AUTOMATION IN INDIAN MINING INDUSTRIES

सत्यमेव जयते

खान मंत्रालय
MINISTRY OF
MINES

Government of India
Ministry of Mines
Indian Bureau of Mines

भारतीय खान ब्यूरो
INDIAN BUREAU OF MINES
सतत कार्यरत
ON WITH THE JOB

Government of India
Ministry of Mines
Indian Bureau of Mines

AUTOMATION
IN INDIAN MINING INDUSTRIES

Issued by
Controller General
Indian Bureau of Mines
NAGPUR

FEBRUARY, 2025

INDIAN BUREAU OF MINES

Controller General (In-charge) &
Chief Controller of Mines- MDR
Peeyush Narayan Sharma

Chief Controller of Mines - MES
Pankaj Kulshrestha

TECHNICAL CONSULTANCY, MINING RESEARCH & PUBLICATION DIVISION

Controller of Mines
B. L. Gurjar

Superintending Mining Geologist
P.S. Hegde

Deputy Controller of Mines
K Dhruw

Senior Mining Geologist
Smt. Pranita A. Sawant

Junior Mining Geologist
Rahil Usmani

Assistant Survey Officer
S.B. Rinke

EDITING, VISUALIZATION & GRAPHIC DESIGNING

Assistant Editor
K.D. Singh

Preface

The mining industry has always been a cornerstone of economic development in India, contributing significantly to the country's industrial growth and employment. However, the sector faces numerous challenges, ranging from labour-intensive operations to resistance to adopt new technology , environmental, concerns to the need for improved human safety, efficiency and sustainability in mining sector. In recent years, the integration of digitisation and automation technologies in mining have become a transformative force, offering new opportunities for innovation and growth. This work, *Automation in Indian Mining Industries*, aims to explore the current landscape of automation in the Indian mining sector, examining both the advancements and the barriers that have shaped its evolution.

The motivation for writing this book stems from the growing interest in technological advancements across industries and the recognition of the mining sector's need for modernization. Despite the potential benefits, automation in Indian mining has been relatively slow compared to global trends. This book delves into the various facets of automation technologies, including robotics, artificial intelligence, and machine learning, and assesses how these innovations are being applied to improve safety, productivity, cost effectiveness and environmental management in mining operations.

We would like to extend our gratitude to the experts, miners. industry leaders, and researchers who have contributed to this study, providing valuable insights into the practical application of automation in mining areas. Special thanks to the IBM Officials who have worked tirelessly on the ground to implement these systems and overcome various obstacles.

In the following chapters, readers will gain a deeper understanding of the technologies currently shaping the mining industry in India, the hurdles that remain, and the potential future developments. From improving operational efficiency to reducing environmental impacts, automation presents a unique opportunity for India to modernize its mining sector.

I hope this book will serve a reference for policymakers and industry stakeholders and a call to action for the continued development and adoption of automation technologies within the mining industry. Our goal is to shed light on the importance of innovation in driving the future of mining, one that is more efficient, sustainable, and safe for all. Thank you for embarking on this journey through the evolving landscape of automation in Indian mining.

Nagpur
Dated: /02 /2025

Sd/-
B.L.GURJAR
Controller of Mines(TMP)
Indian Bureau of Mines

CONTENTS

Acknowledgement

The Indian Bureau of Mines extends its sincere gratitude to the various government organizations/departments, mining industries/organizations, and mining equipment manufacturers whose direct and indirect cooperation, assistance, and technical contributions have greatly enhanced the value of this publication.

Vast bodies of prevalent and existent information that have connection with this publication were resourced and consulted during the course of the preparation of the publication.

The contributions from the in-house divisions of the Indian Bureau of Mines, such as the Mineral Development and Regulation (MDR) Division and the Technical Consultancy, Mining Research & Publication (TMP) Division, along with the efforts of several internal experts, have been crucial in the development of this publication from its initial stages to its current form. Every modicum of contribution received is worthy of praise and thankfully acknowledged.

Disclaimer

The aim of this publication is to provide the mining stakeholders with information that may be useful regarding technological upgradation and modernization in the mining sector. However, it does not claim to cover all the information that may be necessary in relation to these topics. The statements and details provided here may not be complete, accurate, sufficient, or correct. Mining stakeholders are encouraged to conduct their own investigations and analysis, and to verify the accuracy, adequacy, correctness, reliability, and completeness of the information in this publication, seeking independent advice from relevant sources.

The Indian Bureau of Mines and/or its employees/advisors accept no responsibility for the accuracy or interpretation of information and opinions expressed herein. They make no representations or warranties and will not be held liable for any loss, damage, cost, or expense that may arise from or be incurred due to the content of this publication, including any inaccuracies, inadequacies, or reliability issues associated with the statements or information provided.

Introduction

Minerals are a valuable natural resource being the vital raw material for the core sectors of the economy. Exploration, extraction and management of minerals have to be guided by national goals and perspectives, to be integrated into the overall strategy of the country's economic development. The deployment of modern automated equipment to improve the efficiency, productivity and economics of mining operations and mineral beneficiation processes.

In recent times, there has been an increased emphasis on Mine Digitization and Automation due to technology that has presented tremendous opportunities. It has given rise to new possibilities to change our lives for the better, turned it easier and made it more efficient. Each business is now data-driven and industries of the future are all powered by technology. The digitalization wave is passing through every industry and the mining sector is no different. Advancements in science and technology, and a vision for sustainable future is likely to accelerate the adoption of digital technologies, artificial intelligence and analytics in the mining industry.

Mining ecosystem is undergoing a rapid technological transformation to reinvent itself. So, mines of the future would look quite different to those that we see now. Today, this massive industry is at an inflection point in which high-end technologies have potential to unlock new ways of boosting productivity.

Digital transformation is accelerating across the mining and metals sector and companies have an unprecedented opportunity to capitalize on this momentum. Digital Mine helps miners to put the right technology in the right place at the right time, overcoming margin pressures today and reshaping for a digital future tomorrow.

In India, Mining companies are creating an enterprise-level digital strategy that outlines the value that the business will receive from the digital activities. In recent years, the integration of digitisation and automation technologies in mining have become a transformative force, offering new opportunities for innovation and growth as the this sector understand their importance in safety, efficiency, productivity and economics of mining operations.

Additionally, it considers every product and platform that contributes to a comprehensive solution for the entire future digital mining. A broad range of digital capabilities are being used to automate core mining value chain operations. IoT (Internet of Things) and machine learning are employed, for instance, to automate and enhance the dependability of mining equipment and trucks, sensors to gather data in real-time, drones for data collecting, inspection, and stock control, and wearable's for field maintenance and operator safety.

Under the guidance of the Controller General, IBM in Annual Plan for the year 2024-25, TMP Division (Technical Consultancy, Mining Research and Publication Division) has been assigned to bring out a publication on "Automation in Indian Mining Industries". This publication covers available informations/best practices collected from Indian Mining industries, wherein the mine management has initiated mechanization and introduced innovative practices in all sphere of mining activities such as exploration, survey, mine design and planning, drilling and blasting,

Heavy Mining machineries for excavation and transportation , Green- energy etc.

This publication covers automation, digitisation, technology and innovation practises adopted in Indian mining sector with seven chapters viz. (1) Drilling Automation (2) Blasting Technology (3) Excavation & Loading Machineries (4) Developments in Transportation of Minerals (5) Innovations in Survey (6) Digital Technology & Innovation in Mine Planning and Monitoring & (7) Green Energy. The furnished informations as well as details of Suppliers of Survey instruments, Drill Machines, Electric Equipments,Heavy Earth Moving Machineries and address of the Manufacturer of authorised Explosives are for reference purpose and benefit of all mining stakeholders to adoption of new technology for their requirement if any.

CHAPTER 1

Drilling Automation

1.1 Drilling Automation in Indian Mining industries

Drilling and its technology plays a major role in the mining industry and optimization of drilling parameters is an integral part of the economic success or failure of any mining operation. Operators and manufacturers are continually exploring ways of reducing costs and increasing the productivity by enhancing drill penetration rates and decreasing the perforation drill bit wear.

Drilling is used in exploration; its purpose is different from drilling done for blasting. Exploration drilling requires drilling deep holes to locate reserves of important minerals. Drilling is used to obtain detailed information about rock types, mineral content, rock fabric and the relationship between the rock layers close to the surface and at depth.

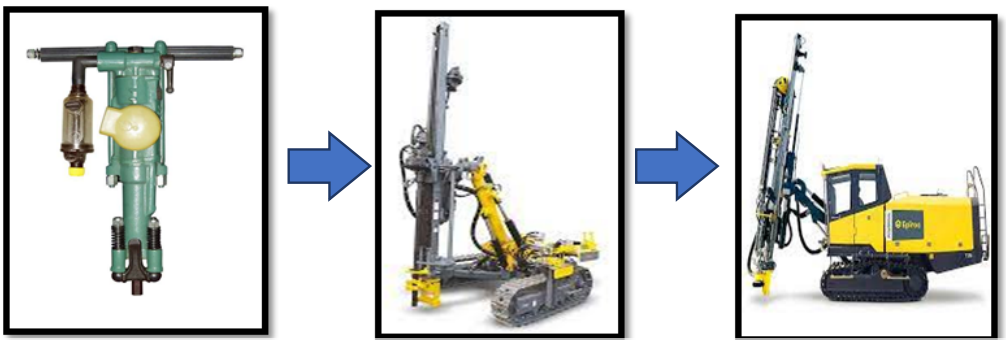
Drilling and rock cutting are the basic concerns in all underground and surface mining operations. Rock Drilling in the field of blasting is the first operation carried out and its purpose is to open holes, with the adequate geometry and distribution within the rock masses, where explosive charges will be placed along with their initiating devices.

Drilling in Indian mines has changed in last 2- 3 decades from Jack hammer to remotely operated drill machines. Automated and remotely operated drilling solutions can ensure mining personnel's safety and improve efficiency during drilling operations. A tele-operated drilling solution comprises of an easily installable operator station on a range of mobile platforms connected to the drilling rig through wireless network. The technology allows the operator to carry out drilling operation from a remote location without entering hazardous areas. The real time video and data communication including all drilling controls and equipment status are displayed continuously on a graphical screen installed at the operator centre with the use of remote-controlled pan/tilt/zoom camera for drilling, rod-handling and tramming controls transmitting real-time images.

Today, improvements not only are advancing in drilling equipment but also in the accompanying software used. Modern drills are advancing to being self-sufficient without the need for an operator in the cab. These drills are auto-positioning and automatically drilling a hole to the exact depth that is designed – and this is no easy task for a human operator. Drills are automatically recording key parameters such as penetration rates to develop automatic borehole logs to help understand the characteristics of rock such as compressive strengths, tensile strengths and Young's modulus. This technology is likely to advance into fully autonomous drilling fleets on sites that are not only developing information on penetration rates but also are automatically sampling the rock to give properties. This can help the blaster to optimize hole loading to get better results, but it can also be used by engineers to delineate different grades of rock and ore.

1.2 Details of various drilling equipments used in mines

At the beginning of mining industry, rock drilling was being done with the help of handheld drills, which was comparatively unsafe to operate in context of handling as well as other parameters if compared to latest drill machines with adjustable seat, ergonomically designed closed AC cabins and many more safety features.



Hand Held Jack Hammer Drill machine

Drill Machine without cabin

Drill Machine with Closed Cabin & AC

Fig. 1.1: Types of Drill Machines

Pneumatic Drill Rigs
- Unsafe to work
- Max hole length-150m
- Manual handling
- Productivity-2.5m/hr

High Speed Drill Rigs (MCR)
- Advance safety features
- Drills more than 500m deep holes
- Automatic operation
- Productivity-5m/hr

Fig. 1.2 Types of Drill Machines

1.2.1 Old type of Drill machine:

This type of drill machine is still used in some of the mines. It has no cabin and operator operates from outside, but this drill has the facility of wet drilling to control generation of dust while drilling.

Fig. 1.3: Drill machine *(Courtesy: Bhavanipuram Limestone Mine of M/S Deccan Cements Ltd.)*

With the advancement in the technology, drill machines available in the market that are being used in the mines are intelligent, self-propelled, self-contained, crawler based, surface drilling rig equipped with a cabin and a rod changer. These drills with practical intelligence fits perfectly for production drilling in open pit mines. To customize the rig it can be equipped with a variety of options to meet special requirements. Figure below shows the picture of the drill.

Fig. 1.4: Sandvik Pantera DP1100i Drilling Machine

As mentioned before, drilling of hole for blasting of insitu rock is a major activity in mining process. Conventional drilling machine was not equipped with safety and eco-friendly features. Hazards related to dust, noise, erection of chips are related with the drilling machine. Drilling machines are equipped with the following features:

1. Ergonomic Cabin for operator.
2. AC Cabin.
3. Cabin with ROPS / FOPS.
4. Wet Drilling.
5. Automatic rod handling system.

Wet drilling technique is adopted to suppress the dust generated by drilling equipment. A state of art wet drilling machine is deployed. The wet core drill bits utilize water to help the drill pierce through the surface of the material. Water drives the drill bit through the material faster than other core bits.

Fig. 1.5: Use of wet drilling technique

1.2.2 Automatic drill sample collection system in drill machine

Blast hole chips sampling is a very important aspect in quality control and blending process. Installation of auto sampler on DTH drill machine is done through OEM to collect samples. The Sampler is operated from the drill cabin by the drill operator, and it automates the sampling process. The sample collection of time interval is set through the potentiometer provided in control in such way that the representative sample of the entire blasthole is collected in the sample holder. This drastically reduces the time and samples are available for analysis before the blasting is done, and accordingly pre-planning of mineral supply grade wise can be achieved.

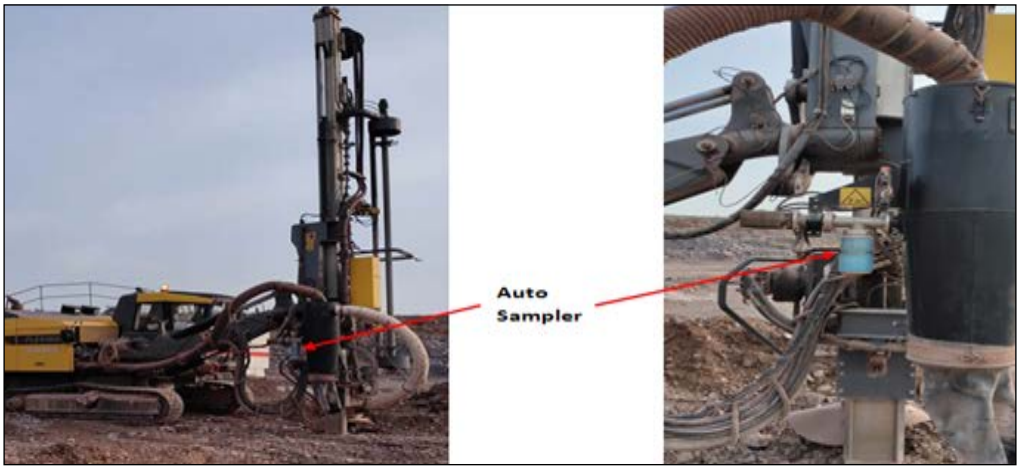


Fig. 1.6: Drill machine with Auto-sampler

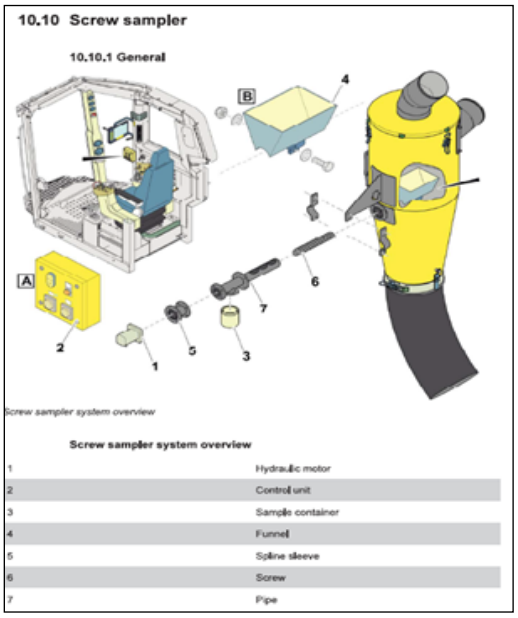


Fig. 1.7: Screw Sampler system overview with control unit

Advantages: -

1. Automatic sample collection process without manual intervention, thus improving accuracy of sample collection.
2. Fast and Safe process.
3. Timely availability of analysis of samples helps to pre-plan the blending ratio of various muck pile (sub grade and high grade), thus improving utilization of mineral which in turn helping in mineral conservation.

Use of Electric Open Cast Compressor in Drill machine

In mining, drill machines with electric compressor have been used in the field of drilling and exploration in India. As the compressor runs on electricity, it causes minimum damage to the environment and no fume is generated in the process of drilling whereby making it environment friendly.

Electric Compressor (O/C) Electric Compressor (O/C) Drilling

Fig. 1.8: Electric compressor (O/C)
Courtesy: Ramrama Manganese Mines of M/s. A.P. Trivedi Sons

1.2.3 Tele remote Operation of drilling

To eliminate the risk of geotechnical challenges due to presence of sheared rock, fault planes and dangers associated with mining method tele operated drill machines are also being used.

In Tele remote Drilling, the operator is provided with a remote either at a specific distance away from the machine (usually 25 meters from the machine) at the site or at the surface from control room. With the help of wi-fi network, live visuals from the site are transferred by two cameras present on the sideways of the machine to the remote screens. The cameras can be manually rotated in any direction by the operator and has a functional zoom in and zoom out capability to ease the operation of the machine for the operator.

This helped in achieving 100% utilization during changeover timings and in a safe operating condition for the operator wherever needed.

Fig. 1.9: Operator monitoring drilling operation from office

1.2.4 Autonomous vehicles

Some of the latest innovations include autonomous vehicles that can safely navigate underground tunnels, real time analysis tools that enable geologists to quickly identify mineral deposits, and automated drilling rigs that can operate around the clock with minimal human intervention.

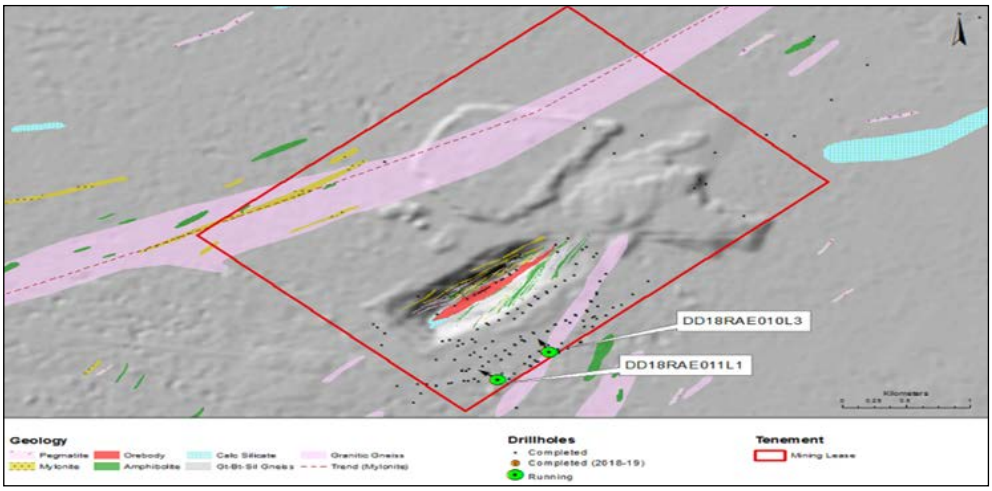


Fig. 1.10: Location of Bore holes on Surface geological map

These technologies are helping to increase the efficiency and accuracy of drilling operation, while also reducing the risk of accidents and injuries for workers, additionally, they are enabling mining companies to extract resources from previously inaccessible or uneconomical sites, which is helping to meet the growing demand for critical minerals and metals.

Of course, implementing these technologies requires significant investment and on-going maintenance and support. However, the long-term benefits in terms of increased productivity, improved safety, and reduced environmental impact are well worth the effort. As such, mining companies are actively investing in this cutting-edge exploration and drilling technologies to secure their place as leaders in the industry.

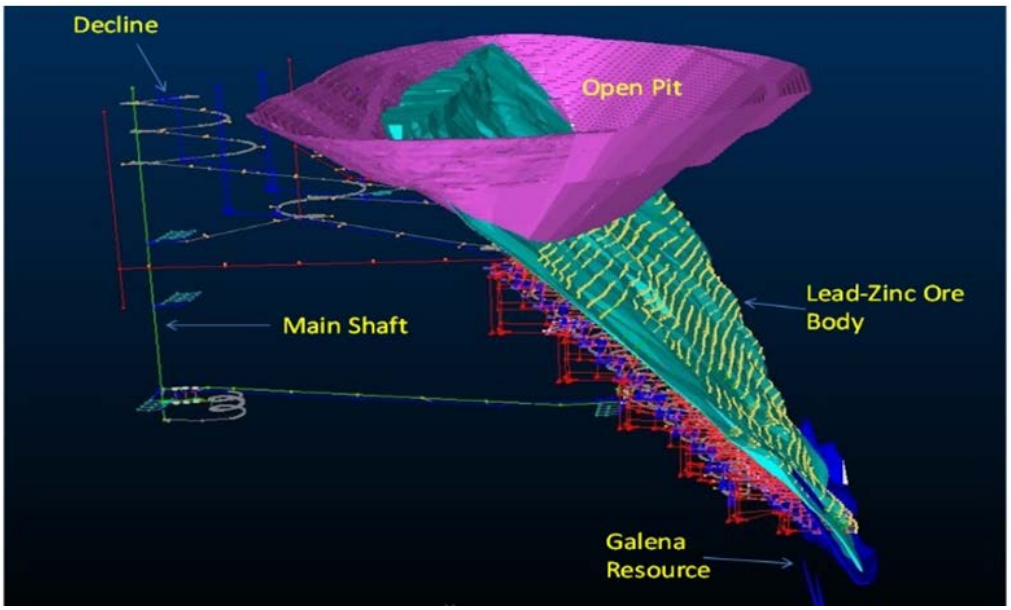


Fig. 1.11: 3D Model of Rampura Agucha lead Zinc of mines of M/s HZL

1.3 Development drilling in underground Mines

Developmental drilling in underground mines refers to a specific type of drilling activity conducted to create openings, access points, or pathways within the underground mine workings. This drilling is essential for various mining operations, including exploration, development, and production phases.

Exploration Drilling: In the early stages of mine development, exploration drilling is often conducted to determine the presence, size, and quality of mineral deposits. Developmental drilling in this context involves drilling boreholes or core samples at specific locations to gather geological and geophysical data.

Access Drilling: Once a mineral deposit is confirmed and mining operations commence, developmental drilling is used to create access points to the ore body.

This includes drilling shafts, ramps, and declines to reach the desired depth and extract the mineral resources.

Raise Drilling: Developmental drilling is also used to create vertical or inclined openings within the mine workings, known as raises. Raises serve various purposes, such as ventilation, ore passageways, or shaft connections between different levels of the mine.

Infill Drilling: During the development phase, infill drilling is often conducted to delineate the boundaries of the ore body and obtain detailed information about its characteristics. This helps in optimizing mining operations and resource estimation.

Production Drilling: While not strictly part of developmental drilling, ongoing drilling activities are conducted during the production phase to extract ore from the deposit. This includes drilling blast holes for explosives to fragment the ore and drilling boreholes for ore extraction.

Development Drilling Equipment: Developmental drilling in underground mines utilizes specialized drilling equipment, such as jumbos (drill rigs mounted on tracks or wheels), raise boring machines, and handheld drilling tools. These machines are designed to operate in confined spaces and challenging underground conditions.

Advantage of use of Autonomous drill rigs: Solo DL-421

- Auto-drilling in smoke hours
- Faster and accurate development drilling by navigated M2C.
- Automated production drilling
- Benefits of increased productivity, safety, and cost efficiency
- Operation from surface control room.
- Multiple PTZ type cameras for good visibility.
- LASER protection for safe operation

Drill rigs -DD 421

Solo DL 421

Fig. 1.12: Advanced Autonomous drill rigs
Courtesy: Sindesar Khurd underground mine of M/s Hindustan Zinc Ltd.

1.3.1 Tele–remote operation of Production Drill rigs

Monitoring Drilling Activity from Control Room: Drilling activity, its depth can be monitored in the control room, A picture of the computer monitor and area of drilling operation are shown in figure given below.

Fig. 1.13: Real time monitoring of drilling operation

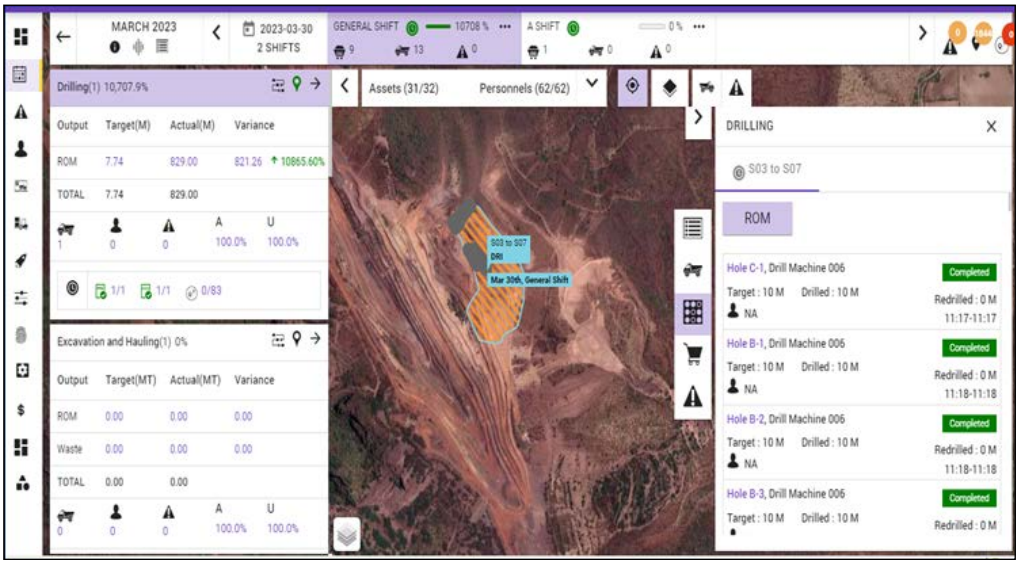


Fig. 1.14: Real time monitoring data of drilling operations by App

Digital-to-physical conversion: In mining, use of tele-remote and assisted-control equipment is becoming common, and deployment of fully autonomous equipment is taking hold in haulage, drilling, and other processes.

Fig. 1.15: Vehicle going out of the lease boundary - Real Time Alerts to Operators and Management

1.4 Exploration Drilling

The drilling of boreholes from the surface or from underground workings is required to seek and locate mineral deposits and to establish geological structure. Exploration drilling is conducted to find and evaluate potential reserves. There are two main methods of exploration drilling.

(i) Core drilling yields a solid cylinder shaped sample of the ground at an exact depth.

(ii) Reverse Circulation (RC) drilling yields a crushed sample, comprising cuttings from a fairly well determined depth in the hole. It is a quick drilling method used in mining exploration for evaluating chip samples and gathering preliminary geological data in respect of soft and powdery nature of deposit.

