequently, the optimal method is one that offers the least problems. Selection of an appropriate mining method is a complex task that requires consideration of many technical, economical, political, social, and historical factors. The appropriate mining method is the method which is technically feasible for the ore geometry and ground conditions, while also being a low-cost operation. In this paper, a various approaches for underground mining method selection are evaluated for the optimal underground mining method.

The approaches discussed except the one used by Amir Azadeh (2010) in the modified Nicholas Technique, do not include economic parameters for the consideration of selection of mining methods. Also there is no Indian perspective available for the use of the above approaches. Therefore the author aims to build an integrated approach with the inclusion of techno-economic parameters for the selection of the mining method with an Indian perspective.

Once economic analysis decided to underground methods, the selection of a proper mining procedure hinges mainly on finding the appropriate pattern of ground reinforcement, if necessary, or its absence; and designing the openings and their sequence of operation to conform to the spatial characteristics of the mineral deposit

The limitations of the existing MMS tool are:

1. Some of the approaches were neither adequate nor comprehensive to cover most important aspects of geological, technological and economic parameters in the process.
2. Some of the approaches were not a decision problem to be considered under the broad preview of decision sciences
3. Most of the approaches focused mainly of geological, spatial and parameters related to ore and rock strength.
4. Most importantly all these approaches lacked important parameter of selection criteria of the economics and the mining cost.
5. Also non-conventional methods of MCDM and related models have not used combination of two or more approachesin selection of underground mining method.

DEVELOPMENT OF MULTI CRITERIA DECISION MAKING TOOL FOR THE SELECTION OF MINING METHODS

With this background the authors have developed an integrated approach with the inclusion of Geo-Technical &Techno- Economic parameters for the selection of the mining method with an Indian perspective.

The tool developed is created with an aim of development of a model to select the most suitable and economical stoping method for hard rock mines considering the site specific geo-technical and prevailing techno-economic parameters.

The application of the MCDM in carried out by the authors in three levels (three tier) as given below:

Level (Tier) 1 – Application of Rank Sum method or Application of Rank Reversal Method for the determination of the associated weights of main eight geotechnical parameters identified for the purpose of this study.
Level (Tier) 2 – Application of Rank Sum method or Application of Rank Reversal Method for the determination of the weights of five sub-parameters under each respective main eight parameters is carried out.
Determination of the Stoping Index which is a weighted sum of the weights obtained under the level 1 and level 2.
Top three methods based on the stoping index are identified
Level (Tier) 3 – Economic assessment of top three underground mining methods with the application of the economic model.

CONCLUSION

- The selection of suitable stoping method for a given deposit primarily depends on eight number of geo-technical factors – Ore strength, Wall Rock strength, Deposit shape, Deposit dip, Deposit thickness, Ore grade, Ore uniformity and Depth.

- The application of multi-criteria based decision making (MCDM) techniques is necessary in selecting suitable stoping methods for a given deposit as the selection process involves the interaction of several factors or criteria affecting such selection.

- Both the Rank Sum Method (RSM) and Rank Reciprocal Method (RRM), two MCDM techniques, may be applied effectively for selecting suitable stoping methods for a given deposit.

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Why India Still Needs the Dirty Fuel - Coal

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ABSTRACT

The Govt of India's "National Climate Action Plans, known in UN parlance as nationally determined contributions (NDCs), under the Paris Agreement set three major goals—increase the share of non-fossil fuels to 40% of the total electricity generation capacity, to reduce the emission intensity of the economy by 33 to 35% by 2030 from 2005 level, and to create additional carbon sink of 2.5 - 3 billion tonnes of CO2 equivalent through additional forest and tree cover."However, at present things do not look bright in India with regards to the above context. The infrastructure required for Renewal Energy is far from satisfactory due to the lack of huge Foreign Direct Investment etc. in this sector. Hence, the Indian economy and industries must fall back on the fossil fuel coal to meet its huge electricity demand though it has a huge potential for the Renewal Energy. The attempt of this paper is to investigate the problems faced by the energy sector, pollutions due to mining, present and future demand of coal etc. and the way forward by India to adhere to the Paris Agreement.

Keywords— Coal, Pollution, Electricity, Renewable, Supply, Demand

INTRODUCTION

For a very long time, the burning of fossil fuels has generated most of the energy required to drive our cars, power our businesses, and light our homes. Even today, oil, coal, and gas provide for about 80 percent of our energy needs.

And we're paying the price, using fossil fuels for energy has exacted an enormous toll on humanity and the environment—from air and water pollution to global warming and beyond and hence it's high time to move toward a clean energy future.

DEFINITIONS, OBJECTIVES, AND SCOPE

The Coal Industry is under the responsibility of Ministry of Coal, GOI for determining policies, strategies in respect of exploration, development of coal and lignite reserves, sanctioning of important projects of high value and for deciding all related issues. These essential functions are exercised through its public sector undertakings, namely Coal India Limited (CIL), Neyveli Lignite Corporation India Limited (NLCIL) and Singareni Collieries Company Limited (SCCL) besides the coal blocks which has been auctioned to private players and those allotted to State Govt organization for development and extraction.

A. Coal Defination

Coal is a sedimentary rock which is combustibly formed from ancient vegetation by coalification process. It generally consists of Carbon – 50 to 98%, Hydrogen – 3 to 13%, the balance being Oxygen, Nitrogen, Sulphur, and others.

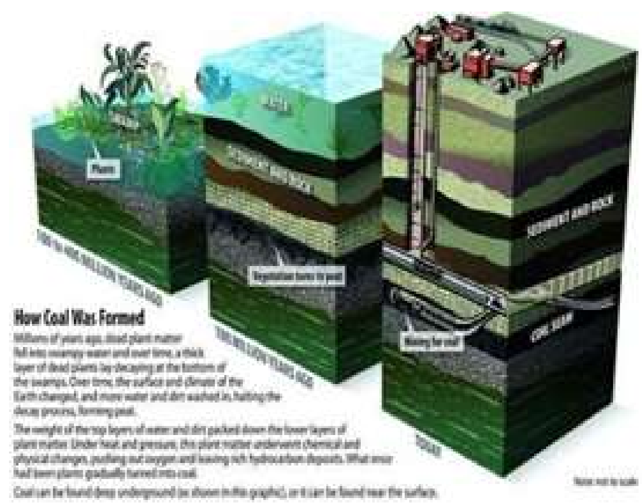

Fig. 1: Coal formation

B. Classification of Coal

Classification is done based on the sedimentation age, based on geological, geophysical and palynological data lignite coal has been assigned a Miocene period (24 - 5 million years ago) while Anthracite to Permian Age (290 - 250 million years ago).

C. Coal Mining in India

Coal Mining was first started in 1774 by East India Company in Raniganj Coalfields near Damodar River. All the private mines which were operating after the Independence was subsequently nationalized in the early 1970s.

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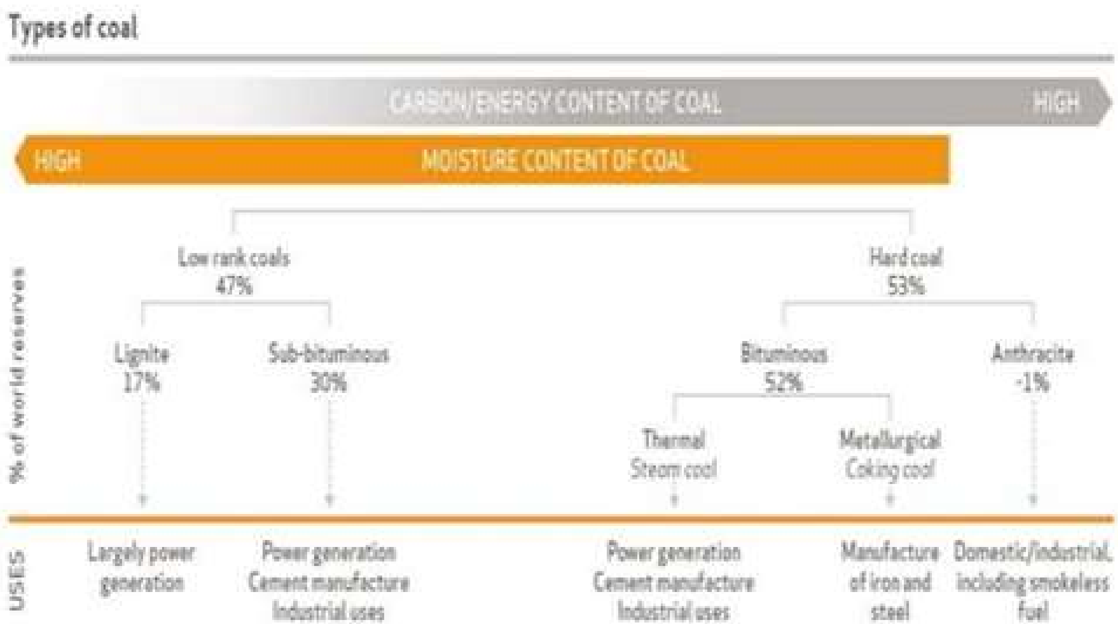

Fig. 2: Classification of Coal

Coal is mined by two system – surface or 'opencast' mining and underground or 'deep' mining. The system of mining method is technically determined by the geology, depth of the coal deposit, and the mode of entry. In India Opencast Mining is generally done from 0 – 300 meters depth whereas Underground Mining from 300 – 1500 meters depth.

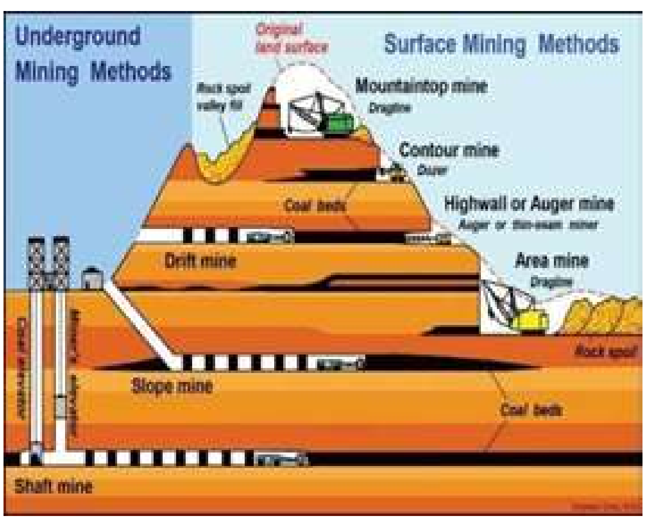

Fig. 3: Surface and underground mining

OBJECTIVES

Objectives are to go into an in-depth analysis of varies pollutions from Coal Industries, hazards, understanding the implementations of India's and World's Environment Policies, present and future demand and supply of Coal in India, present and future Power Demand Scenario, the future scope of Renewable Energy, etc.

RESEARCH QUESTIONS EXPECTED TO BE ADDRESSED

A. Pollutions and environmental effects due to coal industries in India

Air Pollution

As per the Air (Prevention and Control of Pollution) Act, 1981 "air pollutant means any solid, liquid or gaseous substance (including noise) present in the atmosphere in such concentration as may be or tend to be injurious to human beings or other living creatures or plants or property or environment; and air pollution means the presence in the atmosphere of any air pollutant."

In the coal mines the significant sources of air pollution are due to drilling and blasting operations in underground and opencast mines, coal fires due to spontaneous heating, heavy dumpers plying on haul roads, loading/ unloading of coal from mines and stockyard, wind erosion from overburden dumps, etc.

And the significant pollutants are oxides of N and S, fine coal dust, suspended particulate matter, respirable particulate matter, polyaromatic hydrocarbons (PAHs) and benzene soluble matter which causes diseases of lungs and skin such as asthma and chronic bronchitis, etc.

The soot and particulate matter released from coal mine fires decrease the visibility in the area. Also, coal fires volatilize a large number of potentially harmful heavy metals like arsenic, selenium, mercury, lead, sulphur, and fluorine. These could condense on dust particles and get inhaled or ingested by the local people, or they could gain entry to local water bodies and thus enter the food chain, causing severe diseases.

Heavy metals, along with PAHs, can cause many ill effects on health like cancer, neurotoxicity, fluorosis, cardiotoxicity, immunotoxicity, arsenicosis, CO poisoning, etc.

Fig.4: Coal dust pollution

Water Pollution

As per the Water (Prevention and Control of Pollution) Act, 1974, "pollution means such contamination of water or such alteration of the physical, chemical or biological properties of water or such discharge of any sewage or trade effluent or of any other liquid, gaseous or solid substance into water (whether directly or indirectly) as may, or is likely to, create a nuisance or render such water harmful or injurious to public health or safety, or to domestic, commercial, industrial, agricultural or other legitimate uses, or to the life and health of animals or plants or of aquatic organisms."

The significant sources of water pollution in mines are from the drainage of mining sites, sediment runoff from the mining site, erosion from OB dumps and spoils heaps, leaking from tailing ponds/OB dumps, heated and heavy metals loaded effluents from coal industries and sewage effluents. Mine water discharged from underground mines has high hardness due

to dissolved sulphates and chlorides. Vast volumes of polluted water from underground mines are channeled into the nearby streamlets and rivers thus polluting it chemically.

Apart from actual mining activities, coal beneficiation and preparation plants also release a large number of water effluents in the river, which poses a threat to the aquatic ecosystem and prevailing biodiversity. Mining also affects groundwater. Continuous pumping out of mine water may lead to lowering of groundwater table in the region. Besides, potable water is scarce due to both increased demand and contamination. Some elements such as heavy metals, hardness, nitrite, conductivity, total dissolved solids (TDS) in the surface and groundwater exceed the defined qua

Fig.5: Water pollution due to mining

Soil Pollution

As per the Environment (Protection) Act, 1986, "Environment includes water, air and land and the inter-relationship which exists among and between water, air and land, and human beings, other living creatures, plants, microorganism and property; "Environmental pollutant" means any solid or gaseous substance present in such concentration as may be, or tend to be, injurious to environment; "Environmental pollution" means the presence in the environment of any environmental pollution"

Strip mining pollutes the soil as it involves removal of topsoil, dust generated from heavy machinery used in mines, wind erosion from overburden dumps, coal dumps, tailing ponds as this dust settles on nearby areas. The soil has poor texture, low organic matter, and exhibits change in nutrient content due to heavy metal toxicity, change in pH and electrical conductivity. Also, the soil above the fire areas is devoid of moisture and is baked, making it biologically sterile. The soil friendly organisms (bacteria, nematodes, earthworms, etc.) die under such harsh conditions, thus limiting the ability of the land to support vegetation. The existing vegetation also dries up and ultimately dies due to the lack of water and other nutrients.

Fig.6: Soil pollution due to mining

Noise Pollution

Noise is generated in the underground from running of ventilator fans, drilling machines, haulage, etc. While in the opencast mines, noise pollution is due to the operation of Heavy Earth Moving Machineries, deep drilling machines, heavy blasting (140 - 160 dBA), etc. Generally, the noise level varies from 80- 105 dBA. However, it increases due to poor maintenance of machines and surpasses the allowable limit of 90 dBA for 8 hours per day exposure. Results from noise survey conducted by DGMS of an underground coal mine is as shown below.

Table 1: Noise level in underground mines

Noise Level in Underground Coal Mines	
Location of Survey	Average Noise Level dBA
Near Shearer	96
Transfer Point	99
Tail End Belt Conveyor	89
Power Back Pump	91
Drive Head of Armoured Face Conveyor	96

Fig.7: Effects of noise pollution

Changes in Vegetation Pattern

In a coal mining area, vegetation is directly affected by both opencast mining and underground mining. Satellite data from Oceansat-2 OCM through Bhuvan portal of NRSC/ISRO facilitates the download of Normalized Difference Vegetation Index (NDVI) data of selected areas, offers help in quantifying the changes in vegetation pattern by giving a numerical indicator that uses the visible and near-infrared bands of the electromagnetic spectrum. This indicator is adopted to analyze remote sensing measurements and assess whether the target being observed contains live green vegetation or not. The NDVI images collected over a long period of any of the mining areas will show the drastic changes/degradation of vegetation in the selected region.

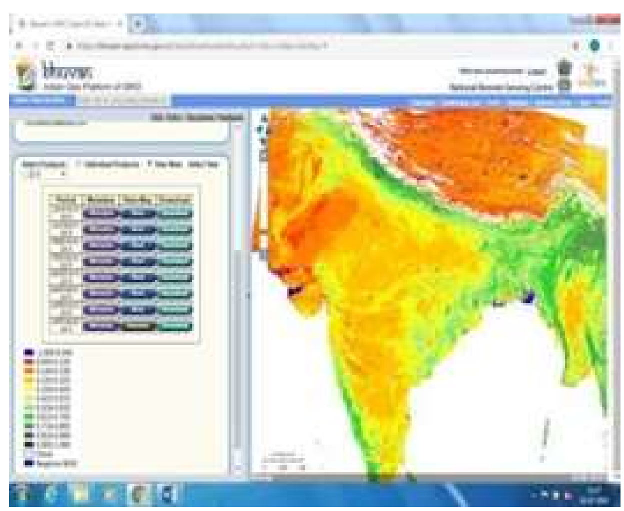

Fig.8: NRSC/ISRO Bhuvan Image

Changes in Topography

Variations in topography are derived due to the clearing of land for opencast mining, erecting infrastructure related to underground mining, dumping of OB in nearby areas, subsidence due to fires as there is volume loss when coal turns to ash.

Mining area faces significant subsidence due to underground mining. Variations in OB geology, the existence of a thick competent layer immediately above the coal bed, topography, structural features, presence of a groundwater aquifer above the coal, and geotechnical characteristics of the floor rock are significant factors responsible for subsidence. Generally, subsidence occurs after mining has ceased in an area. But sometimes it happens when a mine is still in function. In such a scenario, it may lead to the destruction of mining infrastructure, and a lot of mineable coal becomes locked and inaccessible due to subsidence. Subsidence also leads to damage to manmade infrastructures, such as houses, roads, pipelines, etc. In rare cases, subsidence could also lead to changes in the natural drainage pattern of the area.

Fig.9: Changes of Topography due to mining

Changes in Land Use/Land Cover

Changes in land-use are due to both opencast and underground mining and surface and subsurface coal fires. Since coal mining is a dynamic process, the areas regularly change with one land-use class changing to another. Quantification of these changes can be done using temporal change detection from ISRO satellite data.

