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Slope Monitoring Systems in Opencast Mines – A Brief Review

Sathish Kumar Mittapally* Ravi Teja Bollam**

ABSTRACT

The opencast method of mineral extraction is more prevalent than the subterranean method because it allows for extensive mechanization to accomplish bulk production at a lower cost. Heavily Earth Moving Machinery (HEMM) is utilized for bulk production, increasing opencast mine parameters such as bench height, bench breadth, slope angle, and other related geometry. The deployment of big capacity machinery on the seats compromised the stability of the benches as the bench height increased. The slope of benches in opencast mines must be monitored to ensure the safety of employees and machinery placed in the pit.

This paper discussed the importance of Slope Monitoring as well as the other methods utilized for Slope Monitoring. Deals specifically with recent developments in slope monitoring technologies using various types of slope monitoring systems with current trends in the opencast mining industry and also describes the various challenges to be focused on in the near future for the success effective slope monitoring in opencast mines.

Key words: Slope Monitoring, Slope Stability, Wireless Sensor Networks, Internet of Things

INTRODUCTION

Mining is the process of excavation of economic minerals and materials such as gold, coal, diamonds, galena, sphalerite, sand, limestone etc. It also includes in the extraction of any non-renewable natural resource such as petroleum, natural gas, or even water. In order to meet the ever-increasing demands of the modern generation, the mineral production in our country and world are continuously increasing along with the scale of mining operations. Extraction methods are generally like the opencast method and the Underground method (Rock Onwe, 2015). By the underground method, only 40%-50% mineral is extracted and the remaining is left inside in the name of pillars, barriers, etc. Underground mining has the potential chances for tunnel collapses, land subsidence and more (Kishore, 2018).

The opencast mining method has a cone-shaped excavation and is usually deployed to extraction near the surface. If often results in high production rate and also requires very large scale of capital investment with low operating costs and good safety conditions (Awwad, 2002). Maximum rate of extraction can be obtained thru opencast mining method. The country has to import coal from other countries to meet demand in India. Generally underground is very much suitable for the extraction of mineral from greater depths, whereas in Opencast Method is suitable to extract mineral from shallow depths. However, opencast method is dominating in India as shown in figure.1 (Opencast coal production is increasing from 686.21 MT to 839.59 MT during the years 2018 to 2023, whereas in the same period underground production increased from 42.5 MT to 53.6 MT only). (Ministry of Coal GoI, 2023). Underground coal production is in declined trend from last 10 years and also several underground mines were closing every year.

In India, large scale extraction of near-surface coal resources by opencast mining, near-surface coal resources will be depleted in future (Sourav Mukherjee, 2019). Then opencast extraction process will be increased more depths. Increasing depth regulates the increasing in the stripping ratio and also costly operation.

Opencast method of coal extraction with high mechanization is the best method of extraction for deeper depths. The fundamental challenge in deeper opencast mines is slope control. The slope may fail due to an increase in shear stress or a decrease in shear strength. Failure of slope can be obtained due to ground vibrations, movement of HEMM etc. A slope failure results in significant socioeconomic losses to men, machinery, and time (Ahmad Zaki, 2014). However, a major issue with slopes is slope collapse or failure, which is a major natural hazard on both a local and global scale. Steeper slopes; excessive water in the slopes, which adds weight and

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Financial year	Opencast coal production in (MT)	Underground coal production in (MT)
2018-19	686.21	42.50
2019-20	690.39	40.48
2020-21	683.87	32.21
2021-22	745.01	33.18
2022-23	839.59	53.6

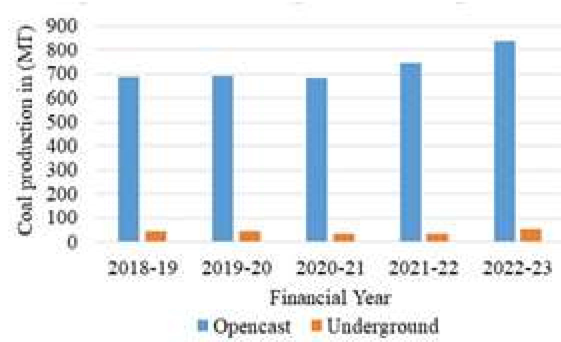

Figure 1: Coal production from Opencast and Underground in India (Ministry of Coal GoI, 2023)

weakens cohesiveness; human modifications such as blasting, passage of heavy vehicles, fractures developed on the surface of the slope; uneven pit design; erosion on the slope surface, and so on are among the causes (Yadav, 2019). Landslides occur when a slope transitions from a stable to an unstable state. Several causes, either together or separately, might induce this change in a slope's stability. Natural causes include ground water pressure acting to destabilise the slope, rivers or ocean waves eroding the slope to an all-time low, earthquakes adding hundreds to a barely stable slope, and earthquake-caused state changes weakening slopes (Pitambar, 2019). Table 1 explains about various slope failure-related accidents in India.

Table 1: Slope Failure-Related Accidents in India (after Yadav, 2020; Envis, 2020)

Sl. No	Date	Name of mine	Incidence	Fatal
1	24.06.2000	KawadiOpen-cast (OC) Mine of M/s Western Coalfields Limited (WCL)	Slope failure of 31 m high OB benches.	10
2	09.12.2006	Tollen Iron Ore Mine of M/s Kunda R Gharse in Goa	Failure of slope 30 m to 46 m high dump.	06
3	17.12.2008	Jayant OC Project of M/s Northern Coalfields Limited (NCL)	Failure of dragline dump	05 persons 01 shovel buried
4	04.06.2009	Sasti OC Mine of WCL.	Dragline OB dumps of 73 m height failed and slide down the pit.	02 persons 02excavators buried
5	25.02.2010	Hansa Minerals and exports Granite Mine.	Granite mass slide along an inclined joint plane and failed from height varying from 10 to 55 m.	14 persons
6	22.06.2014	Amlai Opencast Mine, South Eastern Coalfields Limited (SECL).	Dump failure due to sudden development of cracks in the embankment and unstable ground conditions.	2 persons 1 dumper 1 dozer 1 crane
7	29.12.2016	Rajmahal OCP of Eastern Coalfields Limited (ECL)	Dump failure due to development of cracks and unstable ground conditions	25 persons 12 tippers 6 excavators and 1 dozers
8	02.12.2017	Codli Iron Ore Mine Vedanta Limited	a person was dozing muck on OB dump, suddenly a portion of dump slithered and collapsed	01 Person 01 Dozer
9	24.04.2019	Kalane Iron Ore Mine Minerals & Metals	Six overlying benches were fallen while levelling the bench by excavator	01 person 01 Excavator
10	23.07.2019	Bharatpur Opencast Mine Mahanadi Coalfields Ltd	Accident occurred due to rib failure	04 persons 1 excavator
11	23.07.2020	Kusmunda OC Mine (SECL)	Heavy inrush of rain and mud leads to workmen fatal	01 person

Slope failures are classified depending up on several criteria such as movement, materials, groundwater conditions, geotechnical properties of rocks (Meryem, 2018). Failure of slopes are four types Plane failure, Wedge failure, Circular failure, Toppling failure. During the last four decades, the concepts of slope stability analysis had emerged within the domain of rock engineering to address the problems of design and stability of excavated slopes. There is a scientific reason for each slope failure and failures do not occur without any warning, if the failed area is well monitored (Ajay Kumar, 2008). To avoid slope failures, slope monitoring systems are required to monitor day to day in the opencast mines. Monitoring instruments are ranging from simple piezometers and extensometers to highly sophisticated RADARs and global navigation satellite systems are employed for prediction impending instabilities and subsequent failure of rocks (Ali, 2010; Vinoth, 2016).

RELATED WORKS

The Conventional techniques which are included in manual inspection technique and mapping of tension crack along the slope face. These methods are chiefly utilize manual supervision for Slope Monitoring. All the methods which are regularly practiced for the slope stability assessment on the daily basis from early days. Visual inspections were mutually conducted by routine monitoring of slope, pit, access ways, high wall, low-walls such as those in coal mines and crest. Highly unstable slopes are warned or known by the production of Tension cracks in the particular area. Surface Movements Monitoring were done by Digital Photogrammetry, Robotic Total Stations, Global Positioning Systems, Non-Reflective LiDAR and Radar monitoring. Subsurface Movements Monitoring of slopes are done with sensors such as Tilt sensors, Displacement sensors, Strain Gauge sensors, Moisture sensors, and so on (Vinoth, 2016). Numerical Modelling Methods (NMM) analysis was done in the laboratory with the help of known field and to know the location of Slope Failure. The Internet of Things (IoT)-based network uses wireless modules for communication between individual sensors to the data logger and from the data logger to an internet database (Abraham, 2020). IoT monitoring systems are often used for geotechnical information, alone or in combination with innovative technological elements.

Traditional manual reading is being progressively replaced by the deployment of wireless networks of commercially available instruments to collect, transmit, and process land displacement data, as displayed in figure. 2 for a mining environment (Denis, 2021). Different forms of slope monitoring employing sensors, Artificial Intelligence, and the Internet of Things have been proposed by many researchers and academicians.

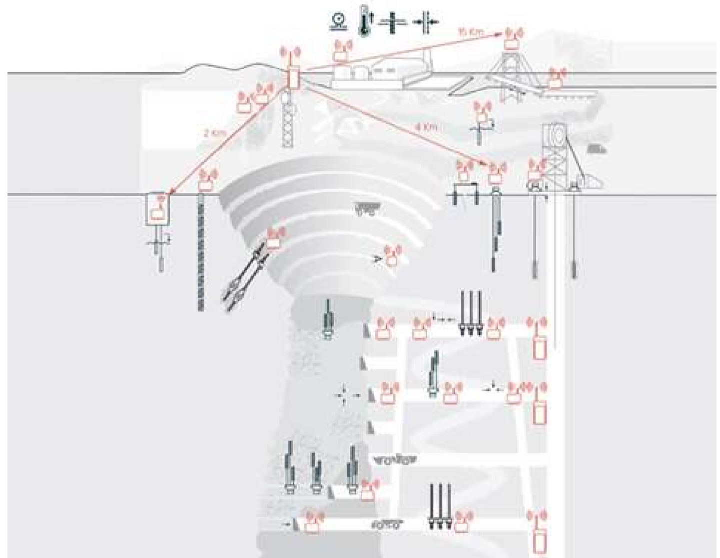

Figure 2: The IoT-based monitoring of a mining site (Denis, 2021)

A research work for monitoring of partition stability above underground coal workings was done by Dorthi & Karra (2020), thru ZigBee based wireless data acquisition system. This wireless network is cost-effective, 2-way communication and provides continuous monitoring along the analysis of data. In this paper ZigBee based WDAQ was developed for transmission of data. Researcher considered different partition thickness of 4.12m, 5.91m, 6.86m, 7.91m, 10.21m and 12.10m over U/G workings. Strain Gauge and LVDT were installed for monitoring of strain and deformation on the benches respectively. Sensors were installed on the bench at three adjacent places and data will be continuously monitored at surface and along with analytic (sensors) data, authors also done cross-examination with numerical analysis. ultimately concluded that, increasing in the partition thickness will leads to decrease in the strain and deformation.

Yadav, (2019), proposed the implementation of an online, Cost-effective wireless sensor network (WSN) for slope monitoring with Time-Domain Reflectometry (TDR) in opencast mines. Research work was done using coaxial cables, namely Radio Guide RG6, RG59, RG213, and RG58/U with TDR, to monitor ground movement. Also developed Graphical User Interface (GUI) using Python for automatic storing and plotting of data. Overall system was designed on an Arduino board with a ZigBee module. It is also well implemented with a visible warning system at the time of Failure. Firstly experiment was performed in laboratory with creation of movable bench slopes with glass plates. After that entire developed system was installed at DongriBuzurg Mine and monitored for 5 months, later monitoring stopped due to no changes in the ground movement. And also for further researches, they suggested utilization of LoRa for wireless data transmission in slope monitoring.

An efficient IoT-enabled landslide monitoring was suggested Mathew (2019), for limitation of the current scenario landslide monitoring methods and also implementing new wireless technologies incorporated to continuous monitoring of slopes. In this paperwork autonomous sensing devices were equipped suitable for monitoring with low cost. Transmission of the data was done by SigFox network to the data server. This system was successfully deployed at Bournemouth, UK for detection of landslide. Research paper provides information about presently available conventional methods and designed wireless sensor network methods for monitoring landslides. Firstly, testing was performed to ensure communication between SigFox and nodes at the landslide. Then the proto-type devices were successfully installed in the ground up to depth of 10 inches, and data transmission was done efficiently. Research presumed that implementing wireless sensors for landslide detection will reduce hazardous situations.

A case study on slope stability monitoring in opencast coal mine based on Wireless Data Acquisition System (WDAQ) was done (Dorthi & Karra, 2018), stated that the main reason for slope failures in opencast mines is the movement of Heavily Earth Moving Machinery (HEMM). For the case study, authors have monitored slopes above the old underground workings. LVDT is used as a sensor to observe the deformation and ZigBee was considered for wireless data transmission from WDAQ to monitor. Researcher were also compared with existing conventional instruments for monitoring and with ansys in numerical modelling with the same parameters. Finally, the research paper concluded that increasing the slope angle may lead to increasing the slope failure.

A case study on stability evaluation of highwall slope in an opencast mine was done by Satyanarayana, (2018). This paper provides the results of stability evaluation of pit slope at Medapalli Opencast Project (MOCP), SCCL. The highwall was monitored thru visually and by using CYCLOPS. Researchers also did stability analysis by using FLAC software to evaluate groundwater effect on slope. In this paper authors provided design parameters and hydrological conditions of highwall. Analysis of highwall slope was done only in 2D modelling because no major discontinuities were observed during formation of highwall. Basic input parameters were assigned to block and stability analysis was done for both in dry and undrained conditions. CYCLOPS was used for validation of numerical simulation data. It will be directly connected to software Geoscope and alarms were set at every prism for providing warning signals incase of failure. Finally authors came to an end with simulation analysis data and real time monitoring data are matching and said that improper maintenance of groundwater may leads to slope failure.

Jayanthu, (2017), published a research paper which represents about accidents occurred in Indian mines due to problems associated with ground control. This paper also describes the accident that took place in Rajmahal Mines, ECL. Main theme of paper is to establishing the application of electronics and communication work by eliminating the manual slope monitoring. Here TDR is used as a sensor for monitoring ground movements The RF module was integrated with sensor to acquire data. RS232 was considered with the combination Arduino for monitoring the readings in Arduino IDE software. Equipment is successfully tested in laboratory and later on installed at mine site. The installation depth of coaxial cables in the holes A,B,C are at 20m, 80m, 25m respectively. Movement of ground can be captured thru the coaxial cables to monitoring device. Finally, the work concluded that the TDR sensor successfully transmitted the data from locations to the monitoring site. Also included that XBee Pro RF module and Arduino Mega Microcontroller board suggested to use additionally for wireless data transmission.

A research paper by Karthik, (2016), describes about the laboratory and field investigation of range testing of XBee Pro module for effective transmission of slope monitoring data in mines. In this case, TDR was used as sensor for Slope monitoring. XBee Configuration and Test Utility

(XCTU) software was used for testing XBee module. CTS (Clear to send) will send the signals to Micro-controller and RTS (Request to send) for receiving the data. The communication between the transmitter and receiver was done through the RF communication. A wireless communication system was designed for Wireless transmission of TDR data with the help of Arduino and ZigBee. And all the experimental setup was carried for field test at National Mineral Development Corporation (NMDC), Panna Diamond Mine at Madhya Pradesh. Wireless Data transmission for 400mts was successfully carried out and other remaining distance was continued by placing intermediate router. Finally 100 packets of data was transferred from transmitter and 99 packets of data received at end. With this paper authors suggested to carry further works by using Tilt-meter, Accelerometer, etc.

An IoT based Landslide Detection and Prevention system was suggested by Jadhav, (2018). The paper's main theme is to save lives and prevent property in case of any slope failure. IoT network was used in this project which helps us to updating the information about landslide on the internet. Here, researchers have chosen Moisture sensor and Vibration sensor for monitoring and also additionally warning system was allocated incase of failure occurs. For the collection of information authors took Raspberry Pi and transfer to MQTT thru internet. Finally, researchers concluded that this system's deployment leads to providing safety for saving lives and property by giving pre-warning signals at mine site.

To reduce in the landslide risks developed by Swathi (2017), a Wireless Movement Sensor Network for Real-Time Monitoring of Slope Instability. In this research work, low cost wireless strain gauge sensors are adopted in the place of Inclinometers. Mutli-level strain gauge probe is installed in the soil (SG-C1, SG-C2 and SG-C3), consisting of 8 strain gauge at each level. Those strain gauges are used in different directions and detect slip surface movements. It will be given as voltage drop using wheat stone bridge configuration. Then data will be stored in the storage. If any abnormality detects in the data, the alert messages will be sent to people in the critical area. Modelling and simulation was done in Ansys Workbench with various field parameters and strain gauge measurements, displacement. From this paper, the authors concluded that exceeding the threshold value will give warning signals to people and numerical analysis comparison was correlated successfully.

A low cost wireless personal area network and IoT was designed for landslide prediction system by Srinath, (2016). Soil Moisture Sensor and Vibration Sensor are arranged and connected on Arduino board along with Micro-controller and Wi-Fi connection. This device was coded with C programming software to carry the instructions the user gave. The data will be monitored on Arduino IDE software for wired connection and Thingspeak for wireless connection. Authors were concluded that monitoring of slope can be done by WPAN setup.

The research paper focused on giving the alert to the general population and the disaster management authorities in case of any occurrence of a landslide. An accelerometer was used for detecting changes in the ground movement. Accelerometer was deployed for monitoring horizontal movements as well as angular movements. It was very accurate to note the values for any minor changes in the area around the sensor. The nodes of sensor was connected.

With Renesas GR-Kaede processor. ZigBee was chosen for transmitting the data to the server. The server was programmed by using XAMPP and PHP, which continuously monitors the incoming data from the ZigBee attached at the COM port. If any landslide detects by the sensor, it will directly transmit data to Android application to warn and alert. With that data user can make counter decision to escape from that area and give information to the disaster management authorities in case of any kind of query. Finally the researcher Shashank Kapoor (2016), concluded that transmission of data and alerting system worked successfully and also suggested that implementation of other sensor useful to detect on various basis.

Landslides Risk Analysis by Robust Wireless Sensor Network (WSN) was done by (Andrea, 2016). In this paper author designed a system and deployed in field for testing. Due to the harsh environments, researchers have deployed a new network protocol and dedicated hardware for the sensor nodes. Data collection was done thru sensors and transmitting data by the network to a remote unit for online analysis and alerting. On a landslide, the WSN has been installed in Torgiovannetto (Italy) for an experimental campaign of several months where performance metrics, such as radio link and path statistics and battery levels, have been collected. At last, authors have concluded that an equipped system for monitoring landslides in critical conditions also gave early warning and recorded data was collected, organized into a database for logging of data and processing for remote server.

Study on Application of Wireless Sensor Network (WSN) to slope stability monitoring was made by Chang, (2013). Author have been divided work into two stages, in the first stage, the Mems Sensors were chosen and calibrated. Researchers had prepared own self-made tilt calibration apparatus which was used to calibrate the accuracy of 33 Mems Sensors respectively placed on the side slope. The monitoring of slope stability repeatability were validated multiple times in the laboratory. In the second stage work was done at National Highway No. 3 3K+100 and TW PHW62 were chosen at test locations, and 23 an d 10 sensors were placed at selected locations respectively. The data were collected in the in-situ industrial computer, and were transmitted via 3G wireless network card to the remote management unit of monitoring side slope.

Due to increase in Landslide hazards Amirah (2012), were developed a Wireless Sensor Network for Slope Monitoring. In this paper, authors discussed about the deployment of Wireless Sensor Network interfaced with suitable sensors for slope monitoring. Soil moisture sensor, Pressure sensor and Flexible bend sensor were included in project for monitoring. This system equipped for the collection of the data from sensors to surface. Collected data will be represented graphically, and a warning will be given at the cross-over point. Data comparison between the numerical and analytical values were performed. Finally, the results concluded that warning signals from sensors were given early at the time of slope failure.

VARIOUS METHODS USED FOR SLOPE MONITORING

Slope monitoring is crucial for assessing the stability of natural and man-made slopes, such as hillsides, embankments, cliffs, and excavation sites. Monitoring these slopes helps identify potential hazards, prevent accidents, and inform decision-making for mitigation measures. Various methods are employed for slope monitoring, depending on factors like the type of slope, the level of detail required, and budget constraints. As shown in figure 3, some common methods used for slope monitoring.

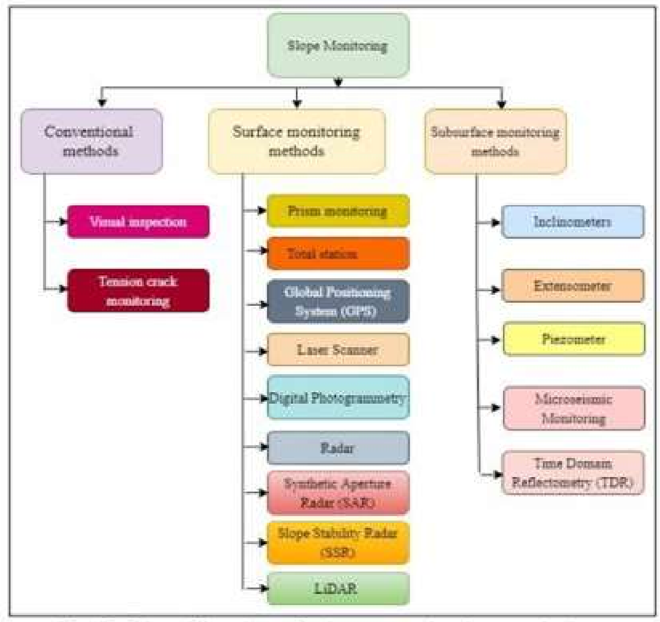

Figure 3: Classification of Recent Slope Monitoring systems (after Vinoth et. Al, 2016)

VISUAL INSPECTION

The Geotechnical Engineer did visual slope monitoring through routine walkover inspections of the pits, access ways, high walls, and crest close to potentially hazardous working areas. The engineer will compares the new data and records of deleterious slope stability changes of opencast mine (Kayode & Osasan, 2010; Kayesa, 2005)

TENSION CRACK MAPPING

Cracks produced on the slope will directly indicate failure for any reason. Monitoring and measuring the cracks were performed through the width and direction of the crack propagation. Painting on the cracks and pegs installation method will be followed for monitoring. In first case, they will paint on the cracks for easy identification. Common procedure is to installing wireline extensometer with counter weights. One end will be fixed into an unstable stop, and the other is attached with weights. If any movement occurs, it can be directly measuredigitally or electronically (Portal). For second case, pegs were installed on either side of the crack and measured the distance between them. Weekly or monthly monitoring of measurements will be done (Boyd, 1973).

DIGITAL PHOTOGRAMETRY

The Digital Photogrametry (DPG) technology was developed to monitor the behaviour of a slope by using the digital camera pictures of the slope. Mainly, it deals with a monitoring system that allows the highly precise reproduction of slope shape from a number of images which was clearly taken from various directions. An analytical method based on Moore–Penrose generalized inverse matrix to derive an equation from the geometrical relation between the camera, measurement points and photographed images. Thru that equation we can get the distance between measurement points installed on the target slope by the minimum-norm least-squares solution without setting any control points. By changing of directions and distances, prediction of slope failure can be done Ohnishi, (2006).

TOTAL STATION

A total station is an electronic transit theodolite integrated with Electronic Distance Measurement (EDM) to measure vertical and horizontal angles andistance from instrument to particular point Cosser, (2003). Total station is shown in figure 4, for slope monitoring contains of three components. Firstly, a network of known beacons is established on the constant stable ground observed from the instrument station. Secondly, establishing the number of transferred stations on stable ground from visible site. Thirdly, installation of monitoring prisms at suspected unstable area on slopes. Direction of measurement and movement should be preferable on the same line of sight for tracking distance readings on the actual slope. Monitoring prisms and reflectors can be used for better accuracy Afeni, (2013).

Figure 4: Total Station

GLOBAL POSITIONING SYSTEM

Global Positioning System (GPS) is based on satellites which are orbiting the earth and can be utilized for real time positioning at any location (or) 24/7 in any weather condition. It is very much suitable instrument used for measuring the ground displacements on an extensive area in various engineering projects such as opencast mines, subsidence, landslide, etc. It requires three satellites to determine the horizontal 2D position and chooses fourth satellite for determining the 3D altitude. GPS will not affect any climatic conditions and weather forecasts such that it is an efficient and accurate instrument andequires labour-less than conventional techniques Mohammed, (2021).

NON-REFLECTIVE LIDAR

Laser imaging system or 3D scanners are well suited for slope stability monitoring and deformation measurement. It can provide virtual data of a mine in minutes and photographic images. LiDAR pictographic is shown in figure 5. System will automatically use pan and tilt mount adjustment of scanners to operate in multiple access. The instrument's main difference is that it will calculate overall area instead of making one measurement. The system will acquire data nearly 6000-10000 points per second. Data will be directly transmitted to office at surface thru Ethernet connection (Ajay Kumar, 2015).

SLOPE STABILITY RADAR

Slope Stability RADAR (SSR) will consist of radar and a scanning antenna mounted on a motor- controlled tripod and gears used for both horizontal and vertical movements. Radar will move automatically based on the requirement in the pit and relocate in an hour. The main advantage of SSR (figure 6) is that can easily detect and alert movements of the strata in the pit. The precision of the system is in millimetre with continuity and broad coverage area. Customized software will provide complete image of the slope movements in particular time interval (Bryan, 2001).

Figure 5: LiDAR

Figure 6: Slope Stability RADAR at mine site (Ajay Kumar R. R., 2017)

EXTENSOMETER

Extensometer as shown in figure 7, is used for measuring the deformation of landslide. Extensometers consist of a steel wireline firmly connected to a fixed location on the slope face on one end and to a track- mounted weight, located off the slide on the other end. If any sliding occurs then wire will pulls the weight along the graduated track. The rate of movement of weight will represent the rate of slide occurred. It will measure manually or digitally, electronically (William Kane).

Figure 7: Wire line Extensometer System (Joseph, 2017)

INCLINOMETER

Slope inclinometers/indicators which are used to determine the magnitude, rate, direction, depth, and type of landslide movement (Choi, 2008). Generally Slope inclinometers are geotechnical instruments used to measure horizontal displacements along various points on a borehole. Probe inclinometers and Fixed- in- place inclinometers are two types of inclinometers (Laplante, 1998). The grooves are well designed to fit wheels of probe type inclinometer and the angle of probe is measured from the vertical axis by the help of pendulum. Deflections will be measured automatically from the known angular measurement and distance from the wheel. Comparison between the old values and new values will represent landslide if any (Marek Cala, 2016).

PIEZOMETER

Piezometers are the geotechnical sensors which are utilized for measuring pore water pressure thus, piezometers are also known as pore pressure meters. Piezometers are the pressure transducers that to install below the ground to measure the sub-surface piezometric level within the groundwater level, soil, etc. (rite). Vibrating wire type piezometer works on the principle of tuning wire of guitar or piano. Frequency becomes higher or lower with reference to the increasing or decreasing the tension in the wire. Electromagnetic coil will sense the vibration frequency and then be transferred to the device.

One end of the sensing wire is attached to the diaphragm, which is utilized for sense deformation by eater pressure entering the pores. An increase in the water pressure will decrease the piezometer levels thru tension in the wire. Magnetic coil is maintained to pluck the wire to vibrate. Variable excited frequencies will allowed to turn into natural frequencies by plucking the wire. Then the magnetic coil will act as a sensor that can count the number of vibrations taken. Coming output signals will be converted into units of pressure (William Kane).

