TUNNEL ENGINEERING

- POINTS TO BE DISUCCESED

- **Soft ground**
- **Methods of tunneling in soft ground**

TYPES OF GROUND

- HARD GROUND
  - Self supporting
- SOFT GROUND
  - Running ground
  - Soft ground
  - Firm ground
  - Self supporting ground

TYPES OF SOFT GROUND

- RUNNING GROUND : Required support immediately ,e.g. dry sand
- SOFT GROUND : Roof requires immediate support while sides can remain standing for few minutes.
- FIRM GROUND : Roof can stand for few minutes and sides for much longer time ; e.g. dry earth
- SELF SUPPORTING GROUND : remain unsupported up to short length

of 1.5 to 4 m. ; e.g. sand stone

FACTOR AFFECTING THE CHOICE OF A METHOD

- SIZE OF TUNNEL
- TYPE OF GROUND
- AVAILABLE EQUIPMENT
- METHOD OF SEQUENCE OF EXCAVATION

METHODES OF TUNNELLING IN SOFT GROUND

METHODES REQUIRING USE OF TIMBERS

- fore poling method
- Needle beam method
- Army method
- Belgian method
- English method
- American method
- Austrian method
- German method
- Italian method

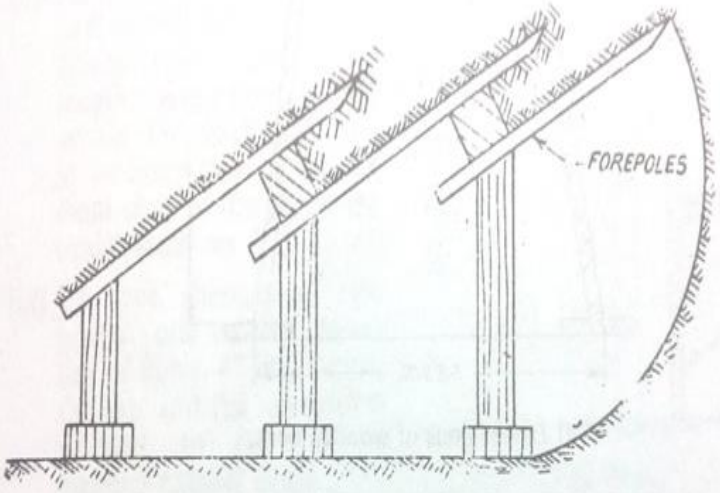
OTHER METHOD

- Linear plate method
- Shield method
- Compressed air method

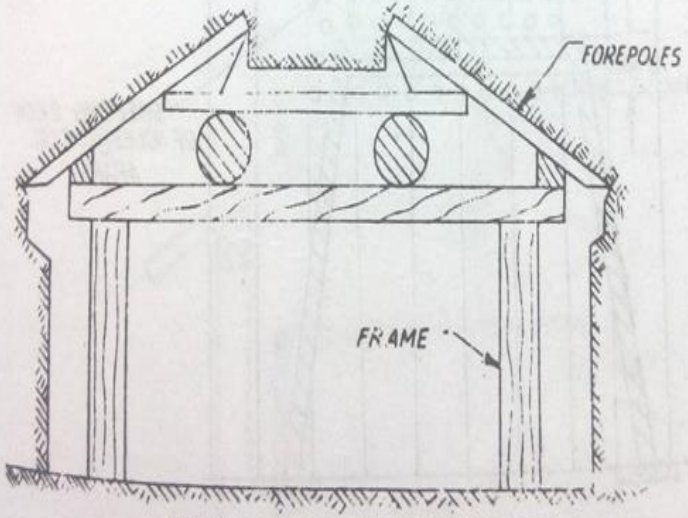
❖FORE POLING METHOD

- USED FOR RUNNING GROUND
- NOW REPLACE BY COPMRESSED AIR TUNNILING METHOD

- **SEQUENCE OF OPERATIONES FOR 1.52X1.52 MTR.**
- SUNKING OF SHAFT
- BENT IS PLACED FROM THE SHEETING
- HOLES ARE DRIVEN IN THE SHEETING FROM 7.5 C/C ABOVE THE CAP AND BELOW THE CAP.
- FORE POLE CONSIST OF PLANK WITH WEDGE ENDS ARE ENTERED ONE AT A TIME
- DRIVEN THROUGH HALF LENGHTH AT 15 CM/MTR INCLINATION

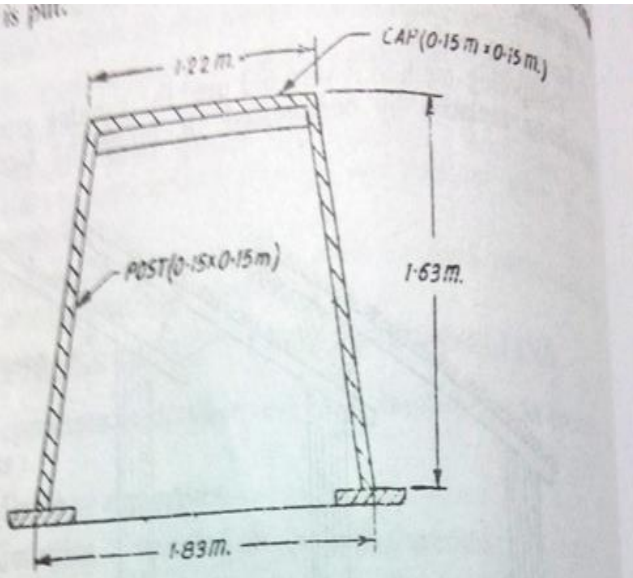


(*a*) Longitudinal poling-board system of roof supporting.

