THE INDIAN MINING & ENGINEERING JOURNAL

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

www.theimejournal.com

VOLUME 60: Number 10-11 **OCTOBER-NOVEMBER 2021** ISSN 0019-5944

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

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17-18 th December 2021,
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The Indian Mining & Engineering Journal, Vol. 60, No.10-11, October-November 2021, pp.03-09
Printed in India, @ IME Publications, ISSN 0019-5944

Diamond Processing with Sustainable Water Management

Anurag Kumar Sahu*

ABSTRACT

The processing of precious, rarely available diamonds is unique and special in the world. In India, diamonds are produced from kimberlite tuff that occurs as a primary deposit (kimberlite pipe) at Majhgawan Mines in Panna District, Madhya Pradesh, having an average incidence of 9.5 CPHT (carat per hundred tons).In order to process Kimberlite ore without losing diamond in the mechanized methods,a Plant designed with a capacity of treatment of 8.0 Lakh Tons Kimberlite ore per annum is installed in the Panna Diamond mines.Heavy media separation, one of the most reliable and robust gravity separation techniques, issued for density separation of heavy from light ore of coarse size fraction. Being Asia's only mechanized mines, Majhgawan mines are operated with sustainable water management by maintaining the plant operation with zero discharge.

This technical paper aims to provide basic information involved in extracting diamond from Kimberlite ore and ensuing environment-friendly sustainable water management system.

Figure 1: Panna Diamond Mines

INTRODUCTION

The kimberlite pipe at Majhgawan is the only diamond-producing primary rock source in the country. It is located in the Majhgawan village, 20 km south west of the Panna district of Madhya Pradesh. NMDC Ltd has set up a fully mechanized mine and a processing plant with associated services at Panna Diamond Mines. This project has adopted an open cast mining methodology for the production of Kimberlite ore.

The excavated kimberlite ore from the mine pit is transported to the processing plant through Dumpers for feeding at Hopper and further processing. The processing plant is designed to treat 8 lakh Tons of Kimberlite ore annually. The entire plant operations are monitored under a surveillance system for optimum utilization and to ensure cover security and safety aspects during the plant operation. In addition, all the electrical installations are also monitored through a PLC control system.

*AGM(Mech) NMDC Ltd

Figure 2: Panna Processing Plant

The final product derived is rough diamonds consisting of three categories, namely –

1. Gem variety
2. Off-color variety
3. Dark brown or Industrial variety

The Diamond produced from the plant is classified, weighed, evaluated, and finally put for selling through e-auction at Majhgawan and Surat.

PROCESSING OF DIAMOND

The Processing plant's primary function at Diamond Mining Project ranges from eliminating all the waste material from ROM Kimberlite Ore to producing the final Diamond concentrate for manual picking of diamonds. Basically, it is a reduction process that provides the ROM feed materials in the proper size and acceptable to the Dense Media Separation plant for further effective separation. It is also noted that for every 100T material fed to the plant from mining, approximately 1-1.5% of the material is derived as concentrate diamond-bearing material, which is again fed to the X-ray section for fine separation of diamonds from the rest of the material.

The processing plant mainly comprises four vital functional units, i.e.

1. Crushing
2. Heavy media separation (HMS)
3. Concentrate Reduction Circuit (CRC)
4. X-ray Unit

All the units are designed to perform specific activities to yield the desired results.

CRUSHING SECTION

Kimberlite ore is fed to the ROM grizzly (400mm x 400mm size aperture), and the under-sized material is passed through the apron feeder for feed control. The ROM further passes over fixed grizzly to tap -80mm size material before feeding to jaw crusher. The +80mm size materials are fed to the Jaw crusher and get reduced to -80 mm at the rate of 130T/hr. All resized -80 mm material will be thrown down to conveying system for further processing.

Figure 3: Crushing Plant

The crushed product is reported through a launder to Double Deck Vibrating Screen on a 900 mm Nylon Conveyor belt to separate the material size and properly wash the adhered fine material on the ore (top deck upper size 20mm and bottom deck 1.2mm). Subsequently, +20 mm size material is conveyed to a secondary crusher where a four feet size hydraulic cone crusher reduces the material size to -20 mm and conveys back to the Double Deck Vibrating Screen in a closed circuit.

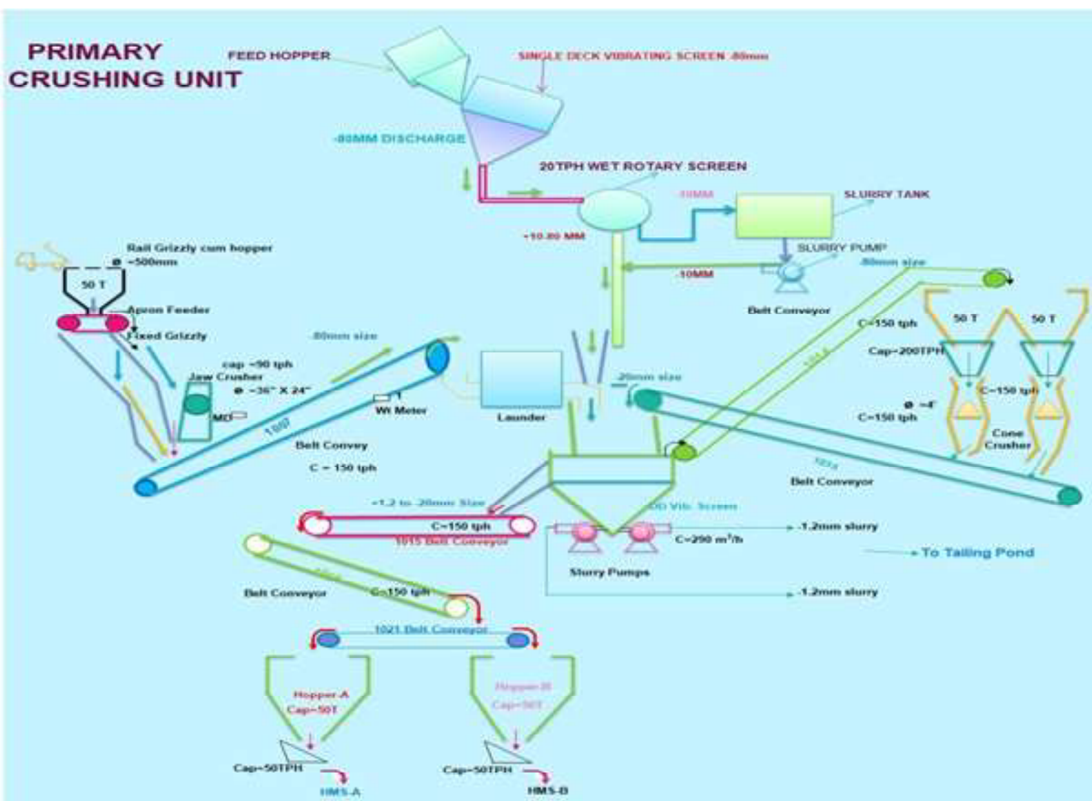

Figure 4: Crushing Section Flow sheet

The yield from the Double deck screen, +1.2mm and -20mm kimberlite material, is transported to Heavy Media Separation Bins through the conveying system, the feed material to the Heavy Media Separator. The discharge from the Bottom deck screen (-1.2 mm material)is regarded as waste as it is economically not viable for treatment to recover micro diamonds. Therefore, this tailing is pumped to the tailings pond at a distance of 700 meters through 200mm diameter HDPE pipeline for further recovery of water for reuse in the plant.

HEAVY MEDIA SEPARATION SECTION

The material sizes of -20 mm and +1.2 mm are fed to the Heavy Media separation plant, consisting of two modules of 50T capacity each. The sized gravels report to the feed preparation screen, where it enters into the mixing box. The Ferrosilicon slurry with the pulp density of 2.6 to 2.7 kg/liters is added to the de-slimed feed (- 20mm to +1.2 mm) materials in the mixing box. The washed underflow material of size -1.2mm are considered rejects as fine tailing and pumped to the tailings pond through an effluent pump.

Figure 5: Heavy Media Separation Plant

The process pulp density of 2.6-2.7 Kg/liters is maintained for better separation of non-diamond material, which normally has a density of less than 3.1 g/cm^3. The mixture of ferrosilicon and kimberlite material Slurry is pumped to 400mm diameter Heavy Media Cyclone at a 100K Pa pressure to produce a cyclonic effect. The Hydro cyclone executes a gravity separation of the feed at a slightly higher density than the medium, while the lower density material reporting to the cyclone overflow (floats) and the higher density material is discharged to cyclone underflow (sinks). The float screen overflow material is discarded as coarse tailings. It is observed that 98-99% of the feed material is rejected as light (coarse tailings) through overflow, and 1-1.5% feed material is reported as concentrate through underflow, which passes on sink screen, respectively. The coarse tailing is transported through a conveyor and discharged outside the plant area and sink screen concentrate is conveyed to Concentrate Reduction Circuit (CRC) through tube feeders for further separation.

In order to recover ferrosilicon media from the process, high-pressure water washing is being carried out both in float and sink screens, and part diluted quantity is collected in a tank for further intensifying the density through the densifying cyclone. The remaining washed off ferrosilicon slurry from the float, and sink screen are collected in the circulating media tank. The collected dilute media is again pumped to densifying Cyclone for effective separation. The ferrosilicon being highly magnetic, the overflow pulp from densifying Cyclone is then passed through a Drum magnetic separator which holds most of the ferrosilicon media and directly discharged to the circulating media tank. In the underflow, approx. half of the material is passed through the Magnetic separator and is then directed to the circulating media tank. The remaining 50% is added back to the dilute media circuit.

Ferrosilicon recovered from the magnetic separator is collected in the circulating media tank to utilize again for making the desired density of mixtures. It is a well-known fact that almost 98% of ferrosilicon will be recovered in this process. The Average Water Consumption in two HMS modules is 3500 M^3/Day.

CONCENTRATE REDUCTION CIRCUIT

In the CRC (Concentrate Reduction Circuit) section, the concentrate is passed through a rotary dryer for eliminating the moisture. The dried concentrate is transported through a pocket conveyer and triple deck screens for size separation. Diamond bearing heavy concentrate is divided into four size fractions, i.e., 10mm, 5mm, 2.4mm, and -2.4mm and then collected in a storage bin of each 7 Tons capacity.

The segregated concentrate is passed through the Perm Roll Magnetic separator, where the non- magnetic material (diamond-bearing concentrate) splits from magnetic material in a batch-wise process. Each size fraction is subjected to a double pass Permanent Rolling Magnetic drum for separating the magnetic and non-magnetic material. The Magnetic material considered as unwanted is rejected in coarse tailings conveying system and

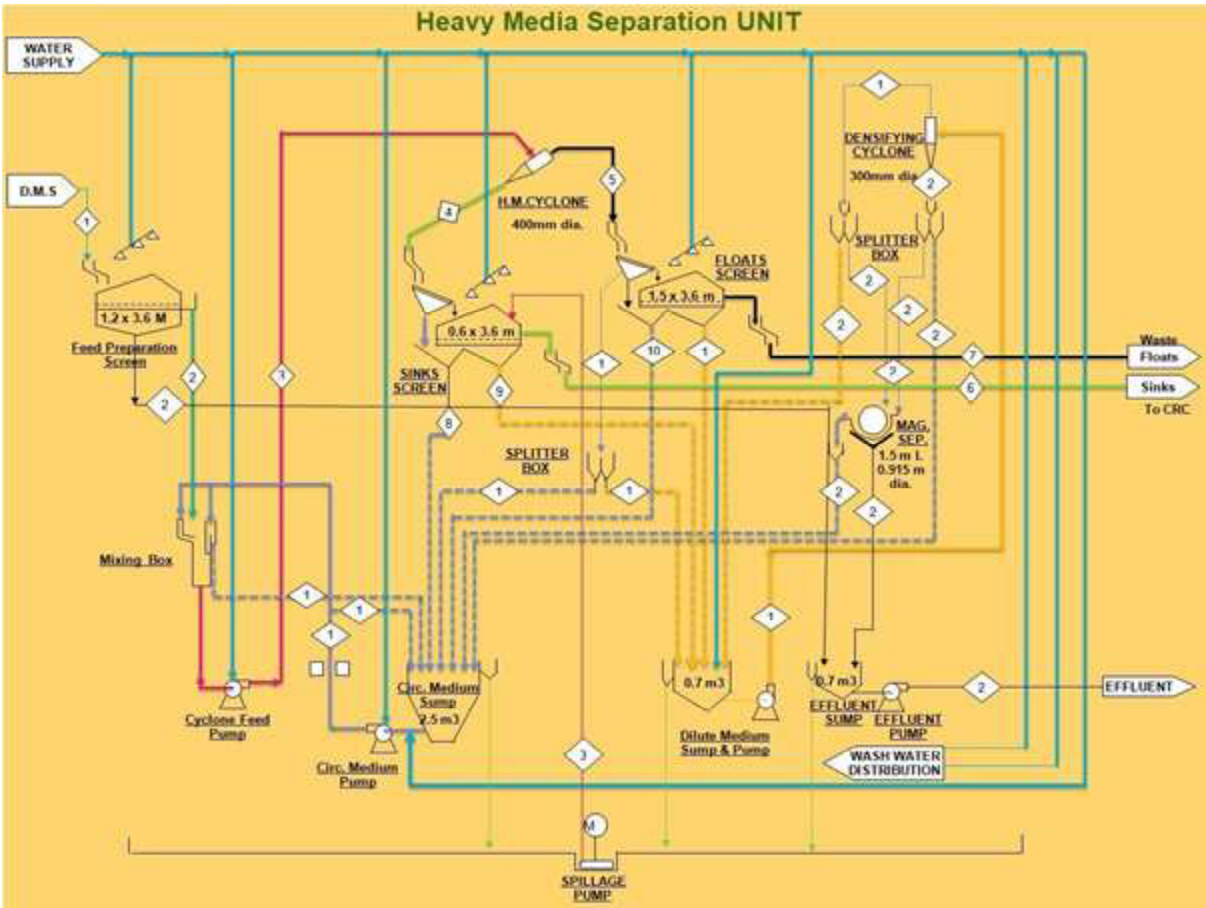

Figure 6: HMS plant flow sheet

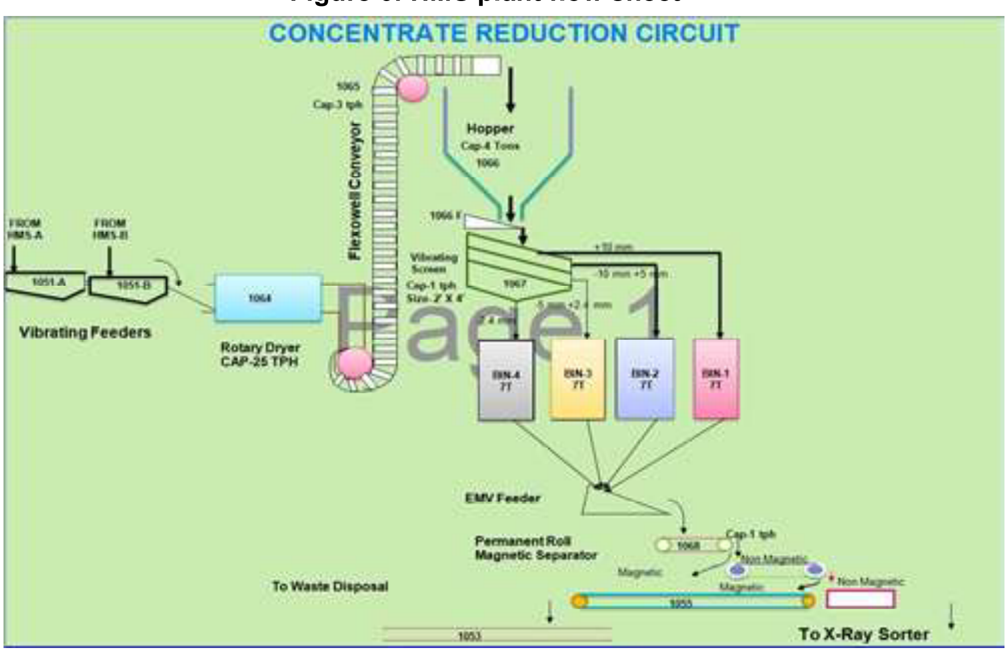

Figure 7: CRC plant flowsheet

discharged outside the plant location. The non-magnetic concentrate is diamond-bearing material, which becomes a feed material for the next stage operation,i.e., X-ray sorting.

X-RAY SECTION

The non-magnetic material size fraction (+1.2mm to –2.4mm), (+2.4mm to -5mm), (+5mm to -10mm), and +10mm to -20mm (Diamond bearing concentrate) is passed through a two-stage X-ray sorting machine to recover diamonds.

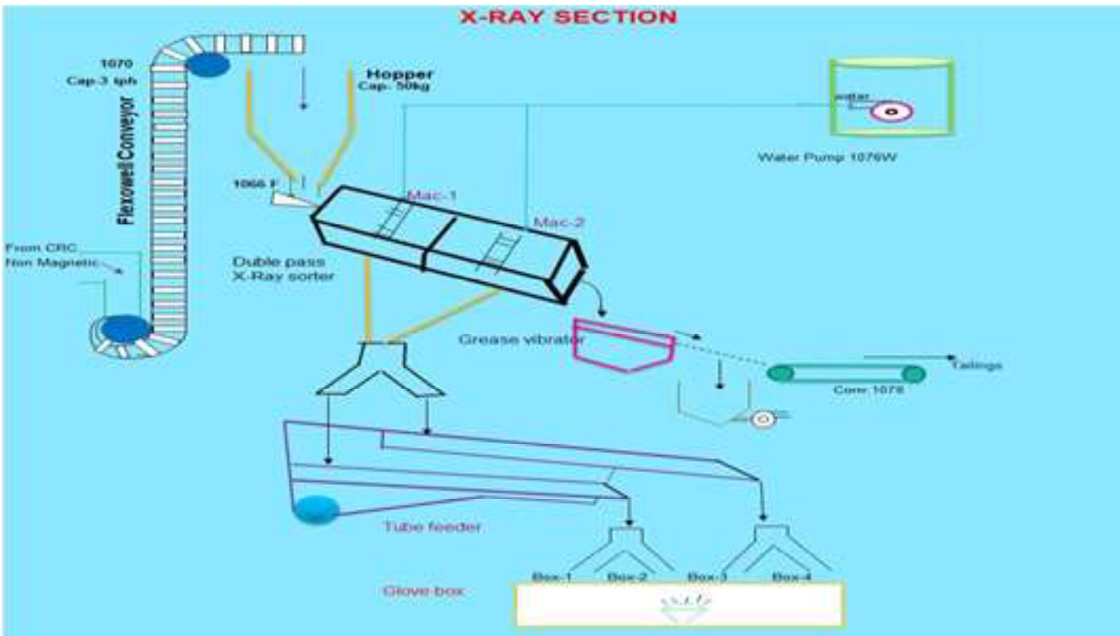

Figure 8: X-Ray flowsheet

In this stage of operation, the concentrated material of each size fraction is individually fed to the X-Ray sorting machine of 1-3 TPH capacity. The basic concept of the operation of the X-ray sorting machine is to utilize the fact that diamond is fluorescence and phosphorescence when exposed to X-ray radiations. The diamonds are separated at the detecting zone, where it gets exposed to X-rays. Light emitted from diamonds that have been excited by X-ray is detected and converted into electrical signals. The visible blue light emitted by diamonds is detected by Photo Multiplier tubes and triggers a mechanical ejection gate where diamond along with some surrounding material physically separated from the rest of the materials and conveyed to the glove box through a vibrating tube feeder.

The Diamond concentrates (from X-Ray and Grease table) collected in glove boxes are hand- picked by Diamond Classifier and then is sent to the picking yard for grading. The rest of the material is passed through the Grease table to ensure that no single diamond escapes from the process. DB grease, special purpose grease that is hydrophobic in nature (water repellent), retains diamonds in the grease. The other material is considered as X-ray tailing and is reported to the conveyor system for further discharge to the outside area.

SUSTAINABLE WATER MANAGEMENT SYSTEM AT PROCESSING PLANT

The processing plant is designed to process the kimberlite material under wet conditions to ensure the plant's dust-free operation and proper washing of Kimberlite ore to eliminate waste. Excluding the primary crushing operation, all other plant equipment's needs a huge amount of water for washing material and exclusion of the material of size -1.2mm from plant system, i.e., -1.2mm material is collected from both crushing and heavy media plant and further discharged to tailing dam through slurry pumps. In addition, water is required in dense media plants to bring ferrosilicon powder in slurry form to produce a pulp density of 2.6 to 2.7 g/cm3 and mix with kimberlite ore of size fraction +1.2mm to -20mm.

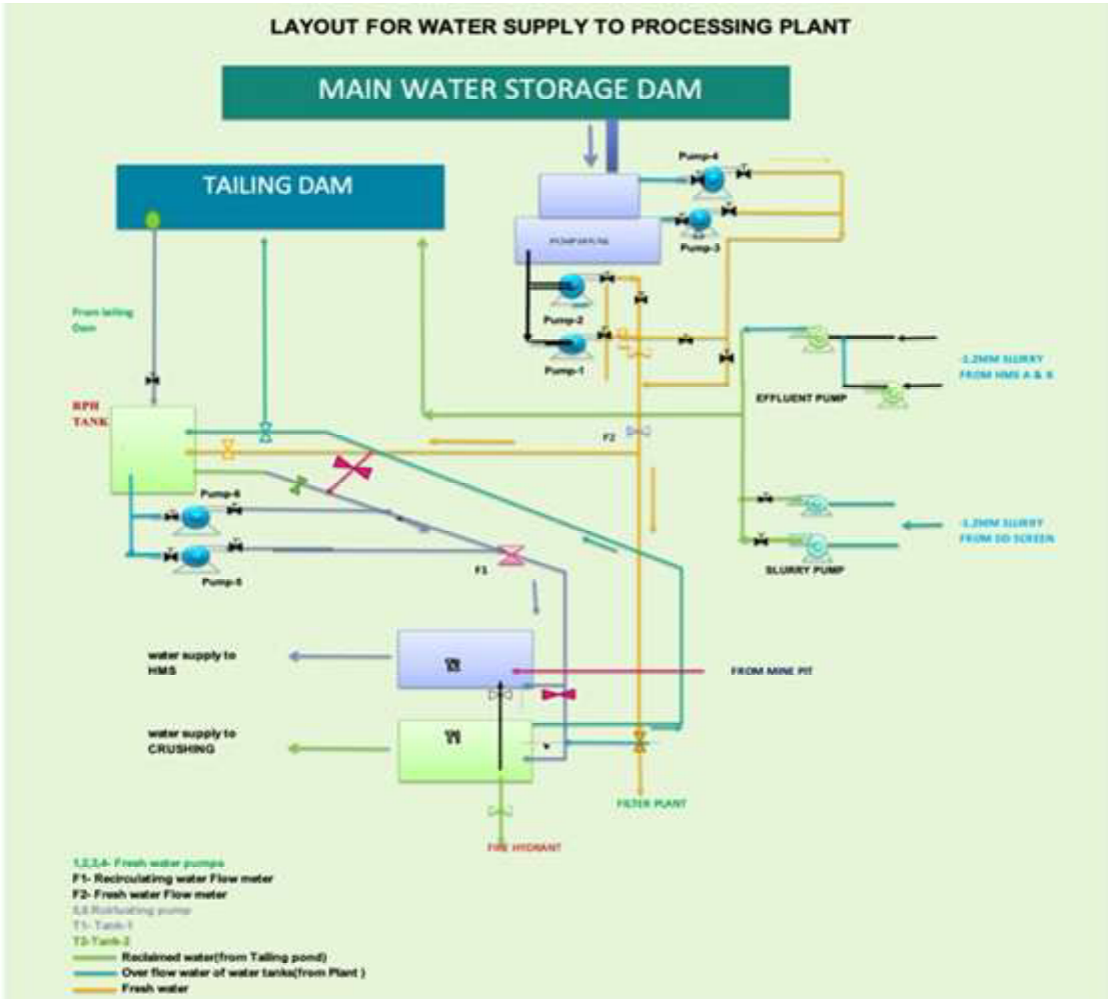

Figure 9: Water supply system flowsheet

Water is used in a dust suppression system to mitigate generated free dust during plant operation and is also used in the X-ray section to feed concentrate material in a wet state for the recovery of diamonds.

The primary source of water for supplying to the Processing plant is from Earthen Dam, located about 1.5 km from the plant. However, seepage water and rainwater collected from the mine pit are also being pumped into the plant for processing during the rainy season.