TIME DOMAIN REFLECTOMETRY

Time Domain Reflectometry (TDR) (figure 8) has an ability to monitor slope movement in a variety of geotechnical setup including opencast s, waste dumps, railways, etc. (Wahab, 2015). Then the method has been utilized to measure the material properties such as water content in soil. This technique was employed to identify the zones of Rock deformation and blasting performance along with slope stability monitoring in pits and dumps (Su, 1998). For slope monitoring TDR will involve in the filling of the borehole with grouting material with coaxial cable inside. When a vibration of voltage regulates down in the cable, then it will reflects from a point, at where there is a fluctuation in gap between the conductors.

TDR with coaxial cable mechanism proved to be economical and efficient method for detecting sudden movements and shears on slope (Yadav, 2019).

WIRELESS SENSOR NETWORKS

Wireless Sensor Network (figure 9) is well suited technology for monitoring data because it is less cost, more flexibility, and high safety (Nishikawa, 2018). WSN which as an infrastructure-less network that is deployed in more number of wireless sensors in an adequate manner which is used to continuous monitoring of environment conditions or physical conditions. A review on Wireless Sensor Networks and Real-Time Slope Monitoring was done by (Mittapally, S. K., & Marichamy, R. K. 2023). WSN with processor manages and monitor the conditions in particular area thru sensor nodes. Processing unit in WSN represents the nodes connected to base station. Base station in a WSN will be connected thru internet to share data. Processing, Analysis, Storage, Mining of the data will be done by the WSN (Geeks, 2021). Sensors in WSN are not only for detect and monitoring

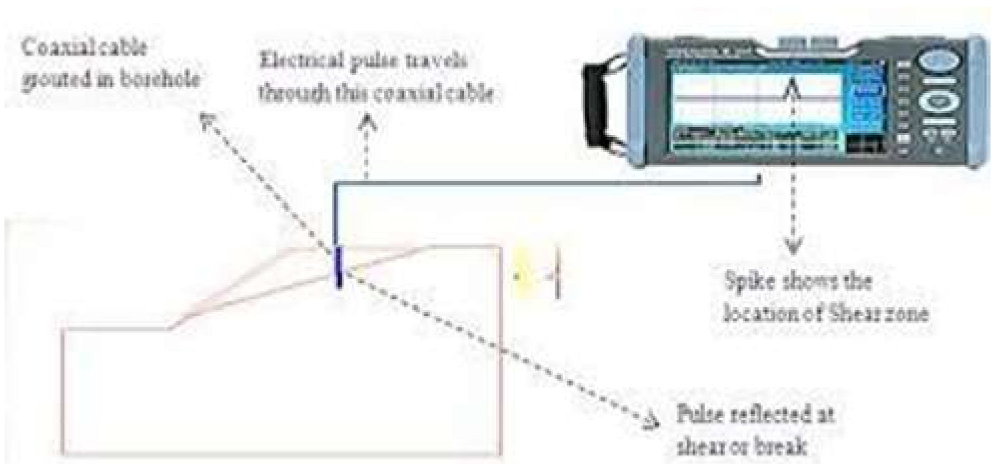

Figure 8: TDR Principle (Singam Jayanthu, 2017)

the slope stability but also collecting the data and storing in a secure mode for further references. Researchers (Mittapally & Karra, 2023), done reaseacr on Functions and performance of sensors for slope monitoring in opencast coal mines at laboratory scale and developed an alert system for slope monitoring using wireless sensor networks and cloud computing technique (Kumar, M. S., & Chandar, K.R 2023).

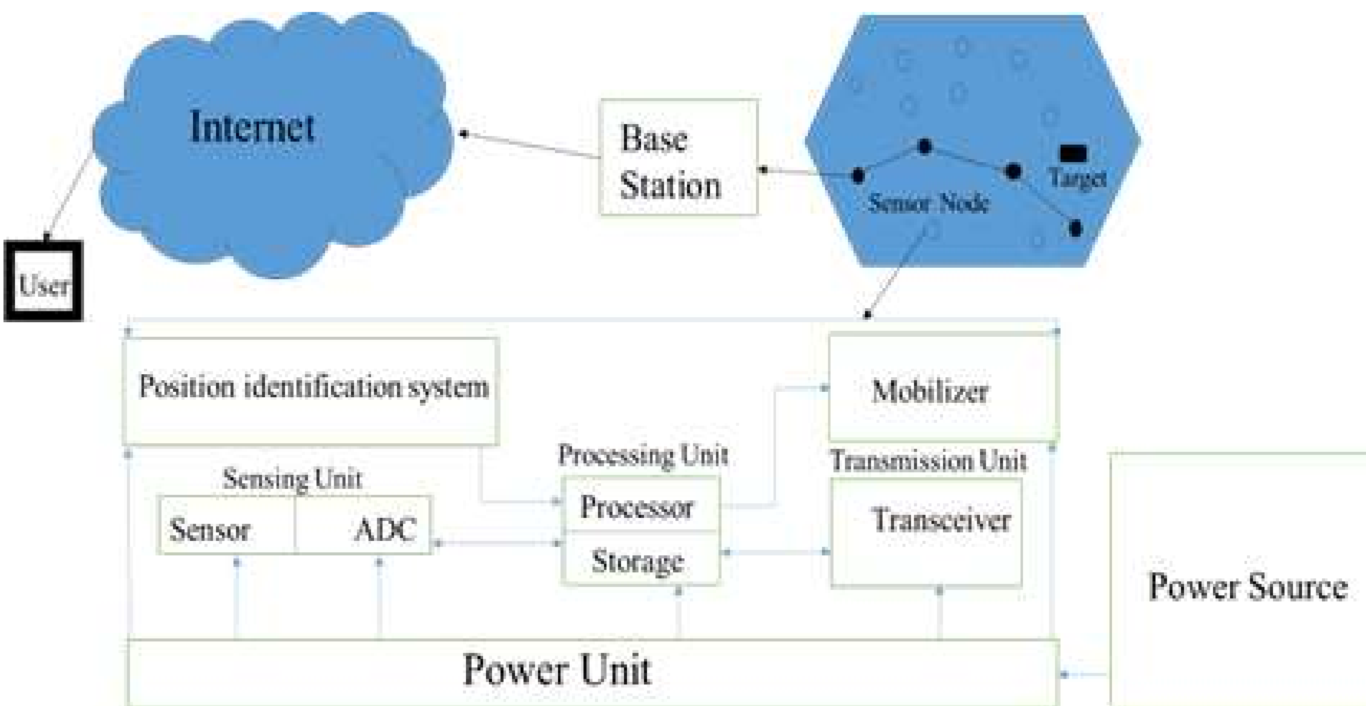

Figure 9: Major components of a sensor node

If the base stations are at longer distance from node then routing network must be adopted with group of sensors for transferring data (Evans, 2003). Proper maintenance for the battery should be followed. The structure of the sensor module is divide into four parts: (i) Sensing unit, (ii) Processing unit, (iii) Transceiver unit and (iv) Power unit (Akyildiz, 2002).

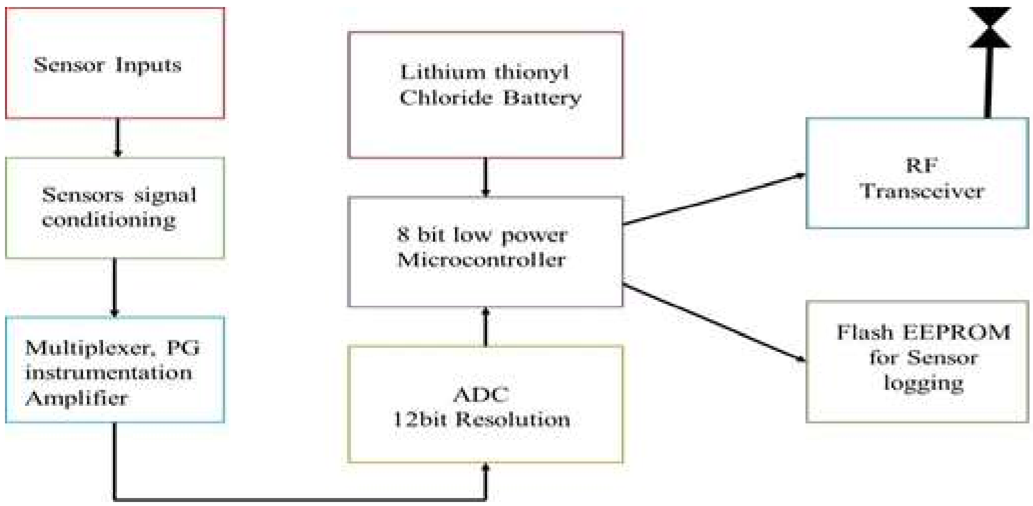

Figure 10: Functional block diagram of a sensor node

Sensing units are commonly assigned with two sub-units: Sensors and ADC (Analog-to-Digital Converter). The signals which are produced by the sensors based on observed field phenomenon are converted to digital signals by using ADC. Then process will be fed into processing unit, which is generally consisted with a less storage unit. The assigned sensing task will be produced from the sensor node which is collaborated with sensors. Transceiver unit is utilized for connecting the node to the network. Power unit is considered as major part which may supported by solar cells (Rabaey & Ammer, 2000). Based on the applications of Wireless Sensor Network for Displacement Monitoring in Opencast Coal Mine Slopes was done by the athors (Kumar, M. S., & Karra, R. C. 2023) and obtained the validated results. Further, Cloud Computing- Based Advanced Slope Monitoring System for Opencast Coal Mines also designed and published the works by the researcher (Sathish Kumar Mittapally and et. al., 2023). Radio Frequency (RF) communication is well chosen for sensor network research projects due to conveying of packets in sensor network is very small.

CONCLUSION

A relatively comparative study and review has been done with reagrds to the implementation of new techniques for slope monitoring in the opencast mining method. Many researchers and scholars have done detail study and application of monitoring methods in opencast slopes with their merits and demerits. Wireless Sensor Network will considered in future applications which uses for control the stability of slopes. Comparing with conventional and surface monitoring methods, IoT is a key factor for making data available at any time and in anywhere. Thus, combined solution is provided thru WSN and IoT, which is help for monitoring and quick for warning in the mines. By this solution slope failures and accidents due to the failure will be avoided. WSN is best method in terms of cost effectives and efficient energy consumption at fractures without any physical connection. Maintenance cost will also be less compared to other techniques. Sensing of the slope motion could be sent to the base station and then the processed data is stored in the server through IoT. Accurate data transmission be done thru combination of WSN and IoT. The flexibility, fault tolerance, high sensing fidelity and rapid deployment characteristics of sensor networks create many new and exciting application areas for remote sensing. In the future, this wide range of application areas will make sensor networks an integral part of our lives. The advances of wireless networking and sensor technology open up an interesting opportunity to manage human activities in a smart home environment. Real-life activities are often more complex than the case studies for both single and multi-user. Investigating such complex cases can be very challenging while we consider both single- and multi-user activities at the same time. Future work will focus on the fundamental problem of recognizing activities of multiple users using a wireless body sensor network.

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Keynote Address

Climate Change-Sustainable Mining and Need for Accelerated Development of Coal

D.N. Prasad*

The World is facing tough environmental challenges and the countries are struggling for decarbonisation of the economy for addressing climate change and ensuring sustainability. Achieving 'Net Zero' is the ultimate objective. We are aware that minerals are essential for modern living and Mining, Minerals and Metals are important to the economic and social development. Coal is the mainstay of India's energy with a share of over 50% in primary energy supply and over 75% in power generation. It still supports some 36% of world electricity generation and 20% of primary energy supply. Coal is likely to continue to be the India's mainstay of energy for quite some time into the future.

Mining Industry challenges all three dimensions of sustainable development: economic, social, and environmental.To recapitulate what is sustainable development, the UN World Commission on Environment and Development defined sustainable development as "A system of development that meets the basic needs of all people without compromising the ability of future generations to meet their own life-sustaining needs".

The 1992 Rio Declaration on Environment and Development stated that "the right to development must be fulfilled so as to equitably meet developmental and environmental needs of present and future generations'. The 2002 World Summit on Sustainable Development (WSSD) identified poverty as the underlying barrier to sustainable development. The summits plan of implementation recognised the important contribution of mining and metals to a sustainable future.

The mining industry causes some of the most dramatic impacts on the natural environment and human health. Mining activities can affect social and environmental systems both direct and indirect ways. Mine exploration, construction, operation, and maintenance may result in land-use change, leading to deforestation, erosion, contamination and alteration of soil profiles, contamination of local streams and wetlands, and an increase in noise level, dust, and emissions.

Mine abandonment, decommissioning, and repurposing can also result in significant environmental impacts, especially soil and water contamination. The infrastructure that supports mining activities, including roads, ports, railway tracks, and power lines, can affect migratory routes of animals and increase habitat fragmentation. When governments and mining companies do not address these challenges, the areas around mine sites often become degraded landscapes filled with informal settlements and scrambling artisanal miners eking out a living adjacent to the garish mine infrastructure and swarming monster trucks.

Coal and fuel oil combustion emit fly ash particles into the atmosphere, which contribute to air pollution problems. Upon burning, coal produces a number of gaseous by- products, including carbon dioxide, nitrogen oxide, sulphur dioxide and methane gas, all of which contribute to global climate change. The available mining deposits are increasingly deeper and of declining ore grade. Together, this will lead to increased demands for water as well as greater mine waste, thereby raising energy consumption, and increasing the industry's climate footprint.

Mines theoretically can fully decarbonize (excluding fugitive methane) through operational efficiency, electrification, and renewable-energy use. Capital investments are required to achieve most of the decarbonisation potential, but certain measures, such as the adoption of renewables, electrification, and operational efficiency, are economical today for many mines.

Significant growth of low-carbon technologies will occur if industries commit to cutting emissions in line with Paris Agreement targets. Technologies that support decarbonisation include wind turbines, solar photovoltaics, electric vehicles, energy storage, metal recycling, hydrogen fuel cells, and carbon capture and storage.

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The mining industry will be part of the decarbonisation solution by providing the raw materials needed for these technologies. Simultaneously, their growth will alter demand patterns for upstream mining commodities. For this to happen mines have to be safer, smarter and greener. Safer mining practices involve the implementation of strict safety protocols with regular training programs for workers. The use of advanced technologies such as collision awareness systems and drill guidance systems helps mines detect and avoid potential hazards in real-time, further enhancing safety.

Smarter mining incorporates the use of advanced technologies such as Machine learning, data analytics, digital twins and remote monitoring to improve the efficiency and productivity of mining operations. These technologies allow mines to gain valuable insights into their operations and make data-driven decisions that help increase output and reduce costs. Digital technologies like Internet of Things, real-time business management with advanced analytical capabilities like predictions, cloud based solutions and mobile based solutions are expected to deliver multiple benefits for the Mining Industry covering improved asset utilisation and availability of equipment; help predict and corrective actions in advance by reducing breakdowns; improved mining fleet utilisation and real-time control; improved safety of operations; real-time visibility for improved business process; higher productivity; improved mining process cost visibility and resultant savings.

Greener mining involves the adoption of environmentally friendly technologies and practices. This is typically achieved when mines operate in a safer and smarter way.
Enhancing the contribution of mining, minerals and metals to sustainable development includes actions at all levels to support efforts to address the environmental, economic, health and social impacts and benefits of mining, minerals and metals throughout their life cycle, including worker's health and safety through a range of partnerships, stakeholders etc. to promote transparency and accountability. To truly shift to "sustainable mining," governments and companies must recognize the social impacts of mining, and enact laws and regulations that require community consultation throughout the life of a mine.

In this regard it is imperative to discuss about ESG Mining which refers to the integration of Environmental, Social and Governance factors into the Mining Industry. ESG Mining is driven by the increased demand from investors and stakeholders for more ethical, sustainable and responsible practices. ESG Mining is also essential for the global transition to the sustainable production of critical minerals and the reduction of carbon emissions.

The major risks amongst others, being experienced by mining companies are environment and social issues; decarbonisation - both risk and opportunity and license to operate. Others being geopolitics, capital, uncertain demand, digital and innovation, workforce, new business models and productivity and costs. Responsible mining companies have always been concerned about sustainability, care of the environment and working with their host communities towards achieving these goals. ESG now brings together these in a comprehensive framework that can help a mining company navigate and balance the benefits to the planet, people and profit successfully.

A mining company's ESG agenda would ideally include, among many others:
- **Environment**: biodiversity, ecosystem services, water management, mine waste/tailings, air, noise, energy, climate change (carbon footprint, greenhouse gas), hazardous substances, mine closure
- **Social**: human rights, land use, resettlement, indigenous people, gender/diversity, labor practices, worker/community health & safety, security, small-scale miners
- **Governance**: legal & regulatory compliance, ethics, anti-bribery and corruption, transparency.

Long-term mining projects must consider the impact on local climate and communities, balancing the bottom line with societal value. ESG-driven business models mean embracing big data, supply chain automation and AI, as well as learning from other industry sectors. Struggling to attract new talent to a legacy industry, mining companies look to technology and environmental stewardship. Many mining companies are already taking steps to assess and improve their ESG performance. However, experts say that the real benefits come when companies move beyond mere compliance and into maximizing the opportunities arising from ESG.

Mining is currently responsible for 4 to 7 percent of greenhouse-gas (GHG) emissions globally. Scope 1 and Scope 2 CO_2 emissions from the sector (those incurred through mining operations and power consumption, respectively) amount to 1 percent, and fugitive-methane emissions from coal mining are estimated at 3 to 6 percent. A significant share of global emissions about 28 percent would be considered Scope 3 (indirect) emissions, including the combustion of coal.

Under the 2015 Paris Agreement, 195 countries pledged to limit global warming to well below 2.0°C, and ideally not more than 1.5°C above preindustrial levels. To keep global warming to no more than 1.5°C, greenhouse gas emissions need to be reduced by 45% by 2030 and reach net zero by 2050 and 2070. It requires economies to 'achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century'. As of November 2023, around 145 countries had announced or are considering net zero targets, covering close to 90% of global emissions. Among these countries are China, the EU, the USA and India, who jointly represent more than half of global greenhouse gas emissions.

India is presently on the throes of managing two major resources for energy: the coal, the traditional resource which India had been effectively managing and renewables like wind & solar with very aggressive promotion of the latter. It is an admitted fact that the future of the world has to be with energy which will leave no carbon footprint. Much that one would like it to the contrary coal is certainly an unclean form of energy but an essential one since there is no real substitute, at present in the country. Emergence of cheap renewables with solar price coming down from Rs.17 a decade back to Rs.2.50 per unit today and the nation having taken a commitment to attain net zero by 2070 there is considerable hope that in energy term also renewable will slowly but surely substitute other forms of energy unless newer forms like cheap thermo- nuclear energy and others emerge, as worthy competitors.

Given this background it is important to look at how India can best utilise the limited window of opportunity available for optimal utilization of its existing coal resources. The currently estimated geological coal reserves of the country stand at 361 Billion Tonnes (Bt) of which the Proved/ Measured reserves are estimated to be 187 Bt (52%), but more than 40% of the prognosticated coal bearing areas are yet to be explored. But we also know that all the proved reserves are not economically extractable and that majority of coals in India are of poor quality and high in ash content.

It is important that India considerably enhances the pace of exploration and validation involving private sector and latest technology to significantly augment the proven reserve mapping of coal. For that India should go ahead with accelerated UNFC or JORC rating of its resources. Primarily Coal India Ltd., (CIL), the biggest coal company of the world, through its eight subsidiaries and Singareni Collieries Company Ltd., (SCCL), a joint sector between Government of Telangana (GOT) and Government of India (GOI) are the predominant coal miners. In addition, the captive miners and the recently allotted commercial miners also extract coal, but to a lesser degree.

The latest data reveals that country produced 893.08 million tonnes of coal in 2022-23 (CIL - 703.21 million tonnes, SCCL – 67.14 and Captive and others 122.72 million tonnes) as compared to 778.19 in 2021-22 showing a growth of 14.78 percent. Coal production is envisaged to reach 1.2 Billion tonnes by 2024-25 with major contribution from the coal PSUs, CIL and SCCL and envisaged to cross 1.5 Bt by 2030. Over 75% of the coal output of major coal companies CIL & SCCL goes to end use in power sector and about 25% to other sectors.

Keeping in mind rapidly growing need of energy it is imperative to facilitate accelerated development of the coal mines and to attract major investors or operators into Indian coal mining and ensure sustainable mining practices through adopting a safer, smarter and greener approach. The accelerated development of coal production on sustainable principles is the crux of the matter today. We should put in place an aggressive accelerated coal mining development plan and a mid-term plan to invite investments with latest technology taking care of safety, productivity and sustainability into coal mining by accelerating the exploration, validation, optimization of resources creating a level playing field transparent marketing apparatus and a regulator who will be able to bring in the necessary over sight and coordination amongst the many agencies but with complete focus on India's primary energy resource - The Coal.

Setting up a steering committee at the National level with participation of States may expedite the process of accelerated coal mining development ensuring responsible ecosystem, regulation, sustainable mining etc.

(Note: Views expressed are purely personal and acknowledge the use of literature available on public domain on climate change and sustainable mining)

Keynote Address

Rock Fragmentation Research in Mining and Port Construction – Some Applications

V.M.S.R.Murthy*

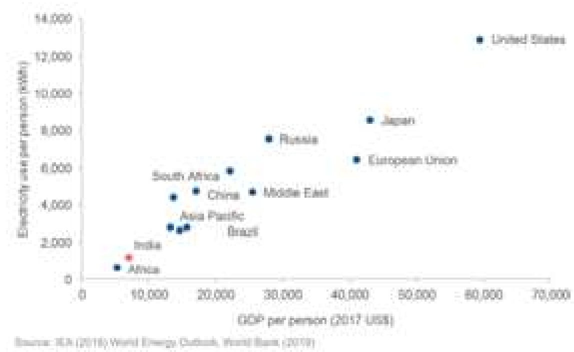
Rock excavation for mining and infrastructure development is on steep rise in the path Indian mining and construction industry is treading at present. This paper dwells cases from two prominent sectors, namely, mining and port construction contributing to the economic growth of the country. Some key rock excavation challenges alongwith solutions are discussed.

COAL MINING –DRAGLINE BLASTING

Share of coal as a primary source of energy will continue for atleast a decade to two while renewable energy picks up due to the commitments on carbon emissions. Mining industry is currently unleashing its internal capacity through operationalization of allocated coal mines and it is expected that the coal production will touch close to a billion tonne target in the next 4 to 5 years. The projected coal based power generation [1] emphasizes the need to gear up with efficient coal mining methods with lesser emissions for economic development of India (Table 1).

Table 1 – India's projected installed capacity, Electricity use [1]

Fuel type	June 2019 (actual)	2021–22 (projection)	2026–27 (projection)	2018–19 (share)	2021–22 (share)	2026–27 (share)
Unit	GW	GW	GW	%	%	%
Coal	201	217	238	56	45	38
Renewable	79	175	275	22	37	44
Hydro	45	51	63	13	11	10
Gas	25	26	26	7	5	4
Nuclear	7	10	17	2	2	3
Total	358	479	619	100	100	100



In the current coal production scene surface mining methods contribute close to 95% of the total coal produced in India and this trend is expected to continue for the next two to three decades. Mega mines(+50 Million Tonnes each) with intelligent technology shall take the front seat. Large size equipment, mega blasts with controlled environmental impacts is the need of the hour. Use of draglines as primary excavation equipment demands efficient planning coupled with good material preparation for efficient loading. Challenges in terms of coarser fragmentation and reduced dragline output were a concern in general and a study was taken up in collaboration with one of the mines in NCL. Adaptation of matching explosives as per the rockmass competence, distribution of explosives, progressive relief of blast holes through electronic delay systems coupled with controlled blasting have lead to optimized dragline productivity and reduced back break. The details of investigations and results are outlined below:

STEMMING EJECTION, FRAGMENTATION AND BACKBREAK

Large scale blasting require many holes to be blasted in one go. Due to changes in stratification, variation in explosive density, in-situ cracks and fractures (causing venting of energy), stemming ejection and improper profiling of benches, the results of the blast may suffer by poor breakage. Poor fragmentation is a heavy tax on

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dragline productivity. Because dragline is the cost-centre of this excavation and its productivity is paramount. Over-size boulders pose difficulty to the dragline bucket and also to its operation. Huge boulders damage the adapters and teeth of the dragline bucket. Over size boulders fill the bucket poorly leading to lower productivity. Dragging and lifting over-size boulders causes the electric circuit to trip, thus causing maintenance problems, thus reducing dragline availability and utilization and consequently its productivity. Watery holes cause insufficient compaction of stemming material and explosive leading to poor containment of energy of the explosive leading to stemming ejection and thus poor fragmentation. Backbreak is also caused due large amount of charge and improper delay assignment. High levels of vibrations are recorded at the rear part of the blast, which is responsible for backbreak in high benches. This is shown in Fig. 1.

Fig. 1: Stemming ejection, poor fragmentation and backbreak in dragline bench blasting
This calls for advanced geo-engineering investigations for fine tuning the blasting system.

Geo-engineering investigations
Pre-blast investigations:
(a) Borehole scanning/face mapping

Rockmass characterization helps in optmising the charges and detonation sequences.

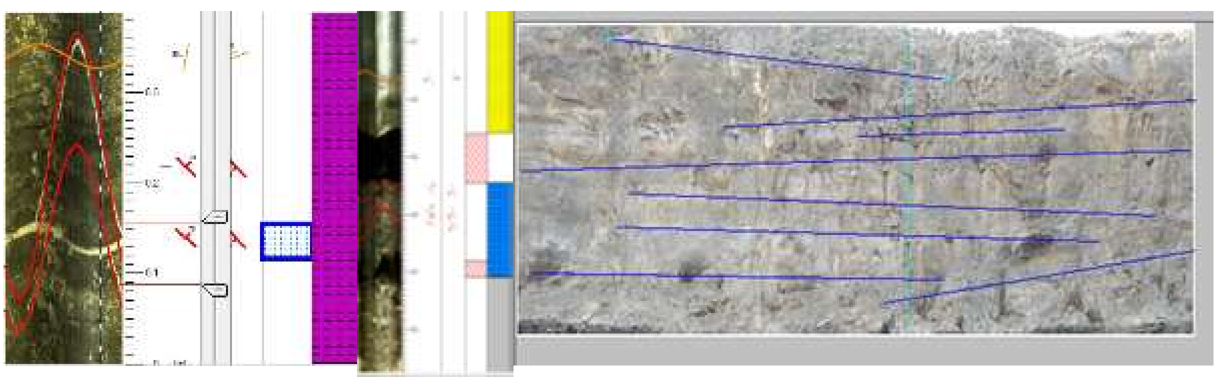


Fig. 2: Borehole scanning and face mapping carried out before blasts

Borehole scanning and face mapping give an estimate of the in-situ rockmass disposition before blasting.

(b) Seismic refraction tomography

Determination of in-situ P-wave velocity for estimating the dynamic properties of the rockmass helps in designing blasts in terms of burden, spacing and charge distribution for achieving optimum fragmentation.

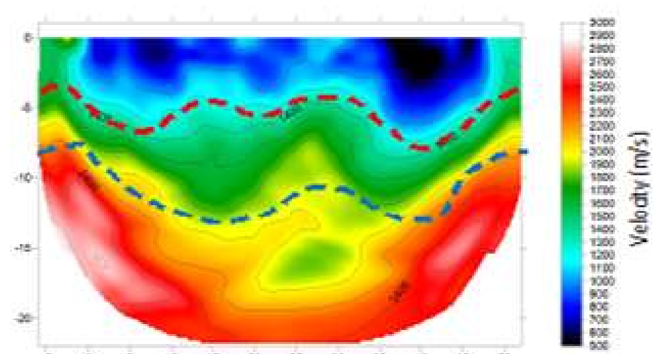


Fig. 3: Seismic refraction tomography

DURING BLAST INVESTIGATIONS

(a) Near-field vibration monitoring

Near field vibration monitoring was carried out to understand the dynamic response of the rockmass close to the blast (Fig. 4 and Fig.5).