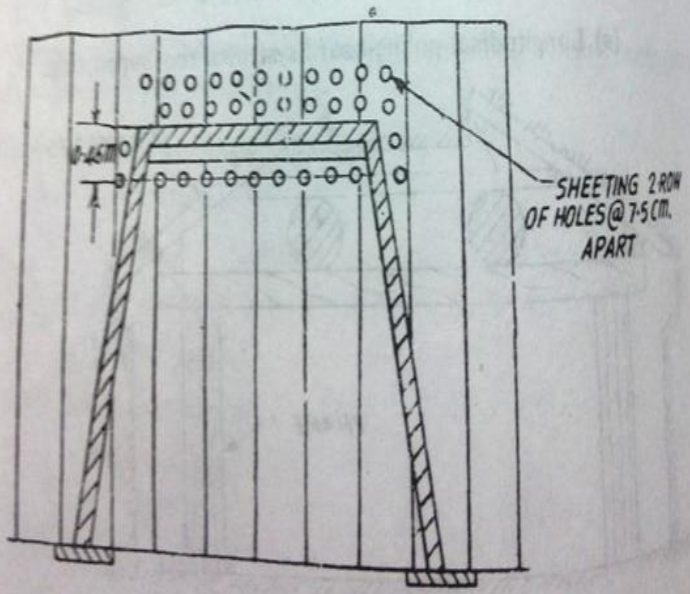


(*b*) Transverse poling-board system.

Fig. 69. Fore-poling systems for supporting roof.