The details regarding water consumption at the plant are as under,

1.	Specific water consumption	: 5-5.8 M^3/T
2.	Fresh water-specific consumption	: 1.5 to 1.80 M^3/T
3.	Total water consumption per Day	: 4300-5000 M^3/day
4.	Annual Total Consumption	: 13 to 15 Lakh M^3

The Earthen dam receives water solely from monsoon rain, and this water is regarded as precious and critical for socio-economic development, healthy ecosystems and for human survival itself. Since the dam is the only source of water for Villagers, animals, and Project Township in the region, proper water utilization is imperative. Discharge of any kind of water, say rain or processed water, is contained within the plant and properly delivered to tailing pond. The processing plant is hence termed as a Zero discharge plant. All the drained or washed water and slurry of -1.2mm size material are collected in Double Deck sump in crushing section and in the effluent tank in Heavy media plant for further pumping to tailing dam for filtering and recirculation purpose.

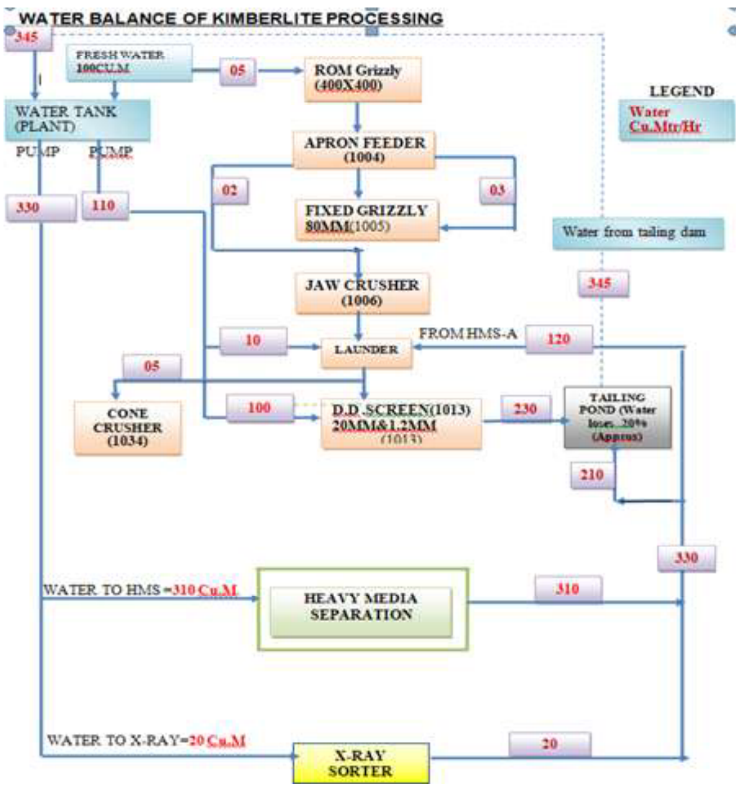

Figure 10: Water Balance Flowsheet

Slurry water in the tailing dam is passed through a long distance of 500 meters inside the periphery of the dam to allow slurry to settle and clean water to enter the intake well through the filter bed for effective stoppage of large, suspended particles. The filtered water collected in the intake well is fed to a large tank (100 Cu.m) in the Recirculation pump house through gravity. The filtered water is again pumped at 500 meters back to plant storage tanks (400 Cu.m) for distribution to crushing and heavy media plants through a pressurized pumping system.

This recirculation arrangement in the project ensures recovery of water to the extent of 75-80% from the tailing pond to supply for the processing plant. Using water in the above way meets current, ecological, social, and economic needs without compromising the ability to meet future requirements.

Apart from this, water spillage in and around the plant area, leakages through pipeline, overflow, rainwater, and other seepages etc., are also recovered through the pumping system and redirected to tailing pond for filtration. Any overflow water from tailing pond or rainwater or seepage water in RPH are collected in a small reservoir located at a lower level than RPH are also lifted through a

Figure 11: Tailing Pond discharge point

Figure 12: Recirculation Pump House

diesel- driven centrifugal pump and dumped back in recirculation tank.

CONCLUSION

Diamond Mining Project, Majhgawan is Asia's only mechanized mines and is unique in its design and operation. World-class techniques are being used for the extraction of Diamonds, where Ferrosilicon is used as heavy media for optimum separation of diamond-bearing material from Kimberlite ore and fluorescence X-ray sorting machine for fine separation, thereby producing Gem quality, off-color, dark brown or industrial rough diamonds. The Processing Plant at Majhgawan is a zero-discharge plant and achieves water conservation by recovering 75-80% of the water through the recirculation process.

The Indian Mining & Engineering Journal, Vol. 60, No.10-11, October-November 2021, pp.10-16
Printed in India, @ IME Publications, ISSN 0019-5944

Energy Conservation & CO_2 Emission Reduction

Santosh Mehra* Ankit Pathak**

ABSTRACT

In recent years, the environmental problems caused by excessive carbon emissions from energy sources have become increasingly serious, which not only aggravates the climate change caused by the greenhouse effect but also seriously restricts the sustainable development of Indian economy.

An attempt is made in this paper to use energy consumption method and input-output method to study the carbon emission structure of world energy system and industry in 2020 from two perspectives, namely energy supply side and energy demand side, by taking into account the two factors of energy invest in gross capital formation and export. The results show that neglecting these two factors will lead to underestimation of intermediate use carbon emissions and overestimation of final use carbon emissions. On energy supply side, the carbon emission structure of world energy system is still dominated by high-carbon energy (raw coal, coke, diesel, and fuel oil, etc.), accounting for more than 70% of total energy carbon emissions; on the contrary, the natural gas such as clean energy accounts for only 3.45% of total energy carbon emissions, indicating that the energy consumption structure optimization and emission reduction gap of world energy supply side are still substantial.

On energy demand side, the final use (direct consumption by residents and government) produces less carbon emissions, while the intermediate use (production by enterprises) produces more than 90% of the total energy carbon emissions. Fossil energy, power sector, heavy industry, chemical industry, and transportation belong to industries with larger carbon emissions and lower carbon emission efficiency, while agriculture, construction, light industry, and service belong to industries with fewer carbon emissions and higher carbon emission efficiency. This means that the optimization of industrial structure is conducive to slowing down the growth of energy carbon emissions on the demand side. Hence, policies aimed at reducing energy consumption and controlling for CO2 emissions may not reduce significantly global economic growth. Investing in the use of renewable energy sources like solar and wind power is an urgent necessity to control for fossil fuel consumption and CO2 emissions.

INTRODUCTION

Global warming has the potential to cause serious, worldwide national security, economic, and environmental problems, including mass migrations, resource shortages, major environmental disruption and species extinction, changes in agricultural patterns, staggering economic and human losses from extreme weather events, and the spread of deadly diseases. There is a significant risk that if we do not act quickly enough and if greenhouse gas levels become too high, global warming will become irreversible for centuries or longer. Addressing energy security and arresting climate change will require a transition to a non-carbon- based economy and more fuel-efficient vehicles. This will take decades, even with strong measures, so new initiatives will have to be durable enough to withstand political vicissitudes and arguments that regulations should be weakened during economic slowdowns. Because efforts to solve both issues are inextricably intertwined, they must be addressed together, and actions to solve one issue cannot compromise the ability to address the other successfully.

The civil society, corporate & government will need to address five key sets of issues in order to confront global warming and reduce our dependence on foreign oil:

1. Identify and set goals that must be achieved to address these issues successfully and create a timetable for action.
2. Implement measures that will accelerate implementation of needed new technologies.
3. Set up a regulatory system that will withstand many decades of political pressures to weaken it.
4. Address the key sectors where CO2 emissions are projected to increase most significantly and the programs necessary to prevent that increase.
5. Enact policies that will enable developing countries to set and agree to mandatory CO2 reduction measures and significantly reduce their use of oil for

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transportation.

SETTING GOALS

Successfully addressing global warming and energy independence will require agreement on a set of goals that are widely accepted both domestically and internationally. Such goals would provide a metric against which proposed legislation to address these issues would be objectively measured. Once goals are set, they will need to be implemented in as cost-effective manner as is possible.

- **Global warming goals**

Almost all scientists agree that global warming is already having an effect on the world's climate. They believe that there is a significant risk that if greenhouse gas concentrations in the atmosphere become too great, they could trigger the mass melting of polar icecaps, disruption of the Gulf Stream ocean currents, and similar events that will "feed" on themselves and become uncontrollable, rapidly accelerating global warming and making it very difficult to stop or stabilize for many centuries at a minimum.

There is no way to determine with absolute certainty when "feedback loops" will occur, since scientific models such as the ones used to model global warming forecast the future but do not guarantee it. Yet the scientific consensus, based on increasingly refined models, is that when the level of CO2 in the atmosphere exceeds 450 ppm5 the risks from uncontrollable "feedback loops" become too great.

Several leading scientists, including James Hansen, have concluded recently that atmospheric concentrations should not be allowed to increase above this level—and, once stabilized at 450 ppm or less, should be reduced after a relatively short period of time. The world should therefore adopt the proposal being considered by the European Union to set an initial goal of reaching equilibrium in CO2 emissions at or before CO2 levels in the atmosphere exceed 450 ppm. Leaders of G8 nations have recognized this and set a target of reducing CO2 levels by 50 percent by 2050, which is roughly equivalent to setting a 450-ppm level.

Scientists estimate that the earth's atmosphere contained 280 ppm of CO2 at the start of the industrial revolution. The CO2 level is currently 385 ppm and is increasing at a rate of about 2.0 ppm to 2.4 ppm per year. If atmospheric concentrations continue to increase at this rate, we will reach a level of 450 ppm in 27 to 32.5 years. We have no time to wait if we hope to achieve equilibrium at the 450-ppm level, but we will have more time within which to achieve atmospheric equilibrium if we can decrease the rate of increase below 2 ppm. For example, if the rate of increase could be reduced to 1 ppm per year, we would have 65 years before reaching a 450-ppm level of CO2 in the atmosphere.

The India's target of reducing emissions to net zero emission by 2070 will need to be coupled with equally aggressive targets for other developed nations and credible, if initially less dramatic, targets for developing countries, particularly China, in order to limit atmospheric levels of CO2 to 450 ppm or less. Cumulative global reductions will need to be of sufficient magnitude and speed to allow us more than 27 years to 32.5 years before reaching the 450-ppm level and then enable us to stabilize CO2 concentrations in the atmosphere at or below that level.

- **Energy Security Goal**

The greatest energy security risks are not 27 years or more in the future. India is suffering from dependence on imported oil greatly. We can only achieve energy security by ending oil's global monopoly on transportation fuels. This monopoly not only leads to higher prices, it also places the United States, Europe, China, Japan, and other nations in an impossible strategic position because there are no current, viable alternatives to meeting transportation fuel needs.

The primary energy demand in India has grown from about 450 million tons of oil equivalent (toe) in 2000 to about 770 million toe in 2012. This is expected to increase to about 1250 (estimated by International Energy Agency) to 1500 (estimated in the Integrated Energy Policy Report) million toe in 2030. This increase is driven by a number of factors, the most important of which are increasing incomes and economic growth which lead to greater demand for energy services such as lighting, cooking, space cooling, mobility, industrial production, office automation, etc.

This growth is also reflective of the current very low level of energy supply in India: the average annual energy supply in India in 2011 was only 0.6 toes per capita; whereas the global average was 1.88 toe per capita. It may also be noted that no country in the world has been able to achieve a Human Development Index of 0.9 or more without an annual energy supply of at least 4 toe per capita. Consequently, there is a large latent demand for energy services that needs to be fulfilled in order for people to have reasonable incomes and a decent quality of life.

Moving from oil & coal-based economy to gas based economy with intermix of latest technologies such as ethanol blended petrol, renewable energy based grid system, hydrogen cell etc. will enhance energy security with demand side intervention for promotion of conservation.

THE TECHNOLOGY CONUNDRUM

The World will have to confront the question of whether it can achieve the necessary deep reductions in fuel consumption and CO2 emissions if it is unable to make major advances in developing and deploying new technologies such as plug-in electric hybrid vehicles, which have the potential to achieve fuel economy standards of 100 miles per gallon or more. Technology development and rapid deployment are key to reducing worldwide demand for oil, cutting worldwide CO2 emissions, and boosting the domestic economy by creating jobs at home and exporting new technologies overseas.

Yet we haven't been able to develop these technologies in a timely fashion. Many experts have concluded that needed technological advances such as hybrid cars, energy efficiency measures, and wind and solar power are ready for use, while others such as capture and sequestration of CO2 emissions from new coal plants, plug-in hybrid cars, and all electric cars are close to ready for use. The conundrum is that new technologies often take decades before they become commercially dominant in a market. One leading commentator on new technologies describes this gap as a "chasm" that separates the commercial development of a product and its deployment.

The most basic explanation for why it takes so long for new technologies to be adopted by a market is that adopting a new technology is risky. It might take years of operating experience before the new technology is understood well enough for it to work as well as promised, and the first-generation plants using a new technology are unlikely to work as well as second- and third-generation plants. Second- and third-generation plants are also likely to cost less to operate and build than first-generation plants.

A good example is carbon capture and sequestration technology. It is almost universally agreed that deploying CCS technology is critical to ensuring that coal remains a viable source of domestic energy in a carbon-constrained world. Yet there is little incentive for most companies to do so now because CCS technology will improve over time and the cost of building and operating a CCS plant will rapidly decrease as the technology evolves. According to a study by the Electric Power Research Institute, if there is aggressive research, development, and deployment, the capital cost of building a CCS plant in 2030 will be 30 percent less than the cost of building one in 2005. Moreover, a plant producing at 30 percent operating efficiency today could be operating at 45 percent efficiency in 2030—an improvement of 50 percent.

There are several possible ways to speed up the implementation of a new technology. The first is to rely on market mechanisms such as a system that sets a market price for CO2 emissions. For example, if the cost of building a coal-fired power plant with CCS is greater than the cost of building a plant without CCS, a system that requires a non-CCS plant to internalize the cost of emitting CO2 might make plants that capture CCS cost-competitive. But assuming that incentivizing the construction of coal-fired plants with CCS is only one aspect of a system that sets a market price for CO2 emissions, the market might not set a CO2 price that is high enough to overcome the cost differential between plants with and without CCS. Seeking to push up the price to overcome the difference runs the risk of distorting the market price for other participants in the market. In fact, in the case of CCS, the market price for CO2 is likely to be far lower than necessary for many years to make plants with CCS cost- competitive with plants without CCS that have to pay for their CO2 emissions.

Another way to speed up the deployment of a new technology is to mandate the level of performance that the new technology can achieve once one or more new technologies are available to achieve the performance level. Such a mandate overcomes the non-price barrier to entry since all participants in the market have to achieve a comparable level of performance and cannot wait for second- and third-generation plants before adopting the technology.

Implementing selective and carefully chosen mandates to complement a general market-based system of achieving CO_2 reductions will be the key to making the deep changes necessary to address climate change and speed up the achievement of energy security. Such mandates would set a performance level in reducing CO_2 emissions or increasing energy efficiency, and it is appropriate to implement such mandates after at least one proven technology exists that can achieve the performance standard.

Because performance mandates require a performance level and not the use of a particular technology, they do not force a choice between different technologies and, thus, the selection of winners and losers—the key objection that free market economists have to technology deployment programs. Performance mandates therefore allow full-market competition over a range of options that could ultimately achieve the prescribed performance standard.

ESTABLISHING A ROBUST REGULATORY SYSTEM

A cap-and-trade system, a tax on carbon, and various mandates have all been proposed to arrest greenhouse gas emissions and reduce use of oil in vehicles. A system that combines the best elements of each is needed to address these issues.

Virtually all proposed global warming legislation establishes a cap-and-trade system to reduce greenhouse gas emissions. A cap-and- trade system sets up a continuously declining cap on emissions. It assigns or sells through an auction process permits (often called allowances) to emit greenhouse gases, and authorizes those regulated entities to retire those allowances or sell them if they can generate reductions more efficiently than other regulated entities. If the system does not auction 100 percent of its allowances, the free market aspect of the system—where entities can buy and sell allowances to each other—markedly increases its efficiency. Similar economic efficiencies would occur in a 100 percent auction-based system. Outside “offset” allowances from non-regulated sources, such as from reforestation and avoided deforestation, or from entities in developing countries that are not subject to regulation, are permitted up to a prescribed limit in most proposed bills.

A cap-and-trade system can also build in economic incentives similar to those provided by a tax by providing for the auction of some or all of the CO_2 allowances. Building in a price for emitting greenhouse gas would encourage regulated entities to reduce greenhouse gas emissions as quickly as economically practical while at the same time retaining the certainty in emission reductions provided by a cap-and-trade program. Auction revenues would also provide a dedicated source of funding for new energy technology subsidies and incentives, and for payments to lower-income persons to offset increased energy costs from global warming and energy security programs. Most of the proposed global warming bills include an auction system in which the number of allowances auctioned increases each year, and many politicians have called for a 100 percent auction requirement.

ADDRESSING OIL DEMAND AND CO2 EMISSION GROWTH

The first step toward reducing greenhouse gas emissions and limiting oil imports will be to minimize the effect of new sources of emissions and oil use by new vehicles. The transportation sector and the electricity generation sector, of particularly new coal plants, are likely to generate the greatest increase in CO_2 emissions in the coming years, and the transportation sector will use the most imported oil.

Coal-fired plants account for 80 percent of all CO_2 emissions from power plants, and about 90 percent of transportation emissions come from household vehicle use. The transportation and power sectors are also the sectors where greenhouse gas emission growth has been the greatest since 1990. Emissions have risen an average of 1.5 percent per year in the transportation sector and 1.8 percent per year in the electric power sector. The growth in emissions in these two sectors is greater than the overall rate of emissions growth for the whole economy, which was only 1 percent per year, and also greater than the growth of emissions from the industrial sector of the economy, which has not increased since 1990.

Continued reliance on high-emitting technologies in these two sectors will lock in emissions increases that will persist for decades, requiring difficult reductions in emissions in future years when emissions reduction requirements tighten and driving up future mitigation costs. The median turnover for the automobile fleet is 15 years, and new coal plants—the largest source of greenhouse gas emissions—will likely be in use for 50 years to 60 years. Using new technologies to drive down emissions in these sectors now is critical to achieving future emission reductions at a reasonable cost and should be a near-term priority for policymakers addressing global warming.

Increasing efficiency in the transportation sector –

• **Reducing demand for gasoline through greater fuel efficiency** -

It will take considerable time for plug-in hybrids to significantly decrease fuel use. The technology must be perfected, and this could take longer than expected. Costs of plug-in hybrids will be higher than gasoline-powered cars, at least in the early stages of plug-in production, and a significant tax credit will be necessary to encourage significant early sales. Financial assistance to the car industry to retool their plants to produce cleaner cars would also speed up their introduction. Nevertheless, if the goal is to improve mileage efficiency for the overall fleet from 35 mpg to 55 mpg from 2020 to 2030, hybrids, plug-in hybrids, and all electric cars make reaching that target technically feasible. They even raise the strong possibility that the goal can be achieved more quickly, and that more aggressive goals can then be set. The Massachusetts Institute of Technology report "On the Road in 2035" concluded that doubling fuel economy of new cars by 2035, the reference date used in the MIT study, "is technically feasible, but achieving this in practice will require aligning the preferences of consumers and manufacturers through strong fiscal and regulatory incentives."

Although plug-in hybrid vehicles must be charged with electricity generated by power plants, including coal-fired plants, "recent studies have found that with today's grid [where about 51 percent of the grid's power is produced by coal-fired plants] and driving patterns, plug-in hybrids would reduce total emissions of heat-trapping gases from vehicles in the United States by 27 percent to 37 percent." The reason is that a traditional internal combustion engine is astonishingly inefficient. A recent joint study by the Electric Power Research Institute and the Natural Resources Defense Council concluded that as older power plants are replaced by cleaner power plants, plants that capture and sequester their CO2 emissions, and renewable energy sources, greenhouse gas emissions from plug-in hybrids will decrease by 40 percent to 65 percent compared to conventional vehicles.

• **Replacing oil with advanced cellulosic biofuels.**

Building Cleaner Coal Plants –

- Reducing the carbon footprint of power generation is essential. The electricity sector is now the largest source of greenhouse gas emissions, and electricity demand could increase with the deployment of plug-in hybrids or all- electric vehicle batteries. The first and most important challenge is to build new coal plants with carbon capture and sequestration technology. Utilities and their partners are now making fuel selections for future power plants that, once built, will have a projected lifespan of 50 years to 60 years. It is estimated that as many as 1,400 gigawatts of new coal- fired plants will be built around the world between now and 2030.
- Current state-of-the-art technology for conventional coal-fired power plants utilizes advanced, pulverized coal technology. A new 1,000-megawatt pulverized coal power plant without CCS produces about 5.4 million metric tons of CO2 annually. This means that if the projected 1,400 gigawatts of new plants are built using pulverized coal technology, as much as 7.56 billion additional tons of CO2 would be generated worldwide each year.
- If a cap-and-trade system results in a price for carbon that is low enough, uncontrolled coal plants might still be financially viable, although the future of the industry will only be truly secure if new coal plants that do not cause significant increases in CO2 emissions can be built. This can be accomplished if coal plants capture and sequester their CO2 emission in deep underground formations. The technology for new coal- fired power plants that is furthest along in development is known as integrated gasification combined-cycle.

ENERGY SECURITY & GHG_EMISSION - INDIA'S EFFORTS & APPROACH

The government aims to increase the share of natural gas in the country's energy mix to 15% by 2030, from 6% today which would allow India to improve the environmental sustainability and flexibility of its energy system. Increasing domestic gas production has been a key government priority, as output has unexpectedly come in below forecast levels over the past few years. India has five operating terminals for liquefied natural gas. Projects under construction could result in up to 11 additional terminals over the next seven years.

India's coal supply has increased rapidly since the early 2000s, and coal continues to be the largest domestic source of energy supply and electricity generation. Amid more stringent air pollution regulations, new coal power plants that are more efficient, flexible and relatively lower in emissions will be better positioned for their economic viability. By contrast, old and inefficient plants, which require expensive retrofits to comply with environmental standards, are in a difficult position. The government is identifying those plants that can and will need to run more flexibly in the system. It is also examining changes to market design to improve the remuneration of the system services they can provide. An efficient coal sector is critically important not only for electricity generation, but also for industrial development in areas such as steel, cement and fertilizers.

India is the world's third largest consumer of oil, the fourth largest oil refiner and a net exporter of refined products. The rate of growth of India's oil consumption is expected to surpass that of the People's Republic of China in the mid-2020s, making India a very attractive market for refinery investment. To maintain India's position as refining hub, the government is pursuing a very ambitious long-term roadmap to expand its refining capacity in line with the country's projected demand growth through 2040. As proven oil reserves are limited compared with domestic needs, India's import dependency (above 80% in 2018) is going to increase significantly in the coming decades.

To improve oil security, the government has prioritized reducing oil imports, increasing domestic upstream activities, diversifying its sources of supply and increasing Indian investments in overseas oil fields in the Middle East and Africa. Commendably, India is promoting domestic production with a major upstream reform, the Hydrocarbon Exploration and Licensing Policy (HELP), and is progressively building up dedicated emergency oil stocks. India's strategic petroleum reserve supplements the commercial storage available at refineries. India's current strategic reserve capacity of 40 million barrels can cover just over 10 days of current net imports. However, given the expected growth in oil consumption, the same volume may cover only four days of net imports in 2040. Therefore, it is important that the government pursue the second phase of its strategic stockholding policy, which would add an additional 50 million barrels, and also prepares subsequent phases.

India has made important progress towards meeting the United Nations Sustainable Development Goals, notably Goal 7 on delivering energy access. Both the energy and emission intensities of India's gross domestic product (GDP) have decreased by more than 20% over the past decade. This represents commendable progress even as total energy- related carbon dioxide (CO_2) emissions continue to rise. India's per capita emissions today are 1.6 tones of CO_2, well below the global average of 4.4 tones, while its share of global total CO_2 emissions is some 6.4%.

India is an active player at international fora in the fight against climate change. The country's Nationally Determined Contribution under the Paris Agreement sets out targets to reduce the emissions intensity of its economy and increase the share of non-fossil fuels in its power generation capacity while also creating an additional carbon sink by increasing forest and tree cover. Although the emissions intensity of India's GDP has decreased in line with targeted levels, progress towards a low-carbon electricity supply remains challenging.

India has taken significant steps to improve energy efficiency, which have avoided an additional 15% of annual energy demand and 300 million tonnes of CO_2 emissions over the period 2000-18, according to IEA analysis. The major programmes target industry and business, relying on large-scale public procurement of efficient products such as LEDs and the use of tradable energy efficiency certificates. The government's LED programme has radically pushed down the price of the products in the global market and helped create local manufacturing jobs to meet the demand for energy-efficient lighting.