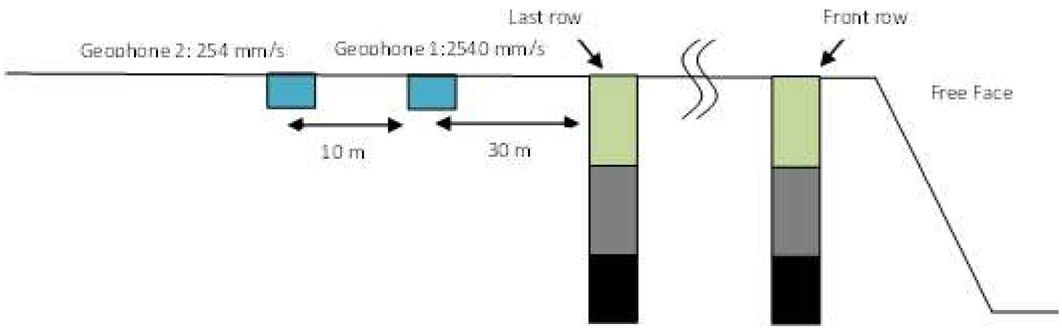


Fig. 4: Schematic diagram of near-field vibration monitoring

Fig. 5: Field placement of near-field sensor

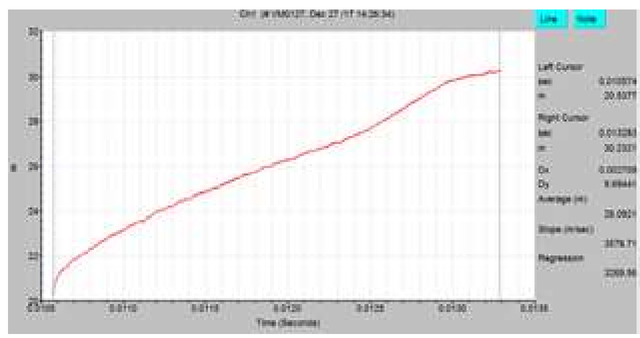


Fig. 6: In-hole VOD monitoring

(b) In-hole VOD monitoring

Continuous in-hole VOD measurement was carried out for holes of diameter 311 mm initiated with electronic detonator (Fig.6).

(c) Blast simulation

Simulation of blast was carried out using JKSImblast software to determine the suitable effective row to row and hole to hole delays(Fig.7).

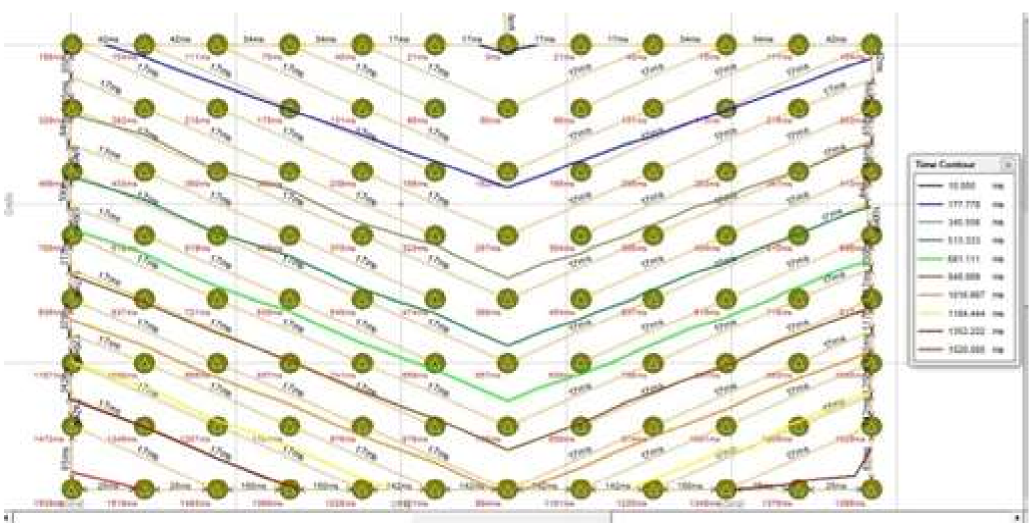


Fig. 7: Blast simulation using JKSimblast

POST BLAST INVESTIGATIONS

Fragmentation analysis

Post blast fragmentation analysis was carried out to assess the blast performance. Mean fragment size was found to vary with rockmass competence and explosive and delay variations.

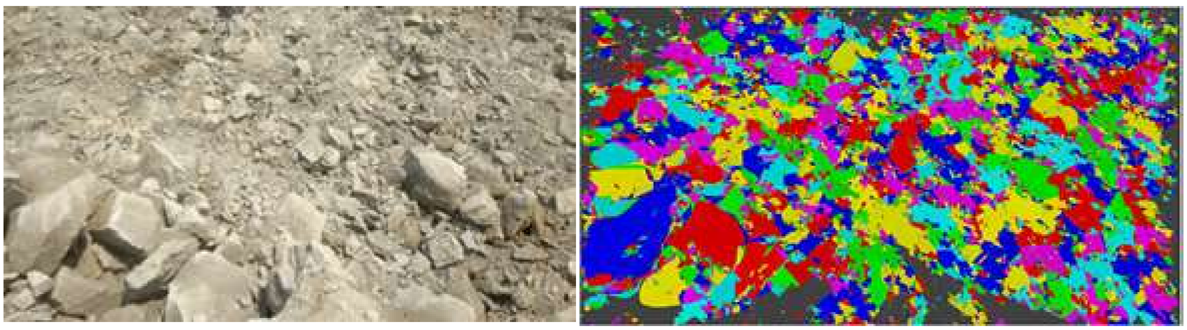


Fig. 8: Fragmentation analysis using Wipfrag software

Modified blast design

Based on the investigations carried out the following modifications were suggested and implemented: Burden: 9-11m; Spacing:10-11 m; Effective delay: 14-20 ms/m of effective burden; Initiation system: Electronic

Results of modifications

The modifications resulted in good results in terms of the blast performance parameters as shown in the Table 2.

Table 2: Comparison of blast performance assessment parameters before and after the blast

Parameters	Before modifications	After modifications
Peak vibration, mm/s	1026	257
Mean fragment size, mm	951.54	354.97
Backbreak, m	10.6	5.5
Dragline Productivity, lakh m^3/month	1.01	1.22

The modifications also yielded half cast impressions on the highwallcontrolling the backbreakas shown in Fig. 9

Fig. 9: Half cast impressions achieved in dragline bench

Providing a stable and unbroken face is the key for effective blast performance (good fragmentation and reduced backbreak). The case discussed presents the role of geo-engineering investigations for effective blast design to improve dragline productivity. Considering the dragline as the key cost centre the study assumes importance.

UNDERWATER DRILLING AND BLASTING

Transport of goods through sea ports has increased phenomenally owing to the long coast and cheaper and environmental friendly movement of goods and services. Most of the ports today are deepened(-20 m) and widened(100 m to 200 m) for facilitating larger ships for achieving higher cargo handling capacity. There are numerous port development projects (renovation of old and new construction) under Sagarmala as detailed in Table 3. These projects involve both deepening and widening for allowing atleast a 14 m draft vessel in most of the ports.

Table 3: Projects under Sagarmala, Govt. of India

Theme	Total		Completed		Under Implementation	
	No.of Projects	Project Cost (Rs.Cr.)	No.of Projects	Project Cost (Rs.Cr.)	No.of Projects	Project Cost (Rs.Cr.)
Port Modernization	236	1,18,352	68	22,551	70	36,998
Port Connectivity	235	2,35,528	35	5,803	94	1,19,360
Port Led Industrialization	35	2,40,234	2	512	17	1,51,745
Coastal Community Development	68	7,369	16	1,362	20	945
Total	574	6,01,483	121	30,228	201	3,09,048

Underwater drilling and blasting is done for the sea-bed excavation aiming for hard rock dredging as well as demolition of the submerged marine structures. Being the most economic method, it is generally preferred over other excavation methods. Currently, the underwater controlled blasting was performed at one of the India's major port for the demolition of older berth to widen the inner harbor channel.

SITE CONSTRAINTS

The blasting process is always associated with a few undesirable outcomes such as ground vibration, air-over pressure, fly rock and water-shock. These may affect the nearby sensitive marine structures apart from causing annoyance to local people if not demolished scientifically. Though the impacts cannot be eliminated completely but can be controlled by exercising suitable explosive, delay and blast design controls. The saffron colored parts shown in the figure are new berths to be protected during the demolition blast where as the red cornered region shows the target berth. The distance between the target structure and nearest structure (to be protected) lies in range between 1.5 mtr to 27 mtr along the 500 mtr long berth. The circled portion in the figure were the closest to protective structures with maximum distance of 2 mtr and 1.5 mtr in left circled portion of Anchor wall & Diaphragm wall.

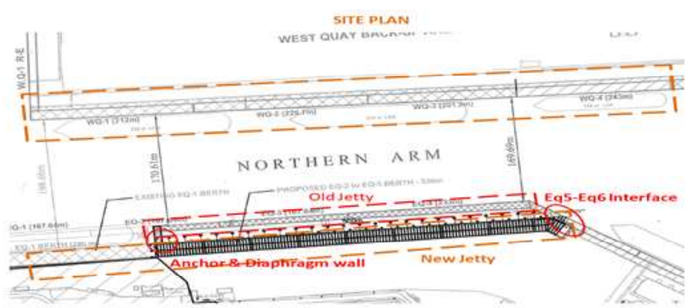
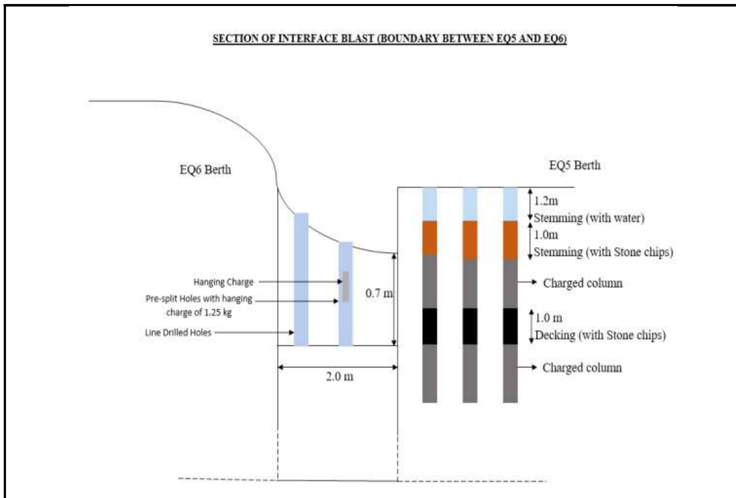


Fig10- Site Plan

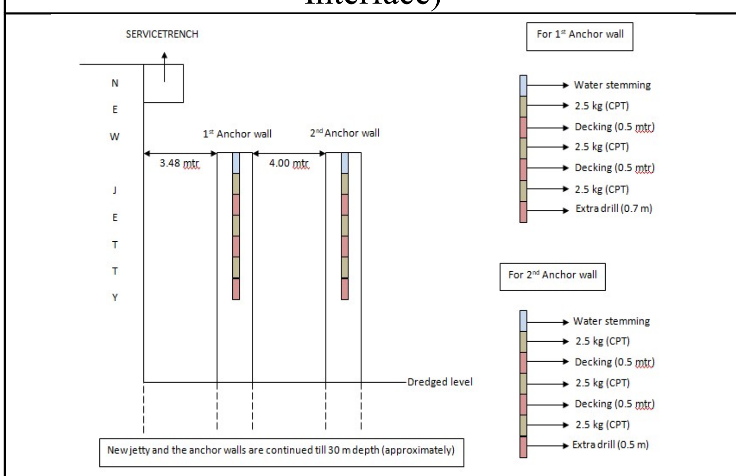
BLAST METHODOLOGY

A detailed study of, the quality and quantity of explosives, blast design parameters such as burden, spacing, sub-grade drilling, hole diameter and it's length, stemming type and column, decking, maximum charge per delay and initiation system, impacts of blasting, is required for improved dredging efficiency. Pre-split, Line drills and Bottom decking were the concepts used for blasting at EQ5-EQ6 interface and Anchor & Diaphragm wall respectively. This technique is termed as Hybrid Controlled Basting (HCB) technique. Special blast designs implemented for controlled demolition of masonry and RCC walls are depicted in Fig.11.

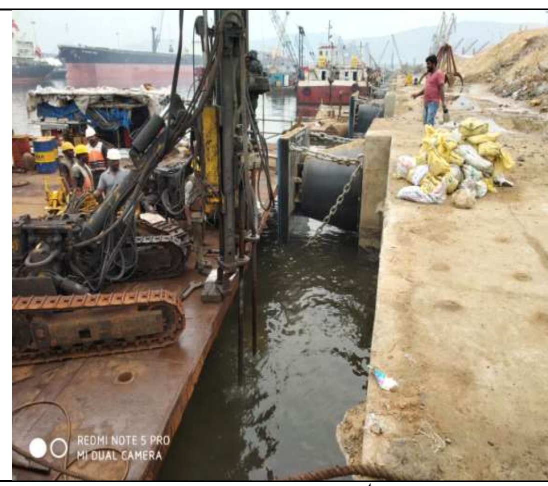


Pre-split + Line drill technique(EQ5-EQ6 Interface)

Drilling in progress(@EQ5-EQ6 Interface)



Bottom decking Concept (for A/W & D/W)



Drilling in progress (@ 1st Anchor wall)

Fig.11: Demolition blasting systems in concrete wall below water

GROUND VIBRATION AND WATER SHOCK MONITORING

It is necessary to monitor the ground and water shock for safe guarding the marine structures and also ensure proper fragmentation of concrete walls with removal of steel plate shoes at the bottom (Fig.12).

	
Ground Vibration Monitoring by Seismograph (Unit –mm/s ; Installed at Ground surface)	Water shock monitoring by Hydrophone (Unit –KPa ; Installed in water)

Fig.12: Ground vibration and water shock measurement methodology

Complete blasting methodology is depicted in Fig.13

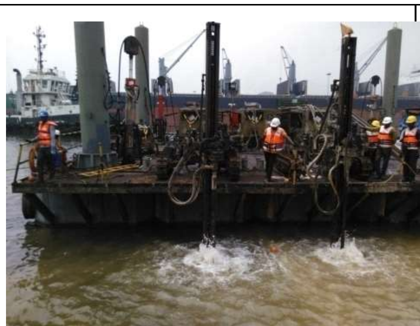
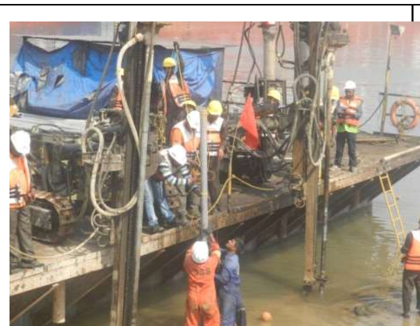
		
Drilling in Progress	Charging of Hole	Muffling
		
Shock tube connections	Initiation of hole	Initial Water Plume

Fig.13: Blasting methodology, Concrete berth demolition

Modified blast design

Based on the investigations carried out the following modifications were suggested and implemented:

- Hole Diameter -115 mm
- Burden: 1.05m (Partial width of wall)
- Spacing:1-1.3 m

Initiation system used is NONEL with proper charge quantities as per the distance of the structure. Charge per delay varied from 2 kg to 20 kg for effective and timely completion of the 16m high 2.1 m thick masonry and RCC wall (different lengths) totaling about 500m. The charges are established using ground vibration attenuation behavior. Based on the scientific investigations the demolition has been successfully completed without any structural distress and 14 m draft vessels could make a grand entry into the inner harbor channel.

CONCLUDING REMARKS

The research discussed has clearly established the need in utilizing advanced rockmass, explosive and blast characterization tools for arriving at effective and safe solutions. Dragline blasting continues to expose sizeable coal in CIL mines and the suggested techniques have already resulted in enhanced dragline production. In a similar manner, measurement of structural and water shock due to near-field basting impacts is the need of the hour as the port sector embraces modernization of berths with huge investments in pace. A close interaction of industry and academia can unlock the huge potential of young budding engineers and make them industry ready.

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Keynote Address

Watershed Management of Rewa Region, Central India: An Overview

R.N. Tiwari*

ABSTRACT

The Rewa region is a part of the Tons Sub-basin within the Ganga Basin. In this region, the aquifer system is characterized by various rock formations of Vindhyan Supergroup. Among these units, the Bhander Limestones have permeable zones that are saturated enough to supply a significant amount of water to wells and springs due to karstification. However, the Rewa Sandstones and Ganurgarh Shales do not meet this requirement as their permeable zones are relatively less pronounced. The area is predominantly tropical and as the hot summer months reach their peak, surface water sources often dry up, placing a heavy burden on the area's groundwater resources. The average annual rainfall of this region is about 1150 mm, with the majority occurring during the southwest monsoon season from June to September. In fact, nearly about 90% of the annual precipitation is received during this time. The remaining about 10% is spread out over the period from October to May.

Hydrogeomorphological parameters were worked out for Rewa region. A drainage map of the study area has been prepared with the help of Arc GIS software. The morphometric parameters suggest that most of the rocks in the area are of quite permeable nature and there are good chances of infiltration. The rock formations are more or less homogeneous in nature and no structural disturbance is noticed. This study aims to explore the potential benefits of integrating traditional indigenous methods into contemporary watershed management strategies. By doing so, we may create a comprehensive restoration plan for the Rewa region that prioritizes sustainable land usage and ensures the availability of groundwater. There are numerous recharge structures available to help replenish groundwater such as check dams, contour bunds, percolation ponds, recharge wells, subsurface dams, check walls etc. The insights found from this research will serve as a valuable resource for decision-makers, environmental organizations, and local communities, promoting a harmonious and cooperative approach to safeguarding water resources of the area, promoting resilient, sustainable development and management of watershed.
Keywords: Watershed management, Rewa region, Central India

INTRODUCTION

Water management is for most challenge being faced today by the organizations dealing with groundwater. In ancient India, architects and town planners gave instructions for planning towns which included the necessity to describe methods of finding water which is of infinite importance for the purpose of life, for pleasure and for daily needs. In present scenario, the irregular monsoons and frequent recurrence of droughts needs to be managed judiciously to ensure adequate supplies of dependable quality. It is natural resource with economic, strategies and environmental value, which is under stress. Therefore, the water management strategies to be aimed for sustenance of life. All water producing, consuming, controlling, developing and concerning organization need to adopt a water cropping plan to harness the limited rainy cycle for appropriate conservation methodology for sustainable development with appropriate inputs for monitoring institutions. Various researchers have been carried out the hydrogeological investigation in different parts of India.

Tripathi and Dwivedi (2016) have described the characterization and mapping of diffuse chemical pollution in industrial area of central India. The study reveals that the pollution occurred due to the industrial effluents and other anthropogenic activities in the ground water quality.

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Prakash and Singh (2016) have discussed the assessment and management of groundwater resources California, USA. The paper is very interesting for groundwater researchers and planners. Tiwari and Dwivedi (2016) have highlighted the groundwater resources development and management of Rampur Naikin micro-watershed area, Sidhi District M.P. They suggested that for sustainable development of water resources, all planning should be based on the character of the hydrological environment of the watershed.

Tiwari and Singh (2016) have carried out the hydrochemical facies and drinking water quality Mukundpur area Satna District, Central India. The study reveals that groundwater of the area is suitable for drinking. Tiwari et al (2016) have suggested the sustainable techniques of surface water conservation for ground water recharge in Jaisingh Nagar block of Shahdol District, Madhya Pradesh. In order to improve the ground water situation, it is necessary to development of water resources and management of rainwater for artificially recharges of the depleted groundwater aquifers. The available techniques are easy, cost-effective and sustainable in the long term. Many of these can be adopted by the individuals and village communities with locally available materials and manpower. Tiwari (2016) has discussed morphometric analysis, water level fluctuation and artificial recharge strategy Majhiyar watershed Rewa District Madhya Pradesh. The area is charactarised by low drainage density and low bifurcation ratio. He also analysed the water level fluctuation. On the basis of analysed data author suggested that the area has huge scope for construction of artificial recharge structures. Mishra et al (2016) have carried out groundwater quality investigation of Pakariyar watershed Rewa district Madhya Pradesh. They stated that higher concentration of sulphate and calcium in groundwater samples of the area is due to lithology. Overall groundwater of the area is fit for drinking. Tiwari et.al. (2023) have done Assessment of Groundwater Quality for Drinking Use in Bichiya River Sub Basin Area, Rewa Region, Madhya Pradesh, India. The assessment of groundwater quality for drinking use in the Deonar River Sub Basin Area, Sidhi District, Madhya Pradesh, India, was completed by Tiwari et al. in 2023. Using multicriteria decision analysis, Tiwari et al. (2022) evaluated the groundwater potential and recharge potentiality in Hanumana Block, Rewa District, Madhya Pradesh, India. Das (2023) has given excellent ideas about Groundwater Sustainability, Security and Equity: India Today and Tomorrow.

STUDY AREA

Rewa district is a one of the districts of in Madhya Pradesh. It is situated in the North-Eastern part of Madhya Pradesh between North Latitude 24°19.07’ 4.23"and 25°11.37’ 22.8", and East Longitude 81° 2.7’ 42.4" and 82° 18.4’23.7". The total area of the district is 6313.6 sq. km. and falls in parts of survey of India degree sheets 63G, 63H and 63L. It is bounded on south by Sidhi district, west by Satna and Maihar district, SE by Singrauli district, on north and NW by Uttar Pradesh State. The district forms a part of the Vindhya plateau of Madhya Pradesh province. The district headquarters is located at Rewa City. For administrative convenience, the district is divided into 6 blocks viz., Gangev, Jawa, Raipur Karchuliyan, Rewa, Sirmour, Teonthar. The district is also been devided into 09 tehsils viz. Jawa, Teonthar, Semaria, Sirmour, Huzur, Huzur Nagar, Raipur Karchuliyan, Gurh, Mangawan. The entire district falls in Upper Ganga basin. Tamas (Tons), Belan, Mahana, Beehar are the main rivers flowing through the district. The district is well drained by Tons River and its tributaries.

Rewa has a subtropical climate, meaning that it has three different seasons: summer, monsoon, and winter. March through June is considered the summer season, when the temperature ranges from 30 to 45°C. The monsoon season, which brings significant rainfall to the area and spans from July to September, comes next. October through February is considered the winter season, when the temperature ranges from 5 to 25°C.

The entire district falls within the Upper Ganga basin, encompassed by the two tributaries of the Ganga river: Tons and Son. The Kaymore Hill range acts as a natural divide between these two rivers. Throughout the district, numerous seasonal rivers and streams form a dendritic pattern. In total, there are 3 significant rivers, including Tons, Beaher and Bichhia. These rivers eventually come together to flow into the Ganga, either through the Tons or Tamas river or the Son river. The majority of these rivers originate from the Kymore ridges, which serve as the main watershed for the district. Notable among these is the Bichiya River, which peacefully winds its way through the heart of Rewa city, while the Beehar River flows just outside its bustling streets.Rewa experiences about 1140 mm mm of yearly rainfall on average, most of which falls during the monsoon season. Rewa's proximity to the Vindhya Mountain range affects the climate as well. The hills and forests contribute to both biological balance and climatic regulation. The area is renowned for its abundant fauna and biodiversity, home to a wide variety of animal and bird species. The Administrative and Tehsil maps of the Rewa district are presented in Fig. 1

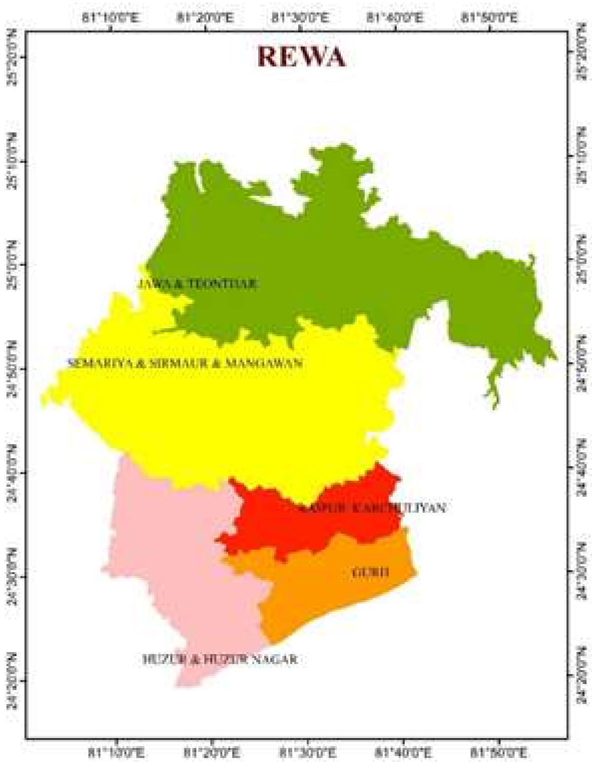

Fig. 1: Administrative boundary of Rewa Region (Not to scale)

GEOLOGY AND HYDROGEOLOGY

Upper Rewa Sandstone

Silica cementation has virtually entirely blocked the sandstones' interstices, so groundwater cannot be effectively stored in them. They provide wells and springs in the local zone of saturation with modest to moderate amounts of groundwater through joints, fractures, and bedding planes in weathered zones. Rewa Sandstones yield more water than Kaimur Sandstones do because of their higher jointing and fracturing (Natarajan, 1967). Given that certain oozes and seepages are occasionally observed releasing along bedding planes, groundwater does exist beneath water table circumstances. Nonetheless, the majority of the examined area has fracture springs, which may indicate the occurrence of a parched water table situation (Singh, 1987 and 1994).

Ganurgarh Shale

The Ganurgarh Shales provide just enough resources for domestic or animal usage through the joints and cracks of brittle shale, where certain pore spaces have evolved due to weathering and fracturing. Groundwater exists in an unconfined environment. Additionally, it has been shown that semi-restricted to confined situations with flowing wells are evident in zones where limestones are encased in shales. Water used to surge roughly 2 metres above ground level during the winter and rainy season. But once the monsoon ended, the hydrostatic pressure dropped, and although though the water flow was minimal, it continued into the winter. Relative to water table aquifers, there may be less recharge regions. Cavities in solutions have formed at the interface between limestone and gypsum. Ganurgarh shale has bands of gypsum at a lower depth. The presence of gypsum promotes the development of artesian conditions; yet, the excessive sulphate concentration of the ground water is said to make it inappropriate.

Blander Limestone

The Bhander Limestone of the area is light to dark grey in colour and massive to karstified in nature. Hydrogeologically, the area is part of Pre-cambrian sedimentary province. Groundwater occurs in semiconfined to confined condition. The karstic features developed in limestone are the main source of groundwater whereas cracks and joints developed in shale formation provide groundwater. Due to high silica cementation in sandstone, the primary porosity is low whereas secondary porosity in the form of joints, fractures form the source of groundwater. The groundwater occurs in confined and semi- confined conditions. The various karstifications-Rillen, Rinnen and Kluft Karrain developed in the study area are potential source of groundwater. The region is a sedimentary Pre-Cambrian province. Groundwater exists in restricted to semiconfined environments. While groundwater is mostly found in the karstic structures formed in limestone, it is also found in the fractures and joints seen in shale formations. The specific yield in the shale aquifer ranges from 81 lpm to

111 lpm, while it varies between 730 lpm and 1150 lpm in the limestone aquifer.

Alluvium

The primary source of the alluvial materials is the hill slopes' erosion caused by several streams that emerge from the hills. The highest thickness of the alluvium is 15 metres, and it varies near Govindgarh, Amilaki, and Kuthulia. Boulders and pebbles are caught in the bore holes in this zone. The alluvium is nearly as thick in some parts. Sand and gravel beds are the most common in both zones. Water from the wells is used for small- and medium-sized irrigation needs.