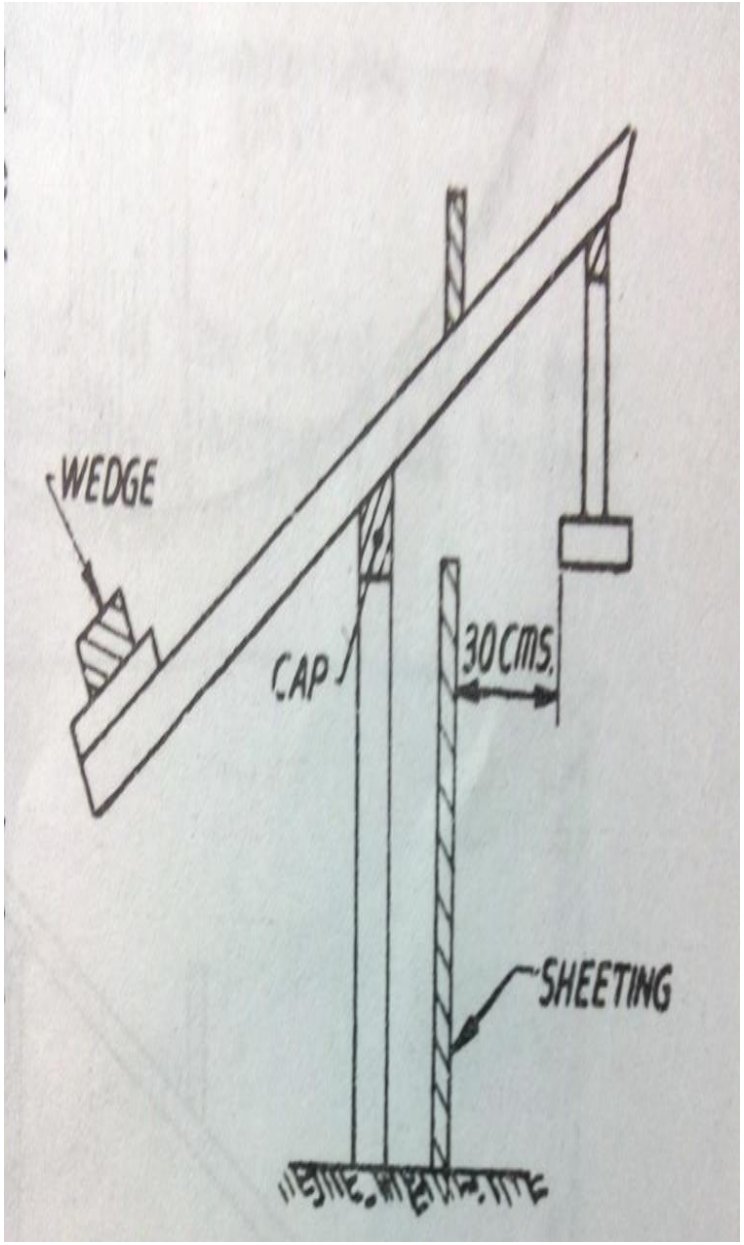
(*a*) Dimensions of wooden bent,

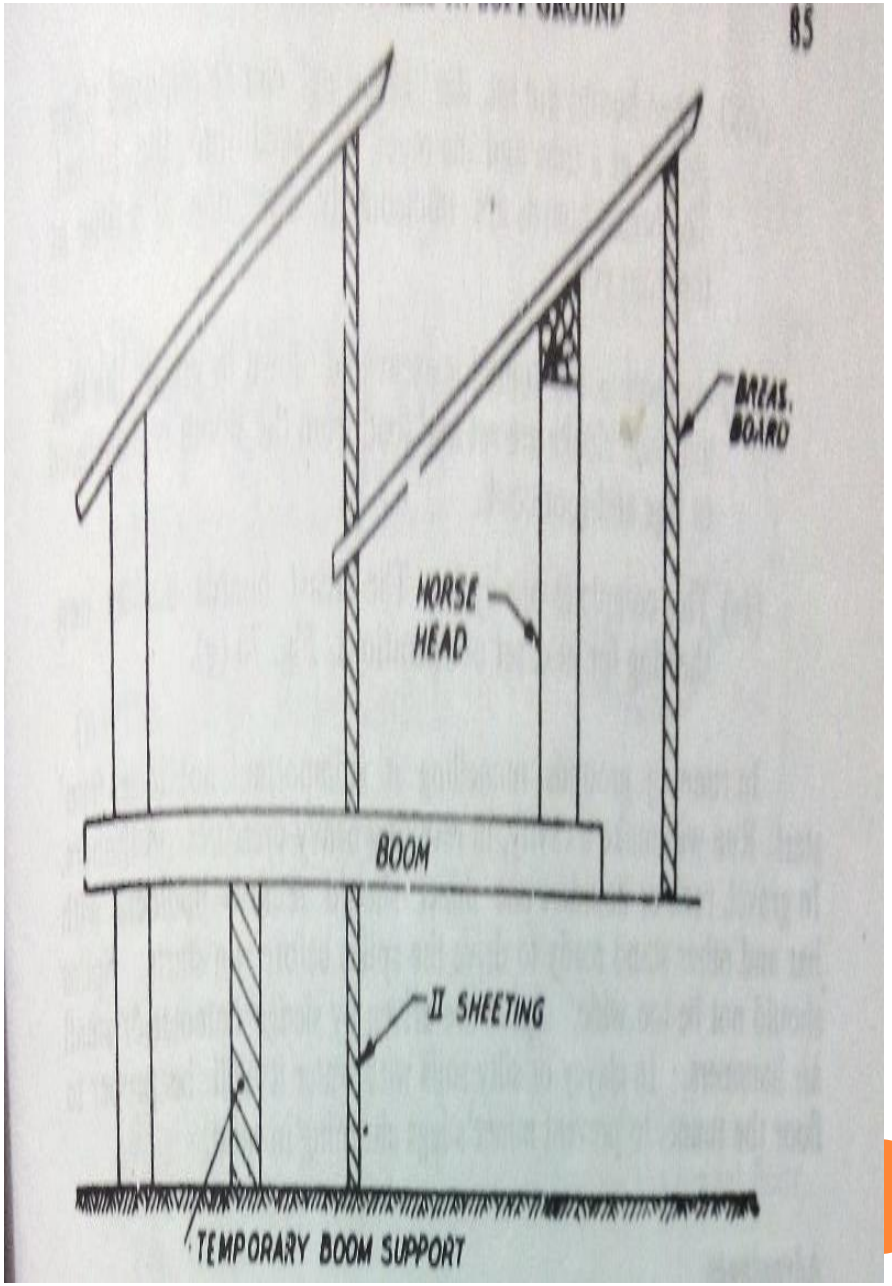


(*b*)

- TIMBER LAID AT THE END OF ALL SPLIES.
- FACE SHETTING BROKEN OUT AND GROUND IS ALLOWED TO RUN.
- PUT TEMPORARY SUPPORTS AT END CALLED HOURSE HEAD.
- THE OTHER END OF FOREPOLE IS SUPPORTED WITH BOARD OF SIZE 45 CM.
- NOW, REPEAT THE PROCEDURE AND INSERTED BOOM FOR THE SUPPORT OF BOARD.

- **MERITS** :
- USED WITHOUT COMPRESSED AIR
- USED FOR SMALL DIMENSIONS IN RUNNING GROUND
- **DEMERITS** :
- SLOW PROCESS
- USED ONLY FOR SMALL CROSS SECTION


WEDGE
CAP
30 CMS.
SHEETING


85
BREAS. BOARD
HORSE HEAD
BOOM
II SHEETING
TEMPORARY BOOM SUPPORT

NEEDLE BEAM

- IT CONSIST OF A STOUT TIMBER BEAM FROM MAIN TEMPORARY SUPPORT
- IT IS USED WHEN THE SOIL ROOF CAN STAND FOR A FEW MINUTES

- **SEQENCE OF OPERATION** :
- A DRIFT OF ABOUT 1 MTS. IS DRIVEN ON WORKING FACE
- ROOF OF THIS DRIFT IS LAGGED WITH SHEETING
- APPLY TREANCH JACK ON IT
- A NEEDLE BEAM OF 5 TO 6 MTR. IS INSERTED AND ONE END IS CARRIED ON PLANK AND OTHER ON STOUT POST.
- WITH HELP OF JACKS , DRIFT IS WIDENED SIDE WAYS

Fig. 71(*b*).