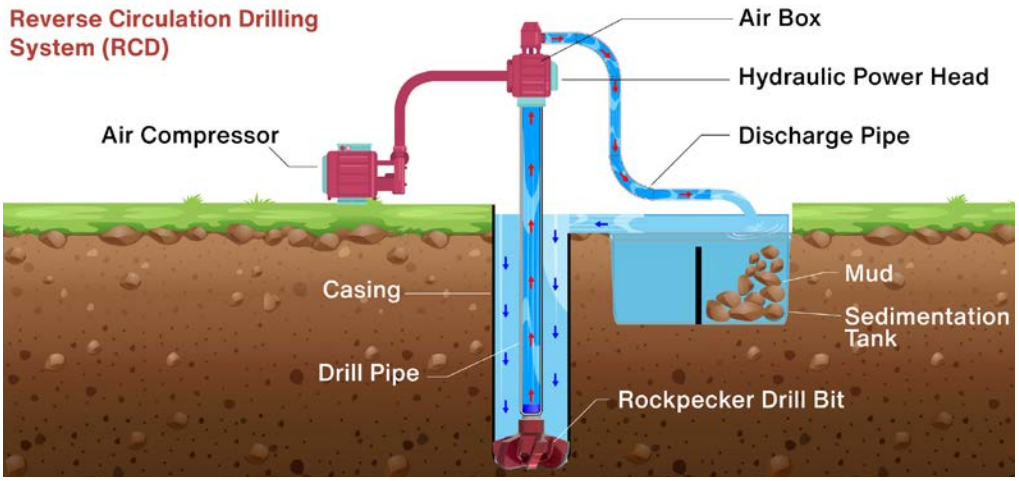


Fig. 1.16: Reverse Circulation Drilling System

Fig. 1.17: Explorac 235- Reverse Circulation Drilling Rig

Core Drilling:-The core logging has been done by studying and recording the details like Lithology, Structure, Mineralization, Recovery percentage and the Rock Quality Designation (RQD) in the field logbook. Drill core of each metre was split into two halves along predetermined marking using a hydraulic core splitter. One half of the cut core was collected for chemical analysis in sample bags and numbered. The other half was kept back into the core box after ensuring that the split cores - hard ones - carried the necessary markings. Every day after completion of borehole, the collected samples were shifted to Lab for preparation and analysis. The samples were prepared (Crushing, pulverizing, grinding, and reducing the sample to -100 size in dry condition).

1.4.1 Conventional Coring: Conventional coring is a continued development of the original rotary coring methods. Special equipment required in conventional coring includes a core bit, which is located on the extreme lower end of the drill stem, and a core barrel, for retaining the core after it has been cut, which is located immediately above the core bit.

Fig. 1.18: Conventional Core drilling Method *(Courtesy: Gudeghar Bauxite Mine)*

Fig. 1.19: Conventional Core drilling Method

Fig. 1.20: Core boxes for keeping cores

Fig. 1.21: Cores kept inside the boxes with proper marking

1.4.2 - Wire-line Coring

In order to overcome the previously cited disadvantages of conventional core drilling, methods have been developed for obtaining a core, bringing the core to the surface and proceeding with normal drilling operations, all without removing the drilling tools from the hole. This is accomplished by inserting the proper equipment in the lower part of the drill stem by means of a wire line which can run inside the drill pipe.

This wire-line coring decreased the cost of obtaining cores and thus many more cores may be obtained than would otherwise be possible. As the average depth of wells continues to increase, the time and money saved by not having to remove the drill pipe in order to obtain a core is substantial.

The only special equipment required on the lower end of the drill stem is a core bit. To obtain a core after the core bit is in place, the core-barrel assembly is forced down the inside of the drill pipe using drilling mud pressure.
Exploration is being done by Hydraulic Wireline Double Tube Barrel; Make – Eicher -2022, HP – 48, size NQ (44.6 MM), Casing- 57.6 mm.

Fig. 1.22: Hydraulic Wireline Double Tube Barrel
Courtesy: Vikram Cement works Neemuch, MP

1.4.3 Diamond Core Drilling

In order to increase both core recovery and penetration rate, use has been made of a diamond-faced coring bit. Diamond bits may be used to advantage in coring hard, dense formations where the cost of the coring with roller cutter bits is high. Although the cost of a diamond core bit may be as much as fifteen to twenty times the cost of a conventional core bit, the reduction in the number of round trips and the increased penetration rate in many cases make the diamond bit more economical.

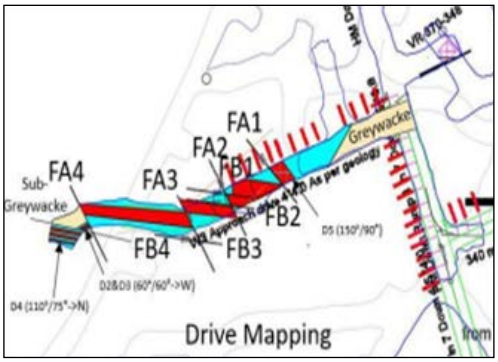
Fig. 1.23: Chain Mounted Diamond Core Drilling Machine
Courtesy: Ramanadurga Iron Ore Mine of M/s. Sri K.S. Mineral Exports Pvt. Ltd

Fig. 1.24: Core Drilling Machine Model No. CS 1000 P4
(Atlas Copco, Series HQ, NQ (63.5 mm. & 47.67 mm)

1.4.4 High Speed Drilling Rigs for Exploration

One of the advance techniques in narrow vein mining is usage of High speed drilling rigs for upgradation of resources into reserves. ATLAS DIAMEC MCR S6 are advance High speed UG exploration rigs which can drill upto 1000m depth. The flexibility of machine is 360 degree. This machine provides high productivity up to 7m/hr. Better core recovery is achieved due to large hole diameter. This high productivity of MCR leads to faster exploration and hence advances ore body delineation. This advance ore body delineation helps in guiding the ore drives hence reducing design dilution and maximum ore recovery. The productivity enhances the rate of conversion of reserves from resources.

ATLAS DIAMEC MCR S6



UG Ore body Correlation in narrow veins

Fig. 1.25: High speed drill rig

CHAPTER 2

Blasting Technology

2.0 Blasting Technology in Indian Mining Industries

Blasting is one of the important operations in the field of mining. Blasting is the backbone of the rock excavation. Though it has many adverse effects but it has been proved that with continuous improvement, Maximum output can be achieved with minimum adverse effects. That is why; manufacturers as well as users are in search of development in this area. In the open-pit metal mines, blasting effect not only has a significant effect on the mine production, but also has a direct impact on the blasting cost. The traditional continuous cylindrical charge structure leads to higher unit consumption, lower economic value, over crushing and bigger blasting vibration damage, etc.

In recent years, the study of interval charging is unceasing at home and abroad, and this technology is being applied to the production practice. Like drilling, many changes and improvements have been achieved in the field of blasting technology and we cannot think of blasting without explosives. In mining, explosives used for blasting has changed from gun powder to cartridge form and from cartridge to Site Mixed emulsion. Likewise, many new technologies have been adopted for mitigation of its adverse effects also. Many changes have occurred and softwares are being used now-a-days for designing of blast geometry taking into consideration of various concerned parameters and its effects which give an idea of blast performance.

Earlier, detonating fuse and delay detonators were used as accessories for initiation of explosives but use of NONEL in blasting has come up with a major change in the initiation system used during blasting. By adopting this technology, blasting effects like ground vibration, air blast, fly rock and sound during blasting can be optimized up to a large extent.

We can say that the major impacts i.e. "vibration and air blast" which occurred during the blasting of rock mass can be optimized if used efficiently which ultimately minimizes its effect to environment and society up to a large extent. Nonel Shock tube contains very low quantity of explosive varies between 2-3 mg/m. whereas in the conventional shock tubes contains 10-15 g/m. Accuracy of the shock tubes is very high and provides accurate delay between hole to hole/ row. It provides True bottom initiation, No disturbance in stemming length, No burning of column charge, Accurate delay for the movement of rock mass, Reducing Misfires & Reduces the noise.

2.1 Explosive and its types

As already discussed earlier that explosives are the important factor for blasting in mine. Let us have a look on Explosive, its properties, its types etc.
Explosive: It is a solid, liquid or mixture of substance which changes themselves into large volume of gases at high temperature and pressure when sudden flame, heat or shock (detonation) is applied to it.
Detonation: It is a process of giving sufficient violent shock to the explosive to bring about almost instantaneous rearrangement of atoms.
Ingredients or components of explosive:
i. Combustible material like wood meal, fibre, sulphur, charcoal etc
ii. Oxidising Agent - Sodium nitrate, Ammonium nitrate, Potassium nitrate etc
iii. Stabilisers – Calcium carbonate, Magnesium nitrate
iv. Anti-setting Agent - to prevent caking salts
v. Sentizers like metallic powder.

Types of Explosives: 1) Low Explosive & 2) High Explosive

2.1.1 Low Explosive

When low explosive is blasted, oxidation of the constituent substances is propagated by rapid combustion from particle to particle through the mass of explosive and the effect of explosion is relatively. It is fired by flame or ignition.

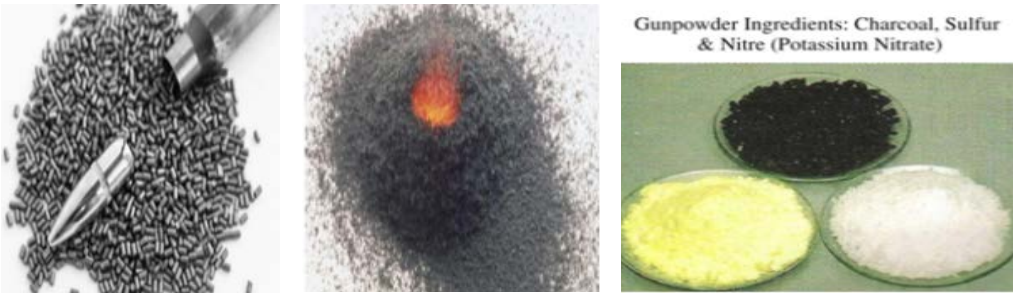


Fig. 2.1: *Gun powder*

- It burns and develop much low pressure
- Gun powder/ black powder
- It is a mechanical mixture of potassium nitrate (72-75%), charcoal (15-16%) and sulphur (10-12%)
- Speed is 450m/sec
- Poor fragmentation with heaving effect
- Used in manufacture of safety fuse; extraction of ornamental blocks

2.1.2 High Explosive:

A high explosive explodes when a violent shock is applied by detonation; the process of detonation does not proceed from particle to particle, it is instantaneous and the constituents react with high velocity.It produces shattering effect.

Common examples of High Explosives are:-

- Nitroglycerin (1845)
- Dynamite (1860)
- Dynamite perfected and Non-NG, High AN, Cap Sensitive (1930 – 50)
- ANFO (1947)
- LOX (1930, in India)
- Slurry (1960-62)
- Cap-sensitive Slurry (1970)
- Emulsion (1978)
- Bulk Explosives (1980 -90)

1. Nitroglycein based explosives:

- Compositions: NG-5%-90%; NC-Gelling/thickening agent &senstizer; Oxidizer-AN & SN; Fuel ingredients- Starches, wood flours, sulfur;
- Sensitive to shock, friction & heat.
- High VOD of 7800m/sec ;temp@detn.- 3150 deg.C.
- Density:0.8-1.45, RBS: 73-79%, Temp.Res:-17 deg. Examples: TEL-GEX-80/90/LD (TEL), OCG(ICI).

Advantages	Disadvantages
High strengths	Risk of accidents
High densities	Sensitive to friction and heat
High detonation velocity	Handling problems
Greater water resistance and chemical stability	High manufacturing cost

2. Ammonium Nitrate Fuel Oil (ANFO):

- 94.3% AN + 5.7% FO (Oxygen Balanced)
- Fuel Oil –Diesel Oil No.2 (for 50 kg of AN-3.7 liters)
- It is a cheap, low-density, cap-insensitive explosive, requiring primer charge of high explosives.
- Sensitivity and Performance of AN, depends on 'quality' of the Prill supplied
- Sensitivity or Energy increased by adding Fuel grade Aluminum and affected by water
- Density: 0.8-0.9, RBS: 51-55%, Temp. Res:32 deg C.

Advantages	Disadvantages
Superior in cost effectiveness	Desensitized in water
Safe to handle	Inefficient in small dia holes
Best suitable for dry holes	Unsuccessful blasting in hard rocks
Explosive is prepared only at the site	Lower sensitivity

Earlier the ANFO (Ammonium Nitrate Fuel Oil) is prepared manually in the licensed Mixing shed, where there were chances of imperfection in mixing percentage of AN & Diesel. Now, the manual mixing is replaced with BMD Vehicle (Bulk mixing delivery), which is very safe in handling and mixing the AN with Fuel oil (Diesel) and is done with pre-programmed in-built unit, where setting of the mixing proportion depends on the blast site conditions.

3. LOX (Liquid Oxygen)

- It is made by soaking cartridge of activated charcoal-27% (combustible ingredient) - in liquid oxygen (73%).
- High detonation pressure (14*10000 atmos.) and explosion temperature (6600 degree C).
- Large volume of gas is released at high temperature.

Advantages	Disadvantages
Suitable for dense and medium rocks	Cost is high
No emission of noxious gases	Quicker evaporation (life is shorter)
It causes less vibrations than conventional explosive	Unsafe
Misfires can be handled safely after lapse of certain duration	

4. Slurry

- Addition of colloid such as 'Guargum' in ANFO, which builds up 'Viscosity', followed by Cross-linking agent which forms a gelled mixture.
- Compositions:
  Oxidizer: AN, SN;
  Fuel: Sugar, Coal;
  Sensitizer- TNT, Al;
- Plant or Truck mixed
- Detonation velocity: 3000-4500 m/sec
- Density:1-1.2, RBS: 53-65%
- Temperature resistance: 4 deg C

Advantages	Disadvantages
Water resistant	Life is only 6 months
Effective utilization of explosives	Not suitable for high temperature conditions
Not subjected to friction or impact	
It produces low non-toxic fumes	

5. Emulsion

- Consists of oxiders dissolved in water surrounded by a fuel – fine particle size
- Senstizer: air/gas bubbles or artificial glass micro balloons-hot spot;
- Emulsifier-waxes, gums
- VOD: 4000-5000 m/s
- Density range of 1.1 to 1.35 g/cc
- High water resistant in full concentration
- Plant of Truck mixed
- High velocity and bulk strength
- Temperature resistance: 4 deg. C

6. Bulk Explosives

- Explosives directly delivered into the blast hole through mechanised and mobile delivery system.
- Supplied to large opencast mines and civil construction projects
- Types – Bulk ANFO, Bulk Watergel, Bulk Emulsion, HANFO.

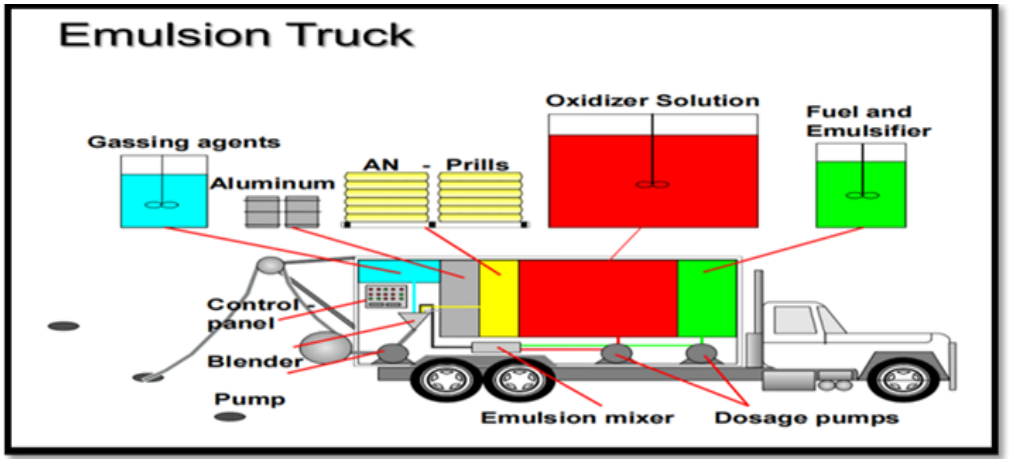


Fig. 2.2: Site Mix Emulsion Truck

- Benefits of Bulk Explosives: Safety, Inventory, Explosive vans, Manpower, Speed of operation, Explosive Product, Blasting effieciency.

Lead Azide:

Lead azide [$Pb(N_3)_2$] is an explosive and toxic crystalline compound frequently used in primers, blasting caps, and fuses. Lead azide is sensitive to heat, shock and friction. The velocity of detonation is approximately 17,500 feet /second. Its color varies from white to buff. It is not very hygroscopic, but when properly protected from moisture it will not suffer a decrease in performance and can be stored for long periods of time. Water does not reduce its impact sensitivity. When protected from humidity, is completely stable in storage.

Mercury Fulminate:

Mercury (II) fulminate [$Hg(CNO)_2$] is highly sensitive to friction and shock and sparks. It is mainly used as a trigger for other explosives in percussion caps and blasting caps. It explosively decomposes to form mercury, carbon monoxide, and nitrogen.

Fig. 2.3: Mercury Fulminate

Ammonium Nitrate:

It is cheap, stable, low brisance value, insensitive and non toxic. It is a high explosive, though about half powerful as TNT and used along with another explosive in making binary explosive. It is dangerous to store near any inflammable material. It cannot be used in contact with the alloy of copper as it forms tetramino cupric nitrate which detonates easily. It has positive oxygen balance and is therefore, used to supply oxygen for other explosives having negative oxygen balance. It can be obtained by passing through Ammonia gas through HNO_3 (40-60%). It decomposes on heating to give N_20, NO_2 and N_2.

Fig. 2.4: Ammonium Nitrate

Fig. 2.5: Trinitrotoluene

Trinitrotoluene (TNT):

It is prepared by nitration of toluene, using nitrating mixture of conc. HNO_3 and $H2SO_4$ in 1:1 ratio, in a tank reactor, in which reactant are vigorously stirred. The liquid product is washed with ammonical solution of Na_2SO_3 and then cold water. TNT will crystallize out. TNT crystals are purified by melting. It differs from many other explosive containing nitrates. In this class of explosives, NO_2 group are attached to the carbon atoms. TNT is a true nitro compound and is a powerful explosive . It is not sensitive to impact or friction and its ignition temperature is 250^0 C. So it is safe explosive in transportations, storage and manufacture. It is explosive of its own but forms a part of many commercial or military explosives i.e. amatol and ammonal.

Penta Erythritol Tetra Nitrate (PETN):

It is an extremely sensitive, powerful and standard military explosive. It is so sensitive, that it can be detonated even by the impact of the rifle bullet. It is formed from formaldehyde and acetaldehyde by the cannizaro reaction.

Fig. 2.6: PENTA ERYTHRITOL TETRA NITRATE

2.2 Blasting accessories:

Parallel to evolution of explosives, different blasting accessories which include various initiating devices and blasting assisting equipments are developed in an attempt to obtain following objectives:

(i) Energetic initiation of the modern explosives, which is much more insensitive than classical dynamites but also safer.
(ii) Control over initiation times to improve fragmentation.
(iii) Reduction of the vibration levels, air blasts and fly-rocks produced in blasts.
(iv) Punctual priming, either at the top or base of the blast hole, or axial priming.
(v) More speed and flexibility in breakage operations while maintaining a high degree of safety for personnel and installations.

Cast Booster

An explosive booster is a sensitive explosive charge that acts as a bridge between a conventional detonator and a low-sensitivity (but typically high-energy) explosive. Booster is made of a high explosive composition cast into a cardboard/plastic shell. Two longitudinal tunnels in the booster accommodate either a detonator or detonating cord. One tunnel has straight walls while the other tunnel is tapered with a detonator retention feature. This end of the tunnel is blocked at the top of the Booster. Detonating cord, signal tube or lead wires are protected from damage by a recessed well at the base of the booster.

Cast boosters are reliably initiated by No. 8 strength detonators or by detonating cords containing at least 5.0 g/m PETN. These boosters have been specially designed to provide reliable initiation of pumped, augured and packaged explosives. The main intended application for Cast boosters is for use with ANFO and Bulk explosives.

Fig. 2.7: Cast Booster

2.2.1 Accesories for initiating Blast (Initiating Devices)

There are various numbers of techniques which can be used for introducing energy into a column of explosives and thereby initiating detonation which are categorizes into three different systems of initiator:

- Non- Electric initiator
- Electric initiator
- Electronic initiator

Non-Electric Initiator

(i) Safety Fuse: It is used to ignite low explosives and detonator to initiate high explosives. It has a core of black powder tightly wrapped with various layers of waterproof textile yarn/tape. It has accurate timing, poor fragmentation and poor safety. Safety tube burns at a rate of 120 seconds per metre.

Fig. 2.8: Safety Fuse

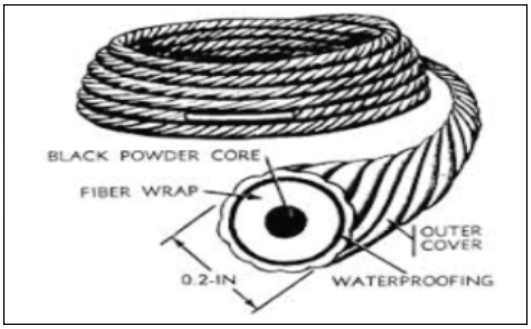


Fig. 2.9: Cross Section diagram

(ii) Detonator:

Detonators are used to initiate safety fuse and detonating fuse. These are of two types:

(a) Plain detonator
(b) Delay detonator

Plain Detonator: Plain Detonator consists of an aluminium tube (32-50 mm) long and 6.5 mm in diameter which contains explosive charge pressed at the bottom of the tube. It is used with Safety Fuse. These detonators are of No. 8 strength and are used for blasting in quarries, opencast mines, surface excavations, well sinking, road construction, civil works etc.

Plain Detonators are non-electric in nature. These are initiated by a strand of safety fuse that is inserted into the cap and crimped with a crimping tool to prevent the fuse from slipping out of the cap and to prevent water or other foreign material entering the cap. The safety fuse should be cut squarely so that it comes into contact with igniting charge of the cap.

Delay Detonator: Delay Detonators are same as plain detonators with a delay element that is included inside the tube to provide delays. It provides short delay & long delay non electric initiation system to be used in conjunction with detonating cord trunk lines or other nonelectric delay systems to provide flexibility in blast design and ease of use.

Cord Relay: Cord Relay consist of millisecond delay detonators of the same delay interval crimped in specially designed plastic housing, which makes the product bi-directional. The plastic housing has a provision for hooking up detonating cord at either end. The delay interval is printed on the plastic housing. Cord relays are used in conjunction with detonating cord trunk lines in opencast, metal and coal mines, quarrying, civil construction and in underground metal mines. They provide an accurate delay between blast holes in a row or between the rows. Cord Relay can be used for developing various delay patterns.

(iii) Detonating Cord :

It is made up of thin plastic tube of radius about 3mm with PETN in its core. It is used as trunk line and down line for initiation depending upon severity of application. Its energy release depends on the amount of petn in the core, which generally varies from 1.5 g/m to 70 g/m.10 g/m is the petn weight of standard detonating cord whose vod is about 7000 m/s. Velocity of detonation of DF is generally 6500m/s to 7000m/s.A detonator is required to initiate a length of detonating cord which cannot be normally initiated by fire.

Detonating cord has two functions:

- To provide simultaneous detonation of several interconnected Blasthole charges, thus avoiding the need for multiple electric or plain detonators.
- To provide continuous initiation of the full length of an explosive Column in a blasthole, as distinct from point initiation with individual detonators.

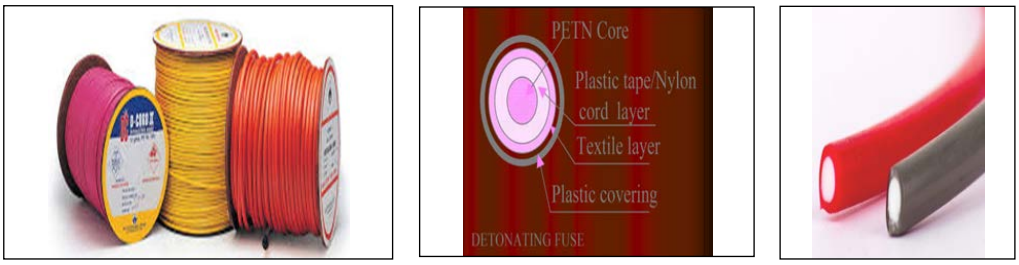


Fig. 2.10: Detonating fuse wound in reels (L) and cross-sectional views (R)

(iv) NONEL or Shock Tube:

Based upon the use, it is made up of a tough sealed plastic tube (OD= 3mm, ID=1.2mm) inside of which is coated with a reactive substance HMX. Both end of the shock tube comprises of nonel detonator with different delay timings associated with each of them. One end of nonel provide down the hole delay initiation while trunk line detonator enclosed in plastic connector. Shock-wave whirls up a dust cloud of reactive material which is initiated by spark and travels at speed of 2100m/s within tube. Being non-electrical and non-metallic, shock tubes are less sensitive to static electricity and radio frequency energy and thus have replaced many uses of electric detonators and are safer to handle and store than detonating cord.

Fig. 2.11: NONEL connector

2.2.2 Electric Initiator:

Basically, electronic detonators are of two types:
(i) Instantaneous Electric Detonators
(ii)Long/Short Electric Delay detonators.

Electric detonators consists of cylindrical metal tubes of aluminium or copper. Inside the tube starting from bottom is base charge of PETN and after this ASA as a prime charge.

Inside the tube fuse head is inserted. Fuse head consists of chrome wire which is covered by flashing composition such as potassium chlorate (oxidiser), charcoal (fuel) and lead thiocyanide (fuel sensitizer). Delay elements are inserted between fuse head and initiating charge (if delay detonator) and the timing are marked on each detonator. A pair of leg wires (TWC/GI) connects the fuse head, which passes the current through fuse head which heats the chrome wire which when ignited burns the flashing composition. This initiated the prime charge which then initiates the base charge then detonator gets blasted. To make it water resistant the leg wire is first inserted into a sealing plug and then soldered to fuse head. The whole set is inserted into metal cylindrical shell containing PETN (base charge) and ASA as prime charge and crimping is done with the help of collet. The delay timing is predetermined by the length, composition and burning speed of delay element.

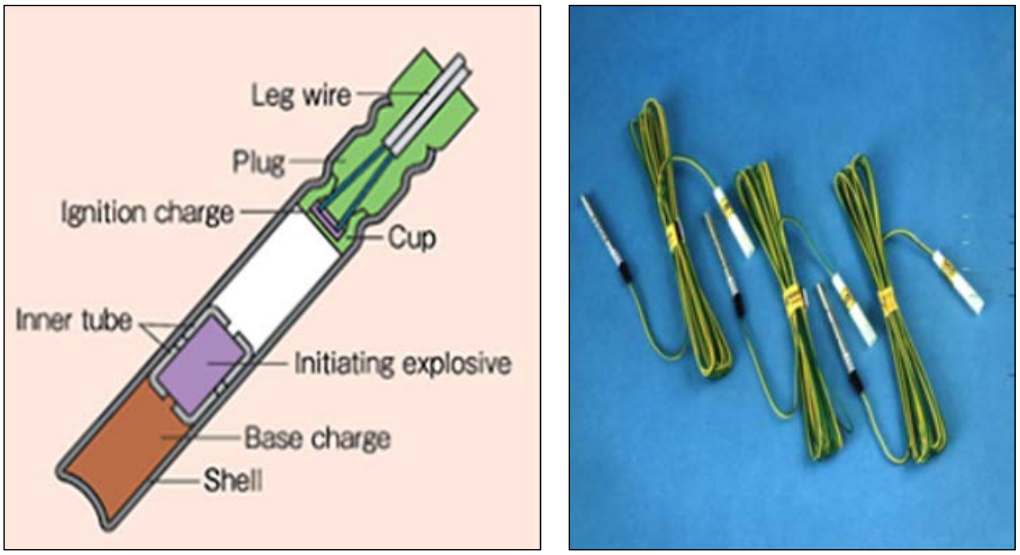


Fig. 2.12: Cross-sectional view of instantaneous electrical detonator (L) and electrical detonator (R)

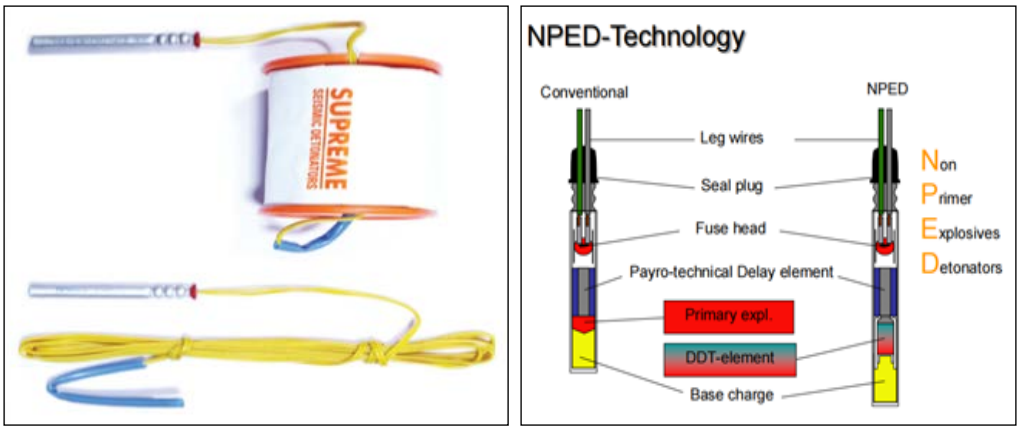


Fig. 2.13: Electrical seismic Detonator

2.2.3 Electronic Detonator:

The Ministry of Commerce and Industry has issued circular in September 2023 regarding phasing out of Electrical detonator by the end of financial year 2024-2025. It says that the explosive, namely, electric detonator (explosive of Class 6 Division 3 or U N Class 1 Division 1) is of a dangerous character and whereas it is expedient for the security concerns and public safety to prohibit the manufacture, possession and import of electric detonator, whereas the Central Government, after consultation with stakeholders of explosives industry, in the public interest has decided that the production of the said explosive shall be completely phased throughout the country with effect from the 1st day of April 2025.