Land Use and Land Cover (LULC) maps of different times throw valuable light on the changing LULC pattern. Earlier, LULC maps were prepared using field data and toposheets, but now remote sensing data is 995 Special Publication, J of EG October 2015 widely used because of its ease of availability and periodic and synoptic coverage of an area.

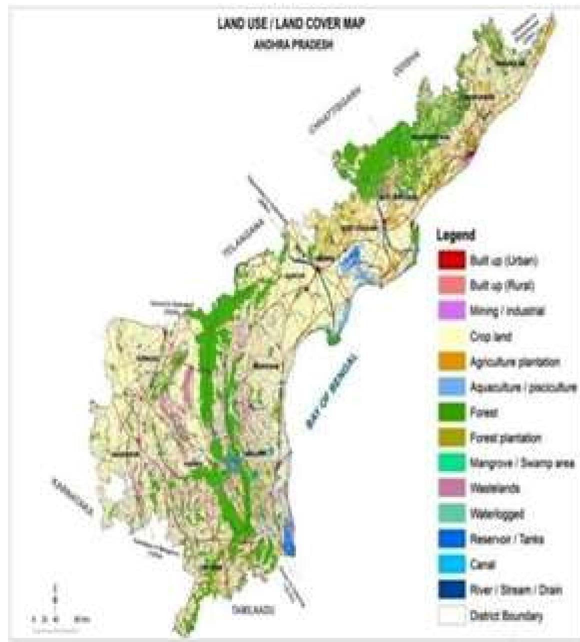

Fig.10: Land Use/Land Cover Image

Surface and Subsurface Fires

Coal fires cast a severe impact on the environment. Oxides of N and S react with volatile organic compounds (released due to coal fires) in the presence of sunlight to form smog. During rainfall, NOx and SOx combine with water droplets, and their pH is reduced, leading to acid rains. The soil above the fire areas is devoid of moisture and is baked. The existing vegetation also dries up and ultimately dies due to the lack of water and other nutrients. Detecting the area covered and the extent of the fires may give estimates of the number of gaseous pollutants released into the atmosphere. And knowing the direction of propagation of fire will lead to the estimation of how much additional area would come under fire in a particular time period. This information could be beneficial to mine planners for planning strategies to how to control the spread. Landsat TM data which carries a thermal infrared band has been the most extensively used sensor for thermal anomaly detection of coal fires in general.

Fig.11: Fire in opencast mines

B.Present Environmental Policies and Statutory Regulations

Besides some of the Statutory Regulations which are applicable to all industries and those mentioned above, other statutory regulations that are more specific to the coal industries and updated, amended and monitored by the Ministry of Coal, MoEFCC, Director General of Mines Safety (DGMS), Coal Controller's Organization (CCO) from time to time are as follows.

1. The Coal Mine Regulation – 2017
2. The Mines Act – 1952
3. The Mine Rules – 1955
4. The Mine Rescue Rules – 1985
5. The Mine Vocational Training Rules 1966
6. The Explosive Act – 1884
7. The Explosive Rules – 2008
8. The Mine Closure Plan
9. Corporate Environment Responsibility 2018
10. Corporate Social Responsibility
11. Forest Rights Act of 2006
12. Forest Conservation Act of 1980
13. The Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013
14. The Mines and Minerals [(Development and Regulation)] Act, 1957
15. The Coal Mines (Special Provisions) Act, 2015.

C. Present and future status of Coal in India Coal Reserves

Proved Resources definition – Coal resources of an area within 200 m from a borehole point.

Indicated Resources definition –Resources occurring in the area between radii 200 m to 1000 m from a borehole point.

Inferred Resources definition - Resources occurring in the area between radii 1 km to 2 km from a borehole point.

India has now adopted the internationally accepted United Nations Framework Classification (UNFC) for resources coding based on the three factors of Economic, Feasibility, and Geological structures.

As on 1st April 2018, India has a total reserve of approx. 365 Billion Tonnes as shown below, the figures as on 1st April 2019 has not been updated yet.

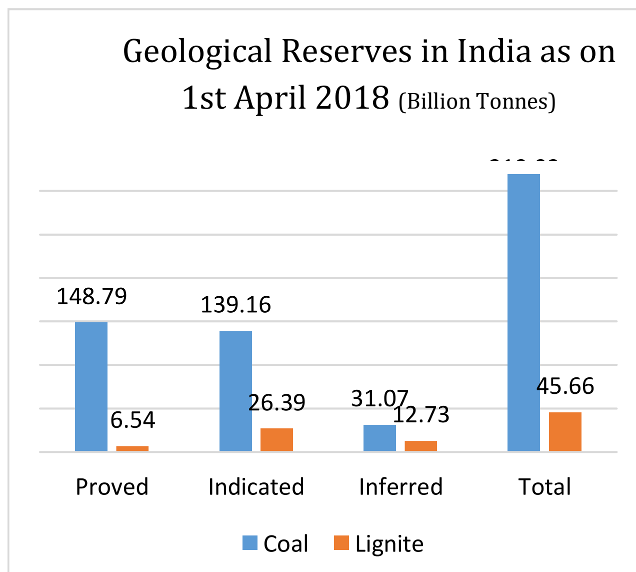

Fig.12: Geological Reserves of India

All India Production, Import & Requirement

As per the MoC, GoI and the Provisional Coal Statistics 2017_18, Coal Controller's Organization, the following graph shows the production of Coal & Lignite and import for the last five years. It can be seen from the figures that there is a huge requirement in the import of coal worth billions of dollars.

Fig.13: Production & Import of Coal in India

Future Demand Projections

Many expert committee and groups had been formed by the GoI from time to time to predict the future demands of Coal & Lignite with regards to the GDP growth. One of the latest studies called "Energizing India," a joint study being conducted in 2017 by the NITI Aayog, GoI and The Institute of Energy Economics, Japan. In this report, the demand of Coal & Lignite has been predicted at 727 Million Tonnes (2021-22) and 901 Million Tonnes (2025) with a rider that 175 GW of Energy supply will be provided from the Renewal Energy Supply which is to be installed and commissioned by 2021-22. In the latest report by BP Energy Outlook – 2019, "Insights from the Evolving transition scenario – India," it is reported that India will require approx. 917 Mtoe (2236 Million Tonnes) by the year 2040, out of which India will produce approx. 708 Mtoe (1729 Million Tonnes) and the rest approx. 510 Million Tonnes will be imported.

A tabulated formatted of various committee's demand projections are shown Table 2.

Supply and Import of Coal

As per the Kirit Parikh Committee Report (Integrated Energy Policy, Report of the Expert Committee, Planning Commission, GoI) published in August 2006, the tabulated format of the demand, supply and shortfall of the commercial energy requirement at 8% GDP growth for the year 2031-32 are shown in Figure 14.

From the above chart, we can conclude that the total import of coal ranges from approx. 72 Mtoe (175 Million Tonnes) to approx. 462 Mtoe (1127 Million Tonnes) when domestic production of coal during the year 2031-32 will be approx. 560 Mtoe (1366 Million Tonnes) with the assumption of 1 Mtoe = 0.41 Tonnes of Coal.

Table 2: Future demand in tabulated format

Demand Projection of Coal by different Agencies in Million Tons							
Source	Base Year	2016-17	2020-21	2021-22	2024-25	2025	2030
X Plan Working Group	2001-02	780		981	1126		
Coal Vision 2025, 7% GDP (TERI)	2006-07	782		992	1147		
Coal Vision 2025, 8% GDP (TERI)	2006-07	828		1079	1267		
India Hydrocarbon Vision 2025	1998-99		1118		1402	1483	
P&E Division, Planning Commission	2001	764	920	957			1417 (2031 -32)
Kirit Parikh Committee, 8% CAGR	2006	824		1131			2037 (2031 -32)
Energizing India (NITI Aayog and IEE, Japan	2017	Scenario with 175 GW installed capacity from RES by 2021-22		727		901 (2026-27)	
Coal Transition in India (TERI)	2010						1356-1469
BP Energy Outlook - 2019	2019	1034					2236 (2040 -41)

Ranges of Commercial Energy Requirement, Domestic Production and Imports for 8 percent Growth for year 2031-32

Fuel	Range of Requirement in Scenarios (R)	Assumed Domestic Production (P)	Range of Imports* (I)	Import (Percent) (I/R)
Oil (Mt)	350-486	35	315-451	90-93
Natural Gas (Mtoe) including CBM	100-197	100	0-97	0-49
Coal (Mtoe)	632-1022	560	72-462	11-45
TCPES	1351-1702	–	387-1010	29-59
*Range of imports is calculated across all scenarios as follows				
Lower bound = Minimum requirement - Maximum domestic production				
Upper bound = Maximum requirement - Minimum domestic production				

Fig.14: Kirit Parikh Committee Report

There is an increase from the present import level of 235.34 Million Tonnes (2018-19) to 1127 Million Tonnes (2031-32), a jump of approx. 379 % over 12 years.

However, the Govt of India is trying to reduce the import of coal by taking the following measures.

1. Source rationalization with part supply from higher-grade coal sources.
2. More coal from various sources including higher grade was offered through multiple types of eauction schemes particularly special forward e-auction for power consumers, not having Fuel Supply Agreement (FSA) with CIL sources.
3. The provisions of the SHAKTI policy of the Government of India for meeting the demand of various categories of power utilities are being implemented.
4. Supply of additional coal to power plants to meet the shortfall within the Annual Contracted Quantity (ACQ).
5. Implementation of Linkage auction for non- regulated sectors
6. Spot E-auction – For any Indian buyer (Consumers & Traders) suitable for short- term planning.
7. Exclusive E-auction — exclusively for the non-power consumers (including Captive Power Plant (CPPs)) suitable for medium- term planning.
8. Streamlining environment clearances & forestry clearances process to expedite operationalization of coal blocks.

D. Present and future requirement of electricity

As per the latest Central Electricity Authority Report of June 2019, the installed generation capacity of India is 357.88 GW out of which Coal & Lignite is 200.75 GW; Gas is 24.94 GW, Diesel is 0.64 GW, Nuclear 6.78 GW, Hydro 45.40 GW, and Renewable Energy is 79.37 GW.

The total corresponding projected values of the same for the year 2029-30 is 834.90 GW, out of which Coal & Lignite is 266.83 GW, Gas 24.35 GW, Diesel 3.4 GW, Nuclear 16.88 GW, Hydro 73.45 GW, and Renewable Energy is 450 GW as per CEA's Draft Report on Optimal Generation Capacity Mix 2029-30 published in Feb 2019. A graph of the same is as shown below.

Almost the same electricity demand has been predicted by TERI's report on "Transitions In Indian Electricity Sector 2017- 2030" where it states that "electricity demand is likely to increase from 1115 BU in 2015–16 to 1692 BU in 2022, 2509 BU in 2027, and 3175 BU in 2030."

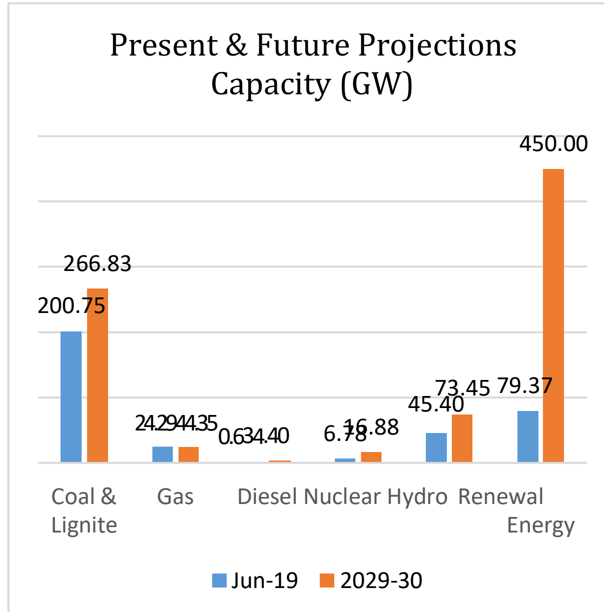

Fig.15: Present & Future Projections of Electricity

Also, as per the above-mentioned CEA's monthly June 2019 report, all India Coal Consumption has been increasing over the years as shown in the following graph and it will continue to grow as the projected installed capacity for Coal & Lignite for the year 2029- 30 is 266.83 GW as against the June 2019 figures of 200.75 GW.

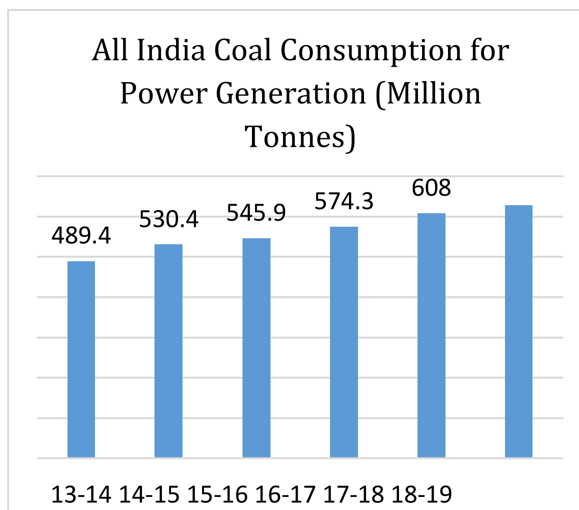

Fig.16: Coal Consumption for Power Generation

E. Present scope of Renewal Energy

The only way forward for India to produce clean energy under the Paris Agreement is, therefore, to focus more on Renewable Energy. The Govt of India's "National Climate Action Plans, known in UN parlance as nationally determined contributions (NDCs), under the Paris Agreement set three major goals— increase the share of non-fossil fuels to 40% of the total electricity generation capacity, to reduce the emission intensity of the economy by 33 to 35% by 2030 from 2005 level, and to create additional carbon sink of 2.5 - 3 billion tonnes of CO2 equivalent through additional forest and tree cover."

Some of the actions taken by the Govt of India to promote Renewable Energy are as follows.

1. Establishment of a separate ministry for promoting RE exclusively (i.e., Ministry of New & Renewable Energy)
2. A dedicated financial institution, Indian Renewable Energy Development Agency (IREDA) to cater to the needs of RE.
3. Setting a target of 175 GW RE capacity to be achieved by 2022.
4. Setting a separate Renewable Portfolio Standards (RPO) for DISCOMs and large consumers.
5. Separate RPO carves outs for solar farms.
6. Dedicated Inter-state transmission infrastructure.
7. Waiver if Interstate transmission tariffs for RE plants.
8. Adaption of the reverse auction for wind and solar capacity additions resulted in price discovery.
9. Managing off-taker risk in the context of the poor creditworthiness of DISCOMS
10. For central bided capacity and to provide additional comfort to investors, Central agencies such as NTPC and SECI to act as a counterparty.
11. Guarantee of payments to be made to investors by the MNRE.
12. Establishing Gigawatt range solar parks with supporting infrastructure plus for off- take arrangements for plug and play investments by the private sector.
13. Availability of accelerated depreciation for taxation purposes.
14. Must run status for Renewables in generation capacity.
15. Establishment of state-of-the-art Renewable Management Centers (REMC) with forecasting and full visibility of RE plants
16. Priority lending status for the RE sector.
17. Permitting Foreign Direct Investment (FDI) up to 100 percent under the automatic route.
18. Notification of standard bidding guidelines to enable distribution licensee to procure solar and wind power at competitive rates in a cost-effective manner.
19. Notification of standards for deployment of solar photovoltaic systems/devices
20. Launch of the new scheme for farmers, CPSU Phase II, and Solar Rooftop Phase II program.

As on 30th June 2019, a cumulative Renewable Energy capacity of approx. 80 GW has been installed as against the target of 175 GW by 2022. Besides that, date, renewable energy projects of 26.62 GW capacity were under various stages of implementation and 43.84 GW capacity under different stages of bidding.

As per the National Electricity Plan 2018, approximately 479 GW of total electricity generation capacity is estimated to be installed by the year 2022, including 175 GW from renewable energy sources.

India has come a long way with regards to Renewable Energy production since the end of the 6th Five Year Plan starting till June 2019, which is shown graphically as below. This is a substantial increase from 0% to 22% during this period.

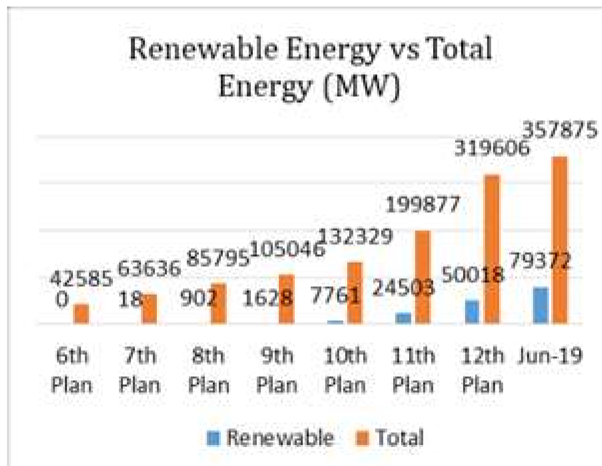

Fig.17: Renewable Energy vs Total Energy graph

Problems Faced by the Renewable Energy Sector

Some of the problems which are presently faced by the Renewable Energy Sector are as follows

1. Delay in payment by some Distribution Companies to renewable energy producers.
2. Delay in the adoption of the tariff arrived at through competitive bidding process by some of the State Electricity Regulatory Commissions.
3. India's target of 100 GW of solar capacity by 2022 and is still 72 GW short of it. To achieve the same India needs to invest $65 billion in the next four years. A significant part of it must be raised within the country, as the renewable sector could so far attract

foreign direct investment (FDI) worth only $7.5 billion in the last 18 years.

4. Issue of GST and the import duty on solar equipment are yet to be resolved entirely.
5. In the domestic manufacturing front, Solar Energy Corporation of India (SECI) to attract bids for the development of the Inter- state Transmission System (ISTS) connected Solar Photovoltaic (PV) Power Plant since May 2018 has been in vain.
6. Land acquisition for Renewable Farms.
7. Low PLF due to technology.

F. Future Scope of Renewable Energy

As mentioned earlier, Renewable Energy is the only way forward as per the Paris Agreement and as per CEA's "Draft Report on Optimal Generation Capacity Mix 2029-30" the target has been set at 450 GW from the present level of approx. 80 GW. Hence there is a vast scope for the development of Renewable Energy in India.