Based on current policies, India's energy demand could double by 2040, with electricity demand potentially tripling as a result of increased appliance ownership and cooling needs. Without significant improvements in energy efficiency, India will need to add massive amounts of power generation capacity to meet demand from the 1 billion air-conditioning units the country is expected to have by 2050. By raising the level of its energy efficiency ambition, India could save some USD 190 billion per year in energy imports by 2040 and avoid electricity generation of 875 terawatt hours per year, almost half of India's current annual power generation.

Recent IEA analysis shows that in 2018, India's investment in solar PV was greater than in all fossil fuel sources of electricity generation together. Large-scale auctions have contributed to swift renewable energy development at rapidly decreasing prices. By December 2019, India had deployed a total of 84 GW of grid-connected renewable electricity capacity. By comparison, India's total generating capacity reached 366 GW in 2019. India is making progress towards its target of 175 GW of renewable by 2022. In September 2021, the prime minister of India announced that India's electricity mix would eventually include 500 GW of renewable energy capacity. Progress towards these targets will require a focus on unlocking the flexibility needed for effective system integration. This can potentially be achieved by improving the design of renewable auctions, with clear trajectories and criteria to reflect quality, location and system value, along with measures to foster grid expansion and demand-side response across India.

India is particularly vulnerable to climate change impacts and is exposed to growing water stress, storms, floods and other extreme weather events. Adaptation and resilience of the energy system to these extreme climate conditions should be a high political priority. Furthermore, the energy sector is a large water user. As India's energy demand continues to grow, the government should ensure that energy planning takes into account the water–energy nexus, as well as future space cooling needs.

CONCLUSION

The conclusion of this paper shows that world has a lot of room to reduce carbon emissions in the future by optimizing the energy consumption structure. Specifically, on the premise of maintaining the demand for economic development, we should gradually increase the proportion of consumption of low-carbon energy such as natural gas through policy support and guidance, so as to reduce the proportion of consumption of high-carbon energy such as raw coal. Third, we need to optimize the industrial structure to save energy and reduce emissions. The research results of this paper show that the carbon emission efficiency of light industry, agriculture, service industry and construction industry is higher. The power sector, fossil energy, transportation, chemical and heavy industries are less carbon efficient.

Hence, in order to control carbon emissions from energy consumption, the world different governments should adjust the assessment and selection mechanism of regulatory bodies officials, increase the weight of people's livelihood and environmental assessment content, reduce the negative impact of local governments on industrial structure upgrading, and achieve sustainable economic development.

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The Indian Mining & Engineering Journal, Vol. 60, No.10-11, October-November 2021, pp.17-26
Printed in India, @ IME Publications, ISSN 0019-5944

Risk Assessment of an UG Coal Mine in Context of Strata Control (Roof Fall)

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ABSTRACT

Mining is a hazardous profession we deal with natural phenomena which inherently are variable associated with the unpredictable forces of nature. As a result, the mining industry continue to be associated with a huge number of accidents, injuries and health hazards. Mine disasters, cause high levels of fatalities and in most cases the mine in question stops it's production within a short time due to occurrence of the disasters. Global dynamics of the technological changes create a need for modern approaches while evaluating and analysing the risk in the mining industry. With systematic identification, assessment/ evaluation and elimination or reduction of hazards in mining operation, the risk can be reduced to an acceptable level. This paper refers to the role of risk management processes and method to control the risk of roof falls in an underground coal mine. By using risk assessment tools in preparation of strata management plan and effective implementation of controls roof fall in UG coal mines are preventable.

Keywords: Risk Assessment, risk management, Hazard, consequence, probability.

INTRODUCTION

The mining industry is an industry with one of the highest rates of accidents at work. Limited space, difficult mining & geological conditions, and work performed under conditions of psychological stress are the reasons why the indices of accidents at work exceed the average values for industry as a whole.

Roof fall is the major contributor towards fatal and serious accidents in underground mines. The analysis in to the causes of fatal accidents in Indian coal mines during the period 1998 to 2010 revealed that, roof fall is the major cause of fatal accidents. In spite of all the precautions taken in this regards, trend of accidents due to fall of roof and sides is not arrested. (D.G.M.S, 2011) [1] Fig.1 shows the cause-wise classification of fatal accidents in India for the period 1998 to 2010 and it can be seen that 32% of the total fatal accidents were occurred due to roof falls. (D.G.M.S, 2011) [1].

Risk assessment process involving the various steps of identify the hazards, analysing, evaluating the risk associated with the roof fall hazard and implementing the controls with review & monitoring becomes very useful system to mitigate this hazard.

RISK ASSESSMENT

A risk assessment is simply a careful examination of what, in your work, could cause harm to people, so that you can weigh up whether you have taken enough control measures or should do more to prevent harm.

- ***Hazard*** is a source of potential harm or a situation with a potential to cause loss, injury or damage.
- ***Risk*** is the chance of something happening that will have an impact upon objectives.

It is measured in terms of consequences and likelihood.

Consequence is the outcome of an event or situations expressed qualitatively or quantitatively, being a loss, injury, damage or gain. *Consequence is the size of the loss or damage.*

- ***Likelihood*** is qualitative description of probability and frequency.
- ***Probability*** is the likelihood of a specific outcome, measured by the ratio of specific outcomes to the total number of possible outcomes.
- ***Frequency*** is a measure of likelihood expressed as the number of occurrences of an event in a given time.

Thus, likelihood is the chance that the hazard might occur. In some cases, personnel are only exposed for a given time. Hence combination of exposure and probability would be more appropriate to determine the likelihood.

Risk assessment – about making right decisions under uncertainty !

- Identify hazards at work

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Cause wise Fatalities in WCL													
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Roof/Side Fall	6	7	7	1	4	2	1	0	0	2	4	0	1
Haulage/Conveyor	1	2	0	1	0	0	0	1	0	0	0	0	0
Winding	0	0	0	0	0	0	0	0	0	0	0	0	0
Explosive/Blasting	0	0	1	0	1	0	0	0	0	0	0	0	0
Electricity	0	0	0	0	0	0	0	0	0	0	0	0	0
Machinery	3	1	4	5	0	6	9	4	2	0	0	1	0
Fall of person	2	0	0	0	0	0	0	0	0	0	1	0	1
Fall of object	0	0	0	1	1	1	0	0	1	0	0	0	0
Extremity caught in between	0	0	0	0	1	0	0	1	1	0	0	0	0
Misc. U/G	0	1	0	0	1	0	0	1	1	0	0	1	0
Misc. O/C	0	2	1	1	1	0	0	0	0	1	0	0	1
Misc. Surf	0	0	1	1	1	0	0	1	0	0	0	0	1
Total WCL	12	13	14	10	10	9	10	8	5	3	5	2	4

Cause wise Serious Injuries in WCL													
	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Roof/Side Fall	7	6	12	7	5	6	4	2	5	1	3	2	2
Haulage/Conveyor	4	3	1	0	2	1	2	1	0	0	3	0	1
Winding	2	0	0	0	0	0	0	0	0	0	0	0	0
Explosive/Blasting	0	1	0	0	0	0	1	0	1	0	0	1	0
Electricity	0	1	0	0	0	0	0	0	0	0	0	0	0
Machinery	2	3	3	3	1	5	5	6	1	2	1	2	3
Fall of person	11	15	10	14	14	15	13	9	4	8	5	5	2
Fall of object	9	6	11	1	2	8	1	2	1	5	1	0	0
Extremity caught in between	6	6	5	12	4	8	7	4	4	2	1	3	0
Misc. U/G	2	3	4	0	0	3	2	1	0	1	0	1	1
Misc. O/C	2	2	0	0	0	1	2	1	1	0	0	2	0
Misc. Surf	0	0	0	0	1	0	1	1	0	0	3	1	0
Total WCL	45	46	46	37	29	47	38	27	17	19	17	17	9

Fatal Accidents Cause wise TAWA MINE

Cause	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Roof/Side Fall	0	0	1	0	0	0	0	1	0	0	1

Serious Accidents Cause wise TAWA MINE

Cause	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Roof/Side Fall	0	0	0	1	0	0	0	0	0	0	0

There is a trend of decrease in fatal and serious accidents due to roof fall in underground coal mines even though the pattern is not definite. To arrest fatal and serious accident due to roof falls in Tawa mine of WCL mine management has implemented Risk assessment process and mine has mitigated/minimised the same.

- Assess risks associated with hazards
- Identify unacceptable risks
- Identify and decide on course of action
- Take action to control hazard
- Monitor effectiveness of those controls
- Monitor for new hazards
- Complete records and reports

Figure-1

Establishing the Context:

Establishing the context means to clearly define the particular task, issue or situation and underlying hazards that one is trying to resolve as part of the risk management activities.

***Hazard Identification**: Are there any significant hazards?*

The identification of source of potential harm or a situation with a potential to cause loss, injury or damage.

For identification of hazard, unwanted release of energy which may cause damage should be considered.

Common Hazard Identification Techniques

- Consultation with mine workers and officials.
- Accident and incident reports on site or offsite
- Inspections of mine and records.
- Checklists and completed audits
- Mine workers' compensation claims
- Supplier/Manufacturer/Importer information
- Specialist consultation
- From Safety Alerts, Safety Bulletins and similar safety publications.

Work Process Model – Nertny wheel

Figure-2

The next step in the risk management cycle is to provide an estimate of resultant risk, in terms of consequences and likelihood.

RISK CONTROL

While developing Risk Control plans for identified hazards it should be remembered that, the higher the risk the higher quality controls are required.

The "hierarchy of controls" is a concept to illustrate what controls are more effective at controlling hazards. There are generally five levels in the hierarchy of controls- elimination, substitution, separation, administration and use of PPE. Apart from these five controls, there is a sixth control reliant on 'human behaviour.

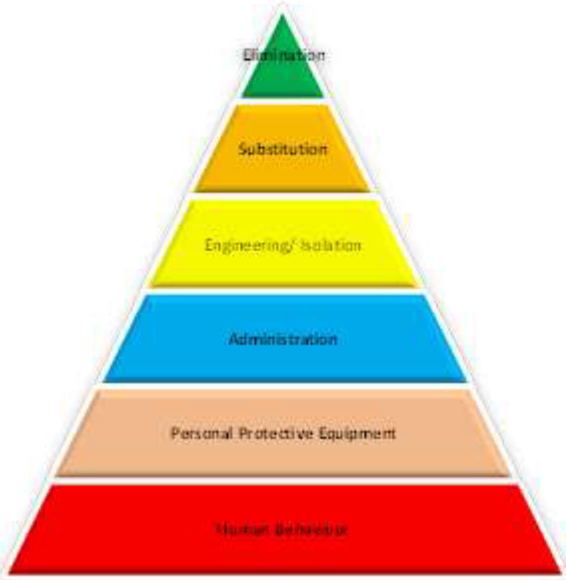
Figure-3

The risk ranking is used only to prioritize the risk for initiating the control measures. Once the Likelihood and consequences of the hazard is determined, by multiplying these two factors, a range of risk ratings are obtained. There are various approaches to calculate risk score. Here we have used DGMS guidelines to calculate risk score for a hazard.

Hazard identification as high Risk - TAWA Mine (Risk>200)

SL NO	DESCRIPTION OF HAZARD	% OF WORKER EXPOSED	CONS.	Prob.	Exposure	Total
1	Roof fall (Strata Control)	>20	5	7	10	350
2	Side fall	<5	5	7	10	350
3	Inundation from Waterlogged working (UG) in the same mine	>40	5	7	10	350
4	Mine Gases	>40	5	7	10	350

Hierarchy of Controls



Control Option	Option Description	Effectiveness
	1. *ELIMINATE* (remove the hazard or the need to perform the hazardous activity all-together)	100%
	2. *SUSTITUTE* (hazardous substance, process, equipment, work method for safer alternative)	75%
	3. *ENGINEERING/ ISOLATION* (redesign, enclose, or isolate/ separate people from the hazard by use of lock out system or use of barriers/ distance/ time)	50%
	4. *ADMINISTRATIVE* (Training, Rules, Procedures or Safe System of Work)	20-30%
	5. *PPE* (includes: eye/ face/ skin/ foot/ head/ respiratory/ hearing/ fall protection/ and contingencies such as fire fighting equipment)	5%
	6. *SAFE BEHAVIOUR* (situational awareness/ alertness and compliance with rules and procedures, instruction)	Unpredictable / can't say

Figure-4

Once a control is in place, re-assess for residual risk
Can we accept the level of risk remaining?

Are the controls adequate?
Is there still a risk (of injury)?

Hazard Identification & Risk Rating: -
Roof fall in multiple sections of an underground Mine

HAZ No	HAZARD	Mechanism	Calculated Risk			
			CONS.	EXPS	PROB	RISK RATING
RFH-1	**Lack of knowledge on procedure**	**1. Documents available are inadequate. RMR report of adjoining section.**	**5**	**10**	**7**	**350**
		2. Workers and supervisors are not trained to follow procedure.	5	10	7	350
		3. Surveillance to implement the procedure	**5**	**10**	**7**	**350**
		4. Improper roof /side dressing	5	**10**	**7**	350
		5. Not using proper dressing tools.	**5**	10	**7**	**350**

HAZ No	HAZARD	Mechanism	CONS.	EXPS	PROB	RISK RATING
RFH-2	Roof fall in development working	1.Presence of slip planes in roofs / geological disturbances.	5	5	10	250
		2. Delay in erection of support.	5	5	10	250
		3. Orientation of roadways parallel to cleats	5	10	3	150
		4. Delay in supply of support material	5	10	3	150
		5. Development workings are not vertically coincident.	5	10	3	150
		6. Excessive gallery width.	5	5	3	75
		7.Not following SSR	5	5	3	75
		8. Guidelines for solid blasting not followed.	5	5	3	75
RFH-3	Roof fall in freshly exposed roof of development working	1. Poor supervision of mining operation.	5	10	3	150
		2. Poor workmanship in installing supports.	5	10	3	150
		3. Inadequate support density for weak and Incompetent roof strata	5	10	3	150
		4. Support consumables not as per standard	5	10	3	150
RFH-4	Roof fall in mine working	1. Shortage of support personnel.	5	5	7	175
		2. Lack of Knowledge to support personnel.	5	5	3	75
		3. Hitting of roof by bucket/canopy of LHD.	0.1	2.5	3	0.75
		4. Weathering of strata.	5	0.5	0.1	0.25
		5. During destructive test by anchorage testing machine	0.01	5	3	0.15
RFH-5	Roof fall in developed working	Excessive time interval between development and extraction of coal panels.	5	5	3	75
RFH-6	Inadequate mine design	Failure to account for interaction from adjacent workings, from underlying or overlying workings.	5	10	1	50
RFH-7	Roof fall in depillaring with caving sections	1. Goaf edge support setting, erection not proper and support density not proper.	5	5	3	75
		2. Non maintenance of prescribed line of extraction.	5	5	3	75
RFH-8	Strata control problem in depillaring with caving sections. (Overriding of pillars)	Leaving of Large remnant pillars in goaf.	5	10	1	50

ROOF FALL HAZARD CONTROL IN MULTIPLE SECTIONS OF UNDERGROUND WORKINGS

Abbreviations: - **RSP-**Relevant Statutory Provision; **DGC-** DGMS Circulars; **MG-**Management Guidelines; **ERCI-** Existing Risk Control Index; **RES** -Responsibility; **MED** - Medium; **YF -** Yellow Flag; **SOP** - Standard Operating Procedure; **COP -**Code of practice

Mechanism	Control	RSP/DGC/MG	Procedure	ERCI	RES	Comments
Roof fall due to inadequate documents	Ensure Availability of adequate documents	REG. 123, DGMS Permissions & Management Guidelines	Organize Workshop for Documentation by internal technical team.	Low	Person concerned, Safety Officer, Colliery Manager, Area Training Officer,	Workshop and training are conducted.
Roof fall due to workers and supervisors are not trained to follow procedure	Provide proper training to workers & supervisors	Reg.123, DGMS Permissions & Management Guidelines for skill up-gradation	Job oriented Training and Retraining & Workshop.	Low	Safety Officer, Colliery Manager, ATO	Regular training sessions is being conducted. Workshop will be conducted within one month
Surveillance to implement the procedure	Ensuring Proper supervision during the course of supporting	Reg. 45,47,48, 123,129 DGC 4/1951, 55/1974, 1/1984, 6/1983	Develop and implement an effective mechanism to ensure the implementation of the procedures.	Low	Mining Sirdar, Overman Shift In-charge, District In-charge	It is in practice
Presence of slip planes in roofs / geological disturbances	Strictly following of SUPPORT PLAN and effective supervision for further improvement , Geological mapping of mine/section & strata monitoring by tale-tell & load cell	Reg 45,47,48,53,129 Reg. 123 DGC 3& 6 /1993, 6/1994	Develop and implement effective mechanism for proper Inspection, Supervision & Monitoring	Med	Mining Sirdar, Overman, Surveyor, Shift In-charge, District In-charge, Strata Control officer	It is in practice and monitored on daily basis.
Orientation of roadways parallel to cleats	Additional supports like W- strap & Roof Stitching	REG. 45, 53, 123 DGC 3 & 6 /1993, Jun-94	Implement the procedures for additional supporting in identified areas	Med	Surveyors, District In-charge, Strata Control Officer, Colliery Manager	System is in practice

Mechanism	Control	RSP/DGC/MG	Procedure	ERCI	RES	Comments
Delay in erection of support	Ensure timely erection of support	REG. 123 DGC 3 & 6 /1993, Jun-94	Ensure availability of support material at work place, spare drill machines, skilled manpower availability,	Med	Mining sirdar, Overman, Shift In-charge, District In-charge.	It is in practice.
Excessive gallery width	Gallery width as per permissible dimensions	Reg.111,45,47 , 48,53, MG	Drivage of face strictly as per approved blasting pattern & Drivage should be as per the center line	Med	Mining Sirdar, Overman, Surveyor, Shift In-charge, District In-charge	It is in practice and monitored regularly.
Lack of knowledge of support personnel	Adequate Training and retraining	MVT rule and MG	Identify untrained person, Device a mechanism to develop training	MED	Person concerned, Mining sirdar, Overman, Safety Officer, Colliery Manager, Area Training Officer	Regular training is being conducted.
Not following the SUPPORT PLAN	Adequate Training and retraining	Reg 123 Reg 45,47,48 Reg 37,43,44	Inspection, Supervision & Monitoring procedure	HIGH	Person concerned, Mining sirdar, Overman, District in-charge, Section in-charge, Safety Officer, Colliery Manager, Agent.	SUPPORT PLAN is followed
Hitting of roof by bucket/canopy of LHD/UDM	Ensure gallery height. Proper Cleaning of blasted coal.	Reg 41, Reg 45,47,48,111	Inspection, Supervision & Monitoring procedure	HIGH	LHD/UDM operator, Mining Sirdar, Overman, Shift In-charge, District in-charge.	SOPs are designed accordingly and distributed to concerned persons.

Mechanism	Control	RSP/DGC/MG	Procedure	ERCI	RES	Comments
Weathering of strata	Ensure proper assessment of stability of strata and provide additional supports.	MG , Reg 123, DGC 5/ 94,6/94	Adequate precaution should be taken while working and it must be ensured that material is available for additional supports.	High	Mining Sirdar, Overman, Shift In-charge, District In-charge, Strata Control Officer	It is in practice.
During destructive test by anchorage testing machine Destructive test must be done as per SOP, and		DGC 3/1993 Reg 123,MG	Formulate and implement sop for preventing such hazard	HIGH	Mining sirdar, Overman, Strata Control Officer, District in-charge.	SOPs are designed accordingly and distributed to concerned persons.
Roof and side fall due to adverse orientation of roadway vis a vis prominent geo. features like cleat etc	Orient proposed main installation and roadways strategically in respect of prominent geological disturbances to reduce strata stability problems	DGC 3/1993 Reg 111,123	Mine planning and design engineer in construction and under the guidance of experts of an academic/research institute to decide orientation of proposed main installation and roadway in mine plan.	LOW	Mining Sirdar , Overman, Surveyor, Shift In-charge, District in-charge, Safety Officer, Colliery Manager,	SOPs are designed accordingly and are being implemented .
Leaving of large remnant pillar in goaf	Avoid leaving large remnant pillars in goaf.	As per DGMS guidelines,	Geological mapping of the mine/section is being done and ensure judicial extraction of remnant pillars .	MED	Mining Sirdar, Overman, Shift in-charge, District In-charge,	It is in practice.
Roof fall caused by overriding of pillars	Deploy competent and trained personnel for goaf edge support setting ,		Frame a code of practice for setting and erection of goaf edge support under competent supervision		Mining Sirdar,	SOPs are designed accordingly and distributed to concerned persons and concerned persons are undergoing training regularly.
Depillaring with caving sections	Erection and adequate support density, Training of support personnel	Reg 123,124,125 DGC- 4/1975	Conduct training of support personnel	LOW	Overman, Shift in-charge, district in-charge, Safety officer, Colliery Manager	

Mechanism	Control	RSP/DGC/MG	Procedure	ERCI	RES	Comments
Roof fall in old galleries of development workings	Ensure cleaning of galleries and dressing of roof and sides by support personnel. Install fresh supports wherever necessary	MG	Develop and implement a procedure to keep secure the old galleries of development workings	LOW	Mining Sirdar, Overman, Shift in charge, Asst manager, Safety officer,	A regular inspection of old working is being done.
Roof fall in depillaring face while extraction with caving	Ensure maintenance of prescribed line of extraction	Permission under reg129(1)	Develop and implement a system of daily surveillance by asst. manager to check compliance by supervisors/workmen& by following SOP for induced blasting and needs implementation	LOW	Mining Sirdar, Overman, Shift in charge, District In-charge	System is already laid for proper inspection.

CONCLUSION

Risk analysis tools depends on various factors like nature of industry, precision required, type of risk to be analysed, level of person doing those analyses, time available for study, infrastructure available etc.

JSA (Job Safety Analysis) and WRAC (Workplace Risk Assessment & Control) are most suitable qualitative formal risk assessment and management tool for our day-to-day repetitive nature of job that can be done by supervisors and front-line executives.

As we are in the initial stage of adopting risk assessment process in our mine with the less skilled and less informed persons, we are just starting it with traditional prescriptive methods to judgmental one of qualitative type. Here worksheet for risk assessment and control plan has been prepared on the basis of DGMS guidelines. Effective implementation and monitoring of control measures within a reasonable time frame will definitely achieve desired results. It must be kept in view that the control measures and the implementation process do not introduce new risks.

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The Indian Mining & Engineering Journal, Vol. 60, No.10-11, October-November 2021, pp.27-30
Printed in India, @ IME Publications, ISSN 0019-5944

Optimum Production by Highwall Mining

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ABSTRACT

The purpose of the Highwall Mining system is to extract coal with an auger machine or a continuous miner from exposed seams. The aim of the method was to recover coal from a surface mine that has reached its economic limit. Highwall mining provides opportunities to extract additional reserves with high productivity compared to underground operations and conventional surface operations. A large amount of coal remains isolated and undeveloped as pillars due to previous indiscriminate mining operations performed by the use of the auger or the continuous miner. Therefore, it is necessary to increase the coal extraction ratio, to reduce the threat of failure of the pillars and to reduce damage caused by subsidence at the surface. This paper reviews the highwall mining experience and design practices with an emphasis on geotechnical considerations. In addition, the relevant design issues for future research topics and challenges on highwall mining are discussed to enhance both the productivity and mine safety from the geotechnical point of view. The major factors in this system are the coal recovery and the stability of the Highwall.

Keywords – web pillar, planning of a Highwall Mining, backfilling the voids

INTRODUCTION

The Sharda Highwall Mine is located 6 km east of Burhar town of Sohagpur area of SECL. It is situated within the Shahdol district of Madhya Pradesh Sharda O/C Mine has mainly four seams which are Burhar VI (T), Burhar VI (B) and Burhar IV & II seams. The details of these seams are given hereby.

Seam wise Mineable reserve

Of these four seams Burhar VI Top seam has already been mined by O/C technology. The remaining Burhar VIB & IV seams in Sharda O/C mine and Burhar IV & II seams in Sharda extension couldn't be mined either by O/C method due to uneconomical stripping ratio or by U/G method due to its low height. These seams was thus planned to be mined by Highwall mining in descending order i.e. from top to bottom.

