CHAPTER ONE: MINE DEVELOPMENT

INTRODUCTION

- Mining is a process for extraction of any mineral or precisely speaking any ore, which can be defined as the portion of a mineral deposit that can be extracted economically (i.e. profit). Mine is the place where this process is carried out. Before carrying out any mining operation the mine needs to be provided with the basic infrastructure facilities such as water, power, means of transport, communication etc. It needs to be equipped with facilities such office buildings, warehouses, workshops, first aid and rescue stations, basic welfare amenities, mine services; mineral handling, transportation and processing plants. At the mines access to the deposit is the first mining operation. If deposit is to be mined by underground mining, then driving openings/entries, which can be horizontal, inclined and vertical or their combination can access it. Once the deposit is accessed, to exploit it, similar types of mine openings are needed. This network of mining openings, to open and finally extract a deposit, is referred as 'Mine Development'. Development required to access the deposit is often termed as Main Mine Development or Primary Development, and the development work required for the final ore exploitation is termed as Secondary Development or Stope Preparation. Development work can also be classified as Vertical and Horizontal/Inclined development. The task of mine development requires a great amount of skill and experience. It is a difficult task amongst all mining operations, as it is tedious, costly and time consuming. The development is tedious due to the fact that the development openings are often driven through the strata about which no or very little advance information is available. The actual mining of the deposit, now called the ore.

- Access to the deposit must be gained either:

1 By stripping the overburden, which is the soil and/or rock covering the deposit, to expose the near-surface ore for mining or

2 By excavating openings from the surface to access more deeply buried deposits to prepare for underground mining.

- In either case, certain preliminary development work, such as:
  - acquiring water and mineral rights,
  - buying surface lands,
  - arranging for financing,
  - preparing permit applications and

- an environmental impact statement (EIS),

Will generally be required before any development takes place.

When these steps have been achieved, the provision of a number of requirements **- access roads, power sources, mineral transportation systems, mineral processing facilities, waste disposal areas, offices, and other support facilities-** must precede actual mining in most cases.

Stripping of the overburden will then proceed if the minerals are to be mined at the surface.

Economic considerations determine the *stripping ratio, the ratio of waste removed to ore recovered*. Some nonmetallic mines have no overburden to remove; the mineral is simply excavated at the surface.

1.1 Definition of common mining term and unit operation of surface and underground mine

Terminology

Bench: is a ledge which forms a single level of operation where ore and waste are excavated.

Berm: is a horizontal shelf or ledge built in to a sloping wall of an open pit or quarry for protection under level.

High wall: is an unexcavated face or slope of rock between benches.

Overburden: is non-valuable mineral above ore which must be removed to extract the ore.

Pit limit: is the maximum vertical and lateral extent which may be excavated economically in an open pit mine.

Pit slope: is the angle from the horizontal which the wall of a open pit stand as measured from crest or toe.

Spoil: is the overburden or non-ore material removed in gaining access to the ore

Stripping: is the removal of over burden.

Stripping ratio: is the ratio of unite of waste material removed per similar unite of ore material removed.

Toe: is the base of a bank bench or a slope.

Waste dump: is the place where waste material is piled.

Adit: a horizontal or nearly horizontal passage driven into a hill or mountain. It does not go completely through the hill or mountain.

Apex: the upper most terminal edge of the vein on the surface or its nearest point to the surface.

Collar: the support device around the opening or top of the shaft.

Country rock: rock in which the ore deposit is enclosed.

Crosscut: a horizontal opening driven across the course of a vein structure.

Decline: a slight inclined opening which usually start at the surface. It may be traveled by foot or rubber wheeled vehicle.

Draw point: a rock loading station which is at the bottom of a vertical or sub vertical opening.

Drift: a horizontal opening which starts from another horizontal opening such as adit or tunnel.

DUMP: a pile of waste rock from a mine.

Entry: a horizontal opening in a bedded mineral deposit (ex. Coal).

Face: the rock surface which excavation techniques are being performed upon to advance horizontal opening.

Float: loose pieces of ore which have weathered and moved from an outcrop.

Foot wall: the wall rock under a vein or bedded deposit. This applies to non - vertical vein.

Gangue: non valuable minerals which are associated with the valuable mineral. The ore is made up of both of these.

Hanging wall: the wall rock on the upper side of an inclined vein or bedded deposit.

Head frame: a structure above a shaft used to house cable guiding systems and rock transferring systems.

Level: all of the horizontal opening which connect to the shaft at a specific point.

Outcrop: the part of the mineral deposit which intercept the surface.

Pillar: a mass of ore or waste not excavated for the purpose of the ground support.

Portal: the supporting structure at the entry point of tunneling, adit and decline.

Raise: a vertical or inclined opening drive up ward from a level or other opening.

Ramp: an inclined rubber wheeled access opening between horizontal openings at different elevation.

Shaft: a vertical or steeply inclined excavation extending downward from the surface.

Shoot: a device for loading ore and waste rock in to the haulage device from the vertical opening.

Stope: an underground opening from which ore has been excavated.

Sub-Level: a set of the horizontal opening immediately above the main horizontal access opening.

Sump: an exaction for the purpose of collecting water so that it may be transferred to a pump. This often the bottom most portion of shaft.

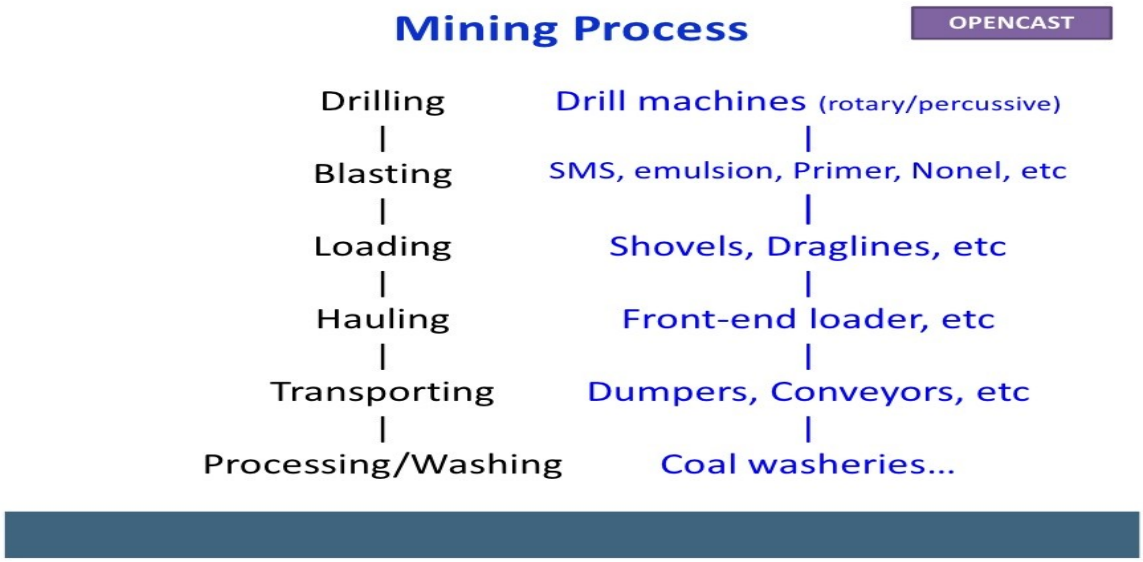
Tailing: any material that has been through a mineral processing plant and has been rejected as a waste.

Tunnel: a horizontal or nearly horizontal opening which intercept the surface at two points.

Vein: a mineralized zone having a tabular form. Its depth and length are much greater than its width. Often the zone is steeply dipping.Waste: the barren rock in a mine which is to low grade to be economic value.

Winze: a vertical or sub-vertical opening that is driven downward from the horizontal opening.

Overview of unit operation surface and underground mines:



CHAPTER TWO:

OPEN UP OF DEPOSIT

A deposit to be mined by underground methods can be accessed by any of the following types of mine openings or their combination:

Adits: can be driven across or along the strike direction of the deposit. Incline can be driven in the overlying strata of a flatly dipping shallow deposit.

An inclined: deposit of low thickness commencing from a shallow depth can be accessed by an incline driven from surface and passing through the deposit itself. Multiple seams can be accessed by an incline driven in the foot wall most (bottom most) seam and connecting it by the cross measure drift.

Decline/Ramp: can also be driven to join different horizons in underground mines. Shallow flatly dipping deposit or steeply dipping deposits extending from shallow depth to a considerable depth can be accessed, at the earliest by declines. Decline ramp are typically developed with gradients between 10 per cent and 15per cent. Ramp systems are less commonly used in South Africa but are commonly used in Australia, where over two-thirds of underground mines are accessed through decline/ramp systems. Declines allow the movement of equipment from one level to another without the need for disassembling, transporting, and reconstructing the equipment, which is often required in a vertical shaft system. Declines must provide adequate turning radius for the largest piece of equipment.

Advantages of decline systems are the low cost of development, ease of access for equipment, and the short period to commencing mining operations. Disadvantages included low vertical development rates, increased ventilation requirements due to the use of diesel equipment, and increase in labour to support truck operations.

Two basic methods are used to transport ore from the decline system, namely truck haulage or belt conveyor. Truck haulage is suitable for tonnages up to 3000 t/d, while belt conveyors are advocated for large-tonnage operations. Figure 3 demonstrates the user of a decline ramp system and adit.

Shaft: serves deeper levels, which could be tracked or trackless. For steeply inclined, almost vertical or deep-seated flat deposits access by a vertical shaft is an obvious choice. If shaft is allowed to pass through the deposit.

Vertical shaft: Shafts are vertical excavations sunk in a position so as to access the ore body as effectively as possible, with the size of the shaft excavation generally being determined by the production and ventilation requirements.

Depending on a variety of considerations, vertical shafts are typically sunk when ore bodies extend deeper than 250 m to 500 m, as shafts then become more economic than a decline ramp system. Shafts are usually placed such that horizontal distances to the ore body are minimized while still allowing for a shaft pillar. Shafts vary in shape and dimension, but are typically circular or elliptical, depending on geotechnical and environmental considerations.

The advantages of shafts are that they support high production rates, and are efficient for the transportation of personnel, material, and rock.

Disadvantages include the high initial capital expenditure, long lead time to production, and difficulty in transporting large equipment.

Incline shafts

Mining engineers in South Africa quickly realized the benefits of sinking incline shafts on the Witwatersrand, as vertical shafts require considerable lateral development to gain access to the ore body. Incline shafts offered quick access to the ore body and minimized development and capital expenditure, resulting in great savings of time and cost.

The benefits of incline shafts over vertical shafts are summarized as:

- Less development required to access the ore body
- Development kept close to the ore body
- Smaller requirements for shaft headgear and winder installation
- Incline shafts are cheaper to sink than vertical shafts.

Despite these advantages, incline shafts are regarded as labour-intensive, and operationally not as efficient as a vertical shaft. One of the biggest negatives regarding incline shafts is the inability to easily clean broken rock when shaft-sinking and the propensity for tracked equipment to suffer derailments. The evaluation of alternative methods of accessing the ore body is one of the first steps of developing a mine plan.

The selection of the proper size, configuration, arrangement and type of opening required to develop a new underground ore body or expand an existing mine is a complex and often difficult engineering problem. Each deposit has it own characteristics and requirements and requires an accurate evaluation of all factors that may affect the mine design to access the ore body.

The basic design parameters that should be considered are as follows:

- Lowest capital expenditure
- Lowest operating cost
- Safe and reliable operating system
- Flexible and efficient system
- Supports the mine planning
- Provides fast access to the ore body to promote early cash flow.

Some of the design criteria that need to be considered are:

Geology and mineral resources

Hydrology

Depth of ore body

Flexibility for changes to mine plan, mining method, or expansion of project

Production tonnage requirements

Geotechnical inputs

Ventilation requirements

Capital and operating costs

Schedule completion i.e. commencement of cash flow

Availability of skills and labour requirements

Safety

Productivity and management of system.

SYSTEM – OPENING UP A DEPOSIT

Mainly the following two approaches are used to mine-out a deposit with the application of underground methods.

