Lecture Note on Surface Mining Technology

FOR 3RD SEMESTER MINING

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SITE PREPARATION

Need of Site Preparation

Main Purpose of Mining is PRODUCTION OF ORE.

It needs a Mining Face to excavate the ore from a Mining Bench. Subsequently, the excavated ore is loaded on to a Tub/ Conveyor/ Dumpers or onward transportation to processing Plant.

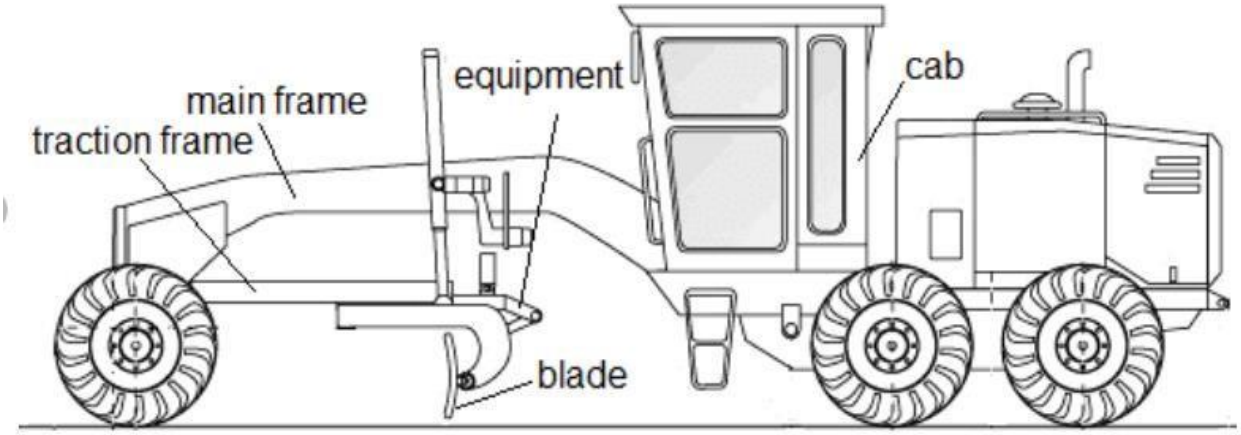
Thus, Mining Face needs **Site preparation** Before & After Excavation of Ore. This is an important part of Cyclic Operation process.

1. Withdraw Explosives from Magazine.
2. Priming of Accessories e.g. Detonator crimping with Safety fuse etc. in Priming station. These days, use of Nonels has eliminated this step.

3. Carrying, Transportation of Explosive to Mining Face.
4. Charging of Holes & connecting of Holes as per desired Firing Sequence.
5. Clearance of Safety Zone of Blasting upto 600 mtrs. In Opencast & 180 Degree blind turns twice preferably in underground blasting.
6. Firing of Shot from Blasting Shelter placed at remote / hidden place/ manhole provided.

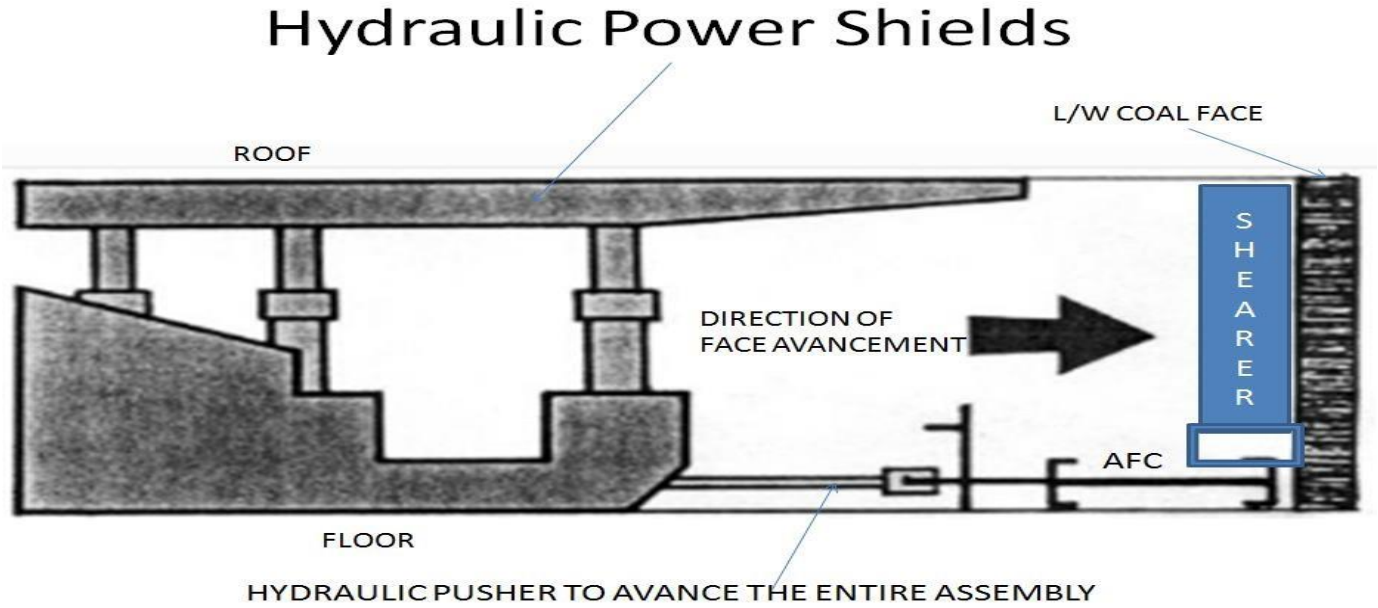
Waiting for 5 minutes and entering to Blast Zone. Dealing with Misfire , if any & giving clearance to next operation after more 5 Minutes. It is done by Sirening/ whistling by Blaster in the beginning & at the end following a particular code. Red Flags / portable red lights are also used to safeguard the area while blasting.