GROUNDWATER LEVEL FLUCTUATION

The data of the last five years show that it is Meager rainfall and indiscriminate hand pump mining, tube wells etc. have brought the ground water level down significantly. In this matter the Reva block has reached the top. There was not much difference in year 2023 in the readings taken before and after the rainy season. In Rewa block water went down by about two and a quarter meters in 2023 as compared to 2022. After this, Jawa block is at second place. According to District Ground Water Survey Unit, the ground water level of Rewa district has been continuously falling for many years. Table:1

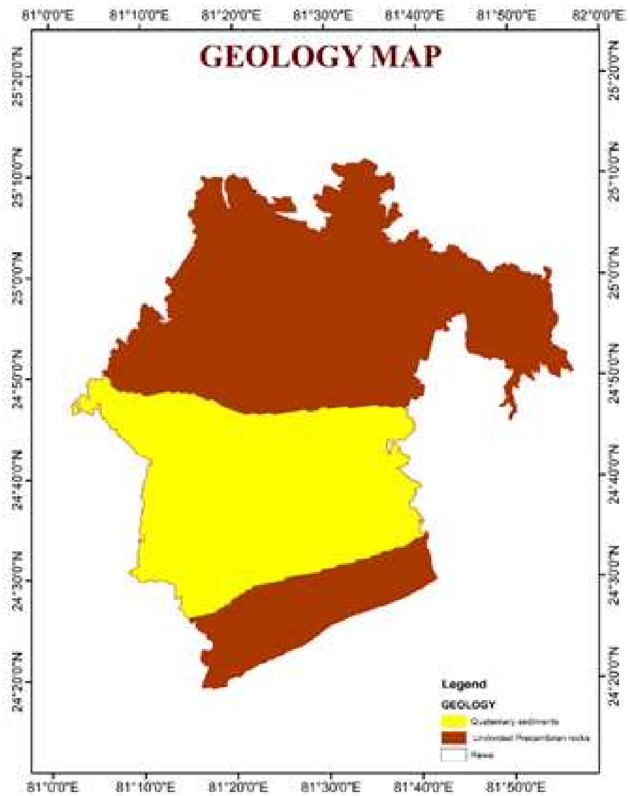

Fig. 2: Geological map of the area (not to scale)

TABLE 1: Groundwater level fluctuation in last five years (in m)

BLOCK	2019	2020	2021	2022	2023
Rewa	5.84	6.31	5.80	6.12	8.34
Sirmaur	3.78	4.49	3.51	4.81	5.60
Raipur Karchuliyan	5.93	5.96	7.17	5.57	6.29
Jawa	9.95	11.22	9.44	8.85	7.91
Gangeo	4.47	4.40	4.58	4.40	5.17
Teonther	4.66	3.74	5.43	5.91	5.95

(Source: District Ground Water Survey Unit 2023)

WATERSHED MANAGEMENT: SUGGESTIONS

Water is traditionally saved for use during the dry seasons of the year through a variety of water harvesting and conservation methods. Many projects including the Flood Programme, NREGS, Hariyali, DPAP, MPDPIP, and the National Project for Repair, Restoration, and Renovation of Valley Project were started. Some of the recharge structures which may be useful for watershed management are given below:

A. **Percolation tank**: An artificial body of water has been constructed by submerging permeable land. This allows surface runoff to seep into the ground and replenish the underground water reserves. The tank does not have any sluices or outlets for water to be utilized for any specific purposes. Its main function is to increase the depth of the water table below the ground surface, providing a source of additional groundwater and aiding in irrigation and drinking water supply during dry periods.

B. **Stop Dam/ Check Dam**: The most frequently built structure in all the mentioned water and land conservation programs is the 'Stop Dam'. These are masonry barriers constructed across the flow of water in shallow rivers and streams. They serve the purpose of harvesting water for irrigation, as well as for domestic and animal use. Stop dams not only enable irrigation but also supply water for human and animal consumption. If the flow in the nala is maintained for some time after the monsoon, it can contribute to the family's income by providing additional fully or partially subsidized irrigation benefits.

C. **Rain water harvesting structure**: In this approach, rainwater is directed from the building's roof into a designated storage tank. It is crucial to ensure that the tank is tailored to fit the specific water needs and takes into account factors such as rainfall and available catchment areas. In urban settings, where houses and buildings have considerable roof space and organized drainage systems, a significant portion of rainwater is often lost through these outlets, making it ideal for use in percolation tanks within the area. Shilpi plaza, samadariya gold, and other long buildings may be suitable for artificial groundwater recharge.

D. **Farm Pond**: The implementation of farm pond technology has significant potential in various state and central government schemes. Serving as a key technology in integrated water shed management programs, farm ponds offer multiple environmental benefits. These ponds are carefully dug-out with a specific shape and size, equipped with inlet and outlet structures to collect surface runoff from the surrounding farmland.

The study region's surface water supply is rather little in comparison to its population, which is the reason for our complete dependence on groundwater, which is constantly in risk of running out. In reality, water management ought to be done at the following levels:

- Prioritize connecting Indian water culture and rituals over linking rivers, emphasizing societal and governmental involvement.
- Implement separate plans for the revival of each small river at the local level, empowering Gram Sabhas for planning and implementation.
- Give priority to the revival of small streams to replenish groundwater and sustain larger rivers.
- Develop a water map for each locality based on cultural boundaries, involving geologists and local institutions.
- Enforce mandatory annual water planning and auditing.
- Formulate comprehensive dam and river policies.
- Establish legislation with the consent of water users.
- Promote traditional and modern water recharge methods.
- Prioritize water usage for drinking, irrigation, and other essential needs.
- Activate Irrigation Water Users' Committees and implement penalty systems for misuse.
- Preserve heritage structures like wells and stepwells in drought-prone areas.
- To organize seminars, workshops at college and university level for watershed management.
- Implement rainwater harvesting schemes in government complexes and promote groundwater recharge.
- Integrate traditional practices with modern science for effective water conservation and management.
- To organize awareness programmes for water conservation are urgently needed.

CONCLUSION

The study highlights the significance of integrated water resource management strategies in addressing the challenges faced by the region. Through the integrated use of surface water, groundwater, and rainwater alongside technological advancements, there exists a promising opportunity to augment impoverished water resources and enhance soil moisture. The revival of water harvesting and recharging structures, coupled with the adoption of sustainable irrigation methods, can significantly contribute to achieving the projected targets of food grain production in the coming decades. Furthermore, the establishment of a local watershed planning methodology that balances technical rigor with community participation is crucial for ensuring the sustainability and effectiveness of watershed management initiatives.

To effectively implement watershed management strategies, it is imperative to establish mechanisms for cross-sectoral coordination and stakeholder engagement at all stages of planning and implementation. This entails raising awareness about community rights and responsibilities, fostering a spirit of self-help, and promoting the sustainable management of natural resources among stakeholders. In essence, the principles of watershed management offer a holistic approach to land and water resource planning, integrating environmental conservation with socio-economic development. By prioritizing community involvement and embracing sustainable practices, the Rewa region of Central India can pave the way towards a more resilient and prosperous future.

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The Impact of Mining in Ecology and Environment

Tozama Kulati Siwisa*

Many negative impacts can result from mining activities. Some examples include climate change, deforestation/habitat destruction, pollution, soil erosion, human-wildlife conflict, and the loss of biodiversity. Mining can have harmful effects on surrounding surface and groundwater. If proper precautions are not taken, unnaturally high concentrations of chemicals, such as arsenic, sulphuric acid, and mercury can spread over a significant area of surface or subsurface water.

WHAT MORE CAN BE DONE TO REMEDY THE IMPACT CAUSED BY THE INDUSTRY

South African Context

There are a number of principal environmental laws that apply to the mining industry and are intrinsically linked to the granting of permits, the licensing and operations of the mining industry. The National Environmental Management Act, No. 107 of 1998 (NEMA) is the principal environmental legislation in the country, governing and regulating all aspects of the environment.

While the Department of Mineral Resources and Energy (DMRE) is responsible for the application and enforces the provisions of NEMA within the mining industry, the Department of Forestry, Fisheries and the Environment provides oversight and additional enforcement of environmental regulations, where appropriate. There are other important environmental laws that have an impact on the running of mining operations, including:

- the National Environmental Management: Waste Act, No. 59 of 2008 (NEMWA);
- the National Environmental Management: Biodiversity Act, No. 10 of 2004;
- the National Environmental Management: National Forests Act, No 84 of 1998;
- the National Environmental Management: Protected Areas Act, No. 57 of 2003;
- the National Heritage Resources Act, No. 25 of 1999; and
- the National Environmental Management Air Quality Act, No. 39 of 2004.

Source : https://www.dffe.gov.za/

WHAT MORE CAN BE DONE TO REMEDY THE IMPACT CAUSED BY THE INDUSTRY

World Gold Council Context

In 2019, the World Gold Council launched the Responsible Gold Mining Principles (RGMPs), a framework that sets out clear expectations for consumers, investors, and the gold supply chain as to what constitutes responsible gold mining. The RGMPs are intended to recognise and consolidate existing standards and instruments under a single framework. A number of leading standards already exist that address specific aspects of responsible gold mining, including the United Nations Guiding Principles on Business and Human Rights, the OECD Due Diligence Guidance for Responsible Business Conduct, and the Extractive Industries Transparency Initiative. However, prior to the development of the RGMPs, there was no single coherent framework that addressed all aspects of responsible gold mining.

Responsible Gold Mining (Source : https://www.gold.org/)

WHAT MORE CAN BE DONE TO REMEDY THE IMPACT CAUSED BY THE INDUSTRY

World Gold Council Context

The World Gold Council and its members recognise that climate change imposes very substantial risks to the global economy and socio-economic development. Policy makers, industry participants, investors, asset owners, and wider society are now eager for a greater understanding of these risks and their potential consequences, and how they might be mitigated or managed in future.

To contribute to a clearer, more consistent appreciation of how climate-related risks (and opportunities) might impact the future prospects of the gold industry and its many stakeholders, we have undertaken a programme of research, in collaboration with leading sustainability experts and academics.

**Head of Corporate Affairs, West Wits Mining*

Gold & Climate Change Source : Https:// Www.Gold.Org/

WHAT MORE CAN BE DONE TO REMEDY THE IMPACT CAUSED BY THE INDUSTRY

World Gold Council Context : Gold mining is a major economic driver for many countries across the world. Well-managed, transparent and accountable resource extraction can be a major contributor to economic growth due to the creation of employment and business opportunities for local people. As well as direct and indirect jobs, gold mining also brings foreign direct investment and tax revenues to countries. Often operating in remote locations, gold mining companies invest in infrastructure and utilities. In addition to supporting the needs of a gold mine, these improvements to roads, water and electricity supplies are a long-term benefit to businesses and communities across the area, that outlives the production years of a gold mine. [Gold contribution to Society, Source : https://www.gold.org/]

Mine Closure in Coal Mines – Safe and Sustainable Mining

M. Subba Rao* Murali V**

ABSTRACT

Mining Industry in India is a significant contributor to the economy of India. Indian Mining Industry, for the last 6 to 7 years has been passing through difficult phases of time, a Total Crisis Management. Mining Community in India has been facing various significant challenges, such as, technological, social, environmental, safety and economical.

Mining Community has confronted and solved various challenges over centuries and contributed to use and development of mineral resources.

Minerals are backbone for Industries and economic growth of the Nation. Minerals constitute the most vital raw materials for many basic Industries and are major source of economic development.

Management of mineral resources has therefore, to be closely connected with overall strategy of development and exploitation of minerals to be guided by long-term national goals and perspective.

There are esteemed natural resources, being limited and non-renewable. In this perspective, it is necessary to evolve a Conscious Strategy for the systematic development of mineral resources and their judicious utilization.

This Paper presents details of undertaking Scientific and Effective Mine Closure Activities for Safe and Sustainable Mining Operations in Coal Mines.

INTRODUCTION

Mining Industry in India is a significant contributor to the economy of India. Indian Mining Industry, for the last 6 to 7 years has been passing through difficult phases of time, a Total Crisis Management. Mining Community in India has been facing various significant challenges, such as, technological, social, environmental, safety and economical.

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SCCL

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MINE CLOSURE

Objectives of Mine Closure

The following are the Objectives of Mine Closure within the framework including environmental, social, re-purposing and other concerns:

- ✓ To ensure safe mining operations;
- ✓ To ensure sustainable mining operations;
- ✓ To ensure appropriate closure of Mines;
- ✓ To ensure effective closure of Mines;
- ✓ To ensure scientific closure of Mines;
- ✓ To allow a productive and sustainable after-use of the site, which is acceptable to the Mine Owner and Regulatory Authority;
- ✓ To protect public health and safety;
- ✓ To alleviate or eliminate environmental damages and thereby encourage environmental sustainability;
- ✓ To minimise adverse socio-economic impacts;

Mine Closure is oriented towards the restoration of land, back to its original, as far as practicable, or further improved condition.

Mine Closure has two (02) components. They are:
a). Progressive or Concurrent Mine Closure; and
b). Final Mine Closure.

PROGRESSIVE OR CONCURRENT MINE CLOSURE

This would include various land use activities to be done **continuously and sequentially** during the entire period of mining operations.

FINAL MINE CLOSURE

This would start towards the end of mine life and may continue even after the reserves are exhausted and/or mining is discontinued till the mining area is restored to an acceptable level.

GUIDELINES ON MINE CLOSURE IN COAL MINES:

Ministry of Coal, Govt. of India, vide F. No. 34011/28/2019-CPAM, Dated: 29.05.2020, has issued Guidelines for Preparation, Formulation, Submission, Processing, Scrutiny, Approval and Revision of Mining Plan for the Coal and Lignite Blocks, Dated: 29th May, 2020.

The relevant Clauses of the above Guidelines on Mine Closure in Coal Mines are:

❖ Progressive Mine Closure Plan shall be prepared for a period of every 5 years from the beginning of the mining operations. These Plans would be examined periodically in every 5 years period and to be subjected to 3rd party monitoring by the Agencies approved by the Central Govt.
❖ Various project specific activities, viz., mined-out land details and their technical and biological restoration Plan, Water Quality Management, Infrastructure to be retained and demolished, disposal of mining machinery, etc. shall be furnished.

❖ **Abandonment Cost**

The total cost for carrying out such activities shall be estimated for assessment of abandonment cost of the Mine involving Progressive and Final Mine Closure activities, such as, barbed wire fencing all around the working area, dismantling of structures/ demolition and cleaning of sites, rehabilitation of mining machinery, plantation, physical/biological reclamation, landscaping, biological reclamation of left-out overburden Dump, filling up of de-coaled void, post environmental monitoring, supervision charges, power cost, protective and rehabilitation measures including their maintenance and monitoring, miscellaneous charges, etc. for the specified post closure period.

❖ **Escrow Account Calculation**

Closure Cost (Base year 01.04.2019) is Rs. 9.00 Lakh/Hectare for Opencast Mines and Rs. 1.50 Lakh/ Hectare for Underground Mines. These rates will be considered as Base Rate to be applicable from 01.04.2019, which may change based on the Wholesale Price Index (WPI) as notified from time to time by the Govt. of India.
Annual Closure Cost is to be computed considering the Total Project Area of the Mine multiplied by Escalated Rate and dividing the same by the Balance Life of the Mine in years.
An amount equal to the Annual Cost is to be deposited each year throughout the Mine Life compounded @ 5% annually.
Further, in case of the Mine, where Escrow account is already open, the annual Closure Cost is to be computed considering the Total Project Area at the above mentioned rates minus the amount already deposited and dividing the same by the balance life of the Mine in years and annual cost as arrived should be compounded @ 5% annually.

❖ **Financial Assurance**

The Mining Company / Mine Owner as a part of Financial Assurance will open a Fixed Deposit Account with the Coal Controller Organization (On behalf of the Central Govt.), as exclusive beneficiary prior to commencement of any activities on the land / Project Area of the Mine and shall submit the same to Coal Controller Organization (CCO) before the permission is given for opening the Mine. The Mining Company shall cause the payment to be deposited at the rate computed as indicated. The Owner of the Company may select the Schedule Bank where the

Escrow account is to be opened and inform the same to the Coal Controller, CCO, Kolkata.

❖ **Final Mine Closure**

The details of the Mining Plan covering Final Mine Closure Plan envisaging the details of the updated cost estimates for various Mine Closure activities and the Escrow Account already set up, shall be submitted to the approving authority for approval at least 5 years before the intended Final Closure of the Mine.
Final Mine Closure would be considered to be completed only after acceptance of the 3rd party Audit Report by the Coal Controller on the compliance of all provisions of Mine Closure Plan.
Failure of restoration within the specified period may result in forfeiture of Escrow Account created.
The details of the Final Mine Closure Plan along with the details of the updated cost estimate for various Mine Closure activities and Escrow Account already set up shall be submitted at the time of approval of Final Mine Closure Plan.

❖ **Time Scheduling for Abandonment**

The Action Plan for carrying out all abandonment operations (Progressive and Final Mine Closure) should be furnished in the form of Bar Chart for a period of life of the Mine plus Post Closure period.

Post Closure period shall be taken as

✓ 3 (Three) years for U/G Mines & OC Mines having Stripping Ratio (S/R) less than 6 (Six) MM^3/Te; and
✓ 5 (Five) years for OC Mines having Stripping Ratio (S/R) more than 6 (Six) MM^3/Te.

❖ Up to 50% of the total deposited amount including interest accrued in the Escrow Account may be released after every 5 years in line with the periodic examination of the Mine Closure Plan.
❖ The amount released should be equal to expenditure incurred on the Progressive Mine Closure in past 5 years or 50%, whichever is less.
❖ The balance amount shall be released to Mine Owner/Lease Holder at the end of the Final Mine Closure on completion of all the provisions of Closure Plan.
❖ This Compliance Report should be duly signed by the Lessee and certify that said Closure of Mine complied all Statutory Rules, Regulations, Orders made by the Central or State Govt., Statutory Organizations, Court, etc. and certified by the Coal Controller.

❖ **Responsibility of the Mine Owner**

It is the responsibility of the Mine Owner to ensure that the protective measures contained in the Mine Closure Plan including Reclamation and Rehabilitation works have been carried out in accordance with the approved Mine Closure Plan and Final Mine Closure Plan.

The money to be provided per hectare of total Project area for the purpose is to be deposited every year on commencement of any development activity on the land for the Mine after opening a Fixed Deposit Escrow Account prior to obtaining Mine Opening Permission from Coal Controller. Mining Company / Owner including all Public Sector Undertakings shall deposit the yearly amount in a Scheduled Bank. If the Mine Owner fails to deposit the required annual amount, the Govt. can withdraw the Mining Permission.

The funds so generated are towards the security to cover the cost of Closure in case the Mine Owner fails to complete the relevant Closure activities. The prime responsibility of Mine Closure shall always lie with the Mine Owner and in case, these funds are found to be insufficient to cover the cost of Final Mine Closure, the Mine Owner shall undertake to provide the additional fund equivalent to the gap in funding, failing which it may be recovered by such other methods as the competent authority may deem fit in this regard.

❖ **Final Closure Certificate**

The Mine Owner shall be required to obtain a Mine Closure Certificate from Coal Controller to the effect that the protective, reclamation and rehabilitation works in accordance with the approved Mining Plan covering Final Mine Closure provisions/activities have been carried out by the Mine Owner for surrendering the reclaimed land to the State Govt.

The balance amount at the end of the Final Mine Closure shall be released to Mine Owner on compliance of all the provisions of Closure Plan duly signed by the Mine Owner to the effect that said Closure of Mine complied with all the Statutory Rules, Regulations, Orders made by the Central or State Govt., Statutory Organizations, Court, etc. and duly certified by the Coal Controller. This should also indicate the estimated extractable Coal Reserves and Coal actually mined out.

If the Coal Controller has reasonable grounds for believing that the protective, reclamation and rehabilitation measures as envisaged in the approved Mine Closure Plan in respect of which financial assurance was given has not been or will not be carried out in accordance with the Mine Closure Plan, either fully or partially, the Coal Controller shall give the Mine Owner a written notice of his intention to issue the Orders for forfeiting the sum assured at least 30 days prior to the date of the Order to be issued after giving an opportunity to be heard.

❖ Chapter-8 of the above Guidelines exclusively deals the Progressive & Final Mine Closure Plan covering the following as detailed:

I. Land Degradation and Restoration Schedule:

i. Tentative Land Degradation and Technical Reclamation (Cumulative Area "Ha")

Year/Stage		Land Degraded				Technically Reclaimed area			
		Excavation	Dump (Extn + Top soil)	Infra structure/ Others	Total	Back fill	Dump (Extn + Top Soil)	Others	Total
Up to									
Y-1									
Y-3									
Y-5									
.									
.									
Post Closure									
Y-20									

ii. Tentative Biological Reclamation: (Cumulative in "Ha")

Year/Stage		Biologically Reclaimed area					Forest land (Return)	Un disturbed /To be left for Public/ Company Use	Total
		Agri culture	Plant ation	Water body	Public/ Company Use	Total			
Up to									
Y-1									
Y-3									
Y-5									
.									
.									
Post Closure									
Y-20									

II. Post Closure Water Quality Management:

III. Post Closure Air Quality management:

IV. Waste Management (Tentative):

(Figures in MM^3)

Year/ Stage		OB Removal (Cumulative)			External Dump (Cumu lative)		Internal Back filling (Cumu lative)		Embank ment (Cumu lative)		Top soil Used in Green Belt area
		Top soil	OB	Total	Top soil	OB	Top soil	OB	Top soil	OB	
Up to											
Y-1											
Y-3											
Y-5											
.											
.											
Post Closure											
Y-20											

V. Top Soil Management - (Including Action plan for Top Soil management) (Tentative)

(All Figures are Cumulative and in MM^3)

Year/ Stage		Top soil Removal Plan	Top soil used				
			Spreading Over Embank ment	Spreading Over Back fill area	Spreading over External OB Dump area	Used in Green Belt area	Total
Up to							
Y-1							
Y-3							
Y-5							
.							
.							
Post Closure							
Y-20							

VI. Management of Coal Rejects

VII. Restoration of Land used for Infrastructure

VIII. Disposal of Mining Machinery

IX. Safety & Security

X. Abandonment Cost and Financial Assurance

i. Abandonment Cost: Cost of Activities to be taken up for Closure of the Mine:

B. Post Closure Activities					
Dismantling of Infrastructure& Disposal/ rehabilitationof Mining machinery	Dismantling of Workshop, infrastructure	Nos			
	Rehabilitation of the dismentaled facilities	LS			
	Dismantling of Office Buildings	Nos			
	Dismantling of CHPs	LS			
	Dismantling of pumps and Pipes/ other facilities	LS			
	Dismentaling of stowing bunker, provisioning of pumps for borewell pumping arrangement	LS			
	Dismantling of UG equipment	LS			
	Rearranging water pipeline to dump top park/Agricultural land	LS			
	Dismantling of Power lines	km			
Safety and Security	Barbed wire fencing around dump	m			
	Barbed wire fencing around pit	m			
	Barbed wire fencing with masonary pillars				
	Concrete wall with Masonary pillars arround the pit	m			
	Securing air shaft and istallation of borewell pump	LS			
	Securing of Incline	LS			
	Cocnrete wall fencing arround the water body				
	Boudandary wall arround the water body				
	Stabilisation (viz beching, pitching etc) of side walls of the water body				
	Toe Wall around the dump	m			
	Drainage channel from main OB dump				
	Garland drain around quarry	m			
	Garland Drain around the dump	m			
Technical and Biological Reclamationof Mined outof land and OB Dump	Filling of void	Ha			
	Top Soil management	m^3			
	OB Rehandling for backfilling	MM^3			
	Terracing, blanketing with soil and vegetation of External OB Dump	Ha			
	Paripheral road, gates, view point, cemented steps on bank				
	Expenditure on development of Agricultural land	Ha			
	Landscaping and Plantation	Ha			
Post Closure managementand supervision	Power Cost	Yrs			
	Post Mining Water quality management	Yrs			
	Post Mining Air quality management	Yrs			
	Subsidence monitoring for 5 years	LS			
	Waste Management	LS			
	Manpower Cost and Supervision	Yrs			
	Sub-Total (B)				
Grand Total (A+B)					

Head	Particulars	Unit	Quantity	Rate Rs/Unit	Amount "Rs. Cr"
A. Progressive Closure	Water quality management	Yrs			
	Air quality management	Yrs			
	Waste Management	MM^3			
	Barbed wire fencing around dump	m			
	Barbed wire fencing around pit	m			
	Filling of void- Rehandling of crown dump	MM^3			
	Top Soil management	m^3			
	Technical and Biological Reclamation of Mined out of land and OB Dump	Ha			
	Plantation over virgin area including green belt	Ha			
	Manpower cost and supervision				
	Toe Wall around the dump	m			
	Garland Drain around quarry	m			
	Garland Drain around the dump	m			
	Isolation stoppings	Nos			
	Noise Level Monitoring	Yrs			
	Sub-Total (A)				

ii. Financial Assurance: Amount to be deposited in Escrow Account as a security against the Mine activities to be carried out for the closure of the Mine:

WPI as on	Apr-19			121.10
WPI as on Base Date				
Escalation Rate of Closure cost				
			UG	**OC**
Base Rate of Closure Cost "Rs. Crs/Ha"			0.015	0.09
Closure Cost "Rs. Crs/Ha"				
Project Area				
Amount to be depostied into Escrow Account, "Rs. in Crs"				
Amount already deposited into Escrow Account, "Rs. in Crs"				
Net Amount to be deposited into Escorw Account, "Rs. in Crs"				
Rate of compounding of Annual Closure Cost			5.00%	5.00%
Balance Life of the project "in Yrs"				
Annual Closure Cost "Rs. in Crs"				
Amount to be deposited into Escrow Account after compounding @ of 5% "Rs. in Crs"				

Amount to be deposited into Escrow Account Annually ("Rs. in Crs")

Year	OC	UG	Total
1			
2			
3			
.			
Total			

CONCLUSIONS

- Scientific and Effective Mine Closure Activities achieve Safe and Sustainable Mining Operations in the Mines within the framework including environmental, social, re-purposing and other concerns.
- Mine Closure orients towards the restoration of land, back to its original, as far as practicable, or further improved condition.

ACKNOWLEDGEMENTS

The Authors are thankful to the Management of the Singareni Collieries Company Limited for permitting to present this Paper. The views expressed here are the views of Authors only, not the Organization to which they belong.

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Enhancing Efficiency and Safety in Deep Underground Coal Mining: A Case Study of the Adriyala Longwall Project Mine with Integrated Air Cooling and Tube Bundle Gas Monitoring Systems

K Venkateswarlu* K Nageswara Rao** K Srikanth***

ABSTRACT

Over the past few decades, opencast mining has dominated coal production due to its economic and productive advantages. However, limitations arise beyond 300 meters in opencast technology due to increased stripping ratios, rendering it economically unfeasible. The Longwall technology emerges as the preeminent underground method for economically extracting coal in substantial quantities from deep mines. The Singareni Collieries Company Ltd has initiated a high-capacity Longwall Project at Adriyala, situated at depths ranging from 300 to 800 meters.

In deep mechanized mines, elevated temperatures coupled with high humidity present challenges in ensuring efficient ventilation, resulting in uncomfortable working conditions. Consequently, an artificial bulk air cooling system has been implemented at Adriyala to supply chilled air to Longwall workings, leading to enhanced safety, productivity and machinery performance. Additionally, advanced mining methods, characterized by accelerated extraction rates and increased ventilation, pose an elevated risk of spontaneous combustion. To address this concern, continuous monitoring of the underground environment is essential for early detection and preventive measures. To meet this requirement, a 20-point Tube Bundle gas monitoring system has been introduced at Adriyala for comprehensive gas monitoring.