1 OPENING DEPOSIT IN PARTS

In this approach the initial part of the deposit or whatever portion that have been explored, is opened by driving shaft at one or two level intervals. First

the levels are developed and stoping process proceeds thereafter. Simultaneously the shaft is sunk through the deeper horizons. This approach is suitable if the deposit is not fully explored and the exploration activity is to be kept as an on-going process along with the stoping at the upper levels. It is practicable if the life of a level exceeds five years or so, which means, if the ore bodies have wider extension along and across their strike direction.

2 OPENING UP THE WHOLE DEPOSIT

In this approach the shaft is sunk through the whole deposit, intersecting or passing through all the levels planned. This may take several years. To exploit the deposit at an early stage, the deposit is often accessed by other modes of entries such as adit, incline, decline or their combination so that development, stope preparation, and stoping activities can be carried out to exploit or mine-out its shallow seated portion. This approach lowers the expenses on sinking by 30–35% and avoids the process of shaft deepening. In this approach several development workings can be driven simultaneously at several horizons/levels. Shaft stations (including shaft insets) are made during shaft sinking to avoid damage to its lining and delays. The cross entries (connection) between intake and return or production or service shaft are not made at each of the levels but at an interval of two or three (sometimes even more) level's interval to reduce the costs. At the main haulage level which usually, is the pit bottom, together with cross entries (cross cuts) to join the two shafts, chambers/excavations are made for providing facilities such as first aid, firefighting, electric sub-station, sumps fitted with pumps, garage, repair shops, battery charging station etc. Ore bins, crusher chambers, loading pockets etc. are the important structures, which are driven and equipped with necessary equipment and fittings. Provision is made to deliver material (ore, waste or supplies) and movement of the man, machine, equipment and mine services, between levels by driving/connecting them through ore passes, waste passes, raises, winzes, inclines or ramps.

Why do we support mines?

Keeping miners' safe (safety factor).
Ensure continuity of ore production to avoid shortage in profit.
Finally, keeping expensive machines in the underground mines safe (e.g. machines used in long wall mining).

When do we need to support mines?
If there are weak or unconsolidated parts of rocks are present in the roof and walls of mines.
If there some geologic structures (e.g. shear zone) that weaken rocks.
If there are voids and spaces in the rocks.

If there are some clay beds that can shrink and expand due to its swelling property, and hence sliding of rocks in presence of water can be expected.
If there is underground water that helps in chemical weathering leading to loose rocks and corrosion of machines.

Types of mine support:

Wooden logs support: Wood logs (trunks) should be straight and about 4-6 m long. Evergreen trees are recommended (e.g. pine trees). Iron wedges must be used to fix the wooden logs.

Support using metal rods: Simply, it is a metal rod consists of two cylinders of different diameters. Length can be controlled using pins and moving upward & downward.

Support using metal pins or roof bolts: Usually used for ceilings only. A 1-1.5 m hole is needed, with 1.4 cm diameter. Bolts and pins must have ribs for good support.

Support using metal fence/ net: Usually used for ceilings only, especially in case of rock fall.
Metal pins are needed to fix the metal fence. Can be used for walls also but if clay beds are missed.

Concrete support and using brick walls: Usually used for walls with clay beds, or when the bedrock is friable and brittle. Concrete can bear more stress than bricks.

Resin support: Usually used for friable and porous ceilings and walls. An organic stuff (polymers) is used for injection.
Factors controlling choice of suitable type of mine support:

- Availability of support material in the local market & costs of support materials (even those
  imported from abroad).
- Distance to brick, cement and steel factories.
- Nature of problem (to be solved) in the mine.
- Durability of the mine.

Surface PLANT SITE SELECTION

Selecting the optimum plant site location is an iterative process that requires the reduction of various geographic, technical, business, legal, and political considerations to economic terms. Once the lowest-cost location has been identified, then the incremental cost of alternative locations that are desirable for various technical, business, or political reasons can be

determined. One starts this process by assembling all of the known information concerning the project and general plant location.

This information would include such items as the following:

- Geographic Considerations

1. Topographic maps
2. Plan metric maps

- Technical Considerations

1. Geologic maps 2. Ground stability
3. Mine(s) location(s) 4. Water sources
5. Utility sources 6. Transportation systems
7. Climate data 8. Plant specifications
9. Refuse disposal requirements

- Business Considerations

1. Competitive environment 2. Royalties
3. Tax laws 4. Materials availability
5. Contractor availability 6. Labor pool
7. Housing availability 8. Medical care availability

- Legal Considerations

1. Property ownership 2. Surface rights
3. Regulatory requirements 4. Statutory requirements
5. Contractual requirements

- Political Considerations

1. Development incentives

2. Environmental limitations

a. Air b. Water c. Noise

d. Subsidence e. Aesthetics

3. Employment rates

4. Business posture

As a general rule, it is most economical to have the plant located as close to the mine(s) as possible. This is especially true when run-of-mine material requires a high degree of concentration as transportation costs are normally reduced then.

Chapter three:

Shaft sinking operation

Considering the Geological, Geo-environment and other related geoengineering information, underground mining have been selected there to extract the deposit. Our concern is about shaft sinking method for underground mining. Depths of the coal seams reveal the necessity of a vertical shaft underground which again needs deep excavation. The problem arises with the excavation because of nearly 138m thick Dupitila Sandstone Formation just 6m below the surface in the area. It is loose, water bearing, containing dominantly porous and permeable sandstone and experiences massive water flow. So, the major concern is that any excavation through this will readily collapse and suffer massive water inrush. This will totally disturb the whole mining work progression and cause economic loss as well. By analyzing the ground condition of the Khalashpir cola field, artificial ground freezing has been identified most appropriate as shaft sinking method to control the ground water and to stabilize the loose soil during excavation. Lawfulness of the method and reason of neglecting other two common shaft sinking methods has been pointed out.

Hydrgeological conditions of these units have been collected from pumping test results conducted in the borehole. By analyzing this information, we have discussed the feasibility of the freezing method over another two very common methods to serve the purpose of the shaft sinking in the coal mine. Overcoming the early stages, areas such as professional research, equipments, technology, and academy, construction level have witnessed rapid development. Its essential function is the solidifying, by freezing, of water bearing ground in which the shaft is sunk. It is also sometimes conducted into water bearing rock. Apart from protecting excavations ground freezing serves the purpose of stabilizing slips, sampling weak ground, constructing temporary access roads and maintaining permafrost below overhead pipeline foundations and below heated buildings.
The method is not limited by soil types and can form nearly all shapes frozen wall at any depth under any complex geologic and hydrogeologic conditions. The preliminary objective is to remove hit from the ground below freezing point to form a vertical ice wall around the perimeter of the shaft prior to excavation. For this, freezing boreholes are drilled around the perimeter of the shaft and freezing pipes are installed within the boreholes. Depending upon the size and shape of the excavation freezing boreholes are configured.

The AGF is carried out in four stages, each of which is subjected to detailed monitoring:
1. Refrigeration plant and coolant distribution system installation
2. Construct ice wall by refrigeration
3. Maintenance refrigeration to allow excavation and installation of the permanent lining
4. Thawing of the frozen ground

HEADING CAISSON SINKING AND DEWATERING METHOD FOR SHAFT SINKING

Two very common methods for shaft sinking are caisson sinking and ground water lowering or dewatering.

1.1 Caisson Sinking: Caisson sinking requires the construction on the surface of the complete structure, ready for sinking into the ground. The method relies on relatively uniform, weak soil through which the caisson can penetrate by cutting and displacement of the soil until the target depth reached. A change of soil density can lead to frustration, while the

random presence of hard obstruction (boulders) can deflect the caisson from the vertical, remobilizing a stood caisson is time consuming and costly.

Ground Water Lowering or Dewatering: In a large open site where it is not necessary to limit the extent of the excavation during the construction stage, a low cost option is ‘dewatering’, i.e. depression of the water table, by pumping, to a level below that of the intended excavation. This may be achieved by a series of well points inserted, usually be jetting techniques at relatively close spacing (approximately 1m) around the perimeter of the area.

Sinking in difficult and water bearing gound

Loose, porous and permeable, low strength sand of Dupitila Formation which again suffers massive water inflow because of high conductivity. These will lead to following soilstructure interaction problems to any excavation at that ground:

- ✓ Massive water inrush into the hole
- ✓ Collapse of the structure due to lose nature of soil

The geological setting of the coal basin in Khalashpir is characterized by loose unconsolidated strata from surface to about 138m below the ground level. In some places it extends further below. Under these conditions it is impossible to sink a shaft through conventional method of drilling and blasting.

Shaft pre-sink activities

1. Initial Site Works

Initial site work includes levelling the site, establishing roadways, installation of boundary fencing, digging trenches for site services, associated buildings and amenities.

The initial site setup comprises of a number of tasks. These are often carried out by different contractors and can occur in parallel.

2. Collar Establishment

The shaft collar is the uppermost portion of the shaft. It typically extends from ground surface level down to solid bedrock, into which the collar is anchored. It should be designed to provide a protective barrier to prevent water and soil from entering the shaft.

The collar also provides a rigid support around the shaft to protect it from external loading conditions caused by both the headframe, which is constructed on top of the shaft, and horizontal stresses resulting from nearby structures such as a winder house. Generally there are two methods used, and each method has its own hazards and risks that should be managed and controlled.



3. Pre-Sink Beyond the Collar

This is the start of the actual shaft sinking activities. The aim is to sink the shaft to a depth where it is possible to install the shaft sinking stage. There should also be enough room for firing to take place in the shaft without damaging the shaft sinking stage. It is carried out utilising a slewing crane or slewing headframe, kibble and a mucking system using traditional shaft sinking cycles such as:

- Drill & blast
- Muck out spoil
- Install ground support
- Concrete line
- Install and extend shaft services: e.g. air, water, and ventilation ducting

Main sink setup – Installation

1. Installation of Winders and Winder House

This involves the installation of the winder including associated control systems, mechanical, electrical and hydraulic components. This activity normally occurs at the same time as the pre-sink and introduces additional personnel to the shaft surface working environment.

2. Installation of Shaft Sinking Headframe

The construction of the headframe occurs after the pre-sink is complete, the headframe can either be solely for the shaft sink or it could the permanent headframe that will be used for construction then production.

3. Shaft Collar Door Installation

Collar doors seal the shaft entrance at the shaft collar to provide safe access to the main winding conveyance when it is on the surface. They also provide overhead protection to personnel working within the shaft when the kibble is being tipped on the surface or when other activities are being conducted at the shaft collar.

Where hinged doors are used, when in the open position, the doors should form a barrier to the open shaft preventing personnel or equipment accessing the shaft.

Shaft lining and support

1. **Installation of Ground Support**

By its very nature as shaft construction progresses, a large variety of ground conditions and rock types are encountered. As the construction of the shaft progresses, geotechnical assessments must (44) be carried out to ensure that the ground support is effective. The purpose of ground support is to secure the ground and control the risk of personnel being struck by falling rocks.

2. **Shotcrete**

There are two types of shotcrete application – wet mix and dry mix. Each method has its particular use to assist with rock support. Shotcrete is a concrete placing process where concrete mixtures are conveyed through a hose then pneumatically projected at high velocity onto a surface to achieve high quality in-place compaction. It produces high-quality dense concrete, with a low water-cement mix (w/cm) ratio, low permeability, and a high cementitious material content.

With new technology available there are remote control spraying methods or hand spraying systems available, using wet or dry fibre reinforced mixes.

3. **Concrete Lining – Slip Formwork (kerb ring & shutters)**

The slip formwork method of shaft lining can be used to line a shaft of any depth and is generally carried out from the top down and is advanced with the shaft sink.

This method of shaft lining also allows temporary or permanent anchor points for shaft services and infrastructure (air/water/power/conveyance guides) to be installed with the concrete pour. These anchor points are commonly referred to as concrete ferrules or ‘nut boxes’. Slip formwork comes in two main pieces - a ‘kerb ring’ and ‘sliding shutters’.

The kerb ring is used to position and anchor the sliding shutters as well as to form the base/floor of the intended concrete pour. The sliding shutters are curved sections of formwork that are assembled on top of the kerb ring to make up the formwork for the concrete lining.