Dozers



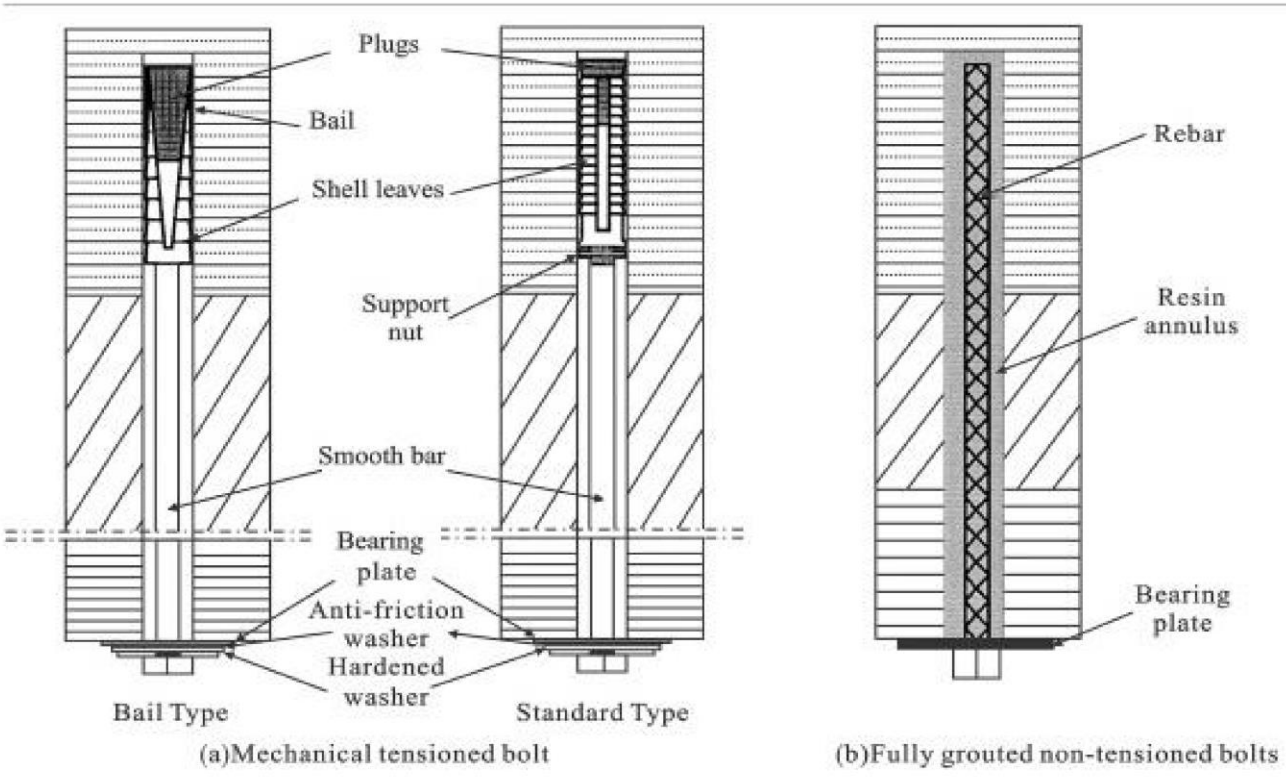
Support withdrawal / Re-setting for extension.

- Use of Silvester Jack for wooden support withdrawal.
- Hydraulic supports can be lowered for dejacking & withdrawal.
- On Longwall face, Armoured Face Conveyor with Shearer mounting & Hydraulic Shields can advance toward next shearing position on mining face. In fact, here no need of blasting. So, only advance ment of support takes place.
- On drifting / drivage faces , these days Rock boltings are preferred to provide wider space for loading.
- At Bord & Pillar face, Wooden Chocks are provided which can be left to support the edge of Goaf. Only new supporting Chocks may be required to erect.



Modes of Loading & Transportation.

- Manual Loading → Tubs.
- Loader/ Scraper Loading → Tubs
- Loader Loading → Trucks/ Dumpers → Haul road→Crusher
- Skip Loading form Pocket Bins Conveyor system
- Filled tubs→ Tippler→ Conveyor.
- Shearer on Coal Face → AFC →Panel Coveyor → Gate conveyor
- Direct & Endless Rope Haulage.



Exploratory Drilling

What is Exploration?

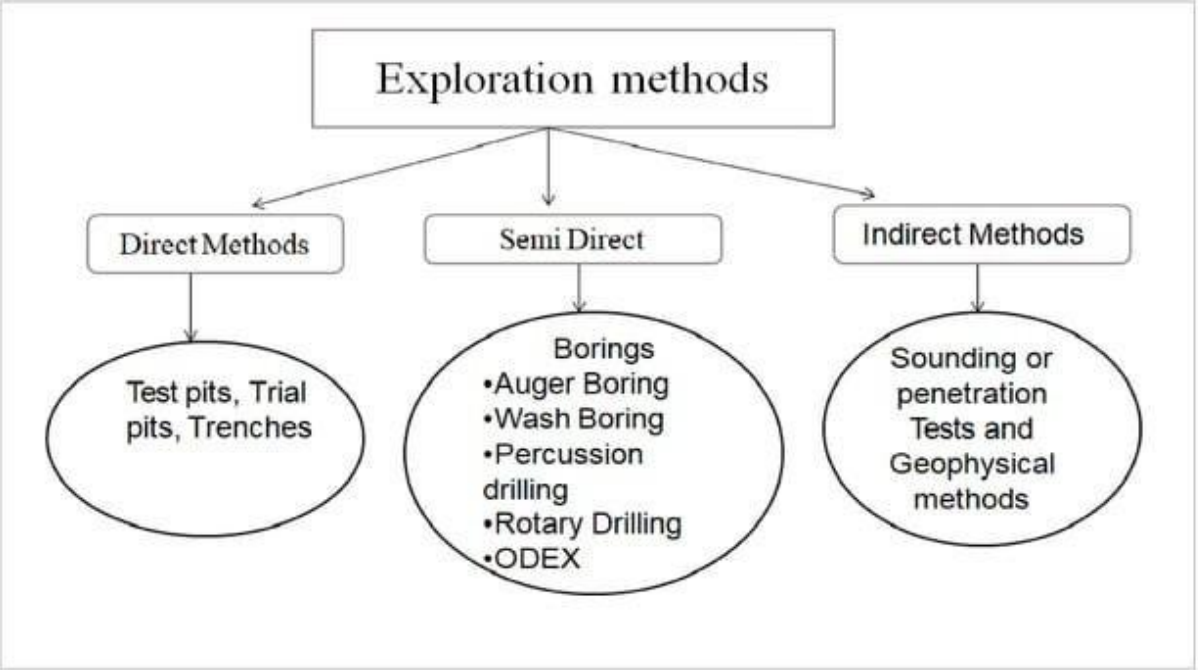
- The process of collection of rock sample data for the assessment of rock properties at a site through series of laboratory and field investigation is collectively called Exploration
- Enables the engineers to draw rock profile indicating the sequence of strata and the properties of rock involved.

Main Objectives

To find out

- Nature of Deposit
- Depth and Thickness of Strata
- Horizontal extent of Deposit
- Depth of GWT and its fluctuations
- Engineering properties of Rock
- Insitu Rock Properties
- Collection of Rock Sample

Methods of Exploration



Direct Method: Test Pits

- Depth upto 3m
- Uneconomical at greater depths.
- Supports are required at greater depths. Especially in case of weak strata.
- Problems with GWT and the same should be lowered.
- Open type Exploration.
- Soils are investigated in natural condition.
- Soil samples are collected for determining strength and Engineering properties.