Electronic detonators are modern, fully programmable and intelligent high strength detonators. Each detonator contains a circuit board that can be programmed to initiate at precise millisecond timing within a firing sequence. Detonators are individually programmed via the use of a handheld tagger and initiated via a bespoke blasting box. Electronic detonator consists of an electronic circuit which controls the delay timing of the detonator. The Microprocessor-based electronic circuit permits setting of variable delay timing. Each detonator has a unique detonator ID number allotted to it at the time of manufacture. Also, each detonator is provided with a unique tag number which acts as a detonator ID number. The electronic circuit has a digital timing circuit and an energy storage device, which will release the energy, only when the arm and then the firing instruction are given.

The electronic detonator is connected to a connector by a Twin Copper/ Copper, coated steel wire. The micro logger can be connected to the twin Copper/Copper coated steel wire through the connector.

The Electronic Detonator consists of the following parts:

1. Detonator Shell: The detonator shell is made of either Aluminium or Copper and having an outer diameter of 7.5 mm. The length of the shell varies from 80-85mm. The Base charge and Primary charge is made of PETN and ASA composition.
2. Network Tester: The Network Tester is used to check the network connection. The connection made with all the detonators will harness wire and check with the network tester. If any one of those is not connected properly, the hole ID of that particular detonator is displayed on the screen of the Network Tester.
3. Micro Blaster: This is used to check the circuit after all hook up is completed. The blaster checks each detonator one after the other and confirms its readiness to 'Arm' and 'Fire' the detonator.
4. Delay Timing: The programmable electronic detonators can be set with a delay interval of 1 ms from 0 ms to 8000 ms. The delay variation is maximum 1 ms for delay upto 500 ms and +/- 0.2% beyond 500ms.

Fig. 2.14: Electronic detonator

The electronic circuit or the Chip controls the delay timing and safely allows the firing sequence.

i. Lead Wire: It consists of twin Copper/Copper coated steel wire with PVC coating.

ii. Connector: This is a hinged plastic device, which would connect the individual detonator through the twin Copper/Copper coated steel wire to the main circuit. The connector is used for quick connection of the detonator to the main bus line.

iii. Lead Wire Spool: For lead wire length of above 10 metres, the wire is coiled on to a plastic spool. The detonator will be inserted and secured in the centre shaft space.

iv. The Micro Logger: This is used to set the delay time and has the capability to store information like hole number, detonator ID, delay time and the blast number. The Micro Logger, when connected to the Electronic Detonator, it allots to that particular detonator the ID number, hole number and the delay time that has been set in to it.

It also checks the integrity of the detonator. The required/ desired delay time thus allotted can be changed, modified before the data is transferred to the blasting machine. After logging all the detonators, the data from the Micro Logger is transferred to the Network tester and Blaster.

Disadvantages of electronic detonators are:

- Higher price because of chip and capacitor.
- Back to electric wiring-risk of ground faults or poor contacts.

2.2.4 Power Source for electrical firing

Electric blasting is energized by Exploders. Storage in dry cells batteries is not recommended for electrical blasting because they cannot be relied on for consistent output. The energizing of blasting with alternating current from an industrial line or a generator is not recommended because, as the tension values fluctuates during a cycle of 20ms, one never knows with what intensity the blast will be energized, which could produce misfires. Power sources for electrical firing are:

1. Exploders
2. Sequential Blasting Machines
3. Mains Firing

2.3 Blasting Circuit Testing

Blasting procedure can be successfully executed only if proper care is exercised in planning and connecting the blasting circuit.A list of possible circuit weakness is given below:

a) Discontinuity	b) Current leakage	c) Stray Electricity
In detonator circuit and in total or any part of blasting circuit.	Leakage can occur when damage to leg wire insulation allows the bare wire to make a contact with the rock especially under conditions or conducting ore body.	Current leakage from extraneous sources.

2.3.1 Two types of blasting circuit tester:

Blasting Ohmmeter	Blasting Multimeter
It is used only to check circuit resistance.	It can be used to check circuit resistance, AC and DC voltage, stray current and current leakage.

Fig. 2.15: Blasting circuit tester

2.4 Blasting Accessories to make Blast Environment Friendly

Only 15-25% of the total explosive energy is used for fragmentation, displacement and throw of the rock and out of which only 50% is used in creating new surface area. Remaining energy is wasted without doing any effective work in terms of fly rocks, ground vibration, air overpressure etc. It is a challenge for mining engineer to increase the use of explosive energy by new innovations and development of blasting accessories. These developments will reduce blasting cost and blasting hazards. These blasting accessories in blasting field may be proved as an efficient tool to increase the utilization of explosive energy by 1%. Blasting control plugs/ Stemming plugs:-Different materials can be used as spacer to provide Air deck in explosive column. They are as follows:

1. Plastic Spacer:

Discarded water bottles were recently tried to provide air deck in blasting in some mines in India. The results were very encouraging. The total explosive cost was reduced by 7-16% with better fragmentation, less fly rock and reduced ground vibration. The carbon dioxide emission was also reduced by 5-11%. In India every year about 0.15 MMT of CO2 is emitted into the atmosphere by detonation of explosive. By using discarded water bottles in blasting, 5-11% CO2 emission could be reduced. Moreover, the technique was found very effective in reducing explosive consumption and other environmental impacts of blasting like ground vibration and fly rock.

Fig. 2.16: Spacer for blast hole and blast hole cross section

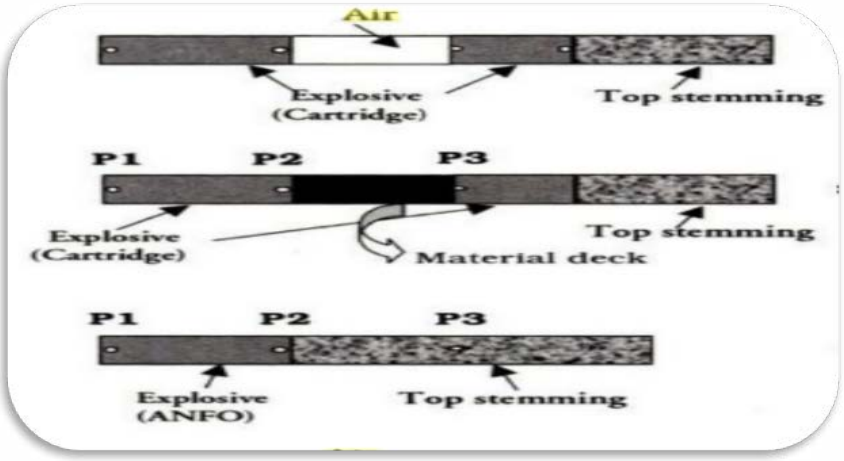


Fig. 2.17: Diagram of Air and material Decking

2. Stemming Plug

The stemming plug is inserted inside the blast hole with narrow end pointing downwards up to the decided length of stemming and then the stemming materials are filled over the stemming plugs to seal the blast hole.
The Stemming plug is manufactured from durable and resilient polymer which works by creating a blocking effect within the blast hole by wedging the stemming material between the blast hole wall and the plug.

Fig. 2.18: Stemming Plug

3. Activated Gas bags:

Gas bags are self-initiating unit via aerosol can inside producing the inflating gas. The gas bag is inflated by depressing the trigger at the top of aerosol can. When trigger is locked down, it releases the contents of the aerosol can into the gas bag and inflate it to the correct pressure to lock the bag in the borehole. Gas bags are available for a variety of drill hole diameter. It can be used to check explosive wastage through fissure and voids where SMS, SME or Bulk explosives are used. Wooden spacers are cheaper, they are restricted to dry hole condition where Gasbag can be used in any condition, they are found to perform well even in watery holes on the top of old underground working.

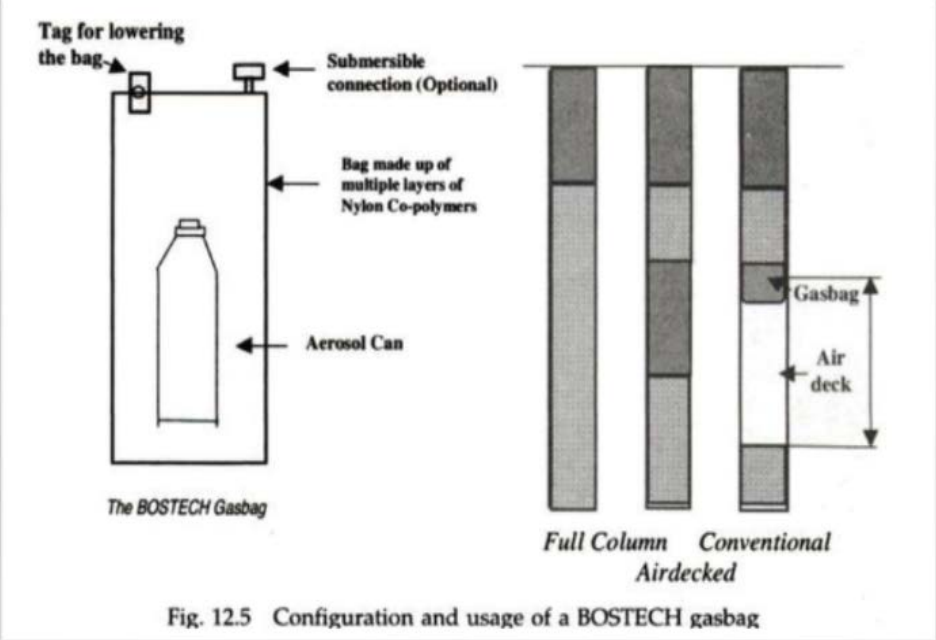


Fig. 12.5 Configuration and usage of a BOSTECH gasbag

Fig. 2.19: Configuration and usage of BOSTECH gasbag

2.5- Monitoring of Blasting Activity

Blasting module: The blasting module is integrated with operations control module, thus all the blast sections taken through LMNOP app gets imposed in live tracking Exhibit along with its own unique ID. This section also shows the sample quality along with slice plan quality of that particular section and block and the blasted inventory which is real time. This integration helps the operations team to keep a better track in quality deviations and live blast inventory tracking as well.

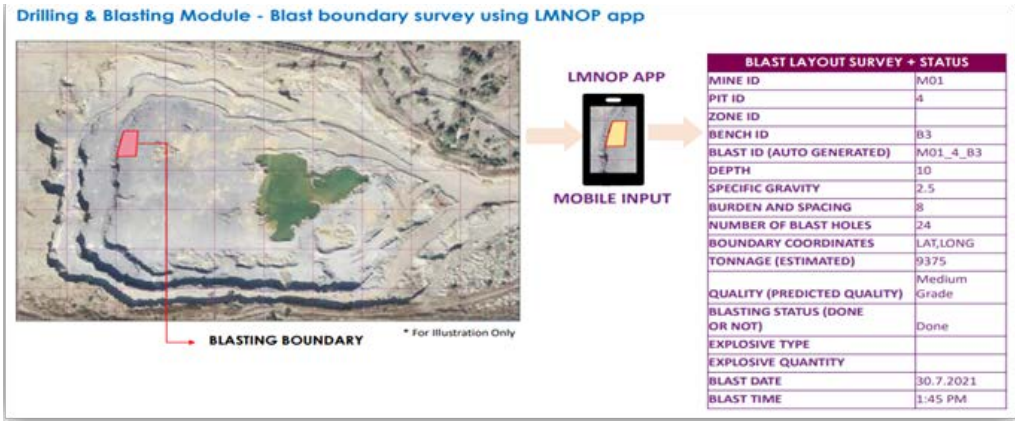


Fig. 2.20: Blasting Module

Monitoring of Blasting Activity: For regular study of data machines like mini mate and seismograph are used which help to know the real time vibration data.

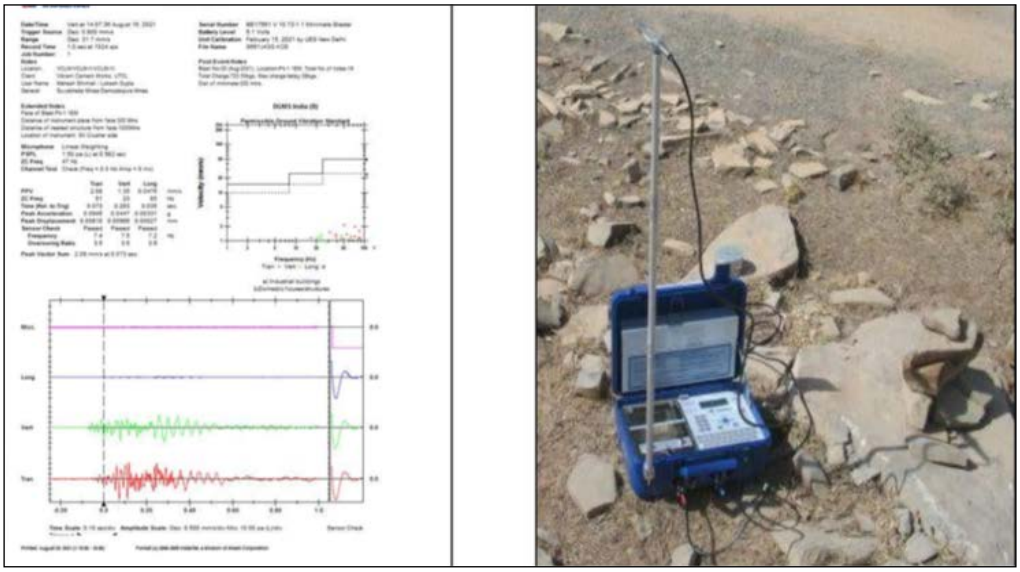


Fig. 2.21: Monitoring of Blasting Activity by mini mate and seismograph

2.6 Alternative to Blasting

In many opencast mines in India and abroad, wherever it is suitable (based on the characteristics of rock), Rock breaker and Surface miner is being used to directly break insitu rock without blasting. This blast-free mining is helpful to overcome many harmful effects occurred due to blasting like ground vibration, air blast fly rock etc.

2.6.1- Terminator Rock Breaker

This is a new generation breaking unit which functions by hydraulically operated gravity impact hammer, designed as an alternative to traditional breaking methods. It is an excellent alternative to the standard breaking machines, capable to deliver more powerful performance and superior results on the job site. The Terminator rock breaker is used for a variety of applications, including primary breaking, secondary breaking procedure in quarries and mines, slag and foundry waste, demolition works, and for other similar applications. The Terminator rock breaker works by lifting hydraulically a forged steel made weight and allowing it to fall freely on the striker pin Equipped with the latest safety features, this machine will provide advantage of extracting high grade limestone from sensitive locations where blasting cannot be done. A part blasting has been replaced by using Terminator, which drastically reduced blasting and minimized vibration up to a greater extent.

Fig. 2.22: Terminator Rock Breaker DX1800A
Courtesy: Arasmeta Limestone Mines

Fig. 2.23: Tata Hitachi Terminator Rock breaker

This rock breaker functions with high energy impacts at low-rate strikes. The Terminator rock breaker offers many positive benefits and advantages in terms of efficiency, productivity, performance, costs, noise, maintenance, durability, longevity etc.

2.6.2- Surface Miner

Surface miner is a good alternative machinery used to avoid both drilling and blasting if suitable for the deposit and is an environment friendly and highly productive machine. Adopted in opencast mines by many industries.

Fig. 2.24: Surface Miner

CHAPTER 3

Excavation & Loading Machineries

3.0 Innovation in the field of Excavation Machineries

The mining industry in India has transitioned from manual to mechanized operations, with technology and automation adoption at different levels of maturity. There has been a major revolution in the field of mining excavation technology also. The meaning of the word "excavate" is to dislodge the rock mass from its original place (in-situ). This involves two operations: digging the ground and its disposal. This process includes interaction of the bucket of the excavator with the rock during which the machine applies multiple forces for excavation and material handling. The loading process is still in semi-independent level of autonomy with some major original equipment manufacturers (OEMs) promoting the tele-operations for the excavators and loaders.

The application of modern technology in the field of excavation is like a boon to the mining industry and it eases the operation in various aspects. New technology makes accurate excavation easier and faster, Enabled on many new heavy equipment models.

GPS technology provides real-time updates on the grade of the land, giving them insight into where and how much earth needs to be moved. Those days are gone when operators fatigue decreases the performance/production of the shift due to tiredness. Nowadays, remote controlled machineries are being used to improve performance in this field. Digital performance report of excavator in shift hours that helps to find their voids/lacking and helps to get maximum output.

Importance of Bharat Standard 6 (BS6) in Mining Industries

While selection of equipments, one should not neglect the importance of CEV 4 or Bharat Standard 6 (BS6) in any industry. The implementation of BS6 emission standards in the mining industry is not directly applicable as it is primarily for regulating emissions from vehicles with internal combustion engines used for transportation purposes. However, the mining industry can still benefit from the use of BS6 compliant vehicles and equipment. Mining operations often use heavy machinery and equipment, such as excavators, loaders, and haul trucks, which can emit significant amounts of pollutants into the atmosphere.

The use of BS6 compliant engines and equipment in the mining industry can help reduce emissions of harmful pollutants such as particulate matter, nitrogen oxides, and sulphur dioxide. This, in turn, can help improve air quality in and around mining areas, which is particularly important for the health and well-being of workers and nearby communities. In addition, the use of BS6 compliant equipment can help mining companies reduce their carbon footprint and improve their environmental performance. This can lead to better public perception, increased investor confidence, and better long-term sustainability of the mining industry.

Excavators used in mining industry are specialized machines designed for heavy-duty excavation and earthmoving tasks in mining operations. These excavators are built to withstand the harsh conditions and heavy loads encountered in mining sites. Their applicability in mines depends on various factors like characteristics of rock/ore/mineral, production requirement, work to be done and the place where it is to be used.

3.1 Types of mining excavators

3.1.1 Bucket Wheel Excavator: Massive excavators with a rotating wheel equipped with buckets. Used for continuous digging and removing overburden in open-pit mining operations. Efficient for handling large volumes of materials in mining.

Fig. 3.1: Bucket Wheel Excavator

Dragline Excavator: Enormous excavators equipped with a long boom and a dragline bucket suspended by cables. Ideal for removing overburden and extracting minerals from deep pits and open-pit mines. Commonly used in coal mining and large-scale surface mining operations.

Fig. 3.2: Dragline Excavator

Electric Rope Shovel: Large-scale excavators powered by electric motors and operated by ropes and cables. Equipped with a large bucket for digging and loading materials onto haul trucks. Commonly used in surface mining operations for digging copper, iron ore, and other minerals.

Fig. 3.3: Electric Rope Shovel

3.1.2 Hydraulic Excavator: Excavators powered by hydraulic systems. Hydraulic cylinders and motors are utilized for digging, lifting, and loading operations. Versatile machines used for various tasks in mining, including digging pits, loading trucks, and moving materials.
i. Hydraulic Shovel: Heavy-duty excavators with a front shovel attachment for digging and loading materials. Designed for efficient loading of haul trucks and handling of large volumes of materials. Commonly used in large-scale mining operations for excavating and loading minerals.

ii. Back Hoe: Excavators equipped with a backhoe attachment for digging and loading materials. Used in mining operations for digging trenches, loading trucks, and other earthmoving tasks. Versatile machines suitable for various mining applications

iii.Loader: A loader is a heavy equipment machine usually wheeled, sometimes on tracks, that has a front-mounted wide bucket connected to the end of two booms (arms) to scoop up loose material from the ground, such as dirt, sand or gravel, and move it from one place to another without pushing the material across the ground.

Fig. 3.4: Back hoe

Fig 3.5: Front-mounted wide bucket loader

3.1.3 LHD (Load, Haul, Dump) Loaders: They are similar to conventional front-end loaders but developed for the toughest of hard rock mining applications, keeping overall production economy, safety, and reliability in consideration. They are extremely rugged, highly manoeuvrable, and exceptionally productive. More than 75% of the world's underground metal mines use LHD for handling the muck of their excavations.

Fig. 3.6: Load Haul Dump: CAT Model R1700G

These mining excavators play a crucial role in the mining industry by facilitating efficient excavation, earthmoving, and material handling processes in surface mining operations.

3.2 Latest Innovations in excavation machinaries

3.2.1 Remote and Tele-remote Operated Loaders: Tele remote operated equipment has become known for its ability to improve safety on a mine site with global mining operations facing a labour crunch, tele-remote operation can tackle the issue on several fronts. As tele-remote allows the operator to control the machine from a distance, the use of offsite command centres can help attract a new workforce, as operators are not required to travel to remote locations or endure potentially rough working environments.

Tele-remote operation of mobile earth-moving machines in underground mines supported by operator assistance functions is attractive for safety and productivity reasons. This way, operators can avoid hazardous underground environments with poor air quality and the productivity can, in principle, be improved by saving the time required to commute drivers to and from the operational areas. The infrastructure needed to do tele-remote control in the form of high-capacity wireless IP network is nowadays being deployed in underground mines.

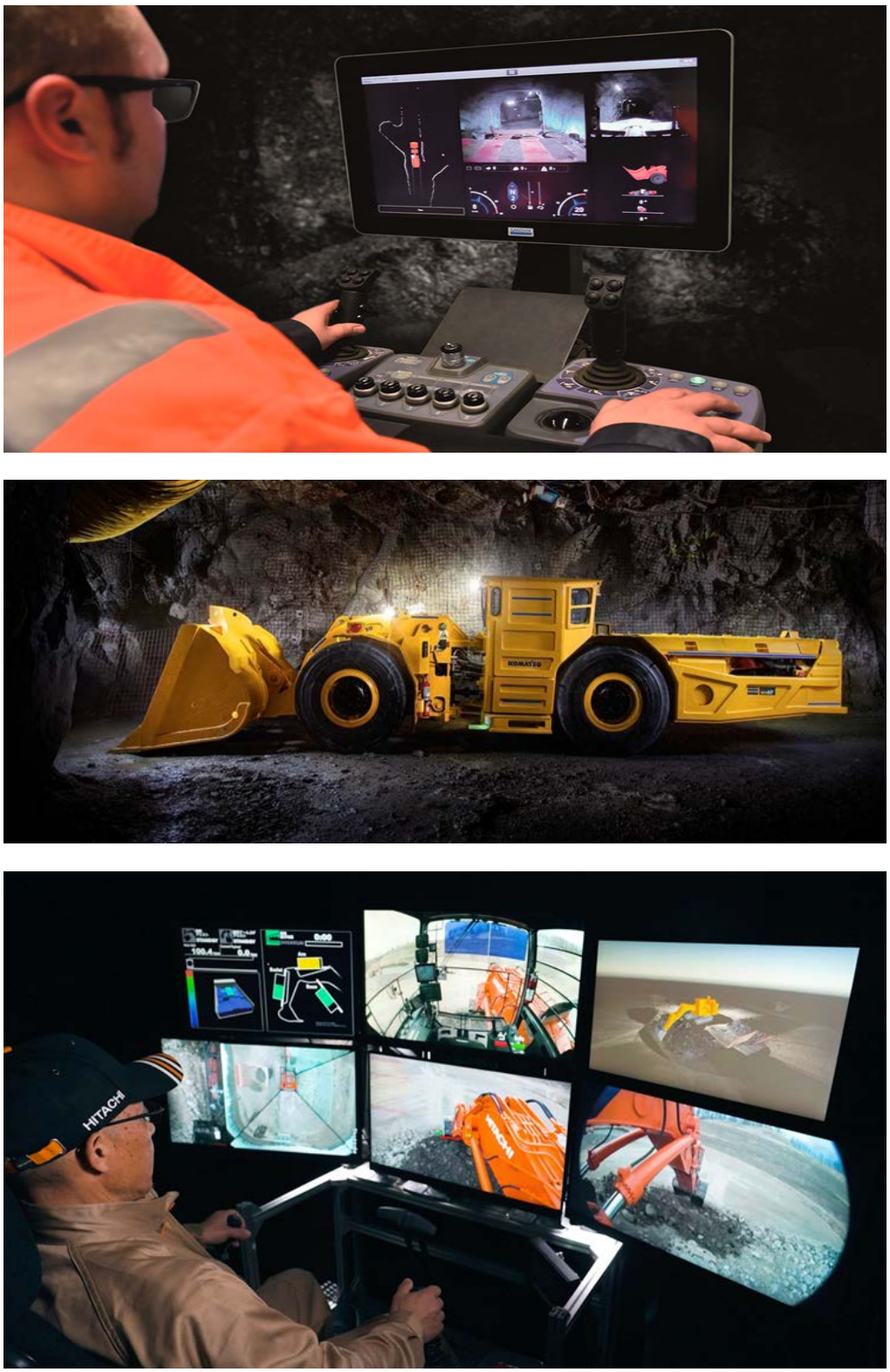


Fig. 3.7: Tele-remote Operated Loaders

3.2.2 Excavators equipped with the mobile tablets:

The rugged devices equipped in the excavators are installed with the Reactor mobile application. This application allows the operator to do the maintenance checks which are already registered in the application. The operator has to go through the Pre checks before starting the equipment. The purpose of the pre check and post check is to ensure the machine safety. Live tracking of the assets can be tracked through the devices installed in it. Mobile Handsets are installed in Tippers and Tablets are installed in Excavators. The Excavator operator can see the available tippers on the screen of the tablet installed in the excavator.

Fig.3.8: Excavators equipped with the mobile tablets
Courtesy: M/s JSW Mines of Karnataka

Fig. 3.9: Electrical-LHD- Operation of Load Haul Dump (LHD's) (electrical and diesel) in underground mines at Hutti Gold Mines

3.3 Different Attachments in Excavator

3.3.1 Rock breaker tool: With the help of rock breaker tool mounted on the excavator, Secondary blasting can be avoided. In some mines, complete drilling and blasting process has been eliminated and rock breaker is being used to break the in-situ rock depending on the characteristics of rock of that area.

Fig. 3.10: Insitu Rock breaking
Courtesy: Ishwaria Limestone Mines of M/s Tata Chemicals Ltd

3.3.2 Mobile Jaw Crusher attachment: An-pit rock breaker and mobile jaw crusher-screener system mounted on excavator to extract the limestone material for the Soda Ash plant while making use of the undersize generated for the cement plant. The mobile jaw crusher can crush approx. 25-30 tonnes of limestone per hour, with a load capacity of 0.9 cubic meters. It operates at a pressure of 220 bar and has an oil flow rate of between 180 and 240 liters per minute. The mouth opening gap of the crusher is 910mm, and its height is 540mm. The hydraulic engineering in the mobile jaw crusher ensures smooth and efficient crushing of limestone boulders, with the use of hydraulic cylinders and a variable displacement piston pump.

Fig. 3.11: Mobile Jaw Crusher mounted on Excavator
Courtesy: Ishwaria Limestone Mines of M/s Tata Chemicals Ltd

3.3.3 Mobile Screener: The mobile screener operates at a capacity of approx. 45-50 tonnes per hour. It has a rotating mesh drum that separates the undersize generated during the crushing process. The rotating drum with a mesh or perforated plate allows smaller particles (less than 50mm) to pass through, while desired sizes are separated and piled on separate piles. The hydraulic motors and a hydraulic drive system of the excavator powers the mobile screener, allowing for easy movement and adjustment of the mesh or perforated plate angle.