The sliding shutters can be up to 6 metres long and are normally able to be split into shorter segments known as rings. This allows for shorter concrete pours in the event bad ground conditions are encountered.
In preparation for a concrete pour the kerb ring is lowered with chain blocks beyond the existing concrete to the desired level. It is positioned, aligned and locked using screw jacks, wedges and hanging rods. Once positioned, scribing bars are inserted in the kerb ring allowing the voids and gaps to be closed with timber, plastic and sandbags to contain the next concrete pour.
Once the kerb ring is set, the sliding shutters are lowered and connected to the kerb ring using chain blocks. The work of moving, positioning and securing the kerb ring and sliding shutters is conducted from the stage conveyance and shaft floor.

4. Concrete Delivery Systems

4.1 Concrete Slick-line

The concrete slick-line system consists of a surface hopper, a steel pipe column in the shaft, concrete kettle (remixer) at the bottom of the pipe column and a flexible delivery hose or hoses attached to the concrete kettle. Concrete is discharged into the surface hopper from an agitator truck. This method can be used for delivery of concrete to any shaft depth. It is also independent of the winding system.

4.2 Concrete Kibble and Octopus System

This method of concrete delivery can be used for any shaft depth. The delivery of concrete is limited by the capacity and speed of the winding system, the size of the kibble and the depth of the shaft.
It utilises a purpose built concrete kibble to transport the concrete from the surface to the shaft bottom, where an ‘octopus’ at shaft bottom distributes the concrete evenly into the formwork. The concrete kibble is designed to carry and discharge wet mix concrete and is attached to the main winding system. The octopus is basically a funnel with multiple discharge hoses.
In preparation for a concrete pour the octopus is lowered down the shaft and locked into position (chaired) in the kibble well of the stage. During filling, the kibble sits on the collar doors to enable a concrete agitator truck to discharge into it.
Once filled the concrete kibble is lowered down the shaft to an overhang mark above the stage position. From there the kibble is lowered under the direction of personnel on the stage to the position where the concrete can be discharged into the octopus.

Installation of shaft services

The shaft services installation can be described as:
• temporary services installed for the purpose of constructing the shaft and removed when construction is complete

• permanent services installed during or after shaft construction.

Temporary services could include the following:
• Compressed air
• Water
• Power cables
• Communication cables
• Mains firing lines
• Concrete slickline
• Water pump lines
• Ventilation ducting
• Plumb-bob lines
• Wall brackets

Permanent shaft services are dependent on the purpose of the shaft and could include the following items:
• pump discharge pipe column
• power cables
• communication / Leaky-Feeder cables
• water lines
• water rings
• concrete slickline.

Equipping the shaft
When shaft construction is completed, depending on the intended purpose of the shaft, additional steelwork and infrastructure may need to be installed. This can include:
• pentice
• rope change out platform
• loading station flasks
• steel guides, bunton beams
• ladders and access platforms

Whilst the shaft construction work itself is generally unde rtaken by a single contractor, shaft equipping can involve a number of contractors or groups working at various locations within and around the shaft.

Chapter four

Main haulage drift and tunnel:

Haulage - The horizontal transport of ore, coal, supplies, and waste. The vertical transport of the same is called hoisting.

Drift - A horizontal passage underground. A drift follows the vein, as distinguished from a crosscut that intersects it, or a level or gallery, which may do either.

Tunnel - A horizontal, or near-horizontal, underground passage, entry, or haulage way, that is open to the surface at both ends. A tunnel (as opposed to an adit) must pass completely through a hill or mountain.

Mine haulage drifts are the arteries of any mine, as they are used to transport the valuable ore out of the mining zones as well as to move operators and equipment. Hence, their stability is crucial in underground mines. Drift instability could lead to serious consequences such as injuries, production delays and higher operational cost. Haulage drift safety and probabilistic methods are used to assess drift unsatisfactory performance. Criteria used to define drift unsatisfactory conditions are: extent of yielding, and brittle shear failure.



Ventilation - The provision of a directed flow of fresh and return air along all underground roadways, traveling roads, workings, and service parts.

Ventilation is the control of air movement, its amount, and direction. Although it contributes nothing directly to the production phase of an operation, the lack of proper ventilation often will cause lower worker efficiency and decreased productivity, increased accident rates, and absenteeism.

Air is necessary not only for breathing but also to disperse chemical and physical contaminants (gases, dusts, heat, and humidity). Mine fans can be installed on the intake airshaft, return airshafts, or both, either on the surface or underground.

Advance ventilation planning involves the consideration of two principal factors:

- ✓ The total volume flow rate of air required by the mine, and its satisfactory and economic distribution, and
- ✓ The pressure required by the mine fan(s).

A well designed ventilation system should be: effective, flexible, and economical.

Ventilation may be effected in various ways

- ✓ Natural ventilation
- ✓ Furnace ventilation
- ✓ Fan ventilation

A full range of tunnelling drill rigs from Atlas Copco, one of the manufacturers, for hole diameter 38 - 64 mm

– One-boom rigs 6 - 70 m^2 □ 120 drill meter / hour

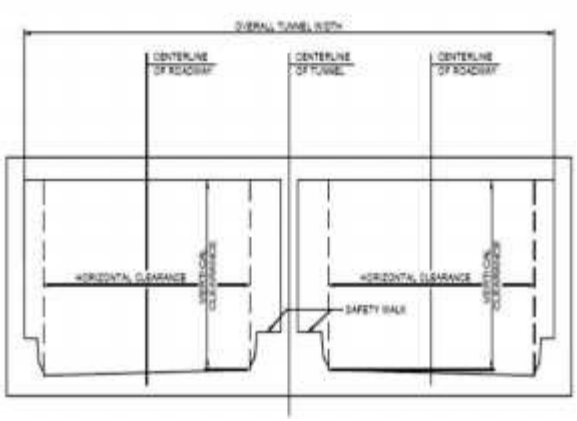
– Two-boom rigs 8 - 112 m^2 □ 210 drill meter / hour

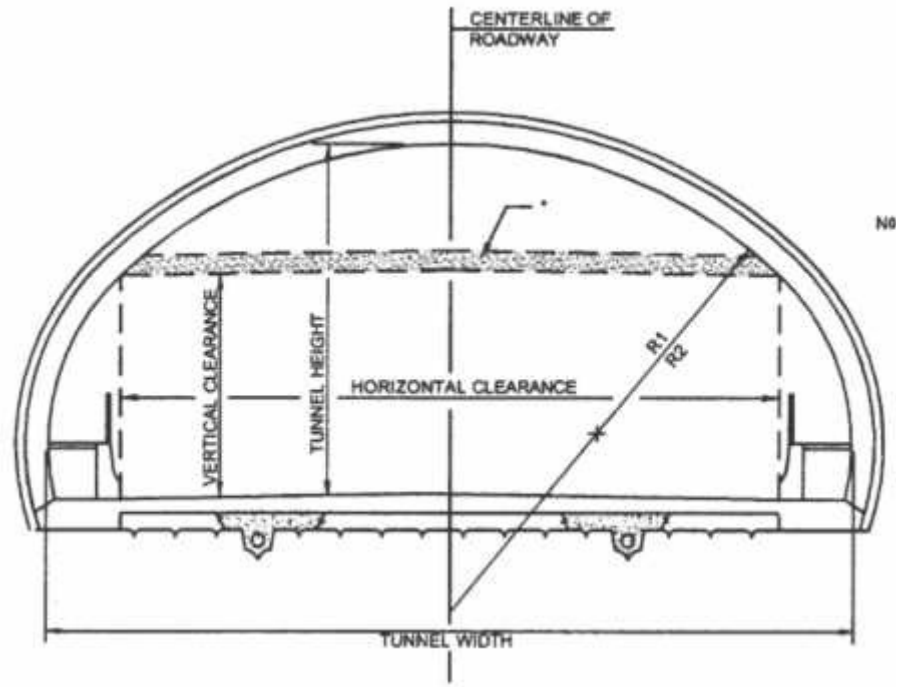
– Three-boom rigs 20 - 206 m^2 □ 310 drill meter / hour

– Four-boom rig 20 - 153 m^2 □ 400 drill meter / hour

Purpose, shape, size and location of tunneling

There are three main shapes of highway tunnels – circular, rectangular, and horseshoe or curvilinear. The shape of the tunnel is largely dependent on the method used to construct the tunnel and on the ground conditions.


CENTERLINE OF ROADWAY
CENTERLINE OF TUNNEL
CENTERLINE OF ROADWAY
HORIZONTAL CLEARANCE
VERTICAL CLEARANCE
HORIZONTAL CLEARANCE
VERTICAL CLEARANCE
SAFETY WALK


CENTERLINE OF ROADWAY
VERTICAL CLEARANCE
TUNNEL HEIGHT
HORIZONTAL CLEARANCE
R1
R2
TUNNEL WIDTH

Tunnel boring machine (TBM)

The complex set of equipment assembles to excavate a tunnel. TBM also called pole. The opening of the tunnel is portal.
The tunnel boring machine including:

- Cutter head with cutting tool and muck bucket
- System to supply power
- Cutter head rotation

Advantage of TBM

- High advance rate
- Continious operation
- Less rock damage
- Greater worker safety
- Remote and automation operation

Disadvantage of TBM

- Fixed circulare geometry
- Limit flexiable response of geologic condition
- Long mobilization time
- High capital cost

THE PROCESS FOR BORED TUNNELLING INVOLVES ALL OR SOME OF THE FOLLOWING OPERATIONS:

- Probe drilling (when needed)
- Grouting (when needed)
- Excavation (or blasting)
- Supporting
- Transportation of muck
- Lining or coating/sealing
- Draining
- Ventilation

PROBE DRILLING

- This type of drilling is done in order to find out suitable method for drilling .
- It consist of drilling in sample, by various method to find most suitable .
- It is necessary part of all drilling operation .

GROUTING

- It is the process of providing additional support to drilled mine.
- It is done by a liquid called grout ,consist of water ,cement ,color tint and sometime fine gravel .
- Good surface is achieved .

EXCAVATION

- Excavation is the digging and recording of artifacts at an archaeological site.
- It is necessary to know the archaeological importance of a site before digging .
- This is performed by experts in a scientific way.
- Many governments grants permission for tunneling after finding a go certificate in excavation.

SUPPORTING

- After initial mining , tunnel need supports for further processing .
- For the sake of life a perfect planning is needed for support.
- In ancient time timber and masonry were the main methods.
- Today support is provided by injecting final pipe or building it completely before further tunneling

TRANSPORTATION OF MUCK

- In ancient time transportation was done by steam engine and by Manual transport.
- Today it is done by modern methods and process is automatic .
- TBMs are also come with proper arrangment for the transport of muck.

LINING OR COATING

- Lining of proper material is done by modern methods like polishing ,painting to prevent wear and tear and corrosion.
- Very necessary part where corrosive metals are being used.