The primary objective of this technical paper is to provide an in-depth examination of the working conditions at the Adriyala Longwall Project, presenting details on ventilation strategies, the implementation of the Air Cooling System, and the introduction of the Tube Bundle system at Adriyala.

INTRODUCTION

Human existence depends on energy on a daily basis, and this requirement is more important than ever. A significant energy source besides other fossil fuels and renewable sources is coal. About 75% of the nation's power is produced in India using coal, one of the least expensive energy sources. Nearly 94% of the coal produced during the past five years has come from opencast mines (MoC, 2023). Out of 893.19 MT coal produced during 2022-23, 858.34 MT (95.0%) of India's coal output came from open-pit mines, while 34.84 MT (5.0%) came from underground mines. Mechanised longwall mines produced around 5% of the underground coal. However, opencast mining method is restricted in application to a depth of 300 m or less. In order to extract coal from deep-seated seams (depth more than 400 m) and to negotiate with high horizontal stress, one needs to deploy Longwall technology ensuring suitable seam thickness and inclinations.

In the modern longwall mining method, mine development is carried out in such a manner that large block of coal usually 100 m to 300 m wide and 1,000 m to 3000 m long, called 'longwall panels', are available for complete extraction.

To meet the increasing demand from power sector and shrinking of ongoing opencast projects, SCCL envisaged the opening up of deep shaft blocks for large-scale production. At present the existing pithead of NTPC, 2600 MW thermal power station, Ramagundam is being supplied by three opencast projects of SCCL (10.20Mt) out of its total requirement of 12.50Mt. In the long run, over a period of ten years, the reserves in the above mines are depleting and opening up of 2.817Mt capacity Adriyala Longwall project along with other deep shaft projects in

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SCCL*

Ramagundam will help to fulfill the coal supply to retain the pithead nature of NTPC Ramagundam power station. SCCL successfully commissioned a state of art High capacity automated Longwall Project at Adriyala Longwall Project (ALP) mine in 2014. The Adriyala Longwall Geological block area is more or less free from any major faults. The project is having 132.2 Mt of extractable reserves within the depth range of 294 to 800m. The project life is about 35 years with a rated production of 2.817MTPA.

The mine has 4 workable seams namely, No.1,2,3 and 4 respectively with varying thickness. At present only, in No.1 seam longwall technology adopted. Till now, 2 longwall panels completed, 3rd longwall panel extraction and 4th longwall panel preparation is under progress. For further scope of the project, development workings for approaching No.2 seam through tunnel from No.1 seam and Punch entries for No.3 seam are under action.

The layout of longwall panels proposed in No.1 seam of Adriyala are shown in Fig.1 and the seam partitions are also marked in the figure.

The Longwall equipment in Adriyala consists of EL3000 Shearer with 2245kW installed capacity, Armoured Face Conveyor(AFC) with installed capacity of 2565kW, Beam Stage Loader(BSL) of 400kW, 145 shields of capacity 2x1152t and 1.75m width, 2x4.5MW of 11kV/3.3kV transwitches and 1600mm wide three kilometers long gate belt with 3x315 kW drives. The package includes SCADA (Supervisory Control and Data Acquisition System). The Longwall equipment was supplied by CATERPILLAR, Germany.

VENTILATION SYSTEM AT ADRIYALA

The Mine is equipped with 400 kW capacity Main Mechanical Ventilators to ventilate the mine, which is capable of delivering 15000 m^3/min of Air quantity at 150 mm of WG and another identical Main Mechanical Ventilator is provided as standby. The Main Mechanical Ventilator is delivering about 12000 m^3/min of Air quantity at 128 mm of WG. An Air-Cooling system of 1200TR capacity is also installed on surface to maintain temperatures and humidity within the permissible limits at working places below ground.

HEAT SOURCES IN COAL MINES

The sources of heat in underground coal mines are well documented (Pickering and Tuck, 1996; Whittaker, 1979).

- Auto compression which increases the wet bulb temperature by approximately 0.4°C per 100m, depending on the surface wet bulb temperature;
- Rapid production and therefore release of heat from broken coal and rock at the working face and within the goaf immediately behind the face;

Oxygen depletion of 0.2 to 0.3% in return air quality measurements would add as much as 400kW of heat.

- High face air quantities and pressures with consequently larger volumes of air sweeping the goaf behind the face and returning onto the face at various locations along the face at near to the strata temperature;
- Increasing equipment power with accompanying heat dissipation;

Assuming 60% of total nameplate power, with as much as 70% of energy converted into heat.

- Two heading development using a single intake traveling road and homotropal belt roadway and single return for longwall operations;
- Down dip advance of workings with consequent auto compression and strata temperature increase.
- Longwall pump stations in panel intakes, and
- Other heat loads such as secondary fans, diesel equipment and ground water.

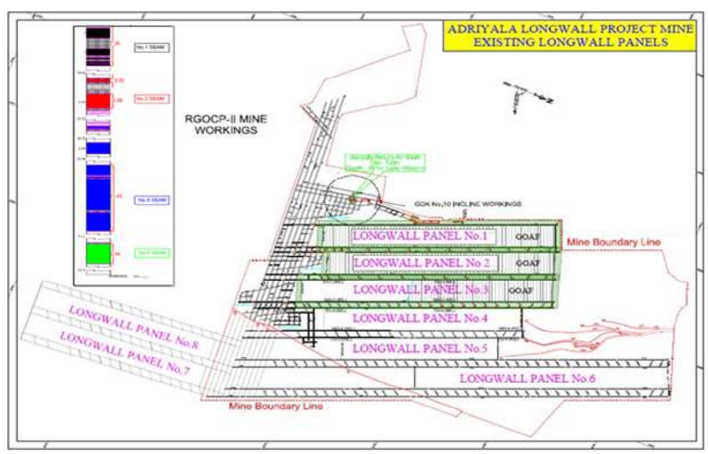


Fig.1: Layout of Adriyala Longwall Project

PSYCHOMETRIC STUDIES AND AIR COOLING SYSTEM AT ALP

To estimate the cooling requirements in Longwall panel, Psychometric studies conducted in Longwall Panel-1, on 16.05.2015. Variation of wet bulb and dry bulb temperatures from surface to Longwall panel tailgate return 30m was as shown below in Fig.2. It was also observed that that Enthalpy raised from 85 kJ/kg to 125 kJ/kg from PE5D surface to longwall tailgate indicating heat addition of about 2500kW.

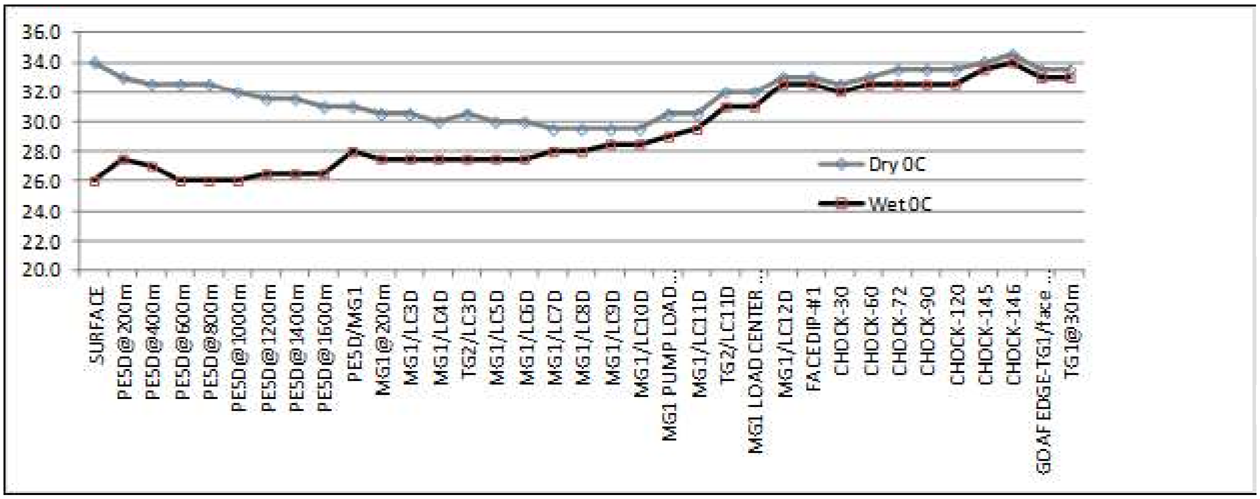


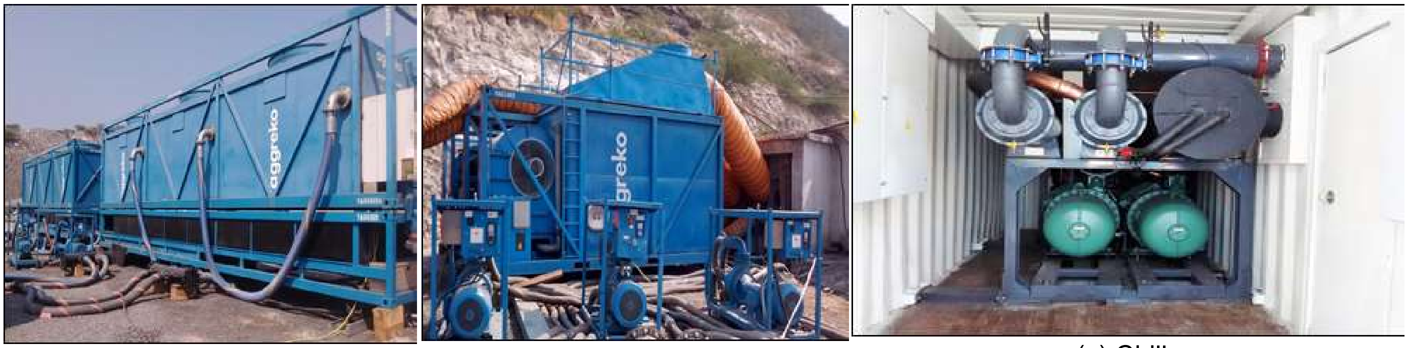
Fig.2: Variation of air temperatures from surface to LWP-1 tailgate

Initially, when longwall panel-1 started wet bulb temperature was about 28^{0}C. But after working for 450m retreat, the face wet bulb temperature gradually increased to 32^{0}C due to heat generation from working machinery, large goaf area, hot strata water (35^{0}C) flowing along the bottom gate roadways and large volumes of coal cutting in the face. This resulted in frequent electrical breakdowns and machinery hydraulic problems after taking into consideration gate belt, energy centre, strata, goaf water; face machinery (Total: 2900kW), 1200TR capacity air chilling plant installation was advised by CSIRO and ISM, Dhanbad.

Air chilling plant was provided on the surface near the entrance of the PE5D on hired basis from M/s Aggreko during November, 2015 for bulk air cooling of intake air. Initially Air chilling plant of 1200TR with Air Handling units (air cooled type) was installed to deliver 50 Cu,m/sec of chilled air at 15^{0}C, which is circulated exclusively to the Longwall Face through a dedicated roadway PE5D, from surface. Due to use of this air cooling system, temperature at Longwall Face reduced from 33.0^{0}C to 28.5^{0}C resulting in improvement is workplace comfort, reduction of failure of electrical and electronic equipment and improvement in productivity. In Air cooled type chilling system water glycol was being used to bring down the temperature of the circulating water in AHUs to below 0^{0}C. It was insisted to discontinue use of water glycol because; it is very dangerous to the health of miners if it get mixed in the air through any leakage in the closed loop system at the AHU. Later, for longwall panel-2 Air handling units were replaced with Bulk air handlers (water cooled) to deliver the chilled air at 9.0^0 C. With the replacement of the air cooled type chilling system with water cooled type the efficiency of the cooling system was improved considerably.

To supplement development of longwall panels in LWP-3, the chilled air plant capacity is increased to 80 cu.m/sec.

The Site Equipments bulk air handling system of M/s Aggreko, consists of **Six no.s of** 406 TR water cooled chillers, Two 10000kW Cooling tower , Three 2500kW Bulk handling air units (BHAU) and One 15MVA*2Nos 11 kV Transformer, one 3.15MVA Transwitch. The operating voltage of Chillers is 415V. Energy consumption varies from 15 to 25MWH per day. The Power Consumption of Water Cooled Chiller is lesser than Air cooled Chiller by 35 to 40%, occupies less space and consists less number of ducts. The overview of Bulk air handling cooling system equipment is as shown in Fig.3.



(a) & (b) Cooling tower and Bulk air handling unit.

(c) Chiller

Fig.3: The overview of Bulk air handling cooling system equipment

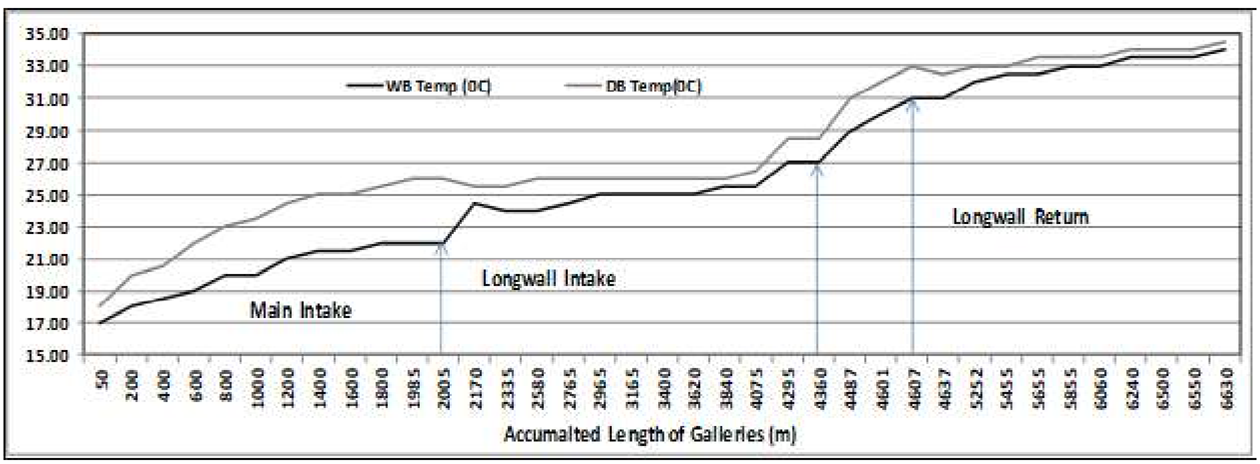


Fig.4: Temperature variation along accumulated length of Longwall panel-2 from PE5D

The variation of wet bulb and dry bulb temperatures of air from 50m of PE5D to Longwall tailgate outbye is as shown below in Fig.4. At the entrance of PE5D, the chilled air nearly **48**00 Cu.m is delivered at 9^{0}C and it is mixed with surface ambient air and the mixed air temperature reaches to 18^{0}C at 50m below the PE5D. The gate belt and energy train are responsible for addition of temperature upto 2^{0}C each. The temperature at the main gate junction of the longwall face reaches to 28.5^{0}C, to enable comfort working conditions at Longwall face.

After the introduction of air cooling system exclusively for Longwall panel, production, and productivity was improved and electrical and electronic breakdowns were reduced to minimum.

TUBE BUNDLE GAS MONITORING SYSTEM

Tube bundle gas monitoring systems were developed by the National Coal Board in the United Kingdom (UK) in the late sixties as a means of early detection of spontaneous combustion (Chamberlain et al 1971). In brief, tube bundle systems are comprised of hollow tubes run from the surface to the desired monitoring location, through which gas samples are drawn to the surface by way of vacuum pumps as shown in Fig.5. By switching from one tube to another on the surface, the sample from each point in turn can be analysed. All analysis, pumping and switching hardware is located on the surface removing the need for equipment to be approved for use underground. Electrical supply to the system can also be separate from mine power allowing operation during loss of power underground.

APPLICATION OF TUBE BUNDLE SYSTEM

The system was originally developed to continuously monitor the carbon monoxide content of the air passing critical points underground in order to detect spontaneous combustion in its very early stages before, the traditional

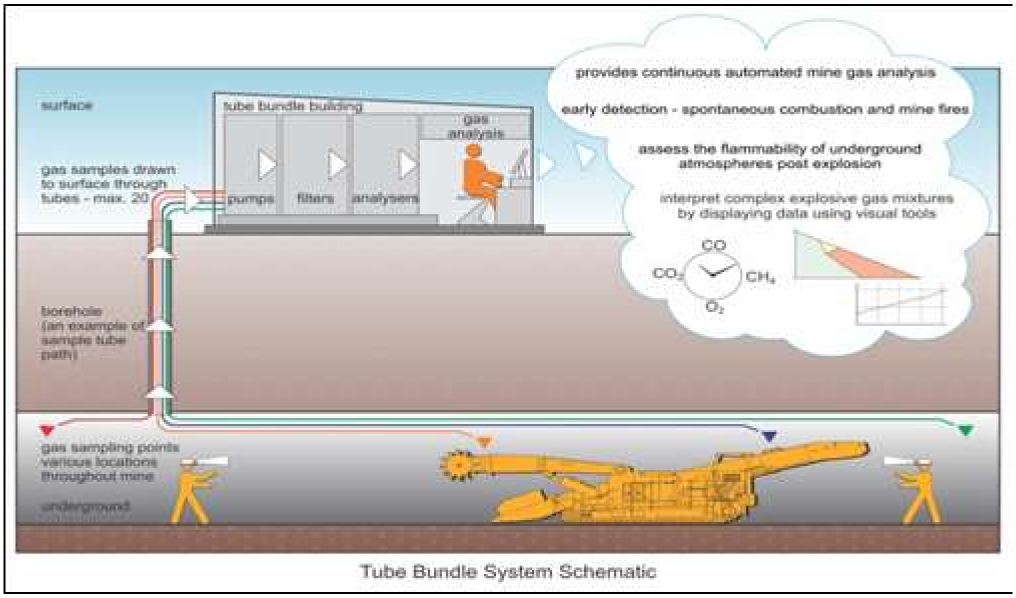


Fig.5: Tube Bundle System schematic diagram

indicators of smell and haze were detectable (National Coal Board 1977). The rate of evolution of carbon monoxide had been established as the earliest indicator of incipient spontaneous combustion. But it was quickly identified that extending the analysis to include oxygen, methane and carbon dioxide was worth the additional expense and provided a much better understanding of the variations in the atmosphere of an underground coal mine. Determination of the explosibility in sealed and active gobs is a primary function of tube bundle systems, equally as important as the early detection of spontaneous combustion and fires.

EFFECTIVENESS AS A PREVENTATIVE MEASURE

- Tube bundle systems have a proven track record of averting mine disasters due to gas explosions. Even in situations where explosions were not prevented, lives were saved as the result of timely information provided by tube bundle systems.
- Tube bundle systems currently provide the most effective means of automated sampling of sealed and active gobs providing ongoing trending and determination of explosibility status even when the mine has been evacuated.

VALUE IN POST-EVENT SITUATIONS

- Tube bundle systems remain available after a mine has been evacuated as they operate independently of underground power.
- There are numerous incidents in many countries/ jurisdictions where mines rescue teams have been deployed underground and subsequently killed in an explosion, largely due to an unknown or incomplete knowledge of underground atmospheric conditions. Tube bundle systems can provide a determination of the mine atmosphere following an explosion or fire before the deployment of rescue teams underground.
- The need for post-event gas analysis has often been identified the need for improved survivability of a mine's existing monitoring system. There are a number of measures that may be utilised during the installation of tube bundle systems that improve the survivability of the underground tubes during an explosion. A key factor is strict adherence to a rigorous installation and maintenance standard.
- Mobile laboratories play an important role in gas analysis in post-event response, but experience indicates they are best used in conjunction with fixed tube bundle systems to extend their capabilities rather than as an alternative to fixed systems.

TUBE BUNDLE SYSTEM AT ADRIYALA LONGWALL PROJECT

A SICK tube bundle gas monitoring system has been purchased from Safety in Mines Testing and Research

Station (Simtars) Australia. Simtars is a professionally independent, functional entity of the Queensland Department of Natural Resources Mines and Energy with extensive experience in the public and private sectors.

SICK is a German based company. The SICK tube bundle systems are installed at the majority of Australian coal mines and SICK have a presence in India to provide assistance with the system and the 6 monthly maintenance on the system. 20 point tube bundle gas monitoring system was introduced in Adriyala Longwall Project, SCCL.

Tube bundle systems have been designed to operate 24 hours a day, 365 days per year. The basic principle is based upon running food grade polyethylene tubes from the surface to the required underground monitoring point and drawing gas samples using surface installed purging pumps for analysis on a dedicated four gas analyser. These tubes can be up to 6 km length for ½" tube and 9.5 km for 5/8" tube.

System is of Supervisory, Control and Data Acquisition (SCADA) software and hardware and developed specifically for continuous automated mine gas monitoring, interpretation and decision support system.

The system consisting of Sick Maihak 715 gas analyser configured specifically for the monitoring of carbon dioxide (CO_2), methane (CH_4), carbon monoxide (CO) and oxygen (O_2) in coal mines. The analyser uses a MULTOR non-dispersive infra-red (NDIR) bench for measuring CO_2 in the range 0-50% and CH_4 in the range of 0-100%, a Unor NDIR for measuring CO in the range of 0-1000 ppm, and an OXOR P paramagnetic bench for measuring oxygen in the range of 0-25%. This analyser typically has an accuracy range of ±1% full scale for each component measured.

The gas conditioning equipment consists of various flow control components, sample gas cooler, gas selection station, filtration and water removal equipment and presents to the analysers gas samples completely free of water or any particulate matter. To ensure maximum safety, each sample tube is equipped with approved flame traps at both the underground and surface ends of the tube. A flow meter shall be provided and visible on the analyser and the analyser generates low flow alarms.

System shall have provision to introduce manually collected gas samples from bags into the analyser for determination of composition, plus the ability to collect samples from any of the sample tubes for additional analysis through the "bag in" and "bag out" arrangement. The schematic line diagram of tube bundle hardware in the analyser room is as shown in Fig.6.

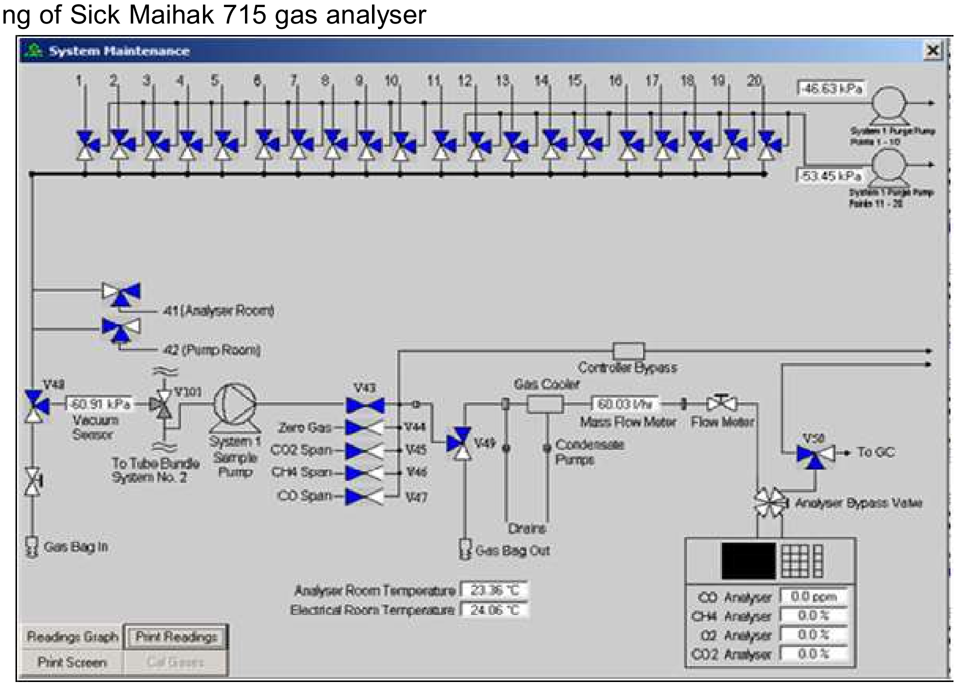


Fig.6: Schematic diagram of Tube Bundle hardware in analyzer room.

Analyzer room is installed on surface near the Punch entry-5 (PE5D). three Bundles of 7 core tubes(ID-0.35", OD-0.5") are laid parallel from Analyzer room to underground along PE-5D up to 61LN/PE5D, PE5R/74LN and PE5R/85L marshalling stations respectively. Individual Tubes (ID-0.35", OD-0.5") are laid up to monitoring locations from respective each bundle tubes connected to marshalling stations. Marshalling station and the components of Tube bundle system are shown in Fig.7.

Fig.7: Marshalling station and the components of Tube bundle system

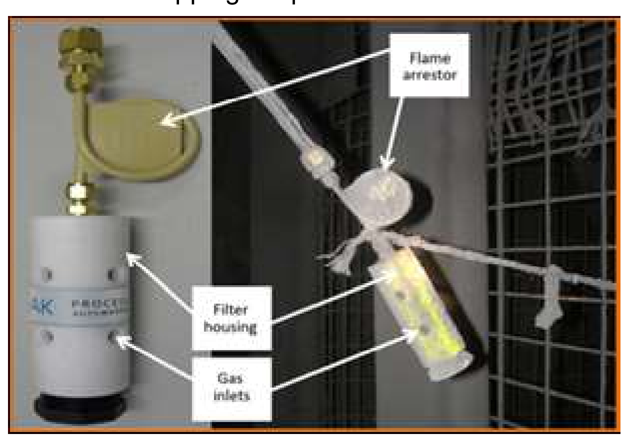
Bundles are supported on supported on gallery side L shaped hooks as well as roof cable brackets. The bundles are attached to the fully tensioned 10 SWG GI catenary wire by cable ties at an interval to prevent sagging. Individual tubes of the bundle as well as the individual tubes are joined with stainless steel or brass connectors and are further taped to ensure no leakage.

The tubes are installed such that, there is the minimum amount of undulation to avoid the settling of water. All tubes are run so that the water runs down dip to the marshalling panels where there are water traps. If single tubes are run down dip, water traps or seal panels are installed at the low point where water accumulates.

Tubes are provided with End of line of filters with flame traps to prevent entering of dust and flame. Flame traps are also provided at the tube end in the analysed room as shown in Fig.8 (a) and 8 (b).

The monitoring points are selected based on the statutory and other mine requirements for gas monitoring in underground coal mines. The requirements are for methane, carbon monoxide, carbon dioxide and oxygen to be continuously monitored at the following locations:

- the return airway of each ventilation split
- the return airway from each gob area
- the return of airway at the upcast shaft
- the return side of each conveyor belt
- the return side of the Free Steered diesel Vehicle's roadways, and
- Isolation stoppings of Sealed off area as well as isolation stoppings of panel under extraction.



(a)

(b)

Fig.8: End of line filters and flame trap at both ends of the tube

The gas monitoring system automatically detects or calculates with the help of Segas professional software coupled with SAFEGAS tube bundle control software, the values and trends of:

- gas concentrations
- the ratio of carbon monoxide and oxygen deficiency (Graham's Ratio)?
- the ratio of carbon monoxide and carbon dioxide gas explosibility and must:
- automatically activate an alarm if a gas alarm level is exceeded
- record the values and trends
- display the record at the surface of the mine where it can be easily accessed by coal mine workers and in a way that the record can be easily read by the workers
- keep the information on which the values and trends were based at the mine in a way that enables the information to be easily accessed and inspected
- Provide for an alternative electricity supply to ensure the system continues to function if the normal electricity supply fails.