Highwall is just a combination of underground and surface mining. The coal left in the highwall can be extracted by this technology which otherwise would be lost forever. The method relies upon the self supporting capacity of the strata above the series of parallel entries driven mechanically to a considerable depth without artificial roof support and ventilation. Moreover this technology provides an economical way to extract coal reserves locked up in the highwall. The extent of opencast project is limited by the financial viability, but the coal continues to exist beyond the quarry limit. This is the reason we go for the combination of underground and opencast to extract coal within economic condition. Highwall mining has several advantages compared to underground operations and conventional surface operations. Firstly, due to its flexibility and mobility, it is easier to recover smaller blocks of coal, which allows additional coal recovery from a final highwall or in constrained areas such as service corridors.

Coal seam	Thickness Range (m)	Depth (m)	Work-able Range (m)	Remarks
Seam VI (T)	0.40-5.64	15	3.0-5.0	Already mined by conventional o/c mining
Seam VI(B)	0.06-2.05	32	0.9-1.5	Virgin & workable by HW mining (**2.637 MT** of reserve)
Seam IV	0.37-1.78	60	0.9-1.5	Worked in the in-crop portion (part), rest virgin & workable by HW mining (**8.164 MT** of reserve)
Seam II	0.47-1.89	88	0.9-1.5	Virgin & workable by HW mining (**3.182 MT** of reserve)

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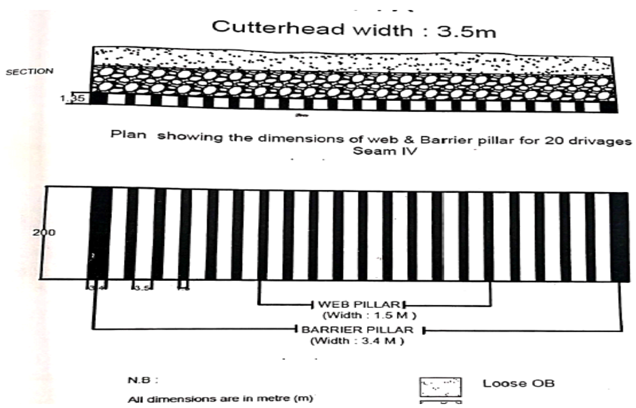
Eventually the continuous miner used in the Underground mining of coal were developed and outfitted to also recover coal from surface high walls. Highwall mining was developed in 1990. As on now more that 60 Highwall miners are in operation in U.S. and they may account for about 4% of total U.S. coal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

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

LENGTH OF DRIVAGE



Study areas

To increase the production by High wall Mining within existing condition maintaining the safety.

1. Reducing the thickness of web Pillar between two adjacent cuts
2. Reducing the thickness of barrier pillar after every 20 cuts
3. Application of backfilling in the cut, suggests that it improves the pillar stability

Planning

The coal is accessed at the base of the highwall from where a series of parallel entries are driven into the coal seam. Therefore, some of open cut mines may consider adopting highwall mining as an alternative mining system when uneconomic conditions are expected due to higher stripping ratios. The major factors in the highwall mining system are coal recovery and the stability of the highwall.

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

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

Factors Influencing Production

(Sharda HighWall, Sohagpur Area, SECL)

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

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

Aerial View Of Trench

DRIVAGES UPTO 250M

Front view of Highwall mining face

Ground Water Recharge and storage in the excavated pit

Stability of the Highwall Top Surface

At Sharda OCP, the mine before commissioning the Highwall Miner, had strictly followed ‘smoothwall blasting’ so as to ensure crack free highwall. This has helped in making the place safer and also the highwall stable. Due to the relatively large difference between the top and bottom of the highwall, any sliding of the top Over Burden material, from of the top surface of highwall will be hazardous to the workers and mining equipment on the working bench below.

The mine planners have examined the stability before commencing highwall mining, to avoid any potential landsliding at the highwall top.

Stability of the Highwall

It is a significant safety concern for a highwall mining operation because of the closeness between the highwall and the workers/supervisors, and the surface equipment. At Sharda, so far no unstable condition was detected nor taken place, during the operation. CIMFR had done a number of studies toi design the web pillar and barrier pillar based on geo-mining conditions.(Lui…………)

Brief on Tata Steel West Bokaro Coal Mines

The third mine where Highwall Mining is being commissioned is at the Tata Steel Coal Mines at West Bokaro. The Mine had introduced Highwall Miner of M/s CAT (through Gainwell), through the Contract concept.

Here the method of work is mining the bottom seam first followed by the Upper seams. At one site they are mining the Vth seam and after the coal is cut and web pillars are left the area is backfilled with Over Burden material so as to create a working platform/space for the High Wall Miner and movement of HEMM for coal evacuation by loader-dumper combination, to mine the VIth Seam. Thus coal is permanently lost in the web pillar. To overcome this the mine management has taken up a number of R&D projects, for selecting a material to be backfill and recover coal from the locked web pillars. Figure explains the same.

Acknowledgement

The authors acknowledge with thanks the permission of AKS University for presenting this paper at ICOMS 2021 at NCL, Singrauli. Thanks are also due to the management of Sharda OCM, Sohagpur Area of SECL and management of Tata Styeel West Bokaro Coal Mines.

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The Indian Mining & Engineering Journal, Vol. 60, No.10-11, October-November 2021, pp.31-37
Printed in India, @ IME Publications, ISSN 0019-5944

On Sustainable Coal Mining in India : Technological Prospects and Looming Constraints

Satyendra K Singh*

ABSTRACT

As per "Glasgow Breakthrough Agenda" deliberated on COP'26 ending on Nov'21 and "meaningful and effective actions, commitments" by majority of countries, including India, businesses and nations have to work together to dramatically scale up and speed up the development and deployment of clean technologies with affordable and attractive choice. It gives a clear inkling that coal mining, per se, is not on an even keel. Much talked of Indian promise at COP'26, i.e., a "net zero" pledge by 2070, the industry need to exploit and augment coal production with the help of high-producing methods, also because they are safe and economically feasible, to secure future energy supplies to the restricted population growth and eventual demand escalation. The Indian coal production, as experts predict, would peak in between periods i.e. today and 2070. If newer and world-established (but not implemented in India) technologies and methods not adopted now, the looming climatic constraints may not provide opportunity afterwards. These methods, discussed in this paper in detail in the context of underground coal mining, have brawny potential of providing high profits also, from where a portion can be leveraged to meet India's climatic goals. With the help of case-studies, this paper also addresses the technological prospects of these methods during their applications on-sites. Mostly, applying the standard operating procedures based on strata geo-mechanics, monitoring and management, have yielded sustainability. Any overlooking or knee-jerk reactions, as illustrated in this paper, may all-through be avoided for better safety, economy and productivity and in the interest of the survival of the methods technologically, also.

INTRODUCTION

As far as coal production is concerned, the future lies in large scale extraction of underground deposits. As opencastable reserves (i.e. 0-300m range) are being fast depleted in India, the ever-increasing demand for coal may necessarily be met by augmenting deep-seated (>300m depth) underground coal production. The preponderance of such deposits cannot be over-emphasized in national perspectives, as detailed in Figure 1 [1]. More concerted efforts of exploration and subsequent extraction efficiently and effectively are now to be planned and implemented on faster track.

The Government of India, through the Ministry of Coal has now made policy framework for augmenting coal production by underground methods. High production methods with Continuous Miner (CM) deployment or by Longwalling or their variants are the need of the hour. The production from underground mining has remained stagnant for many years, and now started diminishing to go down in a death spiral, if the issues are not addressed pro-actively and with professional honesty by all the stake holders in the larger context of our nation's energy security. Environment constraints as discussed above can not be overlooked. The author was fortuitously involved in successful implementations of such methods in India and abroad. Based on comprehensive feasibility and associated research studies after holistically considering

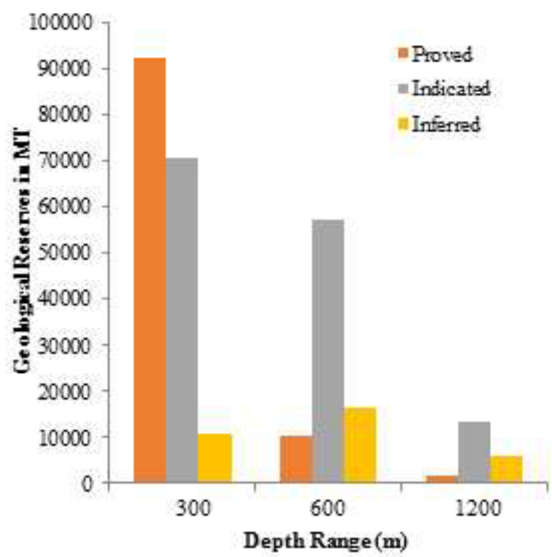

Figure 1. The depth-wise break-up of Indian coal resources (2014 data) [1]

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the geo-mining conditions on case-by-case basis by the him in a team-spirit mode (along with mine-operators), the mines could solve the geotechnical problems, otherwise detrimental to coal production. The safety and economical aspects were simpatico, some of notables success narratives are provided in this paper. The mine could leverage a part of profit-receipts in each case to address environmental issues locally and nationally. It is high time that global issues should also be addressed as per COP26.

MOONIDIH LONGWALL MINE: SUBSIDENCE MANAGEMENT

The deepest longwall mine in India, Moonidih in Jharia Coalfields, has a proposition to extract XV seam, happened in two sections viz. XV Top and XV Bottom with stone parting in between, in identified 5 panels (Figure 2), as per the approved mine-plan. The technical revisit to the approved chain pillars' design of dimension: 55 m width and 160 m length (both rib to rib), was sought by the producing company, BCCL (a subsidiary of CIL) after the award of 'MDO'-job and when the development of (2 nos.) inclines are at the final stage of completion. Numerical modelling, simulating the actual underground situations of would-be goaves nearby, was carried out to calculate the average load on the said-dimension of the chain pillar and factor of safety (FOS) was calculated as 1.13, using CIMFR-Pillar Strength formula. The value was regarded as quite low, by any meaning of FOS. There are villages, water bodies on the surface as well as sub-surface properties more importantly, the overlying goaves – regarded as water-filled unless determined otherwise. The proposed extraction should ensure no adverse subsidence impact on sub-surface and surface properties [2, 3].

In general design parlance, chain pillars should have a FOS> 1.5 with goaf on both sides. But to ensure no subsidence as necessitated above, the following two criteria need to be met:

(a) The excavation spans should either not exceed NEW (0 mm/m subsidence strain) or for sub-critical extraction the subsidence strain should not exceed 3 mm/m- i.e. safe-limit of ensuring no adverse impact (According to Indian standards) on the plane of reference, be it on sub-surface or be it on surface.

(b) The chain/barrier pillars between the excavation spans should have factor of safety (FOS) more than 2.0, i.e., long term stable or stable forever.

Accordingly, two options were recommended, as may be adopted by the mine management in their own stride and as approved by Mines Inspectorate, DGMS:

- Increasing the dimensions of the chain pillars, or
- Adopting a pattern of side rock bolting on the chain pillars of approved mine plans to enhance their strength

In each case, FOS was ensured to be e" 2, as detailed elsewhere [4, 5, 6 and 7].

Figure 2: Mine layout showing workings of XV seam and location of Borehole No. 1

Overlooking the recent subsidence research and management, if not corrected as above, there could be severe land degradation and mining-induced hazards on long-term basis, resulting into closing of production-activities. The re-design is being implemented now at Moonidih.

JHANJRA CM: TRAPPED WHILE SLICING GOING ON

In panel 10 of the highest producing mine in India, Jhanjra colliery, with CM (Continuous miner) deployment, goaf encroachment (and related geo-technical issues) was a major stumbling block, impeding the production and putting men and machineries at risk. The retrospection and re-design made as a result of comprehensive rock mechanics study and implementation done by the mine operator in the adjoining panel 11 after a trapping incidence of continuous miner (CM) in the neighboring panel 10 of this mine has got vindicated. It may be noted that the geo-mechanics complexities and potentiality of goaf encroachment was reported be more in panel 11 comparatively, however the latter achieved production over and above its assigned target with due regard to safety and productivity (Figure 4 & 5).

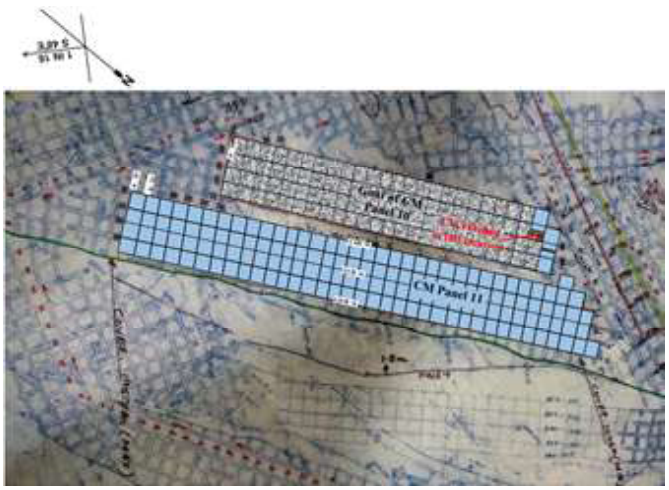

Fig 3: Part plan of Panel 10 & Panel 11

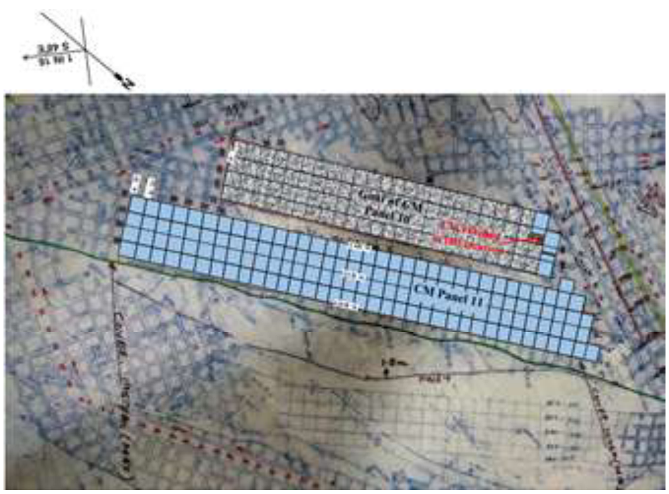

Fig. 4 : on-site scenario in Panel 10 while CM with accesories entrapped

A sequel of roof falls crossed over bolted-breaker lines into the working area but without any fatality or untoward incident as in Figure 4. The improper practice of leaving final under-designed snook after continuous three cuts (3.5 m x 3) and inadequate length of bolted breaker-lines used as goaf-edge supports could not arrest the goaf encroachment and therefore did not oblige the purpose of goaf-edge supports. Panel 10 was sealed prematurely with rest of the pillars left for ever unextracted, a loss of non-replenishable reserve of coal. There was no instance of goaf encroachment in Panel-11. The extraction sequences changed, the snook size modified and goaf-edge supports redesigned, as detailed elsewhere [2, 7, 8, 9,10, 11 12 and 13], were the primary reasons of this success narrative. Jhanjra mine could re-establish its prowess of underground coal mining technologies, the challenges met during longwalling were not included in this paper, for reason of conserving printing space only.

CHINAKURI MINE, THE DEEPEST IN INDIA: DEALING WITH COAL BUMPS

Bumps, roof-sloughages during extraction, even in existing developed galleries with associated problems of degree-III gassiness had upset the applecart such that the workings were disused and Chinakuri Mine no. 1 is waterlogged to the brim of the existing shafts. Coal bumps are characterised by a sudden release of elastic strain energy accumulated in the rock mass or pillars surrounding the mine workings in a short time period, the manifestation of excessive stress results in pillar or abutment collapse, the rotational collapse of cantilevered beds, etc. Obviously, these geotechnical problems have the potential to hazard, to detriment of the safety of mining personnel and equipment. Production was reported in the mine to invariably be disrupted for several days.

With an extractable reserve of ~65 Mt of semi-coking-I grade coal, the R-IV seam in the mine is the most potential workable seam of the mine. The R-IV seam had been extracted in the past by longwall method of extraction (by drilling and blasting) with hydraulic sand stowing, using individual friction props of 40 tonnes capacity. The overlain sandstone is very competent and consisting of massive layers of fine/medium-grained sandstone, having a thickness varying from 9m to 23m. The depth of cover of the working ranges from 500-700m. R-IV, known as Dissergarh seam, is therefore the only bump-prone seam in India, affecting detrimentally to many nearby mines, wherever present for extraction. In the better interest of high production and safety, Wongawilli method with CM deployment, but with stowing was suggested based on extensive numerical modelling and rock-mechanics study as elaborated elsewhere [12-20]. Nowhere in the world, this method with stowing has been tried. However, the method has a potential in its debut application in R-IV seam at Chinakuri mine no. 1, feasible due to following reasons:

I. Adoption of stowing, instead of caving, would help in mitigating bump proneness along with managing high-stress regime at high depths
II. Cutting of coal in place of drilling and blasting is a better method as far as mitigation of bump is concerned

The Wongawilli method has the inherent merits in the context of this mine, like (a) minimum no of entries for the sectionalized proposed panel, therefore less development of the coal in comparison and therefore less gestation period per panel i.e. quick development and quick retreat, a must for dealing with bumps, (b) steady and regular movement of straight face with faster retreat in continuous manner, etc.

The sand stowing scheme proposed would ensure effective and proper packing of sand, thus, ensuring better mitigation of bumps and management of strata as detailed elsewhere [21-22], Figure 5. Once this method is successfully demonstrated in an R&D trial panel, the methodology can be scaled-up:

- ✓ By modification to the existing Wongawilli system of mining
- ✓ The rate of stowing can be increased to a much faster rate
- ✓ Fast rate of coal evacuation and transportation system like Continuous Transport System (CTS) will be adopted

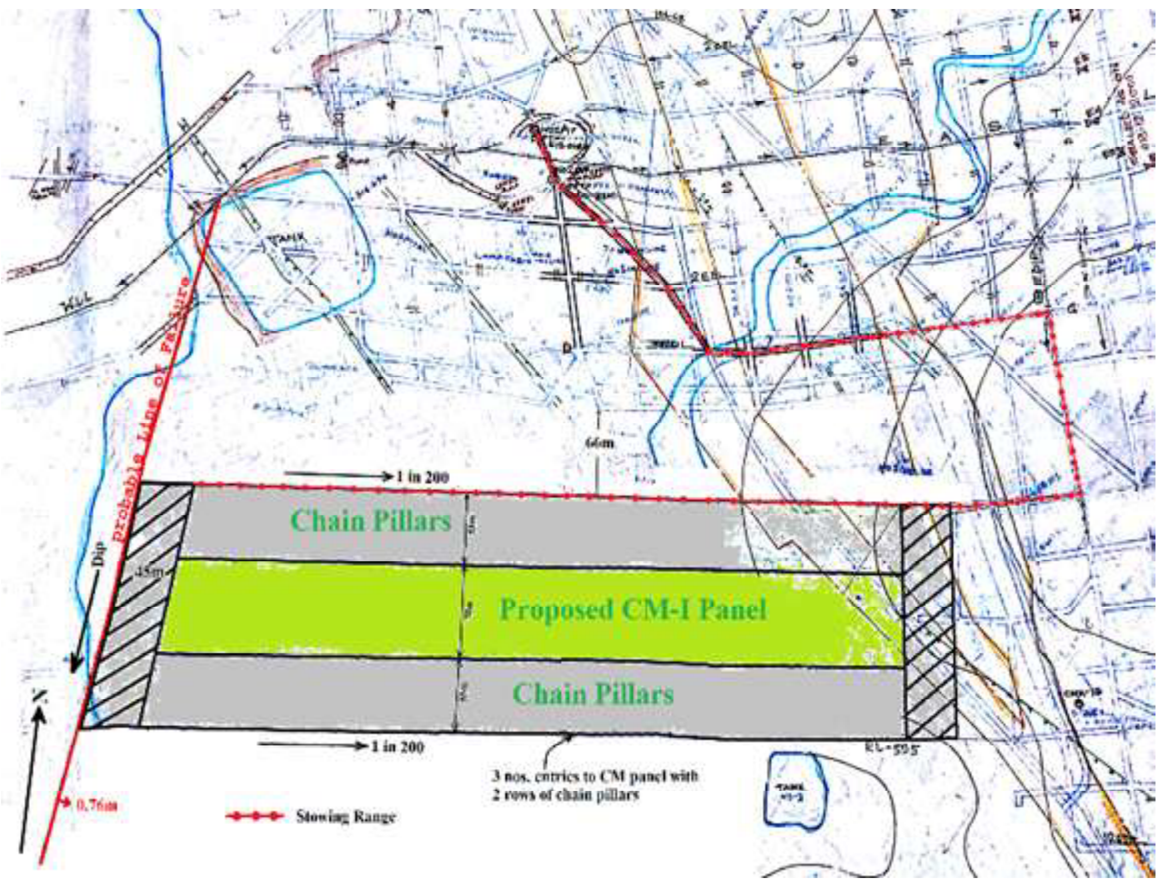

Figure 5. Part plan showing proposed tweaked CM Wongawilli Panel at Chinakuri mine no. 1

The mine at the moment has received due permission from the inspectorate based on the research presented in this paper to go ahead with implementing this innovative method for extraction of R-IV seam with a suite of geotechnical instruments.

DEALING WITH EXTRACTION BELOW MASSIVE COMPETENT STRATA IN AUSTRALIA: THE AUTHOR'S EXPERIENCE

The sandstone strata, competent and massive in nature in the immediate roof, was the main cause of goaf encroachment, also known as feather edging goaf fall, in Blue Mountain Colliery at more than 90 % ground-control related cases encountered. The increase of abutment stresses at goaf edges, as seen by indicator props (also called as 'police prop') consequently builds up high extraction-induced stresses due to the "bridge" of overlying sandstone strata across large spans without failing. This phenomenon is commonly observed in Australia, South Africa, and USA as a source of injury/fatal accidents, burial of machines like continuous miners (CM) etc. and it is very relevant in Indian context too, because in the various studies [23-26], it was found that the sandstones, fine to coarse-grained, is prominently present having a lion share of 65-95 % in Indian coal measures by thickness in a typical underground coal mine. It may be noted that the typical deformation in competent strata during final liquidation by CM following straight line of extraction, akin to longwalling would mitigate the problems and hence advisable. Based on the author's research, the first application of bolted-breakerlines (designed by him, also part of his PhD research) could be successfully applied at Blue Mountain Colliery, as described elsewhere [9, 10, 11 and 13]. He could identify three sets of observations, occurring in a cyclic manner in a panel of "split and slice" method (i.e. in bord and pillar pattern) at a depth 230-260 m with seam thickness of 1.6-2.1 m, having pillar of 20-35 m x 37.5 m (center-to-center) dimension and gallery width of 6 m. The pattern of goaf encroachment (feather edging goaves) at the colliery is consistent and well developed, the adverse effects on production and safety were mitigated by implementation of his research findings.

In about 400 periodic weighting-events monitored in earlier longwall panels at South Bulga, three out of nine serious rapid-convergence events were reported to have resulted into the face stoppages and consequent loss of production, costing (directly and indirectly) well over a million dollars. This required undesirable face recovery operations too. As shown in Fig. 6, up to the face retreat of 80 m from its start line, there were small movements (100 mm) of anchors recorded even for the anchors in the immediate and main roof. The other boreholes of shallower depth located nearby of the two surface boreholes (with extensometry as shown in Fig 1) were found to be holding water. There were no appreciable downward strata movements i.e. subsidence on surface remaining less than 5 mm (Mills, 2000). When the face retreated ~ 200 m from the start line, a dome-shaped zone (shaded portion in Fig. 6) of large downward ('en masse') movements were interpreted to be extended up into the overburden to about the location of approximately 60 m above the seam. The surface subsidence had reached to 600 mm value for a seam thickness of 2.3 m (average). Later on, the maximum subsidence was observed in a delayed manner to be 1.38 m, i.e. 60% of the extraction thickness as observed by the author. It may be noted that such maximum subsidence in Indian mining conditions was observed to maximum 69% of the extraction thickness [3, 7, 23 and 24]. Indian coal measure strata are, in geological history, placed adjacent to Australian counterpart, forming Gondwana land, later on to be separated presumably due to plate-tectonic movements and so the observations of overlying strata are found to be similar. The maximum rate of face (250m width) advance was ~ 30.5 m per day. The maximum daily production was 30449 tonne from a single double-drum shearer, the maximum yearly production being 4.02 Mt (in 1996) [9, 10, 11 and 13].