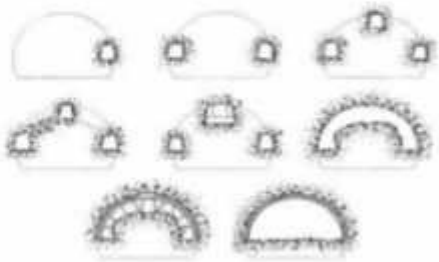
VENTILATION

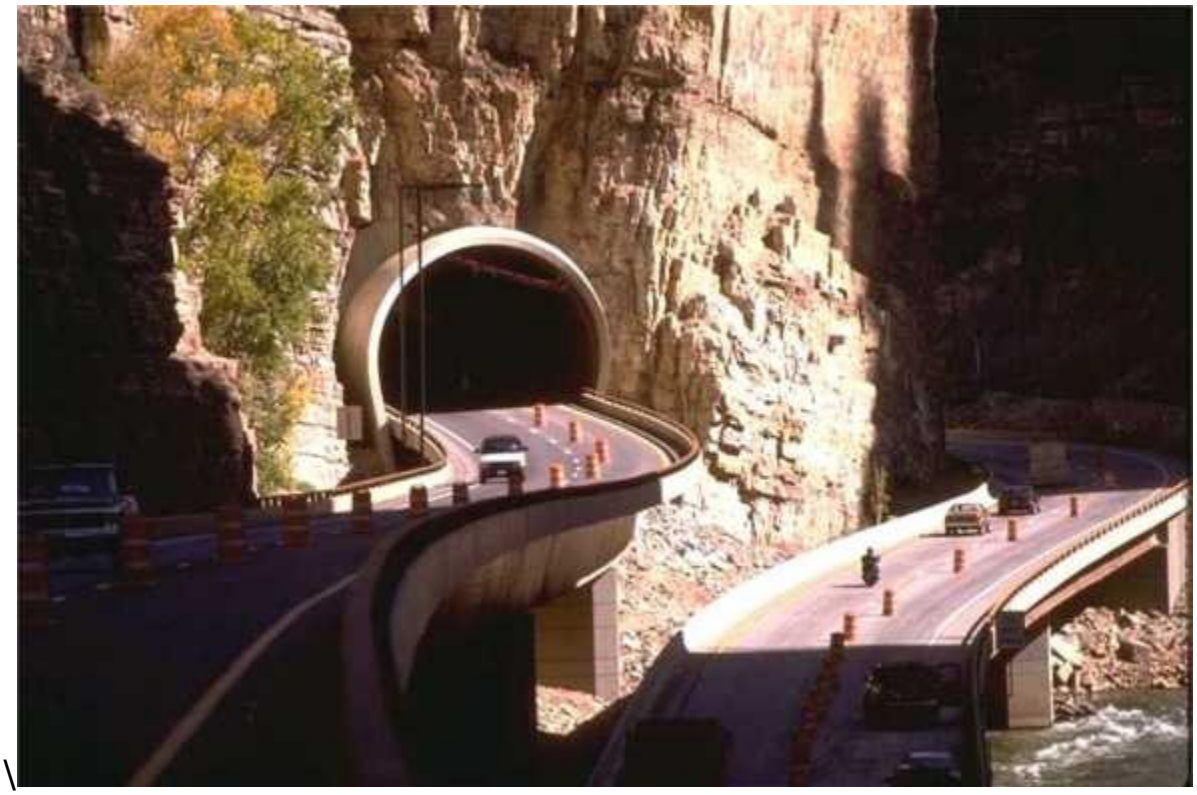
- Proper ventilation is required for safety of workers.
- This is done by proper checking of oxygen and other parameters .
- Proper installations for exit of hazardous gasses coming out from tunneling .

DRAINING

- Draining is the process to remove the water or other liquid from working site .
- Very important where water level is very high.
- Pumps and pipes are used for this purpose.

HOW DRILL AND BLAST IS BEING DONE.



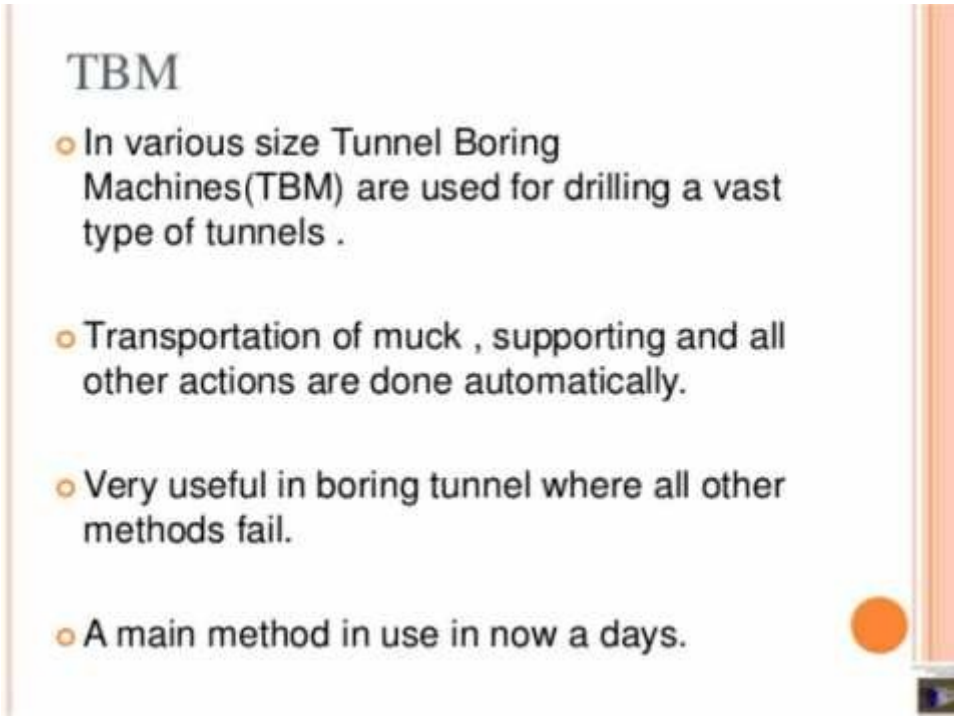


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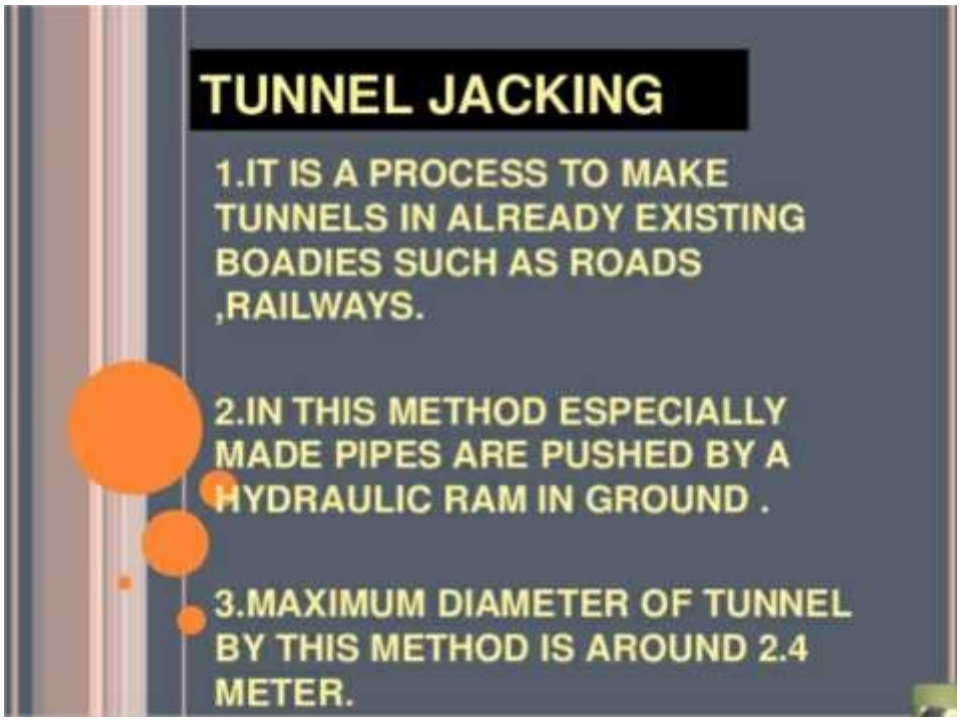
THE CHOICE OF TUNNELLING METHOD MAY BE DICTATED BY:

- geological and hydrological conditions,
- cross-section and length of continuous tunnel,
- local experience and time/cost considerations (what is the value of time in the project),
- limits of surface disturbance, and many others factors.
- Tunnel methods .
- Required speed of construction.
- Shape of tunnel.
- Managing the risk of variations in ground quality

Tunnel construction method







Cut and Cover Tunnelling

Cut and cover tunnelling is a common and well-proven technique for constructing shallow tunnels. The method can accommodate changes in tunnel width and non- uniform shapes and is often adopted in construction of stations. Several overlapping works are required to be carried out in using this tunneling method. Trench excavation, tunnel construction and soil covering of excavated tunnels are three major integral parts of the tunneling method.
Most of these works are similar to other road construction except that the excavation levels involved are deeper. Bulk excavation is often undertaken under a road deck to minimize traffic disruption as well as environmental impacts in terms of dust and noise emissions and visual impact.

Drill and Blast

This tunnelling method involves the use of explosives. Drilling rigs are used to bore blast holes on the proposed tunnel surface to a designated depth for blasting. Explosives and timed detonators are then placed in the blast holes. Once blasting is carried out, waste rocks and soils are transported out of the tunnel before further blasting. Most tunnelling construction in rock involves ground that is somewhere between two extreme conditions of hard rock and soft ground. Hence adequate

structural support measures are required when adopting this method for tunnelling. Compared with bored tunnelling by Tunnel Boring Machine, blasting generally results in higher but lesser duration of vibration levels. A temporary magazine site is often needed for overnight storage of explosives.

Bored Tunnelling

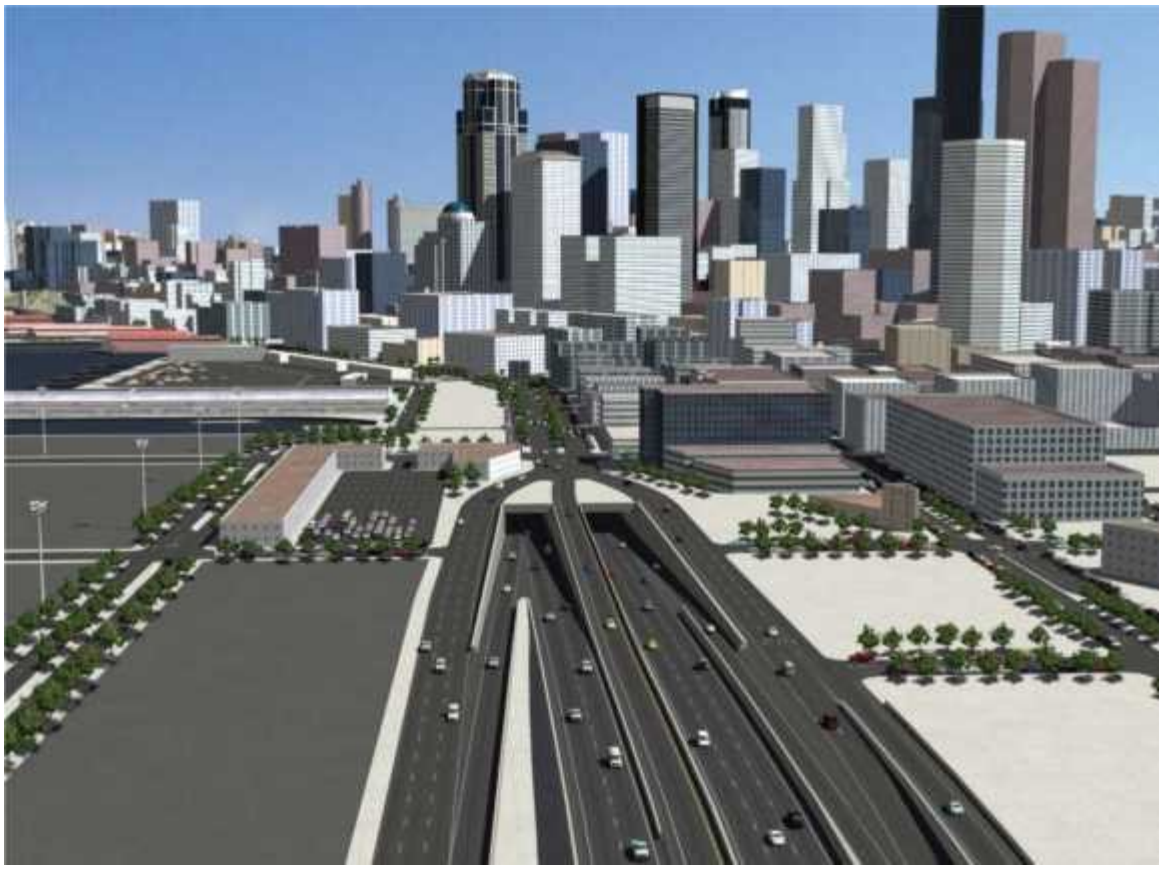
Bored tunnelling by using a Tunnel Boring Machine (TBM) is often used for excavating long tunnels. An effective TMB method requires the selection of appropriate equipment for different rock mass and geological conditions. The TBM may be suitable for excavating tunnels which contain competent rocks that can provide adequate geological stability for boring a long section tunnel without structural support.
However, extremely hard rock can cause significant wear of the TBM rock cutter and may slow down the progress of the tunneling works to the point where TBM becomes inefficient and uneconomical and may take longer time than the drill-and-blast tunneling method.