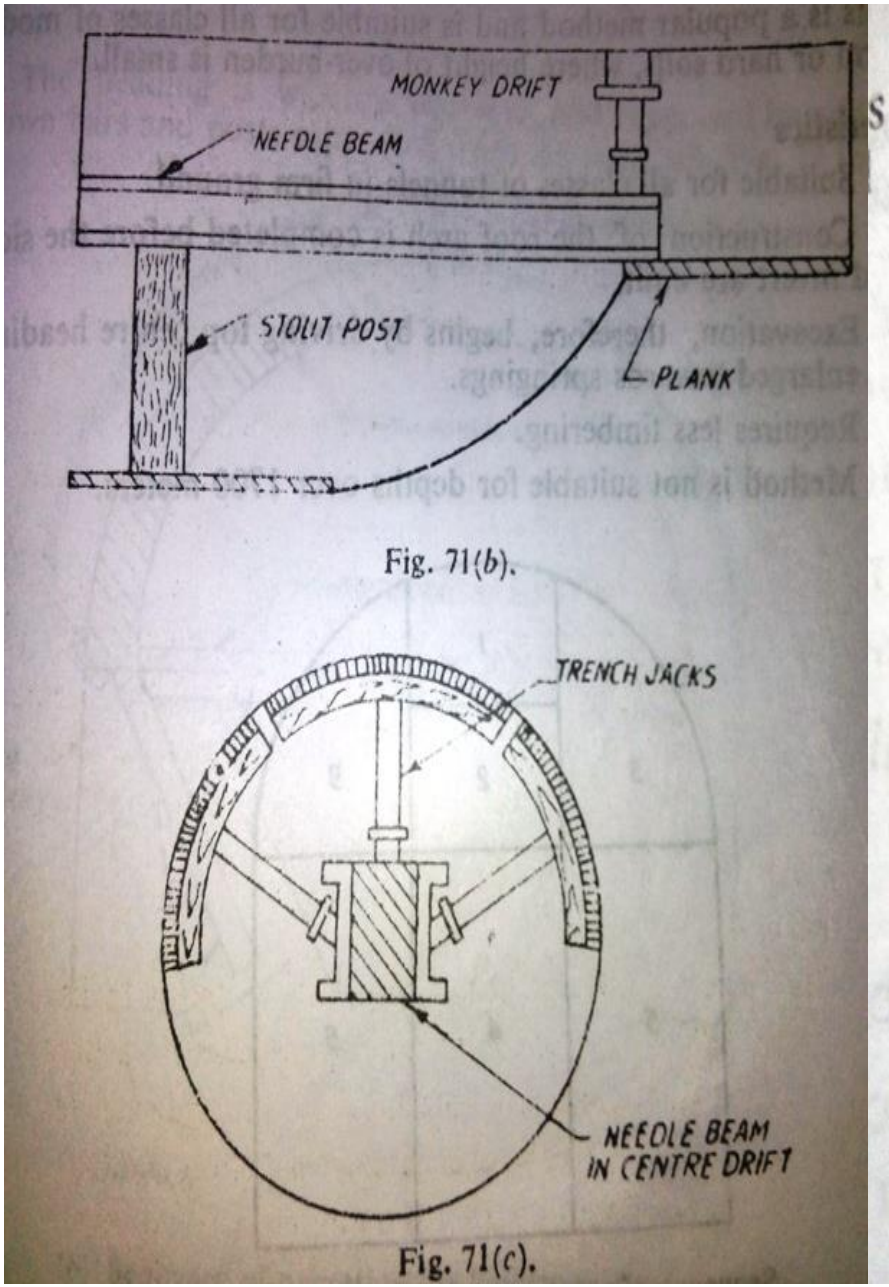
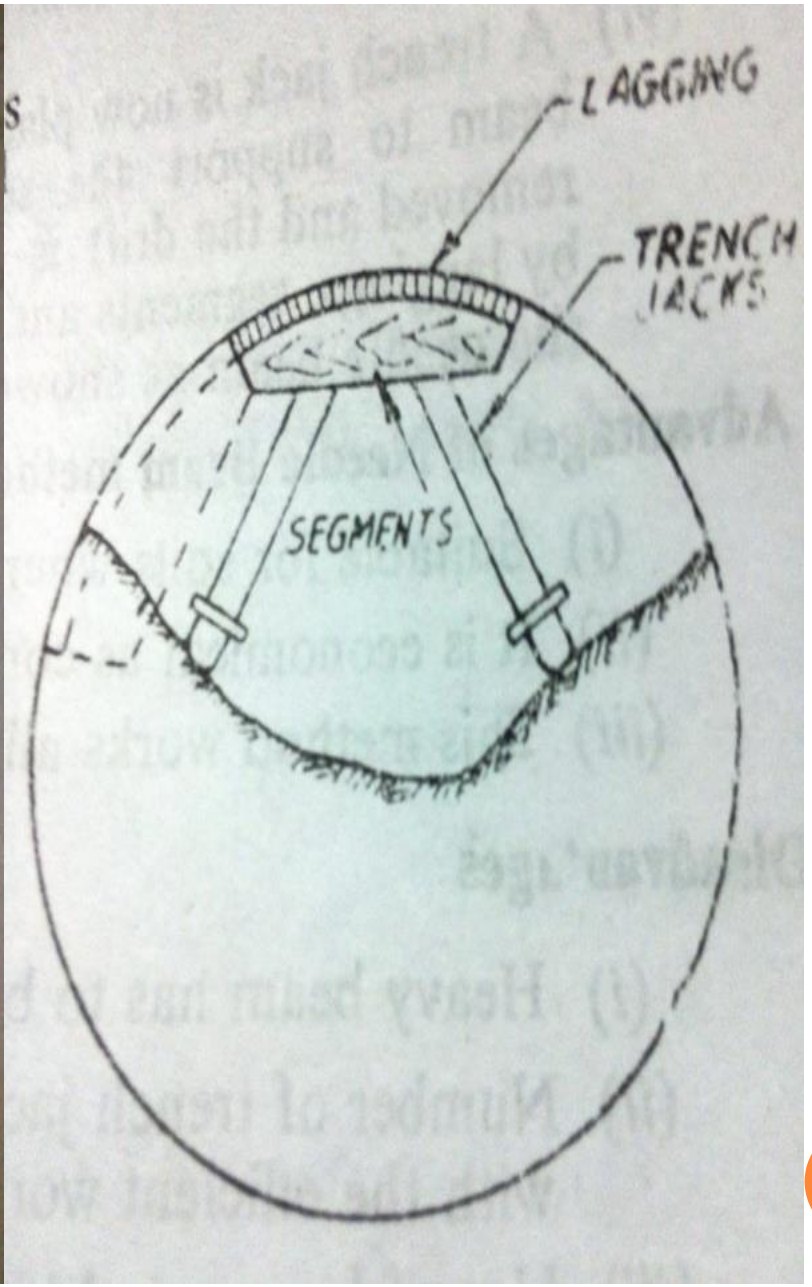


Fig. 71(*c*).



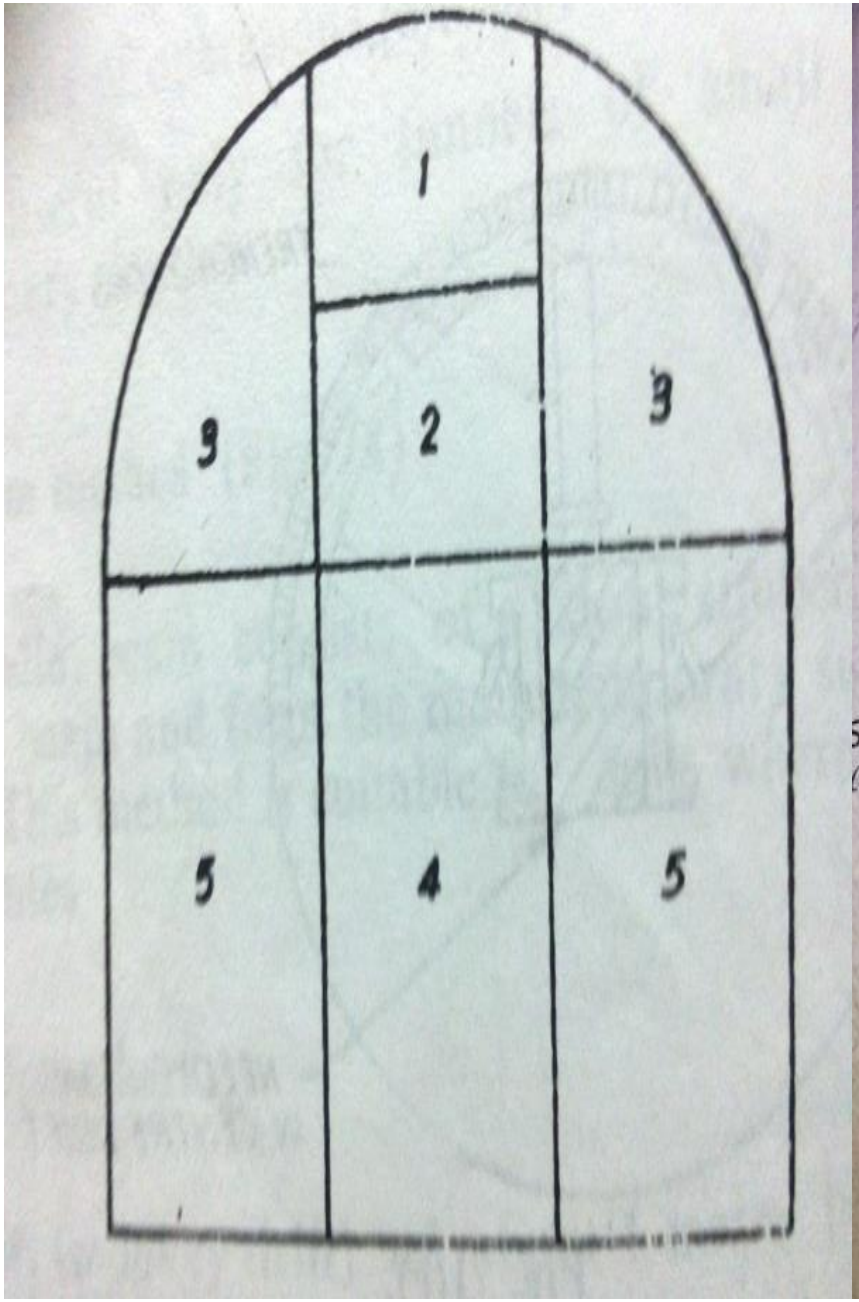
- **MERITS** :
  - ECONOMICAL
  - WORKS ALL RIGHT ON BRICK LINING