The estimated potential of Renewable Power in India as on 31.03.2018 is approx. 1096081 MW, out of which Wind power is 27.58%, Small Hydro Power 1.8%, Biomass Power 1.6%, Cogeneration-bagasse 0.46%, Waste to Energy 0.23% and Solar Energy is 68.33%.

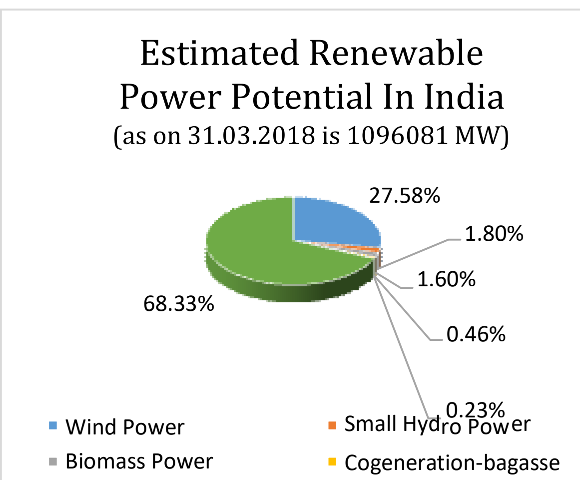

Fig.18: Renewable Power potential in India

CONCLUSIONS AND RECOMMENDATIONS

Even though from the above we can very much conclude that coal is a dirty fuel as the production of the same heavily pollutes the air, water, noise, landscape, topography etc. etc., However, the energy requirement infrastructure in India is not sufficient at present to be fulfilled by fuel sources other than coal even though we have the potential. Some of the highlights are as follows.

a) Supply of Coal – will vary from approx. 730 Million Tons from the year 18_19 to approx. 1370 Million Tons in the year 2031_32 as per the various committee reports mentioned above.
b) Demand of Coal – similarly, the demand will vary from approx. 970 Million Tons from the year 18_19 to an average of approx. 2000 Million Tons for the year 2031_32.
c) Import of Coal - varies from 220 Million Ton from the year 18_19 to approx. 550 Million Tons during the year 2031_32.
d) Environment Technology & Innovation – India is still not developed yet in comparison to the developed nations in terms of the technologies which are required for the prevention and control of many pollutions.
e) Regulatory Implementation – Even though India has different Environmental rules and regulations, the implementation of the same is abysmal due to the ignorance of the general mass of the people, unlike the developed countries.
f) Electricity Demand – will rise from 360 GW (June 2019) to approx. 840 GW (2029_30) out of which the Renewable Energy comprises only approx. 80 GW to 450 GW during the respective periods. However, this is with a rider that 175 GW of Energy supply will be provided from the Renewal Energy Supply which is to be installed and commissioned by 2021-22 which requires massive FDI.
g) Huge Investment Requirement – As mentioned above, India needs enormous Foreign Direct Investment for the development of Renewable Energy Projects, which at present looks very bleak due to the economic crisis.
h) Land Acquisition – is becoming a real problem for any projects and more so for Renewable Energy Projects due to the new Land Acquisition Act of 2013.
i) Clean Technology for Coal Mining – India does not have adequate clean technology for the mining of coal; however, some steps are being taken by the Govt of India in collaboration with South Africa, Australia, and other developed countries.

Given the above conclusion, all stakeholders directly or indirectly involved in the Energy Sector should collectively work together so that India's commitment (during the Paris Agreement on Climate Change) to reduce the carbon intensity of its economy by 33-35% by 2030, compared to the 2005 levels can be fulfilled. And the Govt of India has taken the first step in the right direction by formulating the National Electricity Plan (NEP) in 2018.

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Thermography Technique: A Mechanistic Method for Improving Safety and Productivity in Coal Mines

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ABSTRACT

Use of thermography has a long and successful history as a diagnostic tool in various sectors of industry. In mining industry, thermography may be used to mining safety in detection and monitoring of surface fire, fire in dump and coal stacks, determination of efficacy of fire fighting in coal mines, pillar and gallery fire in coal mines, loose connection and cable fault in electrical cables, overheating of electrical plants & equipments, detection of machine faults including mis-alignment, bearing defects and cost savings via energy efficiency. The technique is useful for proactive reliability maintenance to improve the root cause failure analysis process and to ensure effective long-term machine fault correction. The aim of this paper is to highlights the principle, procedure and use of thermography technique in various aspects of mining safety as well predictive maintenance of mining machinery and energy conservation.

Keywords—Thermography technique, thermal imaging camera, coal mine fire, electromagnetic spectrum.

INTRODUCTION

Coal is a prime source of energy in India and expected to remain so in the foreseeable future. Mining of coal is not an easy task and its exploitation from beneath the ground inherently associates risks and hazards. A number of disasters took place in the past leading to loss of human life, production and productivity, and effecting socio-economic condition and environment. A number of disasters took places in Indian coal mines. Coal mine fire, methane explosion due to electrical sparks, etc., were leading cause of these incidences. Early stage detection and monitoring of coal mine fire, faulty electrical and mechanical plants or equipments reduce the chances of these occurrences.

Detection of coal mine fire is the first important step as prolong continuation of which would enlarge the dimension and all the possible preventive measure became futile. The most common techniques used world over for detection of coal mine fire is thermo- compositional analysis. The infrared thermograph, compared with traditional technique has a greater coverage area, high-efficient and higher precision temperature results. A thermography instrument is a thermal pointer or a thermal scanner. The thermal pointer reads the temperature of a specific dimensional point where as a scanner maps the thermal profile of a surface area. The advantages of Thermography technique are a non-contact type, fast, reliable & giving precise accuracy. A large surface area can be scanned, presented in visual & thermal form in very short time and also have Software back-up for image processing and analysis. This technique requires very little skill for monitoring. Besides these advantages this technique has some disadvantage like, initial investment cost and it is unable to detect the inside temperature if the medium is separated by glass/polythene material etc. Therefore, application of thermographic technique to monitor the status and extent of coal mine fire plays a very vital role in diagnosing and predicting potential of this socio-technological problem. Thermography technique can also be useful for routine condition monitoring of electrical and mechanical equipment used in coal mines to detect the fault and prevent before the breakdown occurs. It is an ideal inspection method for all types of predictive maintenance in the electrical and mechanical equipment. This technique is advantageous for monitoring of different equipments used in coal mining industry. The principle of thermography techniques and some application area of coal mining industry are discussed in subsequent sections.

THERMOGRAPHY TECHNIQUE

The fundamental principle of this technique is that every object emits certain amount of Infrared (IR) energy and the intensity of this IR radiation is a function of temperature. In an electromagnetic spectrum, the IR region varies from 0.8 micron to 1000 micron wavelength (Figure1). This wavelength of IR spectrum is more than that of a visible spectrum. The IR energy representing the surface temperature can be detected and quantified by the help of IR scanning system. The basic IR system

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consists of an “IR energy detector” and a “Monitor”. The scanner is an opto-mechanical device which converts the IR energy received from an object surface to an electrical signal. These signals are further fed into the monitor, where it is processed and presented in simple digital display to indicate temperature level and a video display for thermal profile (Figure 2).

An Infrared thermal Imaging camera measures temperature and gives image of the emitted infrared radiation from an object. The fact that radiation is a function of object surface temperature makes it possible for the camera to calculate and display this temperature. However, radiation measured by the camera does not only depend upon temperature but it also a function of emissivity. Radiation also originates from the surrounding and is reflected in the object. The radiation from the object and the reflected radiation will also be influenced by absorption of the atmosphere. To measure temperature accurately, it is therefore necessary to compensate the effect of a number of different radiation sources. This is accomplished in real time by taking accurate object parameter in the camera. The object parameters viz. the emissivity of object, reflected apparent temperature, distance between object & camera and temperature of the atmosphere must be considered before measuring temperature accurately.

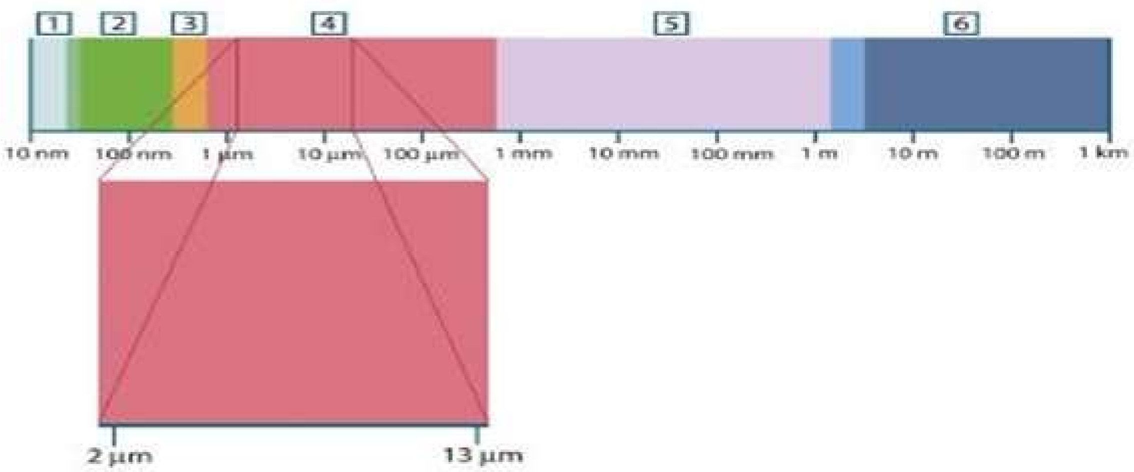

Fig. 1: The electromagnetic spectrum regions: (1) X-Ray, (2) UV, (3) Visible, (4) IR, (5) Microwaves, (6) Radiowaves.

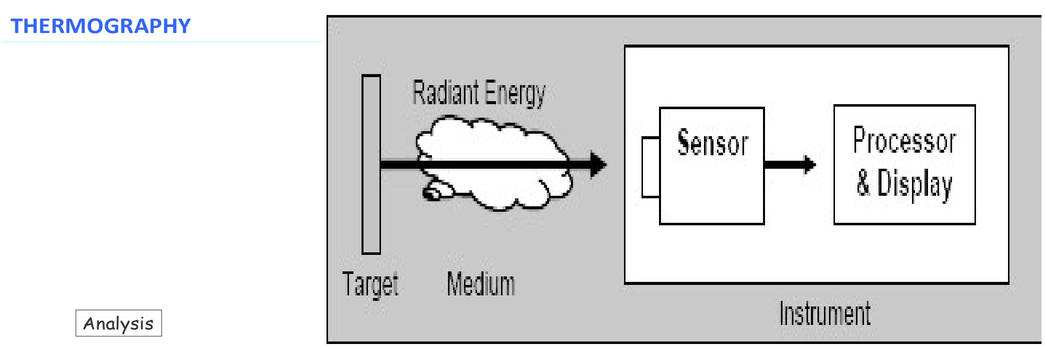

Fig. 2: Working principle of thermal imaging camera

Among above mention parameters, most important object parameter is Emissivity. It is measured by how much radiation is emitted from object compared to that of a perfect blackbody of same temperature. Normally Emissivity ranging from 0.1 to 0.99 of all materials and the emissivity of coal, sandstone, soil has and ranging from 0.91 to 0.95 depending upon their wetness and dry condition. The others parameters like reflected apparent temperature, relative humidity atmospheric temperature are also to be considered before thermal monitoring. The distance between object and front lenses of the camera is set to compensate the radiation from the target absorbed by the atmosphere between object & camera and also radiation from the atmosphere itself is detected by the camera (Figure 3).

The monitoring procedure used for thermography technique can be divided into two stages, acquiring thermal & visual images and analysis of acquired thermal Images. The mine fire division of CSIR-CIMFR equipped with ThemaCAM- P65 Infrared imaging camera (Figure 4) with temperature ranges from -20°C to +2000° C with adjustable measuring ranges of – 40 °C to 55 °C, – 40 °C to 120 °C, 0 °C to 500 °C and 500 °C to 2000°C with temperature sensitivity accuracy is ± 2°C of reading. The camera have inbuilt lenses 36mm with field of view (FOV) 24°X18° (solid angle) and replaceable lenses like wide angle lense 18 mm (45°), micro lense 19 mm (50µ/42µ) and close up lense 150 mm (FOV- 64mm/53mm) with auto calibration with respect to the Emissivity of material.

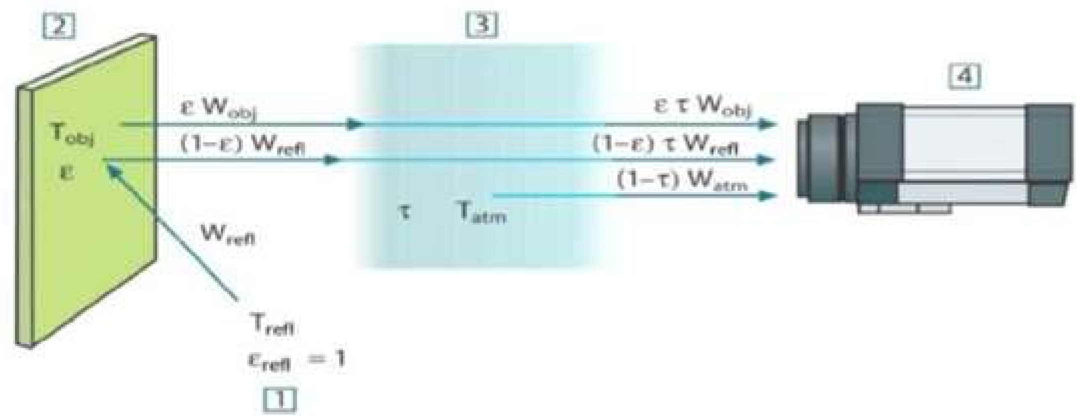

Fig. 3: A Schematic Representation of the General Thermographic Measurement situation. 1: Surroundings, 2: Object, 3: Atmosphere, 4: Camera

Fig. 4: Thermal imaging camera ThermaCAM- P65 (FLIR System - 2006)

The camera acquires visual as well as thermal image and display it on 4" colour monitor with 320X240 pixels size. A high resolution colour thermal and visual images are provided in real time on the LCD. These acquired images and other relevant data can be transferred to computer using USB/ RS232 Plug & Play connection to PC for fast image download and further analysis of images using thermaCAM Reporter 8.3 Pro software.

APPLICATION AREAS OF THERMOGRAPHY IN COAL MINING INDUSTRY

The application of thermography has been successfully used in various sectors of industry. In coal mining industry, thermography can be used to enhanced mining safety viz., detection and monitoring of surface fire, fire in coal bench, overburden dump and coal stacks, determination of efficacy of fire fighting chemicals in coal mines, pillar and gallery fire, fire in loose coal or rib pillars in the goaf in underground coal mines. Apart from the coal mine fire, it can be useful in detection and identification of loose connection and cable fault in electrical cables, overheating of electrical plants & equipments, detection of machine faults including mis-alignment, bearing defects and cost savings via energy efficiency. The various application of thermography techniques used in coal mines are discussed in subsequent sections.

A. Coal Mine Fire

Thermal mapping of fire area in coal mines is one of the important approaches to know fire affected area and its extent thereof. The thermal monitoring needs temperature distribution at every point of fire affected area for demarcation of fire and non fire zone effectively. The main problem of monitoring is how to acquire the surface temperature and its distribution in the affected area quickly and safe manner. The thermography technique is handy tool which can serve these purposes with high accuracy. Thermography monitoring was conducted in various fire affected coal mines using ThemaCAM- P65 Infrared imaging camera is presented in Figure 5 and 6 to illustrate the methodology.

B. Electrical and Mechanical Machinery

Thermography has proved to be an ideal inspection method for all types of preventive maintenance in the electrical and mechanical field. Infrared technology gives us the ability to "see" and measure temperatures on defective components, normal wear, chemical contamination, corrosion, fatigue and faulty assembly in many electrical and mechanical systems. The resistance or friction produced in these problem areas is visible in the infrared spectrum and therefore can be captured by the infrared camera. Overheating can occur in virtually all electrical components and hardware including generators, transformers, pole top connections, insulators, disconnects, jumpers, shoe connections, fuse connections, switchgear, starters, contactors and any other similar hardware. In transmission and distribution systems thermographic surveys can help cut production losses and prevent the eventual failure of these systems. Infrared Thermography is the leading non-intrusive, non-invasive and non-destructive tool available for use in identifying faults within plants and equipments. The technique is invaluable in being able to identify faults before they actually give rise to an unplanned and costly breakdown. The following are the types of mining equipment and processes which can be benefited after monitoring by this technique.

ADVANTAGE AND DISADVANTAGE OF IR THERMOGRAPHY

Due to its capability of recording early thermal changes from remote, the technique is very much effective in early detection of problem areas and identifying the facts. But like any other techniques thermography is also not free from limitations. The advantages and limitations of techniques are summarized as under:

Table. 1:

Electrical Systems	Mechanical Systems
Loose or high resistance connections	HEMM machines faults used for surface mining
Overloaded circuits	Insulation missing or breakdown
Phase imbalances	Rotating Machinery
Blocked or restricted cooling systems in transformers	Hydraulic, steam and hot water systems, Boiler seal leakage
High resistance in fuses and switchgear	Tank levels and insulation
Motors and Rotating Machinery	Refractory lining failure or wear
Motor winding problems	Valves
Misleading of Bearings	Belts and pulleys
Motor / generator overload	Turbines
Belt / shaft alignment, Conveyor systems	Pressure and vacuum leaks

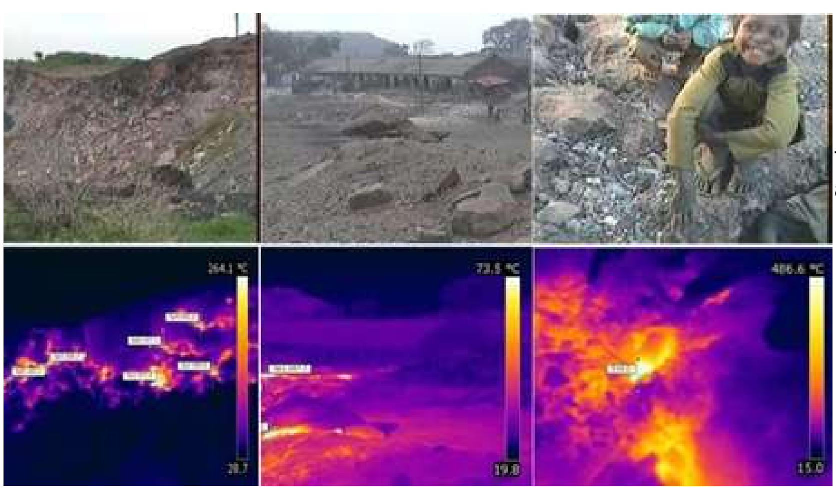

Fig. 5: Visual with its respective thermal images of fire affected areas of Jharia coalfields.