Sequential Excavation Method

This method is also known as the New Austrian Tunneling Method (NATM). The excavation location of a proposed tunnel is divided into segments first. The segments are then mined sequentially with supports.
Some mining equipment such as road headers and backhoes are commonly used for the tunnel excavation. The ground for excavation must be fully dry for applying the NATM and ground dewatering is also an essential process before the excavation. Another process relates to the ground modifications such as grouting, and ground freezing is also common with this method in order to stabilize the soil for tunneling. This method is relatively slow but is found useful in areas where existing structures such as sewer or subway could not be relocated.

Purpose of tunneling

1. Transportation of People
2. Conveyance of Materials
3. Utility Corridors
4. Disposal of Waste
5. Military Defense



Chapter five: Surface mine development

Surface mining is the predominant exploitation method worldwide. Surface mining includes mechanical excavation methods such as open pit and open cast and aqueous excavation methods such as placer and solution mining. Surface mining is used when deposits of commercially useful minerals or rock are found near the surface; that is, where the overburden is relatively thin or the material of interest is structurally unsuitable for tunneling (as would usually be the case for sand, and grave. Is a type of mining in which soil and rock overlying the mineral deposit (the overburden) are removed to extract the economic minerals? In most forms of surface mining, heavy equipment, such as earthmovers, first removes the overburden. Next, huge machines, such as dragline excavators or Bucket wheel excavators, extract the mineral. HOW?

Surface mines are typically enlarged until either the mineral deposit is exhausted, or the cost of removing larger volumes of overburden makes further mining no longer economically viable.

Surface mining enable to start production faster than UG though there is difference among surface mining methods.

- Site preparation: Initial box-cuts, Ramps/Roads, Benches in waste rock
- Development for surface mining of coal and other bedded minerals involves the removing of cover layers of soil and rock to expose the coal.
- When an ore body is steeply dipping and at or near the surface, open-pit mining can start with a small amount of stripping.
- Pre-stripping waste volume and the time it takes varies depending on the deposit.
- The time required for pre-stripping can range from 2 to 6 years.

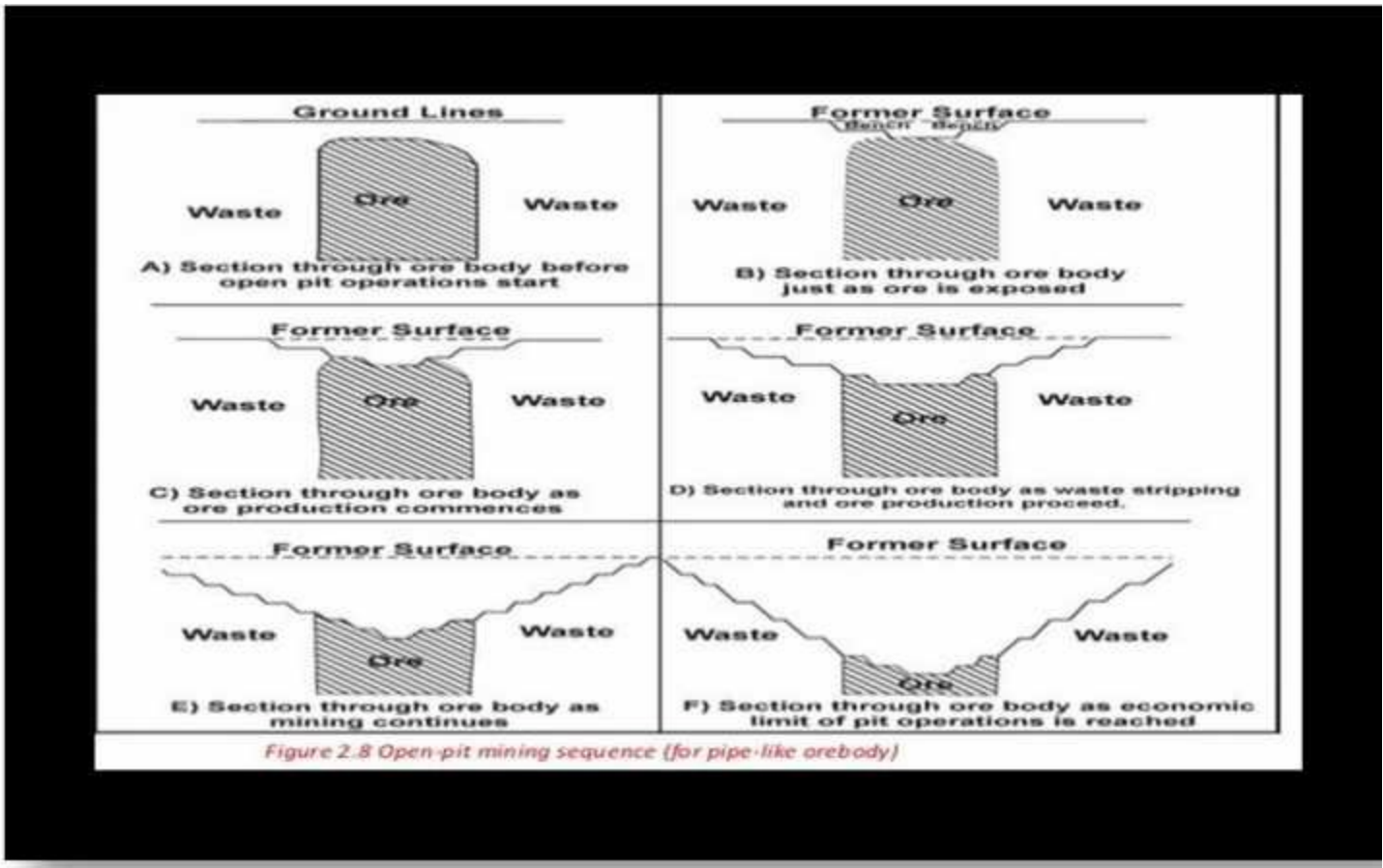


Figure 2.8 Open-pit mining sequence (for pipe-like orebody)

Nature and scope of the tasks

Certain factors in mine development receive special attention in preparation for surface mining. Of the locational factors, climate is of more critical concern in surface operation than underground. Today, harsh climates at high altitudes or in northern latitudes rarely mitigate against surface mining, but they can be detrimental. Among natural and geologic factors, terrain, depth and spatial characteristics of the deposit and presence of water are most important in surface mining. Among environmental factors, certainly antipollution and reclamation requirements rank highest as concerns in surface mining. Noting the steps in the sequence of mine development, there are three that are unique to surface mining:

1. Initiation of a land reclamation plan as part of the environmental impact statement (EIS).
2. Provision of topsoil stockpiles and waste-disposal dumps.
3. Carrying out of advanced stripping of overburden to gain access to the deposit.

Normally, all the other steps identified must be carried out, too, but these three require special consideration in the scheduling of development tasks.

Pit planning and design

The major engineering design task in the development of a surface mine is the planning of the open pit. There are three groups of factors involved.

- *Natural and geologic factors*: geologic conditions, ore types, hydrogeologic conditions, topography, and metallurgical characteristics
- *Economic factors*: ore grade, ore tonnage, stripping ratio, cutoff grade, operating cost, investment cost, desired profit, production rate, and market conditions.
- *Technological factors*: equipment, pit slope, bench height, road grade, property line, and pit limits.

Probably determination of the last-pit limits- is the most pressing and vexing consideration of all. While much importance is attached to the determination of the ultimate or final pit limit at the termination of mining, it is also important as well of developing an optimal mining sequence and production schedule over the life of the mine. The reason is that the initial cash flow generated during the first 5 to 10 years of exploitation is more apt to make or break the mine than the economics of the ultimate pit limits forecast 20 years in the future.
In this regard, the following list can be considered as objectives of pit planning from a feasibility standpoint.

1. Mine the ore body so that the production cost per lb (Kg) of metal is a minimum (i.e., mine the
"next best ore" in sequence).
2. Maintain operational viability (adequate bench width and ready haulage access from equipment).
3. Maintain sufficient exposure of ore to counter miscalculations or insufficient data from exploration.
4. Defer stripping requirements as long as possible without binding equipment, manpower, or the production schedule.
5. Follow a logical and achievable start-up schedule (for training, equipment procurement and deployment, logistics, etc.) that minimizes the risk of delays in positive cash flow.
6. Maximize design pit slopes, while minimizing likelihood of bank failures (provide safety berms, employ rock mechanics, etc.).
7. Examine economic merits of reasonable production rate and cutoff grade alternatives.
8. Finally, subject the favored method, equipment, and schedule to exhaustive contingency planning before proceeding with equipment.

While recognizing the role of computer-based techniques in analyzing and optimizing, the use of manually based pit-design procedures, interfaced with the computer, to operational viability in the resulting model has been recommended.

Long-Range Mine Planning

The initial step in surface mine design is the compilation of a long-range mining plan or final pit
design. In preparing the plan, plotting the location of the various ore types and deposit boundaries based on refined exploration data helps to establish the ultimate pit limits.
In reality, long-range mining plans usually change over time to reflect the effects of a changing economy, increased knowledge of the ore body, and improvements in mining technology.

As a result, as discussed above, long-range mining plans should be updated at regular intervals, using the computer to compare alternative pit limits.

The determination of the maximum allowable stripping ratio SR_{max} of a surface mine is break- even ratio based solely on economics, which establishes the pit limits. It is defined as the ratio of overburden to ore at the ultimate boundary of the pit where, the profit margin is zero. Mathematically, it is computed as follows:

$$SR_{max} = \frac{\text{value of ore - production cost}}{\text{Striping cost}}$$

$$SR_{max} = \frac{\text{Stripping allowance}}{\text{Striping cost}} \ldots\ldots$$

The value of ore in $/ton ($/tonne) is the recoverable value, and the production cost in $/ton ($/tonne) is the overall cost through refining or final processing ,exclusive of stripping .The stripping cost in $/yd^3 ($/m^3)is the cost of breaking and handling a unit volume of standard overburden. Since value minus cost normally equals profit, and the profit is assigned zero at the pit limit, the numerator becomes the stripping allowance.

Because ore grades actually vary throughout the pit and ore prices fluctuate, the maximum allowable stripping ratio can change with time. Thus it is helpful for a given property to prepare a table or graph showing the variation of SR_{max} with ore grade and price.

The maximum allowable stripping ratio also has physical significance

It enables us to locate the ultimate pit boundary or limit for prevailing economic conditions and for existing physical and geometric conditions in the pit (e.g., for a given pit slope and formation dip).Using computing graphics and Mathieson's interactive mode, various alternatives can be explored readily, even for complex geometries and in three dimensions (Fig. 1.4). At the value of SR_{max} where the cost of surface mining first exceeds that of underground mining, the portion of the ore body lying beyond the ultimate pit limit would have to be mined by underground methods.

Short-Range Mine Planning

Once a long-range surface mining plan has been established, it is essential to develop a series of

short-range mining plans. These plans define the intermediate steps required to ascertain the final pit limits under physical, opening, and legal constraints. They also provide the pit boundary, ore grade, stripping ratio, and anticipated profit information necessary for future production forecasts and equipment needs.