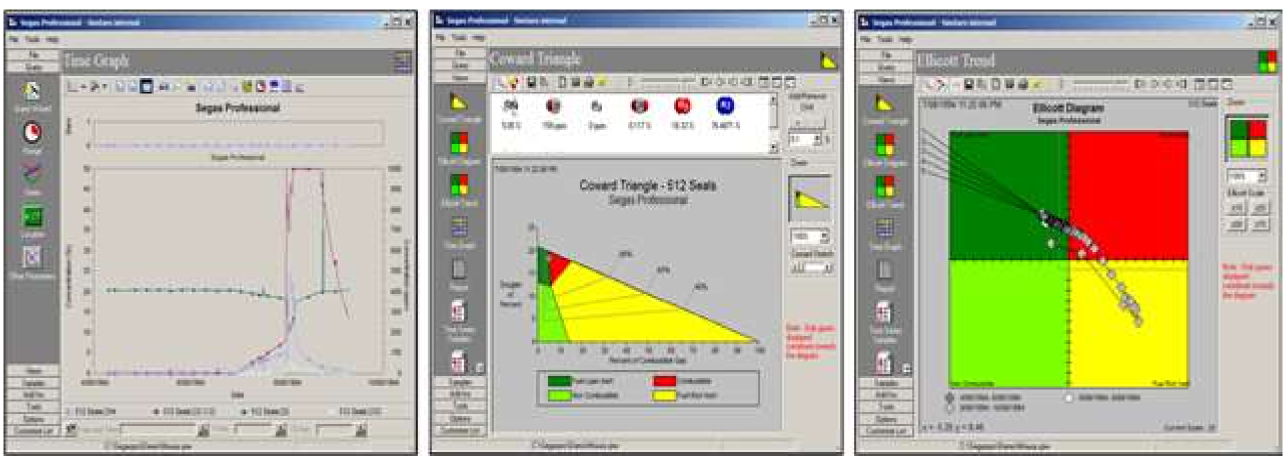


Fig.9: (a) Time graph of Respective Monitoring (b) Cowards' Diagram (c) Ellicott Diagram, of Location or Sampling Point

Segas Professional is also the data interpretation tool used for the Simtars supplied gas chromatographs. Segas Professional is closely integrated with Safegas and allows operators to readily convert complex gas data into easily understood graphs and visual interpretive tools in an effortless fashion as shown in Fig.9.

Analyser calibrated at the time of installation and also at intervals of every month or whenever the drift is observed in analyser. The gases used for calibration are N_2 (Grade 5, 99.999 purity), CO_2 (Grade4.5, 99.995 purity), CH_4 (Grade4.5, 99.995 purity) and CO (1000ppm, balance N_2).

Leak test of individual tubes was done for every sampling or monitoring location with the use of CH4 gas (2.5% CH_4 and balance N_2) injected at tube end to find any leakage of the individual tube and to rectify the same. This should be further done at every month interval or after every shifting or relocating of monitoring point.

Safegas allows four individual alarm thresholds (two levels for high and two levels for low) to be set for each parameter per monitoring location. Any value which equals or exceeds the threshold, in either direction, will trigger Safegas to raise an alarm.

Alarm levels shall be set by establishing what is normal for the sample location. This can be done by reviewing the time graphs for the location and also using statistical analysis of the last month's results for the sample location. The alarm shall be set to represent a variation from normal that is considered unusual and needs investigation. The effects of shot firing as well as presence of diesel vehicles should be taken into consideration while setting alarm levels. The investigation required is identified in the TARP that has been prepared. Consideration shall also be taken of statutory limits when setting alarm levels. Alarm levels shall be reviewed monthly after the monthly ventilation survey, on the introduction of a new tube or after a major ventilation change.

CONCLUSIONS

In order to ensure safe and comfortable working conditions for the miners in the places where the high temperature threats occur, the artificial cooling systems for underground mines must be used. At Adriyala, the air chilling plant was installed on surface on hire basis to supply chilled air to Longwall workings, which gave good results in the form of improved production, safety, productivity. In the longer term run, for further cost effective, mine cooling systems could be mine owned rather than hired and to be utilized for the whole mine.

Gas detection systems in any workplace are necessary to protect the safety of personnel and to prevent the larger accidents. Tube bundle system is a well developed technology used in coal mines for gas detections and needs less maintenance and is user friendly. This system was successfully installed at Adriyala Longwall Project with the cooperation of M/S SICK and SIMTARS, Australia. Tube bundle technology coupled with the assignment of proper responsibility and accountability; effective management systems, practices, procedures and support networks; and competent personnel operating the systems can improve safety in underground coal mines. This can be achieved by providing early warning of spontaneous combustion and fires, by providing critical information following a major event and by continuously monitoring during normal mining operations to ensure atmospheres in active working areas, sealed gobs are not explosive. This has the added benefit of less disruption to production by providing the opportunity for early intervention. In the event of a mine emergency, tube bundle systems are essential in assisting rescue teams in making informed decisions regarding the atmosphere deep inside the mine.

ACKNOWLEDGEMENTS

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Controls and Guides of Mineralisation at Deri Multi-Metal Deposit for Regional Exploration Target Generation

Anirban Das* Vishwanath Uppugundari* Suryanshu Choudhury*

ABSTRACT

The Neo Proterozoic stratiform VMS-type Ambaji–Deri-Basantgarh Zn–Pb–Cu deposit is hosted within meta-sedimentary sequences of the South Delhi Fold belt which has many other occurrences in the belt. The Mineralised zone in Deri-Ambamata Belt occurs in intercalated series of Talc-Tremolite schist and Biotite-Quartz schist or quartzite with either sharp contacts or grading through talc-tremolite-quartz-schist. The massive lodes contain well developed crystals of pyrite uniformly distributed in fine grained galena, sphalerite rich groundmass. The basemetal mineralisation occurs as thin veins and stringers along with foliation planes, as thin films along with fracture planes or randomly disseminated grains in the interspaces of the host rock. Mineralisation in Biotite-quartz-schist is less intense than the talc-tremolite-quartz-schist. Arenaceous rock types predominantly contain pyrite and chalcopyrite.

Talc schist group of rocks are the chief host rock of mineralisation in the region confirming that lithological control is prominent. The mineralisation is of layered type concordant to the bedding and foliation directions. Both the host rocks and the mineralisation are spatially enclosed, either in part or on the whole by sub-parallel shear zones. This mineralisation is considered here to be stratiform of marine association occurring with calc-magnesian and arenaceous metasediments of Upper Delhi Supergroup.

The sulphide bearing lodes occur as a series of closed spaced parallel to sub-parallel lenses separated by poor or barren horizons. The richer mineralisation is generally associated with carbonate layers and less common with arenaceous calc-arenaceous sediments. Present study has done litho-geochemical characterization of the Orebody which would help to generate regional exploration targets.

The structural features and litho-contacts can be well delineated by magnetic anomaly zones. The previous geological/geophysical studies in this area indicate that the high magnetic basic intrusive are well associated with the sulphide mineralization. The mineralized zones are well correlated with geochemical anomaly zones and particularly concentrated in the subparallel shear zones.

In present study, historical drill hole information has been compiled and processed in Datamine Studio RM software for Geological modelling of the explored area. It also has evaluated the resources and also identified the potential gaps target in the study area. Lithology & orebody correlation were done in different level intervals and have established the litho-structural control of mineralisation in Deri area. In order to identify the extensions of the deposit identification of the major alteration zones (e.g. chlorite, sericite) through hyperspectral imaging or alteration mapping would help in identification of the regional exploration targets.

Low resistivity and high chargeability are expected in this disseminated type of volcanogenic massive sulphide system. The main mineralisation is reported only in the sub-parallel shear zones in the western part of Deri. The sixth zone located at the eastern margin of the prospect, is not completely explored. IP resistivity survey may detect the hidden potential of Deri extension. Currently the country is deficit in terms of copper resources and discovery of any additional resources in the belt would help in country achieving Atma Nirbhartha.

INTRODUCTION

The Deri prospect and surrounding region form a part of south-western extremity of Delhi Synclinorium (Heron 1953). The metasediments of the region are correlated with Ajabgarh formation of the upper Delhi supergroup. The lower and middle part of the stratigraphic sequence has predominant calcareous sediments which are associated with subordinate argillaceous and arenaceous rock types. These are followed by arenaceous rock types in the upper part. The arenaceous sediments have a series of pockets of calc-magnesium sediments.

All these rock types are intruded by concordant types of basic igneous rocks. The sedimentation is followed by

**GMDC Ltd.*

folding and regional metamorphism. Calcareous sediments are represented by crystalline limestone, marble and calc-gneiss, while argillaceous sediments by phyllites and mica schist. The arenaceous sediments are characterised by quartzite, quartz-schist, while the calc-magnesium sediments by talc-tremolite schist. The basic igneous rocks are represented by the epidote-hornblende schist.

INDIAN SCENARIO OF VMS DEPOSITS

The South-Delhi fold belt has a number of basemetal prospects and deposits of which the Basantgarh multi-metal deposit occurring in the younger division of Delhi Super group (Ajabhgarh Group).

A regional Location map along with details of all basemetal prospects attached in Figure 1.

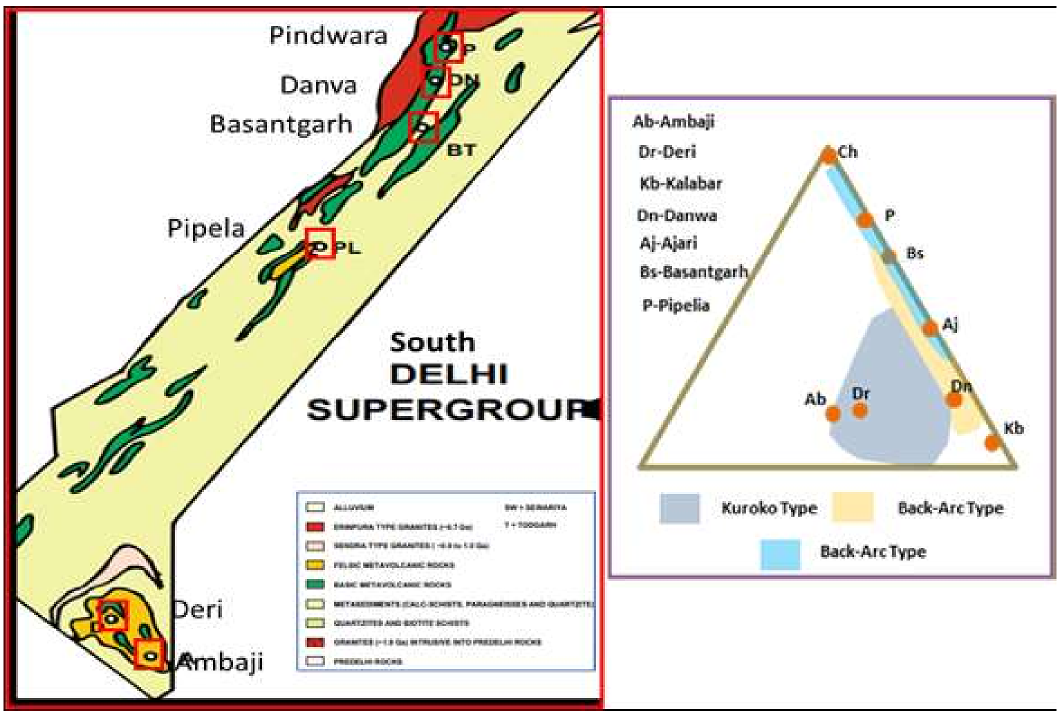

Figure 1: Geological map of Ambaji-Deri-Pindwara area (Modified after Bhattacharjee et al., 1991)

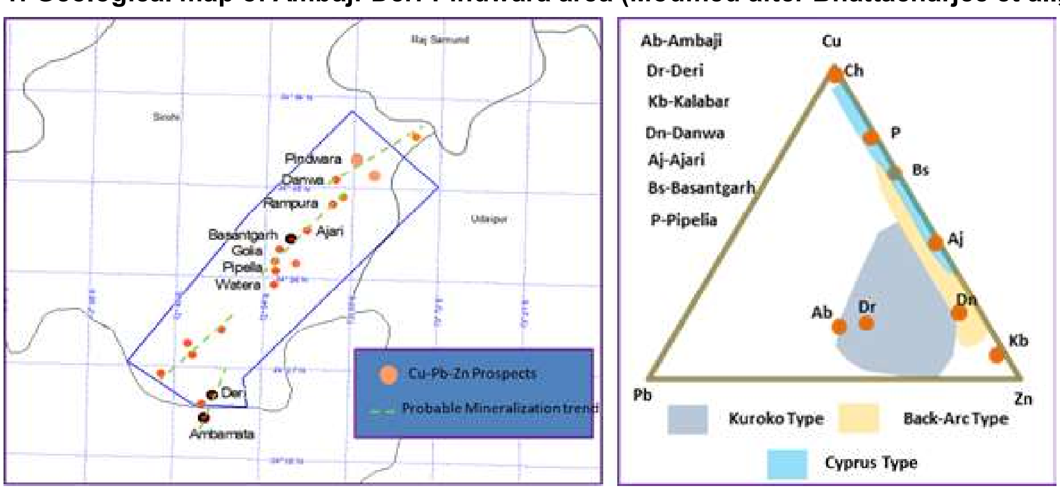

Figure 2: Location of the basemetal prospects and deposits along with Ambaji-Deri-Basantgarh multi-metal deposit occurring within the Delhi Super group rocks.

Table 1: Summary of the estimated reserves and grades of the deposits and the prospects.

Deposit Name	Length (m)	Avg Width (m)	Tonnes (Mt)	Zn (%)	Cu (%)	Pb (%)	Ag (ppm)	Au (ppm)
Kalabar	305	0.17-9.06	1.25	1.25	0.36			
	45		0.19	0.19	0.66			
Chitar	300				1.5			
Birantya-Khurd (North block)	250	1.5 (max)	0.045	10.6	4.6	5.1		
Basantgarh	1150	0.5-12	3.58	1.27	1.74		100	
Pipela	550	0.2-12	1.5	0.5 to 0.7	0.5 to 2.7		5 to 80	
Golia	850	1.4-7.1	1	up to 2.5	0.7-1.4			
Ajari	200	0.5 to 12	0.65	0.57 to 3.3	0.2 to 1.9		20	
Danva	235	1-3.35	0.31	6.42	1.4	0.53	10-110	0.1-14
Deri	1000	8	1	7.32	1.98	4.4		
Ambaji	2140	7 to 12	8.29	5.52	1.75	4.91	2-130	
Source Data: (1) Raghunandan et al (1981); (2) Bhattacharya et al. (1991, 1993); (3) Mukherjee et al. (1992) & Mukherjee & Bhattacharya (1997); (4) Geological Survey of India (1994)								

According to the metal ratios of Zn, Pb and copper, the Ambaji-Deri ore belongs to kuroko type of deposits hosted by bimodal volcanic rocks (Bhattacharjee et al., 1988) while all others are seemed to be Cu-Zn type back arc type and cyprus type. Although many of these prospects are small and/or low grade, the belt continues to attract considerable Exploration interest.

It is generally recognised that, the board tectonic studies of the Ambaji-Deri zone is rift-related while Basantgarh is of Oceanic (Ophiolitic) affinity. Deb and Sarkar (1990), using geochemical characteristics of mafic volcanics suggested that Ambaji-Deri zone represents a back arc set up while lateral zone towards Basantgarh shows an Island Arc affinity.

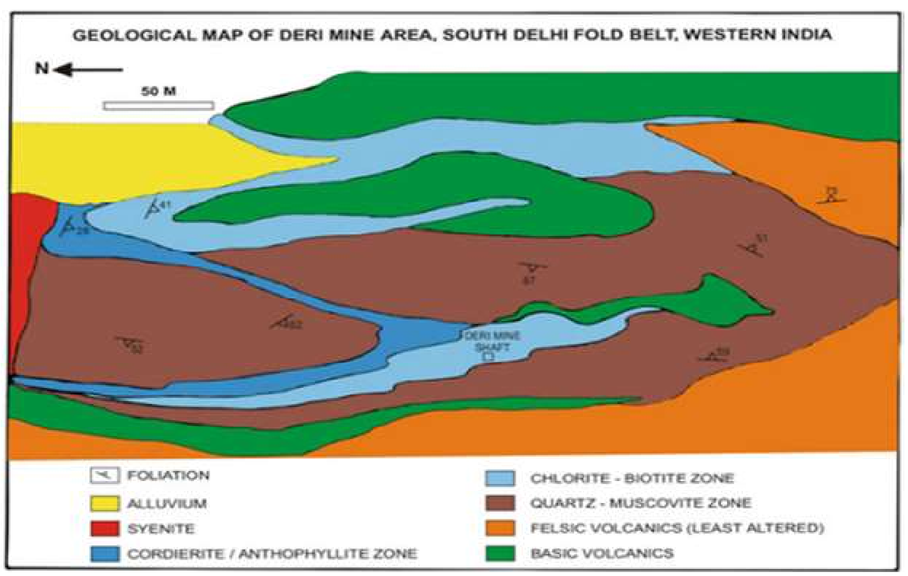

Figure 3: Detailed geological map of the hydro-thermal alteration zones in the Deri VMS (1 Mt @ 6.8% Pb, 9.0% Zn and 1.1% Cu) deposit in the 1 Ga old felsic volcanic dominated volcano-sedimentary sequence in south-western Rajasthan, Western India (Modified after Golani and Narayan 1989).

GEOLOGY OF THE STUDY AREA

The Deri prospect consists of a suite of arenaceous metasediments represented by quartzite, quartz schist and biotite-sericite-quartz schist. They are intruded by concordant bodies of basic igneous rock, which are the products of regional metamorphism represented by mainly epidiorite, hornblende schist and granulite. The talc schist group of rocks are the chief host rock of basemetal mineralisation, occurring as irregular lensoid bodies along the shear zones at the contacts of metasediments, or within the body of the metasediments themselves.

The Rocks encountered in Deri Mines area are quartzite and quartz-biotite-schist. These are enveloped by granite in north-western portion of the area, where the intrusions resulted in the feldspathisation of the Quartzite. These rocks are intruded by amphibolite and hornblende schist, which have been altered to chlorite schist by retrograde metamorphism. The frequent development of talc in chlorite schist has been formed along shear planes. The Talc-chlorite-biotite-schist is generally gossanized. Cordierite dominated in hydrothermal alteration zone are common near Orebody zones at Deri-Ambaji Area (Figure 4).

Chlorite schist forms the host rock for mineralisation. Talc is frequently associated with development of sericite. The rock shows gradation of amphibolite indicating the chlorite schist has been derived from amphibolite by retrograde metamorphism. Amphibolite and hornblende schist contain specks of pyrite and chalcopyrite. At places mineralisation is associated with these rock types as well, and forms the footwall of mineralised zones. Granite is generally very fine grained near the contact with other types and is intrusive in nature. It is frequently mylonitised, becoming coarser away from the contact.

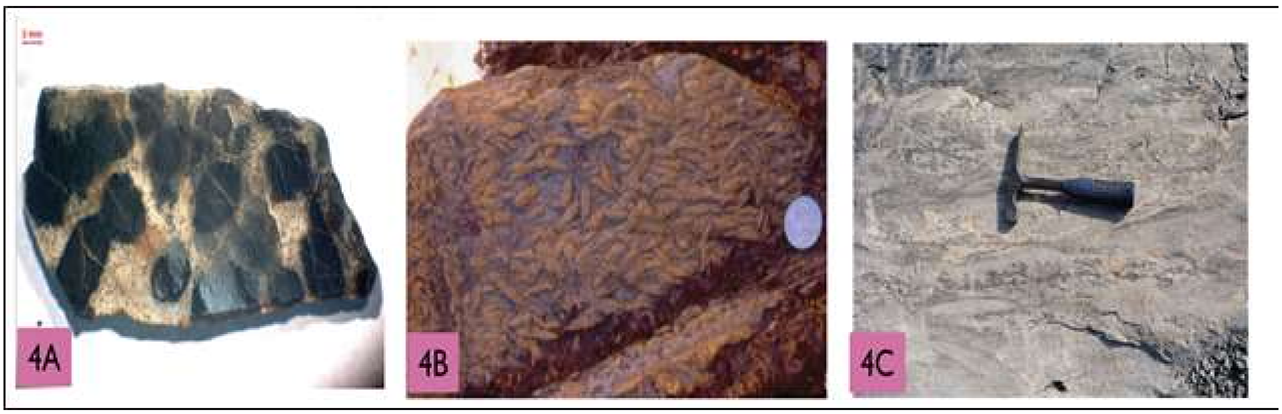

Figure 4: (4A) Cordierite dominated in hydrothermal alteration zones developed in felsic volcanic dominated volcano-sedimentary sequence at Deri Deposit; (4B): Pinnitized cordierite in hydrothermal alteration zones developed in felsic volcanic zone developed in volcano-sedimentary sequence of Deri Deposit; (4C): Cordierite forming greasy irregular patches in freshly exposed alteration zone in Open pit mine at Ambaji VMS deposit.

GENERAL STRUCTURES OF THE STUDY AREA

The Deri prospect forms the part of the eastern limb of doubly plunging syncline plunging at moderate angles towards south-southwest of the prospect. The west-north-west trending formations from the northeastern limb of Ambamata prospect, successively swing towards northwest, north-northwest immediately beyond the Ambamata prospect and extending towards Deri prospect located 3 Km away.

The general trend of the formations at Deri is north-south with a variation up to 20° towards East or West. Dips are generally steep varying from 60° to vertical in either direction.

Several minor folds ranging from a few millimetres to 2m in wavelength are observed within the limb. Shear joints occurs in a series of sub-parallel zones and are well developed in the talc-chlorite group of rocks. Their trend is also roughly north-south, with steep dips either towards west or east. F1 folding is accompanied by the development of two prominent sets of faults and shears. One set trend parallel to the axial plane of the fold and another at an acute angle in north to N20W direction.

REGIONAL MINERALISATION

The manifestations of sulphide mineralisation are evident at surface at Ambaji (Gujarat) and Deri (Rajasthan) in the following forms: -

(a) Presence of oxidation products like malachite and azurite in the debris of the ancient workings and in-situ exposures. These are generally developed in talc-tremolite-schist.

(b) Intense limonitisation in various shapes or colour generally occur in the debris of ancient mining.

(c) Sericitization, kaolinitisation and silicification of the country rocks around the mineralisation at the surface also noticed.

(d) All these are supported by the presence of ancient workings of various shapes and sizes, debris and slag dumps in around the mineralised zones.

The sulphide orebodies occur as replacement zones within the quartz, chlorite-amphibole schist and at the contact of talc-chloride schist.

Pyrite-chalcopyrite occurs at the hanging wall and the foot-wall, while main body containing galena and sphalerite in the centre. The Ore zones are in the shape of elongated funnel with steep dips and plunges.

EXPLORATION HISTORY OF DERI AREA

During the course of mapping, during 1969 DMG located limonitised cap rocks in metamorphosed basic rock near Deri village. Old pits and large slag heaps were also observed in the area which supported ancient mining activity. Samples collected from limonitised gossan gave appreciable values of lead, zinc and copper. This led to preliminary geological mapping and geo-survey of the area.

The detailed geological mapping of 0.50 Sq km on the scale of 1:2000 covering the prospects area was undertaken. This was followed by geophysical and geochemical work. In the Deri prospect, two electro-conductive zones were delineated on talc-sericite-quartz-schist, which is one of the host rock for mineralisation in this area.

Self-potential method was found to be most suitable in Deri area. The values recorded suggested the possibility of 4 parallel to sub-parallel zones confined within a strike length of 340 meters.

GSI completed their exploratory drilling in January 1972 with a total of 2493 meters in 15 drill holes in the western part of the prospect. This drilling was planned to cover close spaced sub-parallel zones in the western part of Deri. The sixth zone located at the eastern margin of the prospect, not completely explored. DMG drilled a total of 3364 meters in 26 surface drill holes. Two boreholes (DDH25 & 28) were abandoned.

The above exploration has confirmed the presence of ore up to a depth of 160m below the surface level (between 130 mRL and 30 mRL). 3D view of orebody and drill holes are shown in figure 5.

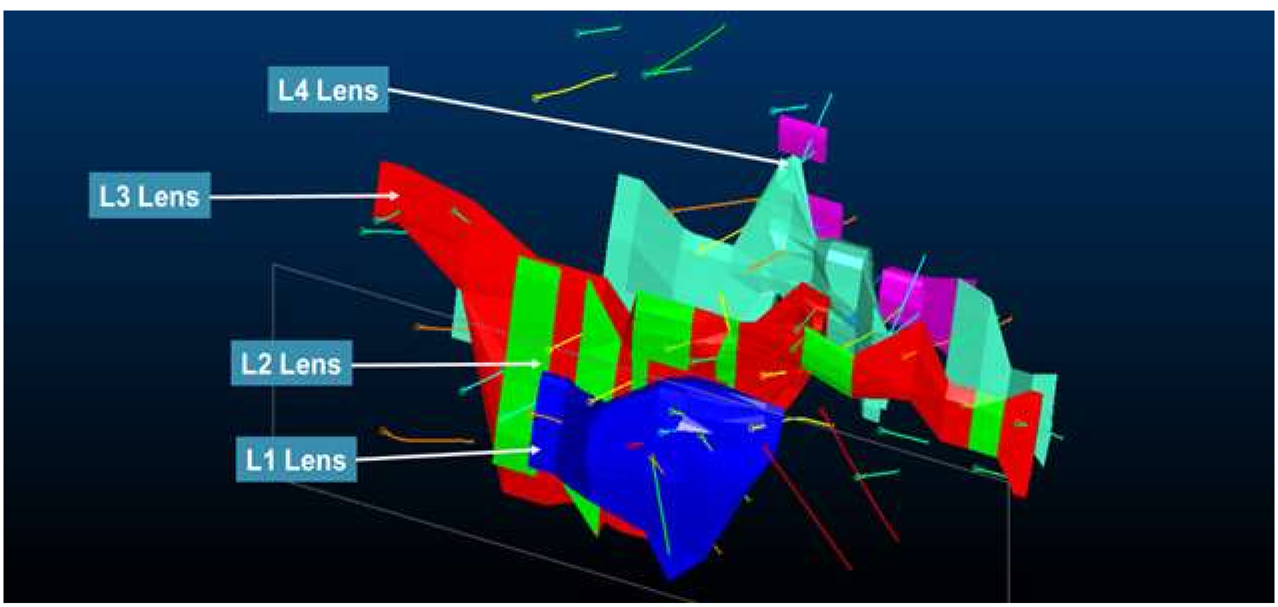

Figure 5: 3D view of Correlated Orebodies (L1, L2, L3 & L4) along with drill holes

GEOLOGICAL MODELLING

Datamine Studio RM®, commercially available geology, and mining software package, was used for creating the geological model, orebody wireframes etc.

(a) **Drill Hole Database**

The database was created in MS Excel, and the output in CSV file format was imported into Datamine Studio RM®. Authors carried out data validation by creating validation queries through Datamine Studio RM. Data validation, and data verification were done to ensure that the database is robust and error-free before using it for estimation. The drill hole database includes the following files–Collar, Lithology, Assay files.

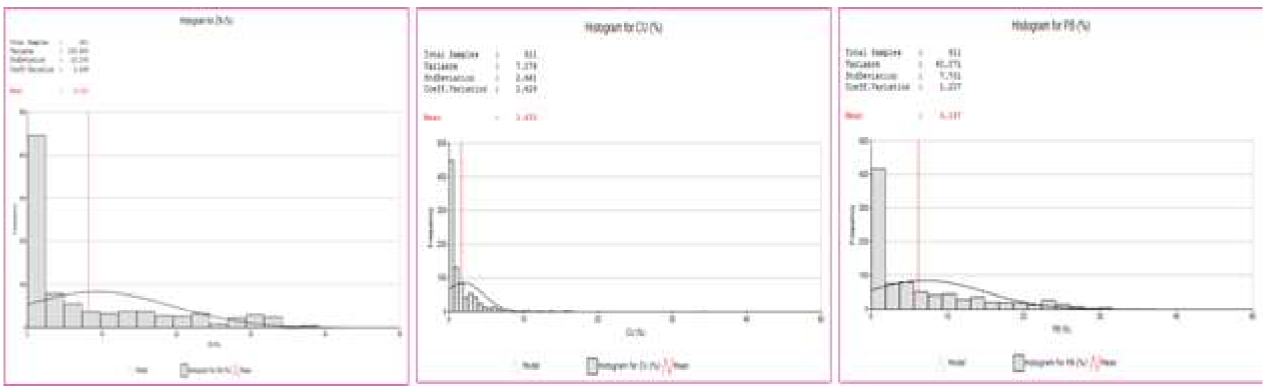

Figure 6: Incremental histogram plot of Deri Orebodies composite drill hole file showing the Mean value and other parameters for Zn (%), Cu (%) & Pb (%).