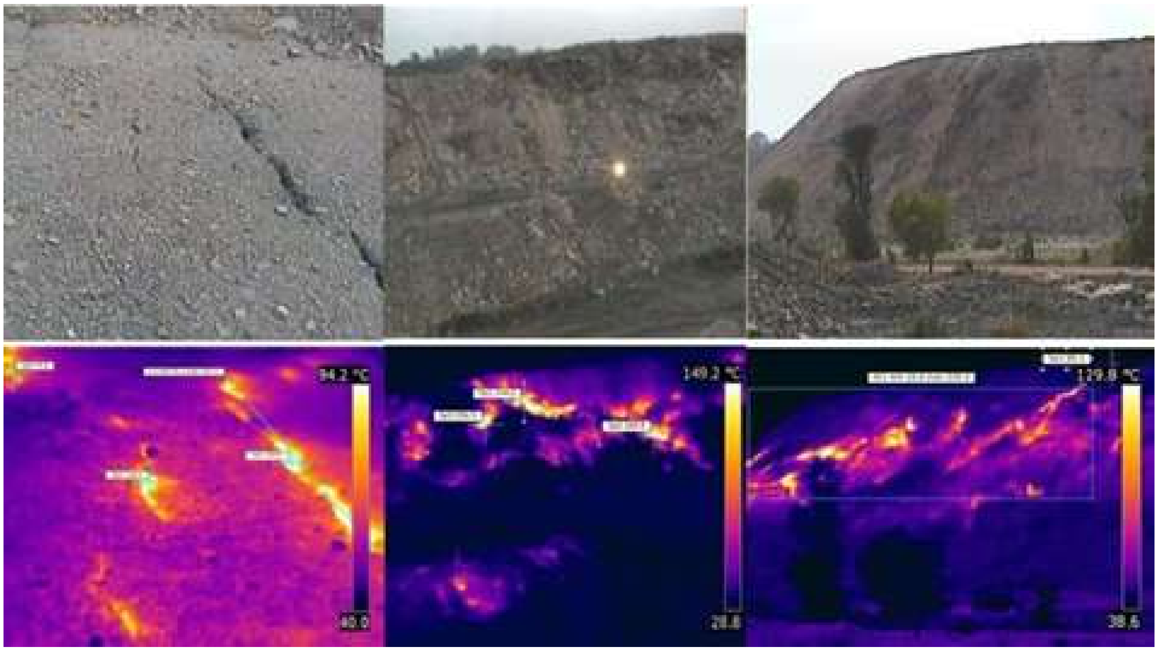

Fig. 6: Visual Image with its respective thermal Image (a) surface fire, (b) bench fire, (c) overburden dump fire.

Advantages:

a) It is non-contact type technique.
b) Capture surface temperature from some distance.
c) Fast, reliable & accurate output.
d) Detection of fault in the image is easy on the basis of temperature difference.
e) Suitable for capturing large area in one image.
f) Capturing both visual as well as IR thermal images.
g) Ease of image processing and analysis using software.

Limitations

a) It is not detect the inside temperature of the medium, detect only surface temperature of the object.
b) Cost of instrument is high.
c) Result may vary if the parameters are missed.
d) Sensitive to carry camera at some dangerous place

CONCLUSIONS

The thermography is handy technique for periodical & effective monitoring system for enhancement of safety in coal mining industry. It has wide range of application in coal mines for early and accurate detection of coal mine fire status in coal pillars, overburden dump, coal stack, extent and status of surface/subsurface fire etc. The thermal image database of an area can be maintained periodically to know the progress, direction and intensity of the fire area. It can also give an early warning and management information system for future. This will be helpful in planning for control strategy and safety.

This technique has also significant role in routine condition monitoring to detect the status and fault of electrical and mechanical equipments used in coal mines. This technique can be useful to predict the failure of plants or equipment and therefore planning to shut down well before. This saves production loss and ensures equipment safety. It will increase the efficiency of equipments and reduces the operating costs. Thus, the technique is more effective for early detection of fault in equipment before its failure.

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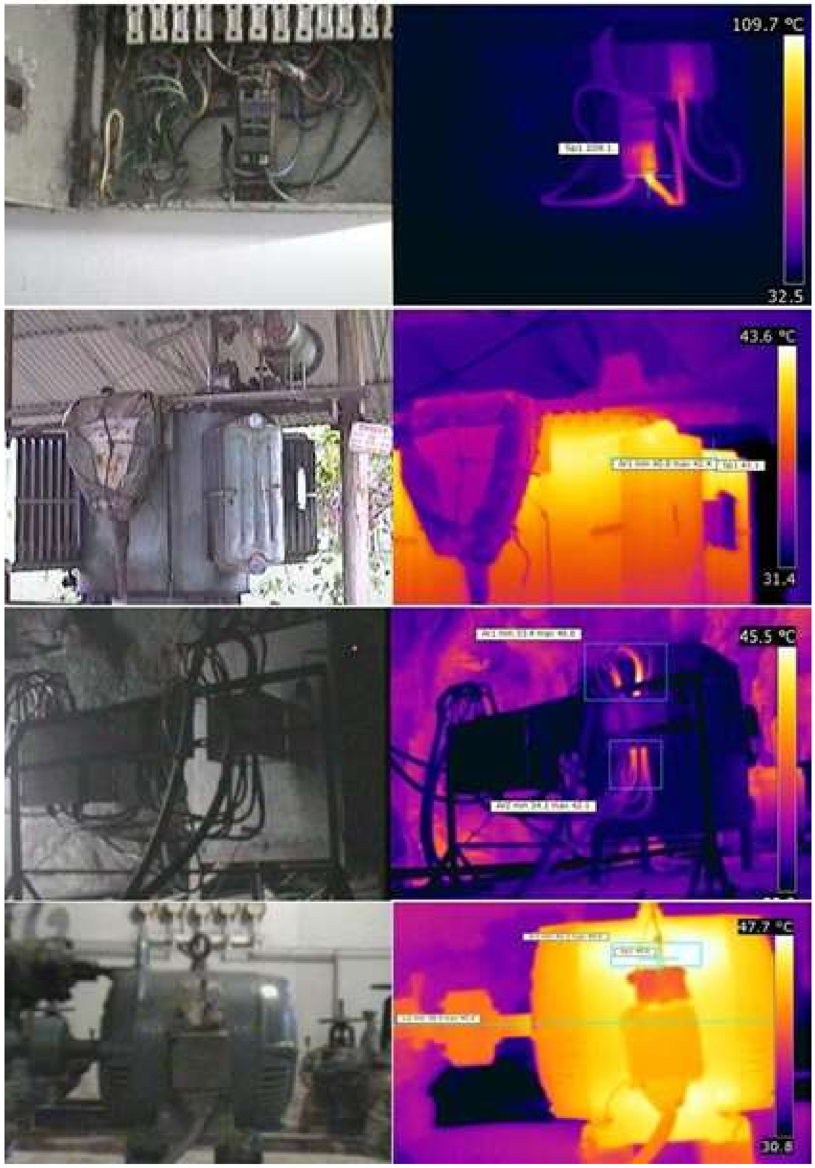

Fig. 7: Visual and its respective thermal images of different electrical and mechanical systems.

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Transition of Open Pit Mine to Underground the Indian Scenario & Problems Associated

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INTRODUCTION

Mining has an important role in the economic development/ GDP of any nation and in meeting the day to day needs of the population. In our quest for better living, mankind had evolved all techniques and method of extracting ores/ minerals (both fuel and non-fuel) from the core of the mother earth. When we talk of India, we had a rich history of exploitation and extraction of ores and minerals right since the days of Harappa and Mahenjodaro. With the increase in depth, limited reserves, and geological set up; many mines are now adoption of transition route to keep the activities alive. It can be Open Pit to UG or UG to Open pit.

DEEP OPENCAST MINES

As the open pit mine gets deepen it is often burdened with excessive waste stripping leading to increasing in overall cost of ore production. Transitioning to underground mining is considered a strategy to maximize both the value of the project and resource recovery along with fear of closure of the opencast operations. In India, a large number of open pit mines have been converted to underground owing to geological and techno-economic considerations. When we talk of sustainable development, the transition phase an important role. The transition brings good will amongst the community around the mines, employees, and also ensures developmental work in the area through CSR & DMF.

TRANSITION FROM OPENCAST TO UG MINING (FIGURE 1 & 2)

Transition started initially at few Chromite Mines in Odisha and in a big way taken up for Rampura-Agucha Mine of Vedanta. Malanjkhand Copper Mine of HCL is the second big mine which had adopted this route of continuing production. In both Rampura-Agucha and Malanjkhand the initial DPR had the provision to go for Underground Mining.A number of manganese mines are in operation at dual mode Open pit & UG and slowly switching over to UG.

Figure 1 : An overview of deepening Opencast Operation of Maanjkhand Copper Mines

Figure 2 : Shows development of Palaspani Mn Mines

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Rampura-Agucha hand Malanjkhand had planned to have an underground mine much before touching the present floor level of open pit. They had executed in a systematic manner by taking help of in-house talent, as well as of consultants having expertise in transition.

PROBLEMS ASSOCIATED WITH TRANSITION STAGE

Several problems arise in such transition stages. Some of them are enumerated below :

- Instability in the areas closer to the underground operation
- Geotechnical challenges and stability of the rock mass with increase in depth and volume of excavation,
- Deteriorating haulage roads,
- Increasing probability of slope failures
- Unsafe working conditions
- Availability of skilled manpower to work in UG Mines
- Re-deployment of Opencast manpower in UG Operations
- Availability of Statutory ,manpower (supervisory and managerial)
- Processing/Beneficiation plant capacity matching to future production from UG. Also, the planning to maintain the required plant throughput during and after transition
- Underground flooding due to the groundwater and/or surface water inflow. Break even cut-off grade

This criterion to define ore as a material that will just pay mining and processing costs. This criterion is not optimal since it only separates the ore from the waste but the mine planner often seeks to optimise the cut-off grade of ore to maximise the NPV. The determination of the optimum cut-off grade for a single metal deposit can be very complex even when price and cost are assumed to be constant.

STRIPPING RATIO

If mineralisation extends beyond a certain depth from the surface of a pit, the stripping ratio (SR) becomes too high. It should then be converted to an UG mine. Optimization of the transition problem was, and still is, an important issue in mining.

ENVIRONMENTAL FACTORS

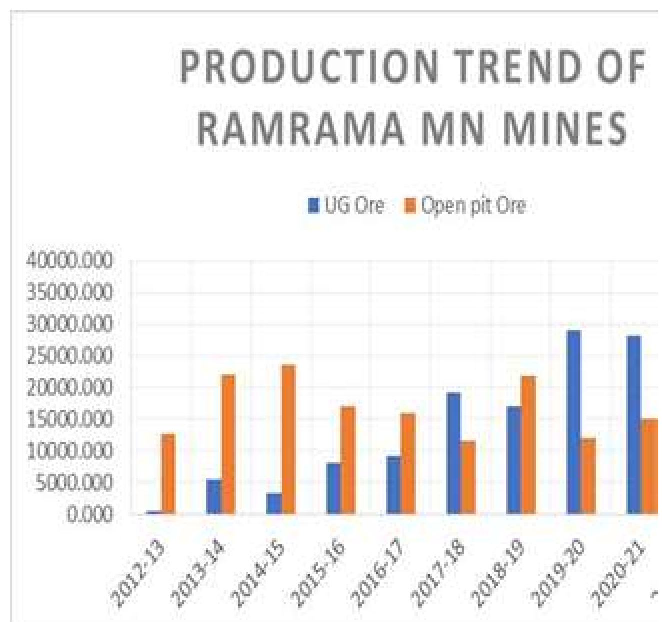
Include subsidence, which sometimes favour open pit rather than underground mining;

CAPITAL REQUIRED TO TRANSITION

For technology support, machineries, development of levels etc, installation of ventilation system, pumping system, Material Handling (network need to be designed and commissioned), etc.

PRODUCTION TREND

When changes are made in the mine as per approved Mining Plan and Permissions granted by DGMS, including obtaining Environmental Clearanaces from MoeFCC; a number of problems are also encountered. This situation creates shrp fall in the prodution. The only silver lining is the simultaneous working of opencast and development of UG mine. This was practised in most mines which had switched over to UG oprations. One such example is of Ramrama Mn Mine of M/s A.P.Trivedi of Balaghat.



Working of opencast mine help in the retention of manpower and training the manpower to meet challenges of UG mining.

CONCLUSION

Now a large number of opencast metal mines are being planned to get converted into UG mining. Indian mines have successfully converted a number of mines from Opencast to UG.

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Dust Suppression in Haul Roads - Key to Dumper Productivity

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INTRODUCTION

Dust generated by moving dumpers can reduce visibility to dangerous levels leading to unsafe conditions in the mines and also harm dumper operation and maintenance. Dust is controlled popularly by application of water to the road surface. In the dry season, watering helps maintain compaction and strength of the surface layer. It also maintains the surface shape and reduces the loss of gravel. Watering also helps reduce wash boarding or corrugation of the haul road surface. The generation of a corrugated running surface is a dry weather phenomenon.

The quantity of water needed to control dust depends on the nature of the road surface, traffic intensity, humidity and precipitation. During the summer months, a typical road may require 1 to 2 liters per square meter per hour. Liquid stabilizers and polymers help in reducing water consumption. In addition to dust suppression, these can help strengthen the surface layer as well as provide a degree of water proofing.

DUST SUPPRESSION METHODS

Many Indian mines use dust suppressants. Some of the dust control chemicals include – emulsified asphalt, calcium chloride, calcium ligno-sulfonate and a surfactant. Enzyme based solutions are also in use. The Chemistry and Mining department of AKS University had also developed an enzyme base chemical for dust suppression and haul road construction and repair.

The characteristics of the chemical products used are as follows:

- Emulsified Asphalt – contains an emulsifying agent, water and asphalt, and cures by evaporation of water from the mixture. A product called DL-10 asphalt emulsion was used for this application.
- Calcium Chloride – a hygroscopic compound that extracts moisture from the atmosphere and dampens the road surface. The product used for this program was natural salt brine with a minimum calcium chloride content of 26%.
- Calcium Lignosulfonate – an organic by product of the sulphite wood-pulping process that can be used to physically bind soil particle together.
- Surfactant – substance capable of reducing the surface tension of the transport liquid, thereby allowing available moisture to wet more dirt particles per unit volume.
- For its use in Indian mines, only DGMS approved solutions are allowed.

Modular design Fugitive Dust suppression system with Mist Blower (Fig. 3)

These days a large number of mines have deployed this system which is very effective and uses less water as compared to conventional water sprinkling dumpers. This system has a air blowing type high pressure atomized mist spray system with radial throw of minimum 40 m, with minimum 7.5 KW blower motor, high pressure pump 100 liters/min, or more and pressure of minimum 12 bar with electronic starters. It has overhead as well as rod fogging downward mist spray attachment on the rear along with fire fighting water gun attachment. The truck assembly has a 14 kl stainless steel water tank, DG set (minimum 25 KVA), piping, GPS devices, valves, electrical and a control panel and other fittings mounted on a 10 wheeled truck chassis.

Dry fog system controls virtually all types of breathable and fugitive dust ranging from 1 to 800 microns in size. The system utilizes a dual fluid, water and air nozzle that produces an ultra fine droplet size fog that achieves dust suppression through agglomeration. No chemical is required in this system and water retention to the process is approx. 0.1% to 0.5% of material being handled.

PRINCIPLE OF OPERATION

The system agglomerates the airborne dust particle to water droplet so that the particle becomes heavy enough to be returned to the product stream by the force of gravity. Consider a water droplet about to impinge on a dust particle, or what is aerodynamically equivalent, a dust particle about to impinge on a water droplet, as shown in the drawing. If the droplet diameter is much greater than the dust particle, the dust particle simply follows the air streamlines around

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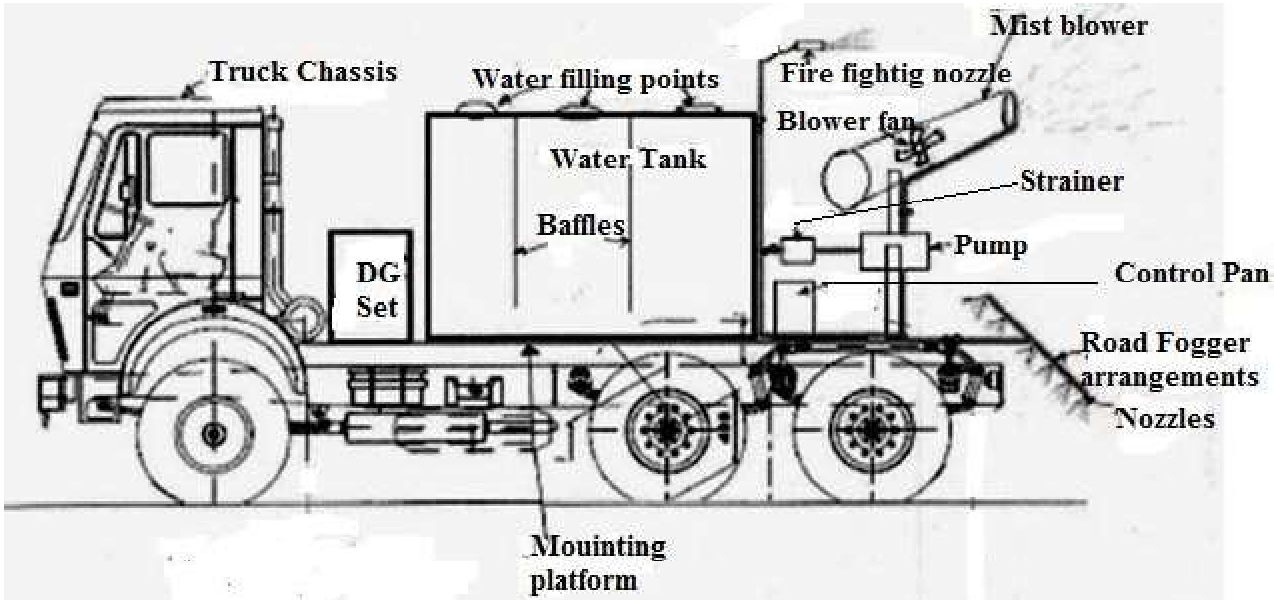

Figure 3 : Wheel truck mounted mist blower cum road fogger cum fire fighting machine (not to scale)

a droplet, a little or no contact occurs. In fact, it is difficult to impact micron - size particle on anything, which is why inertial separators do not work well at these sizes. If, on the other hand, the water droplet is of a size that is comparable to that of the dust particle, contact occurs as the dust particle tries to follow the streamlines.