In preparing a short-range plan, the engineer lays out on a set of horizontal sections a series of proposed mining cuts. The location and extent of the cuts reflect the engineer's judgment of the various operational factors involved. Very likely, more than one ore type occurs in the pit, and more than one pit may be mined. In this case, an annual mining program is developed which depicts the daily production rate schedule for each ore type. A mining schedule for a hypothetical copper deposit producing four

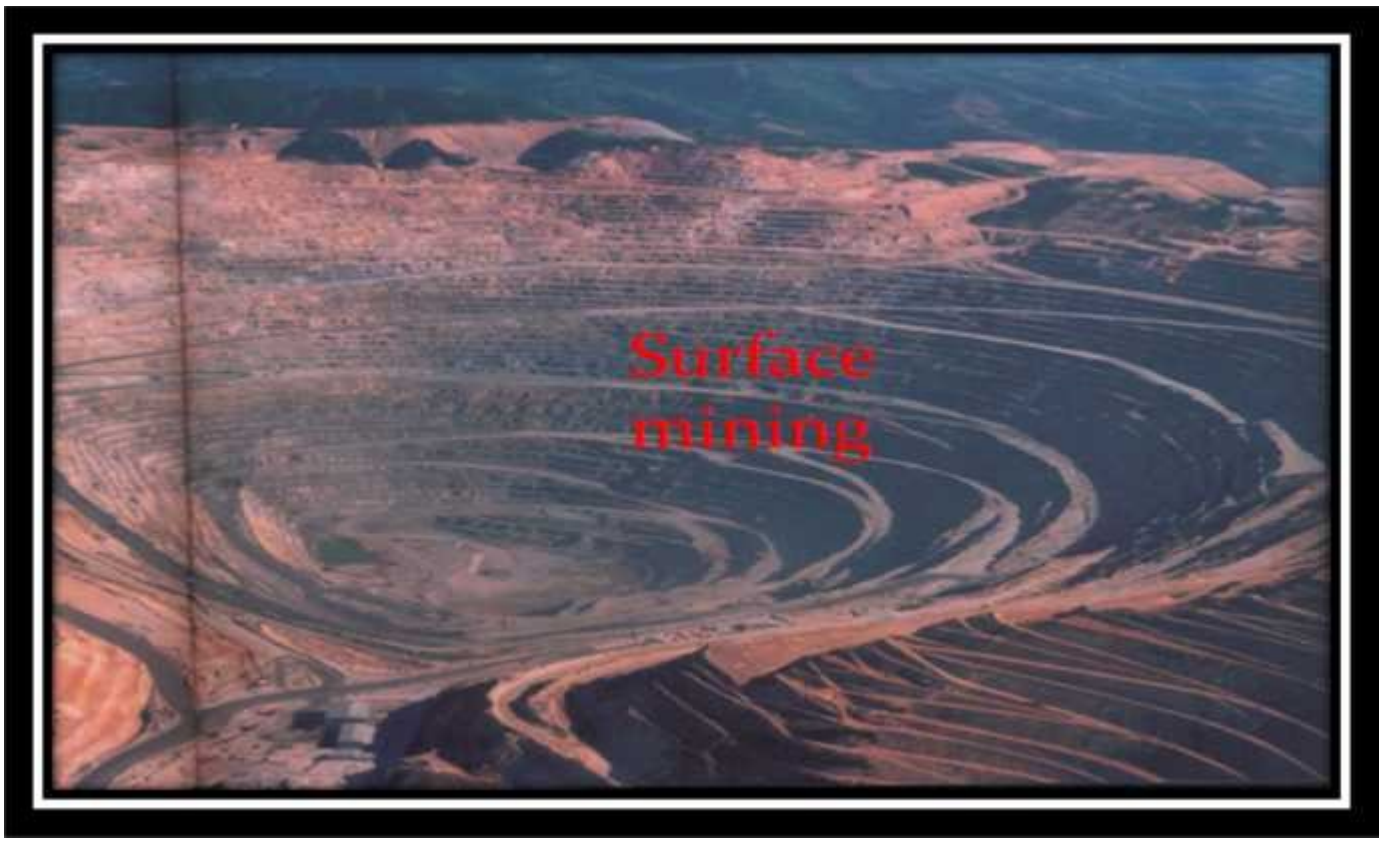
different ore types over a 12 year period is shown in Figure 1.6. The mining strategy for either the short or long range must reflect corporate and management goals. For example, the time value of money suggests a sequence of mining the best ore grade first in order to maximize early profits. However, s strategy of mining a uniform grade may be supported by improved mineral-processing recovery and efficiency and income tax and depletion allowance consideration.
Corporate plans must also reflect operating strategies for other of its mines.

Stripping sequence may be another operating variable to investigate; that is, how far in advance should certain ores or portions of the ore body be stripped? An important element of short-range planning is to program stripping ratios over the life of the property so they are not excessive during any period, especially at the outset of exploitation. An operating technique frequently utilized in the final years of mining is to steepen pit slopes, thus improving the stripping ratio, a practice made feasible by the foreshortened life span of the working benches.

- The following are terms that commonly occur in open pit mine planning and are used throughout this chapter.
- **A *bench*** may be defined as a ledge that forms a single level of operation above which mineral or waste materials are mined back to a bench face. The mineral or waste is removed in successive layers, each of which is a bench. Several benches may be in operation simultaneously in different parts of, and at different elevations in the open pit mine
- **The bench *height*** is the vertical distance between the highest point of the bench, or the *bench crest,* and the *toe* of the bench.
- **Pit limits** are the vertical and lateral extent to which the open pit mining may be economically conducted.
- In order to enhance the stability of a slope within the pit— and for safety reasons— *berms* may be left. **A *berm*** is a horizontal shelf or ledge within the ultimate pit wall slope. The *berm interval, berm slope angle,* and *berm width* are governed by the geotechnical configuration of the slope.
- **The *overall slope angle*** is th at v e angle l of a hig h the wa n pit stands tween the horizo l be an i t joining th and maginary li m be ich toe e top l ch crest wi ott n
- overall ang $\tan^{-1}\frac{n*bench\ h}{n*b}$ eight)/ $n*bench$ idth+(eight/tan angl bench)
- The angle of repose or angle of rest is the maximum slope at which a heap of loose material will stand without sliding.
- For the duration of open pit mining, a haul road must be maintained into the pit.
- A spiral system is an arrangement whereby the haul road is arranged spirally along the perimeter walls of the pit so that the gradient of the road is more or less uniform from the top to the bottom of the pit.
- A zigzag or switchback system is an arrangement in which the road surmounts the steep grade of a pit wall by zigzagging, generally on the footwall side of the pit. The choice of spiral or zigzag is

dependent upon the shape and size of the ore body, truck economics, and pit slope stability.

- ***Haul road width*** is governed by the required capacity of the road and type of haulage unit.
- The **sub outcrop depth** represents the depth of waste that has to be removed before any ore is exposed. This waste is often referred to as preproduction stripping.



Equipment and System Selection

The general principles of equipment selection and system design are applied to the operating circumstances of surface mining. It is not surprising that the selection of equipment is nearly synonymous with specifying the stripping method, because materials handling lies at the heart of surface mining.
In selecting a particular stripping method and its corresponding equipment, the ultimate aim is the removal of material (waste, burden) at the least possible cost.

Many factors are involved, of which the size of the ore body, distribution of values within the deposit, and consolidation and compaction of the overburden are key and limit the range of method and equipment choices. Other factors to be evaluated, however, are the presence of geologic structures (faults, folds, shear zones, water bearing zones, etc.) and alternation products (which may render roads impassable or mineral processing difficult); production rate and life; horizontal haul and vertical hoist distances; and possible future uses for specialized stripping equipment (subsequently during mining or reclamation or at other mines, etc.)

Pit geometry has a major effect on the type and size of equipment which can operate effectively. Each major mechanical extraction method of surface mining has its unique geometry; for example, open pit metallic and nonmetallic mines are designed with many low benches, open cast and auger stone quarries operate from a single high bench.

Open pits tend to be deep and laterally large, open casts are shallow and follow contours or advance across the country in long narrow panels, and quarries are usually very steep and may be quite deep. These geometric distinctions definitely favor or limit the kind of stripping equipment to be selected.
As a general rule, the largest equipment feasible and safe for the conditions is also the best-suited and lowest-cost equipment. Large materials-handling machines especially possess productivity and cost advantages that seem to have no upper limit, but practical limits (e.g., mobility) do prevail.
The choices of equipment and systems to mechanically strip ore, coal, or stone deposits are many in theory but few in practice.
Some of the machines employed in surface mining, arranged by cycle of unit operations. There are three main rock-breakage systems and six materials-handling systems in common usage today, as follows, in order of popularity:

1. Rock breakage

(a) No breakage necessary (material: typical soil)
(b) Drilling and blasting (usual choices: roller-bit rotary and ANFO or slurry; material: typical rock)
(c) Ripping (material: stiff soil, weak rock)

2. Materials handling

(a) Dragline (direct casting)
(b)Power shovel or front-end loader (c) Dozer and front-end loader
(d) Dozer and rubber-tired scraper
(e) Shovel or loader and hopper, crusher, and conveyor
(f) Bucket wheel excavator and conveyor

Stripping Ratios and Pit Limits

Maximum vs. Overall Stripping Ratio

It is on the basis of calculating stripping ratios that we are able to locate pit limits and to express volumes of overburden to be moved per unit weight of ore, coal, or stone uncovered. We must distinguish between two stripping ratios (units: yd^3/ton or m^3/tonne)

1. *Maximum allowable stripping ratio* SR_{max}
= volume of overburden/weight of ore at economic pit limit
= v/w
2. *Overall stripping ratio* SR_o
= volume of overburden/weight of ore entire ore body or cross section
= V/W

In only one instance does SR_{max} not establish the pit limit or exceed SR_o in magnitude, and that occurs when:

1 The surface is flat, and
2 The deposit is flat, tabular, and of constant thickness.

In singular case $SR_{max,}$ lacks and the pit limits are located at the property lines. Another distinction is that SR_{max} is an actual numerical ratio of yd^3/ton (m^3/tonne), whereas SR_{max} is expressed in units of equivalent yards (see the next section).

Under long-range planning, it has been discovered that the maximum stripping ratio, while a physical quantity, is determined solely by economics. The overall stripping ratio, on the other hand, has mainly physical significance. It is because of its economic basis that it can employ SR_{max} to locate the pit limits of a deposit in the general case, that is, an ore body of varying thickness, dip, or grade occurring beneath an inclined or horizontal surface.

- In strip mining, overburden is dumped directly onto mined-out panels rather than outside the final pit boundary, as is typical of open-pit mining.
- Both stripping and mining are from one or a sequence of benches
- The ratio of the total volume of waste to the ore volume is defined as the

overall stripping ratio:

- $Sr=R$ =volume of waste removed to depth/volume of ore recovered to depth.

The cutoff stripping ratio is the one for which the costs of mining the ore and waste are matched by the revenue from that block of ore. Factors used to determine costs should include the added costs of mining as the pit deepens and the interest charges on the pre stripping of waste.

Declining Stripping Ratio Method. This method requires that each bench of ore be mined in sequence, and all the waste on the particular bench is removed to the pit limit.

The advantages of this method are the operating working space available, the accessibility of the ore on the sub sequent bench, all equipment working on the same level, no contamination from waste blasting above the ore, and equipment requirements are a minimum towards the end of the mine's life.