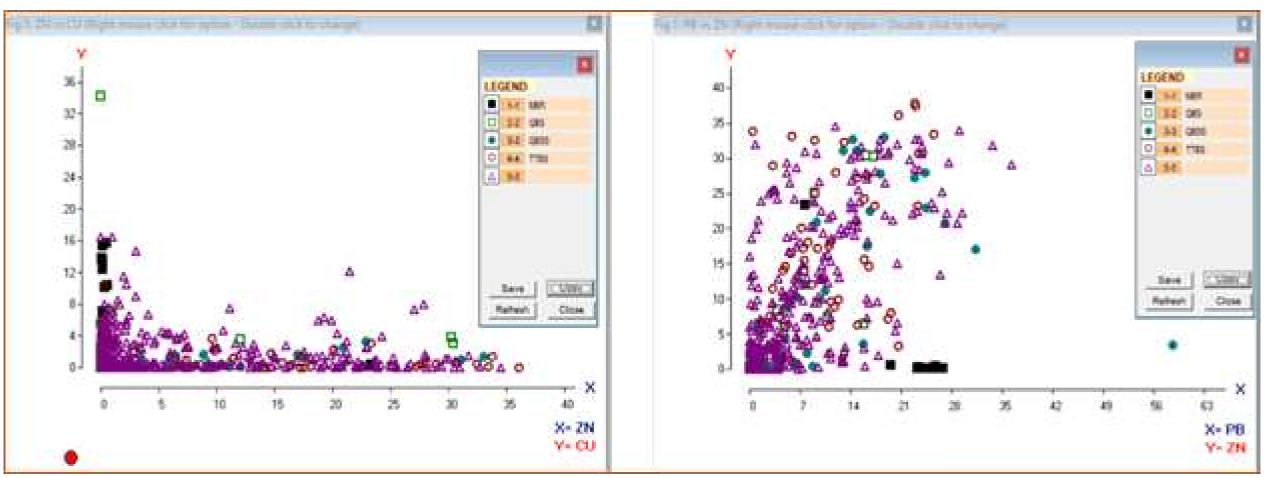

Figure 7: Binary plot of all lens composite drill hole file (MBR: Metamorphosed basic rock, QBS: Quartz biotite Schist, TTBS: Talc-tremolite-biotite-schist, TTQS: Talc-tremolite-quartz schist)

(b) Cut-off Grade

We have decided to prepare the ore envelop at 0.5% Copper Equivalent as it is a polymetallic deposit. 0.5% grade has been devised based on the economic viability and considering the other factors like metal recovery in mining and smelting process and cost of different services. We have considered the price of different metals as per London Metal Exchange value on 28-June-2023.

(c) **3D Geological Orebody Modelling**

A two-dimensional sectional interpretation was carried out using the drill holes information. Sections were created based on drill hole location, at an approximate section line spacing of 50m.

Longitudinal vertical section of both the orebodies has also been prepared (Figure 8). It appeared that there is a depth potential of the Orebody.

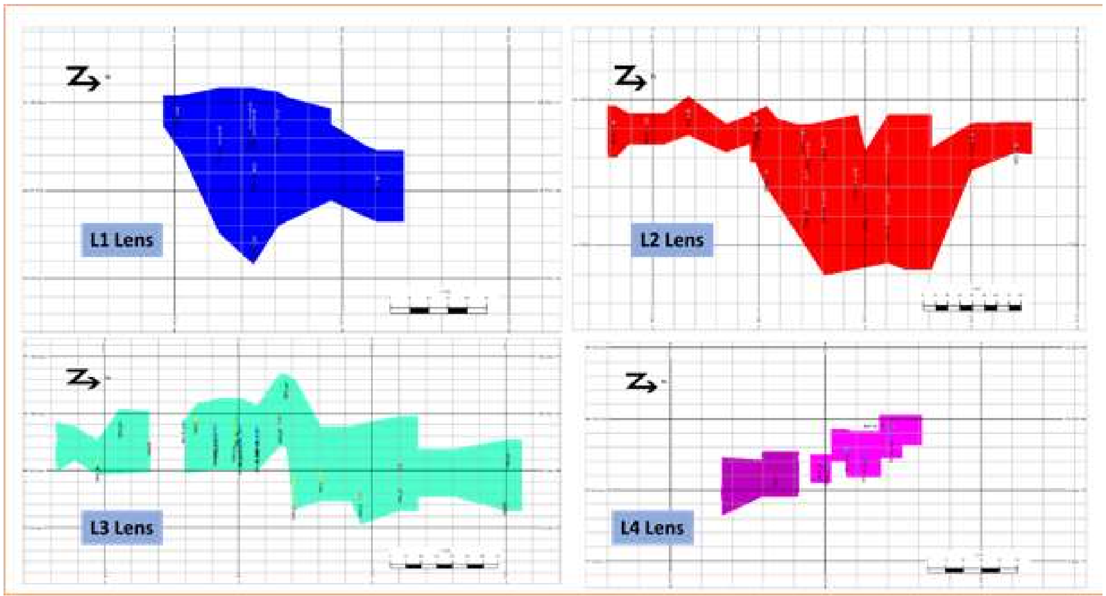

Figure 8: Longitudinal vertical section showing Deri Orebodies (L1, L2, L3 & L4) with historical drill hole intersections.

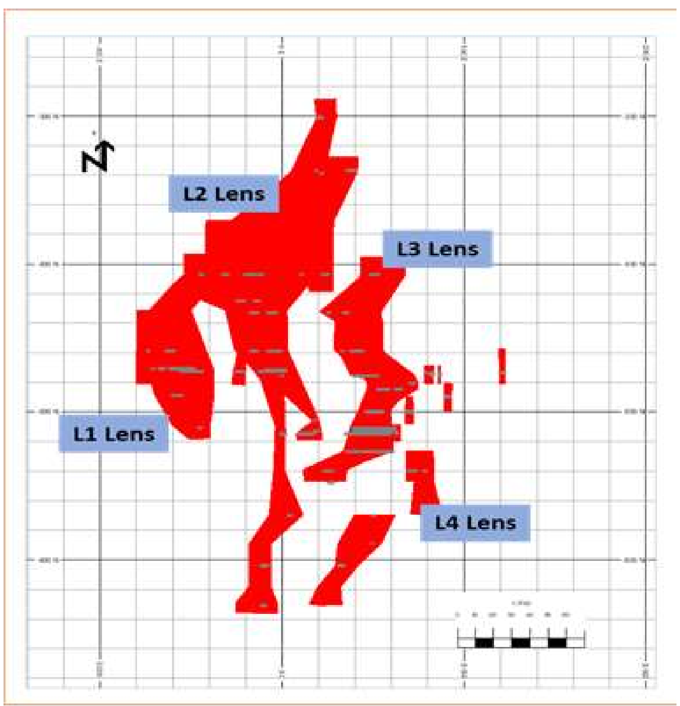

Figure 9: Level plan of Deri Orebodies (L1, L2, L3 and L4) with historical drill hole intersections shown as composite drill hole file in surface plan

EXPLORATION POTENTIAL OF DERI AREA

It can be expected that with directional drilling technology available now, deep seated mineral deposit may be discovered below the existing resources developed through target generation in unexplored area and systematic directional exploration drilling (Figure 10).

Tiwary and Deb (1997) have calculated the alteration fluxes in three distinct alteration facies around Deri deposit and suggested that Mg-Fe-K enrichment and Na depletion can be used as an exploration guide for VMS deposit in the region. Area having mineralisation potential has been highlighted in 3D Geological Ore model (Figure 10). Deep directional drilling technology may be adopted for depth resource delineation.

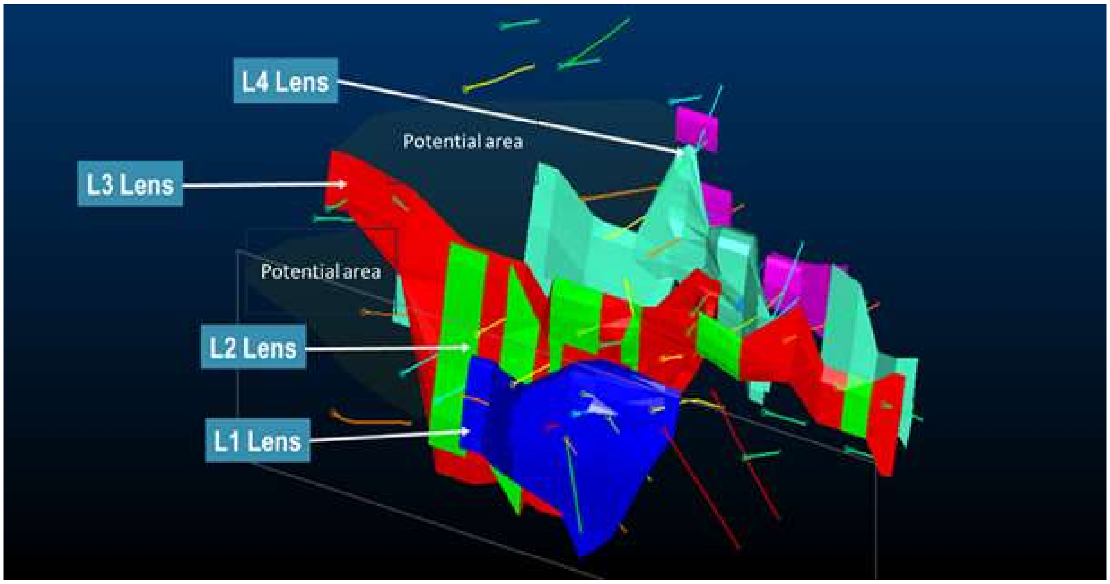

Figure 10: 3D view of Geological Ore model of Deri Mine with historical drill holes (showing existing Lenses & potential resource in dip and strike extension).

CONCLUSION

The South-Delhi fold belt has a number of basemetal prospects and deposits of which the Deri multi-metal deposit occurring in the younger division of Delhi Super group (Ajabgarh Group).

Datamine Studio RM®, was used for creating the wireframes and geological modelling. Drill Hole Database was created in MS Excel and the output in CSV file format was imported into Datamine Studio RM®. Authors carried out data validation by creating validation queries through Datamine Studio RM. Data validation, and data verification were done to ensure that the database is robust and error-free before using it for estimation. The drill hole database includes the following files–Collar, Lithology, Assay, Recovery file.

Cross sections were created based on drill hole location, at an approximate section line spacing of 50m and a two-dimensional sectional interpretation was carried out using the drill holes information. Lithology & orebody correlation were done in different level intervals and have established the litho-structural control of mineralisation in Deri area. The interpretation of the prepared longitudinal vertical section indicates that there is a potential for the orebody to continue in depth. Low resistivity and high chargeability are expected in disseminated type of volcanogenic massive sulphide system.

During formation of VMS deposits in basic volcanic terrains, magnetite is transformed to sulphides that leads to sudden decrease in magnetic susceptibility. Such ground magnetic signatures of sudden lowering of susceptibility have proved to be useful in picking mineralization horizons at basic volcanic-hosted Danva Cu-Zn (Au) in the Mesoproterozoic Delhi Fold Belt in western India (Tiwari et al. 1987). This kind of similar features may be looked into for Exploration target generation of Deri Multi-metal Mines.

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Implementation of Wifi Technology for Communication in Narawapahar Mine

M. Mahali*

ABSTRACT

Mining, a dynamic & intricate operation, demands fast and reliable method of communication from underground mines to surface and vice versa. It is utmost needed for safety and productivity point of view in underground mining. Communication is the activity of transmission of data for the sake of information exchange and majorly required for coordinated teamwork, reliable safety management and efficient operation management in underground mine. However, traditional method of communication i.e wired one is generally used in underground located in strategic places in mines and restricted to voice communication only, a major constraint in dynamic mining operation .

Transmission of data from underground to surface & vice versa consisting of voice , video and real time data requires a reliable medium which could cater speed and transmit huge amount of data , could be achieved through Optical Fiber Network system . This OFC network supports Wi-Fi based equipment's that establish Wi Fi coverage zone and implementation of this prototype will make communication in underground as similar to surface.

Narwapahar Mine, Uranium Corporation Of India Limited has taken a step towards implementation of digitalization by establishing wireless communication network system in underground mine that provides voice communication , visualization , monitoring of gases as well as tracking& tagging of manpower & vehicles and it contributes towards building a rapid communicable ,efficient operation and hazard-free working environment in underground mines.

INTRODUCTION TO WIRELESS COMMUNICATION NETWORK

Wireless Communication network system in Narwapahar Mine is based on Wi-Fi Technology which provides seamless mobile communication in the underground mine. For the sake of Wi-Fi zone with 100% coverage in underground mine and surface of Narwapahar , Wi-Fi Access points that act as antenna are installed at various location in order to transmit and receive signals from wireless mobile handsets and signals to Wi-Fi Access Points are fed by communication server installed in control room . More importantly Transmission of data between Wi-Fi Access Points and communication server is occurring on account of establishment of OFC network from surface to underground mine . For clear understanding of Wi Fi Network, shown pictorial view in fig 1.

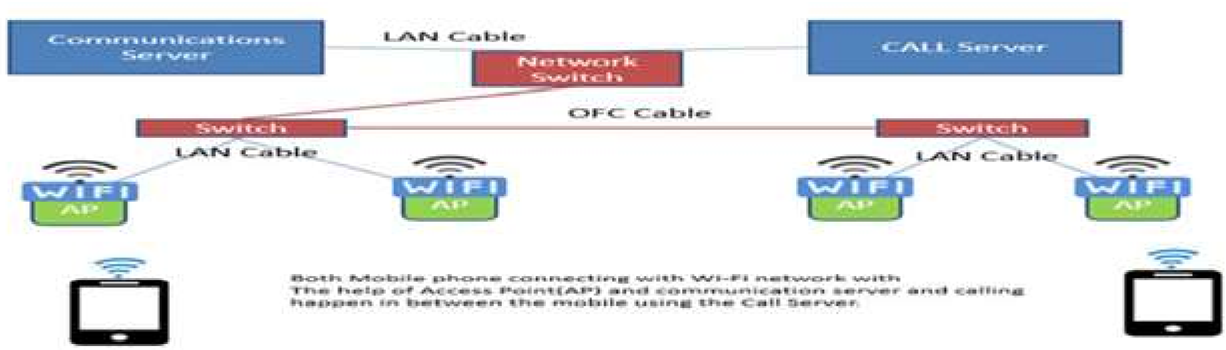

Fig. 01

**DGM (Mines)/Agent, Narwapahr Mines (UCIL)*

In addition to providing Voice communication between wireless handsets in underground mine and surface, establishment of optical fiber network has extended data transmission from tracking & tagging system,gas monitoring system and IP based camera installed at different location to control room where respective servers are installed .

SYSTEM ARCHITECTURE

Establishment of Wi Fi based technology in underground mine has to be architected so that following integrated safety and communication solution could be achieved.

i) Voice Communication through mobile handset
ii) Gas Monitoring System
iii) RFID based tagging & tracking system for employee and vehicle
iv) IP based CCTV camera
v) Control Room

Owing to the advantages of quick and convenient wireless access , easiness of manage and maintain , Wi- Fi based technology is effective in underground mine and it is mainly consisted of Wireless Access Points (AP) , Mobile Handsets , Network switch , IP based camera and OFC network . OFC network is laid from surface to underground through shaft and returned back from 8th level to control room . That means a ring type optical fibre network has been established so that even being cut at a single point , communication will remain in existence.

OFC cable from shaft is distributed to each level i.e 140mL, 185mL, 230mL, 275 mL& 315mL and covering each level stretch of approx. 2 KM . These cable has been terminated in network panels which is mounted on every 200 meters (approx.) and further through Ethernet cable, points such as (Access points , CCTV Camera , Tag Reader) are connected in the field. However each units of access points has limitation of wifi coverage of 80 meter, so installed at regular interval of 160 meter throughout the drift zone and also covered ramp up area too of Narwapahar Mine.

All the Wi fi equipment installed in it are compatible with unfavorable condition of U/G mine because of being robust design and complying with IP 67 .As it is IP based equipment , so its installation and maintenance is easy as well as from control room fault configuration could be done .This makes extension of Wi Fi Coverage zone to extreme area of mine much simpler and less labor oriented . A picture of integration of Access Point, RFID Tags, RFID reader , Mobile handsets , OFC network and network panels is shown in fig 2

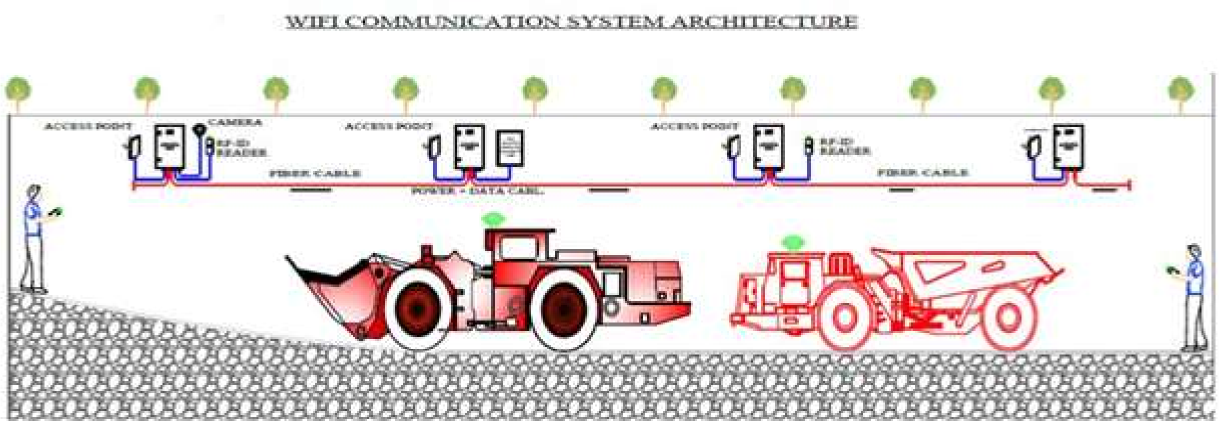

Fig. 02

VOICE COMMUNICATION THROUGH MOBILE HANDSETS

Wi-Fi-based technology enables mobile communication between mobile headsets within the mine, the control room to the mine, and vice versa. Mobile handsets used by persons working in duplex mode with the backbone network of OFC connected to access points (Antenna) through Ethernet switches are shown in fig 2. This network is looped in and out with a communication server in the control room, which is incorporated with Network Monitoring System, which monitors the access point's status, OFC network, and voice communication. Considering harsh environment of underground mine such as dusty, moisture level of 96% , noisy , equipment used in mine as fixed installation have IP67 protection and in case of mobile handset , it has robust design with feature of noise suppression and echo cancellation in addition to IP68 .

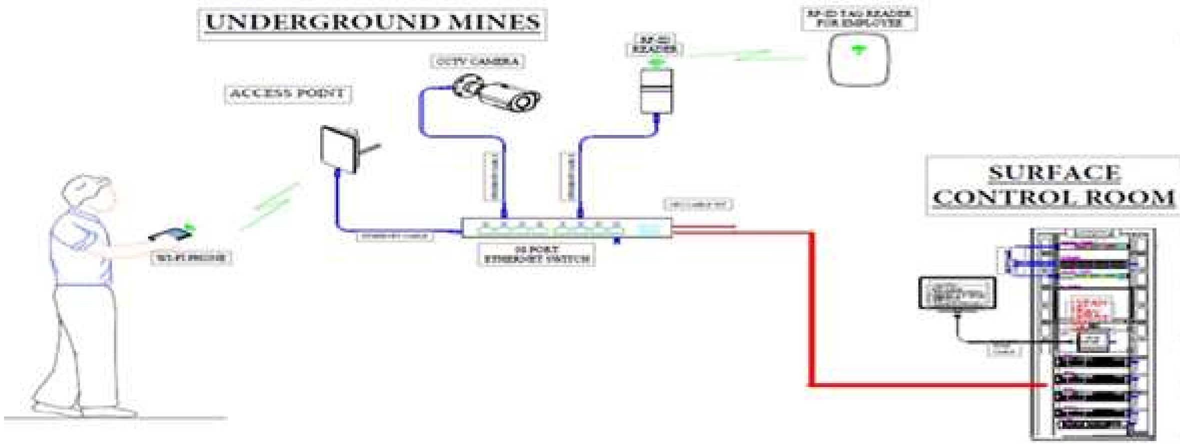

Fig.03

a) Wi Fi Mobile Handset

Wi-Fi phone used in this system is Motorola EVOLVE, which has following multimedia features

- PTT (Push to talk) Voice Communication
- Full Duplex voice Communication
- Group Calling
- Video Calling
- Task Message
- Call Alert
- Emergency

b) Wi Fi Access Points

Wi-Fi Access Points is a Radio modem with an inbuilt Omni Antenna and powered on with PoE. This modem supports dual Wi Fi band of 2.4GHz and 5GHz, it complies to 802.11ac wave 2 with security like WPA2 (802.11i), WPA2 Enterprise (802.1x/EAP), WPA PSK and having the fast roaming features for seamless communication of the support mobile phone. The coverage range of each point is 80 meters, so installed at regular intervals of 80 meters in underground levels for seamless voice communication. Underground mines AP Installation shown in fig-04

c) Network Panel

Network panel is consisted of 8 port Ethernet switch, Optical LIU Box and power supply unit of 110VAC which provide the connection of access points with OFC network It is installed at regular interval of 200 meters to extend the OFC network connection to field equipment.

d) IP based Voice Server (IP PBX) with wireless gateway

A telecommunication device provides voice connectivity to a Wi-Fi Mobile handset within the Wi-Fi zone established by installed access points. This facilitates persons inside the mine to dial the contact numbers of other people at remote locations through their handsets.

Fig. 04

GAS MONITORING SYSTEM

Continuous gas monitoring of Noxious gas through gas sensors installed at various location in underground and data of sensors is transmitted to gas monitoring server through OFC network system which generate Audio/Visual alarm and capable to keep historical data of three months in the server . Gas sensor of following gas has been installed in this mines

a) CO b) NOx c) Sox d)Rn . Connection of sensor with the OFC network in the field is as shown in fig -05 .

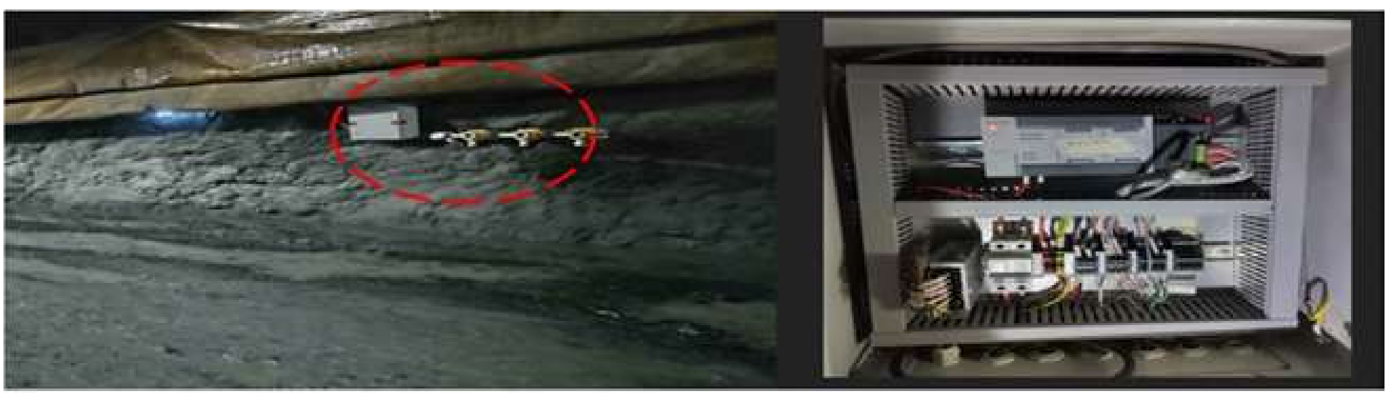

Fig. 05

RFID BASED TAGGING & TRACKING SYSTEM FOR EMPLOYEE AND VEHICLE

RFID based tagging & tracking system is wireless system comprised of hardware and software component. The hardware architecture is consisted of RFID Tag, RFID Reader and server. RFID Tag readers are fixed at certain location in the underground mine for tracking of vehicle & miners. RFID tag for vehicle installed in the underground vehicle and tag for miners are carried by them by fitting in their belt, powered by vehicle battery and dedicated charger respectively. Software architecture is consisted of computer based GUI software to locate vehicles and employee as well as communication between tagging & tracking server and hardware components through OFC network.

The software generate the report having following details with exact location i.e. No of vehicles inside and outside the mine, Lap Count, No of person in inside and outside of mine. Software provide information of tag details i.e. battery, status and extension of configuration setting of tags as well as of tag readers from control room. Picture of installed tag on vehicle and tag carried by employee is shown in fig -06

Vehicle Tag installed in Red mark area

Person Tag

Fig. 06

IP BASED CCTV CAMERA

Network based IP camera is installed at the grizzly, substation and other critical installation inside the mine for area surveillance. This provides keeping eye on employee activity deployed in critical areas such as crusher , underground conveyor . Each IP based camera is 2 MP Bullet type , HD resolution 1920X1080 , frame rate ; 25 and 30 frame/sec , 60 mtr IR , sensor type : 1/ 2.8 inch CMOS , IP67 . It can be easily mounted easily on side wall of underground mine providing clear video on control room .All these BOSCH make camera are connected to NVR having capacity of 32channels and recording storage of 48TB which could keep video record back up of upto 45 days.

CONTROL ROOM

Control room have server for each system i.e NMS , Gas Monitoring system ,Call server for WIFI Calling Tagging & tracking system and NVR For CCTV camera with dedicated monitoring screen on control desk . It provide to monitor the activities inside the mine by visualizing through CCTV camera , voice communication , Gas monitoring system and finally tracking the movement of employee as well as vehicle.Configuration of equipments installed in mines can be done from the control room , avoiding unnecessary dismantling and installing of it . The daily report generation regarding no of persons available in mine , lap count of ore arrying vehicle dumped in grizzly , location details of equipment and employee could be achieved from control room which support in taking decision on improving day to day operation activities.

BENEFITS OF WI- FI BASED TECHNOLOGY

i) Instant voice communication and text messaging from the surface as well as mines via Wi-Fi mobile handsets, making feel like being on surface.

ii) Direct mobile communication is also possible from underground mobile handset to registered mobile number saved in SIP contacts upto 200Numbers

iii) Provision for one to one communication as well as group communication

iv) Easy Installation in new areas of mine: Simply by extending the OFC network, Wi-Fi zone coverage could be attained in new / extremely far located area of mine.

v) Location of each trapped miner can be accurately determined resulting in successful search and rescue operations

vi) Real time gas monitoring can be done at the active working fronts as well as enabling concerned supervisors to take on spot decisions

vii) Breakdown downtime can be reduced by forwarding actual photo / videos from underground site to concerned maintenance person for rectification .

viii) CCTV camera input in control room for real time monitoring of critical areas like crusher, grizzly, shaft, garage area, sump etc.

ix) Daily report generation of Lap Counting of ore carrying mine truck in underground dumping in grizzly, No of vehicle deployed, no of persons in u/g etc.

x) This Wi Fi based technology could be integrated with leaky feeder system so that coverage range could be extended Upto stope area.