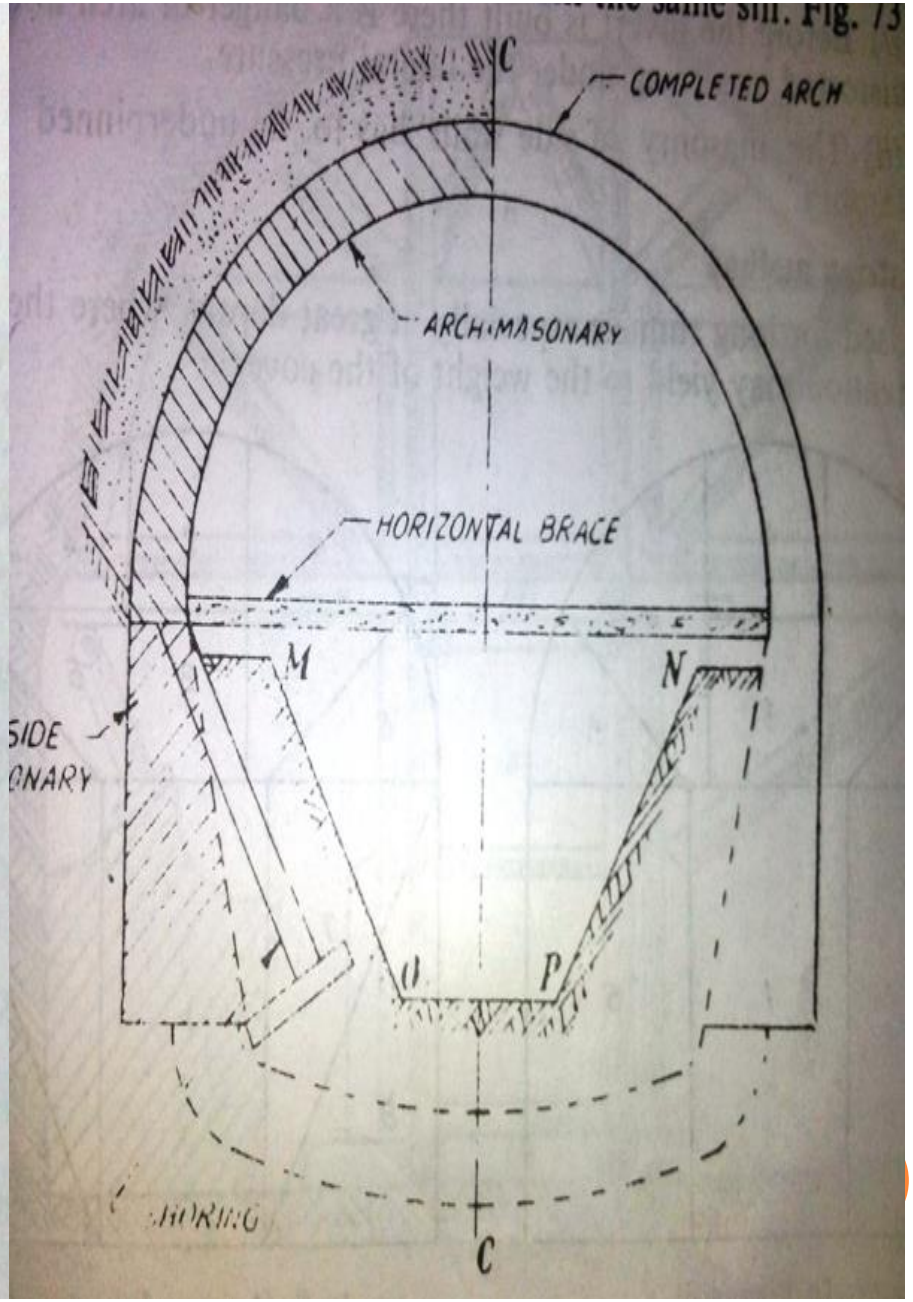
- **DEMERITS** :
  - HEAVY BEAM PUSHED FOREWARD BY HAND
  - NO. OF TRENCH JACKS REQUIRED
  - DIFFICULTIES IN CONCRETE LINING WITH MACHINE