To achieve agglomeration at the dust source point two conditions need to exist – enough water droplets of the same size as the dust particles have to be generated at the same rate as the dust particles, both dust particles and water droplets have to be contained in the same area so that agglomeration can occur.

FOGGERS

The design of the system is based on a unique nozzle that can produce a very dense fog of 1 - 10 micron in size of water droplets that can literally blanket dust source and keep the dust particles from becoming airborne.

The dual flow nozzle is an air driven device for fogging liquids by passing them through a field of high frequency sound waves. This is accomplished by compressing air stream of a specially designed converge section of the nozzle. The result is an air stream that will accelerate past the speed of sound, in the converge section. When it passes the speed of sound, a primary shock wave is generated at the mouth of the nozzle. To enhance the fogging capacity, a resonating chamber in the path of the air stream reflects the air stream back itself to amplify the primary shock wave. Once the shock wave is generated, water is delivered through annular orifices where it is sheared in relatively small droplets. These small droplets are then carried by the primary air stream in to the shock wave and exploded into thousands of micron size fog droplets. The air then escapes around the resonator chamber and carries the droplets downstream in a soft low velocity fog pattern. The unit shown above can also be used for fire fighting.

CONCLUSION

Dust being very harmful for persons working in any mine need to be suppressed and generation and dispersal of dust has been prominent in haul roads. Thus there has been attempts to ensure their suppression.

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Blast Free Mining

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ABSTRACT

The blasting is most popularly used rock breakage practice globally. It is cheaper, gives higher volumes, very high productivity, compared to other methods of rock fragmentation. Use of explosives make this operation unsafe and also necessitates several safety measures in its transportation, storage, use and handling. In addition to safety concerns, it had serious impact on the environment including flyrock, gas emissions, last induced ground vibrations, and frequency. This paper discusses some of the nonexplosive rock breaking methods, particularly the rippers, hydraulic splitter, expansive chemical agents and other methods, which can replace blasting methods.

INTRODUCTION

Blasting has wide range of application in civil and mining engineering operations for rock breaking with the use of explosives. Ever since the human settlements were in existence, some or other form of rock breakage has been there. It started with black powder for breaking rocks in mining and construction projects, so that the blasted pieces can be easily handled by hand loading by labourers and excavators. Since then several changes were made and research had helped to evolve safe, economical, large scale blasting operations. Despite adequate care and following provisions as laid down in various mining Acts & Rules; at many instances blasting had been stopped. In those situations the only alternate method is to have 'blast free techniques'.

RIPPER

Conventional rippers are having an attachment fitted with a dozer. These are widely used in soft to medium hard strata free from boulders. Popular in Bauxite Mines in India and also used in mines where top soil is to be removed without blasting. The cutting action is performed by Ripper shanks which are mounted to the dozer's ripper frame and are adjustable to suit the depth of ripping required. .

These are of two types -
- Single shank, and
- Multiple Shank

Single-shank ripper vs multi-shank ripper

They are used for deep cut ripping, or heavy ripping in a production cycle (like use in Bauxite mining) when the digging conditions are tougher and require greater breakout forces. This is because using a single shank will concentrate the machine's maximum ripping force into a single focal point, delivering maximum penetration.

Multi-shank rippers

They arepopularly used in soft to medium hard rock cutting or if a shallower ripping depth is required. They can also be used when a larger area is required to be ripped. In case of pre-ripping for other earth moving machines such as scrapers, or when ripping adjacent to the highwalls where stability and clearance is to enountered.

Hard rock and stratified deposits cannot be excavated by these convetional rippers are not effective and productive. To replace them a new type of rippers with a single X-centric/vertical ripper attachment (Figure 1 &2) mounted on excavators are adopted and material handled by shovel-dumper system. At Kaniha OCP 03 nos. of MAX BRIO BR55 model vertical ripper machines are in use (Fig. 1), and also at Hindalco's Samri Bauxite Mine (Figure 1).

SPLITTERS

Wedges and feathers (Figure 3), are used to split hard rock. This is one of the oldest method of splitting wood or rock. From this the mechanical splitting was developed and is being used in Indian Mines. In India, Mechanical splitters or Hydraulic Splitters, are used in limestone mines of Chittorgarh Cement and Satna Cement of M/s Birla Corporation Ltd. These are widely used in stone mining where only cracks are generated to extract stone blocks as a part of Dimensional Stone Mining.

*AKS University, Satna

Figure 1 : Showins working on a medium hard to hard coal measure strata using a X-centric/vertical ripper

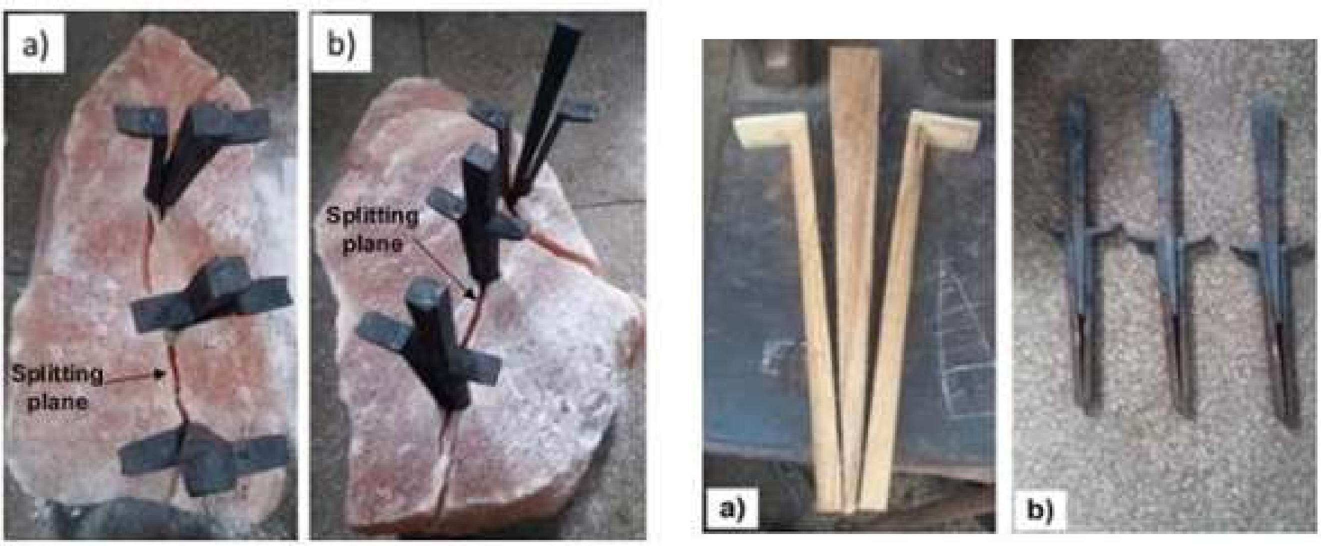

Figure 2 : Explains conventional splitting

ROCK BREAKING PRINCIPLE OF HYDRAULIC SPLITTING

Figure 2, explains the sequence of splitting. To use splitting in a production mine, hydraulic splitting method (Figure 3) is adopted. After drilling 115mm dia drill holes in a 6 to 7 m bench, holes are filled with water. The splitter is pushed through the blast hole and as it enters the wedge expands the diameter thereby by pressuring the rock strata to break. The cracks of one hole reaches the crack of the nearby hole. The spacing between holes is decided by the free face available, rock hardness, RQD, and direction of crack expansion. In any splitter the tensile strength of the rock is much smaller than the compressive strength. Heat generation is very high and cost of lubrication is also high.

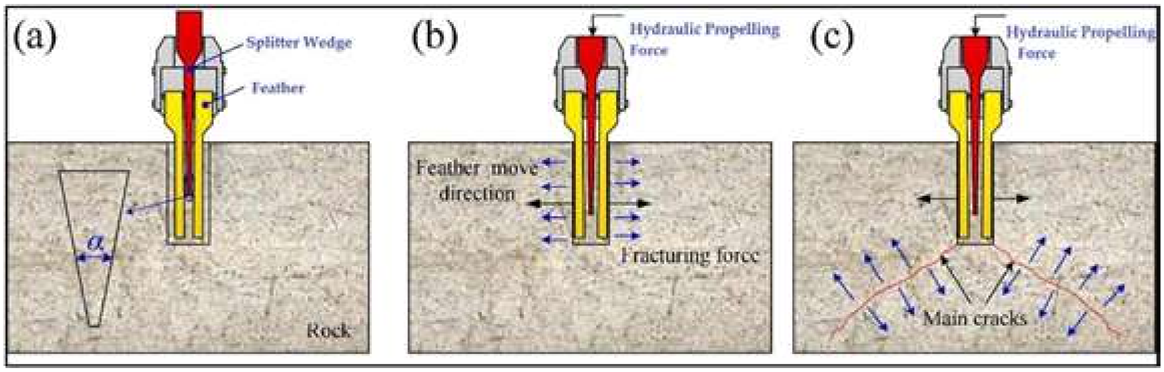

Figure 3 : Rock breakage process using the hydraulic splitting method: (a) hydraulic splitter insertion, (b) hydraulic propelling force, and (c) induced fracture.

NON-EXPLOSIVE CRACKING POWDER

It is a non explosive chemical composition for gently and noiselessly breaking a rock or concrete mass. The composition comprises a principal component which is prepared by calcining a starting mixture comprising 100 parts by weight of quick lime and 1-20 parts by weight of calcium fluoride. When mixed with water at a fixed ratio and the thoroughly mixed aqueous slurry is poured into 32mm dia Jack Hammer dia drilled holes. The slurry spontaneously hydrate and set with development of expansion pressure.

Hole spacing and depth is decided based on the hardness, RQD and compressive strength of the rock. There are three different types of cracking powder available depending on the prevailing temperature of the site of use. The best results are obtained where the temperature is within 25 to 35 Degree Centigrade and within 3 to 4 hours cracks start developing.

Case study of NMDC Bailadila (Figure 4) is presented in the paper. Cost of breaking one Cubic Meter by Chemical (excluding cost of drilling, manpower for charging, and excavation by rock breaker) is Rs. 1074.11.

In some mines in BCCL this is regularly used for boulder cracking.

Figure 4 : Explains use of rock cracking chemicals at Kirandul complex, NMDC

Figure 5 :Explains use of this method in a stone quarry near Kirandul showing benching.

Figure 6 : Shows the use of this method in a bench creating cracks for easy handling by an Excavator.

LIQUID CARBON DIOXIDE BLASTING TECHNOLOGY

Liquid carbon dioxide fracturing device consists of a pneumatic valve, heating device, liquid storage pipe, energy-releasing sheet, sealing gaskets, and a releasing pipe; its structure is shown in Figure 7 and 8.

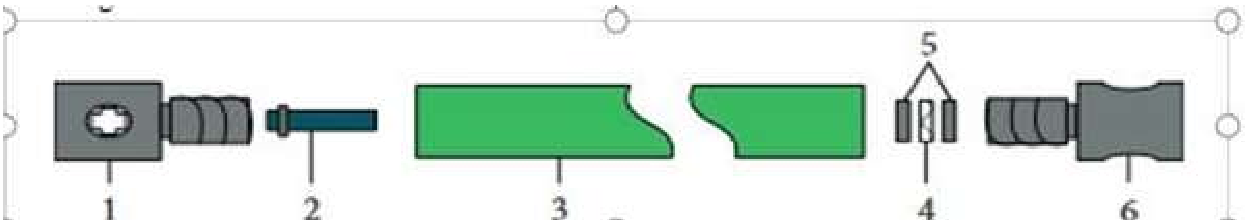

Figure 7(a) : Schematic diagram of a liquid carbon dioxide fracturing device. 1: pneumatic valve; 2: heating device; 3: liquid storage pipe; 4: energy-releasing sheet; 5: sealing gaskets; 6: releasing pipe.

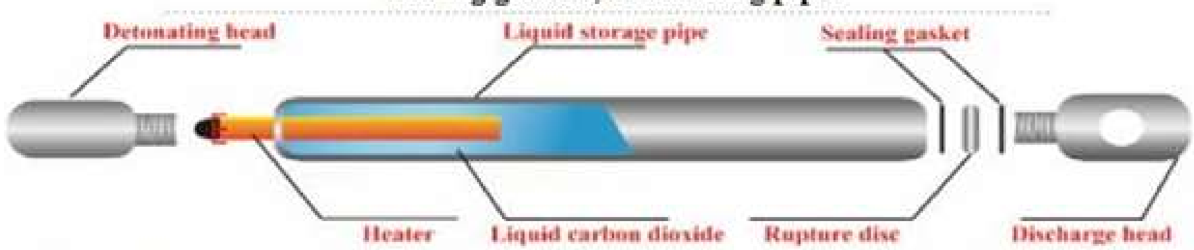

Figure 7(b) : Schematic diagram of Carbon Dioxide Phase Tansition Fracturing Pipe [Source : Zhou, Shengtao et el (2020)]

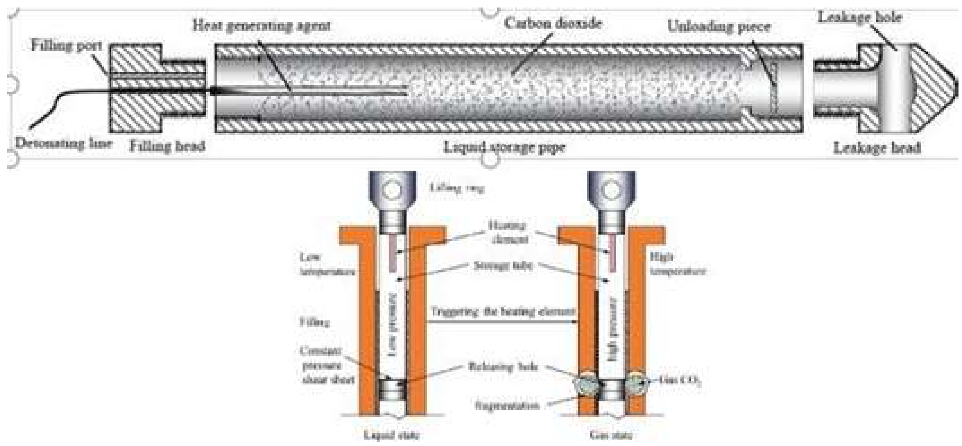

Figure 7 (c) : Explaining the principle/working

The pneumatic valve is used to fill the liquid storage pipe with liquid carbon dioxide. The heating device provides the energy required to transform the liquid carbon dioxide. The liquid storage pipe is used to store liquid carbon dioxide. The energy-releasing sheet controls the maximum explosion pressure of the device. The sealing gasket prevents the leakage of carbon dioxide in the liquid storage pipe, and the releasing pipe controls the release direction of carbon di-oxide. When blasting, the heating device is detonated, heating the liquid carbon dioxide; the liquid carbon dioxide then becomes gasified, which increases the pressure in the liquid storage pipe. When the pressure exceeds its maximum shear strength, the energy-releasing sheet is destroyed, quickly releasing the gasified carbon dioxide from the re-leasing pipe towards the target rock.

Figure 8: shows the various aspects of the blast-free systems currently in use

CONCLUSION

The growing resentment of the neighbours, court cases and situation warranting stoppage of rock excavation by blasting has necessitated the use of blast free techniques. While large mines have gone for mechanical excavation like surface miners, highwall miners and in UG for Continuous Miners & Shearers etc, others have gone for systems in line with the rock conditions and production requirement. In this paper the discussions broadly covered use of Xcentric rippers (being used in MCL OB excavation and in Bauxite Mine of M/s Hindalco Industries at Samri Mines), splitters, chemical expansion powder and use of liquid CO2 for breaking rock.

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We acknowledge with thanks support extended by NMDC, Kirandul compolex to demonstrate the use of cracking powder in one of the hardest rock strata.

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Role Maintenance of Haul Roads on Safety & Productivity of Surface Mines

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INTRODUCTION

Shovel-dumper combination is the most popular means of surface mining excavation technique. Over the years it had been subjected to several changes and every such change has been guided by safety, economics and mine productivity. Ease of operation in small to medium scale mines had popularised the use of all diesel and hydraulic excavation machineres. Transport of blasted material by dumpers are the main production system and they contribute to over 25% of overall cost of mining. So adequate attention is paid to their maintenance and also operation. Productivity, safety and cost of fuel of entire fleet of mobile machineries in surface mine are dependent on the quality of haul road being designed, constructed and maintained.

HAUL ROADS

Haul road surface deterioration is due to many varied actions:

- Wheel rutting
- Spillage of material from trucks
- Heavy rainfall: - washing away any fines and loosening the surface saturating the surface material and turning it to a mud layer flooding of the pavement and causing soft spots and subgrade failure
- Damage by tracked machines
- Incorrect load positioning on truck

- Road profiles are to be maintained at or near to the original design profile. This includes maintaining the drainage systems, the road pavement, the road delineation and signage and the design parameters. Some of the basic maintenance requirements are:
- Scarify soft spots
- Remove wet spots and backfill
- Maintain good drainage
- Top up the running surface material
- Remove any truck spillage material form the windrows when grading. This will help prevent contamination to the surface running material.
- Maintain the cross fall and super elevation profile.
- Adequate water is to be applied during any maintenance grading.
- Regularly scarify areas that show signs of laminations.

Conscientious maintenance of haul roads ensures that machinery reaches its maximum lifetime. Ultimately, costs of operations will be reduced and the upkeep of good road conditions results in fewer safety concerns.

All haul roads deteriorate gradually with time due to the effect of weather and repetitive loading from passing vehicles. Road maintenance can slow the rate of deterioration, but eventually a point is reached where repairs or rehabilitation is necessary.