Fig. 3.12: Mobile Screener

Fig. 3.13: 50mm Mesh Size Rotating Screen drum mounted on Excavator
Courtesy: Ishwaria Limestone Mines of M/s Tata Chemicals Ltd

3.4 Benefits of the System:

The rock breaker and mobile jaw crusher-screener system has several benefits. First, it eliminates the need for blasting, reducing the hazardous environmental impact of blasting. Second, it provides a cost-effective solution for mining operations as it requires minimal equipment and manpower while eliminating the hauling or transportation of the ROM. Third, it ensures the efficient use of natural resources as both the desired and undersize material are used for production, making it a zero-waste mining process. Finally, the system reduces the risk of accidents associated with blasting, making the mining process safer for workers.

3.5 Surface Miners

The surface miners are machines made for an efficient, continuous mining operation. Different types of surface miners are manufactured today based on cutting drum placement and design specifications. Selective mining without drilling and blasting, high production and small size products are some of the prominent attractive features obtained with these moving marvels. This machine can be used with good efficiency in soft to medium hard rock (100–120 MPa). Surface miners are becoming popular day by day because of continuous and versatile selective mining, bulk production capability, reliability and also Eco-friendly machine. Surface miner, a continuous mining machine, is being manufactured in India and abroad owing to enhanced demand of production in various mining industries like coal, limestone, gypsum, bauxite etc. Surface miners are classified depending on the cutting technology adopted in the machine. Basically following three type of cutting mechanism are adopted in surface miners:

- Milling action
- Bucket wheel action
- Ranging-shearer-drum action

3.5.1 Types of Surface miner

1. Milling Type Surface Miner: The milling type of miner, shown in the figure consists of a rotating wide cutting or milling drum, which has spiral ridges carrying conical picks with tungsten carbide inserts. The pick flight can be varied to suit the type of material cut. The drum spirals are in the form of twin helix so that the cut material is pushed towards the drum Centre where it is loaded on a loading conveyor. The conveyor system comprises a wide primary conveyor which picks up the cut and comminute material at the cutting drum, as well as a discharge conveyor to discharge the material onto trucks. The discharge conveyor can be adjusted in height and slewed to both sides. The conveying speed can be infinitely varied.

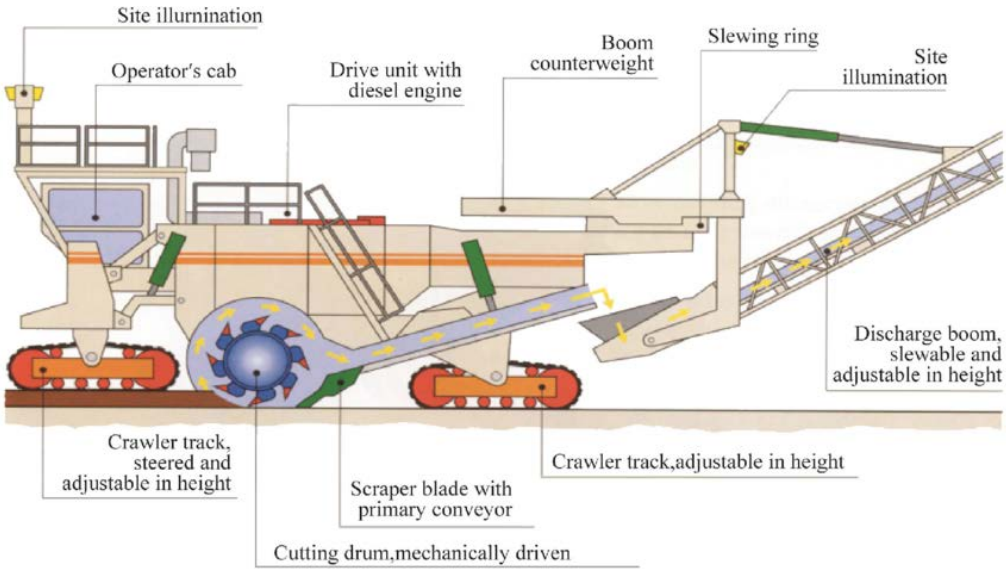


Fig. 3.14: Milling type surface miner
Courtesy: Adanakurichi Limestone Mine of M/s The India Cements Ltd.

2. Bucket wheel type: This machine works on the principle of bucket wheel excavators. This type of surface miner is manufactured by Thyssenkrupp Fordertechnik. In one of the models i.e. KSM2000 four parallel bucket wheels are mounted on a main frame without boom. The theoretical output of these machines is approximately 1000-1400 banks cubic meters/ hour in a mineral having an average uniaxial compressive strength in the range of 20 to 30 MPa.

3. Ranging-shearer-drum type: This surface miner adopts cutting technology of continuous miner, equipment used in underground coal mines. Voest Alpine's VASM-2 and Raheo's CME-12 are the two models of these types of surface miner. These surface miners can cut rocks up to a compressive strength of 120 MPa though their economic range of operation is up to 80 MPa.

Amongst these three types, milling type machines are most preferred machines worldwide and holds a major share of production. The milling action controls the production properly and the machine performance is best as compared to all other types of machines. Mainly, Writgen surface miners are predominantly deployed in Indian mines along with the surface miners of L&T.

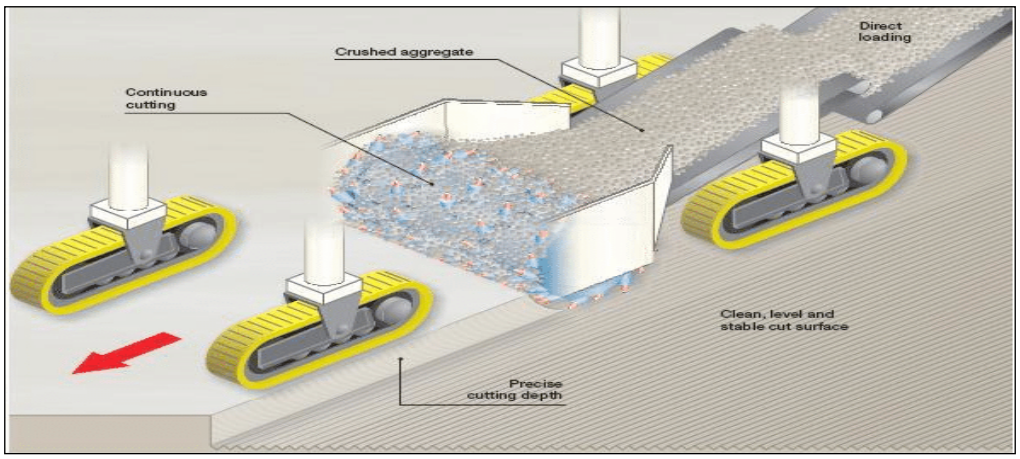


Fig. 3.15: Material discharge system
Courtesy: Adanakurichi Limestone Mine of M/s. The India Cements Ltd

Fig. 3.16: Surface Miner operation

3.5.2 Applications and Advantages of Surface Miners:

- The application of surface miners simplifies the operation (groundbreaking, crushing and loading are combined in one single operation), maintenance and supervision-due to the one-machine concept.
- The application procedure for a mining permit is faster than for a blasting operation.
- Surface miner eliminates primary crushing as the output size is <100 mm, and thus energy is saved, which otherwise would have been required for the primary crushing process.
- Surface miner produces a smooth, clean and even floor facilitating the movement of the hauling equipment, minimizing wear and tear of the tires and chassis of the hauling equipment. Surface miner application dominates in limestone mines, though it is applicable in production of various ore/ mineral.
- Use of surface miner is simplified mining technology and possesses several advantages, namely, selective mining, improved productivity, ability to work close to the habitat/agricultural fields, environment-friendly, reduced noise emission, reduced fugitive dust emission, total elimination of ground vibration, no drilling and blasting, no fly rocks, no secondary blasting/ breaking of boulders, stable, clean surfaces and benches, improved overall availability of the system.
- Reduced operating cost, leading to easier coordination and process planning during planning, dispatching and maintenance.
- Enhanced ROM-quality, improved exploitation of the deposit, reduced processing after mining required, primary crushing stage can be omitted and gentle loading of trucks due to sized material, low investment costs in comparison to the range of equipment necessary for conventional mining, cut steep and stable surfaces and embankments, precise cutting of designed profiles, and improved safety.
- Surface miners can maintain the surface of existing haul roads in virgin rock or in opencast mines.
- It facilitates higher overall travel speed for haulage vehicles due to better road surfaces.
- Less manpower, easy management, better quality control, good ergonomics, Safety & Productivity.

3.5.3 Ripper Dozer: A Ripper is an attachment used for tearing and ripping apart of earth particularly hard or other frozen ground & other hard to dig materials.

Fig. 3.17: Ripper Dozer

Suggestion for efficient ripping:

- Maintain uniform ripping depth, ripping passes for efficient excavation and loading.
- Rip in the direction of excavator and loader.
- Ripping should be done in straight line.
- Rip downward i.e towards the deep end of lamination and seam ripping downgrade can increase production. If the job layout permits, the down-grade approach can be helpful when working a hard spot or seam.
- If material cannot be loosen in one direction, cross ripping should be done.
- Wear of undercarriage unit should be reduced by leaving thin layer of loose material on the top of unripped rock.
- When track start slipping ripper and shank should be raised.
- Shank point should be sharp.
- Choose proper tip as per ripping conditions.
- Use more than one shank if conditions permit.

- At at the end of shift lower the shank to the ground.
- Do not reverse with shank in the ground.
- Do not turn with shank in ground.
- Lift the ripper out of ground when the tractor is in the motion.
- For any ripping job, choosing the right ripping tractor for conditions depends on: (i)Tractor flywheel horsepower (ii) Tractor gross weight (iii) Down pressure available at the tip.
- Proper gear and speed selection is critical to obtaining maximum ripper production and efficient tractor operation.
- Depth and spacing of furrow go hand in hand the deeper the furrow wider the spacing.
- Wet ripping, wetting the surface serve their purpose act as an lubricant for tips and shoes, easing the passage through abrasive trough and lower the wear of parts.
- Don't break lumps with shank.
- Use long points for loosen material and shorter points for hard material.

Factors affecting Ripper performance:

1. Type of rock to be ripped: sedimentary rock is easy for ripping while igneous & metamorphic rocks are difficult to rip.
2. Operation and management efficiency
3. Method of ripping
4. Ripping speed
5. Ripping length
6. Operator skill
7. Condition and type of ripper
8. Degree of weathering of rock
9. Various physical properties of strata such as compressive strength tensile strength, shear strength etc. and depth of furrow
10. Fragility and Crystalline construction of rock
11. Well-known fracture plane
12. Existence of moisture content
13. More the grain size: coarser the grain-size more it is suitable for ripping
14. Union of different type of rock
15. Specific energy

3.5.4 Adoption of High capacity, sophisticated equipment, dust and noise proof AC cabins which meets CEV 4 emission:

Earlier, the concept of air conditioning (AC) system was not there in the heavy equipment's. Later on, with the improvement in technology, AC, display boards, camera, fatigue sensor, indicators with warning sound and many more features added to bring comfort to operator.

Fig. 3.18: HEMM with CEV 4 emission

Fig. 3.19: EVWHEEL Loader SDLG-L956HEV

3.6 Journey towards zero emissions by adopting Electric Vehicles

The entire world is facing the problem of carbon emissions. There has to be an alternative to this, and hence as a result, electric vehicles are becoming more and more popular everywhere and in the mining industry too. The reasons are simple: no fuel required and do not produce greenhouse gases. The research tells us their benefits apart from reduction in carbon emissions and air pollution. Most of the industries are rapidly transitioning to electric solutions.

The trend towards battery-powered construction equipment is on track to accelerate in coming years as governments worldwide enforce emission regulations and promote the use of clean energy.

Fig. 3.20: India's Largest Electrical Excavator: Excavator BE 1800E

Electrical heavy earth moving machines are already available in the market. Apart from the reduction of greenhouse gases, the electrical vehicles often have efficiency more than those powered by internal combustion engines. Due to benefits of EVs, the OEM's have come forward to tackle climate change and energy stability. Electric Vehicles/ equipment operate more quietly and smoothly when compared with IC vehicles because electric motor generate less vibration and noise. The big difference between IC engine and Electric is IC engine has diesel engine and a fan for it and electric vehicles have rechargable battery packs.

CHAPTER 4

Developments in Transportation of Minerals

4.0 Transportation of Mineral/Ore

Mining and transport are inextricably linked. Raw materials need to get to the destination place such as crushers or processing plants, which could be very far away from the mine. As such, different transport modes are necessary to carry these minerals to their destinations. The majority of raw materials that industries use today come from some form of mining, whether it be extracting from far beneath the earth's surface or from open-cut mines on the surface.

The importance of transport in the logistics chain for getting raw materials to downstream users has been increased. This has also triggered the need to make innovations in the transport sector to make mining locations more accessible that were once remote and immovable. Quite a lot of transportation takes place by trucks within the mining area, whether to crushers or to processing plants (e.g. concentrators) before products are moved away from the mine.

Recent years have seen substantial innovations in road transport within and outside the mining sector. In the 1960s, the largest trucks in operation carried around 30 tonnes; today there are trucks carrying 200 to 450 tonnes. New developments in the conveying technologies field have led to longer conveyors being installed, with lower energy consumption, higher capacity and lower running costs per tonne per kilometre. Similar to road vehicles, rail locomotives and wagons have improved their efficiency to increase the throughput for the mining sector. Locomotives have been needed to become more powerful as well as more reliable over the years. Some of the Mining transportation systems are discussed below:

4.1 Truck/Dumper Haulage

Truck haulage is the most common form of materials transport in open pit mines. Dump trucks are open vehicles which are capable of carrying and dumping earth, aggregate or other loose material to construction sites on various projects such as dams, highway, ports etc. or they can be used to haul to an in-pit crusher where ore and/or waste can be crushed and then conveyed out of the mine. The trend has been towards larger and larger open pit trucks to match larger shovels and excavators. Trucks have advantage over rail and conveyor systems where the haulage distance is relatively short and flexibility is needed.

Fig. 4.1: Rear Discharge Dumper BH205E;
India's Largest Indigenous Electric Drive Dumper

4.1.1 Rear Dump Trucks or Dumpers

It can travel with higher speeds and has a capacity of 30-450 tons. Dump Trucks in many sizes with pay loads ranging up to more than 450 tonnes are available. Special features of dump trucks usually include heavy, all-welded chassis to sustain rough ground conditions, extra-large wheel and tyre to support load and give good ground clearance, ultra-heavy-duty tipping bodies constructed by high tensile steel to withstand damage from high impact and highly abrasive materials.

These are used off the highway especially in earth moving and mining applications. The body construction is specially designed to absorb high-impact loading. The floor of the body is made up of high-tensile steel to reduce abrasion damage. The ratio of gross vehicle weight to horsepower is generally lower than an on-highway dump truck. Top speed of off-highway dump truck is also slow (30-40 km per hour). Since these are used on rough roads, oversize air cleaners and filters, shock proof mounting of all instruments, dust- proofing of electrical system, cushioned mounting for radiators etc. are provided.

These are suitable to handle many types of materials but are most suitable for quarry rocks. These are also used when:

- Dumping is in restricted hoppers or fill.
- Loading under a large shovel or dragline is subjected to sever loading impact.
- Maximum flexibility is required for hauling a variety of materials such as earth, sand and gravel and more bulky material such as blasted rock, ore, coal etc.
- Maximum grade ability is required.

4.1.2 Bottom Dump trucks or Dumper

These are suitable for long hauls of easy flowing materials like sand, gravel, dry earth and which are to be spread in layers as on a fill of a dam. The material is discharged through bottom while the vehicle is moving at a controlled rate by means of 2 longitudinal gates.

These are unsuitable for big size material or wet or sticky materials due to limited openings.

In bottom dump trucks the material can be discharged while the vehicle is in motion and laid in a long windrow. This way of dumping not only hampers the passage of other vehicles but also reduce the levelling efforts for the dumped material.

These sometimes known as bottom dump wagons, are like semi-trailers, front end of which is supported on the rear of the hauling tractor, and the rear end is resting on their own wheels. Wide top area facilitates quick loading under shovels.

Due to low and long bodies, they have fast speed on suitably maintained roads, but longer turning radius is required and manoeuvring becomes more difficult in restricted spaces. With these, it is difficult to negotiate steep grades.

Fig. 4.2: Bottom Discharge truck

Fig. 4.3: Underground Truck

4.1.3 Heavy Duty Tipper Truck

This type of tipper truck is commonly used in some of the limestone mines these days. This is rear dump truck. It is designed to work in hard conditions due to which it is successfully being used in mines.

Safety Features

1. Rear Camera: State-of-the-art technology that aids in safer and faster reversing.
2. Driver State Monitoring System Standard: Identifies and alerts drivers from falling asleep or being distracted at the wheel.
3. Seatbelt Reminder: Ensures superior safety to the occupants.
4. Diffuser Tailpipe: Helps in exhaust temperature management and reduction of dust throw.
5. Daytime Running Lamp: Ensures vehicle visibility during daytime as well.

Comfort of operators

1. Heating, Ventilation & AC HVAC: High throw air conditioning and climate control for all extreme weathers.
2. Air Suspended Seat Premium: Ensures maximum driving comfort even on rugged terrains.
3. Power Windows: Windows that can be raised or lowered just with the press of a button.
4. Central Locking: Locks the whole cabin with just a flick of the driver-side lock handle.
5. Static Steering: Enables easier manoeuvrability during tight turns.

Fig. 4.4: Heavy Duty Tipper Truck

4.1.4 Shuttle Cars

A shuttle car is a pneumatic tire mounted, electrically driven and low-height transport vehicle of 5-7 te capacity with an open topped and open-ended body, used for transport of mineral from face to a central loading point. One shuttle car operating within 90 m range and fed by a 4 te/min mechanical loader.

Fig. 4.5 (a): Shuttle car

Fig. 4.5 (b): Shuttle car

4.2 Conveyor Haulage

A conveyor system consists of two or more pulleys with an endless loop of carrying medium that rotates about them. One or both of the pulleys are powered, moving the belt and the material on the belt forward. There are 3 types of Conveyor Haulage.

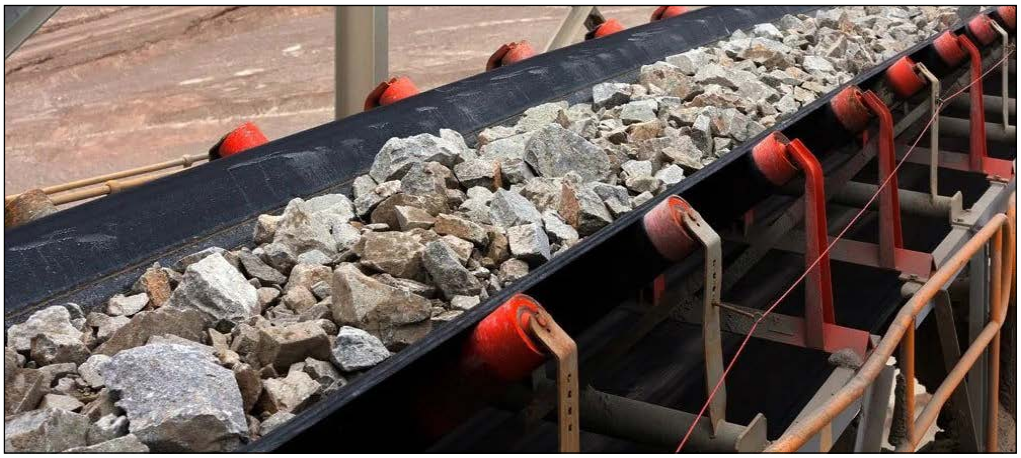


Fig. 4.6: Conveyor Haulage

4.2.1 Conventional Belt Conveyor:

This is the most widely used type of conveyor. It can transport up to 1000 tons of ore per hour.

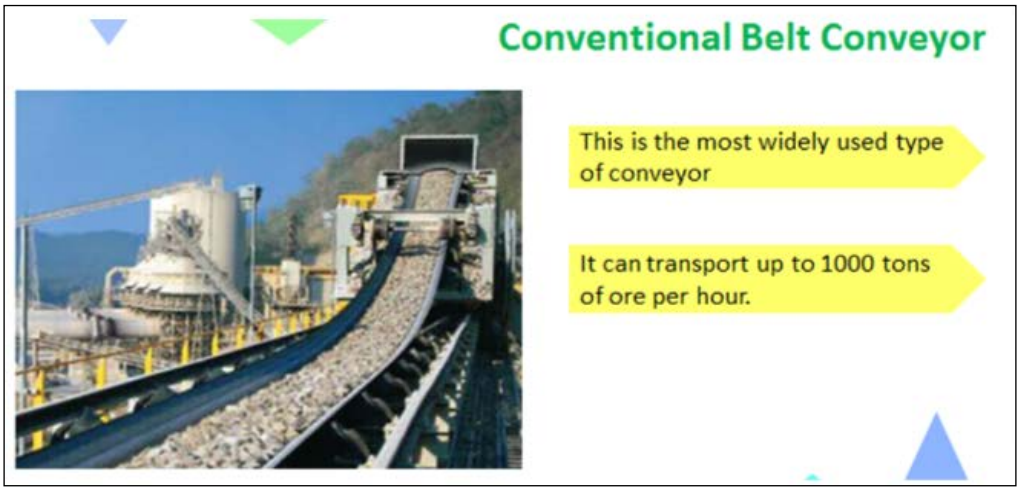


Fig 4.7: Belt Conveyor

4.2.2 Cable Belt Conveyor

Cable Belt is a unique conveyor design that is well suited for long distance conveyor applications where vertical and horizontal curves are required. The design differs to that of conventional conveyor designs. The conveyor belt is supported by two endless wire rope cables, one on each side of the belt, in lieu of idlers. The belt has almost no tension induced as it simply "goes along for the ride". Belt is not used to transmit any forces but is simply a material support element of the system. Low power consumption & Minimal wear of the belt is there. Huge Savings in terms of diesel/oils which would have been consumed towards transportation of ore through trucks.

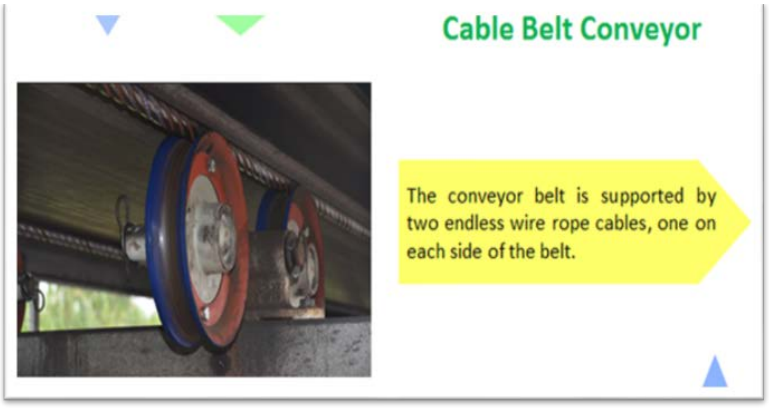


Fig. 4.8: Cable Belt Conveyor

Fig. 4.9: Cable belt conveyor; Asia's longest (14.6 km) single flight multi-curve cable belt conveyor
Courtesy: Panchpatmali (C&N Block) Bauxite Mine of M/s NALCO

4.2.3 Pipe belt Conveyor

The Pipe Conveyor is an enclosed curve going transportation system for all kinds of bulk materials. At the loading and discharging points, the conveyor system is identical with open troughed conveyors.
Limestone in majority is conveyed through high speed (5 meters per second) Over Land belt conveyor (OLBC) from mine crusher to plant. OLBC stretched up to a distance of 7.5 Kms crossing highway and railway tracks, and covered completely with rain hood along with acoustic hood provided near habitant areas to minimize dust and noise pollution and reducing carbon footprints.

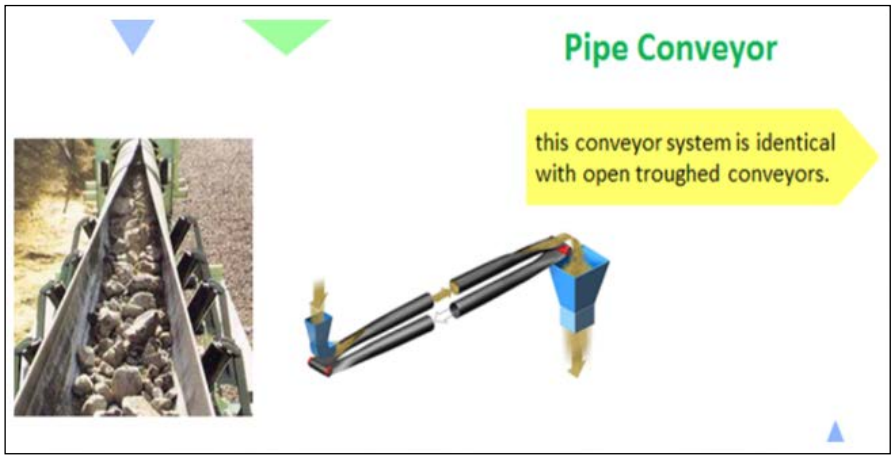


Fig 4.10: Pipe Conveyor

Fig. 4.11: Pipe Conveyor

Use of Pipe Conveyor for iron ore transportation is the best mean to ensure zero spillage, conservation of mineral resources and reduce emission associated with road transportation.

Applications of pipe conveyor belts is a perspective trend in the transportation of mining and agricultural enterprises, an attempt in this sphere has been started as early as in 1970s. Most countries around the world were introduced with substantially strict measures for environmental protection which facilitated the intensive development of closed-type technologies in the transportation of goods. A flat belt passing through the end face cylinder is gradually folded and attains a cylindrical pipe form with the help of the specially-positioned rollers at one section. Technological processes in the mining industry include various raw material transportation operations which consume significant amounts of energy and generate a substantial share of overall mining costs. The pipe conveyor systems can transport all forms of ores. They cover a wide range of applications, from mining to manufacturing plants where they move materials over long distances, passing through undulated terrains and curves.

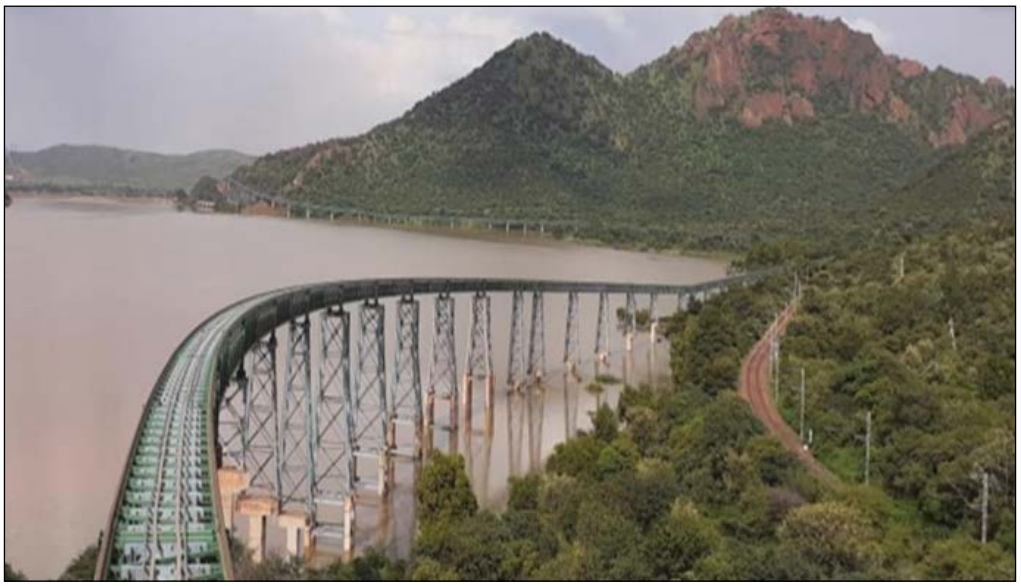


Fig. 4.12: Special safety features considered during the Design & Operation of Pipe Conveyor

Example: M/s JSW Steel Limited is transporting Iron ores from various their mines to Vijayanagara steel plant at Bellary sector using a closed pipe conveyor system called Main Pipe Conveyor (MPC) since 2019. These pipelines are located downhill, parallel to roadways and traditional trucks carry ores from mines to feed in MPC. Adhering to it, JSW has erected a 24 km pipe conveyor system of capacity 3500 tonnes per hour (20 MTPA) from Nandihalli to Vijayanagar plant. JSW has implemented it as the Longest Pipe Conveyor Project. It was constructed in record time of 24 months.