Excavated test pit

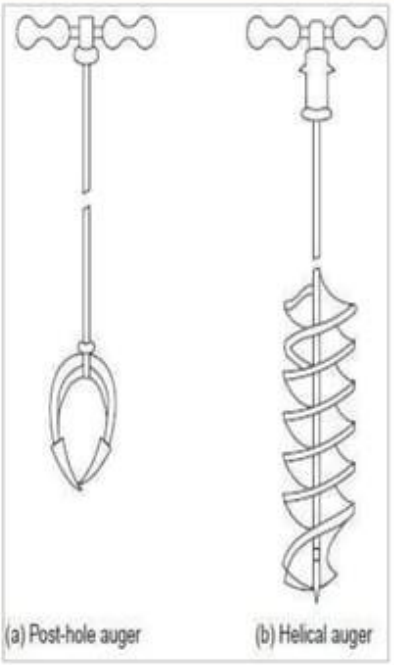
Semi-Direct Method: Drilling/Boring

Drilling a hole into the soil or rock strata up to specified depth is known as Boring. The Exploratory Drilling methods are classified are as follows:

1. Auger Drilling
2. Wash Boring
3. Percussion Drilling or Churn Drilling or Cable tool
4. Rotary Drilling
5. ODEX

Auger Boring

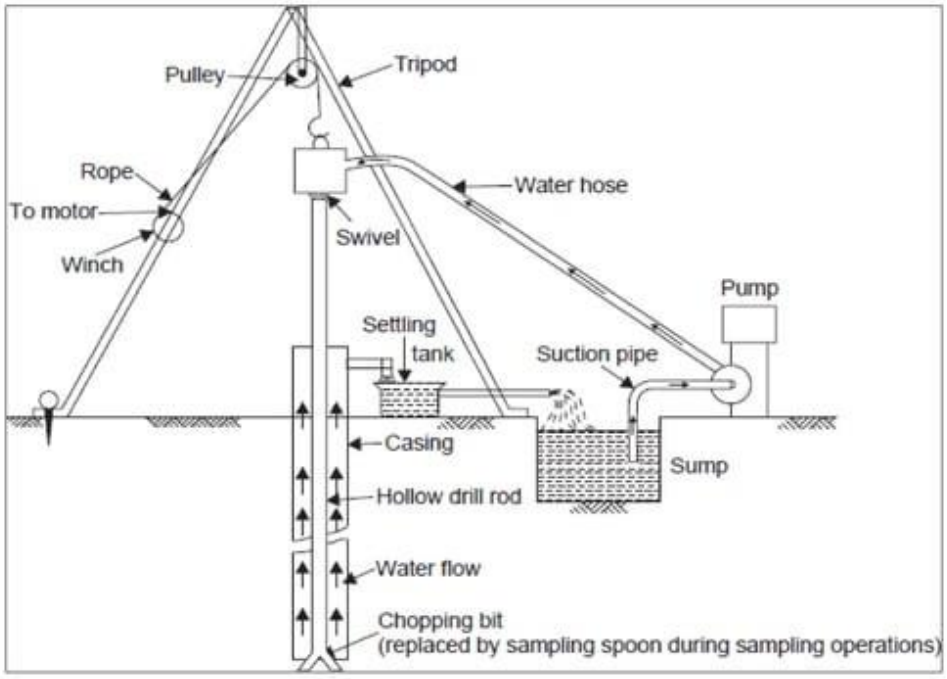
- Drilling is made using a device called Soil Auger
- Power driven (upto 3 to 5m) and Hand operated (Greater than 5m)
- Advancement is made by drilling the auger by simultaneous rotating and pressing it into the soil
- Dry and unsupported bore holes
- When the auger gets filled with soil same, it is taken out and the soil sample collected



Wash Boring

- Below GWT, It may not be used for soils mixed with gravel and boulders.
- Initially, the hole is advanced for a short depth by using an auger.
- Then a casing pipe is pushed in and driven with a drop weight. The driving may be with the aid of power.
- A hollow drill bit is screwed to a hollow drill rod connected to a rope passing over a pulley and supported by a tripod.
- Water jet under pressure is forced through the rod and the bit into the hole.
- This loosens the soil at the lower end and forces the soil-water suspension upwards along the annular space between the inner wall of the drill hole and outer wall of the hollow drill rod.

Typical set up for Wash boring

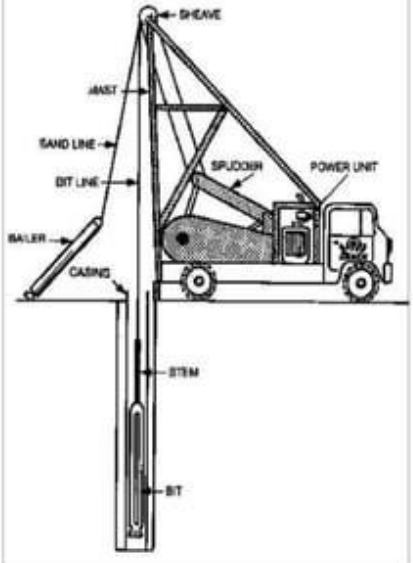


Percussion Drilling or Churn Drilling

- A heavy drill bit called 'churn bit' is suspended from a cable and is driven by repeated blows.
- Water is added to facilitate the breaking of stiff soil or rock.
- The slurry of the pulverised material is bailed out at intervals.

Disadvantages:

- Cannot be used in loose sand and is slow in plastic clay.
- The formation gets badly disturbed by impact.



Percussive Drilling Bits

Rotary Drilling

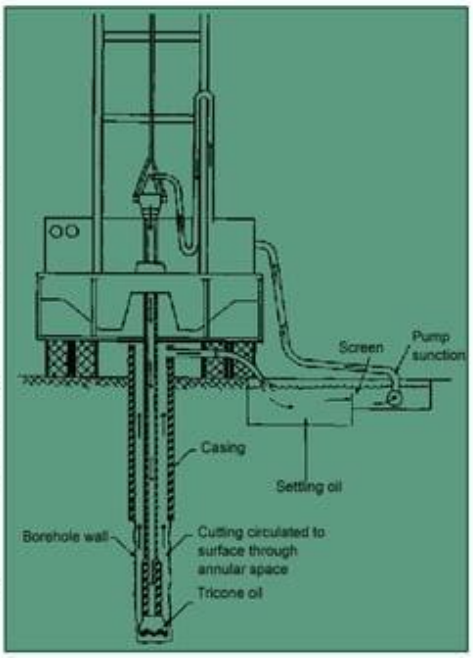
- Suitable for rock formations.
- A drill bit, fixed to the lower end of a drill rod, is rotated by power while being kept in firm contact with the hole.
- Drilling fluid or bentonite slurry is used under pressure which brings up the cuttings to the surface.
- Even rock cores may be obtained by using suitable diamond drill bits.

Disadvantage:

- Not used in porous deposits as the consumption of drilling fluid would be high.

Rotary Drilling

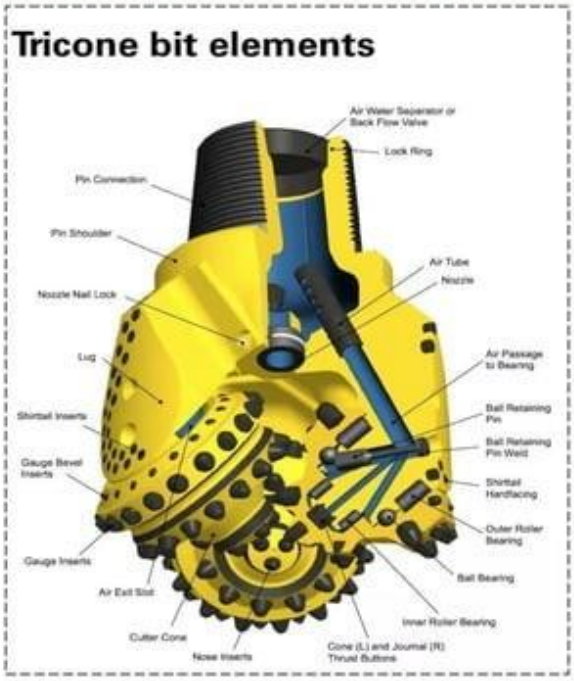
- Rotary drilling method of boring is useful in case of highly resistant strata.
- It is related to finding out the rock strata and also to access the quality of rocks from cracks, fissures and joints.
- Here, the bore holes are advanced in depth by rotary percussion method which is similar to wash boring technique.
- A heavystring of the drill rod is used for choking action.