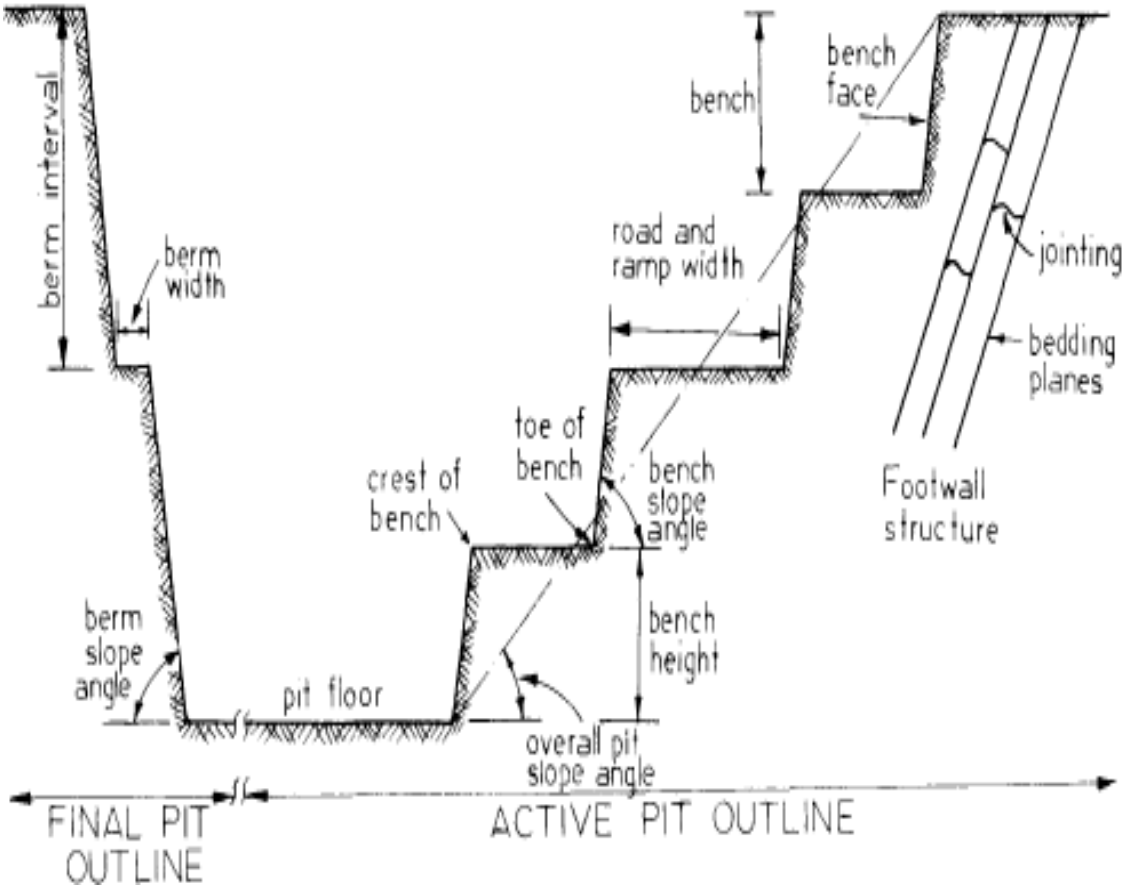
The primary disadvantage of this method is that the overall operating costs are a maximum during the initial years of operation when maximum repayment of capital

Increasing Stripping Ratio Method. In this method, stripping is performed as needed to uncover the ore. The working slopes of the waste faces are essentially maintained parallel to the overall pit slope angle.

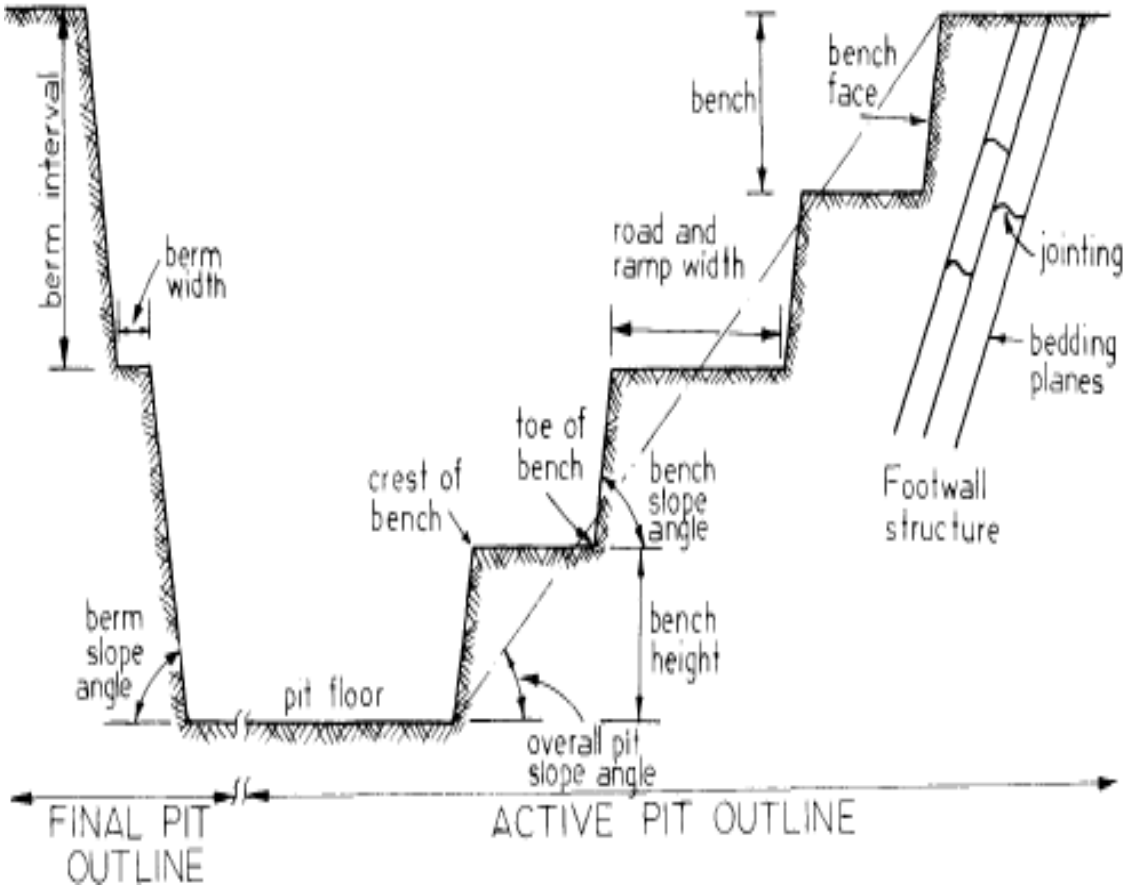
- This method allows for maximum profit in the initial years of operation and greatly reduces the investment risk in waste removal for ore to be mined at a future date. This method is very popular where the mining economics or cutoff stripping ratio is likely to change on very short notice.

The disadvantage of this method is the impracticality of operating a large number of stacked, narrow benches simultaneously to meet production needs.

OPEN PIT PLANNIN



OPEN PIT PLANNIN



Chapter six

Underground mine development: Introduction

Development for underground mining is generally more complex and expensive. It requires careful planning and layout of access openings for efficient mining, safety, and permanence.

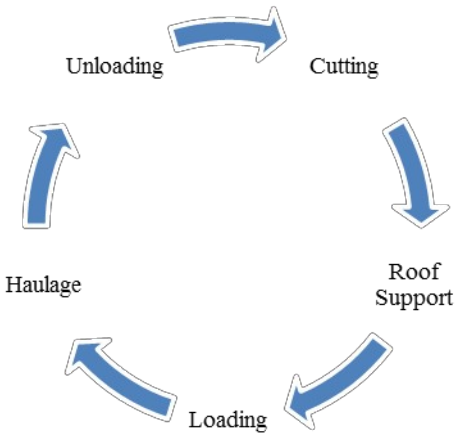
In an underground mine, a significant amount of infrastructure must be installed before mining begins. This will include shafts, hoists, ventilation fans, underground shops, travel ways for workers and machinery, ore storage bins, underground crushers, and so forth.

The driving/excavation of openings to a proved and explored deposit for digging out / production of the mineral are known as development. Development does not stop, it continues throughout the life of the mine. While developing a mine different choices are used for the mode of entries e.g. Shaft, tunnel, inclines, levels etc. A number of factors influence the method and extent of development including topography, local geology, location of mineral, life of mine, production rate, utility of mineral etc.
The principal openings may be shafts, slopes, or adits; each must be planned to allow passage of workers, machines, ore, waste, air, water, and utilities. The excavation consists of openings for human entry below the earth's surface.

Factors affecting the choice of these underground coal mining technologies are including:

- Capital requirements
- Resource recovery
- Labor
- Production and productivity
- Environmental impacts, and
- Health and safety

Underground methods are differentiated by the type of wall and roof supports used the configuration and size of production openings and the direction in which mining operations progress.



Underground mining is used when the deposit is too deep for surface mining or there is a restriction on the use of the surface land. The deposit is accessed from the surface by vertical shafts, horizontal adits, or inclines (Figure 3-5). The deposit itself is developed by criss-crossing openings (called levels, cross-cuts, raises, etc.) in the orebody, not only to create blocks of ore to be extracted according to a scheme but also to provide for human access, the transport of ore and waste, and adequate ventilation. The drilling, blasting, loading, and transporting of ore from active working areas (faces) are carried out according to a mining plan. If the deposit is soft, such as coal, potash, or salt, mechanical means can be used to cut and load the deposit, thereby eliminating the need for drilling and blasting. In hard-rock mines carefully planned drilling into the ore and blasting with dynamite or ammonium-nitrate explosives are common. Underground metal-mining methods may be unsupported, supported, and caving methods, and there are numerous variations of each.
Open stopes, room-and-pillar, and sublevel stoping methods are the most common unsupported methods; cut-and-fill stoping when the fill is often waste from the mine and mill tailings is the most common method of supported underground mining (Figure 3-6). Because of the high costs associated with supported and unsupported mining methods, open stoping with caving methods is used whenever feasible. Underground coal mining today is basically done by two methods: room-and-pillar mining with continuous miners, and long wall mining with shearers. The former is essential for developing large blocks of coal for long wall extraction.

The selection of underground mining methods is primarily based on the geological/spatial setting of the deposit. Candidate methods can therefore be chosen and ranked based on estimated operational/capital costs, production rates, availability of labors and materials/equipments, and environmental considerations. The method offering the most reasonable and optimized combination of safety, economics, and mining recovery is then chosen.

Reflecting the importance of ground support, underground mining methods are categorized in three classes on the basis of the extent of support required: unsupported, supported, and caving.

The most appropriate mining methods must be selected according to the natural/geological conditions and spatial/geometric characteristics of mineral deposits.
Considerations include:

1. Spatial/geometric characteristics of the deposit concerned: the shape, size, thickness, plunge, and depth.

2. Strength of the hanging wall, footwall, and ore body.
3. Economic value of the ore and grade distribution within the deposit.

Underground mine ventilation

- **Underground mine ventilation** provides a flow of air to the underground workings of a mine of sufficient volume to;
  - dilute and remove dust and noxious gases (typically NO_x, SO_2, methane, CO_2 and CO) and
  - to regulate temperature.
- The source of these gases are;
  - equipment that runs on diesel engines,
  - blasting with explosives, and
  - the orebody itself.

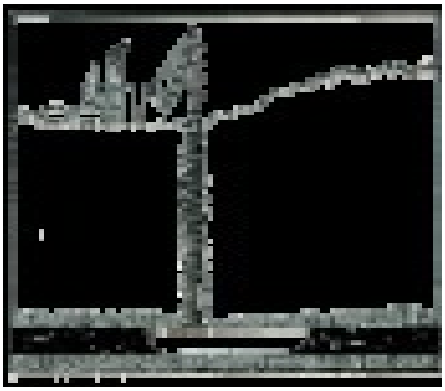
- The largest component of the operating cost for mine ventilation is electricity to power the ventilation fans, which may account for one third of a typical underground mine's entire electrical power cost.

A design span limit of 10m has been recommended for mining in areas of good rock mass quality. Without underground exposures an initial conservative extraction ratio of around 75% was anticipated to account for major structures, adverse small scale structure, or zones of lower rock mass quality. This would meet the 1:1 pillar height criteria. The required ground support systems to increase spans through zones of reduced rock quality should be tested during early mine development.
For most mining areas, superimposed 5m by 5m pillars are planned to limit spans to 10m. These spans would be mined using a cut height of 5m. Pillars over 5m height should be assessed on an individual case basis, and rock support or fill should be utilized.