4.2.4 Downhill Pipe Conveyor

The downhill pipe conveyor is an elevated transportation method used for moving Iron ores from uphill to downhill. A flat rubber belt is rolled using idlers which are circular in structure and evenly spaced throughout the length of the conveyor to ensure that the belt remains closed. When the pipe reaches the loading or unloading point, it reopens. The operation is identical to that of standard pipe conveyors, with the exception of loading and unloading points at different elevations uphill and downhill respectively. In pipe conveyor, all drive motors start simultaneously on a load sharing basis through the Programmable Logic Control (PLC) system provided for the intended purpose. The speed control for the drives is achieved through Variable Voltage Variable Frequency (VVVF) units. The signal for starting of motor is transmitted through Optical Fibre Cable (OFC), installed along with the belt pipe conveyor structures from head to tail end. The entire stretch of downhill pipe conveyors, works in this method. M/s JSW Steel Limited has planned to connect three mines with MPC using a downhill transport mechanism called Downhill Pipe Conveyor (DHPC) to that of standard pipe conveyors, with the exception of loading and unloading points at different elevations uphill and downhill respectively.

Fig. 4.13: Downdhill Pipe Conveyor

- Pipe conveyors replace haul trucks (and their associated exhaust and noise emissions) to ensure reliable long-distance transportation.
- The flexible belt pipe design allows directional changes without the need for additional transfer stations. Their curves can either be horizontal or vertical, or a combination of both. The belt opens on its own before reaching the material discharging point. Following the material discharge, the belt on the lower strand is closed again on its return. This eliminates spilt material over the entire pipe conveyor line and has the advantage that the carrying (dirty) side of the belt is once again inside the tube.
- The main benefit of belt conveyors compared to other material handling machines like trucks & trains is the higher efficiency in the mechanical system, energy consumption and total cost over the long term, especially when conveyor system is design optimized.

Comparison between Dumper & Conveyor Transport

Dumper Transport	Conveyor Transport
Diesel oil operated	Electrically powered
40% of total energy is used to transport pay-load. 60% is used to move self-weight of the dumper	80% of total energy is used to transport pay-load. 20% is used to move weight of the belt and overcome frictional resistance of the moving parts. Energy cost savings up to 70% is obtained as compared to dumper transport
Can overcome maximum gradient of 6-8% only	Can safely overcome gradients up to 35% and more by high-angle belt conveyor
Discontinuous system	Continuous system.
Dumper fleet requires large manpower for operation and maintenance	Operation and maintenance is simple and requires less manpower
Dumper technology of only upto 85T capacity is indigenously available in India, posing limitations to increase volume of mining activity	No such limitations
Pollution of mine environment with exhaust fumes, dust and noise	No pollution
Dumper operation is severely affected by bad weather e.g. fog, rains, heat, snow etc.	Insensitive to weather conditions, hence, can be effectively used round the year.
Dumper needs specially built and maintained haulage roads with heavy investment.	Through careful mine planning costs of conveyor routing can be reduced or avoided.

The evacuation of iron ore using pipe Conveyor has many advantages. Some of these are described below:

- Best means of transportation to ensure zero spillage and save precious mineral resources.
- Saves fossil fuel which otherwise would be used for road transport.
- Reduces burden on the transport infrastructure such as road and rail, prevents accidents.
- Reduces emissions associated with road transport such as gaseous pollutants, dust and particulate matter.
- Minimal particulate emissions at loading and unloading points.
- Faster means of transportation and saves times and resources.
- Flexibility in transportation and continuity of Conveying
- Hassle free transportation and least logistic issues.
- Extremely high environmental friendliness. It is pollution free transportation and no dust, fugitive emissions as in case of any other means of transportation.
- Less strain on the existing government infrastructure and facilities

Due to its tubular shape, the conveyor is able to comfortably negotiate horizontal and vertical curves as well as high inclinations. The fully enclosed transportation system not only protects the conveyed material against external contaminants such as climatic conditions, but also avoids material loss and spillage and thus, protects the environment.

Other advantages are as follows:

- Protection of the conveyed material against external contaminants
- Protection of environment against escaping material by dust free transport
- Possibility of tight curve radii
- Realization of steep inclination
- Low space requirements
- No need for transfer towers
- Adaptation ability to topographic requirement.
- Possibility of downhill transportation
- Simultaneous double load transport of different kinds of material in the upper and lower strand
- Low maintenance issues
- High operational safety.

4.3 Rail Haulage

Rail haulage is directionally guided by the tracks on which they run. Tracks usually consist of steel rails, installed on ties (sleepers) and ballast, on which the rolling stock, usually fitted with metal wheels, moves on it. There are 2 types of Rail Haulage.

4.3.1 Diesel Locomotive: It is powered by diesel and was widely used in the mining before the conveyor and trucks became popular and took over the industry. It is commonly used locomotive in the underground mines.
Their weight ranges from 3 to 15 tonnes and the power from 15 to 75 KW. The power unit is a diesel engine with 2, 3 or 4 cylinders of 4 stroke cycle, compression ignition type. Heavy duty locos are of 6 cylinders. The intake air going to the engine passes first through a filter and then through a flame trap. Similar flame trap is fitted on the exhaust side of the diesel engine.

4.3.2 Electric Locomotive: It is electrically powered which also runs in the top of rail roads.

Fig. 4.14: Diesel Locomotive

Fig. 4.15: Electric battery locomotive

CHAPTER 5

Innovations in Survey

5.0 Survey Technology in Mining Industry

Surveying is the most important part of mining industry. Before the commencement of any mining operation, the first work which is to be done is survey of that area which involves fixing of benchmark, demarcation of certain points etc. Survey has to be performed to determine the benchmark, ground position, OGL (original ground level) and other details.

The primary objective of a survey is the preparation of a plan or map to show the relative positions of the objects on the earth surface. The map is drawn to some suitable scale.

5.1 Uses of surveying:

1. To prepare a topographic map which shows the hills, valleys, rivers, village towns, forests etc. of the ML area.
2. To prepare a contour map to determine & find the best routes for roads, PC, etc.
3. To prepare a geological map showing areas including the resources.
4. To prepare a cadastral map showing the boundaries of houses, fields, and other properties.
5. Volume Calculation of Stockpiles in mines.

5.1.1 Mines survey and mapping solutions

Surveys and mapping services are being used in a range of mining applications to achieve safety, productivity, and security goals. They play a crucial role in mineral exploration, mine design and expansion planning, measurement of areas and volumes mined, environmental rehabilitation, risk assessment, as well as monitoring tailings dams, acid mine drainage, and the stability of slopes.

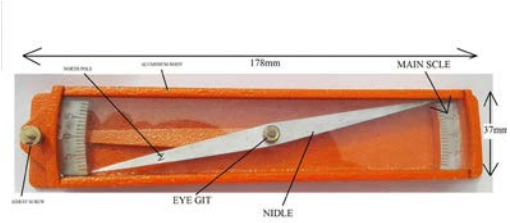
5.2 Methods of Surveying in Mining Industry

5.2.1 Plane Table Surveying: Plane tabling is a graphical method of survey in which the field observations and plotting proceed simultaneously. It is a means of making a manuscript map in the field while the ground can be seen by the topographer and without intermediate steps of recording and transcribing field notes.

5.2.1.1 Instruments used: The following instruments are used in plane table survey.

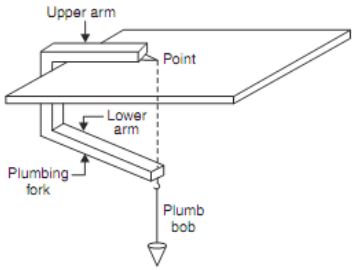
- The plane table with levelling head having arrangements for (a) Levelling, (b) rotation about vertical axis, and (c) clamping in any required position.
- Alidade for sighting
- Plumbing fork and plumb bob.
- Spirit level.
- Trough Compass.
- Drawing paper with a rainproof cover.

Now a days, use of plane table survey is obsolete.

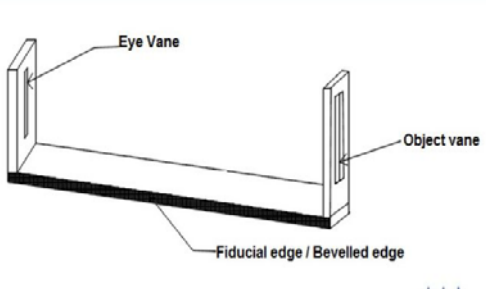


Trough Compass

Spirit Level



Plumbing fork and Plumb bob



Alidade

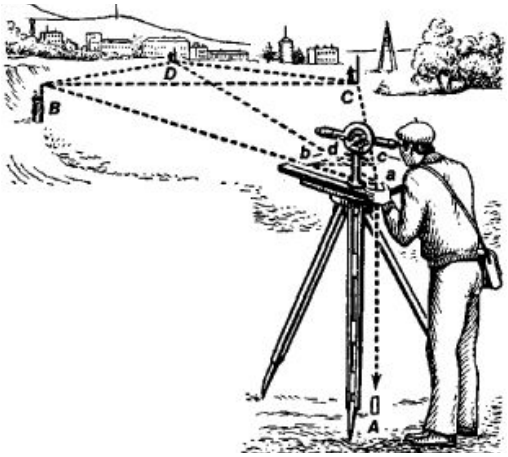


Fig. 5.1: Plane Table Survey instruments

5.2.2 Levelling: Levelling is a branch of surveying, which is: (i) to find the elevations of given points with respect to a given or assumed datum, and (ii) to points at a given elevation or at different elevations with respect to a given or assumed datum.

5.2.2.1 Levelling Instruments: The instruments commonly used in direct levelling are:

i. A level
ii. A levelling staff.

Fig. 5.2: Auto Level

Fig. 5.3: Metal Level

Fig. 5.4: Auto Level and Levelling Staff in the field

5.2.3 Theodolite:

1. Theodolite is a measuring instrument used in surveying to determine horizontal and vertical angles with a tiny low telescope that may move within the horizontal and vertical planes.
2. It is an electronic machine which looks sort of a tiny telescope.
3. It is extensively used for the measurement of vertical and horizontal angles for scaling functions and within the housing industry.
4. The accuracy with that, these angles may be measured ranges from 5 mins to 0.1 secs. It is utilized in triangulation networks.
5. Theodolites are employed everyplace from construction sites to main road points. It measures angles using age-old principles of pure mathematics and assists surveyors in establishing precise locations.

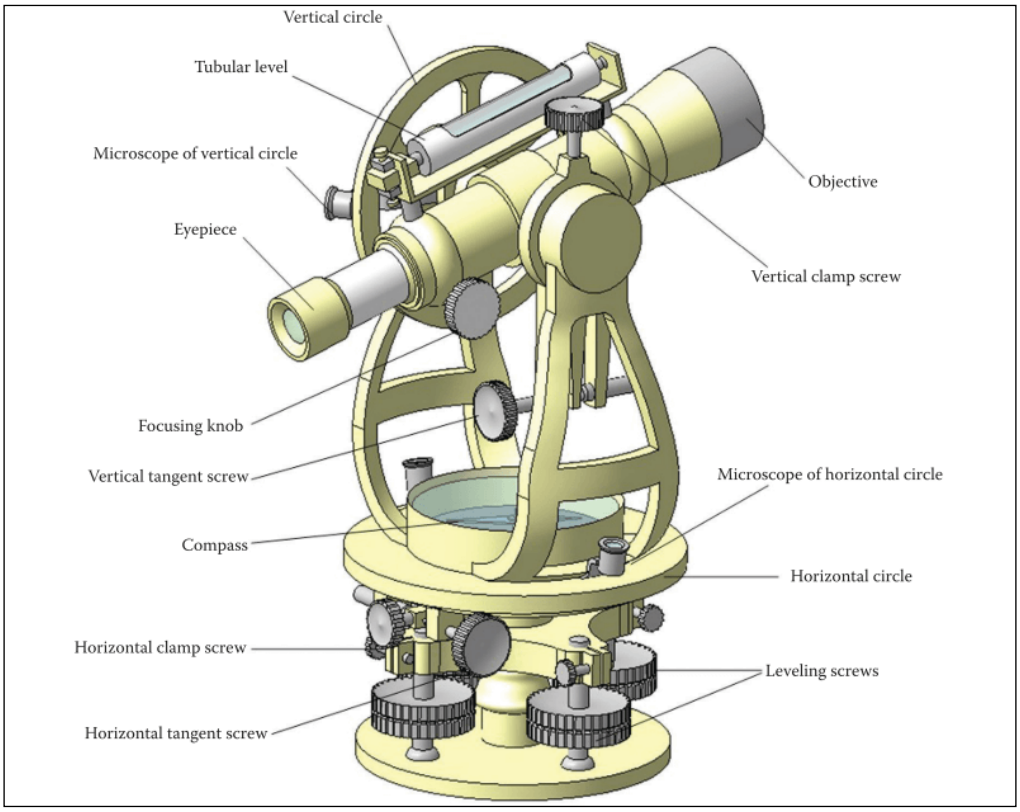


Fig. 5.5: Theodolite

Followings are the major uses of theodolite:

- Measuring horizontal and vertical angles
- Locating points on a line
- Finding the difference in the level
- Prolonging survey lines
- Ranging curves
- Setting out grades
- Tacheometric surveying

5.2.4 Tacheometric Surveying:

Tacheometry or Telemetry is a branch of angular surveying in which the horizontal and vertical distances of points are obtained by optical means as opposed to the ordinary slower process of measurements by tape or chain.

This method is very rapid and convenient. Although the accuracy of Tacheometry in general compares unfavourably with that of chaining. It is best adopted in obstacles such as steep and broken ground, deep ravines, stretches of water or swamp and so on, which make chaining difficult or impossible.

The accuracy attained is such that under favourable conditions the error will not exceed 1/1000, and if the purpose of a survey does not require greater

accuracy, the method is unexcelled. The primary objective of tacheometry is the preparation of contoured maps or plans requiring both the horizontal as well as vertical control.

An ordinary transit theodolite fitted with a stadia diaphragm is generally used for tacheometric survey. The stadia diaphragm essentially consists of one stadia hair above and the other an equal distance below the horizontal cross-hair, the stadia hairs being mounted in the ring and on the same vertical plane as the horizontal and vertical cross-hairs.
Stadia is a tacheometric from of distance measurement that relies on fixed angle intercept.

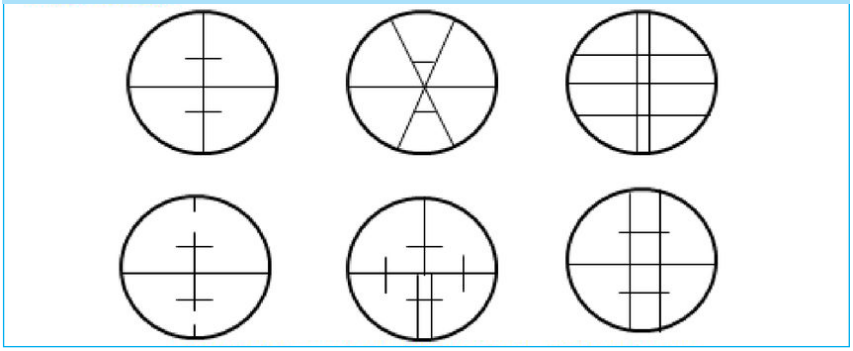


Fig. 5.6: Different forms of stadia diaphragm commonly used

5.2.5 Electronic Total Station (ETS):

1. It is an electronic or optical instrument used to measure horizontal and vertical angles as well as the sloping distance of the object to the instrument, and has an on-board computer to collect data and perform triangulation calculations.
2. It is an electronic transit theodolite integrated with electronic distance measurement (EDM), microprocessor, electronic data collector, and storage system.
3. It is also known as total station theodolite.
4. Accurate calculation with the help of a computerized system installed in this device makes it one man army.
5. You can do surveys with this device easily and effectively.
6. It can give you more accurate results than any other device. So surely Total station is a great innovation of the modern era.
7. Microwaves and infrared signals are emitted from the total station which determines the distance between the points.
8. Coordinates and angles are determined by the triangle and trigonometry methods.

5.2.5.1 Total station survey:

Direct measurement

- A tiny solid-state emitter located within the instrument's optical path generates a modulated infrared carrier signal, which is then reflected by a prism reflector, or the item being surveyed to determine distance.
- The computer in the total station reads and decodes the modulation pattern of the signal.
- By sending and receiving signals at various frequencies and counting the integer number of wavelengths to the target for each frequency, the distance is calculated.
- It gives the slope distance from the instrument to the object.
- The 2.8 km to 4.2 km range varies with automated target recognition. It can accurately measure 5 mm (about 0.2 in) to 10 mm (about 0.39 in) per km measurement.

Angle measurement

- It can measure both horizontal and vertical angles.
- We can measure it in shorter times like 2 to 6 seconds.
- Reference directions are important here which is the selected zenith point in a vertical angle and the conventional point in a horizontal angle.

Coordinate measurement

- If a direct line of sight can be established between the two points, the total station can be used to identify the coordinates of an unknown point in relation to a known coordinate.
- Measurements of angles and distances are made from the total station to the points being surveyed, and trigonometry and triangulation are used to determine the coordinates of the surveyed points in relation to the location of the total station.
- A complete station must be set up over a known point or with a line of sight to two or more points with known locations to do line of sight observations, free stationing is being called.

Fig. 5.7: Electronic Total Station

5.2.5.2 Optical Survey Prism:

Optical Survey prisms are a specially designed retro reflector, specifically a corner reflector that is used to reflect the Electronic Distance Measurement (EDM) beam from a total station. A survey prism reflects the EDM beam back to its source with both a wide angle of incidence and with high precision. Prisms reduce the scatter of the beam as it is reflected back to the total which allows for both a more accurate and a longer range of measurement.

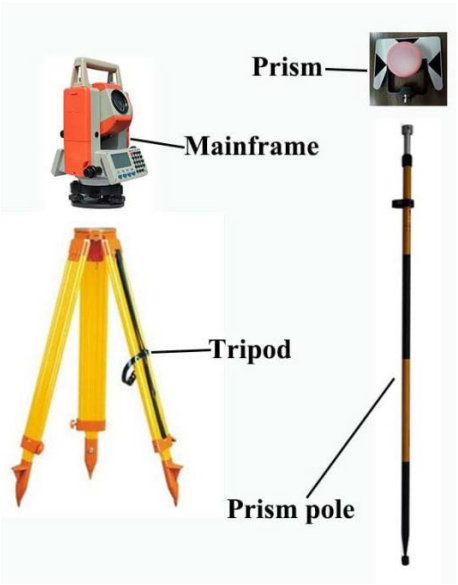


Fig. 5.8: Optical Survey Prism

5.2.5.3 Capabilities of Total Station

- The average of multiple angles and distances can be measured.
- Distances between any two observed points
- Elevations of objects on the surface
- Three coordinates of the unknown observed points

5.2.5.4 Advantages of Using Total Stations

- You can quickly set up the instrument on the tripod with the help of laser plummet. It can be used as a multidisciplinary instrument.
- Working capability is high as well as time saving.
- There is no recording or writing errors.
- It gives more accurate measurements than any other device.
- We get graphical views of lands and plot as well as computerized old maps.
- Computation on-board area is used to calculate the area.
- Integrated Database is used which can be transferred to a Personal computer.
- Multiple surveys can be made by one set-up location.

5.2.5.5 Disadvantages of Total Station

- Expensive
- While operating, the errors may be unseen.
- Highly skilled operators required.

5.2.6 Global Positioning System (GPS):

The Navigation Satellite Timing and Ranging Global Positioning System (NAVSTAR GPS) developed by the U.S. Department of Defence (DoD) to replace the TRANSIT Navy Navigation Satellite System (NNSS) by mid-90s, is an all-weather high accuracy radio navigation and positioning system which has revolutionised the fields of modern surveying, navigation, and mapping.

For everyday surveying, GPS has become a highly competitive technique to the terrestrial surveying methods using theodolites and EDMs; whereas in geodetic fields, GPS is likely to replace most techniques currently in use for determining precise horizontal positions of points more than few tens of km apart.

The GPS, which consists of 24 satellites in near circular orbits at about 20,200 Km altitude, provides full coverage with signals from minimum 4 satellites available to the user, at any place on the Earth. Simultaneously, the observer can determine his geometric position (latitude, longitude and height), Coordinated Universal Time (UTC) and velocity vectors with higher accuracy, economy, and in less time compared to any other technique available today.

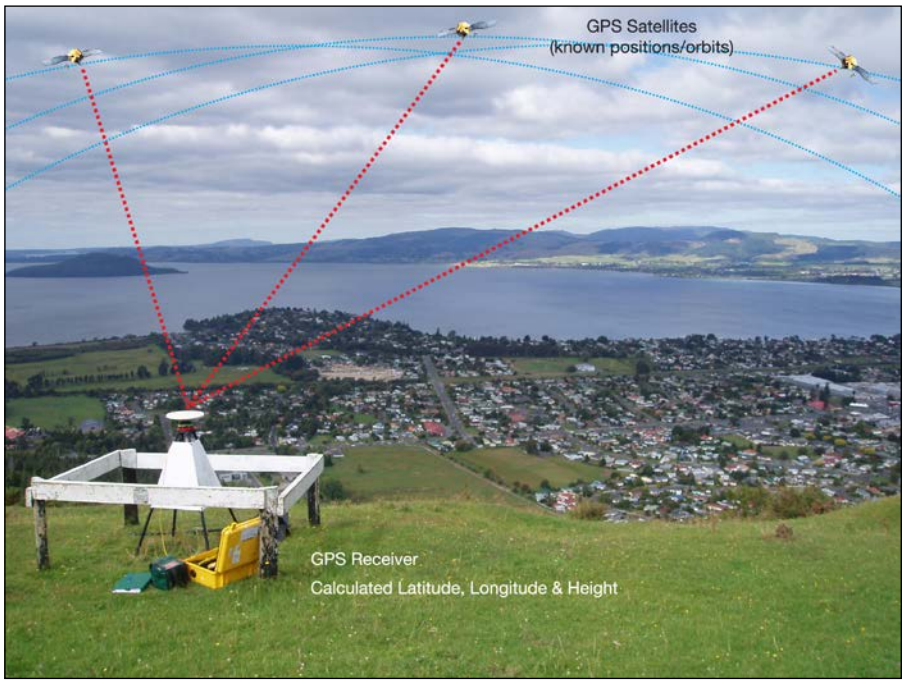


Fig. 5.9: GPS point positioning

Fig. 5.10: Geodetic GPS receivers

5.2.7 Differential Global Positioning System (DGPS)

- The underlying premise of differential GPS (DGPS) is that any two receivers (like Base station and Rover) that are relatively close together will experience similar atmospheric errors.
- DGPS is essentially a system to provide positional corrections to GPS signals.

- DGPS uses a fixed, known position to adjust real time GPS signals to eliminate pseudo range errors.
- DGPS requires that a GPS receiver be set up on a precisely known location. This GPS receiver is the base or reference station.
- The base station receiver calculates its position based on satellite signals and compares this location to the known location.
- The difference is applied to the GPS data recorded by the second GPS receiver, which is known as the roving receiver. The corrected information can be applied to data from the roving receiver in real time in the field using radio signals or through post processing after data capture using some processing softwares.

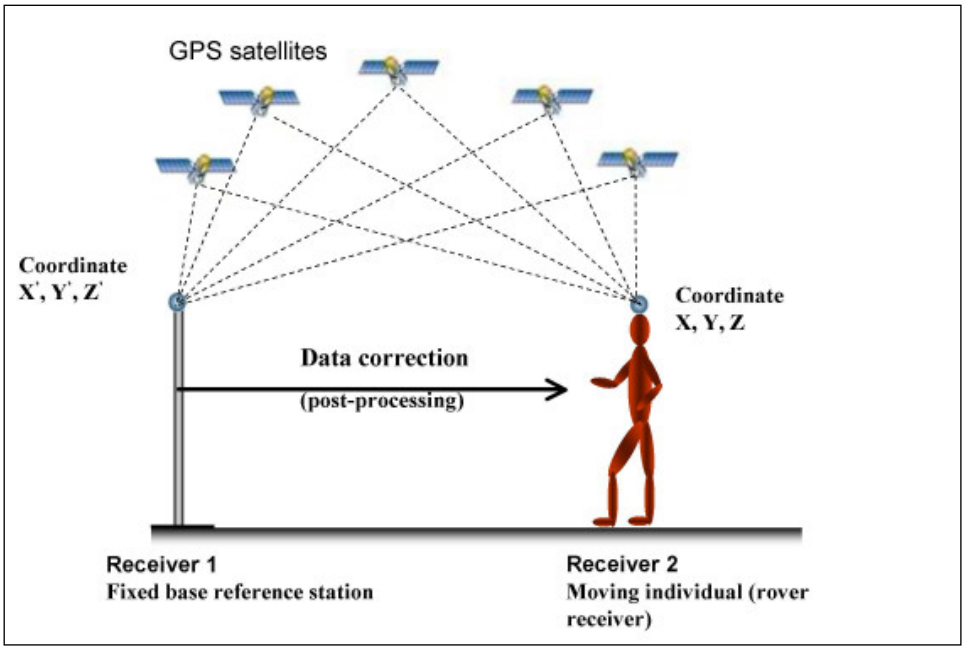


Fig. 5.11: Working principle of Differential Global Positioning System (DGPS)

5.2.7.1 Components of a DGPS System

5.2.7.1.1 Reference Stations:

- A network of ground-based reference stations is installed throughout the area. The DGPS system leverages this network of stations.
- These reference stations contain very accurate clocks.
- They receive signals from the satellites and compare them to their known position.
- Reference stations are also known as fixed receivers or known points or base station.

Fig. 5.12: DGPS Reference Station

5.2.7.1.2 GPS Receivers:

- A GPS receiver is the primary component of the DGPS system. First, it receives GPS signals from satellites and decodes them.
- Next, the receiver calculates the user's position.
- This is based on the information received from the satellites, which includes those from the reference station. This is how it obtains an increased accuracy.

Fig. 5.13: Differential GPS Receiver

Fig. 5.14: DGPS survey in Open cast mine

5.2.7.2 Advantages Of DGPS:

- Time Efficiency: DGPS allows for rapid data collection and significantly reduces surveying time. This increased efficiency transforms into cost savings and improved project timelines.
- Large Area Coverage: Unlike total stations, which have limited range due to line-of-sight requirements, DGPS can cover vast areas effortlessly.
- Real-Time Kinematic (RTK) Capabilities: DGPS receivers equipped with RTK technology provide instantaneous, centimetre-level positioning accuracy. This real-time positioning capability allows surveyors to observe and verify measurements on-site, improving data quality and enabling immediate decision-making during the surveying process.
- Flexibility and Portability: DGPS equipment is compact, lightweight, and easily transportable, making it convenient for surveyors to move from one location to another without hassle.
- Reduced Human Error: By relying on satellite signals for positioning, GNSS minimizes the chances of human error associated with manual measurements using total stations.

5.2.8 3D Laser Scanner:

Background: Previously, the Mine survey was carried out with the Manual Survey method, where Total Station with Prism-staff combination was used to derive the location details in which the horizontal and vertical distance details and manual calculation process involved. With the obtained details, all the points and details were marked manually in the Plotting sheet to create the Plans and sections. In this method, survey helpers must go through all the working areas physically, which was time-consuming and unsafe for the helpers while surveying.

Intervention & Impact: 3D laser scanner is an extra-long range survey system combining fast, accurate sensing, high-resolution digital imagery, and powerful modelling software for improving overall productivity and site safety.