Rotary Drilling

- The broken rock or soil fragments are removed by circulating water or drilling mud pumped through the drill rods and bit up through the bore hole from which it is collected in a settling tank for recirculation.
- If the depth is small and the soil stable, water alone can be used
- However, drilling fluids are useful as they serve to stabilize the bore hole. Drilling mud is slurry of bentonite in water.
- The drilling fluid causes stabilizing effect to the bore hole partly due to higher specific gravity as compared with water and partly due to formation of mud cake on the sides of the hole.
- As the stabilizing effect is imparted by these drilling fluids no casing is required if drilling fluid is used

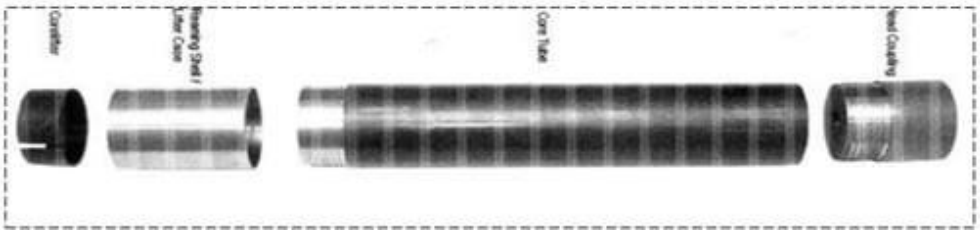
Rotary Drilling Bits



Single Tube Core Barrel

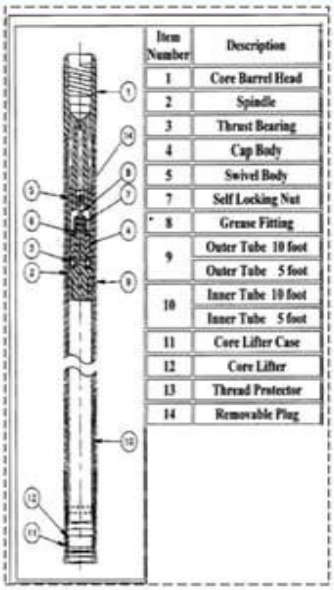
Limitations:

- Wrong interpretation of stratification.
- Probability of loss of information during core recovery.



Double Tube Core Barrel

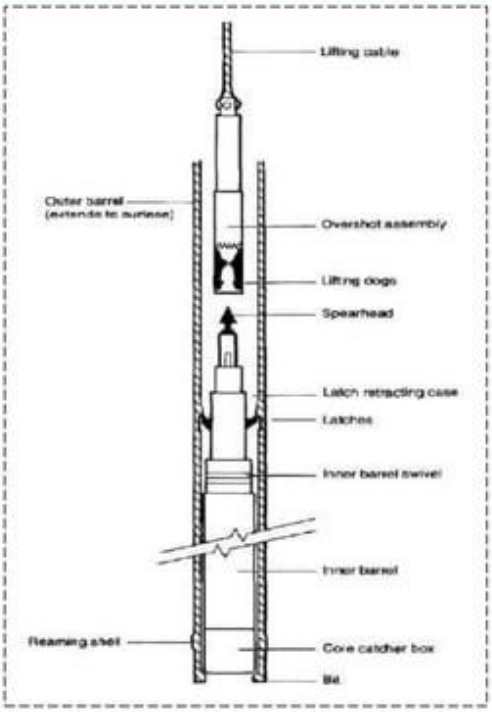
➢It offers higher percentage of core recovery and little erosion of core.
➢Water in the double tube core barrel passes in between the outer tube and inner tube.
➢Perforation at the lower end of the inner tube permits the flow of water



Item Number	Description
1	Core Barrel Head
2	Spindle
3	Thrust Bearing
4	Cap Body
5	Swivel Body
7	Self Locking Nut
* 8	Grease Fitting
9	Outer Tube 10 foot
	Outer Tube 5 foot
10	Inner Tube 10 foot
	Inner Tube 5 foot
11	Core Lifter Case
12	Core Lifter
13	Thread Protector
14	Removable Plug

Wire line Core Barrel

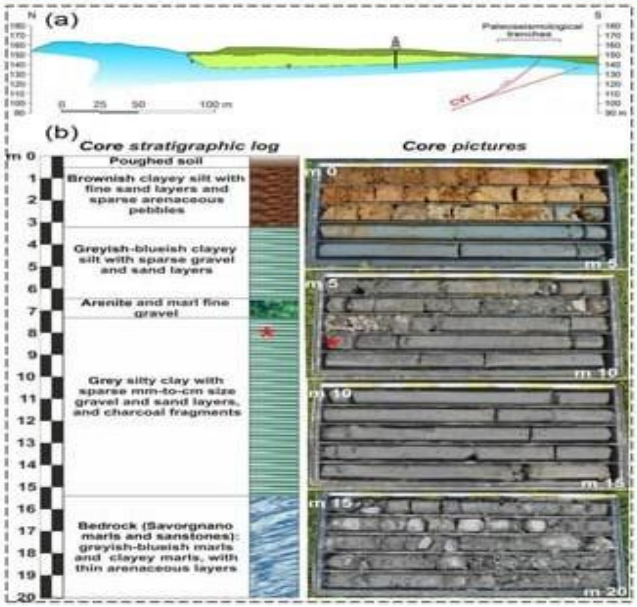
➢Wire line Drill rod: Drill rod having coupling that are nearly flush in the inside and designed so that the inner tube of wire line core barrel and overshot assembly can be run inside the rod.



Core Logging

➢No details should be ignored, as this log may be the only record obtained for the particular site & will be relied upon in future years

➢Detailed descriptions of core logging are presented by the Geological Society (1970) & ISRM (1978)



Storage of Cores

➢Once the first groove is completed the cores are placed from right to left in the second groove and so on and so forth.

➢Book fashion is preferred the most as it speeds up core logging, identification of footage at any point in the hole and less chance of error.