For permanent haul roads, the repair may involve removal of the surface layer and replacement and compaction of portions of the damaged base and sub-base. Often the existing surface layer can be scarified and re-compacted followed by placement of an additional thickness of compacted gravel on top. Rehabilitation of the road may be a strategy used to extend the life of a road.

GRADING ROADS

Haul road maintenance is with the deployment of grader, road roller, mobile sprinkler, and dust controlling vehicles. The grader is an important haul road management tool. Proper maintenance of the road surface minimizes the effect of bumps, holes, spillage, and rolling resistance on the haulage fleet. Graders in combination with road roller (preferably tire mounted) are used to keep the road surface smooth to maintain cross slope, and to remove loose rocks from the surface. Graders are also used to remove spillages, keep ditches clean, and build the road. Grading should be performed when the roads are damp so no loose material is lost due to wind or traffic. Another advantage of this is that damp materials fill all low spots and hollows and can be easily compacted by passing traffic.

MATERIAL SPILLAGE

Spillage of material from dumpers is a common occurrence at most mine sites and is particularly prevalent on corners

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and switchbacks. If spillage is not prevented or is not cleaned up, bumps and irregularities in the road surface will be allowed to develop.

It can be prevented in the design stage through good design of corners incorporating superelevation and adequate turning radius. However, if spillage does occur a grader should be used to clear spills, and to fill and smooth any depressions that spilled material creates. Care must be taken not to clear this material into drains or to disrupt safety berms. Accumulated material from this maintenance procedure should be removed.

Spillage on haul roads and cleanup around excavators and shovels is usually carried out with a rubber-tired dozer.

MAINTENANCE OF DRAINS

Roadside drains and culverts need to be kept clear of obstructions to prevent overflowing in heavy rainfall leading to damage to road pavements or saturation of the sub-bases. Inspection of these facilities and action to clear the drains if need be, is required on a regular basis.

V- drains are preferred for drainage of roads not only for the ease of their construction, but also for the simplicity of their maintenance. V-drains only rely on a grader to excavate them and then to regularly clear them of obstructions. These drains should be regarded when the depth has been reduced by 50%.

V- drains are usually located alongside the majority of roads and are a key component of the drainage system. These drains are essential to maintain the integrity of the haul roads, thus must be kept in good condition to protect the roads.

V- drains often have a large amount of water to accommodate, particularly during the wet season, and at times, the flow of water can be considerable. This can cause scouring and loss of condition of the drain lining. Frequent maintenance of these drains is required. Grading the drains to remove debris and fines, which may hinder flow, and also to restore the design geometry is a mandatory procedure. Any scouring of these drains needs to be considered and in problem areas, drains may need to be lined with rock or another durable, non-weather able material.

MAINTENANCE OF TRAFFIC SIGNS

Traffic signs are an integral part of the safety scheme at any open pit mine. Road signs need to be unambiguous and obvious to drivers in all conditions. It should be clearly written in Hindi and local language. It is important to keep signage clean so they are clearly readable at all times. Signs should be washed after periods of rain to ensure that they remain clear and free build-up of dirt and spray.

Washing down signs regularly prevents any build-up obscuring the sign and ensures that the reflective qualities that are important at night, are preserved. Damaged or ineffective signs need to be replaced and inappropriate or out-of-date signs need to be removed. All road signage needs to be closely monitored to make sure that it is as effective as possible and promotes optimum safety.

CONCLUSION

Apart from following the OEM Recommendations to maintain dumpers there have been several SOPs devised by the mine management to have a site specific Guidelines.

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Use of Eco-Friendly Fuel in ANFO Explosives

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ABSTRACT

Ammonium Nitrate & Fuel Oil mix is widely used in mining operations. One of the important ingredient has been 'Fuel(Diesel-HSD)' and liquid fuel has been popularly used because of several advantages. However, due to rising cost of liquid fuel (HSD), efforts were made to use alternate fuel type. The main considerations has been 'eco-friendly' characteristics. Research has shown that the replacement of diesel oil has been partially, so as to meet the complete detonation of the explosives.

INTRODUCTION

Ammonium Nitrate in prill form is used for blasting. Besides, AN is the best chemical to offer maximum Oxygen content to manufacture explosives (in cartridged as well as bulk SME form). Table 1, presents production of AN during last 3 years. To meet the huge requirement of AN for explosive grade, India also imports AN. Currently, M/s Deepak Fertilizers & Petrochemicals Corpn. Ltd. is the sole producer of prilled grade AN. During 2020-21, India imported AN for explosives of worth Rs. 140 Cores(approx.). Majority of blasts in dry holes in non-coal opencast mines use ANFO. Very recently ANFO has been proposed for trial use in opencast coal mines of WCL, and MCL.

Table 1: Presents AN produced in India in last 3 years (Source : PESO Annual Report 2020-21)

Description	2018-19	2019-20	2020-21
Ammonium Nitrate(Solid)(MT)	452,939.15	380,889.40	358,321.13
Ammonium Nitrate(Melt)(MT)	359,075.44	351,852.90	369,572.40

Singh (2021) highlighted the suitability of ANFO vis-à-vis powder factor, size distribution in the muck pile, etc in Mines of Mahanadi Coalfields Ltd (MCL). In order to ensure effective use of explosive energy, use of ANFO is an encouraging step, and MCL can immensely benefit economically as well as from productivity view point. Every tonne of high explosive used in blasting releases 0.20 tonnes of CO_2 into the atmosphere. By increasing use of ANFO and also alternate oxidizer and fuel in SME, CO_2 release can be further reduced.

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AMMONIUM NITRATE FUEL OIL

Properties & Chemical Composition

ANFO is a mixture of AN prills and fuel oil (6% by weight of fuel oil) in which AN acts as the fuel. Diesel oil should have a flash point higher than 38an performance of ANFO depend upon the quality of the prill. Prilled AN should contain low clay content, low moisture roughly between 6 - and 20-mesh U.S. standard screens (oil absorption, low particle density (073 to 0.82 g/cc), non -caking etc.

ANFO is chemical reaction of AN/FO is:
Salient features

a) Low Cost
b) Safer to handle because of its lack of sensitivity
c) Best suitable for dry holes
d) Explosive is formed only after mixing. The best of oxygen balanced ANFO mixture is 5.7 fuel oil and 94.3 % AN prills.

$3NH_4NO_3 + CH_2 = 7$

e) Percentage of fuel has a significant role in maintaining Oxygen Balance and quality of ANFO. Figure 3, shows the influence of fuel. Figure 4, Shows the Influence of Fuel Oil % on fume generation in CO in litres/kg at STP

ECO-FRIENDLY FUELS ANVO

In countries where vegetable oil is available in abundance, in place of HSD Vegetable Oil was also used.

POLYOLEFIN WASTE-DERIVED PYROLYSIS OILS

Biessikirsk, A et el(2021) have worked on a research on the possible application of Polyolefin Waste-derived Pyrolysis Oils for ANFO Manufacturing.

BIODEGRADABLE/VEGETABLE OIL FUEL

Austn Powder had developed and is marketing Austinite HD consists of porous ammonium nitrate and mineral oil or biodegradable vegetable oil. Austinite HD has a little higher apparent density in comparison to Austinite S. Austinite HD is not water resistant and can only be used in dry conditions. Austinite it is not detonator sensitive. Advantages

- High gas volume.
- Very low sensitivity against mechanical and thermal stress.
- Borehole volume is perfectly utilized, therefore high degree of efficiency.
- Perfectly free flowing.
- May be used for pneumatic loading.

Table 2, shows the properties of Austinite HD. Austin Powder had recommended the use of an Emulsion or a Cast Booster. The amount of booster explosive in boreholes with a diameter of 50 mm or more should be 6 % minimum of the total explosive mass. In boreholes with a smaller diameter the amount of booster explosive should be 10 % minimum. They have reported 6 months shelf life from the date of manufacture.

Table 2, shows the properties of Austinite HD

PROPERTIES

Properties	Value
Density [g/cm^3]	0.80
Oxygen balance [%] (1)	-1.6
Gas Volume [L/kg] (1)	981
Heat of Explosion [kJ/kg] (1)	3,752
RWS [ANFO=100] (1)	102
RBS [ANFO=0.85 g/cm^3] (1)	91
Velocity of detonation [m/s] (confined) (2)	2,900

(1) Theoretical values based on Austin modeling which assumes ideal detonation. Values calculated with other codes may differ. For additional information please contact our sales team.
(2) The velocity of detonation will depend on application, diameter and confinement.

BIOWASTE DUNG AS ADDITIVE

Uranchimeg, E et el (2021), reported about the fuel in ANFO detonation parameters by biowaste addition. According to them, ammonium nitrate fuel oil (ANFO) composition modified by biowaste dung as additive to generate efficient explosion and to result low cost blasting. The experiment results of modified ANFO with biowaste dung as additive illustrate that physical stability and absorption increased by 5% percent compared to regular ANFO. Also was revealed that average detonation brisance increased from 20.5 to 27.5 mm and detonation speed increased from 2300 to 3800 m/s compared to regular ANFO. This modified ANFO is lowered blasting cost from 50 to 150 tugriks per 1kg ANFO compared to aluminium and TNT additives.

CONCLUSION

Indian mines have always accepted the challenge to reduce the percentage of FO (HSD) and have undertaken several experiments. However in the areas of eco-friendly fuel, we are yet to undertake studies. There is lot of scope in this area due to rising cost of Diesel.

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Study on Access Ramps & Haul Roads of Surface Miners

Chaturbhuj Sahoo* G.K.Pradhan**

INTRODUCTION

Evacuation of coal/ore and OB/waste from the surface mine benches is done through a main haul road and number of temporary haul roads and ramps connecting the benches .The access connecting one bench to the other is called a ramp. While haul roads are permanent features, ramps have limited life.

LOCATION OF ACCESS RAMP

The location of access ramps and haul road are guided by the following:

1. Generally located at the minimum depth of in-crop of bottom most seam So as to reduce initial waste stripping (unproductive work).
2. Should facilitate maximizing of internal dumping and sectional working.
3. Should be near the External dump / Coal yard / Mine service facilities etc.
4. Main haul road up to the pit limit should be planned in the beginning only.
5. Since haul costs constitute about more than 40% and tire costs about 10% of the total mining costs, priority for design, construction and maintenance should be given.
6. Gradient, width, drainage, curves, super elevation, base, sub base, type and thickness of top dressing should be like that of national high ways for heavy traffic.

With it begins the actual mining of the deposit, now called the ore. Access to the deposit must be gained either - (a) by stripping the overburden, which is the soil and/or rock covering the deposit, to expose the near-surface ore for mining or (b) by excavating openings from the surface to access more deeply buried deposits to prepare for underground mining.

HAUL ROADS

Haul road forms the lifeline of the opencast mining. These roads are used by HEMMs mainly for hauling of OB and Ore/Coal. Haul roads becomes potentially hazardous area in dumper application if they are not designed, constructed & maintained properly. Majority of the accidents in opencast mines take place in haul roads & associated roads.

DEFINITIONS

Stopping Distances

Stopping distances must be calculated for each vehicle and the alignment of the road adjusted to the vehicle with the longest stopping distance. Sight Distances.

The sight distance that a driver has must be equal to or greater than the stopping distance of the vehicle. Both horizontal and vertical curves must be planned with this criterion.

HAUL ROAD WIDTHS AND CROSS SLOPES

The width of the travelled portion of a haul road is usually calculated as a multiple of the width of the widest vehicle that regularly travels it. In most cases, a straight stretch of road will be 3 to 4 times the width of the widest heavy hauler. On corners, the width will usually be designed wider than the straight stretch to allow for overhang of vehicle on the corner. Cross slopes should be approximately 1:25 to ensure proper drainage off the road.

MAXIMUM AND SUSTAINED GRADE

Grade (steepness) of roads is a function of safety and economics. In most cases, grades will vary between 0 and 12% on long hauls and may approach 20% on short hauls. However, most haul road grades in mines will have a grade between 6% and 10%. It is usually best to design haulage with a long sustained grade rather than a combination of steeper and flatter sections.

Intersections - Intersections should be made as flat as possible and should be avoided at the top of a ramp. Curves and Super-elevation.

The curves should be so designed that a dumper can see another dumper or any obstacle on the road at a distance more than stopping distance. (Figure 1 & 2). Sufficient radius of curvature provides, (a) a stable dumper speed, (b) higher tyre life due to less wear of tyres, (c) higher

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dumper productivity. The radius of curvature should be designed in such a manner that the centrifugal force on the dumper during rotation and the friction between the truck tire and road surface are balanced.

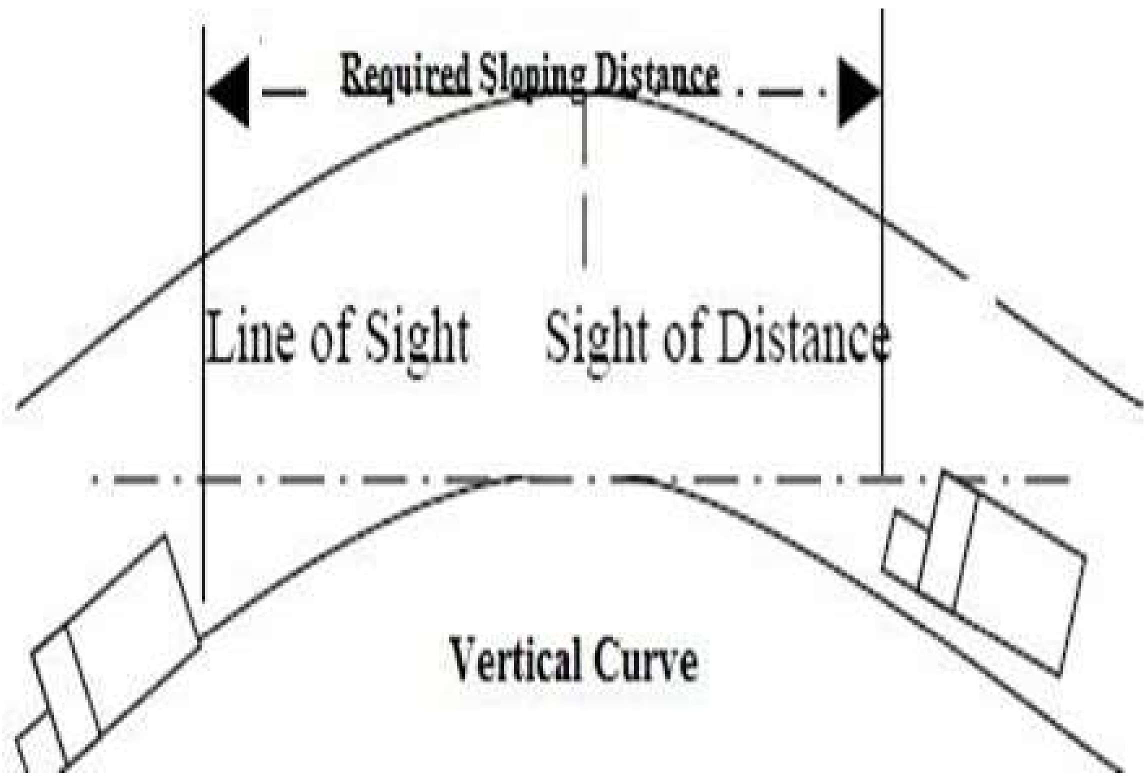
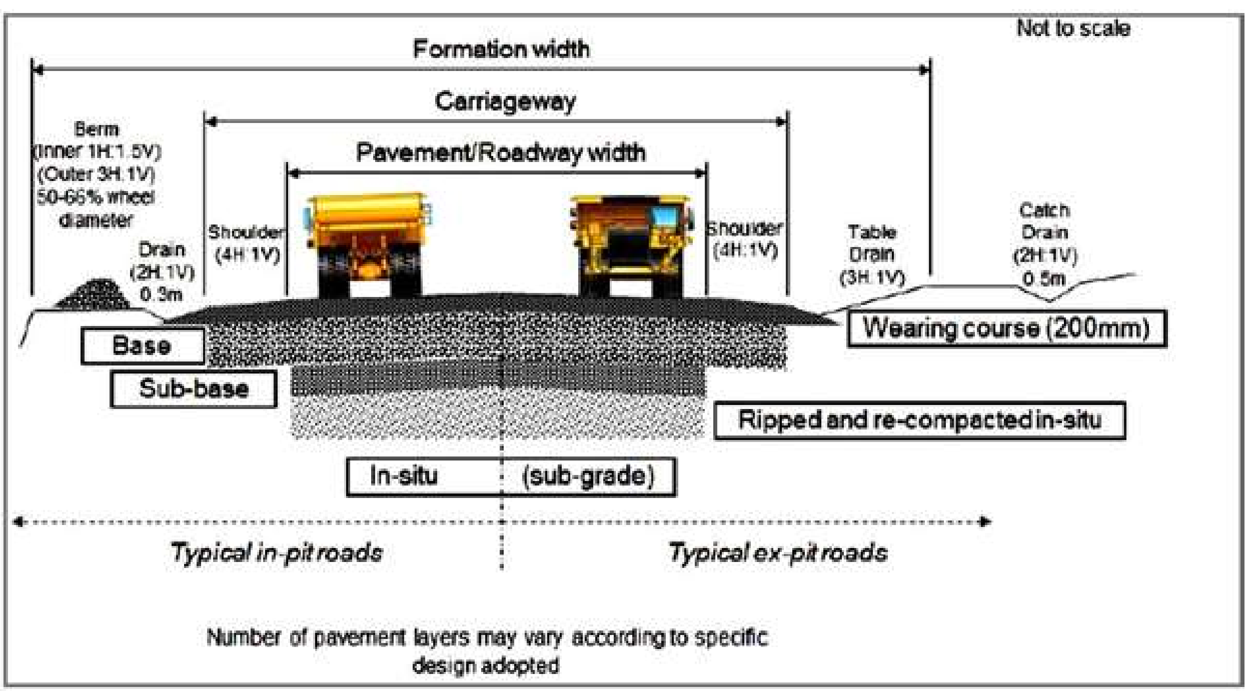


Figure 1 : Shows movement of dumpers on a curve



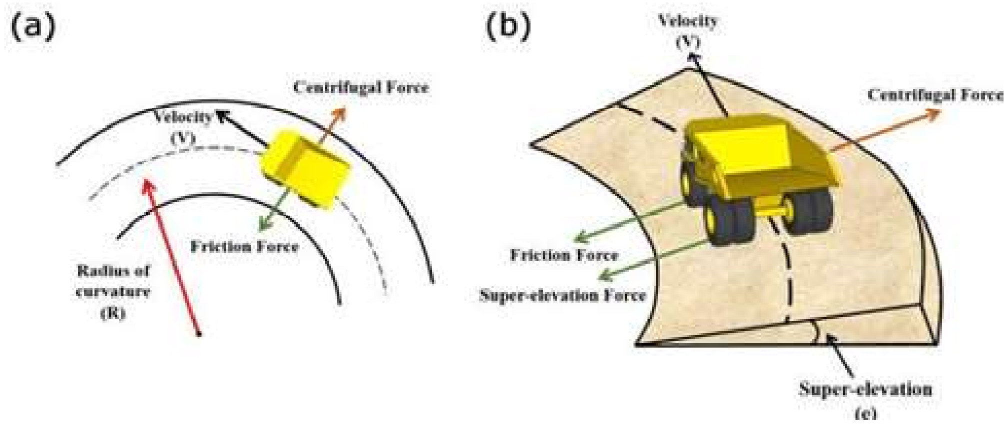


Figure 2 : Shows the cross section of a haul road.