Benefits:

- Safety: The most portable scanner for rapid survey in dangerous or inaccessible environments, also able to be vehicle mounted, removing pedestrian access in heavy vehicle work areas
- Productivity: Designed to guide survey workflow, making field tasks and delivery of results more efficient.
- Accuracy: Detailed 3D geological mapping and reliable end-of-month volumes, ensured by the level of accuracy.
- Versatility: Short- and long-range scanning in one premium, easy-to-use instrument.
- Integration: The system combines extra-long range scanning with digital imaging and modelling software

Features:

- Laser scanner: Collects data capturing with 50kHz, 100kHz and 200kHz speeds at a range of up to 2400 meters, 100° vertical and 360° horizontal fields of view.
- Integrated digital camera: 147-megapixel panoramic camera, with no user calibration or alignment required.
- Ergonomic design: Developed for one person operation and field portability, all features are built in.
- Alignment telescope: Integrated, motorised survey-grade telescope for back sighting.

Fig. 5.15: Maptek XR3 CT 3D Laser Scanner

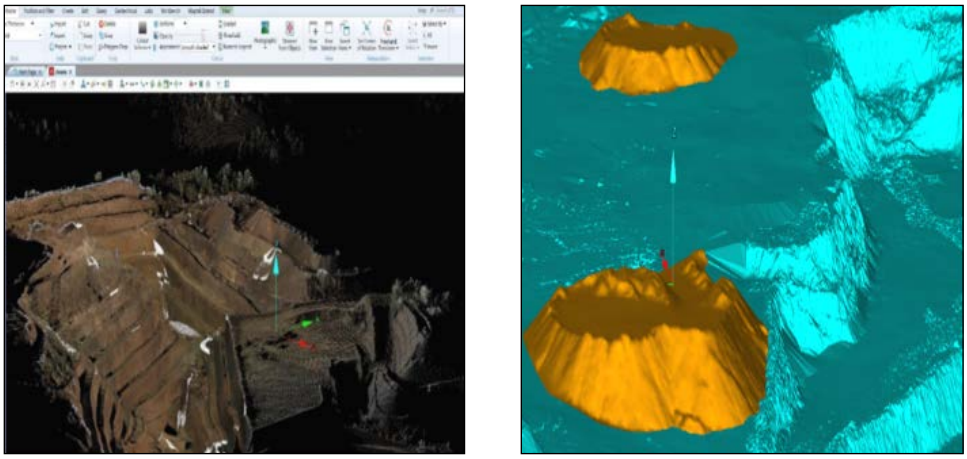


Fig. 5.16: Maptek 3D Scanner Output image of Open Pit and Stock Piles

5.2.8.1 Advantages of 3D Laser Scanning

- Fast & Thorough: 3D laser can record thousands to tens of thousands of data points per second as the laser is moved over the surface of the object or terrain.
- Accurate: With 3D laser scanner, an accuracy of 0.01 mm to 0.1 mm may be achieved.
- Non-Contact: Because 3D laser scanning is an optical-based technology, there is no need for the scanner to touch the object. This can be helpful when seeking to measure small, intricate, or fragile features that may be distorted or damaged when touched. Distorted objects will likewise yield incorrect measurements, so 3D laser scanning is suggested in such cases.

- Safe: Worker safety is the primary concern for construction sites, and 3D laser scanning can improve on this aspect for surveying. The portable 3D laser scanners used for surveying can record accurate measurements from any distance up to several hundred meters. This can help keep operators safe when the survey area is dangerous due to topography.

5.2.8.2 Disadvantages of 3D Laser Scanning

- Line of Sight: It is impossible to measure any surface that is out of the scanner's line of sight. This means that hidden or internal geometry that is not visible to the scanner is unable to be measured. Scans are taken from many different angles in order to ensure a complete model.
- Ambient Light: Because 3D laser scanners read the light of a laser in order to record data, ambient light may blend with the laser and interfere with the scan's accuracy. Depending on the severity of this interference, the scan may be noisy or even unusable.
- Initial Cost: 3D laser scanner can be quite expensive.

5.2.9 Drone Survey

- A drone survey refers to the use of a drone or Unmanned Aerial Vehicle (UAV), to capture aerial data with downward facing sensors or Multispectral cameras and LIDAR (Light Detection and Ranging) payloads.
- During a drone survey, the ground is photographed several times from different angles and each image is tagged with coordinates.

5.2.9.1 Benefits of Drone Survey

- Drone Survey in mining improve the overall efficiency of large mine site and quarry management by providing accurate and comprehensive data detailing site conditions in a very short time.
- The data accuracy and authenticity is better than the traditional survey.
- High resolution (cm level) data of Drone provides high accuracy and more precise volumetric measurements than traditional surveying methods.
- Stockpiles of irregular shape and exhibiting craters can be easily surveyed with great precision than using traditional methods.
- Drone Survey is faster, less human intervention in mine and easily repeatable mining surveys at low cost.
- Changes between two surveys can be tracked and highlighted automatically.
- Drone aerial images can be used to generate point clouds, digital surface models, digital terrain models and a 3D reconstruction of a mining site, including its stockpiles.

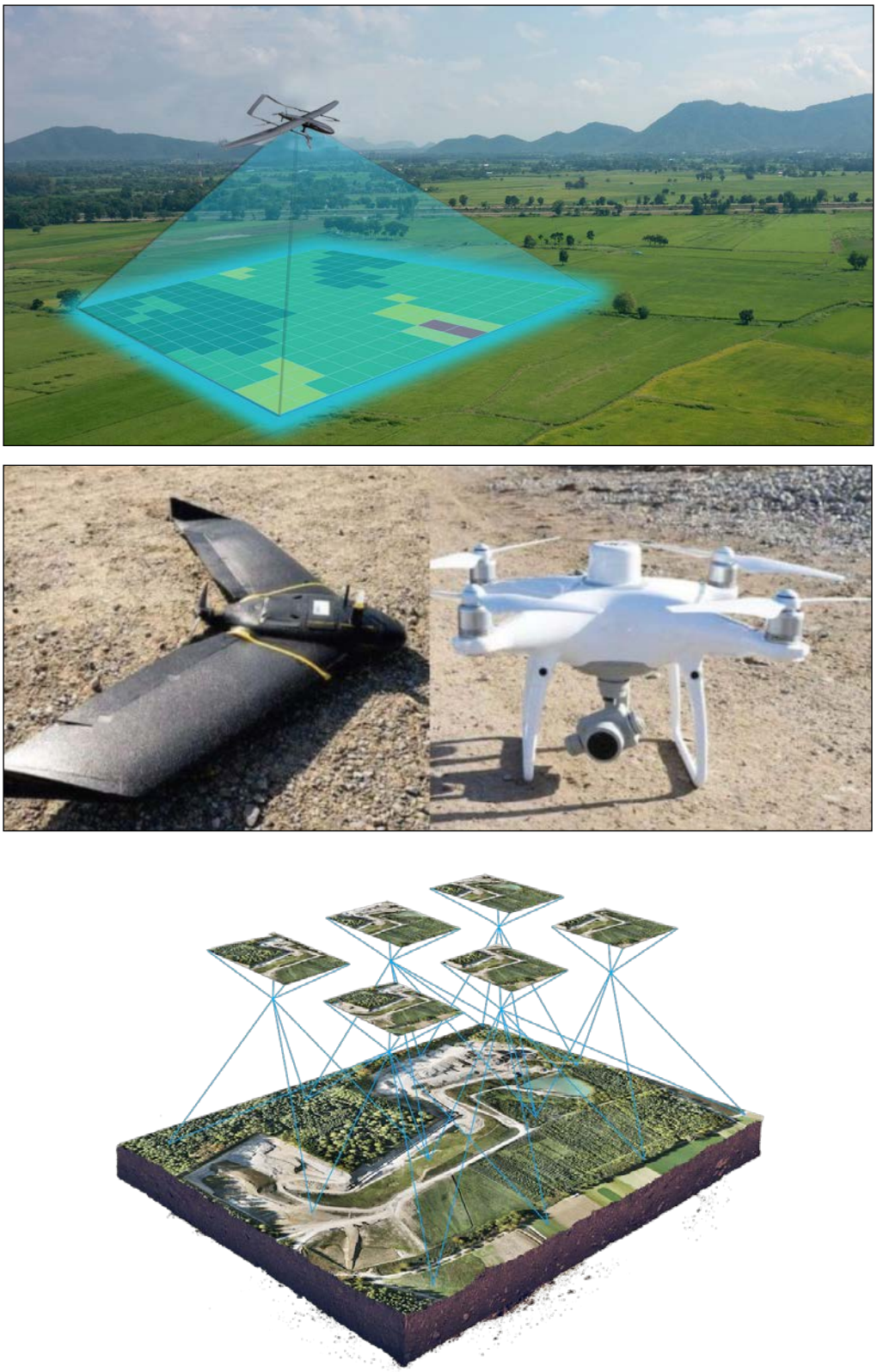


Fig. 5.17: Capturing of Aerial Data through Drones

- Helps in creating a digital data base which can be used and retrieved at ease and compared.
- Data generated over a period of time can be stored in digital platform and the time series data can be compared. The data can be used for systematic and scientific mine closure planning, monitoring of reclamation, rehabilitation activities in lease area.

Fig .5.18: Benefits of Drone Survey

Fig. 5.19: Drone Survey in Mines

5.3 Softwares used for processing of Survey data

Mine Planning is the most crucial part of any mine. Mine planning involves both mine design and scheduling of mining activities. The goal of mine design is to create a mine that will allow exploitation of the reserve in a safe, economic, and environmentally responsible manner. The following Softwares are used in Mining industry.

5.3.1 AutoCAD Civil 3D:

- Survey data import: Civil 3D has the facility to directly import survey field data and the surface plan can be prepared by joining the imported data from the field.
- Borehole data interpretation and preparation of geological cross sections: It can also import borehole data for different ores and can create surface geometry for different ores below the surface. When the same procedure is carried out for all the cross sections present in the mine lease area, geological cross sections are prepared.
- Geological Plan preparation: Surface mapping carried out on the field can easily be imported on the Civil 3D software. Readings of litho-contacts measured on the field are incorporated on the software and the contacts are joined to form the Geological Plan of the Mine Lease area.
- Resource estimation: AutoCAD Civil 3D has a powerful tool for calculating volume. The volume of ore calculated for each section when multiplied by the tonnage factor for a particular ore type gives the estimation of total resources for that ore type present within the mine lease.
- Google earth integration: AutoCAD Civil 3D can be used for exporting the open and closed polylines of a Georeferenced file to a Google Earth file needed for Mining Plan submission in an online portal.

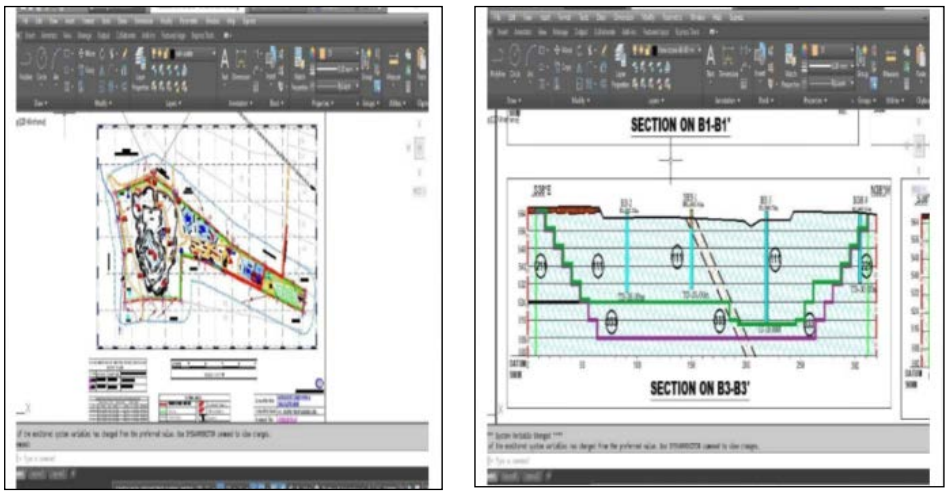


Fig. 5.20: Processing of Survey data in AutoCAD civil 3D

5.3.2 Global Mapper:

- Global Mapper is also a GIS Software. It helps to view Digital elevation modelling which is generated by Drone survey. With Global Mapper we can easily create KML file from AutoCAD.
- KML is a file format used to display geographic data in an Earth browser such as Google Earth. You can create KML files to pinpoint locations, add image overlays, and expose rich data in new ways. KML file supports to track the day-to-day Actual Mine workings limits vs planning with the help of Google Earth.
- It also helps in Digitization of revenue maps of villages that form part of the mining lease along with information on the status of purchase. We intend to digitalize and centrally store all information of future acquisitions using this software.
- Global Mapper helps to smooth the learning curve and ensure that users will be up-and-running in no time, efficient data processing, accurate map creation, and optimized spatial data management.

Besides, other softwares used in Indian Mining Sector for Survey and Planning are as follows:

i. ArcGIS
ii. Bentley
iii. Surpace
iv. Data-mine

5.4 Offshore Areas Mining and Survey/Mapping

Offshore Areas Mining/Deep sea mining, a relatively new and intriguing field, involves extracting minerals and metals from the ocean floor. It refers to the process of extracting minerals and metals from the seabed, which holds vast reserves of valuable resources. This method involves utilizing specialized machinery to excavate, collect, and bring these valuable minerals to the surface for further processing.

The Offshore Areas Mineral (Development and Regulation) Act, 2002, their amendments and the rules made thereunder are applicable to mineral resources in the territorial waters, continental shelf, exclusive economic zone (EEZ) and other maritime zones of India. India's EEZ spans ~2.3 million sq. km., equivalent to 70% of India's land area.

Recently, the Administering Authority, Ministry of Mines has notified 13 no's of offshore Mineral Blocks for grant of Composite Licence through electronic auction on 28 November 2024, in accordance with the Offshore Areas Mineral (Auction) Rules, 2024 as amended from time to time. The details of the same are furnished below.

Sl. No.	Name of the Block	Mineral	Offshore	Coast/ Sea	PL/ CL	Area in Sq. Kms	Reserve Price
1	Kollam CS Block-1	Construction Sand	Off Kerala	West Coast, Arabian Sea	CL	79	1%
2	Kollam CS Block-2	Construction Sand	Off Kerala	West Coast, Arabian Sea	CL	78	1%
3	Kollam CS Block-2	Construction Sand	Off Kerala	West Coast, Arabian Sea	CL	85	1%
4	Porbandar LM Block 1	Limemud	Off Gujarat	West Coast, Arabian Sea	CL	66.64	1%
5	Porbandar LM Block 2	Limemud	Off Gujarat	West Coast, Arabian Sea	CL	69.81	1%
6	Porbandar LM Block 3	Limemud	Off Gujarat	West Coast, Arabian Sea	CL	66.64	1%
7	West Sewell Ridge PMNC Block-1	Polymetallic nodules and crusts	Off Great Nicobar Island	Andaman Sea	CL	84.63	1%
8	West Sewell Ridge PMNC Block-2	Polymetallic nodules and crusts	Off Great Nicobar Island	Andaman Sea	CL	84.63	1%
9	West Sewell Ridge PMNC Block-3	Polymetallic nodules and crusts	Off Great Nicobar Island	Andaman Sea	CL	84.63	1%
10	West Sewell Ridge PMNC Block-4	Polymetallic nodules and crusts	Off Great Nicobar Island	Andaman Sea	CL	84.63	1%
11	West Sewell Ridge PMNC Block-5	Polymetallic nodules and crusts	Off Great Nicobar Island	Andaman Sea	CL	84.63	1%
12	West Sewell Ridge PMNC Block-6	Polymetallic nodules and crusts	Off Great Nicobar Island	Andaman Sea	CL	84.63	1%
13	West Sewell Ridge PMNC Block-7	Polymetallic nodules and crusts	Off Great Nicobar Island	Andaman Sea	CL	84.63	1%

Bathymetric survey is very essential requirement for offshore exploration and mining.

5.4.1 Bathymetric surveys:

Bathymetric sometimes referred to as a fathometric survey, is a type of hydrographic (water-based) surveys allows us to measure the depth of a water body as well as map the underwater features of a water body. Multiple methods can be used for bathymetric surveys including multi-beam and single-beam surveys, ADCPs, sub-bottom profilers, and the Ecomapper Autonomous Underwater Vehicle. We use bathymetric surveys for many different types of research including flood inundation, contour of streams and reservoirs, leakage, scour and stabilization, water-quality studies, dam removal, biological and spill, and storage and fill in reservoirs and ponds.

Bathymetric surveys allow us to measure the depth of a water body as well as map the underwater features of a water body.

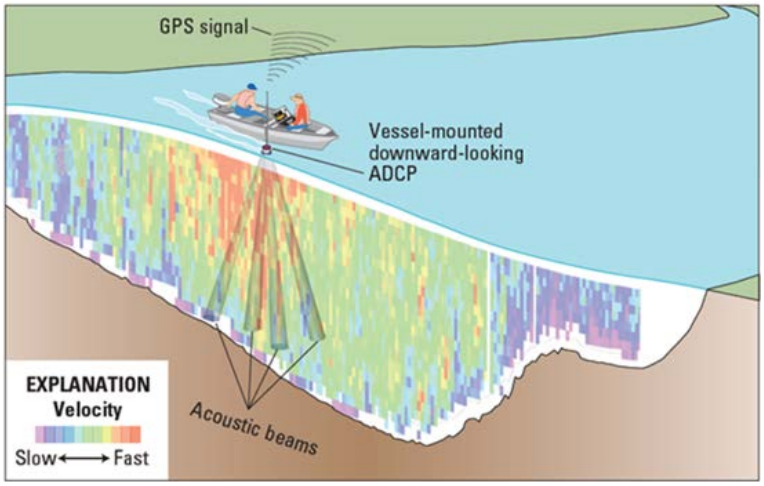


Fig. 5.21: Typical bathymetric survey picture

5.4.2 Multiple methods can be used for bathymetric surveys:

- **Multi-beam surveying**: A multibeam echo sounder attached to a boat sends out a wide array of beams across a "swath" of the water body floor. As the beams are bounced back from the waterbody floor, the data is collected and processed. The processed data can be viewed in real time on the boat during the survey. Multi-beam surveying is generally done in larger water bodies.
- **Single-beam surveying**: Rather than sending out a wide set of beams, single-beam bathymetry measures the water depth directly under the boat. Single-beam surveys are generally used for smaller water bodies.
- **Acoustic Doppler Current Profiler (ADCP)**: ADCPs are used throughout USGS to measure stream flow. ADCPs measure water velocity by transmitting sound waves which are reflected off sediment and other materials in the water. Data collected from ADCPs can then be used to for bathymetric mapping.
- **Sub-bottom profilers**: Sub-bottom profilers are most commonly used to view the layers of sediment and rocks under the water body floor. A transducer sends a sound wave to the water body floor. This sound wave can penetrate the water body floor. The data returned from the sound waves can be mapped to show the layers beneath the water body floor.
- **Ecomapper Autonomous Underwater Vehicle**: The Ecomapper can collect detailed bathymetric data, down to one-foot contours, in places that are difficult to reach with boats. The Ecomapper uses side-scan sonar and a Doppler velocity log.

5.4.3 Technology used in bathymetry

Today, scientists are use single-beam and multibeam echosounders to make their bathymetric measurements. Echosounders send a pulse of sound from where they are mounted (generally on or near the hull or bottom of the vessel) to the seafloor. The sound wave travels to the ocean floor and bounces back.

Bathymetric data is available for the entire world, collected by satellite, but only at low resolutions. Higher-resolution data must be collected using hydrographic survey methods, the most common of which is multibeam sonar systems, and it is only available for parts of the ocean.

Underwater mapping: Multibeam sonar signals are sent out from the ship. With about 1500 sonar soundings sent out per second, multibeam "paints" the seafloor in a fanlike pattern. This creates a detailed "sound map" that shows ocean depth, bottom type, and topographic features.

The spacing for bathymetric surveys: To ensure surveys are systematic, even where bathymetric coverage is specified at less than 100%, the horizontal distance between registered positions of depths should be no greater than 3 times water depth or 25 metres, whichever is greater.

Collection of bathymetric data: Bathymetric data is available for the entire world, collected by satellite, but only at low resolutions. Higher-resolution data must be collected using hydrographic survey methods, the most common of which is multibeam sonar systems, and it is only available for parts of the ocean.

The data used to make bathymetric maps today typically comes from an echosounder (sonar) mounted beneath or over the side of a boat, "pinging" a beam of sound downward at the seafloor or from remote sensing LIDAR or LADAR systems.

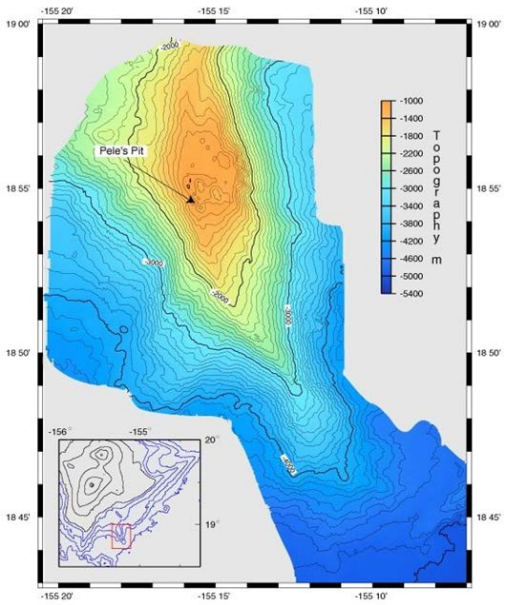


Fig. 5.22: A Typical bathymetric map

CHAPTER 6

Digital Technology & Innovation in Mine Planning and Monitoring

6.0 Mine of Future

With digitalization, it is now possible to control, fine tune and catalyse the whole mining operation in underground mines which is resulting in attractive careers in safe control room environments which provide space for the employee's expertise and creativity. Further introducing emerging technologies like Cloud, AI, Robotics and Big Data will enable industry to optimise production and exploration processes, improve supply chain and logistics and increase sustainability.

Digital technologies offer the potential to deliver significant improvements by improving the quality and availability of data and information, which in turn can be the key to significant productivity gains. From day-to-day data management to the prevention of bottlenecks and inefficiency, information and communication technologies are transforming the way the mining industry operates.

Increasing demands for efficient production and workers' safety are requiring traditional mining companies to embrace innovation and implement information technology to ensure advanced manufacturing and competitiveness throughout the industry.

One of the key issues that hinders data transformation in the mining industry is the fact that most companies have specific point solutions already in place to address the numerous areas of operations, drilling, operations management, safety, maintenance, mining, transportation etc. all with their own data and reporting functions. Most of these organizations have little appetite for totally replacing these systems to a complex and expensive all-encompassing system, so they use error-prone manual spread sheet processes to extract data and cobble together reports for decision making, management and statutory reporting. The time demands a breakthrough revolution in the mining industry to boost its production. There is no easier way to succeed, but one can definitely opt for a smarter path to amp production. To obtain fruitful outcomes from regular tasks in a smarter way is exactly what innovations in digital technology bring to humankind.

What is really needed is an end-to-end process which automates the integration function, replacing these manual and repetitive reporting functions with a single source of the truth which provides decision makers with up to date and accurate information they can rely on. The clever implementation of digital technologies, like Internet of Things (IoT), Wireless Technologies, Artificial Intelligence (AI), Drone and Cloud Technologies will make organizations more efficient, productive, safe, sustainable, and profitable. Digital Transformation is helping industries in bringing transparency, accuracy and speed into the business processes. Traditionally, mining industries are laggards in implementing new technologies due to different challenges which include inherent complexity of processes, variation in skill levels, aging workforce, and managerial conservatism. Some of new technologies are listed below.

6.1 GEOVIA SURPAC:

GEOVIA Surpac is the most widely used 3D mining software in supporting Drill hole data, Geological modelling, Block Modelling, open pit design, Resource Estimation, Exploration Projects and Data Management. Surpac enables mining practitioners to quantify and evaluate mineral deposits and to plan the efficient extraction of reserves. Using Surpac we can work in multilayer of data which is time saving and easy for referring various database which will increase the accuracy while panning.

Mine survey and ore control:

- Calculate and validate volumes quickly.
- Compare kriged models against raw drill hole data to optimize reserve extraction,
- Road and pit design tools are geared towards surveying, designing of pit by following the recommended parameters like height, width, slope angle, overall slope angle, gradient and more are marked out accurately.
- Integrated resource models, pit designs and survey data results in up-to-date ore mark outs and excavation plans with grade and tonnage reports.

Mine Production:

Surpac is used at mine sites for mine production, providing integrated applications for mining engineers, geologists and mine surveyors, ensuring clear plans, effective communication and consistent data utilization. The software manages borehole, blasting and survey information, while linking to other databases used at mining operations.

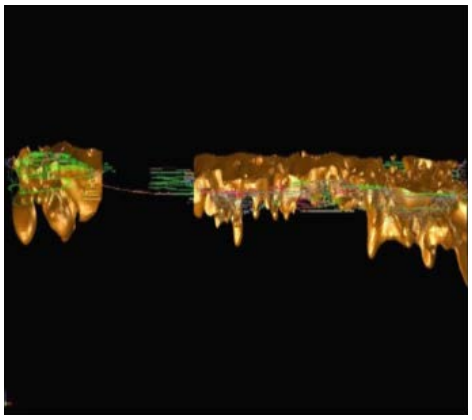


Fig. 6.1: Geological Model in 3D for using Bore Hole Data

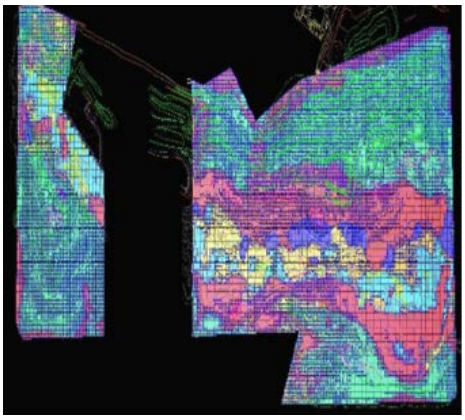


Fig 6.2: Classification of various materials using colour identification

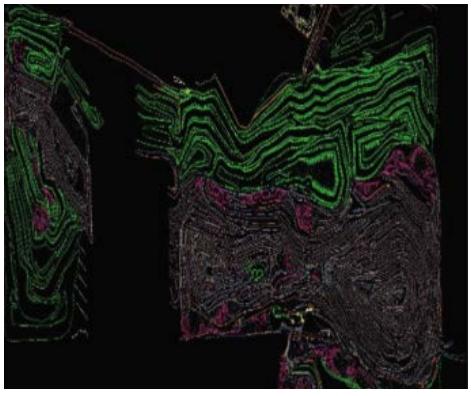


Fig. 6.3: Survey files in Digital form

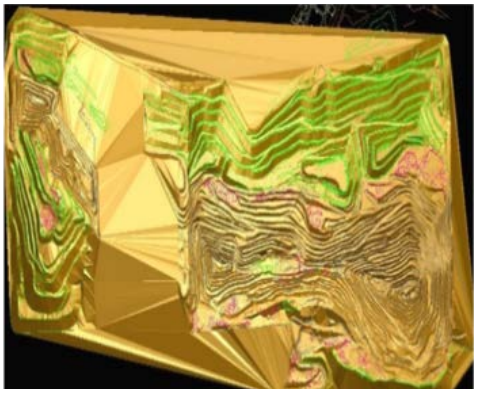


Fig. 6.4: 3D modelling of Survey files

6.2 Monitoring of truck Dispatch System

For monitoring the inbound mineral from mine to plant, integrated Weighbridge (WB) hardware with Radio Frequency Identification (RFID) are deployed by many lease holders. The system is automatic and almost man-less. Once the dumper/ truck is loaded it comes to mines weighbridge, if load is within limit, driver gets GREEN light, then the data of truck is captured in system through RFID scanning and the operator cuts royalty slip and the truck leaves for plant. If the driver gets RED light means overload or under load and proceeds as instructed by WB operator. As the truck reaches the plant, data is being captured here automatically by RFID and the truck proceeds for unloading to crusher as instructed by the supervisor there. Wherever the truck goes to empty again its RFID is captured as place of Delivery Transportation Monitoring through GPS in each tipper.