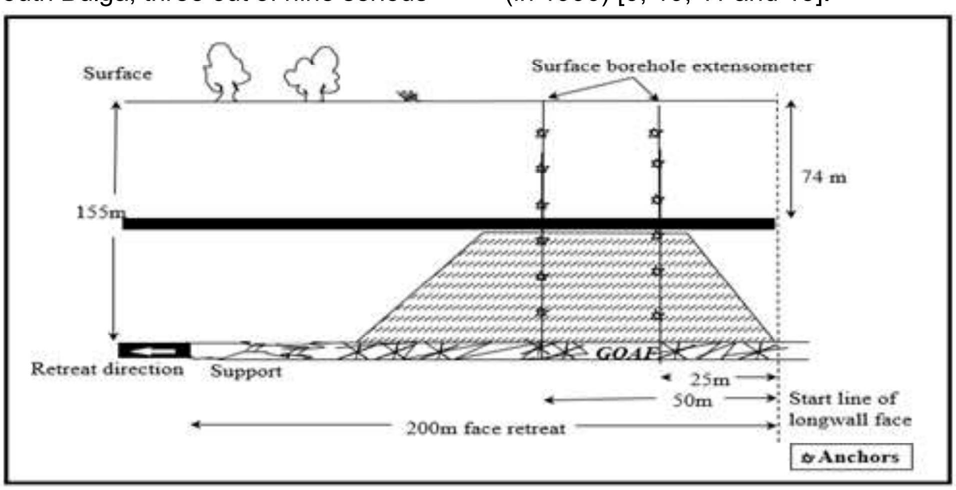

Fig. 6: Schematic diagram showing surface extensometry over longwall panel E1 (not to the scale) when the face retreated 200m.

CONCLUSIONS

In India, extraction of coal by underground methods of mining could not its due importance, primarily due to geo-mining complexities likely to be encountered and due to non-application or sometimes reluctancy of application of holistic and comprehensive R&D back-up and support. However, the reserve amenable by an open cast mining method is fast exhausting and future of Indian coal mining industry lies with underground mining only. The conventional mining methods practicing majority of the coal mines in India yield less production, productivity as well as safety in comparison to high-producing continuous-mining based fast-retreat methods as discussed above. Underground coal mining at deeper cover encounters difficult rock mass structure, complex stress regimes, complex geo-environment due to increase in gas content, rise in temperature etc. Technological development for extraction of coal from deep-seated coal seams and locked-up coal from developed pillars are vital requirement for the industry. Adoption of highly mechanized underground mining technologies may play a leading role to meet the challenges of Indian underground coal mining industry.

Underground winning of coal is considered to be a part of clean coal technology in comparison to opencasting. Proper R&D initiatives should be taken to overcome the technological hiatus for sustainable underground extraction coal. Development and application of robot and remote operation technologies will technologically empower Indian coal industries for efficient exploitation of underground coal seams with due regard to safety, economy and environment. Indigenous R&D efforts, taking steps meeting the clarion call "Atmanirbhar Bharat', are needed to overcome the problems of underground mining for sustainable underground extraction of coal.

As also being done on pan–India basis with (CM) Continuous Miner deployment, only in Coal India Ltd., the state-of-art high-production technologies would be expected to meet target capacity of 2.78 MTPA from 8 u/g mines. There are 20 u/g projects (in 19 Mines) also in pipeline with CM deployments with a total capacity of 12.11 MTPA. In this direction, this paper would be a path-setter in the sense that it provides understanding of geomechanics and related geo-technical issues on site-by-site basis and underlines their importance. With at-site observations and followed by in-depth analysis with application of necessary engineering judgements, it is possible to address complexities of underground coal mining at depths, along with operational issues in working areas, which may go a long way to ensure better safety and productivity in many such locales in future. It is to be noted that coal production, transport, usage and ash disposal employ more than one million persons. Income from coal royalties constitute almost 50% of the total earnings of states like Jharkhand and Odisha [27 and 28] which are some of the least developed large Indian states. Path dependencies of coal use therefore have strong socio-economic and political linkages, in addition to the huge investments in coal infrastructure that would have to be managed in the case of an accelerated coal transition in India. These issues are now important especially in the context of COP 26 and its pledges. These aspects are not discussed in this paper so as to keep the intent of presenting here only technological aspects only. However, the adopted policy of a targeted and simultaneous strong push towards renewable energy in India, apart from 'effective' resource utilization of coal resources is admirably relevant, estimated to need additional investment to the tune of US$ 140 billion [29]. The higher profit receipts may be utilized for the purpose. CIL, NTPC and other profit-making private coal companies are aggressively inveting in renewables.

ACKNOWLEDGEMENTS

The author is thankful to the organizers and reviewers of National Seminar on Sustainable Development of Minerals and Coal Resources, to held on 17-18 December 2021, to accept this paper for presentation AKS University at its diamond jubilee celebration at Satna City and also providing necessary guidance, especially Prof G. K. Pradhan. A profuse thanks are also due to the Area General Managers of various mines-areas, Manager, Surveyors and other Mine Officials for helping the comprehensive research works to complete, parts of which have become important inputs for the preparation of this technical paper. The author could get opportunity to be involved in subsequent implementations at the sundry sites, thus understanding practical application aspects also and validation of his approach, a brief of what has been detailed in the paper. Thus, gratefulness is due to many persons involved who had helped the authors, though indirectly, to present in this paper, what may be for the benefit of the readers/seminar delegates. The Australian case-studies as described in section 5.0 were thankfully presented, in detail, to a limited audience at 37th US Rock Mechanics Symposium (6-9 June 1999) by the author.

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The Indian Mining & Engineering Journal, Vol. 60, No.10-11, October-November 2021, pp.38-42
Printed in India, @ IME Publications, ISSN 0019-5944

Impact on Ambient Air Quality Due to OCP-1 Working in the Srirampur Area, SCCL

Racharla Sravan Kumar* Ajeet Mehra**

ABSTRACT

Demand for coal has been rising frequently which is to be matched by making increase in production with high productivity. So, to achieve this goal, open cast mining has been widely applied. In open-cast mining, the production activities directly affect the environment. The problem of air pollution is increased by mechanization and increased production rates. The main sources of pollution are drilling, blasting, haul roads, dropping, crushing, and conveyor These activities released dust particulate matter and gaseous pollutants into the environment. Which are needed to maintain within the limit to avoid danger to the environment. For this continuous monitoring and assessment of air quality are required. In this paper, ambient air quality assessment has been conducted at Srirampur OCP-1, SCCL, Telangana. Samplings have been done in seven locations namely, core zone SRP-OCP site office, SRP-OCP base workshop, and buffer zones- Srirampur village, Srirampur colony, Sitharampalli village, Ramaraopet village, and Indaram village. The air quality index for the given site was calculated, and parameters such as PM10, PM2.5, SO2, and NO2 were compared to CPCB and NAAQS.

Keywords— Air quality, Air Quality Index (AQI), Monitoring Stations

INTRODUCTION

The major sources of pollution in open cast mines are blasting, drilling, OB loading and unloading, material handling, and workshops Mining dust is a serious health hazard and can cause diseases like pneumoconiosis and silicosis (respiratory diseases). Because of their negative impact on human health and vegetation and their contribution to environmental acidification, sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) are significant primary environmental pollutants.

Polymers such as PM10 and PM2.5 can be divided into various categories, based on the part size, generally measured in terms of particle weight per metre cube. The production of dust is well known to be linked to each mining activity. Dust generation is associated with each operation Clean air is important to our health and the environment. However, since the industrial revolution, the quality of the air we breathe has deteriorated as a result of human activity.

Opencast coal mining includes a variety of operations, such as overburden removal, drilling, blasting, mineral loading, haulage, and unloading, all of which produce particulates through various mechanisms. Overburden removal contributes 7% of total particulate matter, while topsoil removal contributes 1%, coal production contributes 72%, coal extraction contributes 3%, and wind contributes 17%

Here, Dragline, bucket wheel excavator, surface mineral, drilling machine, shovel, loader, dumper, dozers, graders, etc. were the major HEMM producing/responsible for generations of dust in opencast mines. Surface Miner also generates dust but the quantity is less as compared to blasting etc.

The dust generated by mining activities is classified into three categories:

1. Point source
2. Line source
3. Area source

Drilling, loading, overloading (O.B.) and dumping of coal are point source. Similarly, haul roads, unpaved roads and mining paths are Line sources and the entire mine is covered by Area Source.

The dust concentration will be higher in the mine sites than outside of the mine, and the workers employed in the mine will be the most affected, and long-term exposure may cause severe diseases to protect them from various diseases caused by dust. To minimise dust concentration, we must forecast it and implement appropriate control steps.

Meteorological parameters have the greatest effect on dust dispersions; during the winter season, dust dispersal is greater, it is more in the downwind direction, and dust

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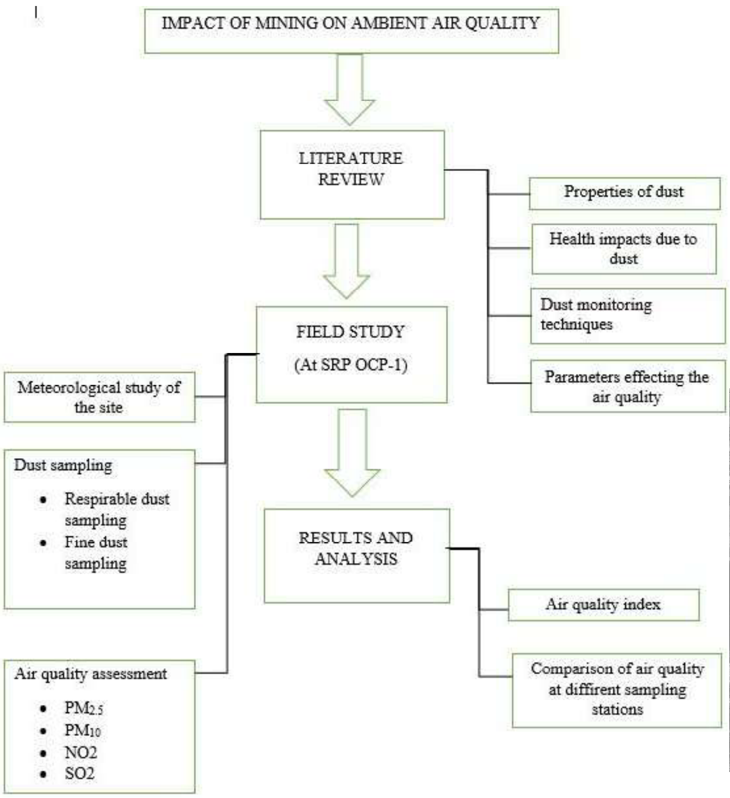
concentrations can be found up to 500 metres from the source.

METHODOLOGY



STUDY AREA

In the present work, Srirampur opencast I&II integrated project of M/s. Singareni Collieries Company Ltd. was taken for monitoring Air Quality Assessment.

The Mining lease of Srirampur opencast Project-I&II integrated project block is located in the southern part of the somagudem-indaram coal belt between Srirampur-1 Inc. block and Indaram-1 Inc. block in the south Godavari valley coalfield. This Srirampur opencast block is covering an area of 5.33 sq.km lies between the north latitude 18°49'04" - 18°51'12" and east longitude 79°29'17" - 79°32'02" and falls in the survey of India topo sheet No. 56 N/5, 56 N/6, 56 N/9 & 56 N/10.

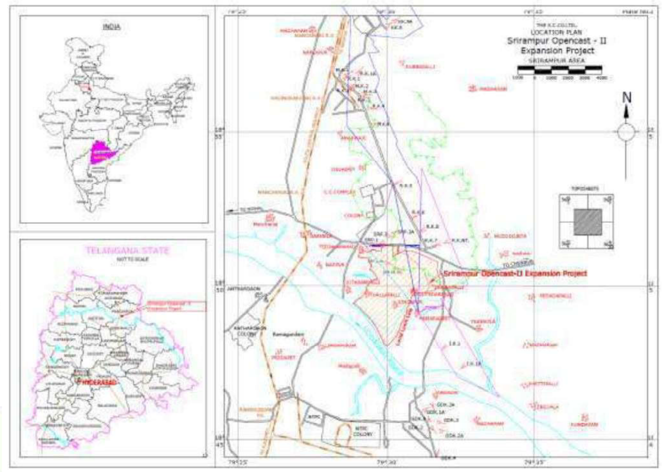


Figure 1: Location of Srirampur opencast Project

Figure 2: Satellite View of Srirampur OCP

Method of working

The project is a mechanized opencast coal mining project with the Shovel Dumper combination. The Overburden is proposed to be removed by outsourcing throughout the life of the Project whereas coal of G – 9-grade extraction is by departmental HEMM.

The proposed project is a "Category–A" project as per the SO 1533 dated 14.09.2006 and subsequent amendment vide SO 3067 dated 01.12.2009. As such, the project area (Core Zone) and 10 Km area around the project area (Buffer Zone) is taken as the study area. The mine is covered in Srirampur Village, Naspur Mandal & Mancherial District of Telangana State.

The study of the mine is broadly divided into four headings like.

- Selection of air quality monitoring sites in and around SRP-I OC
- Assessment of air quality of the study area.

- Calculation of Air Quality Index of the study area.
- Recommendations to mitigate Air Pollution.

Study period

The baseline data for pre-project environmental status was collected during July 2020 – September 2020 and is.

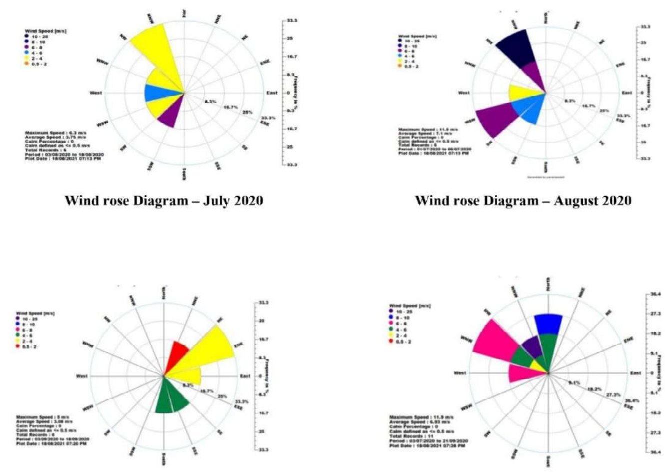
Summary of Micro-Meteorological Data (01.07.2020 To 30.09.2020):

The predominant wind direction is West- North West (W-NW) i.e. wind is blowing from west to North West direction and Calm conditions prevailed is 20.93% during the study period. The maximum wind speed recorded was 11.4 m/s. The maximum temperature recorded was found to be 45.6°C while the minimum temperature was 19.3°C and the average temperature is 30.90°C. The average relative humidity was found to be 46.12%, whereas solar radiation is in the range of 1.0 to 874.0 W/m2. The total rainfall was found to be 599.4 mm. The summary of micro-meteorological data (wind speed, wind direction, temperature, relative humidity, rainfall and solar radiation) for the entire study period is given in **Table** , Summary of micro-meteorological data generated for the entire study period (July 2020 - September 2020) is given in **Table No. 1** and the monthly wind rose diagrams along study period shows in the **Figure No 3**.

TABLE 1: MICRO-METEOROLOGICAL DATA

Sr.No	Parameter	Min	Max	Mean
1	Temperature (°C)	19.3	45.6	30.90
2	Wind Speed (m/s)	(calm %) 20.93	11.4	1.7
3	Relative Humidity (%)	8.6	99.9	51.4
4	Solar Radiation (W/m2)	0	874	175.17
5	Predominant Wind Direction for the entire study period	(North- West), followed by West-North West (W-NW)		
6	Total Rain Fall (mm)	599.4		

The locations for air sampling were selected based on joint site survey, ex-animation of topo sheet of the project area, secondary micrometeorological data analysis, historical wind direction pattern and availability of resources for ambient air quality monitoring and noise level monitoring.



Wind rose Diagram – July 2020 | Wind rose Diagram – August 2020 | Wind rose Diagram – September 2020 | Wind rose Diagram – Entire study period

Figure 3: Monthly wise Wind Rose diagram

Different air pollution parameters like particulate matter less than 10ìm size (PM_{10}), particulate matter of less than 2.5ìm ($PM_{2.5}$), Sulphur Dioxide (SO_2) and Nitrogen Oxides (NO_2) have been identified as critical parameters relating to project activities. To assess ambient air quality, seven air quality monitoring locations were identified in the core zone and buffer zone (10 Km. radius study area) of the project, two air sampling location represents core zone and five locations represent the buffer zone of the project site. Details of sampling locations are given in **Table No 2.**

TABLE 2: AMBIENT AIR QUALITY MONITORING LOCATIONS

Station Code	Station Locations	Zone	Direction w.r.t Project	Distance w.r.t Project Boundary in KM	Category
CA1	SRP OCP Site Office	Core			Industrial
CA2	SRP OCP BWS	Core			Industrial
BA1	SRP Village	Buffer	N	0.664	Residential
BA2	Srirampur Colony	Buffer	N	1.1	Residential
BA3	Sitharampalli village	Buffer	NW	0.903	Residential
BA4	Ramaraopet village	Buffer	SE	1.4	Residential
BA5	Indaram	Buffer	E	2.6	Residential

Figure 4: Ambient Air Quality Monitoring Locations on Map

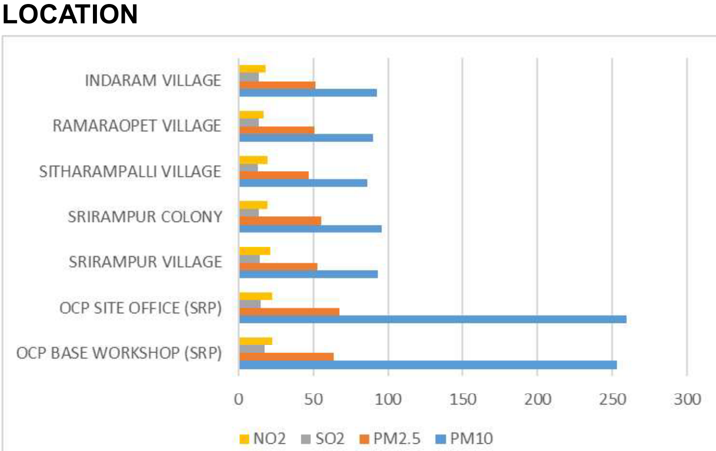
RESULTS AND DISCUSSION

Ambient Air Quality Monitoring of Srp Ocp-1

The air quality assessment has been carried out from the sampling point obtained from the wind rose diagram. From monitoring at various locations around Srirampur opencast coal mine-1, a comparison can be made for the dust concentration between different locations in core zones and buffer zones.

The comparison of average concentration around Srirampur opencast coal mine reveals that in core zone near OCP site office location PM_{10}, $PM_{2.5}$ and NO_2 was recorded maximum and remaining SO_2 was maximum at Srirampur OCP base workshop. In the buffer zones near Srirampur colony location, PM_{10} and $PM_{2.5}$ were recorded maximum and the remaining SO_2 and NO_2 was maximum at Srirampur village.

TABLE 3: COMPARISON OF AVERAGE CONCENTRATION OF DUST AT DIFFERENT LOCATION



Results of AQI of Srp Ocp-1

An overview of the AQI for the readings recorded by the AAQMS network in OCP-1 (Srirampur) has been calculated based on 4 parameters- PM_{10}, $PM_{2.5}$, SO_2 and NO_2; using the calculation method provided by CPCB. According to this methodology, the highest sub-index value from that AAQMS (Ambient Air Quality Monitoring Station) is considered as the AQI.

TABLE 4:COMPARISON OF AVERAGE CONCENTRATION OF AQI RANGES IN DIFFERENT LOCATION

LOCATION	OCT	NOV	DEC	JAN	FEB	MAR
SRP-OCP SITE OFFICE	168	183	191	189	192	196
SRP-OCP BASE WORKSHOP	181	181	191	194	193	198
SRIRAMPUR VILLAGE	87	93	87	93	82	83
SRIRAMPUR COLONY	91	91	93	90	91	94
SITHARAMPALLI VILLAGE	62	67	81	76	76	77
RAMAROPET VILLAGE	78	78	84	87	83	85
INDARAM VILLAGE	82	85	87	80	88	80

CONCLUSIONS

This study was conducted at OCP-1, working at Srirampur SCCL, Telangana. Ambient air quality monitoring has been conducted in this mine. In monitoring, the following parameters are considering for ambient air quality monitoring data are (PM_{10}, $PM_{2.5}$, SO_2 and NO_2).

Air quality assessment has been done using monitoring data collected from the proposed sampling point; from the above data we have noticed core zones and buffer zones. In core zone PM_{10}, $PM_{2.5}$ and NO_2 were recorded maximum in OCP site office are 265.000µg/m^3, 67.900µg/m^3 and 22.720µg/m^3, and remaining SO_2 recorded maximum in OCP base workshop location are 17.500µg/m^3. In buffer zone PM_{10}, $PM_{2.5}$ was recorded maximum in Srirampur colony location are 96.000 µg/m^{3}and 56.100µg/m^3, and remaining SO_2 and NO_2 recorded highest in Srirampur village location are 14.100µg/m^{3}and 22.100µg/m^3. Which are under the standards of NAAQS (National Ambient Air Quality Standards) and CPCB (Central Pollutants Control Board).

The air quality index has been determined from the above monitoring data area from October to March. In the core zone, both monitoring locations OCP base workshop and OCP site office are in moderate categories of AQI. The maximum AQI 198 was noted in March in the OCP site office which was indicated as moderate categories. In the buffer zone, all the five monitoring locations Srirampur village, Srirampur colony, Sitharampalli village, Ramaraopet village and Indaram village are in satisfactory categories of AQI. The maximum AQI value 94 was noted in March in the Srirampur colony.

It has been noted from the literature survey that even one million tons per year of coal production from an opencast mine may significantly damage the surrounding environment to an extent if proper control measures are not adopted in the mine. It is the control measures adopted at various polluting sources that decide whether the environment in the mining and surrounding area will be affected or not.

From field monitoring data collected for air quality in and around ocp-1 Srirampur mine, it is evident that the control measures adopted by the mines at most of the dust generating sources were effective, and the air quality of the area was least affected except some locations even at the current production levels.

However, if coal production has to be further increased, then additional effective control measures as suggested in the recommendations have to implement in mine for better control of air pollution.

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The Indian Mining & Engineering Journal, Vol. 60, No.10-11, October-November 2021, pp.43-46
Printed in India, @ IME Publications, ISSN 0019-5944

"e Det ft"- Electronic Initiation System: A versatile tool for environment Friendly Blasting

Ajit Tatwadi* D. Halmare**

ABSTRACT

After a period of development and experimentation of around 20 years, Electronic Initiation System have now come to maturity and are becoming first choice of many mining applications like Tunneling, Civil Works, Demolition Works, quarrying, large Scale Open Pit Mining and underground mining.

The main objective that pushes electronic detonator development was improving the delay accuracy to the extent unreachable by conventional pyrotechnic delays (Electric / Non Electric). This highly improved accuracy firstly benefited to the field of vibration control (vibration induced due to blasting), where because of consistence similar results, it is possible to have repeatable results. This repeat-ability ensures then to the reliability of firing sequence optimization. With Electronic Detonator along with optimized firing sequence produces smoother seismic results as compared to conventional Pyrotechnic system.

The Vibration based approach was then been extended to fragmentation field, where size distribution of blasted rock has been analyzed and linked to the accurate & repeatable firing Sequence. Another step ahead was tried with Drill to Mill Concept for the project for evaluating blast performance based on downstream processes indicators like Shovel Productivity, Crusher throughput, Energy drawn by crusher per unit etc.

Today Electronic Initiation System is often regarded as insurance against poor blast performance and safety hazards. Electronic Initiation System is best available Initiation System, a term employed in regulations dealing with risk mitigation. May the risk be of Blast Induced vibration, Fly rock, Air Over pressure etc. These risks can be environmental (vibration, Fly Rock, AOP) but they can also relates to Safety Standards and Financial matters.

In terms of safety, the occurrences of out of the sequence firing has been greatly reduced. Frequency of the blasting can also better managed. The main advantage of Electronic Initiation System is that, most initiation related issues are now known before the blast because of testing facilities at each step with electronic Initiation System, this help us to take adequate and corrective measures before the blast happens, thus avoiding hazardous situation like excavating in presence of explosives, fly rock and excess vibration due to extra effective burden etc.

INTRODUCTION

GOCL Corporation Limited and IDL Explosives Limited developed ingeniously, "e Det ft" Field Programmable Electronic Initiation System with In House R & D. "e Det ft" is having in built electronic chip (Circuit) to fire a detonator after a preset delay time is designated. Unlike Conventional Pyrotechnic Detonators, which are factory made delays, with e Det ft desired delay timing can be defined or programmed in field as per requirement on bench. "e Det ft" incorporates self-diagnostic/ Self calibration properties. "e Det ft" require specific signature / Digital Coded signals from special Exploder (e Exploder) to initiate thus make it safest technology.