The equation for the minimum radius of curvature that should be considered when designing a road is as follows [Source : Kaufman,W.W.; Ault, J.C. Design of Surface Mine Haulage Roads-A Manual; United States Bureau of Mines (USBM), United States Department of the Interior: Washington, DC, USA, 1977; pp. 1–49.]:

$$R = V^2 / 127(e + f)$$

Where
R is the radius of curvature (m),
V is the vehicle speed (means the maximum speed when the truck runs on a downward slope without a load) (km/h), e is the super-elevation rate (m/m), and
f is the friction coefficient between the tire and road surface.

SUPER-ELEVATION

It is the degree of banking along one edge of a road (see Figure 15.6: b). Applying the difference in altitude at both edges of the road decreases the centrifugal force on the truck during rotation and allows the truck to rotate stably. The super-elevation should be designed not to exceed 5%–7% (approximately $3^0$to 4^0). In general super- elevation on a haul road is dependent on radius of curvature and vehicle speed. The friction coefficient varies according to the road surface and is assumed as 0.3 if the surface is sandy and soft or muddy or as 0.45 if the road surface partially consists of gravel.

SUPER-ELEVATION RUN OUT

When approaching a super-elevation corner from a straight stretch, there must be a gradual change from level to super-elevation to allow the driver to safely man oeuvre the truck through the curve.

Determination of thickness of Flexible pavement:
Gray's Formula – d = 0.564 W/B – L Where,

- d - Thickness of Flexible pavement in inches
- W - Static wheel load in lbs. = 1.2 X load per pair of wheel
- The maximum wheel load (load per tyre) for a double-axle vehicle should be increased by 20% extra for Impact)
- B - Bearing value of the ground in lbs/Sq. Inch (CBR value)
- L - Radius of equivalent area of tyre contact = contact area of tyre.
- The example below shows how to determine the structure specifications of a haul road of 78 tones class dump trucks.

Example: Preconditions: Dump Truck used: KOMATSU HD 785, Hauling capacity: 78 tones, Gross Hauling capacity: 129, 555 kg, Front axle load: 41,855 kg, Rear axle load: 87,700 kg. Road condition expressed as - Soil conditions: CBR = (silty clay)

Calculation method: Maximum wheel load: 21,925 x 1.2 = 26,310 kg

From Nomogram provided by the manufacturer, the intersection of 26,310 kg and CBR = 5 lies at a depth of 81 cm. Sandy soil with a CBR of about 15 can be used as the sub base material, and the intersection lies at a depth of 40 cm. Gravel with a CBR of about 80 can be used as the base and the intersection lies at a depth of 18 cm.
Good quality (fine) crushed rocks (CBR = 80) can be used for the road surface.

Types of the haul roads: (1) Permanent Haul roads, (2) Haul roads connecting the Permanent haul roads to faces & dumps, (3) Ramps connecting different benches.

PERMANENT HAUL ROADS

Since haul roads are considered to be the permanent source of dust in opencast mines, construction of haul roads with flexible pavement reduces pollution of environment from dust to a considerable extent.

The road alignments are also used by crawler-mounted equipment like dozers. Since plying of crawler-mounted equipment is likely to damage the flexible pavement, a 5-meter wide flank has to be kept on one side of the flexible pavement for use by such crawler-mounted equipment.

Haul roads should be designed according to appropriate specification, taking into consideration the weight and the amount of traffic. Otherwise, the road surface is likely to develop unequal subsidence; making maintenance different and increasing the costs of haul road maintenance.

DGMS GUIDELINES FOR HAUL ROADS

1. All roads for truck, dumper or other machinery shall be maintained in good condition.
2. All roads from the OC workings shall be arranged to provide one-way traffic. Where this is not practicable, no road shall be of a width less than three times the width of the largest vehicle plying on that road unless, definite turn outs and waiting points are designated.
3. All corners and bends in the roads shall be made in such a way that the operators and drivers of the vehicles have clear view for a distance of not less than 30 meters. Along the road and be provided with proper parapet wall or road dividers etc.
4. No road shall be steeper than 1 in 16 at any place, except in cases of ramps over shall patches which may be up to 1 to 10.
5. Where any road exist above the level of the surrounding area, it shall be provided with strong parapet walls or embankments not less than one meter in height to prevent any vehicle from getting off the road. Same type of embankment shall be provided on coal/OB stockpiles/dumps (in addition to the spotter/supervisor).

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Planning for Design of Mine Benches in Surface Mines

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INTRODUCTION

In the post coal mine nationalisation period the number of surface m ines in coal sector had increased to meet the growing demand for power grade coal. Since the late 70's the mining companies have adopted several state-of-the-art techniques to plan safe and productive mines. MIne benches are essential for andy surface mines for ensuring safe and productive handling of blasted or unblasted material. Unblasted material can be top soil or loose and soft material found in most OB benches and material cut by surface miners where blasting has been replaced by surface miners.

DEFINITIONS

Bench is defined as a
… a ledge that, in open-pit mines and quarries, forms a single level of operation above which minerals or waste materials are excavated from a contiguous bank or bench face ….

As per MCDR 2017 Rule 13

1. In open cast workings, the benches formed shall be so arranged that the benches in ore or mineral and overburden are separate so as to avoid mixing of waste with the ore or minerals.
2. The benches in overburden shall be kept sufficiently in advance so that their workings do not interfere with the working of ore or minerals.
3. Orientation of the workings and sequence of mining operations shall be such that different grades of ore or minerals can be obtained simultaneously for blending with a view to achieve optimum recovery of ore or minerals from the deposit.

Rule CMR 105 and CMR 106 of CMR 2017 and MMR 106 incorporates the various safety measures to be adopted for manual mines and mechanized mines respectively.
Classification of Benches

Types of Benches (Figure 1, shows Bench Geometry)

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1. Working bench
' .... *The mineral or waste is removed in successive layers, each of which is a bench, several of which may be in operation simultaneously in different parts of , and at different elevations in, an open pit mine or a quarry'*

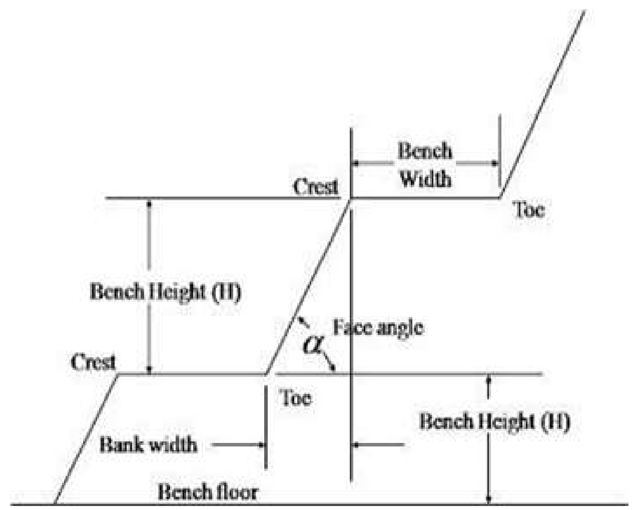

Figure 1: Bench Geometry

2. Catch bench - remnant bench left to:
* catch the material/rock falling down the slope
* facilitate access to the face 3.Safety bench
3. Double bench

SELECTION OF HEIGHT AND WIDTH OF BENCHES

Bench Height is influenced by –

i. Geology of the area - i.e. ground could be hard, compact, loose, friable, soft, consolidated, unconsolidated etc. In strata such as gravel, mourn, sand, alluvial soil, clay, running sand or any other similar strata, the bench height should not exceed 3 m.
ii. Hydrology of the area – the ground or strata could be dry, wet, porous, non porous, above or below the water table etc.

iii. Statutory norms –
(a) Height of benches shall not exceed the maximum

reach of the machine used for digging excavation or removal.

(b) Unless otherwise permitted by the Regional Inspector of mines (now designated as
Director of Mines Safety) by an order in writing, the width of bench shall not be less than twice the diameter of the turning circle of the largest machine working on the benches. Provided, that where there is one way traffic over the benches, the width of a bench may be reduced to not less than twice the length of the largest machine working on the bench.

iv. Equipment size and type - Excavator dimension influences the bench height – for shovel/excavator benches it is maximum height of the reach of the bucket. In case of dragline it is digging depth of the unit.

v. The optimum digging height of the excavator for efficient excavation, one pass drilling length should preferably be more than the bench height, and the blending requirement dictated by the geological parameters. For benches worked by rope shovels and draglines, the bench height is generally selected on the basis of optimum digging height of the excavator. In case of hydraulic excavators, the bench height is generally selected on the basis of maximum digging height. In case of bucket wheel excavator (BWE) workings, the bench height depends on –the height of the cutting boom pivot point, the effective length of cutting boom including the cutting wheel and the allowable maximum angle of inclination of cutting boom in the vertical plane limited by the dynamic angle of repose of the cut material. Bench width is the horizontal distance between the crest of a bench and the toe of the immediately upper bench.

vi. Quality of ore/coal – blending requirements

vii. Overburden and Ore Properties - These properties include rock strength and the number and direction of rock discontinuities. Benches are just like smaller pit walls with a much lower height (usually 6 to 12 M). Therefore, benches should also be designed in such a way that no risk of instability is created due to excessive height of benches. There is a direct relationship between rock strength and safe values for the bench face angle and bench height.

viii. Production Rate - Production rate of a mine is a parameter that is usually determined by market demand and selling capacity. When the required production rate is determined based on the market situation, then the annual mine production rate that includes ore and waste extraction is determined in such a way that enough product for the sale purposes is guaranteed. Higher benches are normally required to achieve higher production rates.

ix. Influence of bench height on mine operational cost and efficiency/productivity – Kose et el (2005) had studied the impact of bench height. Reproduced below his observations relating to a quarry designed for an annual production capacity of one million tons has been studied separately for both pit and hillside cases.

In both cases, unit cost analyses were carried out for bench heights of 10, 12.5, 15, 20 and 25 m. and for each bench height, blast hole diameters of 89, 102, 115, 127 and 152 mm, as well as for road grades of 8 per cent and 10 per cent. Models for both quarries are shown in Figures 15.11. Overall slope angle of the model quarry has been fixed at36° for each bench height and a suitable slope angle for each bench in accordance with bench height has been determined.

When unit blasting cost is considered, the most economical bench height arrived at has been 15 m. Furthermore, it has been found that blasting unit cost decreased as Hole diameter grew larger.

Loading and transportation - For the loading process, a front-end wheel loader with 2 m^3bucket capacity has been selected by taking the cost and capacity analyses and previous studies into account. For transportation processes, trucks of 25-tons capacity have been preferred because of their low initial investment and high employment in quarries. In order to determine operational expenses that influence the transportation unit cost, condition and grade of the road, truck-road interactions (road resistance, rolling resistance and loaded-unloaded trip durations for both pit and cast quarry cases have been included in the cost analyses. In Figures 2, 3,4,5 & 6, results of loading-transportation unit cost analyses are illustrated for road grades of 8 per cent and 10 per cent. In the case of hillside quarrying, the trend resulted in a decrease in loading-transportation unit cost as the bench height and hole diameter increased and an increase in unit cost as the road grade increased, while, in the case of pit quarrying, the trend resulted in an increase in unit cost as the bench height and hole diameter increased and loading transportation unit cost grew as the road grade decreased.

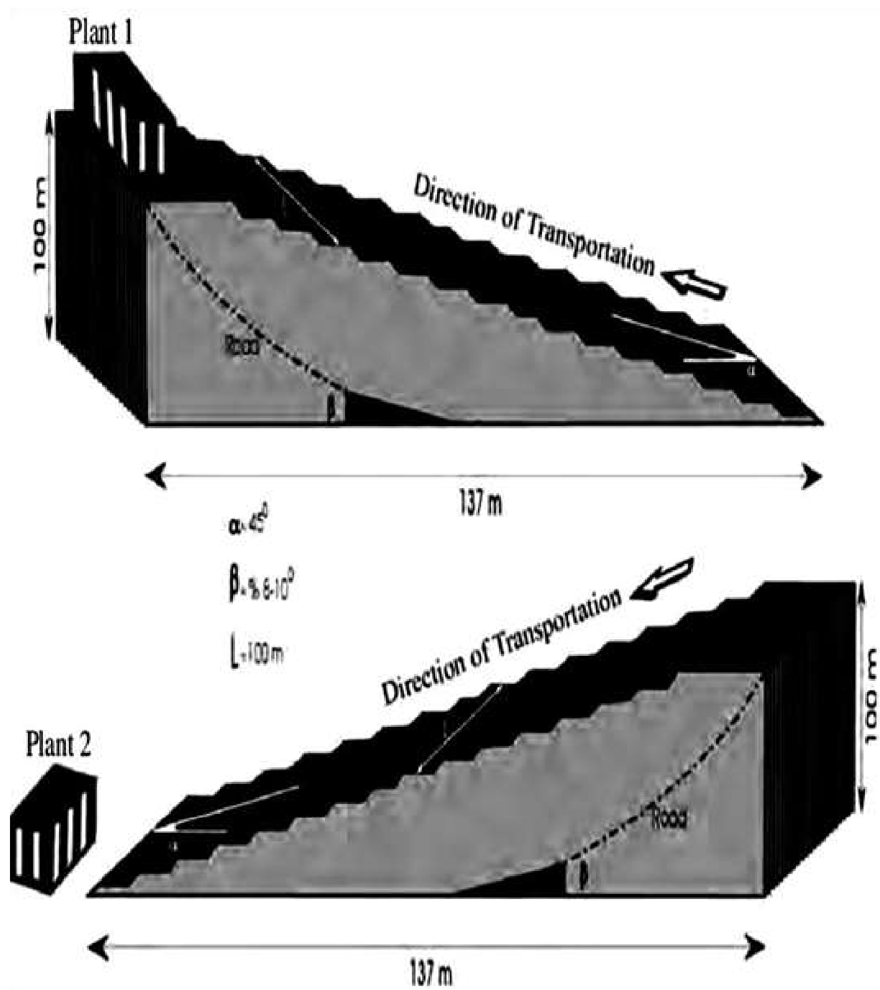

Figure2 : Model geometries for pit and hillside quarries
(Plant 1 is for the Quarry having 100m depth and Plant 2 is for Hillside having 100m elevation)

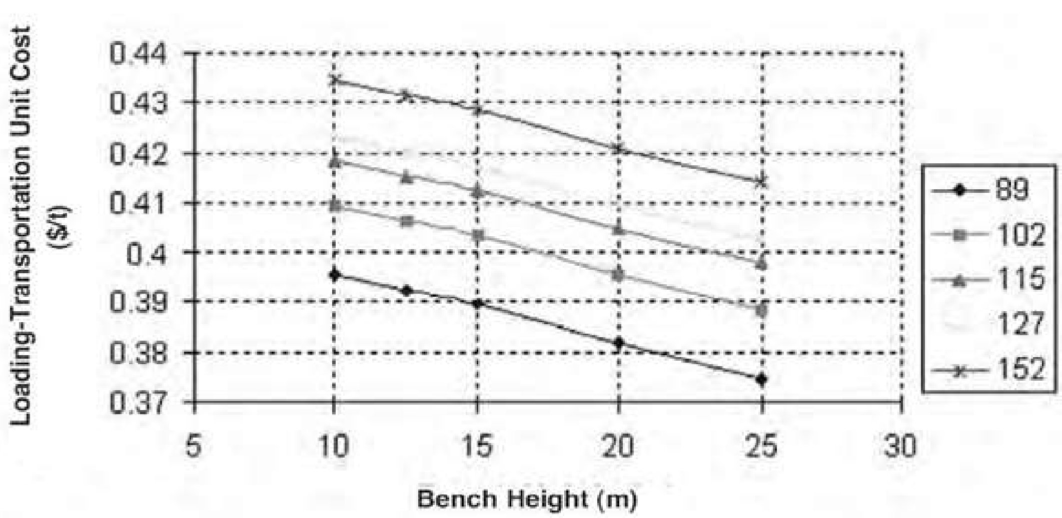

Figure 15.12 : Results of loading –transportation unit cost analysis

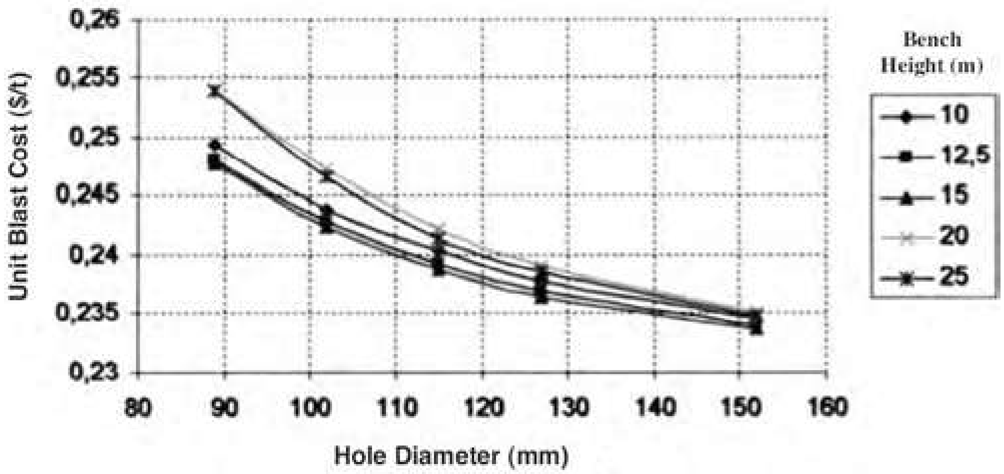

Figure 3 : Unit blasting cost analysis for bench height-hole diameter

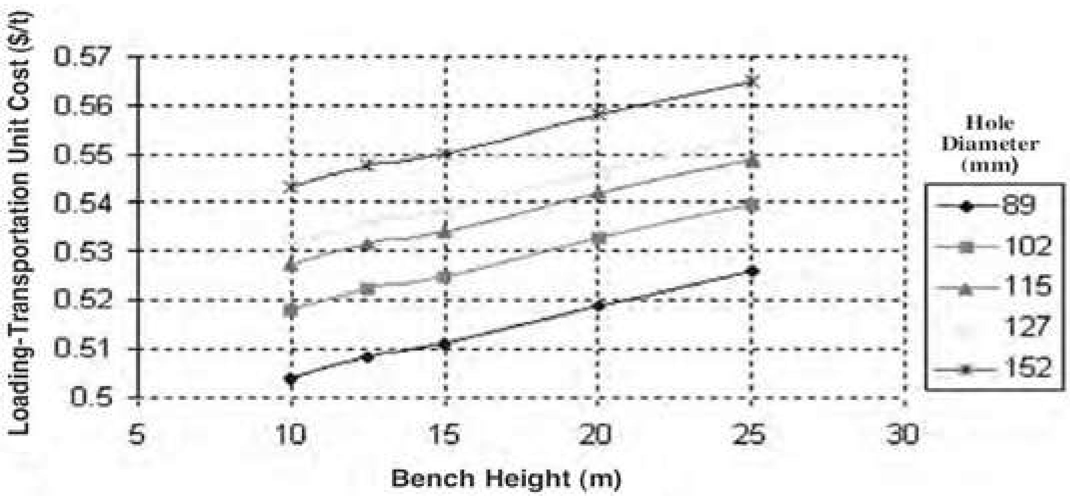

Figure 4 : Results of loading-transportation unit cost analysis for a pit quarry case and a road grade of 10 per cent