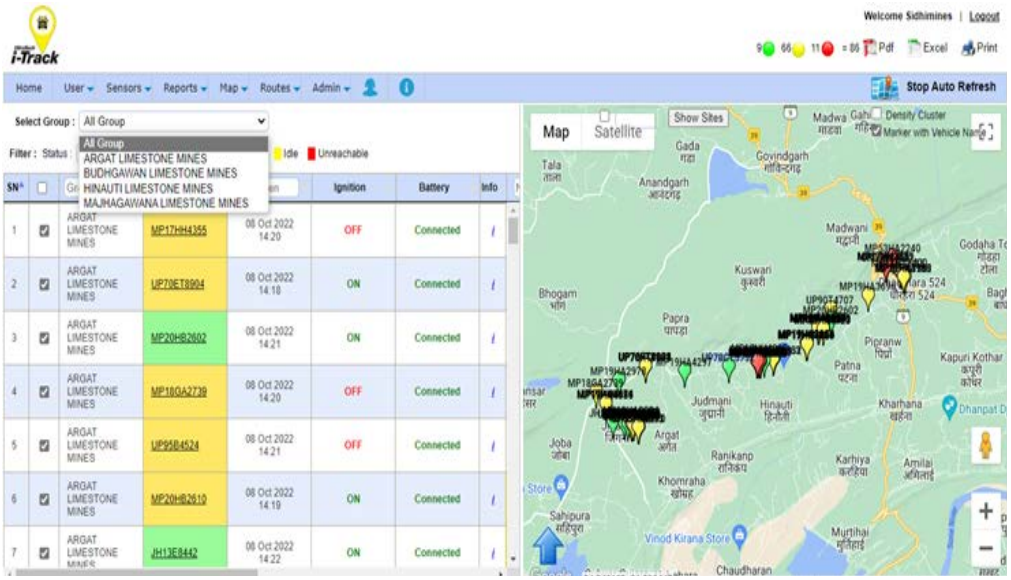


Fig 6.5: Location of trucks in different areas
Courtesy- Ultratech Cement Limited, Unit: Sidhi Cement Works

Benefit of GPS base monitoring:

a. Notification of over speeding to driver, tipper owner and shift Engineers to verify event of any tippers in history record.

b. Tracking of actual location of tippers and helps Tipper's owner to monitoring idle hrs. of his tippers and fuel monitoring.

6.3 Digital strategies in mining Industry

In India, Mining companies are creating an enterprise-level digital strategy that outlines the value that the business will receive from the digital activities. Such tactics enable longer-term transformation while facilitating digital business transformation at a pace that meets short-term objectives. Additionally, it considers every product and platform that contributes to a comprehensive solution for the entire future digital mining. A broad range of digital capabilities are being used to automate core mining value chain operations. IoT and machine learning are employed, for instance, to automate and enhance the dependability of mining equipment and trucks, sensors to gather data in real-time, drones for data collecting, inspection, and stock control, and wearables for field maintenance and operator safety.

Example No. 1- Rampura Agucha Underground mine of M/s Hindustan Zinc Limited

Using Digitalization, M/s Hindustan Zinc Limited (HZL) at Rampura Agucha Underground mine is making it possible to control, fine tune and catalyse the whole mining operation which is resulting attractive careers in safe control room environments which provide space for the employee's expertise and creativity. Further introducing emerging technologies like Cloud, AI, Robotics and Big Data will enable HZL to optimise production and exploration processes, improve supply chain and logistics and increase sustainability.

They have also set up Centre of Excellence focused on analytics, automation, asset management, energy and climate change, ore body knowledge, underground mining, and processing. These smart mining teams help them to make the right technical judgments and decisions to help manage major hazard risks and assure the safety of assets and operational excellence. HZL mines are becoming increasingly connected with more robust communication systems that can transmit data and equipment that are constantly producing data; digitalization is yielding concrete, and sometimes astonishing results.

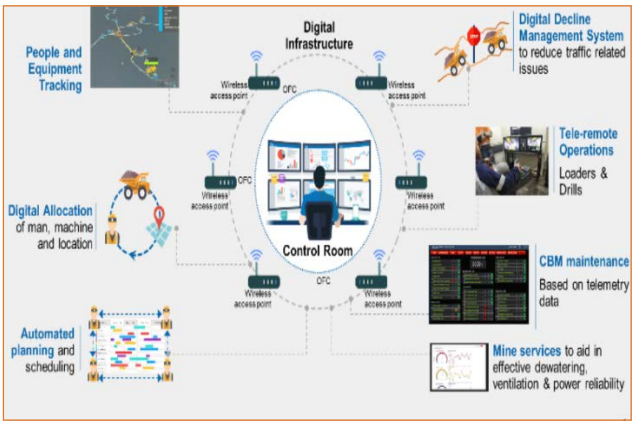


Fig. 6.6: Digital initiatives at RAMPURA AGUCHA

1. Personnel & Equipment Tracking and Emergency SOS- Personnel at RAUG Mines operate in challenging work environments are provided with RFID based Digital Cap-Lamp that enable the logging of their movements from one zone to another inside the network zone on real time basis. This allows Control Room and Leadership team to track and pinpoint their exact location and provide immediate response and protection, particularly in emergency situations where safety is a concern.

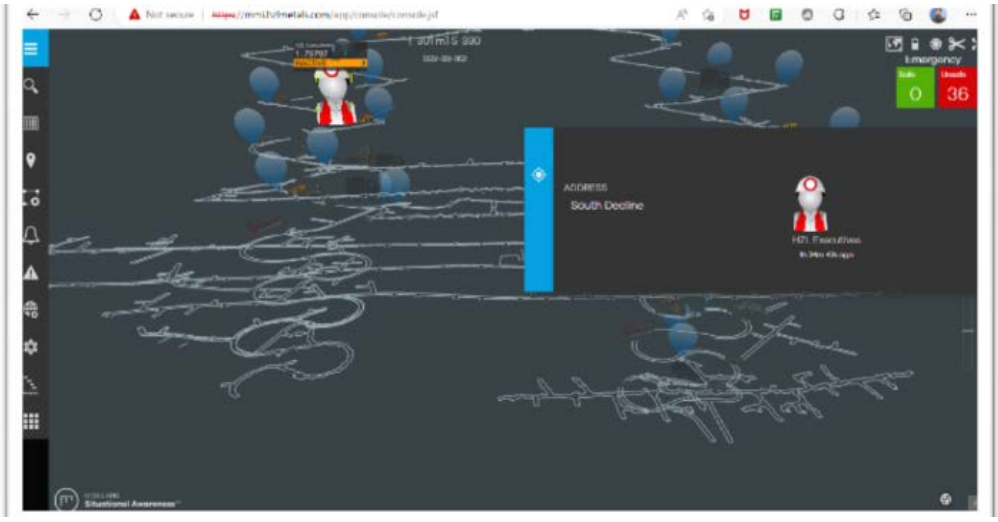


Fig. 6.7: 3D Visualization tool for Personnel and equipment tracking

2. Digital Allocation: Fetching instant operators' details through Biometric System which is used to enter in mine premises and Fetching fleet status report from system itself filled by previous shift in-charge eliminating instances of wrong reporting or miscommunication.

Fig. 6.8: Daily Shift Allocation portal providing present Operators details as soon they enter Mine Premises and equipment status filled by previous shift in-charge

3. Virtual Reality Simulators: To improve the performance of winder driver and HEMM operator with full safety for both service and production winder and HEMM vehicle respectively, innovative VR based first of its kind winder and LPDT simulator has been designed. So that winder drivers and operators can thoroughly practice and improve their driving skills. This simulator training provides a smooth virtual walkthrough for operators and familiarises them with the mine equipment. It allows operators to practice in different scenarios and critical situations, thus serving to not only improve performance but also enhance safety and productivity.

Fig. 6.9: Virtual Simulator

4. Tele remote Operation: To eliminate the risk of geotechnical challenges (due to presence of sheared rock, fault planes and dangers associated with mining method), the mine attempted for Tele-remote drilling operation testing. This helped in achieving 100% utilization during changeover timings and in a safe operating condition for the operator wherever needed.

Fig. 6.10: Tele remote operation

5. Advancement in Exploration: The structural disturbances and the discontinuity occurred due to the same can only be identified by closed space advanced exploration prior to development and rigorous face and roof mapping during the development.

For advanced exploration, high speed drilling rigs have been procured with a capacity of drilling up to 500m depth at a penetration rate of 5-7m/hr.

Advance exploration data at 25m x 25m interval gives a broad picture of the orebody at deeper or upcoming levels.

Fig. 6.11: High Speed Drill Rigs (MCR)

These technologies are helping to increase the efficiency and accuracy of exploration and drilling operation, while also reducing the risk of accidents and injuries for workers, additionally, they are enabling mining companies to extract resources from previously inaccessible or uneconomical sites, which is helping to meet the growing demand for critical minerals and metals.

Example No. 2- At Aditya Limestone Mines of M/s UltraTech cement Limited

A cement industry having its own captive mines, has understood the need of business and leveraged the benefits by adopting digitalization in mining process to overcome the redundant technologies and various bottlenecks. At Aditya mines, digitalization plays a significant role by offering new opportunities to expand efficiency and operational excellence.

In general, the infrastructure components of software used by Aditya mines include:

1. Hardware components (such as various sensors, RFID tags, IOT based technology, wireless & GSM infrastructure, drone for surveying, embedded systems); and
2. Software components (such as cloud and platform solutions, data analysis solutions, 2D imaging and planning modules, application-based software for drilling and blasting, data management solutions, etc.)

These technologies are used in their web-based mine digitalization solution which is covering various modules to improve overall mining efficiency and safety.

1. Mine Planning module-By identifying the potential value in the given mineral resources and providing a practical and realistic optimal strategy for extraction that considers all the material options and scenarios. A good mine planning process provides the foundation for high performance.

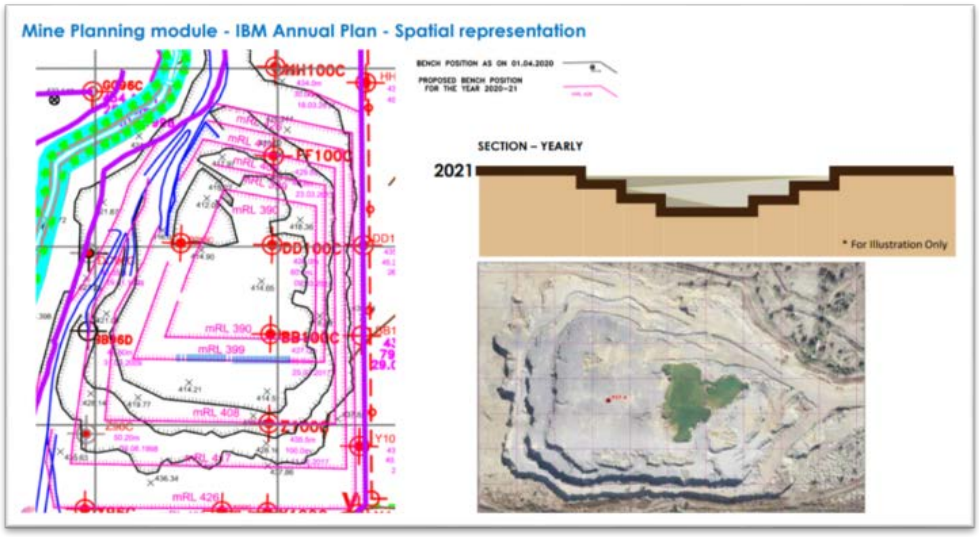


Fig. 6.12: Mine planning module – spatial representation

2. Operations Control module: This module is particularly used to monitor the entire mining operations from a single dashboard which helps in improving productivity, enhanced efficiency and better safety.

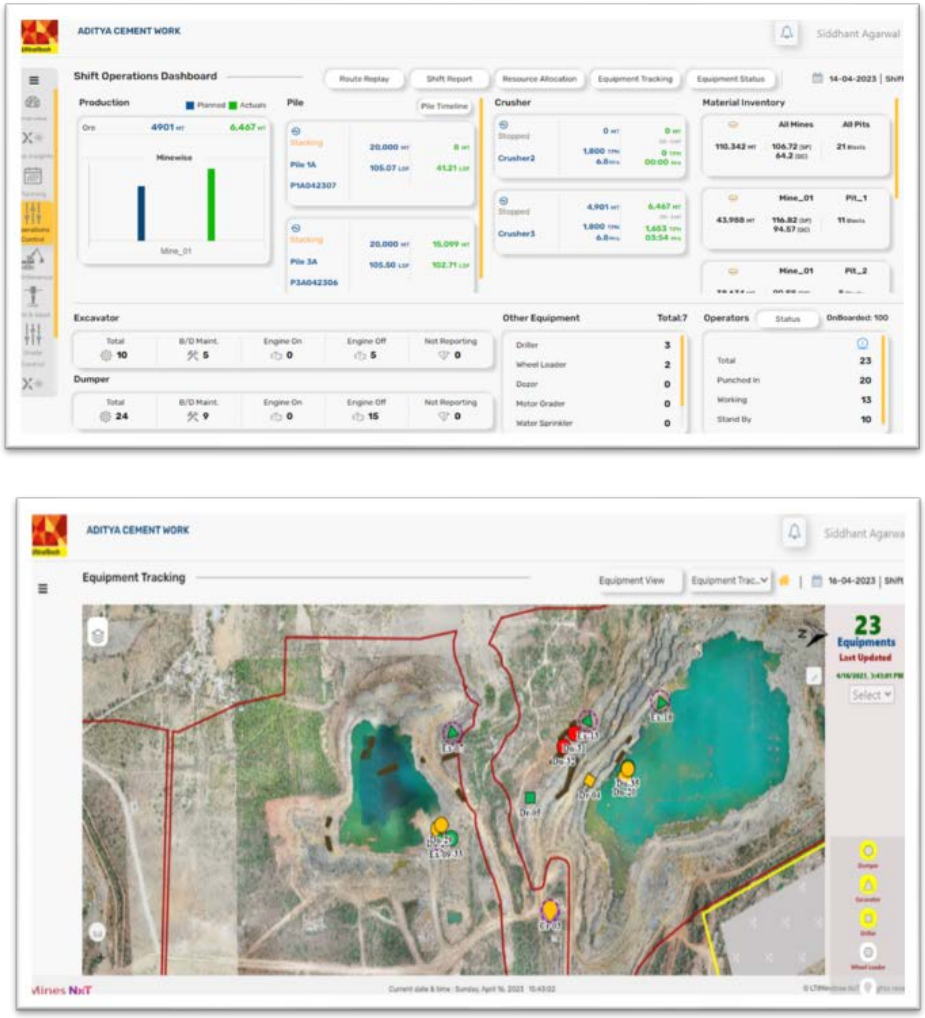


Fig 6.13: Operation control module –representation

3. Maintenance module: Mining companies typically collect huge amounts of data from drills, dumpers, excavators and crushers. Yet rarely is this information used to generate insights or for better analysis. They use the information collected from equipments for improved anticipation of failures and predictive maintenance.

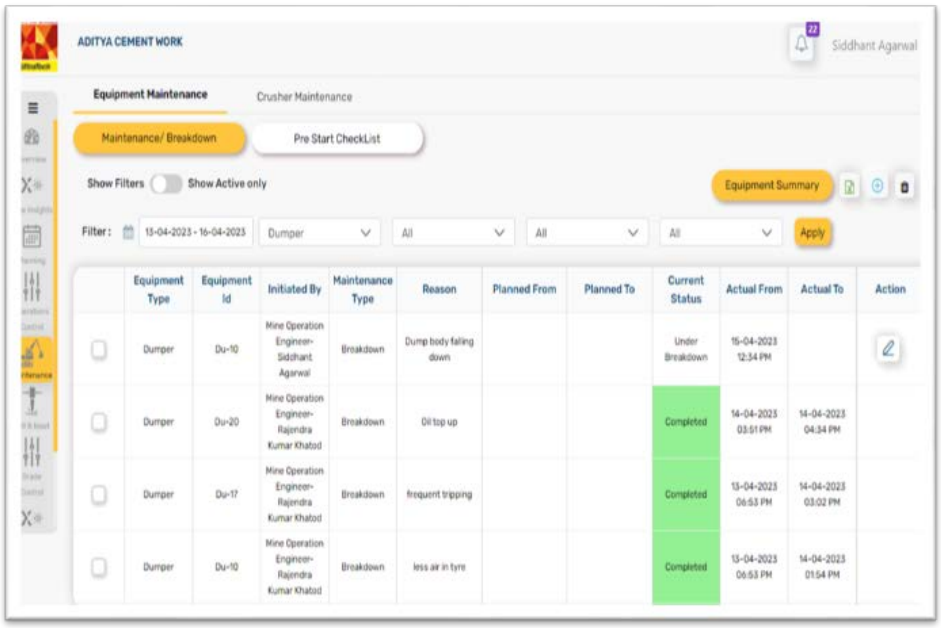


Fig. 6.14: Maintenance module –representation

4. Drilling and Blasting module: This module covers the backbone of mining that is blasting and its performance parameters. It holds the data which is generated through the blast survey app called LMNOP, such as blast section survey, sampling survey and blast parameters.

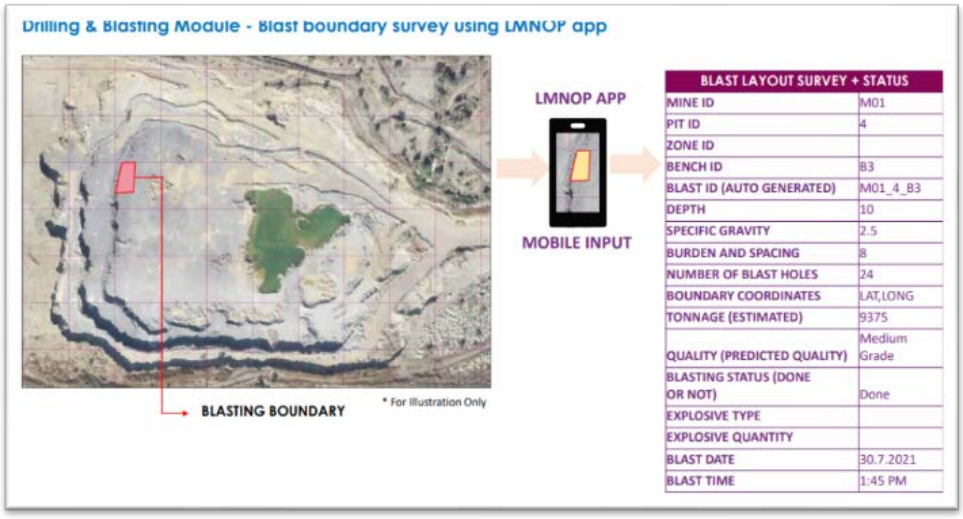


Fig. 6.15: Drilling and Blasting module –representation

5. Grade Control Module: Grade control module is a database which stores the sample analysis fed by the Quality control department.

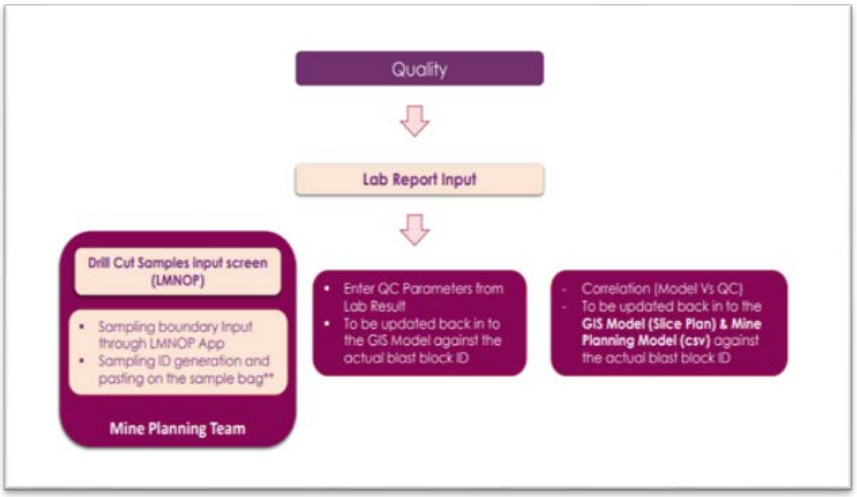


Fig. 6.16: Grade Control module –representation

6. Mine Optimization module: This module takes data from all other modules and provides the best allocation scenario to achieve the desired output.

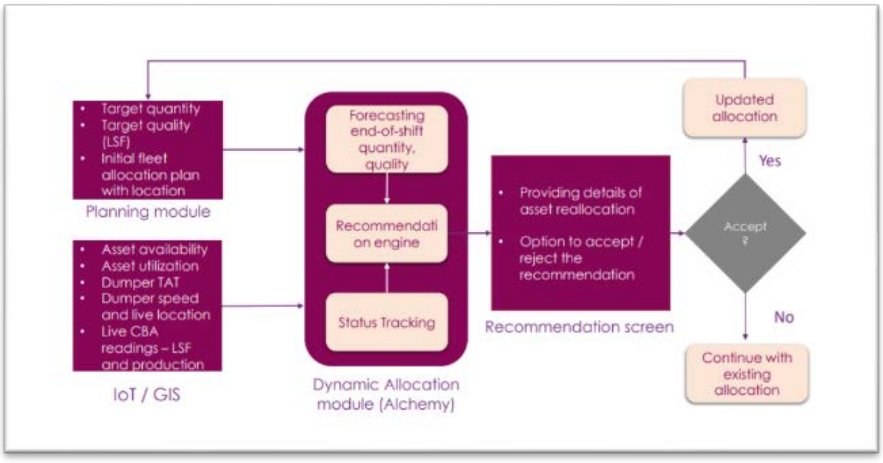


Fig. 6.17: Mine Optimization module –representation

CHAPTER 7

Green Energy

7.0 Green Energy

Green energy is an energy that can be produced using a method, and from a source, that causes no harm to the natural environment.

As a source of energy, it often comes from renewable energy technologies such as solar energy, wind power, geothermal energy, biomass and hydroelectric power. Each of these technologies works in different ways, whether that is by taking power from the sun, as with solar panels, or using wind turbines or the flow of water to generate energy.

Green energy refers to energy derived from natural sources that are environmentally friendly and non-polluting. The primary objective of green energy is to minimize environmental impact. These energy sources are typically characterized by their cleanliness, renewability, and sustainability, making them a preferred choice for those focused on reducing their carbon footprint. Green energy is invariably clean and renewable, with a strong emphasis on environmental benefits and sustainability.

One thing that green, clean and renewable energy all have in common is that they're being increasingly used to generate electricity in order to phase out the use of fossil fuels, like coal and gas, which are a key cause of climate change.

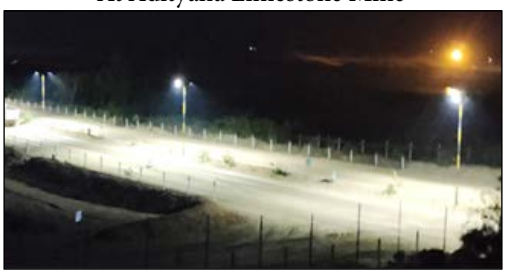
7.1 Types of Green Energy

Power is a critical infrastructure for development process and due to constant demand of the power over the supply and consequently environments and ecological hazards associated with the power generation through fossils fuels, has resulted a worldwide concerned and increasing the importance for renewable sources. The main sources are wind energy, solar power and hydro-electric power (including tidal energy, which uses ocean energy from the tides in the sea). Solar and wind power can be produced on a small scale at people's homes or alternatively, they can be generated on a larger, industrial scale.
The six most common forms are as follows: 1. Solar Power; 2. Wind Power; 3. Geothermal Energy; 4. Hydropower; 5. Biomass, & 6. Biofuels.

1. Solar Power: This common type of renewable energy is usually produced using photovoltaic cells that capture sunlight and turn it into electricity. Solar power is also used to heat buildings and for hot water as well as for cooking and lighting. Solar power has now become affordable enough to be used for domestic purposes including garden lighting, although it is also used on a larger scale to power entire neighbourhoods.

In Mining industry also, the concept of green energy has been adopted for many years by many mines to protect the environment. It has been adopted in very common form as "SOLAR POWER" energy.

At Adityana Limestone Mine



At Adityana Limestone Mine

Harudi Kharai Limestone Mine

Harudi Kharai Limestone Mine

Fig. 7.1: 05 MW SOLAR POWER PLANT – Sewagram Cement works

Fig. 7.2 : Roof Top Solar Panel at Mine Office
Courtesy: My Home Limestone Mine of M/s My Home Industries Pvt Ltd

Fig. 7.3: 9MW Solar Power Plant at Mine Level
Courtesy: Thummalapenta Limestone Mine of M/s Ultra Tech Cemets Ltd

Fig. 7.4: 3.3 MW solar power plant Noamundi Iron ore Mines of M/s Tata Steel Ltd.

Solar Powered Wi-Fi Trolleys, Street Lights & Solar Power: On the view of the same, mine has implemented solar power system for office area utilization by installing solar panels at site. Solar Trolleys provided for networking purposes: The Power Trolley is a unique portable power back-up system designed for basically any situation when you do not have power. Just about any type of load can be connected to the Power Trolley as long as it is within the power rating indicated. The super structure shell for solar panel mounting is out of square tubes of rectangle tubes of size 40x40x2 mm. All other pillars, longitudes of the sides and other intermediate cross members of the super structure are rectangle tubes. Necessary reinforcements to the structure is provided and entire super structure is mounted on the under frame and unit welded.

Wherever necessary, structural plate's reinforcements are provided and welded to the structure for mounting of the equipment. Pre-treatment is carried to all the structural components of the structure and primer is coated. The entire structure after welding is coated with anti-corrosive coating. Steel fasteners are used in the construction of the trailer components.

Fig. 7.5: Working mechanism of Solar Wi-Fi Trolley

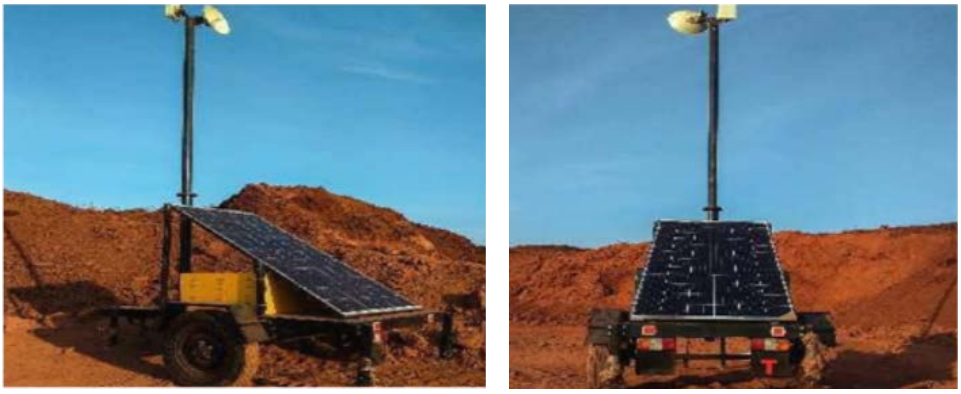


Fig. 7.6: Existing solar Wi-Fi trolley under operation at mine head

Fig. 7.7: Innovation in energy savings by use of solar power or other sources
Courtesy: JSW Mines of Bangalore

Fig. 7.8: Streetlights glowing with stored solar power

2. Wind Power: Wind Power or Wind Energy is a form of renewable energy that harnesses the power of wind to generate electricity. It involves using wind turbines to convert the turning motion of blades, pushed by moving air (kinetic energy) into electrical energy/electricity.

It's a green energy, environmentally friendly and cheaper source of electric energy. India is having huge proven potentials to harness the Wind Energy. Wind Energy Projects are also awarded carbon credits, carbon emission ratings and carbon credits are internationally tradeable.

Example: During the year 2006, to promote non-conventional source of Energy, Manganese Ore (India) Limited has installed a 4.8 MW (6 x 800 KW) Wind Energy Farm at Nagda Hills, Village Rajoda, Distt. Dewas for Captive Use of its mine and plant situated in Balaghat district in MP with a total cost of Rs. 22.2 Crores. 4.8 MW Wind Energy Farm consisting of 6 machines of 800 KW, EN-48 Enercon Make having synchronous generator, gear less technology, erected on tubular tower, to harness the wind energy.

Besides, 15.2 MW wind energy farm has been installed at Ratedi hill of Dewas in the year 2008 for sale to utility.