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Why Electronic Detonator???

Parameter	Pyro Technic Delays	E Det ft (Electronic Det)
Accuracy	High Scatter -2 to 5 % . Timings may overlap in small delays	Very Accurate, Typically +/- 1ms for assigned delay
Reproducibility	Poor depends on Element Length, Accuracy & composition	High - Precise Electronic Components are available
Shelf Life	Poor - Timing changes with longer storage	Very good - No timing changes with longer
Security	Poor - Can be initiated by ant DC battery Static source	Very High - Can be initiated with Manufacture f Blasting machine
Safety	Poor - Not safe against static / emf	Highly safe- against Static and emf and odd field conditions
Communication	Not Possible	Two way ommunication in all stages

System:

"e Det ft" System consists of following:

1. **"e Det ft"** - Precise field Programmable electronic Detonator, with desired length of lead wire
2. Programmer Tester
3. Field Circuit Tester
4. e- Xploder
5. Polarizing Connectors
6. Surface connectors

1. **"e Det ft"** - "e Det ft" is a precise Electronic Detonator having built in electronic circuit to fire the detonator. E Det ft is standard size detonator, with precise electronic detonator at one end and a male female connector at other end that will function in all standard size boosters that are used in non electric blasting. E Det ft uses two core insulated copper wire for down-line. Higher resistance to electronic discharge and high induced ground current make it safer to use in all mining conditions.

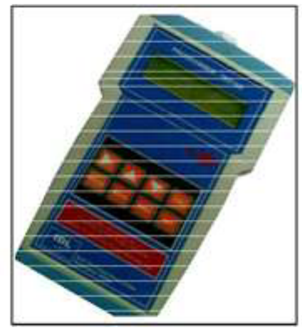
Features:

- Firing Time range - 0 ms to 9000ms at increment of 1 ms
- Accuracy - less than 1ms scatter
- Operating temperature - -20 to 60 degrees

2. Programmer Tester-

Hand held, rechargeable battery operated unit that can perform following functions

- Programming the identity number and delay time to a detonator in the field.
- Test the functional integrity of the detonator.
- Read the programmed data.
- Delay period of 0ms to 9000 ms can be assigned to any detonator



3. Filed Circuit Tester:

Hand held, rechargeable battery operated unit to test the field connection

Tests one row of connected Detonators Communicates with each Detonator using Detonator Number and waits for an acknowledgment

It can test individual detonators or a sequence of detonators in a row.

4. e Xploder-

Rechargeable battery operated unit to initiate the Detonator Circuit

- Powers the connected circuit
- Sends digital signature signal to the detonator and initiates the blast by signaling the start of the delay timing.
- Digital Safety key.
- The firing sequence can be aborted after powering detonators
- Powers 300 detonator connected in 4 rows Maximum of 75 detonators in a row

5. Polarizing Connectors -

- Used to connect the e-Xploder to the field circuit
- Enable non-polarized connection of the blasting cable to the field circuit
- Ensures polarized connection of the field circuit

Improved Accuracy -

The Single most driving driving force that pushes development of electronic detonators is its accuracy. The average accuracy of best pyrotechnic delay system is around 2 to 5 % but these can deteriorate with aging of the product or even if products of different batches are used together. This means for a 400 ms DTH delay even with high accuracy (2 %) , the scatter can be 8ms. There is high risk of overlapping if short delay surface connectors are used, which leads to hole overlapping or firing out of sequence. Such situation can potentially create excess vibration, Fly-rock and poor fragmentation.

These Long down-hole delays (called Cooking time) are used to create total / limited burning front. All surface detonates fires before the first blast-hole detonation, thus avoiding cut offs of DTH/ Surface lines by the movement of rock mass.

On one hand Long Down-hole delays increases safety of blast but on the other hand create inherent cause of inaccuracy, can lead to other safety issues.

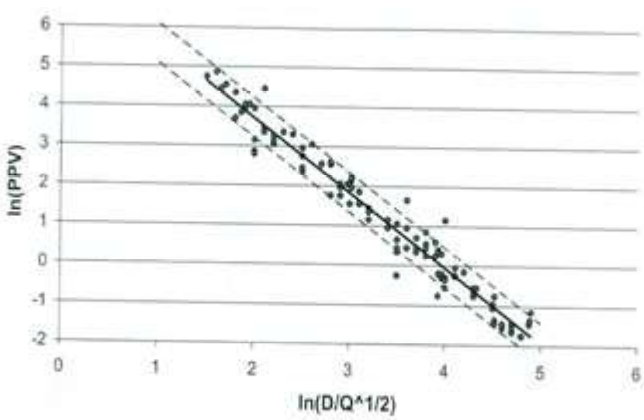
Electronic System brought remarkable improvement in delay accuracy, improving precision of Pyrotechnic delays by a factor of 100. The accuracy of ranges for + or - of 1 ms for the programmed delay. This drastically improved accuracy completely eliminate overlapping of delays and firing out of the sequence, because all detonators receives coded signals simultaneously and the delay is counted down by digital clock when the firing capacitor releases energy to set off the detonator. Thus all electronic blasts have total burning front.

Vibration Based Approach

The first area benefited by improvement in delay accuracy is Vibration Control. The predication of blast induced vibration is done by Scaled Distance formula

PPV = K (D / W^0.5) ^ b
Where,
K & b are Site Constants
W is the maximum charge per delay in Kg
D is the distance between blast and measuring point in meter

This formula is used to determine maximum instantaneous charge when no other information is available for a new site



In the graph above, data from a Limestone quarry are plotted and the trend-line giving the best coefficient of correlation (0.95) gives K= 1740 and α=1.88 The two dotted lines enveloping 90% of the data have the same α (parallel lines) and K=1056 and K=2870.

This means that for a Maximum Instantaneous Charge of 120 Kg, the vibration prediction at 300m would be

PPV = 1740 x (300/”120)^-1.88
= 3.54 mm/s

But the same calculation repeated with values of the 90% confidence envelope gives

PPV = 1056 x (300/”120)^-1.8
= 2.09 mm/s

PPV = 2870 x (300/”120)^-1.88
= 5.69 mm/s

This hints that even with a nicely fitting regression analysis, a 90 % confidence level gives a very vague range in the prediction (- 1.36 mm/s to+2.24mm/s) with respect to the nominal values of 3.45 mm/s. This amount to an overall variation 3.60 mm/s and shows that forecast derived with this methods are are not very accurate or too broad to be of any practical use (if 90 % confidence level is used).

Similarly calculating Max Instantaneous Charge ensuring PPV value below threshold of 5 mm/s at distance of 300 m would give value of 178 Kg with average parameter K &b, but same calculations will give a MIC of 105 Kg when using 90% interval parameters This amounts to only 59 % of the Original value and shows the inaccuracy of the prediction formula. This formula does not take into account the confinement of the charge. It is well known for instant that over-drilling will certainly lead to high PPV. Similarly excessive burden will also cause high PPV values. But this is not properly taken into account into this basic formula.

Inaccuracy because of
• Not considering confinement of explosives (over drilling / excessive burden leads to higher vibrations !!!)
• Scatter in pyrotechnic delays are too high
• Repeatability of identical blasts are not possible with pyrotechnic.

Vibration Based Approach

Once vibration control field proved that new;y achieved accuracy in delays allowed an optimization of the firing sequence with respect to one of the results of blasts, it is simple step forward to attempt optimizing firing sequence but now with respect to other result of blast ie blast induced fragmentation of the rock mass. The size distribution of the muck-pile can be determined by digital image analysis software and compared to distribution of other muck-piles where different timing sequence is used. If the rock mass is consistent enough this method allows optimizing firing sequence.

For a metal mines, the key performance indicator is not fragmentation itself but it is the performance of the down-stream process. What really matters to profitability of mine is not size distribution of muck pile but diggers' productivity or the ease of ability to recover greater percentage of metal. This concept of assessing the performance of blast not on physical properties but on the actual performance of down-stream process led to what is called " Drill to Mill" optimization project. This means that optimization is still possible even if physics of phenomenon is not completely understood. Drill to Mill concept fully take into account the vertical integration of the performance of the blast through entire processing chain

Improved Safety

Safety of electronic Detonators is one of the highest standards with respect to radio frequency interference, stray ground current and any external source of electricity. This is because an electronic module acting as a fuse, with the fuse head not directly connected to the wires. This is also due to the parallel configuration of the system, no loop, no dipole antennas like in case of standard electrical connection. Electronic System also gives additional benefits of communications with the detonators with the help of Hardware at all stages may be at Initial Checking, Programming, network testing or Firing of the detonators. Total burning front ensures there is no cut offs due to line cut once the firing command is given, dramatically reduces the occurrences of misfires.

Financial Benefits

Apart from benefits of Electronic Initiation system like, improved accuracy, Vibration control increased case etc, some benefits are inherent to the system used like flexibility in firing sequence, repeatability, it will be unwise to expect all the [potential benefits of electronic initiation system every time for every application. All these benefits cannot be achieved without control on two factors which influence the blast results beside timing ie. Energy distribution (Accurate and type of drilling pattern) and amount of energy (type and strength of the explosive). In some sites it will be necessary to go from fragmentation based to a vibration based timing sequence as blasting may come closer to sensitive locations. Or vibration based timing sequence may lead to an inappropriate muck pile shape for the given type of diggers being deployed. There are many outcome of blast that are influenced by timing sequence (Vibration, Air-blast, Back Break, damage control, throw, fragmentation, timing of the blast etc) and one must first prioritize them in order to select most appropriate timing sequence. In this situation there is no substitute for experience

Electronic Initiation System has vast applications in Tunneling, Civil Works, quarrying, Large Open Pit Mines, metal mining, under-ground mining.

Conclusions

Electronic Initiation system has brought huge improvement in terms of accuracy and programmability (ability to choose desired delays on bench). Most of benefits are derived from these two factors. Where Non Electric and Electric system are restricted to use of factory programmed fixed standard delays. Electronic system offers freedom for choosing desired suitable delays for optimizing firing sequence. But this freedom is a success, if one knows what to do with it. The advanced technology of electronic detonator must be followed by a better understanding of firing sequence design and its application. The blasting Software can be tried to define for calculating burden relief vector in ms/sec rather than fixed intervals to define the delays. This method will ensure consistency, which keeps smoother results. Future studies will definitely will throw more light on by professional process where assumptions & objectives are clearly defined and results are scientifically quantified. **Blasting is more an art than science**

I am thankful to the management of M/s GOCL & IDL Explosives Limited, who not only inspires me to write this paper but also gave their kind permission. The views expressed in this paper are solely of the author and in no manner GOCL/ IDL Explosives Limited is responsible for it.

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The Indian Mining & Engineering Journal, Vol. 60, No.10-11, October-November 2021, pp.47-56
Printed in India, @ IME Publications, ISSN 0019-5944

Evaluation of Stability of Bench Slopes in Opencast Limestone Mines – Case Studies

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ABSTRACT

This paper presents the overview of slope stability problems, challenges and importance of various approaches including numerical models, empirical approaches etc. Details of the findings of scientific studies on application of slope mass rating and the modifications made in the conventional system of slope mass rating through the project sponsored by the Ministry of Mines -Government of India is also presented. Basic slope design criteria and its application for design of slopes is also illustrated. As a part of the studies, the details of investigations, geomining conditions of study sites, empirical models developed and applied for some of the limestone mines is included in this paper.

INTRODUCTION

Presently, due to ever-increasing demand of minerals for the country, it is very much required to have the opencast mines at a greater depth. Increasing depth also increased the severity of slope stability problems of the opencast mines. Unlike the previous quarrying practices at shallow depths, now-a-days, study the stability of slopes of working benches and waste-dumps of opencast mines and analyzing their stability has become a challenge for the mining community. For the purpose, besides design of slopes by modeling or analytical methods, it is pertinent to utilize various techniques for monitoring the slopes to understand the status of its stability and early detection of instability of slopes for opencast mines. Many fatal accidents due to slope failures in Indian mines indicate the urgent need of conducting slope monitoring for the working benches as well as dumps. With increasing depth of surface mining excavations, the problem of stability of slopes is becoming a major concern for the mining engineers (as shown in Figure 1). In mountainous regions, landslides are a major safety hazard, particularly in the rainy season. Stability analysis of the benches & design of slope parameters, Design of ultimate pit limits, inter-ramps, and safety berms, Design of barrier between water bodies and the open pit, Design of spoil dumps. Monitoring of slopes and landslide hazards are important. working benches of a typical coal mine is shown in Fig 1.

Slope stability is a major problem in opencast mines. Slope stability in a large scale open pit mining operation is a matter of concern for the mine management so as to establish safety throughout the life of the mines. Again

Figure 1: Benches in a typical opencast mine

the profitability of the open pit mines is dependent to a large extent on the use of steepest pit slopes possible, provided they do not fail during the life of the mine. Steep slopes do need a great amount of analysis so that the whole operation is safe and profitable. Now days the open pits are whether large or small scale industries reaches more depth results unstable it is major concern in designing the unstable slopes. The most common methods used for designing the slopes are by conventional methods such as (Limit equilibrium, Kinematic analysis) methods and Numerical methods, convenient methods can be applicable for different mode of failures.

Instability of rock slopes may occur by failure along pre-existing structural discontinuities, by failure through intact material or by failure along a surface formed partly along discontinuities and partly through intact material. Although certain fundamental failure modes are recognized, the mechanisms of slope failure are varied and complex. Such mechanisms are governed by the engineering geology conditions of the rock mass, which are almost always unique to a particular site. An understanding of failure

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mechanisms requires a knowledge of the physical, mechanical and strength properties of the intact material and discontinuities which make up the rock mass, as well as the structural geology and hydrogeology. These engineering geology parameters also must be evaluated with respect to the slope geometry to determine failures which are kinematically possible. Only after obtaining a reasonable appreciation of the possible failure modes can a rational mechanical stability analysis be carried out. Both two-dimensional and three-dimensional failure mechanisms should be considered in assessing the design of rock slopes. Simple analyses methods are used initially to identify those possible failures which could control slope stability. More complex and detailed analyses usually are required for a few critical failure modes which could control stability, or where a more complex type of failure mechanism is envisaged. Complex failure mechanisms are usually identified when assessing previous slope failures. More detailed information concerning slope geometry and engineering geology parameters must be acquired where analyses must be more rigorous.

SLOPE STABILITY PROBLEMS

Slope stability problem is greatest problem faced by the open pit mining industry. The scale of slope stability problem is divided in to two types:-

Gross stability problem: It refer to large volumes of materials which come down the slopes due to large rotational type of shear failure and it involves deeply weathered rock and soil.

Local stability problem: This problem which refers to much smaller volume of material and these type of failure effect one or two benches at a time due to shear plane jointing , slope erosion due to surface drainage.

To study the different types and scales of failure it is essential to know the different types of the failure, the factors affecting them in details and the slope stability techniques that can be used for analysis. In this chapter we will try to study the different types of the slope failure, factors affecting them, stability analysis technique and software available and which are developed. It is critical to pay attention to the pore water pressures as they tend to increase over time. This means that cheap, undrained shear strength tests are only useful if looking at very short term stability. The geological sequence and history must be known so we are sure if there are existing tectonic shears.Excavations are more susceptible to the effects of tectonic shears than embankments because embankments raise the normal effective stresses on potential sliding surfaces, and these offset the increased levels of shear stress they imposed.

The Economic Impacts Associated With An Unstable Slope

1. Loss of production.
2. Extra stripping cost for recovery and handling of failed material.
3. Cost of cleaning of the area.
4. Cost associated with the rerouting the haul roads.
5. Production delays.
6. Risk of production delays.

The stability of slopes is basically judged by the factor of safety. Factor of safety is defined as the ratio between the resisting forces to the distributing forces. Resisting forces depends on cohesion and angle of friction, while the Distributing force is related to gravity and ground water condition. If the factor of safety is greater than unity then the slope is stable but if it drops below unity the slope becomes unstable.

FACTORS AFFECTING SLOPE STABILITY

(a) geological discontinuities
   1. nature of occurrence
   2. orientation and position in space
   3. continuity
   4. intensity
   5. surface asperities
   6. genetic type
   7. gauge

(b) properties of rock mass

(c) ground water and hydrology
   1. direct effect of water pressure
   2. indirect effect of water pressure

(d) mineralogy, lithology and weathering
   1. fundamental consideration for different rocks
   2. consideration of mineralogy and lithology
   3. adverse physical and chemical processes

(e) regional stresses
   1. evidence of high horizontal stresses
   2. effect on surface excavation
   3. potential areas of high horizontal stresses

(f) time

(g) slope and pit geometry

(h) blasting
   1. pre splitting
   2. post splitting

LIMITATIONS FOR SLOPE DESIGN

To improve the open it slopes with flexible design criteria that could be easily adapted to changing geologic conditions, a series of design concepts were developed. Each concept consists of a basic slope type, and specific slope design criteria. Basically for designing slopes required the collection of data, the use of appropriate design methods, and implementing of excavation method and stabilization/protection measures suitable for the particular site conditions. In developing the slope design concepts, some basic slope parameters first need to design the slopes. These includes fixed criteria, such as bench height increment and minimum catch berm width (which were based on the size of the mining equipment and regulatory requirements), and more subjective consideration, such as the overall design factor of safety and acceptable level of risk. In some cases more than one slope design concept has applicable. For example, artificial supports were an alternative that provided a steeper slope design than a conventional approach, this alternative slope design provides with additional flexibility.

Rock slope stability analyses are routinely performed and directed towards assessing the safe and functional design of excavated slopes (e.g. open pit mining, road cuts, etc.) and/or the equilibrium conditions of natural slopes. In general, the primary objectives of rock slope stability analyses are:
- To determine the rock slope stability conditions;
- To investigate potential failure mechanisms;
- To determine the slopes sensitivity/susceptibility to different triggering mechanisms;
- To test and compare different support and stabilization options; and
- To design optimal excavated slopes in terms of safety, reliability and economics

Methods of Rock Slope Analysis

Conventional methods of rock slope analysis can be generally broken down into kinematic and limit equilibrium techniques. In addition, analytical computer-based methods have been developed to analyze discrete rock block falls (commonly referred to as rockfall simulators). All limiting equilibrium techniques share a common approach based on a comparison of resisting forces/ moments mobilized and the disturbing forces/moments. Methods vary, however, in the assumptions adopted in order to achieve a determinate solution. Graphical analysis using stereonet techniques can also be carried out using block theory techniques to assess critical keyblocks. Critical input Parameters , and limitations are presented in Table 1.

Table 1: Critical input Parameters and limitations

Analysis Method	Critical input Parameters	Advantages	Limitations
Stereographic and Kinematic	Critical slope and discontinuity geometry; representative shear strength characteristics	Relatively simple to use and give an initial indication of failure potential. Some methods allow identification and analysis of critical keyblocks. Links are possible with other analysis methods. Can be combined with statistical techniques to indicate probability of failure and associated volumes.	Only really suitable for preliminary design or design of non-critical slopes. Need to etermine critical discontinuities that requires engineering judgement. Must be used with representative iscontinuity/joint shear strength data. Primarily evaluates critical orientations, neglecting other important joint properties.
Limit Equilibrium	Representative geometry and material characteristics; soil or rock mass shear strength parameters (cohesion and friction); discontinuity shear strength characteristics; groundwater conditions; reinforcement characteristics and external support data	Wide variety of software available for different failure modes (planar, wedge, toppling, etc.). Mostly deterministic but increased use of probabilistic analysis. Can analyse factor of safety sensitivity to changes in slope geometry and material behaviour. Capable of modelling 2-D and 3-D slopes with multiple materials, reinforcement and roundwater profiles.	Factor of safety calculations give no indication of instability mechanisms. Numerous techniques available all with varying assumptions. Strains and intact failure not allowed for. Do not consider *in situ* stress state. Probabilistic analysis requires well-defined input data to allow meaningful evaluation. Simple probabilistic analyses may not allow for sample/data covariance
Rockfall Simulation	Representative slope geometry; rock block sizes and shapes; coefficient of restitution	Practical tool for siting structures. Can utilise probabilistic analysis. 2-D and 3-D codes available	Limited experience in use relative to empirical design charts.

The main approaches for slope stability analysis are model studies and limit equilibrium methods. The model studies include physical and mathematical models. Physical models have been used quite extensively to simulate the behaviour of full scale structures (Hoek, 1971). Equivalent material models give valuable information regarding various parameters of open pits in complex geo-mining conditions. The most important factors which affect stability of the slopes are geological factors, hydrological factors, rock types, physico-mechanical properties, etc,. The stability of slopes depends upon the presence and nature of geological discontinuities within the rockmass. The potential failure surfaces are guided by the structural weaknesses, e.g., fault zone, fold axis, joints, bedding plane and foliation planes (Kutter, 1974).

Ground water can cause slope instability in different ways. Slopes, which are stable in dry season, may become highly potential for failures during rainy season. Water pressure on the joints is probably more responsible for slope failure than all other causes. Hence, a thorough investigation of the hydrological characteristics of the region is necessary before any surface mining operation (Piteau, 1970; Morgenstern, 1971). It is the water pressure, not quantity of water, that causes slope instability (Hunt, 1986). The water pressure at critical locations in the rockmass should be determined or assumptions on the flow conditions have to be made (Hoek & Bray, 1981). It is not very easy to calculate the water pressure behind the slope face precisely. However, due to its importance an engineering judgement is required to select the most likely ground water conditions during the life time of the mine for slope stability analysis (Hoek & Londe, 1974). Patton and Deere (1970) concluded that where joints are open, water pressure can not develop. However, in the rather tightly closed joints, water pressure can develop and increase against the slope face to cause instability. Geotechnical field investigations include collection of geological data, joint mapping to identify the discontinuity trends and nature, and collection of all relevant information related to the slope design analysis. Acceptability criteria and various analysis methods are presented in Table 2.

Stability of the slopes is evaluated from empirical, analytical and numerical techniques. In homogenous, isotropic ground conditions, the factor of safety can be determined for predefined failure modes using limit equilibrium method. Some design charts are available, which are useful to analyse only simple types of predetermined failures, but not for determining the slope angle which depends on the rock mass stability, particularly the unfavourable joints. Accordingly, this project was taken up with an objective to develop design charts and design guidelines to determine slope angles for different slope heights in different rock mass conditions, which can be readily used by the practicing engineer. For the detailed studies, ten mines, namely Nanjankulam (ICL), Tirodi (MOIL), Dongri–Buzurg (MOIL), Pandalgudi (MCL), Medapalli (SCCL), Jayanthipuram (MCL), Pandarathu (MCL), Majhgawan (Panna, NMDC), Rampura-Agucha (HZL) and Malanjkhand (HCL) mines, were selected *(Jayanthu et al, 2002a and 2002b)*.

Limit equilibrium analysis

The limit equilibrium analysis for slope stability estimates the factor of safety against shear failure along a predetermined surface. Factor of safety is the ratio of stabilising forces and destabilising forces existing on the failure surface under study. The shear strength is mobilised to resist the shearing stress caused by the gravitational forces. The failure surface can be planar, circular or non-circular. Different failure surfaces are analysed to identify the surface with minimum factor of safety. Circular failure analysis is done using Bishop's method for the whole slope to assess deep seated failures, and for slopes covering a few benches to assess the local failures. On the other hand, non-circular failure analysis is done using Sarma's method, which mainly checks the possibility of failure through different rock types. For the benches in the selected mines, two dimensional limit equilibrium analysis was performed for plane, non-circular, circular and toppling failures. For this purpose, software named GALENA, originally developed by BHP Engineering, Australia (GALENA, 1990) was used.

Numerical modeling

The limit equilibrium method, however, does not take into account the in-situ stress existing in the rock medium. The excavation in a mine will alter the stress state, and the deformation caused by the induced stress may be excessive. In order to study the effect of in-situ stress on the stability of the slopes, stress analysis using numerical modeling was performed in some of the cases. The numerical analysis was performed using UDEC (Universal Distinct Element Code), of Itasca Company, USA (UDEC, 1993). This is a discontinuum numerical technique first proposed by Cundall (1971). In this the rock mass is simulated as an assemblage of blocks which interact through corner and edge contacts. Discontinuities are regarded as boundary interactions between blocks, and joint behavior is prescribed for these interactions. The method utilizes explicit time stepping algorithm which allows large displacements and rotations and general non-linear constitutive behaviour for both rock matrix and the joints.