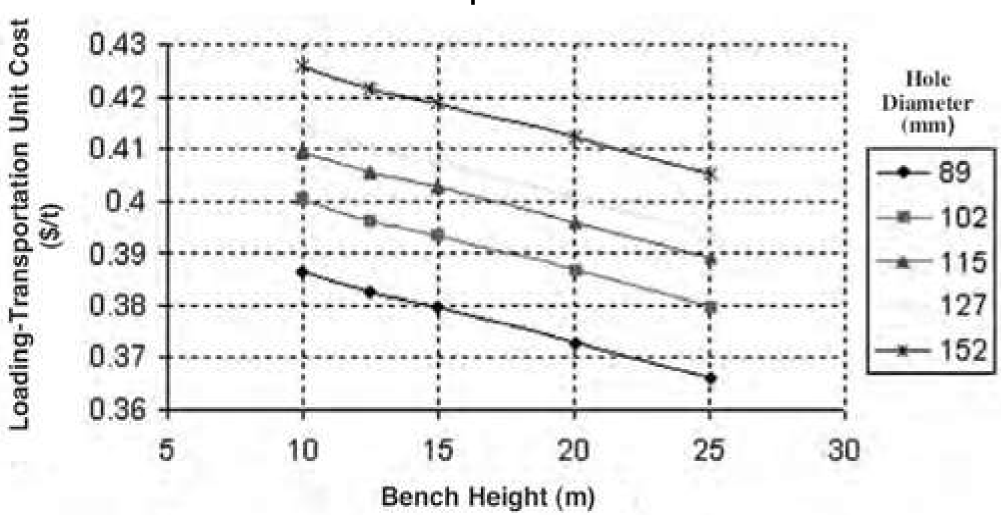

Figure 5 : Results of loading-transportation unit cost analysis for a hillside quarry and road grade of 8 % cent

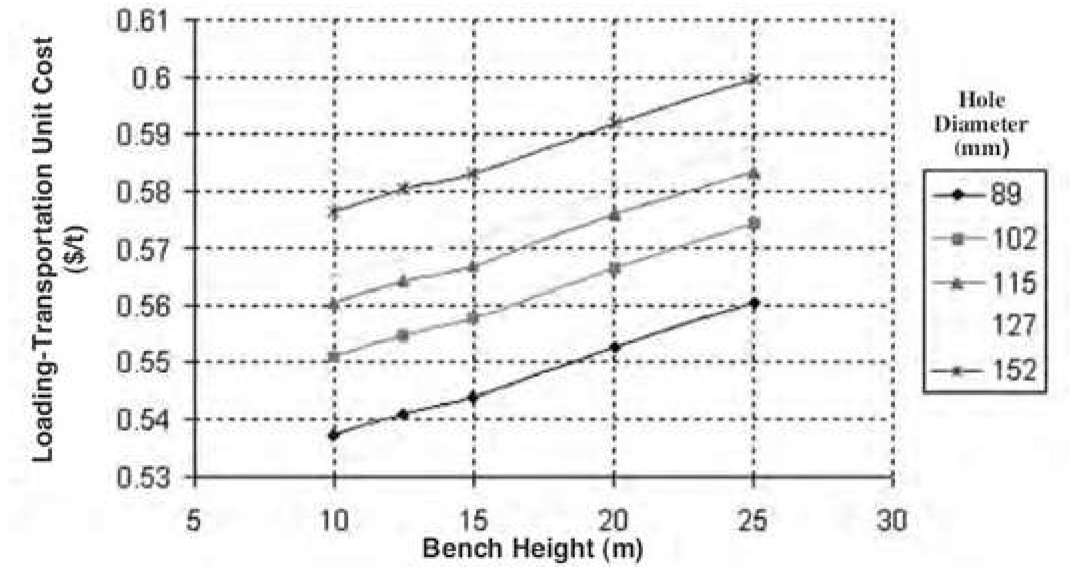

Figure 6 : Results of loading-transportation unit cost analysis for a pit quarry and road grade of 8 %.

WORKING BENCHES

DGMS Permission for Working Opencast Mines with HEMM, has explained clearly the measures to be taken to ensure safety of men and machineries in a working mine. They are –

Every mine had to seek permission for exemption from the provisions of Regulation105 (1) & (3) of the Coal Mines Regulations, 2017 for working opencast mines with the help of Heavy Earth Moving machineries (HEMM) in conjunction with a system of deep shot hole blasting subject to the following conditions being strict complied with:

No topsoil, clay, alluvium or black cotton soil shall be dumped so as to form the base of the internal overburden dump. Such materials, if any, shall be dumped only on top of the internal overburden dump.

The width of the cut taken by the dragline in overburden shall as far as practicable be maintained constant throughout the face so that the alignment of the coal face and the toe of the internal overburden shall run parallel to each other.

The coal/overburden face shall be laid so that any make of water at the overburden/coal face or in the dump shall gravitate unhindered automatically towards the sump located at the centre of the face (s) or the out bye end of the face as the case may be. The gradient along with floor of the coal seam or the bed rock shall be maintained preferably 1 to 70 but in no case shall be less than 1 in 80 towards the central sump.

Where the inclination of the bedrock does not exceed 5 degree from the horizontal, the height of overburden dump nearest to the coalface shall not exceed 60m. A bench 10-15m. wide in the overburden shall be maintained between this dump and the final dump created by the dragline. If the inclination of the bedrock exceeds 5 degree, the height of the fore bank shall be suitably reduced.

BENCH HEIGHT

In addition to statutory provisions related to safety of men and machinery working in the mine, and operational efficiency the following factors influences in the height-

A. Geological parameters (structural, lithology, hydrology-drainage pattern, stone bands or inter-calations etc)
B. Method of work by shovel dumper and dragline, Table, shows a general rule of thumb, based on the concept that the bench height should not be greater than that of the sheave wheel. Approximate bench height guidelines based solely on loading equipment match

Bucket size m^3	Bench Height (m)
<5.0	9
5.1 – 8.0	12
8.1 – 20.0	14
20.1 – 30.0	16
> 30.0	18

A. Type of drilling unit, mostly for single pass drills.
B. Coal Seam/Ore body - No. of seams in case of coal mines and their thickness, gradient. Np. of benches planned in Ore and OB.
C. Fragmentation of in-situ rock by blasting or blast free techniques
D. Maximum digging height in case of hydraulic excavators/rope shovels, Maximum reach of the dragline,
E. While using BWE (Bucket Wheel Excavators), height of the cutting boom pivot point and the effective length of cutting boom including the cutting wheel and the allowable maximum angle of inclination of cutting boom in the vertical plane limited by the dynamic angle of repose of the cut material.
F. Level of mechanic ratio
G. Refer Figure 7: where the Section A-A' of the mine plan explains the bench height (H), bench width (W), and bench slope ().

BENCH WIDTH

It is the horizontal distance between the crest of a bench and the toe of the immediate upper bench. This has to be more than the bench height, maximum width of the largest machine + 2 m, and three times the width of the largest size dumper that is plying on the bench.

From the Operational Point of view, Minimum width of a working bench should equal to -

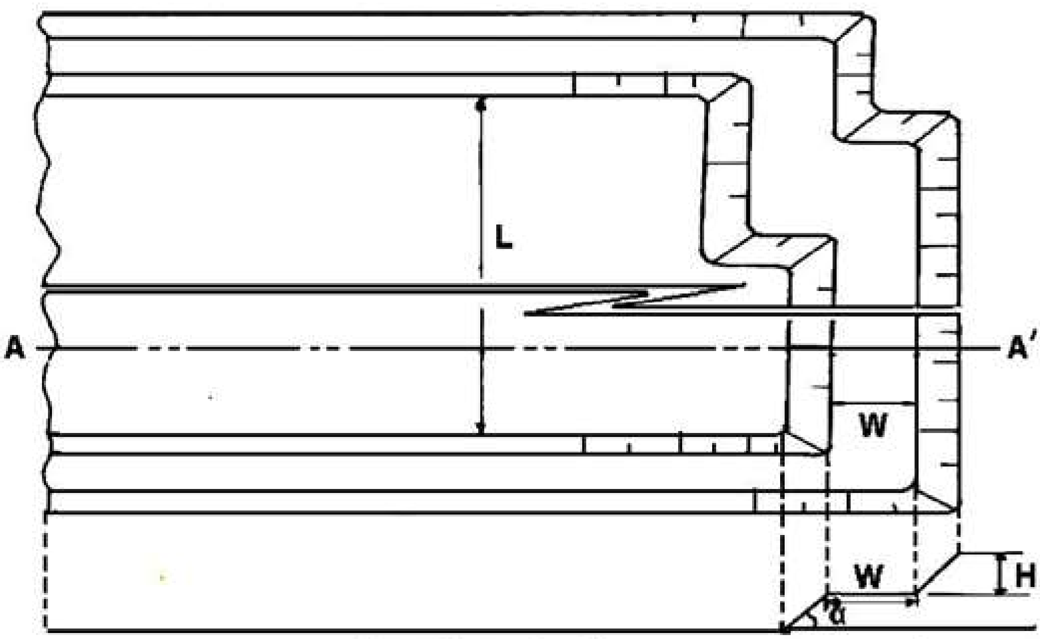

Figure 7 : Bench Parameters

Operational Point of view, Minimum width of a working bench should equal to
=0.8 X bench height + shovel dimension + 4m Now according to the Practical Calculation of mines Bench height = 9m (can be 3m more than the boom height)
Dumper width = 2.49 m
Shovel width = 3.44 m Now,
Working bench = 0.8 x 9 + 2.49 + 3.44 +4
= 17.13 m

Bench length: - Bench length in a surface mine is the length (Straight or curve as the case may be) measured along the floor of the bench between its two extremities. It is generally decided based on the operational requirements and conveniences. The minimum bench length required is generally dictated by the frequency of primary blasting and the advancement of the face along the length of the bench per blast and also on the type of excavator used.

In a mine that is being worked by shovel- dumber combination with full scale blasting, minimum bench length required may be calculated as follows Let,

The frequency of blasting in the bench is one once per

week.
The volume of material to be handle per week from the bench is V The height and width of the bench are H and W Respectively
The length of broken material required per week, 1=V/ (H x W) The minimum bench length. L = 3 x1

The Minimum bench length L shall be equal to 3x1 as an additional length of I will be required for drilling of 1 for maintaining the flexibility. For Dragline benches, the minimum bench length should be 300m to 500m in view of marching requirement and operational conveniences.

For the mines being worked by bucked wheel excavator (BWE) – conveyor combination. The minimum bench length should be decided on the basic of the production requirements, the method of work of BWE (full block or half block). Shift able belt conveyor shifting frequency and other operational conveniences.

CONCLUSION

Entire safety and productivity of any surface mine is dictated by design and construction of benches as per provisions of CMR 2017 & MMR 1961 and also various Technical Circulars issued by DGMS from time to time.

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Rock Breakage by Non-Explosive Expansion Chemical Method : Case Study

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INTRODUCTION

Rock breakage by blast free techniques had gained much wider application. This is due to the blasting close to human habitation, historical buildings, civil structures (buildings, dams, etc). One of the popular method has been use of expansion chemicals which helps in developing multiple cracks even on very hard rock strata. An attempt has been made to present pone of our experimental data showing the application of this method.

CASE STUDY

'Blast free Excavation' at the hard Rock Zone of the Zone 1 of SP3 project site in Kirandul VComplex of NMDC Ltd was considered as am alternate method to blasting. To study the application of use of expansion chemicals, field study was undertaken and few trials were undertaken. The steps involved are enumerated.

1. Site visit : The team visited the site and after seeing the safety of the excavation, took field testing of the hard rock in 25 locations comprising of both hard stacked/ excavated boulders as well as of the in-situ rock.

2. In-situ measurement of the hardness expressed as Schimdt Hammer Number was recorded and the values were converted to Compressive Strength in MPa. It was observed that the Compressive strength values varied from 120 to 150 MPa. Taking the average value it is in the region of 140MPa.

3. Rock Type : The hard rock comprised of Granite, Fine Grained,, with very thin clay and or quartzite intercalations.Weathering was noticed on the sdlope of the hill slope, which was covered by clay and green belt. The entire hard rock were having no cracks, folds or faults. Seeing the rock conditions, the RQD (Rock Quality DEsignation) indicator for compaction of the rock can be + 95.

4. Blast-free excavation : Mine management and PMC team had evaluated several options to adopt most suitable, cost-effective, fast method of excavation. Currently, the blast-free operations adopted globally and in India are -

(a) Use of Rock Breakers (attached to hydraulic excavators)
(b) Ripping - primarily for soft to medium hard fractured rock like bauxite etc are best suitable.
(c) Surface Miner - Best suited for rock compressive strength upto 140 MP in mines having well planned benches, and long benches.
(d) Use of Terminator (mounted on higher HP hydraulic excavators)
(e) Use of non-explosive Chemicals to crack the hard rock.

Of all these systems stated above, NMDC had experimented with 'Use of non-explosive Chemicals to crack the hard rock' and 'Rock Breaker mounted on 210 HP Hydraulic excavator' of the existing Contractor.

It concluded, that the existing volume of excavation and conditions of the Zone 1, the above systems {except (a) and (e) } are not at all feasible technically and in cost-effective mode.

5. Evaluation of the 'Use of non-explosive Chemicals to crack the hard rock' -

Mine management had conducted the use of FAST CRACK Chemical on 32mm dia. holes drilled on a 300 x 300 mm pattern on a in-situ rock, in the month of November 2018.

Photographs showing crack development on in-situ hard granite block

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Summary of the experiment is stated below -
i) No. of holes - 10
ii) Dia. of holes : 32 mm by Jack hammer
iii) Average Depth of holes - 5 ft.
iv) Average Burden as measured in the site - 300 mm
v) Average spacing as measured in the site - 250 mm
vi) Hardness of the rock as measured by Schmidt Hammer is 140 MPa.
vii) Total Qty. of chemical used - 20 kgs.
viii) Qty. of chemical mixed with water (1.5 litres for every 5 kg chemical) - 1.7 to 1.9 kg.

Excavation

Excavation of the cracked zone - by Rock Breaker attached to 210 HP excavator. Total time taken to excavate the area of cracked zone is 36 min.

Total block size of the cracked zone - 1.9 x 0.70 x 0.70 = 0.931 Cubic M. Total hole meterage - 15.24 M
Qty. of excavated material per M is 0.061 Cubic M.

Cost per kg of the chemical : Rs. 50/- Total cost of chemicals Rs. 1000/-

1. To undertake few more experimental trials of excavation by using FAST CRACK (5 to 25 Degree).

Accordingly, two blocks were identified and Jack Hammer was arranged.

Block 1 (where holes were previously drilled, and cleaned before charging) -
i) No. of holes - 5* +15** = 20
ii) Dia. of holes : 32 mm by Jack hammer
iii) Average Depth of holes (cleaned of water & measured) - 2.5 to 4.0 fft.
iv) Average Burden as measured in the site - 300 mm
v) Average spacing as measured in the site - 300 mm
vi) Hardness of the rock as measured by Schmidt Hammer is 140 MPa.
vii) Total Qty. of chemical used - 30 kgs.
viii) Temperature at the site at the time of charging : 33 Degrees
ix) Total charging time (including mixing) - 20 Min.
x) No. of labourers engaged with all safety gadgets - 4

Observations - With 4 Hrs we could observe prominent cracks on the 15 holes (**). However, no cracks observed on the remaining 5 holes even on the next day.

Block 2 (where drilling of holes were in progress)
It was suggested to drill 5 ft holes on a 200 x 200 mm pattern of holes. Drill at this face had commenced in the late evening.

Cost of breaking one Cubic Meter by Chemical(excluding cost of drilling, manpower for charging, and excavation by rock breaker) is Rs. 1074.11.

Granite Quarry located near the Kirandul Rly. Station

During our discussions it was stated that in the nearby Granite Quarry, chemicals were used to fragment the hard granite mined for ballast and aggregates by a private contractor. It was found that the top benches of the quarry had used expansion chemicalsloaded into jack hammer drilled holes (of 32 mm dia) on regular basis on a 5 ft bench. The results were quite encouraging and the photograph below shows stable benches.

CONCLUSION

This is a proven technique. But it has limited application due its high cost despite being eco-friendly, noise less, vibration free and have no impact on air pollution etc.