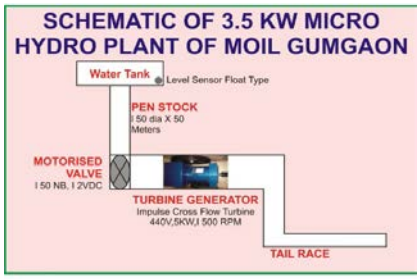
Fig. 7.9: Wind Energy Farm at Nagda Hills

3. Geothermal Energy: Geothermal energy is thermal energy extracted from the earth's crust. It is a renewable energy source because heat is continously produced inside the earth. Geothermal power plant draw fluids from underground reservoirs to the surface to produce heated materials. This steam or hot liquid then drives turbine that generate electricity before it is re-injected back into the reservoir.

This type of green power uses thermal energy that has been stored just under the earth's crust. While this resource requires drilling to access, thereby calling the environmental impact into question, it is a huge resource once tapped into. Geothermal energy has been used for bathing in hot springs for thousands of years and this same resource can be used for steam to turn turbines and generate electricity. The energy stored under the United States alone is enough to produce 10 times as much electricity as coal currently can. While some nations, such as Iceland, have easy-to-access geothermal resources, it is a resource that is reliant on location for ease of use, and to be fully 'green' the drilling procedures need to be closely monitored.

4. Hydropower: This is one of the oldest and largest source of renewable energy which uses the natural flow of moving water to generate electricity. The basic principle is using water to drive turbines. To produce electricity, a turbine generator set converts mechanical energy to electrical energy. This type of green energy uses the flow of water in rivers, streams, dams or elsewhere to produce electricity. Hydropower can even work on a small scale using the flow of water through pipes in the home or can come from evaporation, rainfall, or the tides in the oceans.

Example: The new concept of 3.5 KW micro-hydro electric plant developed by M/s MOIL at their Gumgaon Mine was inaugurated by the then Chief Controller of Mines (I/c), IBM on 19/11/2024.



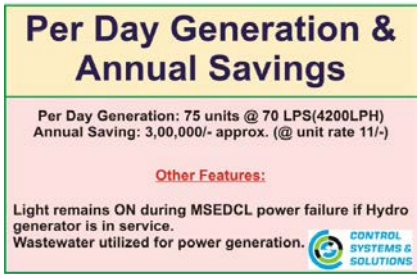


Fig. 7.10: 3.5 KW Micro-Hydro Electric Plant developed by M/s MOIL, inaugurated by the then Chief Controller of Mines (I/c), IBM

5. Biomass: This renewable resource also needs to be carefully managed in order to be truly labelled as a 'green energy' source. Biomass power plants use wood waste, sawdust and combustible organic agricultural waste to create energy. While the burning of these materials releases greenhouse gas these emissions are still far lower than those from petroleum-based fuels.

6. Biofuels: Rather than burning biomass as mentioned above, these organic materials can be transformed into fuel such as ethanol and biodiesel. Having supplied just 2.7% of the world's fuel for transport in 2010, the biofuels are estimated to have the capacity to meet over 25% of global transportation fuel demand by 2050.

Fig. 7.11: Installation of biogas plants to treat organic wastes.
Courtesy of: Panchpatmali (C&N Block) Bauxite Mine

7.2 Clean Energy

Clean Energy is energy that when used, creates little or no greenhouse gas emissions. Recently Indian mining sector has also started using of different type of electric vehicles (EV) as one of clean energy initiatives. EVs are better for the environment than gas-powered cars, not just because gas-powered cars rely on fossil fuels, but because EVs are more efficient. Efficiency measures how much of the energy in fuel is converted into kinetic energy to get the tires rolling. The implementation of battery electric vehicles (BEVs) in mining is relatively recent. BEVs offer several advantages over diesel machines, including enhanced working conditions through reduced noise and heat and the lack of toxic exhaust gases or diesel particulate matter.

7.2.1 Use of Electric Vehicles

The mining industry is starting to benefit from a new generation of low emission "driverless" mine vehicles that are transforming the image of the industry and heading towards decarbonisation. Electric vehicles (EVs), for use in both open pit and underground operations, are added to fleets either through purchase or by the retrofit of existing diesel engine vehicle fleets.

Global Data, the parent company of MINE, believes that electrification is advancing in underground projects faster than open pits, but that both will become a focus in the 2030s.

Electric vehicles use electricity to charge their batteries instead of using fossil fuels like petrol or diesel. Electric vehicles are more efficient, and that combined with the electricity cost means that charging an electric vehicle is cheaper than filling petrol or diesel for your travel requirements.

As miners strive to reduce greenhouse gas emissions, many, particularly those with underground mines, are beginning to invest in battery-powered and electric-powered mining fleets.

Few mining companies have taken initiative and as a "Innovation in energy saving" have introduced Battery Electric Vehicles in mines. In underground as well as opencast mines, the use of EV shall become very common in near future in Indian mining industry too.

Fig. 7.12: Normet SmartDrive Battery Electric Vehicle (BEV)

Example 1- Hindustan Zinc, Vedanta group of company

In a first-of-its-kind initiative in the Indian mining sector, Hindustan Zinc, a Vedanta group company, has introduced Normet Agitator Smart Drive EV, into its underground mining operations. BEVs are more energy efficient than internal combustion engine vehicles. They do not have to waste energy by carrying a heavy engine and fuel tank which means they can potentially reduce fuel consumption and lower operating costs.

Using electric vehicles will result in reduction of carbon prints. As there are many advantages of BEV, some risks are also involved in these types of vehicles also, like it shall be used with more care as compared to IC engine vehicles. Proper training of BEVs to operators with its pros and cons to be provided. Some of the other factors are higher initial costs, limited driving range, and battery packs can be expensive to replace.

Electric open cast compressor has also been deployed and has been used in the field of drilling and exploration in India. As the compressor runs on electricity, it causes minimum damage to the environment and no fume is generated in the process of drilling whereby making it environmental friendly.

Example 2- Surjagarh Iron Ore Mines, M/s Lloyds Metal & Energy Ltd

M/s Lloyds Metal & Energy Ltd is conducting iron ore mining with a strong emphasis on producing low CO_2 emission iron ore products. Their entire operational chain, from 'Drilling to Dispatch,' will exclusively utilize non-fossil fuel energy sources. Transitioning from diesel-powered machinery to electrical equipment in open-cast iron ore mining operations presents a holistic solution for achieving efficiency, cost savings, and environmental sustainability.

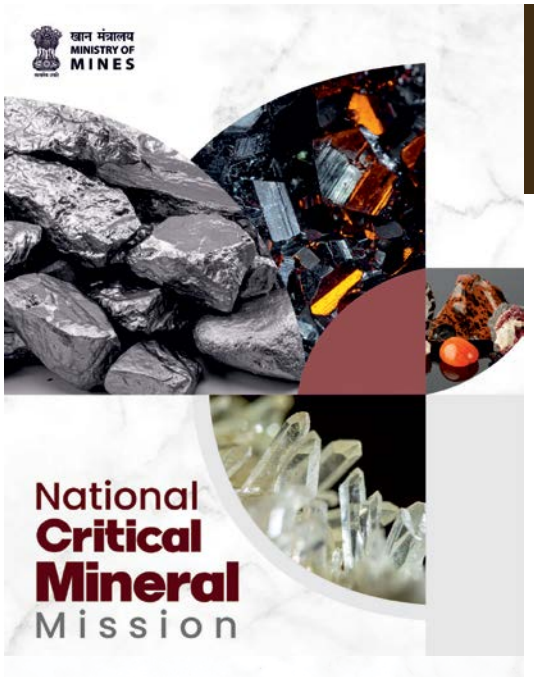
At Surjagarh Iron Ore Mines in India, the hauling trucks (SANYE SKT105E) are the first of their kind, being battery-operated. Energy is generated self-sufficiently and stored in batteries. Electrical energy is produced at the top of the hill using downhill gradient energy and stored in batteries. This stored energy is then used when the trucks climb uphill. The matching loading equipment (EX 1200) is utilized for excavating iron ore, while drills are operated using an electrical compressor. Furthermore, battery-operated wheel loaders are deployed for the loading process.

Embracing this transition allows to significantly reduce environmental impact while securing a competitive advantage and demonstrating their commitment to responsible and sustainable mining practices. Earlier, their mining equipment operating on diesel fuel emit approximately 18,000 tonnes of CO2 annually. By transitioning to electric equipment, they anticipate reducing net CO2 emissions by 3,000 tonnes per year.

SURJAGARH IRON ORE MINES, ETAPALLI TEHSIL, GADCHIROLI DISTRICT, MAHARASHTRA

Fig. 7.13:The hauling trucks (SANYE SKT105E) and loading equipment (EX 1200)
Courtesy: Surjagarh Iron Ore Mines, M/s Lloyds Metal & Energy Ltd.

7.3 National Critical Mineral Mission



The Union Cabinet, chaired by the Prime Minister Shri Narendra Modi, has approved the launch of the National Critical Mineral Mission (NCMM) with an expenditure of Rs.16,300 crore and expected investment of Rs.18,000 crore by PSUs, etc on 29 January 2025. As part of the Atmanirbhar Bharat initiative, and recognizing the indispensable role of critical minerals in high-tech industries, clean energy, and defense, the Government of India has undertaken several initiatives over the past two years to address challenges in the critical minerals sector. The National Critical Mineral Mission, approved by the Union Cabinet, will encompass all stages of the value chain, including mineral exploration, mining, beneficiation, processing, and recovery from end-of-life products. The mission will intensify the exploration of critical minerals within the country and in its offshore areas. It aims to create a fast track regulatory approval process for critical mineral mining projects. Additionally, the mission will offer financial incentives for critical mineral exploration and promote the recovery of these minerals from overburden and tailings.

Critical minerals such as copper, lithium, nickel, cobalt and rare earth are essential raw materials required to fuel the growth of rapidly-growing clean energy technologies and their expanding uses ranging from wind turbines and electricity networks to electric vehicles and battery manufacturing.

This Mission will certainly enhance and encourage the green/clean energy utilisation at Indian Mining sector in future.

Conclusion and Future Outlook

1) Minerals are a valuable natural resource being the vital raw material for the core sectors of the economy. Exploration, extraction and management of minerals have to be guided by national goals and perspectives, to be integrated into the overall strategy of the country's economic development. The deployment of modern automated equipment to improve the efficiency, productivity and economics of mining operations and mineral beneficiation processes, in-line with the paras no.s 6.3 to 6.5 and 9.2 to 9.4 of National Mineral Policy 2019.

2) Under the 'Make in India' initiative, the Government of India aims to increase the share of the manufacturing sector in the economy. This national initiative requires a holistic development of the mineral sector on a sustainable basis in order to fulfil the demand of downstream industries dependent on mineral/ ore supply. The mining industry has always been a cornerstone of economic development in India, contributing significantly to the country's industrial growth and employment. The adaption of Automation and Innovative Practices in Mining sector shall achieve the goal of sufficient supply of mineral/ore for demand of industries.

3) The Indian mining sector is advancing towards mechanization and automation on various aspects viz. Drilling and Blasting Technology, Excavation & Loading Machineries, Transportation of Minerals , Survey, digital technologies (like Internet of Things (IoT), Wireless Technologies, Artificial Intelligence (AI), Drone and Cloud Technologies etc), Green Energy innovation with policy/ support by Government initiatives. This work of State of Automation and Innovative Practices in Indian Non-Coal Mining Sector, aims to explore the current landscape of automation in the Indian mining sector, examining both the advancements and the barriers that have shaped its evolution.

4) However, the mining sector faces numerous challenges viz. resistance to adopt new technology, environmental issue, area constrains, connectivity problems, domestic manufactures faces high costs, competition & technology constraints as compare to Global mining equipment etc. Therefore, the development and encouragement of indigenous mining equipment's manufactures is need of hour to overcome the global competition. The following aspects may be observed to be addressed in future.

(a) There is a need for development of mining machinery and technology upgrading compare to global scenario. Interlinking of miners, manufactures, and research/education institutions/organizations for technology upgrading is the need of hour to create open innovation challenge/platforms/startups to evolve solution to problems being faced. It also requires to provide training and skill development programme for the mining stakeholders on the issue.

(b) Thrust for development and upgradation of mining machineries of low to medium capacity (20 to 60 tonnes) beside high capacity with high energy efficiency and lower cost & maintenance machines considering smaller extent of mining lease area, width of ore body and topography of area etc.
(c) Currently, the majority of transportation of ore/minerals is being carried out through road and railway sidings to the end users plants/export. The slurry pipeline system is more appropriate in future, keeping in view the future requirement of increase in ore/mineral production, to reduce the burden & dependency on rail/road transport, to promoting eco-friendly and reduce the transportation cost etc. Hence, there is a need for upgradation, encouragement and development of automated ore/mineral transportation through slurry pipeline system.
(d) Remote operated equipments are safe, smart, sustainable & efficient. The utilization of robotic & automated machines/ technology in mining shall reduce not only accidents but also occupational diseases along with increasing the productivity. These equipments are necessary to reduce manpower and promote safe mining activity as well as reduction in the operation cost. Generally, most of these equipment's/their parts used in the mining and beneficiation are being imported. Imported equipments are costlier as compared to indigenous machineries Hence, Government shall make all possible Incentive / Steps to be taken to augment capacities of indigenous industry as well as appropriate fiscal measures to facilitate import of automated equipment after consultation with the stakeholders. The following steps may be addressed in future for the achievement of the goal.
(i) Promote and Reduce duties on green energy vehicles (electric, hydrogen, solar) and wireless charging for mining equipment for cost effective implementation in mining.
(ii) Re-establish machinery manufacturing hubs and simplify certification processes via the Revised National Capital Goods Policy and Enforce quality control orders to curb low-quality imports.
(iii) Incentivize critical components of manufacturing and develop local capacity for heavy vehicles and Establish performance criteria for mining vehicles and conduct periodic reviews. (iv) Establish testing and rating facilities for mining equipment.
(v) Create SEZs near mining clusters to foster manufacturing ecosystems.
(vi) Enforce quality control measures for imports and develop local alternatives.
(vii) Regularly review mining vehicle performance and ensure adherence to standards.
(viii) To develop a local ecosystem a comprehensive strategy is needed that spans innovative approach in Investment in Research and Development, technology Acquisition, building strong supply chain skill development, and government support for infrastructure improvement.

Annexure-I
Suppliers of Survey instruments (Total Station, DGPS, 3D Scanner)

S. No.	Name of the Company	Address
1	LEICA GEOSYSTEMS	Hexagon Geosystems H.O The Vatika Atrium, 2nd Floor, Tower-B, Golf Course Road, Sector -53, Gurugram-122002, Haryana, India Tel: +91 124 6434501 Mobile: +91-9810893431 Fax: +91 124 4300643 E-mail: info.india@hexagon.com haribansh.babu@hexagon.com Website: http://leica-geosystems.in
2	TOPCON	Gurugram (HO & Service Centre) Unit No 101-106A, 1st Floor, ABW Tower, M G Road Sector 25, IFFCO Chowk, Gurugram, Haryana-122001 Tel: +91-124-4847676 Email :sales_ind@topcon.com
3	SOKKIA	Gurugram (HO & Service Centre) Unit No 101-106A, 1st Floor, ABW Tower, M G Road Sector 25, IFFCO Chowk, Gurugram, Haryana-122001 Tel: +91-124-4847676 Email :sales_ind@topcon.com
4	PENTAX	Lawrence & Mayo Pvt. Ltd. 274, Dr.Dadabhai Naoroji Rd. Mumbai 400001 INDIA Tel: +91 22 22 07 7440 Fax: +91 22 22 07 0048 E-mail: instmum@lawrenceandmayo.co.in Website: www.lawrenceandmayo.co.in

Annexure-II
Suppliers of Drill Machines

S. No.	Name of the Company	Address
1	Atlas Copco (India) Private Ltd.	Atlas Copco (India) Private Ltd. Sveanagar, Dapodi, Pune, INDIA- 411012 Tel: +91 80 2296 3200 , +91 80 2296 3250 Email: info.compressor@atlascopco.com
2	KOMATSU	Komatsu India Private Limited Plot No. A-1, Sipcot Industrial Park & Growth Centre,Panruti Village, Oragadam, Thenneri Post (Via), Sriperumbudur Taluk Kanchipuram Dist, Tamil Nadu - 631 604 Website: www.komatsuindia.in
3	Revathi Equipment Limited	Revathi Equipment Limited Pollachi Road, Malumachampatti Post, Coimbatore – 641050 Tamilnadu, India. Phone : +91 422 665 5100 Email : sales@revathi.in
4	VOLVO Construction Equipments	VOLVO India Pvt. Ltd. 7&8, Phase 1, Peenya Industrial Area, Peenya, Bangalore, India Phone: 080 41291500 Email: function.volvoce.india@tata-bss.com
5	Caterpillar India Pvt. Ltd.	Caterpillar India Pvt. Ltd Pestige Shantinikaten, Tower B, 6th Floor, White Filed, Bengaluru- 560048, Karnataka, India +91-8048976769 www.caterpillar.com

Annexure-III
Suppliers of Electric Equipments

S. No.	Name of the Company	Address
1	Normet India Private Limited	Normet India Private Limited Regus Elegance, 2F Elegance Jasola District Centre, Old Mathura Road, South Delhi- 110025 Phone: +91 141 4737000 Email: india.info@normet.com
2	VOLVO Construction Equipment	VOLVO CE India Pvt. Ltd. 7&8, Phase 1,Peenya Industrial Area, Peenya Bangalore, 560058 Phone: 080-41291711 Email: function.volvoce.india@conneqtcorp.com
3	Propel Industries Pvt. Ltd.	Propel Industries Pvt. Ltd SF.No: 38/1-B, Kangayampalayam,Trichy Road, Sulur. Coimbatore– 641 401,Tamil Nadu, India Phone: +91 99940 60001, +91 99940 60002 E-mail: marketing@propelind.com
4	EPIROC MINING INDIA LIMITED	EPIROC MINING INDIA LIMITED 14th Floor, Tower 1, Fountainhead, Phoenix Market City, Nagar Road, Viman Nagar, Pune - 411 014. Maharashtra, India Phone: +91-72197 22200 Website: www.epiroc.com Email: miningtechnique.india@epiroc.com
5	Atlas Copco (India) Private Ltd	Altas Copco (India) Private Ltd Sveanagar, Dapodi, Pune, Maharashtra, 411012 India. Phone: 1800 120 110030 Email: contactus@atlascopco.com info.compressor@atlascopco.com
6	Revathi Equipment Limited	Revathi Equipment Limited Pollachi Road, Malumachampatti Post, Coimbatore–641050, Tamilnadu, India. Phone : +91 422 665 5100 Email : sales@revathi.in

Annexure-IV
Suppliers of Heavy Earth Moving Machineries

S. No.	Name of the Company	Address
1	BEML Limited	BEML SOUDHA CORPORATE OFFICE, 23/1, 4th Main, SR Nagar, Bangalore - 560 027,Karnataka, INDIA. Tel: +91 80 2296 3200, +91 80 2296 3250 Website: www.bemlindia.in
2	Larsen & Toubro Limited	L&T Construction and Mining Machinery Head Office: Lakshminarayan Complex, First Floor, 10/1, Palace Road, Bangalore -560 052 Tel: (080) 40401700 L&T EQUIPCARE: 1800-833-9990 Website: www.lntcmb.com E-mail: CMB@larsentoubro.com
3	KOMATSU	Komatsu India Private Limited CHENNAI OFFICE (Head Office & Manufacturing Facility) Plot No. A-1, Sipcot Industrial Park & Growth Centre,Panruti Village, Oragadam, Thenneri Post (Via), Sriperumbudur Taluk Kanchipuram Dist, Tamil Nadu - 631 604 www.komatsuindia.in
4	TATA HITACHI	CORPORATE OFFICE TATA HITACHI Construction machinery company Pvt. Ltd. Jubilee Building, 45 Museum Road, Bengaluru – 560 025 Contact: 080-66953301-05/080-67714200/1800 121 6633 Email: info@tatahitachi.co.in
5	VOLVO Construction Equipment	VOLVO CE India Pvt. Ltd. 7&8, Phase 1,Peenya Industrial Area, Peenya Bangalore 560058 Tel: 080-41291500 function.volvoce.india@tata-bss.com
6	Caterpillar India Pvt. Ltd.	Caterpillar India Pvt. Ltd Pestige Shantinikaten, Tower B, 6th Floor, White Filed, Bengaluru- 560048, Karnataka, India Tel: +91-8048976769 www.caterpillar.com
7	EPIROC MINING INDIA LIMITED	EPIROC MINING INDIA LIMITED 14th Floor, Tower 1, Fountainhead, Phoenix Market City, Nagar Road, Viman Nagar,Pune - 411 014. Maharashtra, India +91-72197 22200 www.epiroc.com Email: miningtechnique.india@epiroc.com

Annexure-V

List of authorised explosive manufacturers as per PESO website

Sr.	Manufacturer
1	M/s. AKS Expo-Chem Pvt. Ltd. 524-526, Somdutt Chambers-II, 9, Bhikaji Cama Place, New Delhi-110066
2	M/s. A.P. Explosives Pvt. Ltd. Plot No. 29/B, P&T Colony, Trimulgherry, Secunderabad -500015
3	M/s. AMA Industries Pvt. Ltd., Maimoon Chambers, Gandhibagh, Nagpur – 440032
4	M/s. Amin Explosives Pvt. Ltd., 837, "Amin Chamber", Chitra Talkies Square, Bhaldarpura, Nagpur – 440018
5	M/s. Asian Explosives, 837, "Amin Chamber", Chitra Talkies Square, Bhaldarpura, Nagpur–18
6	M/s. Anjana Explosives Ltd., Plot No.58, Pragathi Nagar, Yousufguda, Hyderabad- 500045
7	M/s. Aravali Explosives & Chemicals, 59/5, Basement, Near 'K' Block, Kalkaji, New Delhi – 110019
8	M/s. Bharatiya Barood Udyog, Sanyal House, Op. to Corpn Park, Gandhi Chowk, Sadar, Nagpur -01
9	M/s. Bharat Explosives Ltd., 9K.M. Lalitpur Jhansi Road, Lalitpur – 284 403. (U.P)
10	M/s. Black Diamond Explosives (P) Ltd., Vill. Napara, PO Barabani, Dist. Burdwan–713334 (WB)
11	M/s. Blastec (India) Pvt. Ltd., 153, Vasant Enclave, Rao Tula Ram Marg, New Delhi – 110 057
12	M/s. C DET Explosive Industries Pvt. Ltd. "Mayapakhar", 79, Shivaji Nagar, Nagpur - 440 010
13	M/s. Deccan Explotech Pvt Ltd., 1216/7, Amrut Chambers, F.C.Road, Shivaji Nagar, Pune –411004 (MS)
14	M/s. Deejay Dynamix Explosives Pvt. Ltd., C-111, Shastri Nagar, Nr. Shyam Mandir, Bhilwara – 311001
15	M/s. Economic Explosives Limited, 11, Zade Layout, Bharat Nagar, Nagpur – 440 033 (MS)
16	Emul Tek Pvt. Ltd., 161, Vasant Enclave, Rao Tularam Marg, New Delhi-110057
17	M/s. Gajraj Chemicals, Bh. Central School, Nehru Nagar, Singrauli, Dist. Sidhi (MP) - 486889
18	M/s. Gauthami Explosives Pvt. Ltd.,Plot No.53, Opp. HP Gas Godown,Rajiv Gandhi Nagar, L.B Nagar, Hyderabad-500074
19	M/s. Gulf Oil Corporation Ltd., Kukatpally, Post Bag No. 1, Sanathnagar (IE), PO, Hyderabad – 500 018 (AP)
20	M/s. Haryana Explosives Pvt. Ltd., D-131, IInd Floor, Mohammadpur, Bh. Bhikaji Cama Place, NewDelhi – 110066
21	M/s. Indian Oil Corporation Ltd., IBP Division, 34 A, Nirmal Chandra Street, Kolkata - 700013
22	M/s. IDEAL Detonators Pvt. Ltd., 1st Floor, Arundeep Complex, Opp. Bhel Enclave, Akbar Road, Tadbund, Secunderabad - 500009
23	M/s. IDEAL Industrial Explosives Ltd., 1st Floor, Arundeep Complex, Opp. Bhel Enclave, Akbar Road, Tadbund, Secunderabad - 500 009 (AP)
24	M/s. IDL Explosives Limited, Kukatpally, Post Bag No. 1, Sanathnagar (IE), PO, Hyderabad – 500 018 (AP)
25	M/s. Indian Explosives Ltd., 10A, Lee Road, Kolkata – 700020
26	M/s. Keltech Energies Ltd. [Formerly Karnataka Explosives Ltd.] Crescent Towers, 6th Floor, No. 32/1-2, Crescent Road, Bangalore – 560001
27	M/s. Mahanadi Metals & Chemicals Pvt. Ltd., Shop No.50, Tarangni Market,Pan Posh Road, Rourkela – 769004
28	M/s. Navbharat Explosives Co. Ltd., Navbharat Udyog Bhavan,Ring Road No.1,Telibandha, Near RTO Office, Raipur– 492006
29	M/s. Navbharat Fuse Co. Ltd., Navbharat Udyog Bhavan, Ring Road No.1, Telibandha, Near RTO Office, Raipur – 492006
30	M/s. Orient Explosives Pvt. Ltd., 04, Jagat Apartment, Ravi Nagar Square, Nagpur – 440033. (Database Name : M/s. Orient Explosives Pvt. Ltd.)
31	M/s. Orient Fuses Pvt. Ltd., #11-12-58/A, Road No.3, S.R>K.Puramm Saroornagar
32	M/s. Orissa Explosives, W-17, Civil Township, Rourkela, Distt. :- Sundergarh (Orissa) 769004
33	M/s. Prasad Explosives & Chemicals, "Prasad Manasion" Ratu Road, Ranchi
34	M/s. Premier Explosives Ltd., 202 & 203, Minerva Complex, 2nd Floor, S.D.Road, Secunderabad – 500 003
35	M/s. Raja Explosives (P) Ltd., No.60, Thangaperumal Street, Erode – 638 001 (TN)
36	M/s. Rajasthan Explosives & Chemicals Ltd., 13, Ist Floor (OPP. Shri Venketeswara College), Satya Niketan, New Delhi – 110021
37	M/s. Regenesis Industries Pvt. Ltd.(Formerly M/s. Vijaya Explosives Pvt.Ltd.) Plot No. 29/B, P&T Colony,Trimulgherry, Secunderabad – 500015
38	M/s. Salvo Explosives & Chemicals Pvt. Ltd., Plot No.21, Gruh Laxmi Colony, Kakaguda, Secunderabad– 9

Sr.	Manufacturer
39	M/s. SBL Energy Limited, 84, Hill Road, Rama Niwas, Flat No. 204, Ramnagar, Nagpur 440010
40	M/s. Shankar Explosives Industries, Prop. Naresh Kumar Gupta, Azad Chowk, Katni– 483501
41	M/s. Singareni Collieries Co. Ltd., Ramagundam-II Area, Centenary Colony
42	M/s. Sivasakthi Industrial Explosives Pvt. Ltd., Meenakshi Illam, 64/11, Udaiyappa Colony, Salem – 636007 (TN)
43	M/s. Solar Industries India Limited, 11, Zade Layout, Bharat Nagar, Nagpur–440033(MS)
44	M/s. Special Blasts Limited,Nathani Building, Shastri Chowk, Raipur-492001

Sr.	Manufacturer
45	M/s. Sri Krishna Explosives & Accessories Company, No.18-1-26/2, II Main, II Floor Dwaraka Nagar, Near Geethanjali Public School Tirupati –517507
46	M/s. Sri Vishnu Explosives Pvt. Ltd., "Sudarshan", # 18, Priya Colony, (Phase1), Near AOC Centre, Secunderabad – 500015 (AP)
47	M/s. Sua Explosives & Accessories Pvt. Ltd., Sua House, No.26/1, Kasturba Cross Road, Bangalore – 560001
48	M/s. Super Shiv Shakti Chemicals Pvt. Ltd.,C-112, Shastri Nagar, Bhilwara, Rajasthan
49	M/s. Tamil Nadu Industrial Explosives Ltd., TEL Post, Vellore - 632 059 (T.N)
50	M/s. Vetrivel Explosives (P) Ltd., 135-A, Kennedy Nagar, Salem – 636005 (TN).