Shaft Sinking Method

content

- Introduction of shaft, shaft sinking ,its purpose
- Factors for selection of shaft sinking
- Shape & size of shaft
- Shaft centering
- Temporory support
- Permanent support – various methods
- Walling platform
- Lighting in shaft
- Drilling ,blasting & mucking process
- Sinking rider
- Special methods of shaft sinking
- Deepening and widening of shaft
- references

Shaft Sinking

- **Shaft:** A vertical or inclined opening from surface for the conveyance of men, materials, hoisting ore, pumping water and providing ventilation.
- **Sinking:** The work in excavating a shaft
- **Shaft sinking** It may be described as an excavation of vertical or inclined opening from surface for conveyance of men, materials, ventilation, pumping water, in addition to hoisting ore and waste rock
- It is also called **Shaft Construction** or **Shaft Mining.**
- It is a part of mine development, after the complete development it is used for production of ore purpose and dewatering of mine sumps

PURPOSE OF SHAFT SINKING

- To transport men and materials to and from underground Workings.
- For hoisting ore and waste from underground.
- To serve as intake and return airways for the mine (ventilation shaft).
- To access body
- These shafts are used in applications such as hydro electric projects, water supply, waste water shafts and tunnel projects.
- Drilled shaft machine is used in such process, where it consists of special type of units that are used in both stable and unstable

FACTORS GOVERNING SELECTION OF SHAFT POSITION

Surface consideration:-

1. Configuration of the Surface and land available
2. Convenience of Railway
3. Convenience of Roadways
4. Water Supply
5. Surface Drainage
6. Landslides
7. Running Sands

Underground Considerations

1. Presence of Faults
2. Direction and Amount of Dip
3. Direction of Underground Transport
4. Ventilation
5. General Considerations:

Nowdays, however, if the seams are fairly flat and assuming other condition permit, the tendency is to fix the shaft near the centre of mine property.

a) Shape of Shafts :

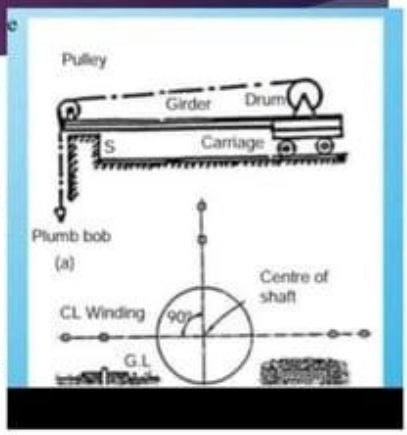
- **The most common shapes of shafts are : (1) Circular, (4) Elliptical. (2) Square, (3) Rectangular, and In colliery practice, circular shafts are almost invariably used.**
- **A circular shaft has the following advantages :**
- **(1) It is the strongest form to resist heavy rock and water pressure.**
- **(ii) For a given cross-sectional area it presents the least resistance to the passage of air.**
- **(ii) It is best suited to sinking under difficult conditions and to the insertion of a water tight lining.**
- **(iv) It is suitable for greater depth.**
- **vi) It can be sunk quicker than a rectangular shaft**

b) Size of a Shaft :

- The size of the shafts depend on the following factors-
- (i) The purpose of the shaft, whether for raising coal or man, or pumping water, or ventilation, or stowing. etc. or combination of these.
- ii) The desired output from the mine and the type of winning. By the deputation of skips it larger output than would be possible with cage winding for a given shaft section.
- The degree of mechanisation of the mine required.
- The most economical size of a shaft is determined by careful consideration of all the costs involved, including capital COst of sinking and equipment, depreciation and interest charges, and running costs for power and maintenance.

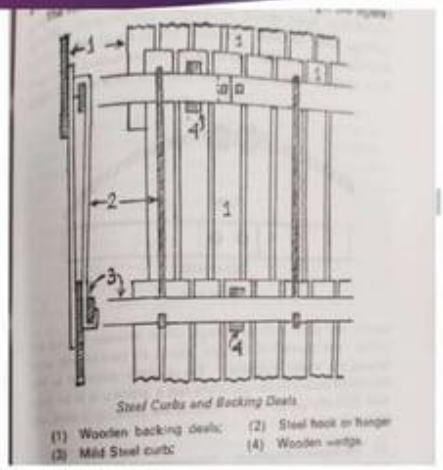
Shaft centering

- The precise position of the shaft centre may be fixed by lining out two cross-lines in line with the winding engine and at right angles thereto, being their point of intersection being the shaft
- station marks are formed by concrete pillars, 0.6 m square and 1m deep having iron bolts inserted into each pillar with centres marked as shown in the figure. The exact centre of the shaft may be found at any time by cross-stringing from these pillars.
- shaft's centre and inclination (i.e. verticality in case of a vertical shaft) are checked from time to time, by the use of a centering device
- The centering apparatus consists of (a) a centre pulley frame running in a guide rail, (b) a centre pulley, (C) a plumb- wire ieel, and When the apparatus is in use the accurate positioning of the (d) a rack and pinion device for sliding the frame into the shaft, centre pulley is ensured with the stop blocks provided for the purpose.



TEMPORARY SUPPORTS IN A SHAFT

- a heavy wooden frame or a frame of steel Frame for suspending Temporary Supports girder is built across the shaft top from which the temporary support is suspended.
- Temporary supports to the shaft sides may be done by a system of steel curbs or skeleton rings which have behind them a close lining of wooden backing deals or steel plates. The system of wooden backing deals is shownlin the figure :
- It consists of mild steel curbs or skeleton rings 100m x 25mm made in segments 3 m long and joined together by bolted lap joints forming the shape to the circumference of the shaft.
- The ring may also be of channel section for greater strength and joined by fish-plates.



Permanent Supports :

- A permanent support is necessary for at least one of the following reasons :
- (a) To seal off the country rock from the weathering effects of air and water and thus preventing the slabb- ing and flaking of the sides.
- (b) To support jointed and broken rocks.
- (c) To resist the static pressure of running ground such sands, alluvium, gravels, etc.
- (d) To seal off water and to resist its static pressure:
- (e) To prevent any damage or collapse of the shaft section due to bursting of rocks at great depths.

A)Brick walling.

- **Brick walling is a common practice for ordinary compact and moderately wet strata where the stresses are not high. First class, well burnt bricks (225mm x 115mm x 75mm) are commonly used. Usual thickness of brick lining may vary from 0.4m to 0.6m.**
- **A 150 mm thick la- yer of concrete is then laid down to form a perfect level bed. A walling curb or crib made of cast iron or of concrete is then set on the top of the hardened concrete.**

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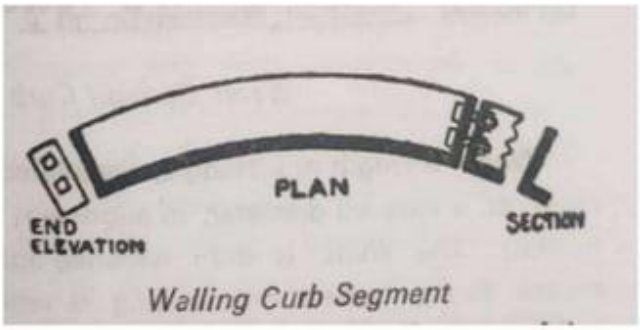
The brick walling is built up from this curb beginning with a thicker wall at the ledge and gradually decreasing to the normal thickeness. To ensure verticality of the brickwork, side plumb lines (auxiliary to the main central plumb line) are suspended in the shaft.