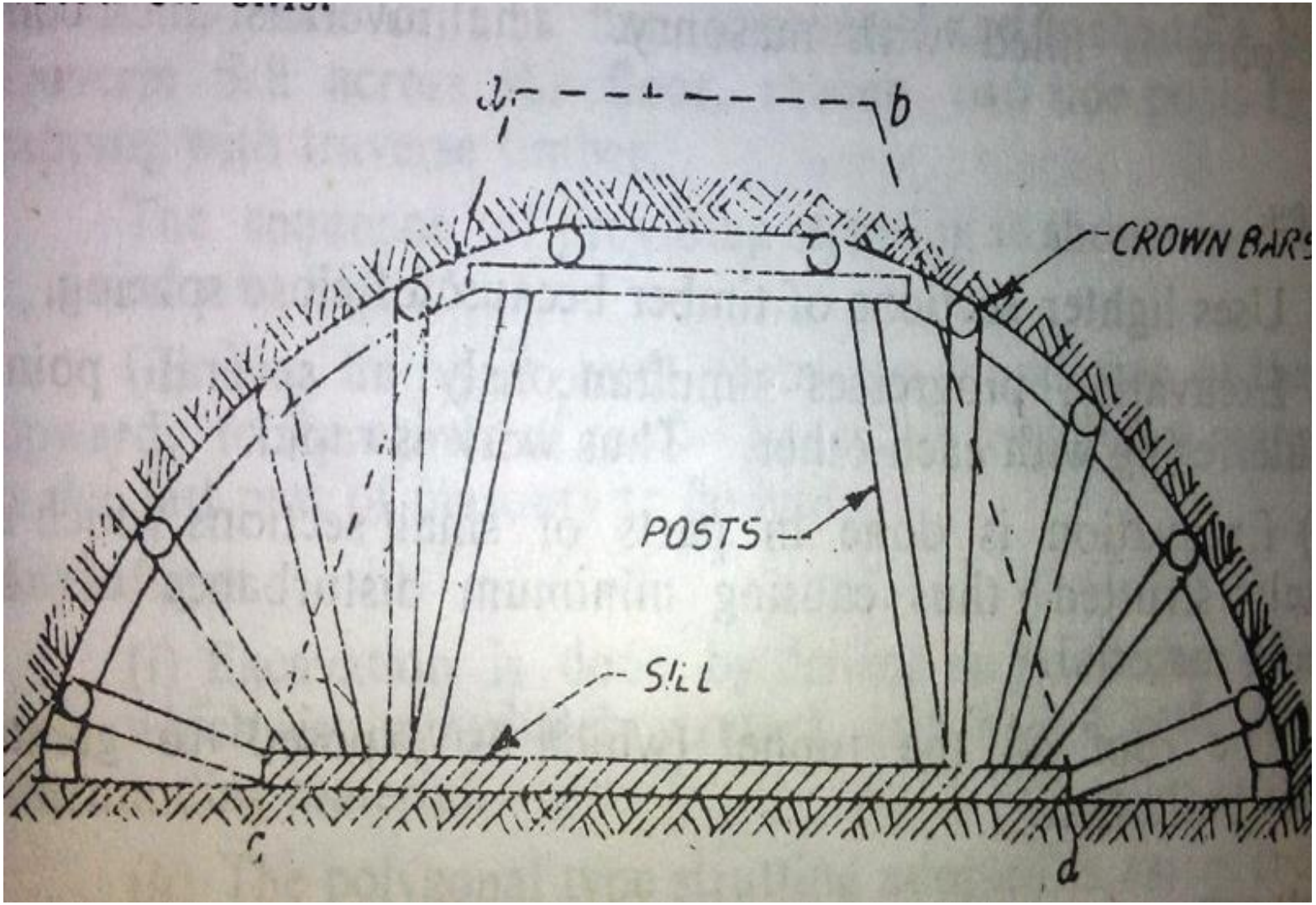
❖BELGIAN METHOD

- IT IS USED FOR MODERATELY FIRM OR HARD SOILS.

- **SEQUENCE OF OPERATION** :
- A TOP HEADING ABCD FOR THE FULL RISE OF THE ARCH IS DRIVEN & SUPPORTED.
- HEADING IS WIDENED SIDEWAYS , AND SUPPORTED BY ADDITIONAL CROWN BARS ON SILL.
- LINING THE ARCH
- INSERTED THE SHORE AT SIDE AND EXCAVATE THE MNOP.
- SHORING IS REMOVED AND SPACE IS FILLED WITH MASONARY.