CONCLUSION

Communication is indispensable part of underground mines in view of safety, operation and productivity .Integrating safety and communication in Wi Fi based communication technology with incorporation of OFC network system is fulfilling all the criteria of being platform to carry out more efficiently, effectively and safely mine operation in Narwapahar.

Regression Analysis Approach on Fibre-Reinforced Expansive Soil Using Direct Shear Test

Harshita Bairagi* Dr. B. K. Mishra**

ABSTRACT

The Regression analysis considers the uncertainties associated with design input parameters and implements those uncertainties on the output response. In the research paper, the performance of the system is examined by the reliability index. The analysis provides a mathematical equation for treating uncertainty and rationality to take the right decision. Using the regression index, the decision can be made whether the system performance in a given uncertain environment is acceptable or not. It is one of the statistical methods used to prepare a mathematical model between dependent and independent variables. The paper aims to prepare mathematical models between the geotechnical properties of lime-treated expansive soil as a dependent variable and fibre length and dosage as independent variables. Highly clayey Black cotton soil is used as an expansive soil. The regression method examines the influence of independent variables on dependent variables. Data obtained from the laboratory results were incorporated with the Linear regression program to obtain reliability index values.

In the deterministic approach, the uncertainties associated with soil performance are not considered; hence, the difference increased the soil's actual and calculated performance. This will lead to a reduced soil reliability level and an increased safety factor. The cost of any construction work is directly proportional to the factor of safety. For some important projects, this may extend more than three also. It will increase the construction cost multiple times. The main reason for increasing the safety factor is the uncertain behaviour of soil with different conditions. Once we achieve the uncertainty model of soil, it will be easy to reduce the safety factor to a certain extent and will ensure the project's success with minimal investment.

In the paper, shear strength is used as dependent variables and fibre length (6mm and 12mm) and dosage (0.2%, 0.35%, 0.65%, 0.8% ,1.02 and 1.25%) are used as some independent variables to prepare the mathematical models. Shear strength is the impact scale on which presence of different fibre length and dosages are evaluated.

Keywords: Regression analysis, fibre reinforcement, shear strength.

INTRODUCTION

Black cotton soil is a type of expansive soil spread mainly across interior Gujarat, Maharashtra, Karnataka and Madhya Pradesh on the Deccan lava and Malwa Plateau. For this study, the soil has been collected from Amanora Township Pune, India, at 3 metres depth, characterized as Highly clayey Black cotton soil. The paper aims to fix the optimum percentage of polypropylene fibre in terms of length and dosages to get the maximum possible improvement in the lime-treated black cotton soil in terms of shear strength by the regression analysis approach.

The unique properties of expansion soil arise from swelling clay minerals, mainly montmorillonite, which undergo significant expansion and contraction during wetting and drying. This process leads to the formation of broad and deep cracks, which can be as large as 0.07 m wide and over 1 m deep and can extend up to 3m or more in the case of high deposits. [Adeniji, F.A 1991] During the dry season, surface material accumulates in these cracks, and during the wet season, it is absorbed by the soil, creating a "self-mixing" or "self-mulching" effect. [Bei-xiao Shi, Cheng-feng Zheng and Jin-kun 2014].

It is critical to understand the behaviour of black cotton soil in geotechnical engineering design and construction point of view, especially in regions where they are predominant. The expansive nature of these soils can cause significant structural damage and failure, resulting in economic losses and in severe cases, loss of life. Therefore, accurate and reliable methods for assessing the properties and behaviour of these soils are essential for ensuring the safety and success of geotechnical engineering projects in such areas. To tackle this challenge, probability theory offers a mathematical tool

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to formally include such uncertainties in engineering design and assess their implications on performance, thereby increasing the reliability of design and construction methods and evaluating the costs and benefits of proposed design strategies. [Yisa, G. L. and Sani, J. E. 2014].

Stabilization of soft soils using hydrated lime, cement, fly ash, and rice husk ash is a common and effective process by mixing soil in situ. The properties of stabilized soil have improved by a chemical reaction between the mineral present in the stabilizer or by increasing the cohesion between soil particles and stabilizer. The stabilizer's presence in the soil makes the soil more brittle, which causes a sudden drawdown in the strength of the soil at the time of failure. It may cause severe damage to the structures. These stabilizers improve the compressive strength of soil up to a certain level, but there is no significant change in the tensile strength. This is a major issue in the summer season when soils are expected to resist the tensile stresses. [Sobhan, K. 2008] A common and most efficient method to improve the tensile strength of any construction material is providing reinforcement. Using randomly reinforced fibre improves the tensile strength isotropy in all directions. The use of fibres are cost-effective, eco-friendly and require minimal machinery. Several fibres (natural and synthetic) with specific properties are in the market for fibre reinforcements. However, natural fibres (jute and coir etc.) are not durable. The durability of natural fibres can be improved by chemical coating, which will protect them from biological degradation. Due to certain drawbacks use of natural fibres in foundations are suitable only for shallow foundations. [Babu, G. L. S., and Vasudevan, A. K. 2008], [Anggraini, V., Asadi, A., Huat, B. B. K., and Nahazanan, H. 2015], [Qu, J., & Zhao, D. 2016]

LITERATURE REVIEW

Several studies have presented the improvement in the geotechnical properties of soil using fibres and other stabilizers by different probabilistic approaches. Some of the studies are presented here.

Moghal et al. (2016) evaluated the hydraulic conductivity behaviour of fibre-reinforced soil in their study. They specifically investigated the effect of lime and randomly oriented polypropylene fibres on the hydraulic conductivity behaviour of expansive soil. Based on the pH response of the soil, the lime dosage was kept constant at 6%. The study looked at how different kinds fibres (fibre cast and fibre mesh), fibre doses (0.2%, 0.4%, and 0.6% by weight of soil), and fibre lengths (6 mm and 12 mm) affected hydraulic conductivity behaviour. The hydraulic conductivity of treated expanding soil and the dosage and length of randomly oriented polypropylene fibres were correlated using statistical analysis. Consequently, two exponential best-fit equations based on the dosage and length of the two types of polypropylene fibres were presented to predict the hydraulic conductivity of treated expansive soils. Furthermore, a reliability analysis was conducted to determine the viability of the modified expansive soils for waste containment in Municipal Solid Waste (MSW) landfills. This investigation aimed to determine the treated soil's efficiency in preventing pollutant leakage from the landfill. [Moghal Arif Ali Baig Basha B. Munwar & Chittoori Bhaskar 2016].

Moghal et al. (2016) contributed to the increasing research on using same fibres for expansive soil stabilization in their study. Because of its importance in analysing pavement effectiveness, the California Bearing Ratio (CBR) was chosen as a performance metric. The study looked into a number of variables, including fibre length, fibre quantity, and curing period. There were both deterministic and probabilistic (reliability) assessments performed. The deterministic analysis sought insights from the observed experimental data, whereas the probabilistic approach considered the data's stochastic character, offering a more reasonable foundation for design processes. According to the deterministic analysis, higher fibre contents and longer fibre lengths resulted in higher CBR values, especially when lime was used as a stabilizer. However, notice some exceptions to this pattern, which were thoroughly examined. According to the probability study, the amount and length of fibres were key determinants impacting CBR strength. Furthermore, it was discovered that changing the target CBR value significantly impacted optimizing the length and dosages of fibres employed in the stabilization process. [Moghal, A. A. B., Chittoori, B. and Basha, B. M. 2017a].

Moghal et al. (2017) presented the same fibres in conjunction with lime stabilization as a promising method for treating shrink-swell distress in expansive soils in their article. The researchers tested one-dimensional fixed ring Oedometer swell-consolidation and bar linear shrinkage on two types of synthetic fibres, Fibre Cast (FC) and Fibre

Mesh (FM). With and without lime treatments, several dosages (0.2%, 0.4%, and 0.6% by weight of soil) and two different fibre lengths (6 mm and 12 mm) were examined. The results showed that in the absence of lime treatment, FC fibres performed better in controlling oedema; however, in the presence of lime, both fibre types performed similarly in lowering swelling. Furthermore, shrinkage tests demonstrated that, regardless of dosage level, both FC and FM fibres significantly reduced linear shrinkage stresses when given lime treatment. Non-linear best-fit index (Cr) of expansive clay deposits with and without lime treatment and the amount and dose of FC and FM reinforcements. These equations provided a more efficient method of recognizing patterns in the experimental data and more accurately predicting the compression indices (Cc and Cr). Overall, the study demonstrated the potential of employing synthetic fibres with lime stabilization to reduce swell and shrinkage in expansive soils. The proposed non-linear equations improved the understanding and prediction of treated soil compression behaviour. [Arif Ali Baig Moghal, Bhaskar C. S. Chittoori, B. Munwar Basha & Ahmed M. Al-Mahbashi 2017].

Moghal et al. (2017) investigated the effectiveness of fibre cast (FC) and fibre mesh (FM) (6mm and 12mm length) in lime-treated expansive soil using target reliability analysis. The investigation used the unconfined compressive strength of stabilized soil as an improvement scale. The effect of changes in length (6mm and 12mm), amounts (0.2, 0.4, and 0.6% by weight of dry soil) and curing periods (0, 7, 28, 60, 120, 180, and 360 days) on the unconfined compressive strength and secant modulus of expansive semi-arid soil in the presence of lime was studied. The study calculates the optimal percentage of reinforcement for achieving the desired UCS value of lime-treated expansive soil. UCS as a response variable can be predicted using fibre types. It has also been determined that the Target Reliability approach may be successfully employed in expansive soil to establish the ideal percentage of fibres in terms of length and doses. [Moghal Arif Ali Baig, Basha B. Munwar & Chittoori Bhaskar 2017]
Nguyen et al. (2016) investigated the failure mechanism of fibre-reinforced cement-treated expansive soil. It has been determined that plastic deformation occurs when the mean effective yield stress exceeds the mean starting yield stress and the cementation bonds disintegrate. A pullout or fracture from the soil matrix causes the failure of the fibre. It was determined that at higher stresses, after cementation deterioration and fibre pullout, the failure envelope of reinforced soil is the same as that of unreinforced soil. The research suggested a constitutive model based on Critical State Soil Mechanics and the Modified Cam Clay model simulate the behaviour of cement-treated-fibre reinforced soil. The cementation and fibre-reinforcing effects in the model were included. [Nguyen Lam, Fatahi Behzad and Khabbaz Hadi 2016]
Compared to untreated soil, cement-treated soil has enhanced brittleness due to adding cement. Brittleness is undesirable because it causes a sharp decrease in strength to a residual level. [Lorenzo & Bergado, 2006]
According to Tang et al. (2007), fibre reinforcing improves load transfer from the soil-cement matrix to the fibre. As a result, the fibres build linkages between the soil-cement clusters. [Tang, C. S., Shi, B., Gao, W., Chen, F., and Cai, Y. 2007].

Sani J. E. (2014) used a dependability approach to evaluate the stability of bagasse ash and cement kiln dust-treated expansive soil. They acquired data on the unconfined compressive strength test through laboratory tests, which they subsequently used to construct a predictive model. This model was implemented in a FORTRAN-based first-order reliability programme to determine the reliability index value. The variables considered in the study were optimum water content, hydraulic modulus, bagasse ash and cement kiln dust content, tri-calcium silicate and di-calcium silicate proportions and maximum dry density. However, it was discovered that these factors did not produce an appropriate safety index value of 1.0.t and effectively acted as bridges, inhibiting the propagation of subsequent cracks inside the sample. [Sani J. E., Bello A. O. & Nwadiogbu, C. P. 2014].

Miyata et al. (2012) analyse the accuracy of two geogrid pullout capacity models routinely used in Japan: these models, dubbed Model 1 and Model 2, forecast pullout capabilities in geogrid-reinforced soil barriers. When project-specific laboratory pullout testing data is missing, Model 1 is utilized by default, but Model 2 is used when such data is available. The researchers compare the measured pullout capabilities from a massive database of laboratory experiments to the projected values to determine the correctness of the models. To quantify the accuracy, bias statistics are used, with bias defined as the ratio of measured pullout capacity to projected value. These bias data are critical in calibrating reliability-based load and resistance factor design for the ultimate pullout limit state in geogrid-reinforced soil wall internal stability design. According to the model analysis, model 2 yields highly accurate pullout predictions with minimum scatter. Model 1 is demonstrated, on average, to be too cautious, with a large scatter in the bias values that vary depending on the magnitude of the estimated pullout capacity. To increase Model 1's accuracy, the researchers propose a new formulation with the same empirical coefficients as the existing expression (i.e., two). The updated formulation improves accuracy, as demonstrated by the computed mean and coefficient of variation of the bias values, and also eliminates the many biases present in the current model. Based on a review of all available pullout data, the researchers advocate an acceptable stress design (ASD) factor of 2 when utilizing the present Public Work Research Centre default Model 1. A factor of safety of 1.25 is advised when using Model 2 with project-specific pullout testing. These recommendations are intended to help practitioners build geogrid-reinforced soil walls. [Miyata Y, Bathurst RJ 2012].

MATERIAL AND METHODS

Soil has been collected from Amanora Township Pune (including GPS location) India at 3 metres depth. Particle size distribution curves (figure no. 1) are given below:

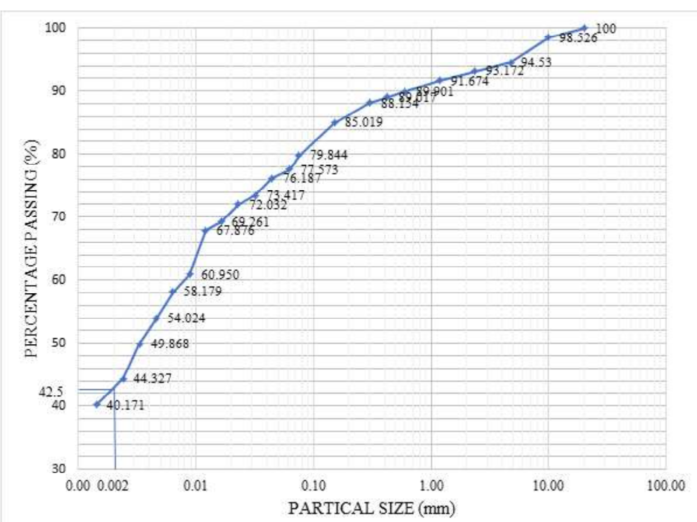


Fig. No. 1: Logarithmic graph for particle size Analysis

The physical properties of soil are given in Table 1, which summarizes the Percentage of Clay (C), Average Particle size D_{10}, Coefficient of Uniformity, Coefficient of Curvature, Atterberg limits, sieve analysis soil classification, hydrometer tests, free swell index and specific gravity.

Table 1: Physical Properties of Soil

Physical properties of soil		
1.	Percentage of Clay (C)	42.500
2.	Average Particle size D_{10}	0.0013
3.	Coefficient of Uniformity	0.0128
4.	Coefficient of Curvature	6.667
5.	IS soil classification	CH group
6.	Liquid limit	79.776
7.	Plastic limit	37.820
8.	Plasticity Index	41.956
9.	Shrinkage limit	19.192
10.	Free swell Index	65.15
11.	Specific Gravity	2.36

Polypropylene fibre has been used for the study. The properties of the fibres are given in table no. 2.

Table No. 2: Physical properties of polypropylene fibre

Physical properties of polypropylene fibre		
1.	Density (g/cc)	1.47
2.	Average Diameter (μ)	30-40
3.	Average Length (mm)	6mm and 12mm.
4.	Construction	Fibrillated
5.	Melting Point	165°C
6.	Absorption	Nil
7.	Acid Resistance	High
8.	Alkali Resistance	Full
9.	Dispersibility	Very Good
10	Salt Resistance	High
11	Thermal Conductivity	Low
12	Specific Gravity	0.92 g/cc
13	Tenacity	Low
14	Aspect Ratio	171 (6 mm), 342 (12 mm)

In the Indian Standard soil classification system, the soil is classified as highly plastic clay (CH). As the soil is highly plastic clay, initially, the soil is stabilized by hydrated lime. "A Quick Test to Determine Lime Requirements for Lime Stabilization" by James L. Eades and Ralph E. Grim is conducted to determine the percentage of lime. The amount of 4.5 % lime on the dry weight of soil is finalized according to the test. Polypropylene fibre with 6mm and 12mm lengths is used with the lime-treated soil purchased from Daffodils Floats Private Limited Pune. The properties of fibres are mentioned in table 2.

DIRECT SHEAR BOX TEST

Direct Shear box test determines the shear strength for the soil under controlled compaction conditions in the laboratory. For the study of shear strength, shear box apparatus is used to perform the shear strength test. This test is can be performed with undisturbed or remoulded soil. For the study remoulded sample is used for the testing. Soil sample is compacted with optimum moisture content and the size of the mould is obtained using cutter provided with the direct shear box apparatus. A normal load applied on the sample and allow to shear in predetermined failure plane between the two halves of the sample box. Measurement of the shear load, normal load and shear displacement are recorded within a certain interval till the shear displacement reached up to 20% of the initial position or till the failure of the sample (whichever occurs first). The test is repeated with the identical specimen under the different normal loading. Data of each test provide a mohr's circle. The common tangent of all the Mohr's circles called the failure plane. Cohesion and angle of internal friction is calculated by the failure plane. The procedure used for the test is followed by the Indian Standard Code IS: 11229-19857.

Figure No. 1 shows the experimental set up of the Shear Box test apparatus.

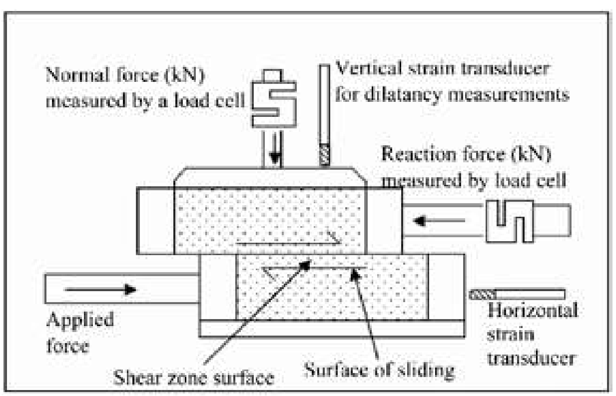


Figure No. 1: Shear Box Test Apparatus

ANALYSIS OF TEST RESULT

The effect of fibre length and dosages on the shear strength of the lime-treated expansive soil has been studied in this research. The length, 6mm and 12mm and dosages, 0.2, 0.35, 0.65, 0.8,1.02 and 1.25 % by weight of the dry soil are used in lime-treated expansive soil (4.5 % of lime by the dry weight of soil). There are multiple sets of samples are prepared with the same fraction of fibre and soil to validate the results. The final results are considered by averaging of the results with the same proportions.

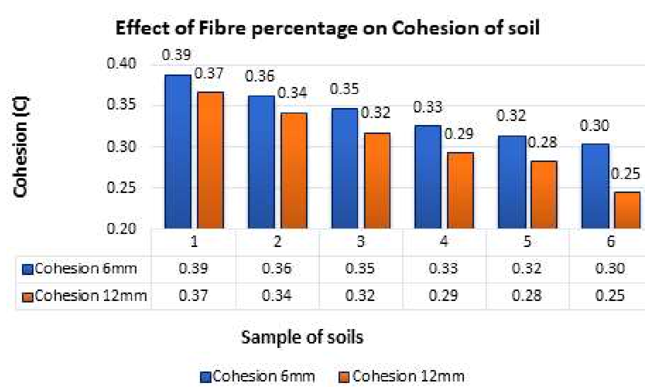
- **Effect of Fibre Content**

Form the graph No. 2 this can be observed that by increasing the dosages of 6 mm. polypropylene fibre from 0.2 % to 1.25 % the Cohesion value varies from .39 to .3 for Direct shear box test and for12 mm polypropylene fibre, the cohesion value varies from .37 to .25 for Direct shear box test.

Graph No. 3 show the influence of fibre dosages in the angle of internal friction. From the graphs it can be observed that, in case of 6 mm polypropylene fibre the dosages increased from 0.2 % to 1.25 %, the angle of internal friction increased from 23.82 to 28.54 for Direct shear box test. By the same time the value of angle of internal friction increases from 25.12 to 30.56 for using 12 mm polypropylene fibre.

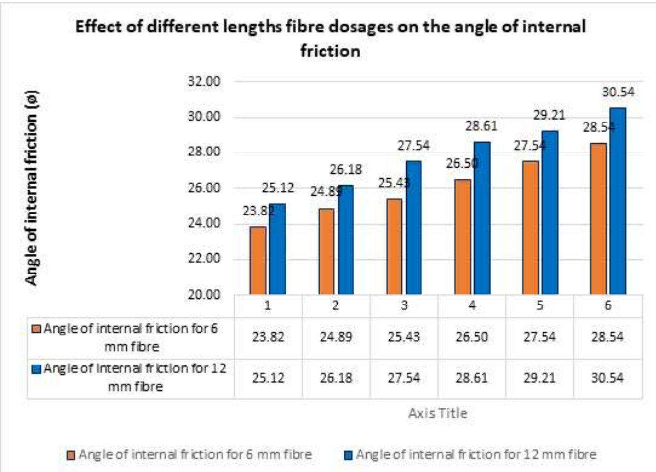
- **Effect of Fibre Length**

The evaluation in the fibre length can be predicted by the observing the 6mm and 12 mm polypropylene fibre behaviour in shear box test results. By looking the results, it can be observed that cohesion value of 6mm fibre is comparatively more than cohesion value of 12 mm fibre length for the same amounts of dosages. The angle of internal friction for the same amount of fibre 6 mm fibre attains less than the 12 mm fibre length. The smaller length of fibre mixes more uniformly compared to the bigger length of fibre and affect the cohesion and angle of internal friction value.



	1	2	3	4	5	6
Cohesion 6mm	0.39	0.36	0.35	0.33	0.32	0.30
Cohesion 12mm	0.37	0.34	0.32	0.29	0.28	0.25

Fig. No.2: Effect of Fibre percentage on Cohesion of soil



	1	2	3	4	5	6
Angle of internal friction for 6 mm fibre	23.82	24.89	25.43	26.50	27.54	28.54
Angle of internal friction for 12 mm fibre	25.12	26.18	27.54	28.61	29.21	30.54

Fig. No. 3: Effect of different lengths fibre dosages on the angle of internal friction

- **Effect of lime**

By the addition of 4.5 % lime the cohesion of soil slightly decreased by 0.398 to 0.392 and the angle of internal friction increased from 21.76 to 22.59. The lime combines with the soil and creates both mechanical and chemical stabilisation. The lime treated soil addition with the fibre increase the shear strength as well as the tensile strength of soil.

DEVELOPMENT OF REGRESSION ANALYSIS

Regression method is most common method to make a relation between the dependent and independent variable. In the present study multiple linear regression method is applied to the experimental data. The variable being described is known as dependent variable. It is continuous in nature and the variable is used to describe is known as independent variable. In the study the fibre dosages and lengths are independent variable and the shear strength of the stabilised soil are the dependent variable. The value of shear strength of soil are depending of the fibre lengths and dosages. The equation for the multiple linear regression comes in the form of

$$y = \alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + \text{——} e$$

Here the y is independent variable and the $x_{1,}$ x_2 — are the dependent variable. $\alpha_{0,}$ $\alpha_{1,}$ α_2 — are the regression coefficient and e are the standard error. Regression coefficient is the value which shows the impact of dependent variable to the independent variable.

There are some assumptions in regression analysis are follows:

1 Errors are random.

2 Errors are normally distributed.

3 The variance of the errors is constant.

4 There is no auto corrections in the errors. [Moghal, A. A. B., Chittoori, B., Basha, B. M. and Al-Shamrani, M. A. 2017b]

- **Linear regression for Direct shear box test**

The equation for Cohesion value (C) obtained by linear regression analysis of the study when direct shear test is performed with shear box apparatus equipment is given by

$C = (-0.00008103)\ x_1 + (-0.1371538)\ x_2 + 1.66178$

$R^2 = 0.8175$

The equation for angle of internal friction (ø) obtained by linear regression analysis of the study when direct shear test is performed with shear box apparatus equipment is given by

$ø = (-0.00008103)\ x_1 + (-0.1371538)\ x_2 + 1.66178$

$R^2 = 0.8175$

SUMMARY AND CONCLUSION

In the study polypropylene fibre of 6mm and 12 mm polypropylene fibre is used with lime treated highly clayey soil and established the model between the effect of fibre length and dosage on the direct shear test results (shear strength of soil). The model shows satisfactory results which has been checked with the observations.

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Ore to Insight: Cognecto's 360° Platform in Mining Operations

Vidya Sagar Singh*

INTRODUCTION

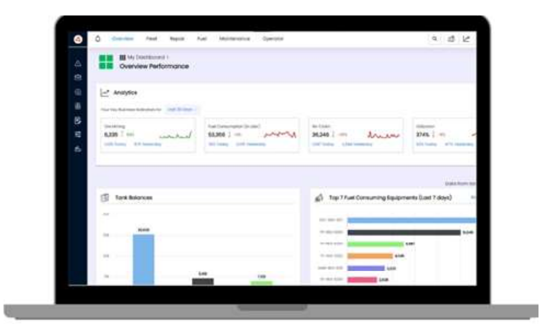
Cognecto, a trailblazer in cutting-edge solutions, stands at the forefront of transforming Mining through its comprehensive view of essential Business Key Performance Indicators (KPIs) and operational parameters. Specializing in providing a 360° perspective, Cognecto's platform seamlessly integrates sensor-based and non-sensor-based data, offering a robust collection of information. From Ore Production to Material Transport, Fuel Consumption to Maintenance Schedule, our solution brings a new dimension to operational efficiency.

VERSATILITY IN DATA INTEGRATION

What sets Cognecto apart is its versatility in data integration. Our platform amalgamates both sensor-based and non-sensor-based data, ensuring a comprehensive and accurate representation of your operations. This approach allows us to capture nuanced insights, enhancing the precision of information related to critical aspects such as Ore Production, Material Transport, Fuel Consumption, and Maintenance Schedule.

HOLISTIC OPERATIONAL INSIGHTS

Our platform is designed to provide a holistic perspective on crucial operational aspects. Cognecto goes beyond traditional silos, offering a unified view of your business's key performance metrics. Whether you are tracking the efficiency of Ore Production or optimizing Material Transport logistics, our platform empowers you with actionable insights to drive operational excellence.



FLEXIBILITY AND ACCESSIBILITY

Cognecto understands the importance of flexibility and accessibility in today's dynamic business environment. Our solution is seamlessly accessible through both mobile and web-based platforms, providing real-time insights at your fingertips. This ensures that you have the flexibility to monitor and manage your operations anytime, anywhere, facilitating quick and informed decision-making.

USER-CENTRIC APPROACH

Cognecto's commitment to user-centric design is reflected in the simplicity and efficiency of our platform. Whether you are a mining professional, an operations manager, or a logistics expert, our solution is designed with your needs in mind. The platform's user-friendly interface ensures a seamless experience, making it easy for users to navigate and derive meaningful insights.

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GLOBAL IMPACT AND FUTURE ENDEAVORS

Cognecto's impact extends globally, providing transformative solutions across industries. As we continue our journey, we aim to further enhance our platform's capabilities. Future endeavors include refining our sensor technologies, expanding our OCR-based identification features, and exploring new avenues for operational optimization. Cognecto remains dedicated to staying at the forefront of innovation and pushing the boundaries of what's possible in operational excellence.

In a world where operational efficiency is paramount, Cognecto emerges as a key player, offering a holistic and innovative solution for businesses seeking a comprehensive view of their operations. From leveraging cutting-edge sensor technologies to introducing QR/OCR-based identification, our platform is built to empower businesses with actionable insights and drive operational excellence.