Walling Curb Segment

B)Monolithic concrete lining.

- **For monolithic concrete lining, concrete in the proportion of 1:2:4 (fresh cement: sand: coarse aggregate) is suitable for dry shafts. For wet shafts, richer mixture is preferable.**
- **To construct monolithic concrete lining, the hard rock from where lining is to commerce, is dressed and levelled in the same manner as for brick lining to provide a base. When erecting the lining it is necessary to retain the wet or plastic concrete in position by a shutterng.**
- **The first ring of shuttering is carefully centered and levelled**
- **precautions have to be taken to prevent the water from washing the cement out of the concrete before it has time to set and this may be done by use of C.G.I. sheets as back heering.**

Lighting in a Sinking Shaft

- **: In addition to electric cap lamps used by individual workers, a cluster of 4 to 6 bulbs, each 100 watt, 110 volt, electric lamp bulbs, enclosed in water-tight fitting with reinforced glass, is fixed at the end of an armoured cable for shaft bottom illumination.**

Freezing Method

- **This method is used when the sinking is proceeding through an unstable or friable Strata with heavy inrush of water, or sand connected with inflow of water**
- **essentially involves the formation of a large block of frozen ground in the water-bearing strata. The frozen block prevents the influx of water into the shaft.**

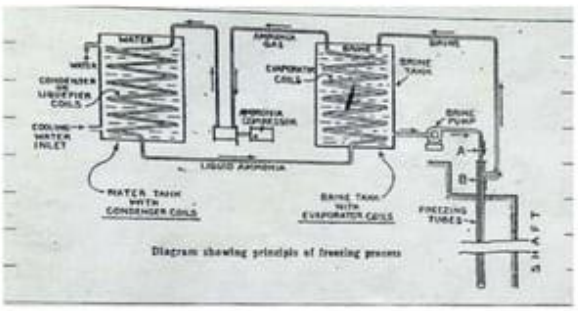


Diagram showing principle of freezing process

OPEN PIT DESIGN

CONTENTS:-

INTRODUCTION:-

An open pit mine is an excavation or cuts made at the surface of the ground to extract ore which is open to the surface for the mine's operational time. In order to expose and mine the deposit, significant quantities of waste rock have to be excavated and relocated (moved). As the lowest possible costs with maximum profits are highly expected, the planning of an open pit mine is closely related to economics, which in turn is influenced by several geologic and mining engineering conditions.

Open pit design is elaborated in several stages that consist of devising (planning) a scheme or set of alternative schemes, followed by an evaluation and selection of the optimum scheme. The most economic final pit design depends on factors that cannot be controlled by the mining engineer such as the

• geometric outline of the ore body,

• the distribution of ore within the ore body,

• topography,

• maximum allowable slope angles, etc.

TERMINOLOGY:-

BENCH: Ledge that forms a single level of operation above which mineral or waste materials are mined from the bench face.

Bench height: vertical distance between upper and lower surfaces of a bench. It is influenced by the size of the equipment, mining selectivity, government regulations and safety.

Bench width: a distance between crest and toe.

Face angle: An inclination of a face of the bench w.r.t horizontal.

Crest: is an upper point of a bench face.

Toe: is a lower point of a bench face.

BENCH SLOPE OR BANK ANGLE: Horizontal angle of the line connecting bench toe to the bench crest.

BERM: Horizontal shelf or ledge within the ultimate pit wall slope left to enhance the stability of a slope within the pit and improve the safety. Berm interval, berm width and berm slope angle are determined by the geotechnical investigation.

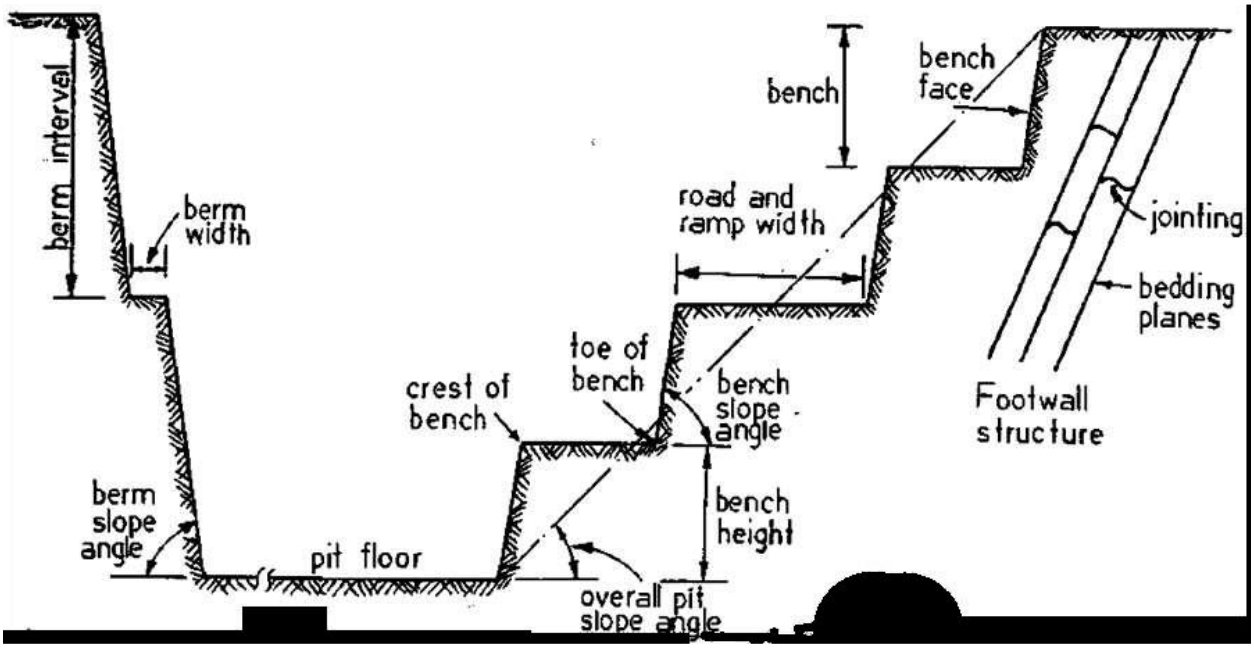
A working bench is one that is in the process of being mined.

Cut: The width being extracted from the working bench is called the cut.

Width of working bench (WB): It is defined as the distance between the crest of the bench and the new toe position after the cut has been made.

HAUL ROADS: During the life of the pit, a haul road must be maintained for access.

Overall pit slope angle: The angle measured from the bottom bench toe to the top bench crest. It is the angle at which the wall of an open pit stands, as measured between the horizontal and an imaginary line joining the top bench crest with the bottom bench toe. It is determined by rock strength, geologic structures and water conditions. The overall pit slope angle is affected by the width and grade of the haul road.



BENCH PARAMETERS:-

FACE: It is an exposed area from where the overburden or mineral/ore is extracted.

CREST: highest point of the face.

TOE: lowest point the face.

BENCH: the step or floor accommodating the mine machinery.

BENCH HEIGHT: each bench has an upper and lower surface separated by a distance “H” equal to the bench height. The bench

height is determined by the size of mining equipment and formation of the area.