In general numerical models can be classified into two categories; discontinuum and continuum models. Although discontinuum models can be more useful for simulation of real life situations, it requires more sophisticated input data and processing time. However, as a preliminary analysis tool, continuum models are most commonly used for analyis and then a detailed analysis with calibration would be carried out for more reliable estimation of the stresses and deformations in a model. Some of the finite difference and distinct element codes of two and three dimensional numerical models such as of FLAC (Fast Lagrangian Analysis of Continuum) are used for understanding stability of slopes in a typical case study. Stability analysis for a typical opencast coal mine is presented in Fig 2. It shows the factor of safety exceeding 0.59, and considered as unstable. It was also observed that the slope in the field was unstable and collapsed recently. Further analysis is in progress for design of safe slope with varying bench heights and angle of the slope and benches in the site specific condition. Generally, if the factor of safety for the slope under analysis was above 1.2, then it was considered stable, and if it was less than 1.2, then the slope was considered to be potential for failure. In cases where the mining has to be carried out fast and the benches have to stand only for a short time, then the cut-off value for the safety factor could be 1.1; with constant and systematic monitoring, the safety factor of even 1.05 could be allowed.

In other hand Numerical modeling is used to design the critical slopes (Table 3) , which will give the better solutions for any type of the problematic slopes in the opencast mine. In comparison, non-numerical analysis methods such as analytic, physical or limit equilibrium may be unsuitable for some sites or tend to oversimplify the conditions, thus the Numerical analysis can evaluate multiple possibility of geological models, failure modes, and design options. Equilibrium is satisfied only on an idealized sit of surface. With numerical models, a full solution of the coupled stress/displacement, equilibrium and constitutive equation is made, given a set of properties the system is found to be either stable or unstable.

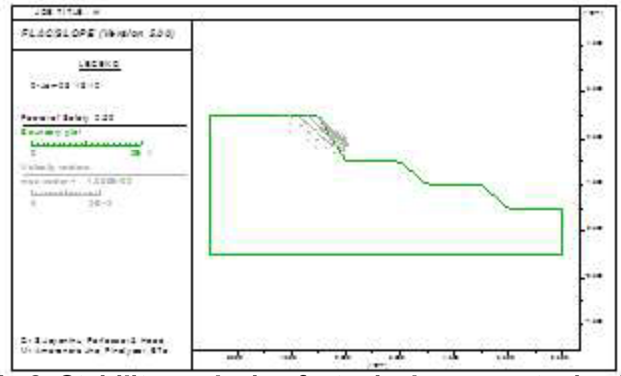

Fig 2: Stability analysis of a typical opencast mine in a Numerical model (Factor of Safety = 0.59)

APPLICATION OF MODIFIED EMPIRICL MODELS IN LIME STONE MINES

Nanjankulam Limestone Mine, India Cements Ltd.

In the footwall quartzite benches at this mine, a cohesion of 60 kPa and friction angle of 37.7^{o} was sufficient for stability against planar mode of failure. This condition was applicable for a bench height of 10 m and bench slope angle of 90^{o} under saturated condition for a discontinuity angle ranging between 40^{o} and 80^{o}. The factor of safety for this was between 1 and 2. For a discontinuity angle between 40^{o} and 50^{o}, the required cohesion was 50 kPa. It was seen that for a block in a bench to be stable under fully saturated condition, it was required to have minimum 50 kPa cohesion. Detailed analysis of the slopes at Nanjankulam mine revealed that the wedges formed by different intersections in the footwall require minimum 15 kPa and maximum 25 kPa of cohesion for the wedges to be stable. In the hangwall, the wedges require minimum 10 kPa and maximum 20 kPa of cohesion for them to be stable. It was observed that cohesion of 25 kPa was sufficient for any wedge geometry located on any wall. Based on two-dimensional numerical analyses, the following slope angles were designed, which were the same for both the footwall and the hangwall :

bench height	10 m
individual bench face angle	80^{o}
berm width	3.25 m
overall slope angle	47^{o}

Pandalgudi Limestone Mine, Madras Cements Ltd.

Based on the kinematic and simple stability analysis, detailed limit equilibrium analysis was carried out. It was seen that in the footwall, some of the blocks were potential to fail by plane failure. The analysis was performed for

Table 3: Advantages of various numerical modeling methods

Analysis Method	Critical Parameters	Advantages	Limitations
Continuum Modelling (e.g. finite- element, finitedifference)	Representative slope geometry; constitutivecriteria (e.g. elastic, elastoplastic, creep, etc.);groundwatercharacteristics; shearstrength of surfaces; insitu stress state.	Allows for material deformation and failure (factor of safety concepts incorporated); can model complex behaviour and mechanisms; 3-D capabilities; can model effects of pore pressures, creep deformation and/or dynamic loading; able to assess effects of parameter variations; computer hardware advances allow complex models to be solved with reasonable run times	Users must be well trained, experienced and observe good modelling practice; need to be aware of model and software limitations (e.g. boundary effects, meshing errors, hardware memory and time restrictions); availability of input data generally poor; required input parameters not routinely measured; inability to model effects of highly jointed rock; can be difficult to perform sensitivity analysis due to run time constraints.
Discontinuum Modelling (e.g. distinct-element, discrete-element)	Representative slope and discontinuity geometry; intact constitutive crit eria; discontinuity stiffness and shear strength; groundwater characteristics; in situ stress state	Allows for block deformation and movement of blocks relative to each other; can model complex behaviour and mechanisms (combined material and discontinuity behaviour coupled with hydro - mechanical and dynamic analysis); able to assess effects of parameter variations on instability.	As above, user required to observe good modeling practice; general limitations similar to those listed above; need to be aware of scale effects; need to simulate representative discontinuity geometry (spacing, persistence, etc.); limited data on joint properties available (e.g. jkn , jks).
Hybrid Modelling	Combination of input parameters listed above for stand-alone models.	Coupled finite-/distinctelement models able to simulate intact fracture propagation and fragmentation of jointed and bedded rock.	Complex problems require high memory capacity; comparatively little practical experience in use; requires ongoing calibration and constraints

different block geometries, which were kinematically possible to slide. These blocks were back-analysed using design friction angle to get some idea about the cohesion mobilized during failure. In the hangwall, the blocks were potential to fail by wedge failure. Therefore, the analysis was performed for different wedge geometries that were kinematically likely to slide. The wedge geometry was back-analysed using design friction angle to get some idea about cohesion mobilized during failure.The stress analysis of the open pit excavation was performed using UDEC, considering the rock mass as an equivalent continuum by reducing the strength and stiffness parameters of the intact rock using RMR. The analysis was performed by discretizing the model region by triangular finite difference mesh. The region near the pit enclosing a distance of 50 m was discretized heavily to model the stress concentration. The displacement vectors showed a definite mass flow pattern. The displacement along the boundary shows movement upwards and towards the opening. The maximum displacement vector was 2.36 cm observed on the footwall and hangwall. No plastic and or tensile failures were observed. The analysis did not show any abnormalities.

Based on the different types of analysis performed, the slope angles were designed as :

bench height (maximum)	10 m
bench width (minimum)	2.5 m
overall slope angle	43.5° for footwall, and 43° for hangwall
bench face angle	57° in the footwall (if the dip of joint set 1 was other than 57°, the bench face angle at those locations should be along the dip of joint set 1) 66° in the hangwall

Jayanthipuram Mine, Madras Cements Ltd.

The slope stability analysis was carried out using Bishop's simplified method and Sarma's method. From the field monitoring, it was found that the ground water level adjacent to the river was about 4.5 m, which may be higher in the worst situations. Keeping this in view, the slope was assumed to be completely saturated (worst possible condition). The rock mass properties estimated from the laboratory test results and the in-situ conditions were used in the analysis. For the top 5 m, soil properties were used. Different possible surfaces were analysed and the least factor of safety determined. The rock mass cohesive strength of 150 kPa and rock mass friction angle of 25° was used in the analysis.

The analysis was carried out for different depths, considering different overall slope angles for both circular and non-circular failure surfaces. Based on the least factor of safety values obtained, the following recommendations were made for different pit depths (applicable to both footwall and hangwall):

Depth of the pit (m)	Overall slope angle (°)
20	75
40	65
60	45
80	35
100	28

Pandarathu Limestone Mine, Malabar Cements Ltd.

There was a wide variation in geology of the pit. Therefore, a minimum safety factor of 1.3 was considered in this mine. The analysis were performed by varying the overall slope angle and pit depth.The joint data was analysed using hemispherical projections. Kinematic analysis showed that the benches in the gneiss were not potential for plane, toppling or wedge failures, but non-circular failures could be expected. So the analysis was carried out for both circular and non-circular failures, and accordingly slope angles were designed for different pit depths. These slope angles can be applied to gneiss portions in any of the four zones (North, South, East or West).

Depth (m)	Overall slope angle (°)
20	80
30	70
40	60
50	50
60	45
70	40
80	35
90	30

Slope Mass Classification

The strata comprising the slopes can now be classified in terms of stability using the MSMR values as follows :

Class	MSMR	Description	Stability
II	> 50	Good	Stable
III	31 – 50	Normal	Partially stable
IV	< 30	Bad	Unstable

For specific expected type of failure and the required support measures, the original SMR approach as given by Romana may be used. The individual bench angle (S_b) and the overall slope angle (S_o) can now be obtained from MRMR as follows :

$$S_b = 22 * \ln (MSMR) – 18$$

$$S_o = 14 * \ln (MSMR) – 16$$

SLOPE DESIGN CRITERIA

On the basis of the engineering geology model and slope stability analysis, the general range of bedding orientations, within which each of the basic slope type is applicable, is accessed for each structural domain. In a given structural domain where bedding dips in the same direction as the slope, for example type I or II slopes may be applicable for bedding dips of less than 25 degree, type II slope for bedding dips up to 40 degree and for III or IV dips in the range of 40 degree to 90 degree. Where bedding dips in to the wall in between the 70 degree and 90 degree, type V or VI may be applicable. Type VII may be applied where bedding dips in to the walls at flatter than about 70 degree and where bedding strikes obliquely or normal to the slope, type VIII slope may be applicable. For each applicable slope type and range of bedding orientations, design criteria are then developed which specify geometrical parameters such as bench height, bench face angle, berm width, spacing of artificial supports, etc as appropriate. These criteria are usually based on result of stability analysis and basic slope design criteria's are described in Table 4.

Table 4. Basic slope design criteria and its application

Basic slope type	General orientation of bedding	Application	General criteria	comments
I Benched (bedding undercut)	Dips shallowly out of slope	Footwall slopes not subject to major plane failure if bedding under cut but minor plane or stepped failure may occur	Benches designed to limit size of and provide catchments for potential minor or stepped failure	Slope angle steeper than the bedding dip is feasible. Unbenched slope is acceptable.
II unbenched	Dips shallowly to moderately in same direction as slope.	Footwall slopes not subject to buckling, ploughing, bilinear or other slab type failures.	Bench faces excavated parallel to bedding. Bench height designed to limit size of potential slab type failures, berms designed to contain minor slab type failure	No assess to slope rock fall protection may be required
III Benched (bench face parallel to the bedding)		Footwall slopes subject to major buckling, ploughing, bilinear or other slab type failures	Bench faces excavated parallel to the bedding. Bench height designed to limit size of potential slab type failures. Berms designed to contain minor slab type failure.	May be used in conjunction with type IV to increase bench height and reduce berm width
IV Unbenched supported	Dips moderately too steeply in the same direction as slope.	Footwall slopes subject to major buckling, ploughing, bilinier or other slab type failures	Slope excavated parallel to the bedding. Support spacing or length designed to prevent major slab type failures.	May be used in conjunction with type III to limit amount of artificial support and provide berms for access rock fall catchments.
V Benched	Dips steeply in to slope	Footwall or hanging wall slope subject to toppling.	Single benches generally preferred. Benches faces inclined to reduce over turning moments. Berms designed prevent	May be used in conjunction with type VI to increase bench height, bench face angle, and slope angle and bedding berm width.
VI Benched supported	Dips steeply in to slope	Footwall or hanging wall slope subject to toppling	Double bench may be suitable support spacing or length designed tom prevent toppling bench faces inclined reduce overturning moments. Berms designed to prevent toppling of multiple benches.	Artificial support allows higher benches steeped bench face angles and steeper overall slope.
VII Benched	Dips shallowly to moderately in to the slope.	Footwall or hanging wall slopes subject to stepped failures.	Benches designed to limit size of and provide catchments for minor steeped failures.	
VIII Benched	Endwall slope subject to stepped failures.	Benches designed to limit size of and provide catchments for minor stepped failures.		

The design criteria will vary depending on the critical failure mechanism and basic slope types. For example in the case of I, IV, VIII slopes, design criteria may consist of fixed bench height, bench face angle, and berm width designed to limit the size of possible failure and bench crest break back, provide assess to slope and provide catachment for small failures , rock falls and raveling debris. In the case of type III and IV slopes which may be applicable over a wide range of bedding orientations, bench height and berm width may variable, depending on the slope angle. For type V and VI slopes, variable bench face angles and bench height may be applicable as described. Typical design bench height criteria for bench foot wall slope as illustrated below. In this example bench heights are limited by two different kinematically possible failure mechanisms which control design over different range of bedding dip. Analysis results are presented in terms of range of conditions which may occur in the slope. Possible design criteria are illustrated for two cases representing optimistic and conservative design respectively.

In some cases, more than one basic slope design concept may be suitable for a given range of bedding orientations. In this regard, comparison of relative cost and operational flexibility may be required to determine the optimum slope design.

CONCLUSIONS

Over the decades, rock slopes have been characterized using the empirical approaches for preliminary assessment of the stability of a natural or man made slope in a rock mass. In the present ten case studies in opencast mines, the SMR values and the classes categorized by SMR did not correspond with the actual slope conditions prevailing at the mines. The MSMR came into existence as a modification in SMR. It was found that in all the case studies the description and category of the slopes obtained from MSMR was in conformity with the actual situations. When the above relation was used for the actual cases, the designed bench slope angles were within 10% variation as compared to the results of numerical / limit equilibrium analyses. It was established that MSMR of 50 and above indicates stable slopes and below 40 indicates instability. The slopes can be assessed for their stability even in the preliminary stages of development prior to mining, and for the future planning. The MSMR may be estimated based on surface joint mapping, assumed slope angles, and the likely inputs proposed for the mining. To make the system universally applicable and to widen the scope of the approach it is desirable to apply the MSMR in a large number of operating opencast mines.

The results of the above slope stability analyses were used to design the individual and overall slope angles at the mines. Generally, if the factor of safety for the slope under analysis was above 1.2, then it was considered stable, and if it was less than 1.2, then the slope was considered to be potential for failure. In cases where the mining has to be carried out fast and the benches have to stand only for a short time, then the cut-off value for the safety factor could be 1.1; with constant and systematic monitoring, the safety factor of even 1.05 could be allowed.

In view of the availability of the state of the art instrumentation in monitoring the slopes, and well accepted impetus on observational approaches in design of many structures in natural materials like rocks, the following action plan would lead to appropriate design of rock slopes:

- Preliminary design based on kinematic analysis and available empirical approaches—RMR, SMR etc
- Verification of stability by using numerical models, and modification of design
- Meticulous field monitoring of designed slope using state of the art modern instrumentation
- Modification of the design depending on the integrated results of kinematics, empirical, numerical and observational approaches.

Many slope failures or uneconomic overdesign of slope in recent times emphasizes the need of proper education to the concerned on the limitations and applicability of the existing guidelines and further studies required for the purpose. Therefore, it is required to create an appropriate task force including statutory, field, academic and research agencies to reevaluate and formulate appropriate guidelines on design of safe and economic slopes in mines and other structures.

ACKNOWLEDGEMENTS

The first Author is thankful to Prof. R,N.Gupta, Former Director, and Dr V Venkateswarlu, Former Head of Mine design division of NIRM for their kind cooperation in critical evaluation of stability of slopes in various mines. The views expressed in the paper are those of the author and doesn't necessarily of the organization.

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The Indian Mining & Engineering Journal, Vol. 60, No.10-11, October-November 2021, pp.57-60
Printed in India, @ IME Publications, ISSN 0019-5944

Blast Induced Ground Vibration in Surface Mining Project- A Bibliometric Analysis for Future Directions

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ABSTRACT

The usage of blasting is mostly to break rock for any excavation projects. It is practiced most often in mining, quarrying and civil engineering but the use of explosive is much higher in mining rather than any other industry. The blasting operation plays a very vital role in the overall economics of opencast mines. In any surface mine, the principal disturbances created by blasting are ground vibrations, air blast and fly rock. One of those, ground vibration is one of the biggest drawbacks due to blasting operation. Therefore, a critical review and analysis in the field of mine blasting operations for vibration analysis are provided in this article. The peak particle velocity (PPV) is the parameter that measure the intensity of ground vibration and the various predictor equation by different researcher is discussed in the present paper. A comprehensive literature search was conducted using Scopus database, for mine blasting operations. The study explores about 382 research documents of the most cited articles in Scopus data base which emphasizing four vital keywords namely mining, blasting and ground vibration. The existing search was further refined by a new keyword such as PPV that provides 82 research documents. The study administers chronological, source clustering, and text analysis of the articles that provide high-level concept map composed of specific words and help to provide direction for future research on the ground vibration of blasting operations.

Key words: Surface mining, Blasting, Ground vibration, Scopus data base, PPV

INTRODUCTION

Surface mines offer benefits when compared with underground mining. Surface mining provides a less expensive operation and can recover more of the mineral resource. Blasting is considered as one of the quickest and vital method for removal of rock in any surface mines project. Blasting is an integral part of surface mining activities that help to uncover the mineral reserves for the rock excavation. Blasting operation is the most economical and practical method, in any open cast mining or pit quarrying for the breakage of rock or rock mass. Productivity, environmental effects and safety is the main part of blasting operation. Productivity defines the fragmentation of desire size and appropriate movement of the rocks in a bench face. Environmental effects are undesirable and mainly consist of the ground vibration, air shock, fly rocks and noises [1, 2, 3]. It is important to control all these effects while carrying out blasting operations as increasingly projects are being subjected to scrutiny and at times closure. In blasting operation only about 20% of explosive energy is doing useful work and remaining energy gets converted into ground vibration [4]. The excess generation of ground vibration can result in permanent damage or failure of nearby structure. Therefore, it is necessary to predict the level of ground vibration for safer blasting operation.

The level of ground vibration depends on various parameters namely peak particle velocity, charge per delay, scaled distance, rock mass characteristics, blast design parameters, geological structures and explosive characteristics [5, 6]. Ground vibration is caused due to the wave motion which is spreading away from the blast point and consisting of innumerable individual particles. These particles are either body or surface wave that affect the building and structure on the surface as well as around the vicinity of the blasting point. The monitoring of these waves is expressed in term of displacement, acceleration, peak particle velocity [7]. Throughout the long term, numerous analysts have examined the relation of peak particle velocity of vibration with the effective parameters. A large portion of them have proposed observational equations to anticipate PPV as a function of explosive weight, distance between blast point to the point of observation, and the site-specific constants which characterize the geographical structures and rock characterstic. By utilizing these relations, amount of explosive weight per delay can be estimated so as to keep the ground vibration value within the permissible limit. These parameters are dependent upon each other and mostly correlated or interrelated.

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In this paper, the presentation of blast generated ground vibration comprehensive study has been performed using extensive documents search on Scopus data base. Many bibliometric papers from other disciplines (mining, civil and tunnel) were studied so as to infer the work flow of the present paper [8, 9, 10]. In this bibliometric paper various research papers were studied, analysed and combined together so as to show the statistics. In this showcase, published research work over the year (by source and type) regarding the blasting induced ground vibration has been shown. This research paper consists of four main headings which starts from introduction. Second headings of the paper explain the methodology which is follow by results and discussion in third headings. The fourth headings of the paper discuss the conclusion of the present research paper.

METHODOLOGY

An intensive search was conducted based on Bibliometrics which is a statistical analysis of the Scopus database (www.scopus.com) [11]. In this research, the Scopus database is used as a source in the bibliometric analysis because it has a huge amount of research articles than Web of Science [12]. Google Scholar is not assessed in this search due to a lack of accurate results [13]. The complete bibliometric search is divided into two different searches in which the first search consists of the keywords of surface mining, blasting and ground vibration whereas the second search is the refined of first search by adding one new keyword such as peak particle velocity (PPV). Based on the keyword search the flow chart of the search pattern is prepared which is shown in Figure 1.

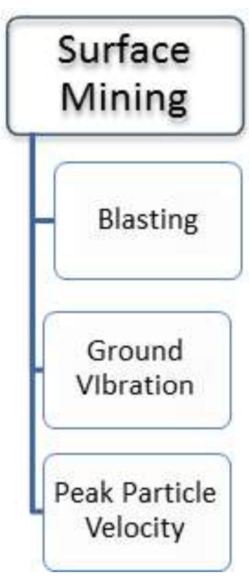

Figure 1. Flow chart of search pattern in Scopus data base

There are some keywords which were eliminated to restrict the document search as the study tried to keep it within the scope of blast induced ground vibration in surface mining projects. The term related to delay detonator, initiation pattern, steaming length, rock characteristics, burden, spacing, hole pattern were excluded from the search pattern. In the total search the earlier papers were just shown to express the trends of research in the area of blasting and later it shifted to the range of papers were published over the period of time.

RESULTS AND DISCUSSION

The result of bibliometric search is presented in two different searches where first search expresses the three keywords-based results and second search express the four keyword-based search results. In the complete search main focus were on the type, source and year of articles.

DOCUMENTS BY YEAR

Based on three key search the published paper were searched. The trend of paper publication is listed from 1972 to 2021 and is presented in Figure 2. It is observed from Figure 2 that the number of research, in the area of blast vibration of surface mining projects, is increases in every succeeding year. This shows an increasing trend of research in the area of surface mine blast vibration. The highest number of 27 articles were reported to publish in one academic year under surface mine blasting topics and the number is still increasing. That means this area have the potential of future research in order to produce some new findings. The search is further modified by introducing a new search word of PPV. Thus, under the search of four key words namely, surface mining, blasting, ground vibration and PPV, the number of documents were found as 82. The documents per year is shown in Figure 3. As shown in Figure 3, the number documents were drop from 382 to 82 that implies a shortage of published articles in the area of ground vibration when it links with PPV. Therefore, there is a need to conduct more research in the ground vibration with the keyword of PPV so that a better understanding of ground vibration can be developed.

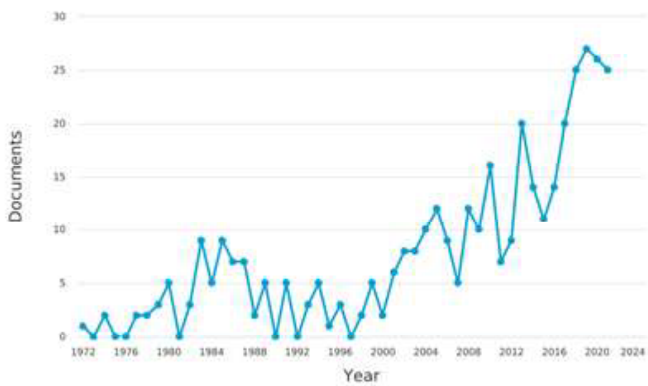

Figure 2. The number papers per year in the research trend with three keywords

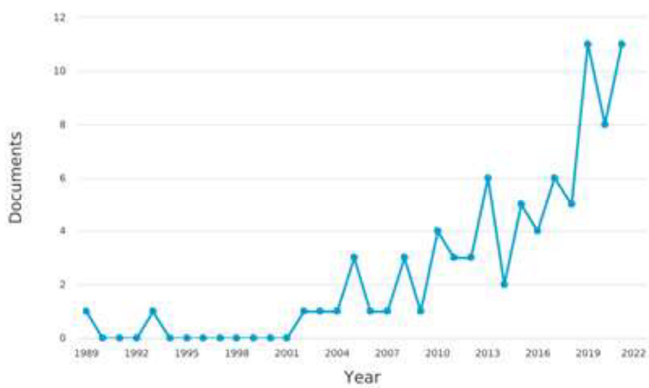

Figure 3. The number papers per year in the research trend with four keywords

DOCUMENTS BY TYPE

For the first key search the documents were sorted based on its type of publication is presented in Figure 4. It is observed from Figure 4 that during the search of Scopus data base the published research article and conference paper have the highest percentage of 68.3% and 25.4% respectively. The remaining documents type (book chapter, letter, review and reports) have a small percentage in the Scopus data base. Similarly, the refined search with four keywords (surface mining, blasting, ground vibration and PPV) shows only three document type such as articles (85.4%), conference paper (13.4%) and review (1.2%) in the search data base which can be seen from Figure 5.