To describe the necessary part of development

- Identification of preferred mining method
  - Equipment requirements
  - mine orientation
- Type and location of openings
- Mine design characteristics
  - Number of main and panel entries
  - Size and number of production panels
  - Determination of most efficient and economical design
- Ventilation requirements
- Material handling requirements
- Surface facility requirements and layout
- Preliminary economic analysis
- Market assessment and sales potential
  - Coal quality
  - mine location relative to potential markets
  - Market demand
  - Transportation infrastructure
  - Government regulations
- Transportation options
  - Railways
  - Waterways
  - Roadways
  - Overland conveyors

Mine Opening Development Requirements



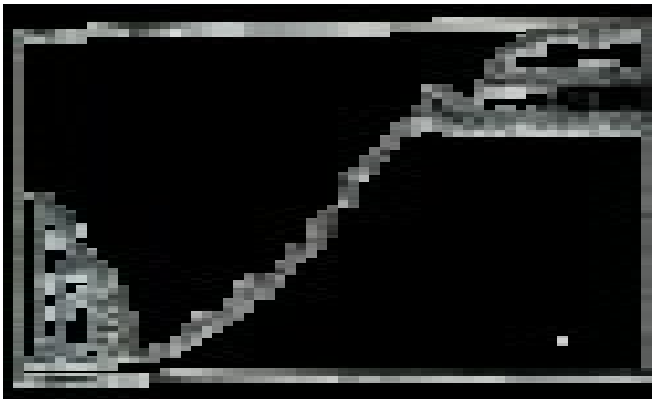
Shaft

Sometimes referred to as vertical slopes
Excavation and removal of overburden predetermined
Diameters

- drill and shoot
- blind hole
- raise boring

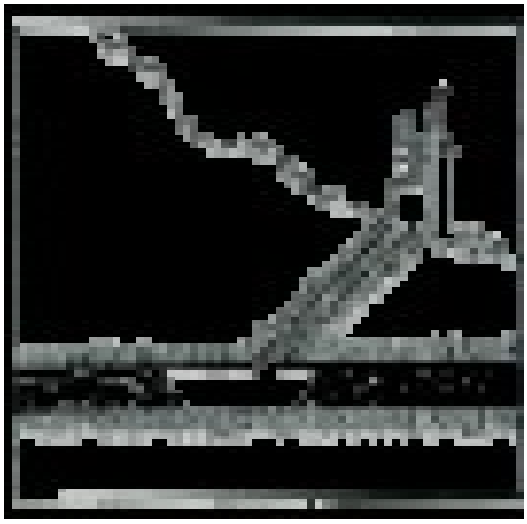
Lined wall various applications

- man-way / escape-way
- coal transportation
- material and supply
- air



Drift

May or may not require excavation
Face-up requirements



Slope

Inclined opening
- 10 to 18 degrees

Overburden tunneling required
- drill and shoot
- rock miner
- tunnel borer

Support, Ventilation, Drainage and Lighting

The **ventilation** system of a tunnel operates to maintain acceptable air quality levels for short-term exposure within the tunnel. The design may be driven either by fire/safety considerations or by air quality; which one governs depends upon many factors including traffic, size and length of the tunnel, and any special features such as underground interchanges.

The two main ventilation system options used for tunnels are longitudinal ventilation and transverse ventilation.

A longitudinal ventilation system introduces air into, or removes air from a road tunnel, with the longitudinal flow of traffic, at a limited number of points such as a ventilation shaft or a portal.

A transverse ventilation system can be either a full or semi-full transverse type. With full transverse ventilation, air supply ducts are located above, below or to the side of the traffic tube and inject fresh air into the tunnel at regular intervals.

Lighting in tunnels assists the driver in identifying hazards or disabled vehicles within the tunnel while at a sufficient distance to safely react or stop. High light levels (Portal light zone) are usually required at the beginning of the tunnel during the daytime to compensate for the “Black Hole Effect” that occurs by the tunnel structure shadowing the roadway as shown on Figure 2-7. These high light levels will be used only during daytime. Tunnel light fixtures are usually located in the ceiling, or mounted on the walls near the ceiling. Tunnel lighting methods and guidelines are not within the scope of this manual. However, the location, size, type, and number of light fixtures impact the geometrical requirements of the tunnel and should be taken into consideration.

Road tunnels must be equipped with a drainage system consisting of pipes, channels, sump/pump, oil/water separators and control systems for the safe and reliable collection, storage, separation and disposal of liquid/ effluent from the tunnels that might otherwise collect. Drainage must be provided in tunnels to deal with surface water as well as water leakage. However, drainage lines and sump-pumps should be sized to accommodate water intrusion and/or firefighting requirements. They should be designed so that fire would not spread through the drainage system into adjacent tubes by isolating them. For the safety reason, PVC, fiberglass pipe, or other combustible materials should not be used.



Primary and Secondary development drivages in underground mines:

Primary development: Shafts, Inclines, Adits, Declines, Levels, Large chambers, Ore & Waste passes

Secondary development: Raises, Winzes, Ramps, Man-pass, Ore-pass Sub levels/horizon

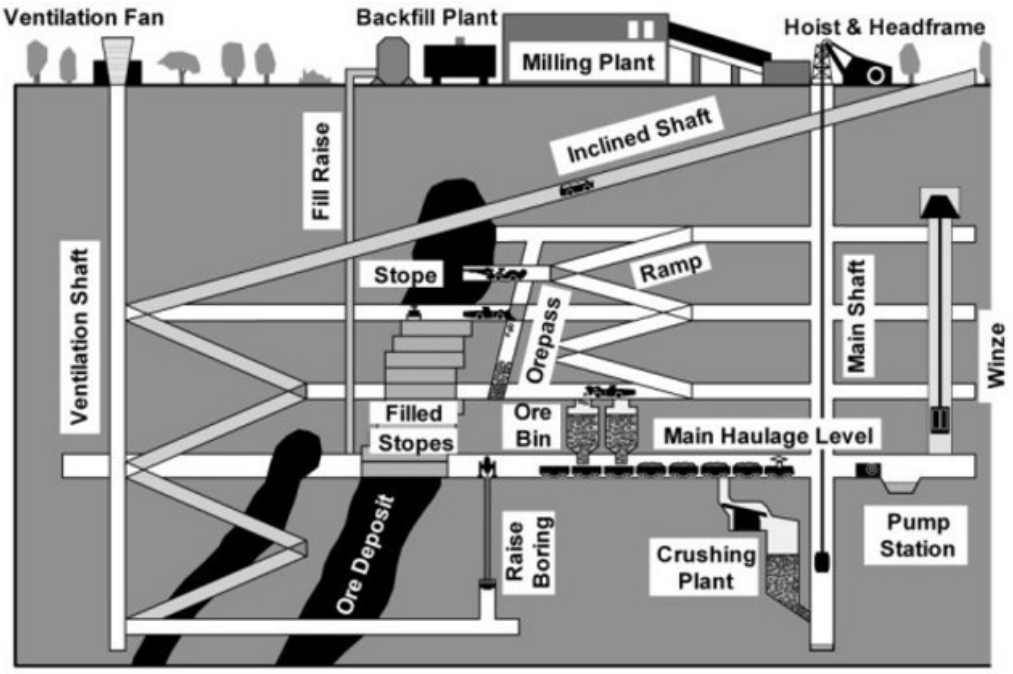
Vertical development: Shafts, Raises, Ore & Waste passes

Horizontal/Inclined development: Drifts, Drives, Tunnels, Cross-cuts, Declines/Ramps, Inclines, Adits, Sub-levels/horizons.

The auxiliary/supporting operations required underground include:

1. Health and safety: ventilation, gas control (particularly in coal mines), dust suppression, noise reduction.
2. Ground control: supporting (rock-bolting, timbering, setting steel arches, etc.), scaling (removing rock fragments from working roofs).
3. Power supply and lighting

4. Drainage and flood control: pump stations and sumps are usually constructed at the bottom level to collect and drain water from underground after removing suspended solids.
5. Maintenance and repair of equipment: underground workshops and warehouses.



An inclined shaft is excavated for transportation of personnel and supplies in addition to a vertical shaft for hoisting mined ore and a ventilation shaft for enhancing circulation of fresh air with the aid of a fan. Alternatively, an inclined shaft can be used for main ore transportation and ventilation, and the vertical shaft can act as the main thoroughfare for employees and materials. The functions of inclined and vertical shafts are usually versatile in mining operations.
Main levels are arranged for main haulage and connection between underground key facilities. A small number of sublevels may be situated between main levels within a stoping area for production. Raises and winzes are either vertical or sub-vertical openings driven between one level and another or the surface. Raises are driven upward, and winzes are driven downward. A ramp is an inclined opening connecting levels or stopes to enable the passage of vehicles and an ore pass is a vertical or sub-vertical hole through which ore is transferred to lower levels.

Equipment selection

The most common equipment for material handling such as loading and hauling excavated ore are slushers, gathering-arm loaders, front-end loaders, overhead loaders, Load-Haul-Dump units (LHDs), and rubber-tired shuttle cars and trucks, as well as transportation by conveyor, rail, and gravity flow. Ore is loaded into underground equipment and transferred to ore passes, where the ore is dumped. A draw point or chute is usually situated at the outlet of the pass on the lower level, where the ore is loaded and transported to the underground ore bins or directly to the main haulage level. Finally, ore is collected on the main haulage level and transferred to an underground crusher for size reduction to facilitate transportation by conveyors or skips through shafts.
The primary operations required in underground are rock breakage and material handling.
If the target is sufficiently soft (e.g., coal and rock salt), mechanical excavation utilizing continuous miners, shearers, ploughs/plows, and so on, can be employed. In contrast, drilling and blasting are usually employed when the ore is too hard for cutting. A drifting jumbo equipped with one or multiple rock drills is employed for penetrating horizontal blastholes and used for driving horizontal drifts and inclined ramps as well as production by crosscutting in room-and-pillar mining and cut-and-fill stoping. Fan/ring/parallel longhole drill rigs are commonly employed for large-scale production in sublevel stoping and sublevel caving. Ammonium nitrate and fuel oil (ANFO), slurries, and emulsions are widely used as explosives in mining operations.

Face rigs / Jumbos

Drilling holes with the objective of
□□□Explosive charging
□□□Rock bolting

In mine development
□□□Drifts, tunnels, adits, ramps

LOAD-HAUL-DUMP VEHICLES (LHD)

LHDs are four-wheeled consisting of two bodies interconnected by an articulation joint
By the mid-1960 the LHD were firmly established as fundamental part of what has become known as the “trackless” mining concept, used in many mines in many countries around the world. The mobility flexibility and versatility of these units have given the industry useful tool and have added new dimension to mine development and production.

Scaling machines

- Scaling may be described as the art and function of making the ground
- In manual scaling, loose or potentially unstable rock is prised off the rock surface with an appropriate scaling bar.
- The ability to correctly "read the ground", or assess the ground conditions, is essential to all people carrying out scaling, no matter how small the area to be scaled.

Explosive charging machine

Charging machines are used to fill drilled holes with explosives. The machine, often, consist of tyre mounted diesel driven machines with facilities to carry vessels to that contain the explosive to be used. In underground application, often two vessels are mounted on the machine. Place is usually set for packed explosives, primers and detonators.
The machine can have its own compressor onboard to produce the pressured air that transports the explosive from the vessel into the holes through charging hoses.

The machine would feature boom that with a basket at the end. The basket will have a roof to protect the operator from the rock above.

Rail transport in UG mining

Mine Haulage

Transportation of coal/ ore inside the mine can be described by two types of haulage locomotives. The first being a main haulage locomotive, the second is a gathering locomotive.

Main Haulage Locomotives

Locomotives of this type are the heaviest of those used anywhere in the mine. The type of work they perform requires high traction effort and a speed rating of six to eight miles per hour. Such locomotives range in size from 6 to 8 tons minimum to 25 tons maximum.

The majority of the locomotives are of the electrically driven type receiving their power from an overhead trolley wire carrying either 250 or 500 volts DC. These locomotives have two sets of driving wheels, with each set driven through gearing by a motor.

Locomotive size will be determined by haulage problems in the mine.

Gathering Locomotives:

Gathering haulage involves the collection of individual cars at the faces of rooms or entries, or at other points where loading is done. Then bringing them to suitable sidings where they are made into trains for the main haulage locomotives. Gathering may be considered as follows:

A. Room gathering. This is where the locomotive handles the cars in the rooms and hauls them to the main sidetrack.

B. Entry Gathering. This is where men handle the cars in the rooms or mechanical loading devices deliver the coal to the entry, or the cars are loaded from chutes and the locomotive handles the cars between the entry and the side track. Locomotives in these classes include cable reel, storage battery or combination locomotives. Gathering locomotives benefit from not needing a trolley wire ran into the tunnels where the work will take place.