The loose/soft rocks allows, bench height up to shovel reach.

In hard and very strong rock, bench height is usually 10-40 meters.

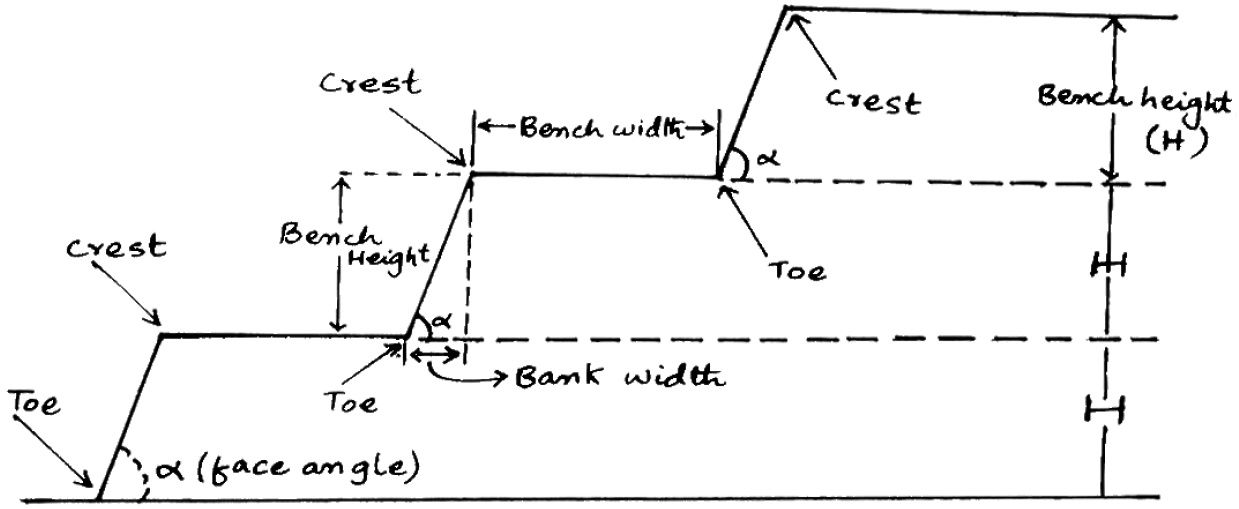
BENCH SLOPE: the bench slope or the bench face angle is the inclined plane of the bench made an angle with the horizontal. Or the average angle that a face makes with the horizontal. The exposed sub-vertical surfaces are known as bench faces. The bench faces are described by the toe. The crest and toe bench face angle ‘α ’. The bench face angle can vary considerably with rock characteristics, face orientation and the blasting practices. In most hard rock pits it varies from about 55^{O} to 80^{O}

BENCH FLOOR: The exposed bench lower surface is called as the bench floor.

BENCH WIDTH: The bench width is the distance between the crest and toe measured along the upper surface.

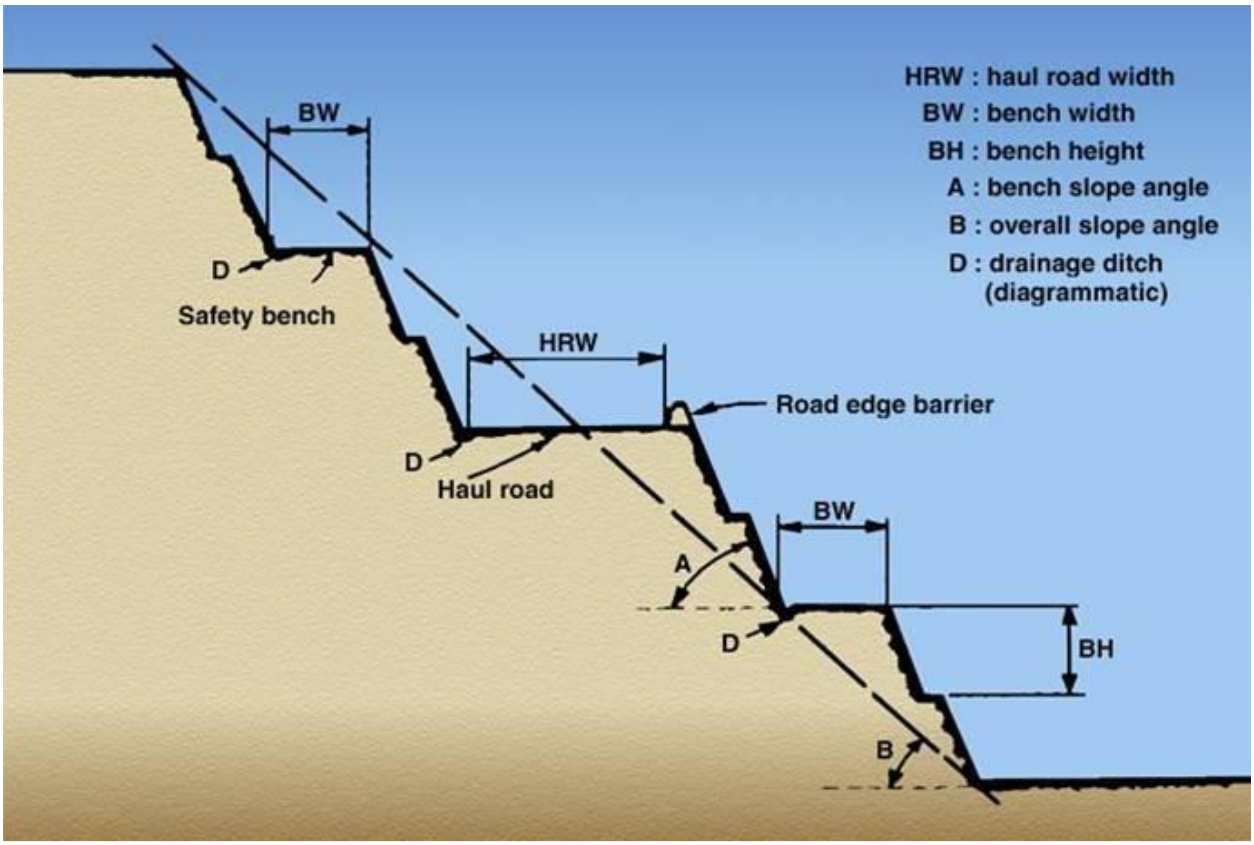
BANK WIDTH: It is the horizontal projection of the bench face.

There are several types of benches; a working bench is that one which is in process of being mined. The width being extracted from the working bench is called the cut. The width of working bench WB is defined as the distance from the crest of the bench floor to the new toe position after the cut has been extracted.



OVERALL PIT SLOPE: The *overall pit slope angle* is the angle at which the wall of an open pit stands, as measured between the horizontal and an imaginary line joining the top bench crest with the bottom bench toe.

Geometrically overall pit slope angle can be computed as follows:



STRIPPING RATIO:-

S**tripping ratio** or **strip ratio** refers to the **ratio** of the volume of overburden (or waste material) required to be handled in order to extract some tonnage of ore. It is expressed in m^3/te.