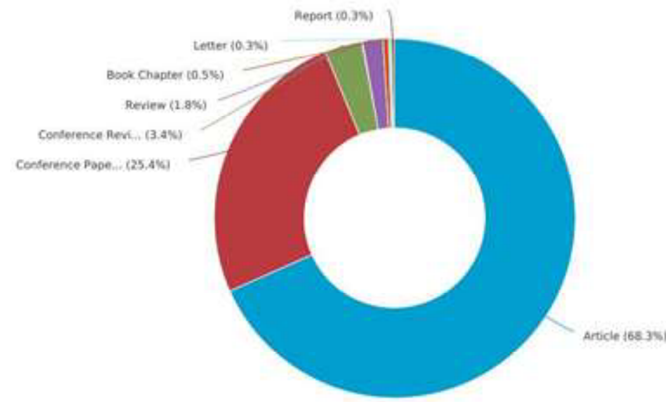

Figure 4. Documents by type for three keywords

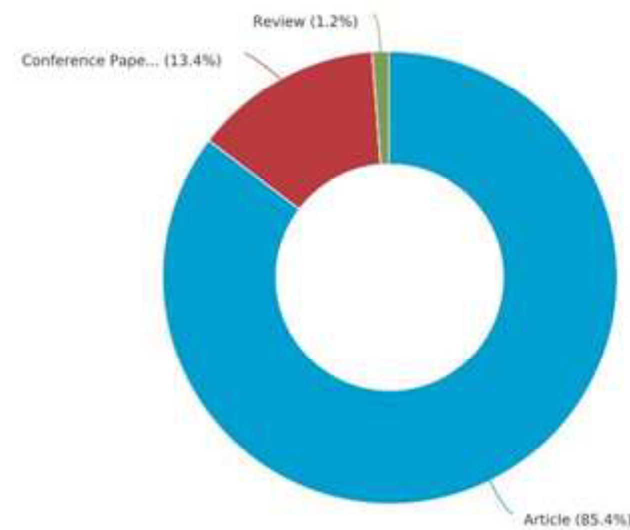

Figure 5. Documents by type for four keywords

DOCUMENT BY SOURCE

Figure 6 and Figure 7 shows the documents per year based on different sources for the three and four keywords search respectively. It is observed from Figure 6 that the most of the documents were found from Journal of Mines Metals and Fuels. Also, it is evident that the engineering with computer gain the popularity in the recent years that show the future potential of research in the area of ground vibration with the application of computers. A similar phenomenon can be observed in the Figure 7. A few numbers of documents were found in the ground vibration topic with four key words (surface mining, blasting, ground vibration and PPV). This is happening due to the additional key search of PPV. This indicates that there is a huge potential to perform the research activities in the area of ground vibration with consideration of PPV.

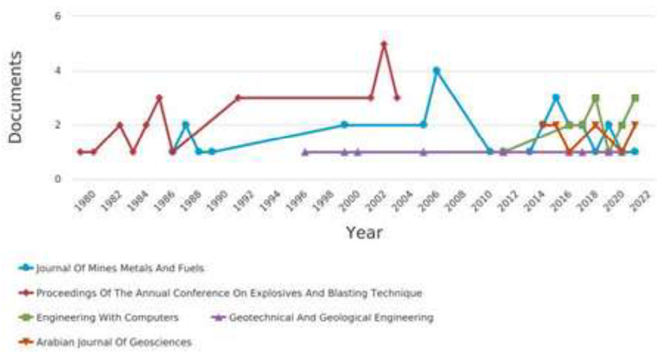

Figure 6. Documents by source for four keywords

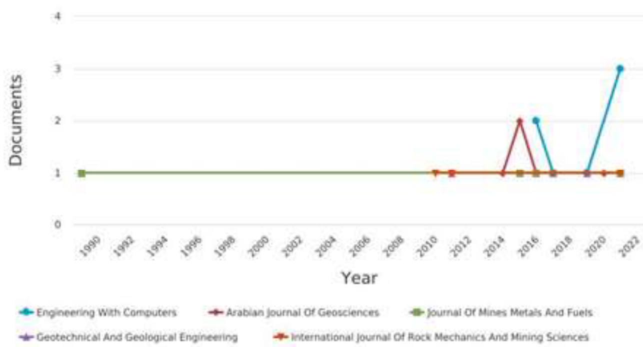

Figure 7. Documents by source for three keywords

CONCLUSIONS

Excessive level of ground vibration due to the blasting activity in surface mines cause severe damage to nearby structures and occupants in and around mine. Therefore, there is a need to conduct more research work on this area so that its effect can be reduced. In this paper an attempt has been made to investigate the publication evolution of the ground vibration field using bibliometric analysis approaches. The compete search is divided in two different key searches like three words (surface mining, blasting, ground vibration) and four words (A surface mining, blasting, ground vibration). A total 382 search documents were found with three keyword search and 82 were found with four key searches. The bibliometric analysis had been performed by searching in the Scopus database. The search documents were sorted and graphs were drawn so as to show the important keywords over the times in the area of blast induced ground vibration. The outcomes of this analysis help the future research to overcome current problem and provide the future path of research in the area of ground vibration.

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The Indian Mining & Engineering Journal, Vol. 60, No.10-11, October-November 2021, pp.61-66
Printed in India, @ IME Publications, ISSN 0019-5944

Role of Technology in Sustainable Mining of Coal in Indian Context

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ABSTRACT

Coal is the critical source not only for India but for the global electricity generations which plays a crucial role in iron, steel and cements industries. Coal contributes to about 60% of the India's total power generation (Ministry of Coal, GOI). Despite these significant contributions of coal in energy sector, coal mining has been the prominent subject of issue. The reason being the huge negative impact of coal mining on the environment like the release of toxic gases(CH4, CO2, SO2 etc.) and the influence on the environmental spheres. The burning of coal causes the huge emission of carbon which ultimately causes climate change and global warming. There has been a global pressure on India to completely phase out the fossil fuel based energy generation. But for developing countries like India whose energy security is based largely on coal based electricity generation while also battling the sluggish growth due to pandemic, it is near to impossible for India to completely phase out coal immediately. Rather than phasing out the coal, the primal focus should be made on phasing it down for which we need a solid proper planning, cutting-edge technology and advanced techniques to make it a smooth transition to low carbon emission so that the global population don't suffer. According to the COP26 summit held at Glasgow (UK), the pressure has been put on countries and it has been out global responsibility to secure global net zero by this mid-century and to keep the average global temperature rise within 1.5 degree centigrade. So the ultimate goal is to transit from fossil fuel based energy to renewable energy but the recent action and aim must be to minimize and bring down the carbon emission within the permissible limit with the exclusive and extensive use of advanced technology. Further, to align the coal mining industry with the principles of sustainable development (Brundtland Commission), we need a paradigm shift in mining technology and techniques. This paper attempts to explain the role of technology and the technological advancement that we need to adopt for sustainable development of coal mining sector including some practices and technology for sustainability in metal mining with the rapt focus on green initiatives, environmental sustainability and economic growth.

INTRODUCTION

India is the 3rd largest producer of coal after china and 5th largest in reserve of coal sharing 9.5% of entire world's coal reserve. These statistics clearly indicates that the India has abundance of coal. The commercial coal mining started in India in 1774 by East India Company in Raniganj Coalfield along the western bank of Damodar river. Since then the coal mining industry has gone through nationalization and de-nationalization and at present coal plays a crucial role in the production of electricity in India. As per the CEA data with regard to installed capacity in India (as of Oct'20), coal based installed capacity is about 53%, followed by Renewable Energy Sources (RES) at 24%, while hydro power (12%), gas (7%), nuclear (2%) and lignite (2%) round up the rest. Due to the high demand of and poor average quality of coal, India is forced to import high quality coal to meet the requirement of the steel plants. India's net import of coal grew at a CAGR of 15.62% over the last 10 years and on future it will go on increasing.

Though coal mining has played a special role since ancient time for the growth and has been a cornerstone for human civilization but coal mining has its downside. The serious concern about the coal mining is it adversely affects the overall environment in and around the coal mining areas. From the degradation of land to the pollution of all environmental spheres (especially opencast mines), the coal mining sector has huge negative impacts, including impacts on socio-economic states of area and flora and fauna.

Currently in the world, in the context of global warming and climate change coal mining has been the point of controversy, as to whether coal should continue or not as coal causes a serious long- term environmental damage. The various summits and conference had been organized in the past like The world summit on Sustainable Development (Johannesburg,2002), The Paris Agreement on climate change(2015) including the recent COP26

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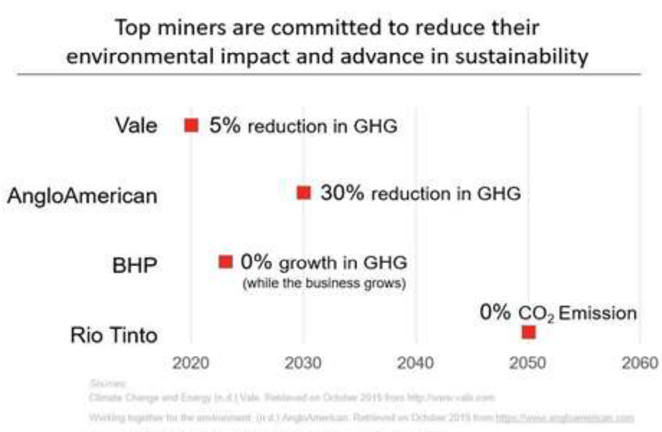
Climate Summit (Glasgow,2021) to implement and work together to achieve a common goal of reducing carbon footprint and to control global warming and climate change. In November 2021 in the Glasgow COP26 summit, our prime minister Shri. Narendra Modi has also reiterated the stand of India regarding “phasing down” of coal in place of “phasing out” of coal.

Due to the availability and affordability of coal in India, the coal is expected to remain as bedrock of energy supply for the country till 2030 and beyond. Until and unless any drastic changes come in energy generation sector, coal is likely to remain as a main option for few decades. So the real challenge here is to make a coal mining a sustainable sector. In the near future the demand of coal is likely to increase but the challenge of decreasing the emission of carbon and achieving environment sustainability is only possible with the adoption of new advanced technology and green initiatives. The adoption of new advanced technology will help the country to align our coal mining industry with the principles of sustainable development and make a coal mining a sustainable sector.

WHAT IS SUSTAINABLE MINING ?

Sustainability is the lowest social cost of getting the job done. For miners, “sustainability is to deliver results with the least environmental impact possible. Across the types of mining, sustainability has many fronts. This ranges from emission of pollutants and disposal of consumables to preservation of water resources.”



CLEAN COAL TECHNOLOGY

Clean Coal Technology (CCT) is a collection of technologies being developed to attempt for lessening the environmental impact of coal energy generation and to mitigate worldwide climate change. These technologies include:

- Chemically washing coal & removal of impurities
- Gasification of coal
- Improved technology for treating flue gases to remove pollutants to increasingly stringent levels and at higher efficiency
- Carbon capture and storage technologies

I. Carbon Neutral fuels

The term “Carbon neutral fuel” can refer to a variety of energy fuels or energy systems which have no net Green House Gas (GHG) emissions or carbon footprint.
There are two classes of carbon neutral fuels:

- Synthetic fuel including methane, gasoline, diesel fuel or ammonia
- From renewable energy sources

II. CARBON NEGATIVE FUELS

To the extent that carbon-neutral fuels displace fossil fuels or they are produced from waste carbon or seawater carbonic acid, and their combustion is subject to carbon capture at the flue or exhaust pipe, they result in negative CO2 emission and net CO2 removal from the atmosphere. Thus they constitute a form of green- house gas remediation.

III. Coal Gasification as a method of Clean Coal Technology

Coal gasification is the **process of producing syngas**- a mixture consisting primarily of CO, H2, CH4 & water vapor from coal, water, air and/or oxygen.
The technology is used in

- IGCC in electricity generation
- Chemical feed stock production
- H_2 obtained is used for making ammonia or powering.
- Hydrogen economy.

IV. IGCC (INTEGRATED GASIFICATION COMBINIED CYCLE)

Integrated gasification combined cycle technology is considered to be one of the clean technologies associated with the generation of power by using syngas in gas turbines and also recycling the exhaust from the gas turbines for forming steams and using the same steam in steam turbines to generate additional power.

By removing the emission forming constituents from the gas under pressure prior to combustion in the power block, IGCC plants can meet extremely stringent air emission standards.

V. Coal Bed Methane- An Energy Source

Methane gas has very high Green House Gas effect, much higher than CO2 and when released in air can contribute largely on global warming process. However, it may be harnessed and utilized as an effective energy source for generation of power and for conversion into transportation fuel.

The following are the major advantages of CBM technology:

- Coal bed methane liberated from the coal seams, when harnessed is an efficient energy source by itself
- Since it is a green house gas having adverse effect on environment about 21 times larger than CO2 per unit volume, by harnessing the methane and not allowing to liberate it freely in atmospheric air, CBM is an effective method to control atmospheric pollution
- By liberating methane gas from the virgin coal seams it becomes safer to carry on mining operations from those coal seams in future. This process can also be termed as "Prior Degasification" of the seam

GREEN TECHNOLOGIES: MAKING MINING MORE SUSTAINABLE & ENERGY EFFICIENT

Despite technological advancements that have made the industry greener mining still uses significant amounts of resources — water, land, carbon and energy — and often causes severe harm to the environment.

VI. LOWER–IMPACT MINING TECHNOLOGY

Traditional mining techniques can have a severe impact on the environment, and some popular methods — like open pit and underground mining — present some of the most significant environmental risks.

By instead using new, alternative low-impact mining techniques — like in-situ leaching — mining companies can reduce their environmental impact.

WITH THE HELP OF THIS TECHNOLOGY IT HELPS IN :-

i. Reducing disturbances in mining sites.
ii. Lower soil erosion.
iii. Moves less material that needs to be backfilled.
iv. Quicker re-vegetation & rehabilitation.

VII. REUSING MINING WASTES

Mining naturally produces significant amounts of waste - such as tailings, rocks and wastewater.

Companies can "**use waste rocks in simple on-site construction, like backfilling voids and reconstructing mined terrain in a way that prevents soil erosion."** Some new technologies even make it possible to further mine from these tailings, reducing the overall amount of minerals that get left behind in mining sites while also reducing the volume of waste stored in tailings dams.

VIII. ECO-FRIENDLY EQUIPMENT

Mining companies wanting to reduce their environmental impact can switch to more eco-friendly equipment.

Battery-driven mining equipment is often powerful enough to replace diesel-driven options. Replacing diesel engines with electric engines where possible can significantly reduce the amount of CO2 produced by mining operations.

- In general, the mining industry is already moving in the direction of electric equipment, with more and more mining manufacturers offering eco-friendly alternatives.
- **Eg.** Swedish mining equipment manufacturer **Epiroc**, which plans to be 100 percent electric within the next few years.

Improved durability can also reduce the environmental costs of damaged equipment — like rubber or plastic shed as a piece of equipment breaks down.

Simple switches, for example — like adopting tires that provide better longevity and higher ROI in rock-strewn environments — can cut down on equipment costs over time while also reducing how much rubber and plastic a mining operation outputs.

IX. REHABILITATING MINING SITES

Many modern mining techniques cause significant disruption to the environment — like stripping the topsoil layer necessary for plant growth and raising soil and water acidity, making the area inhospitable to new vegetation and leaving it prone to soil erosion.

As a result, many former mine sites are left unproductive, unusable by landowners and, in some cases, almost entirely inhospitable to plant and animal life.

- It's possible to use **Bio-solids** to replenish depleted topsoil.

Soil with bio-solids, if seeded and watered, can produce vegetation capable of preventing further soil erosion within as few as 12 weeks.

- Combined with other rehabilitative techniques — like the use of waste rocks to fill in excavated areas — it's possible to significantly reduce the disruption caused by mining.
- Some mining companies — like Alcoa in Australia — have gone further and implemented large-scale reforestation schemes that look to restore every local species present at a mine site before operations began.

X. SHUTTING DOWN ILLEGAL MINING

Illegal mining remains a significant issue for the industry — for example, experts estimate that around 14,000 people are currently involved in illegal mining in South Africa. There, illegal mining often takes place on properties not suited for large-scale mining and without regard to regulations that reduce the environmental impact.

Preventing illegal or unregulated mining operations can help ensure that all mining is bound by the same environmental standards and ensure accountability.

PARTICULARLY IN MINING AREAS
XI. PORTABLE RIGS FOR REMOTE DRILLING

Drilling in remote areas of the world can often be challenging because of accessibility and a desire to have as little an impact on local communities and environment at possible.

- **Vancouver-based Energold Drilling Corp's portable drilling rigs** are made significantly smaller than conventional rigs, four by four meters, rather than 20m by 20m, with the heaviest piece of equipment weighing in at 200kg so they can be broken down and carried to remote locations.
- The rigs, which have worked in altitudes above 1,200m and in environments such as the Andes, are typically carried along established tracks by local people. This provides employment for local people, who then learn to assemble the drilling rig and, if they show promise, are even taught to drill themselves.
- This also eliminates the need to disturb the environment by making further tracks to haul vehicles through, reducing carbon emissions by vehicles and saving time and money.
- Also, because the rig is significantly smaller than a conventional one, it has less of an impact on the ecological environment, making it greener and easier to restore the ground post mine operations.

XII. FIRST HYBRID DIESEL-ELECTRIC LOADER FOR UNDERGROUND

- Loaders capable of shifting several tonnes of ore, sometimes up steep inclines of 11.5 degrees, are an important resource in underground mining and are used by some 95% of underground metal mines, according to National Resources Canada.
- **CanmetMINING, (CMIN) along with Mining Technologies International (MTI),** have developed what they say is the first **Hybrid diesel-electric loader**, which helps combat this problem.
- The loader is powered by an electric motor that can be charged while running on diesel, meaning it doesn't need to be stopped to be recharged and it can conduct the same task as a regular loader.
- Due to the hybrid engine it enables decreased noxious gas emissions of between 40% to 70%, and combined with a high-efficiency particulate filter, enables a reduction in breathable combustible dust emissions of 95%.
- It is also thought these decreases could result in a 20% to 40% reduction in the energy required to ventilate a mine, which according to Natural Resources Canada, accounts for about 40% of the electricity costs of underground mining operations.

XIII. LOWER CARBON CEMENT BINDERS FOR UNDERGROUND MINES

- Portland cement – the most common type of cement used around the world – is commonly used in underground mining to shore-up shafts to prevent collapses.

Although very effective in sustaining shafts, the production of one tonne of Portland cement produces one tonne of CO2, creating a negative impact on the environment.

- **Natural Resources Canada (NRCan)** has developed a new type of environmentally friendly binder for use in mine shafts – called as **SLAG BINDER**. It's made using a composition of slag, which is waste rock from mining operations and calcium hydroxide (from gypsum).
- These materials are usually discarded and stored at mine sites, meaning they are readily available and can be mixed onsite, unlike Portland cement which is made at cement plants that are sometimes very far away. It creates a use for something that is otherwise considered waste.
- Slag binder, which NRCan's Mineral and Mining Science Laboratories (MMSL) holds an international patent for, is a particularly attractive option for mining sites in the north of Canada, or other remote areas, where transportation costs can add up.

XIV. MAKING SOMETHING POSITIVE OUT OF AN ABANDONED MINE :-

A new project announced for the Glenmuckloch mine site in Scotland, one of the biggest open cast coal mines south of the region, is hoping to prove that abandoned mines can give back to the environment. Hailed as a bench mark for future mine restoration projects, the project, which was announced this month, plans to turn the area into a renewable energy park.

The project will landscape the mine, create a large lake with a carbon capture station and eventually create an energy park that utilises a range of complementary utility products.

XV. SEEKING VALUE FROM OLD TAILINGS

Miners of the 19th century US gold rush, who were seeking gold, silver and cooper, may have unwittingly left something of great worth in their discarded mine tailings – so modern day miners believe. This is rare earth minerals, which are used in most modern day gadgets and for building renewable.

It is thought the tailing were never examined for the 15 rare earth minerals so they could hold a small fortune, while also essentially recycling the waste and providing an easily accessible low-energy way to find REMs.

- "If we could recycle some of this waste and get something out of it that was waste years ago that isn't waste today, that certainly is a goal,".

XVI. PROMOTING RENEWABLE :- MOVING TOWARDS NET ZERO CARBON

- In order minimize the carbon footprints of mining and to progress towards the goal of net zero carbon emission, coal/lignite companies are keen on promoting renewable.
- Coal companies are going for both roof top solar and ground mounted solar projects.
- It has also been envisaged to develop solar parks in some of the reclaimed mining areas.

XVII. GREENING INITIATIVES IN COAL SECTOR

Sensitivity and care towards native environment by adopting various mitigation measures including reclamation of mined out areas and extensive plantation in and around coal bearing areas.

STEPS TAKEN AT NIGAHI OPENCAST

- Spreading of 5000 seed balls
- Mixing of grass seeds in manure
- Irrigation by customized water tanker

XVIII. STRINGENT ENGINE EMISSION REGULATIONS REDUCE THE ENVIRONMENTAL IMPACT

- Engine emission regulation got increasingly stringent in recent decades.
- These regulations have significantly reduced the emission of particulate matter (PM), oxides of nitrogen (NOx), & hydrocarbons (HC). Les NOx means less SMOG. Less particulate matter means less accumulation of these particles in soil and in water.
- **CUMMINS ENGINE** used today in mining operations emits 90% less harmful gases compared to engines produced before.
- These engines are in general **MORE POWERFUL** & **MORE FUEL EFFICIENT** than their predecessors.

XIX. REDUCED DISPOSAL OF CONSUMABLES IS CRITICAL FOR SUSTAINABLE MINING

- Advanced analytics & telematics is helpful.
- Two new technologies by CUMMINS are **PrevenTECH** Mining and **FIT**.

- Customers can use these technologies to adopt a condition based maintenance (CBM) routine. Customers using this technology can change consumables only when needed instead of changing at fixed intervals.
- Results in OPTIMIZED MAINTENANCE,

Allow miners to use consumables for longer durations and create less consumables to dispose.

XX. LESS FUEL CONSUMPTION AND CARBON EMISSION DELIVER SUSTAINABLE MINING

A Mining contractor in Australia's **BOWEN BASIN** has reduced carbon dioxide (CO_2) emission of sx trucks over 500 metric ton a year.

The mining contractor simply replaced the old fuel system with a **MODULAR COMMON RAIL FUEL SYSTEM (MCRS).** This fuel system features the latest innovations in combustible technology.

XXI. CAPTURING FUNGITIVE METHANE EMISSION

- First technology is a mitigation unit called as **VAMMIT**, which is a compact flow reversal reactor with a newly-structured regenerative bed to destroy methane in a cost –effective manner,
- Whereas the Second technology is a capture and enrichment unit, called **VAMCAP.** Which essentially collects & separates the methane from ventilated air using carbon composites,
- Third technology**, VAMCAT,** uses a catalytic combustion gas turbine to create electricity from waste product.

XXII. ZERO LIQUID DISCHARGE (ZLD)

Zero-liquid discharge (ZLD) is a water treatment process in which all wastewater is purified and recycled; therefore, leaving zero discharge at the end of the treatment cycle. Zero liquid discharge is an advanced wastewater treatment method that includes **ultrafiltration, reverse osmosis, evaporation/crystallization, and fractional electrodeionization**.

XXIII. FLUIDIZED BED COMBUSTION (FBC)

- FBC is a combustion technology used to burn **SOLID FUELS**.
- FBC plants are capable of burning a variety of low grade solid fuels, including most types of COAL, Coal wastes and woody biomass, at high efficiency & without the necessity for expensive fuel preparation (Pulverising).
- Lower production of NOx due to lower temperature.

CONCLUSION

The contribution of coal mining cannot be denied, but it is a source of environmental pollution, socio-economic issues and ecological destruction. In order to manage the adverse impacts of mines on the environment, care must be taken from the project formulation stage itself by integrating environmental concerns. The adoption of sustainable mining will bring a revolution in coal mining industry with reliant on clean coal technology. The coal mining industry must mandatory adopt green technology during mining exploration to eradicate emission and positively contribute to sustainable environment. Smart technologies for exploration, clean and energy- efficient technology, mineral processing technology, dust control system, pollution control system etc. discussed in this paper will surely contribute to harmonious mining operation. With regards to this, developing affordable technologies are imperative for India so that it can be easily adopted by small-scale mining enterprises as well. This would require putting more impetus to the "Make in India" programme, increased government funding and subsidies (for carrying out R&D specifically in the exploration stage), effective implementation of National Minerals Exploration Policy 2019 (for increasing private sector participation in the exploration process), learning from domestic and international best process practices, and a conducive regulatory and legislative environment to support India's vital mining sector.

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