1
2
3
3
5
4
5


C
COMPLETED ARCH
ARCH-MASONARY
HORIZONTAL BRACE
M
N
O
P
C

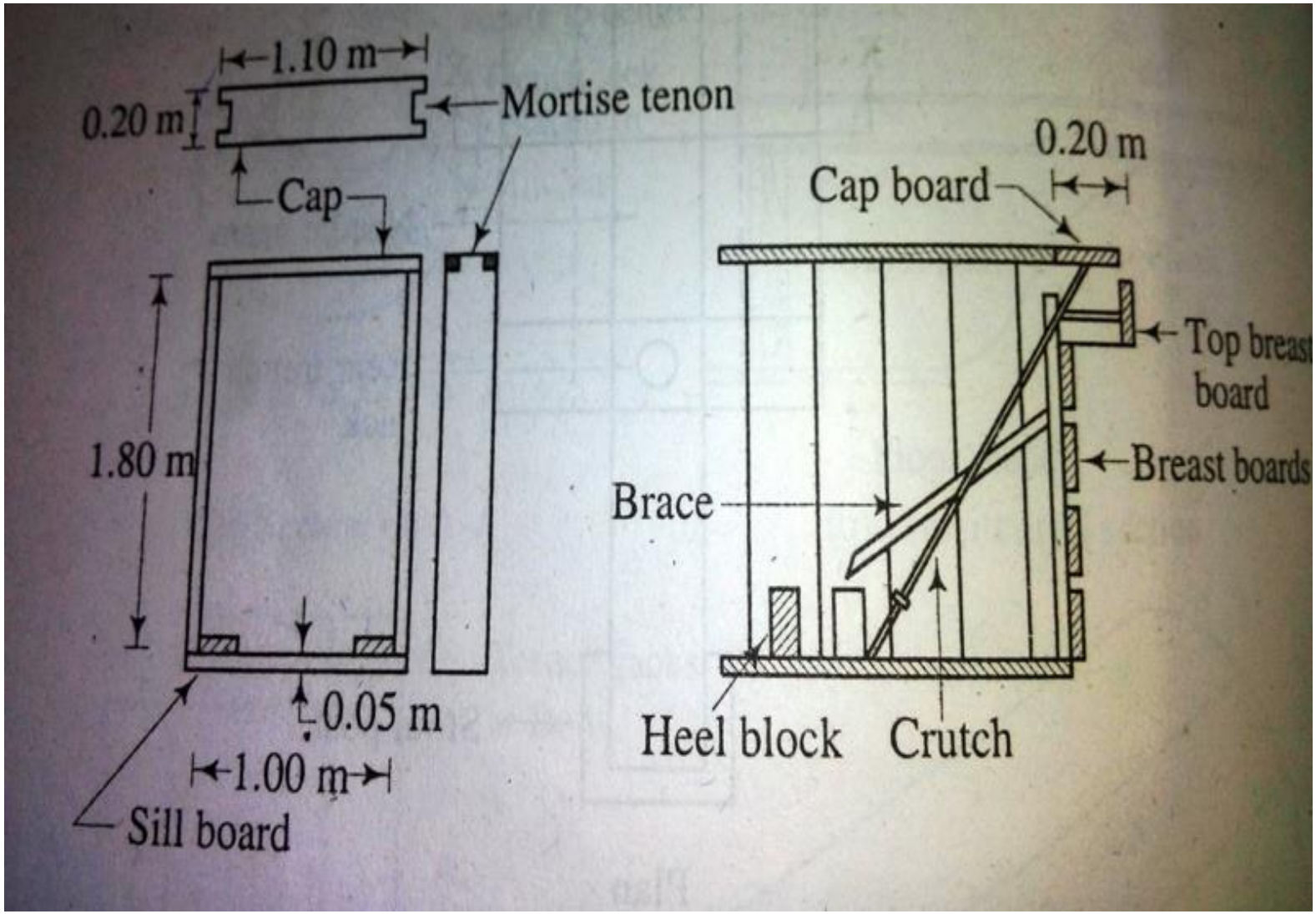

b
b
CROWN BARS
POSTS
SILL
c
d

❖ARMY METHOD OR CASE METHOD

- IT IS DERIVED BY USA ARMY FOR CONSTRUCTING SMALL TUNNELS AT SHALLOW DEPTH,

- **SEQUENCE OF OPERATION** :

- A COMMON GALLERY OF WOOD 1.1X1.8X0.05 MTR. OF WOOD IS USED.
- A TOP BRACED IS REMOVED AND GROUND IS EXCAVATED FOR A SHORT DISTANCE.
- THE BOX IS MOVED AHEAD AND SET NEXT CAP.
- AFTER THAT REMOVE THE BREAST ONE BY ONE AND EXCAVATE .


1.10 m
0.20 m
Mortise tenon
Cap
1.80 m
0.05 m
1.00 m
Sill board
0.20 m
Cap board
Top breast board
Breast boards
Brace
Heel block
Crutch

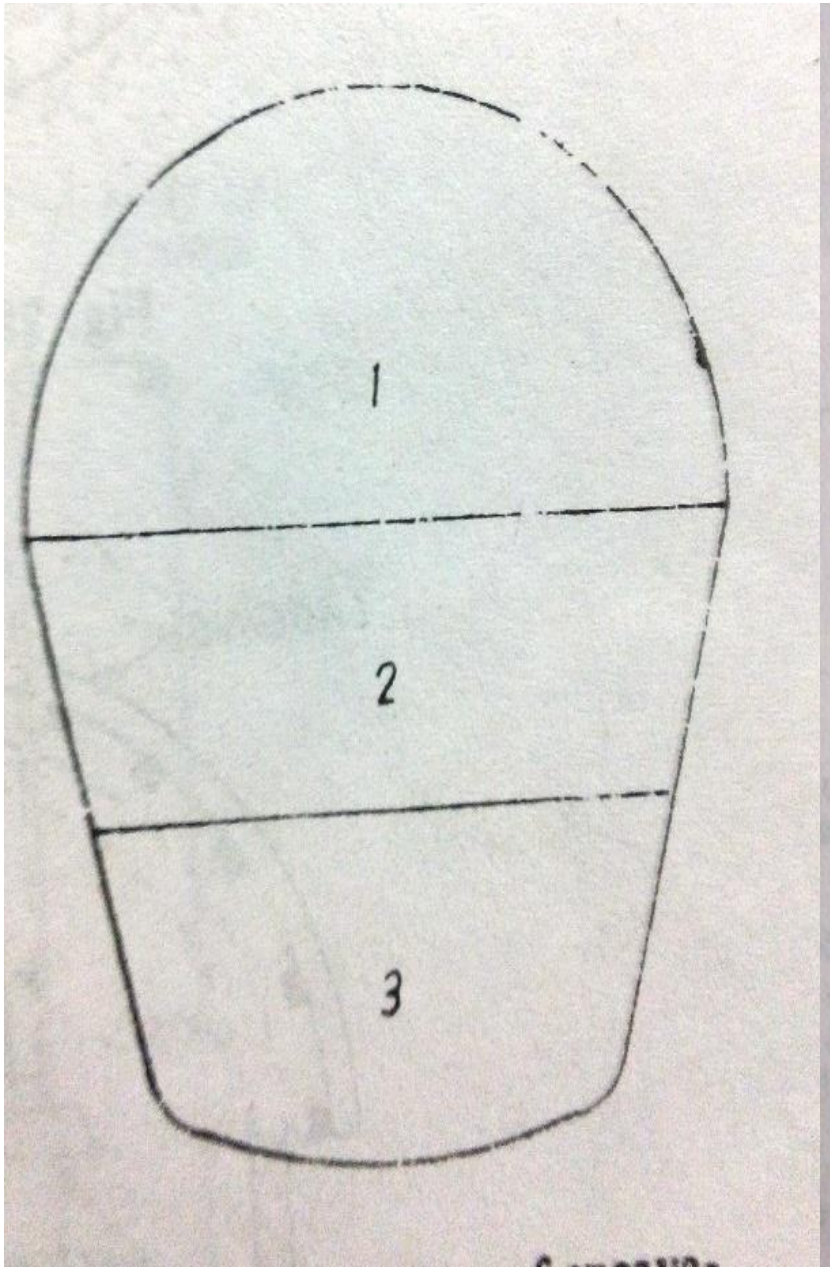
- **MERITS** :
  - SIMPLE,ECONOMIC
  - UNSKILLED LABOUR CAN DRIVEN