Stripping ratio = (m^3/te)

In designing an open pit mine another type of stripping ratio known as Break even Stripping ratio (BESR) has to be taken into account. This stripping ratio is directly related to the cost of whole mine which is an important parameter considered for open pit design.

BESR =

$$\frac{\text{Revenue from ore(Rs./te)} - \text{Cost of mining excluding Stripping cost}\left(\text{Rs./te}\right)}{\text{Stripping cost}\left(\text{Rs./m}^3\right)}$$

PIT SLOPE STABILITY:-

In open pit mines the stability of bench face (slope) has to be maintained throughout the life of the mine. For the purpose various measures are taken into account which include monitoring and stabilisation processes.

- The slope of the pitwall is one of the major elements affecting the size and shape of the pit.
- The pit slope helps determine the amount of waste that must be moved to mine ore.
- The pit wall needs to remain stable as long as mining activity is in that area.
- The stability of the pitwalls should be analyzed as carefully as possible.

In open pit mines the stability of bench face (slope) has to be maintained throughout the life of the mine. For the purpose various measures are taken into account which include monitoring and stabilisation processes.

- The slope of the pitwall is one of the major elements affecting the size and shape of the pit.
- The pit slope helps determine the amount of waste that must be moved to mine ore.
- The pit wall needs to remain stable as long as mining activity is in that area.
- The stability of the pitwalls should be analyzed as carefully as possible.

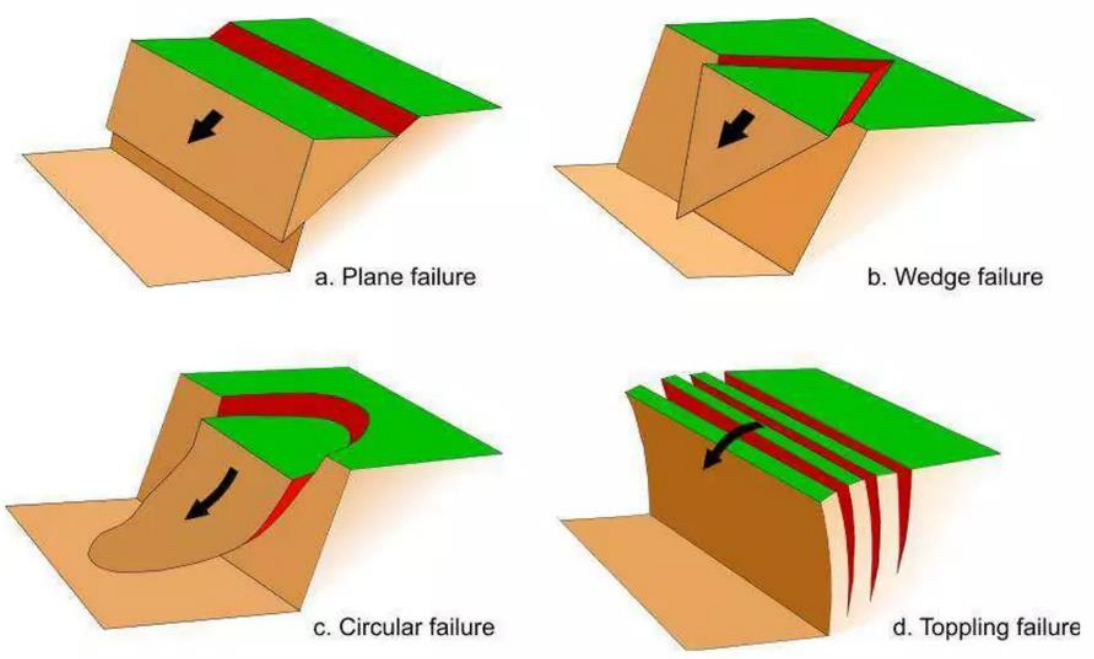


Figure. Simplified illustrations of most common slope failure modes.

FACTORS AFFECTING SLOPE STABILITY

- Geological discontinuities of Rock Mass
- Geotechnical Properties of slope
- Groundwater and Rainfall
- Geometry of slope

- State of stress
- Erosion of the Surface of the slopes due to Flowing Water
- Seismic effect
- Dynamic Forces due to Blasting and HEMM movement
- Slope modification, undercutting
- Presence of UG galleries.

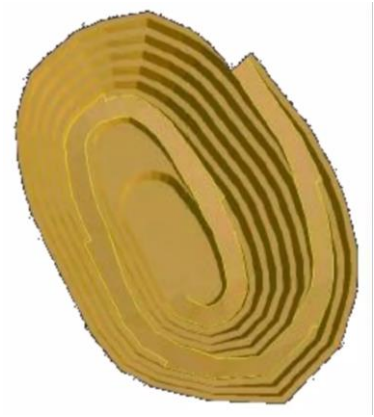
STABILIZATION OF SLOPE

- Drainage system – Surface Drainage system
  – Sub – surface drainage system
- Stabilization through Support – Ground inclusions
  – Ground anchor
  – Soil Nails
  – Rock Bolt
- Rock Mass Improvement and Stabilization Methods – Geosynthetics
  – Grouting
  – Chemical Stabilization
  – Biological Stabilization

HAUL ROAD DESIGN:-

HAUL ROAD: During the life of the pit a haul road must be maintained for access.

SPIRAL SYSTEM: Haul road is arranged spirally along the perimeter walls of the pit.



Consideration for Haul Road Design

- **Visibility**
- **Stopping distances**
- **Vertical alignment**
- **Horizontal alignment**
- **Cross – section**
- **Runaway – vehicle safety provisions**

WASTE DUMP DESIGN:-

Mine Waste Dump

- The Overburden of waste and uneconomic mineralized rock is required to be removed to mine the useful mineral resource in a surface mining operation.

- In this process a dump is formed by casting the waste material and dumping it in nearby area. The dump so formed is known as mine waste dump.
- Waste dump may be classified as internal and external dump.
- External dump is created outside the pit whereas internal dump is created inside back of the mining area.
- These waste rock dumps are heterogeneous in terms of grain size and structure.
- The optimum ultimate pit of a mine is defined to be that contour which is the result of extracting the volume of material which provides the total maximum profit whilst satisfying the operational requirement of safe wall slopes.
- The ultimate pit limit gives the shape of the mine at the end of its life.
- An ultimate pit limit looks for the blocks that will be mined and those that will not thus outlining the part of the deposit that can be mined economically and safely. In an effort to identify the blocks to be mined, an economic block model is created first from the geologic grade model.

The optimum ultimate pit of a mine is defined to be that contour which is the result of extracting the volume of material which provides the total maximum profit whilst satisfying the operational requirement of safe wall slopes.

The ultimate pit limit gives the shape of the mine at the end of its life. Usually this contour is smoothened to produce the final pit outline.

Ultimate pit determination in each period of time is a function of financial affairs. This function is well defined by Break-Even Stripping Ratio (BESR).

BESR= (Revenue per tonne of ore - production cost per tonne of ore) / Stripping cost per cubic meter of waste

Revenue per tonne of ore= grade* recovery* selling price per tonne of ore

Production cost= mining cost + processing cost