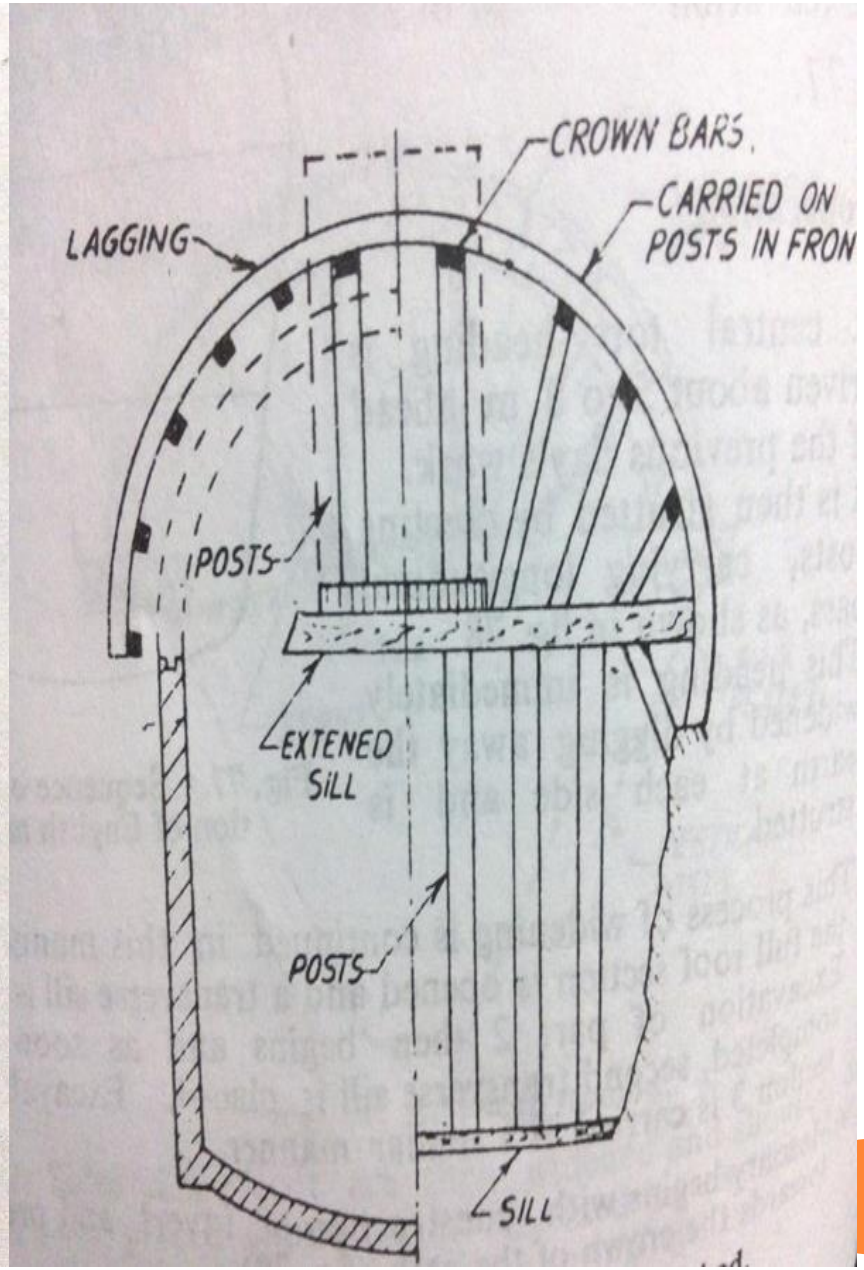
- **DEMERITS** :
  - ONLY FOR SHORT TUNNEL

❖ENGLISH METHOD

- THE MAIN CHARACTRISTIC OF THIS METHOD IS EXCAVATION OF FULL SECTION OF THE TUNNEL AT ONCE USING LONGITUDINAL STRUTING AND ALTERNATE OF MASONARY WORK AND EXCAVATION

- **SEQUENCE OF OPERATION** :
- TOP HEAD IS DRIVEN UPTO 5 MTR.
- IT IS SUPPORTED ON CROWN BARS
- THEN WIDENING OF THE HEADING IS THEN DONE BY DIGGING AWAY THE EARTH AT EACH SIDE.
- THEN STARTED EXCAVTION OF PART -2 AND PUT THE SILL
- PART -3 IN SAME MANOR AND STARTED MASONARY


1
2
3


CROWN BARS
CARRIED ON
POSTS IN FRON
LAGGING
POSTS
EXTENED
SILL
POSTS
SILL

- **MERITES :**
  - SIMPLE METHOD OF HAULING ARE POSSIBLE
  - MASONARY LINING IS BUILT , SO MAKING THE CONSTRUCTION STRONG AND HOMOGENEOUS.

- **DEMERITES** :
  - USE OF LOTS OF TIMBER
  - PROCESS ARE SLOWER DUE TO ALTERNATE OF EXCAVATION & MASONARY

❖AMERICAN METHOD

- IT IS USED FOR RAILWAY OR HIGHWAY TUNNELING

- **SEQUENCE OF OPERATION** :
- A TOP DRIFT IS DRIVEN AND SUPPORTED BY LAGGINGS,CAP TIMBER AND PARTS
- SIDE ARE WIDENED
- WALLS PLATES ARE INTRODUCED AT THE SPRINGING SUPPORTING THE ARCH SET
- VERTICAL POSTS ARE DRIVEN
- SIDES AND BENCHING ARE CLARED & TUNNEL LINING IS STARTED

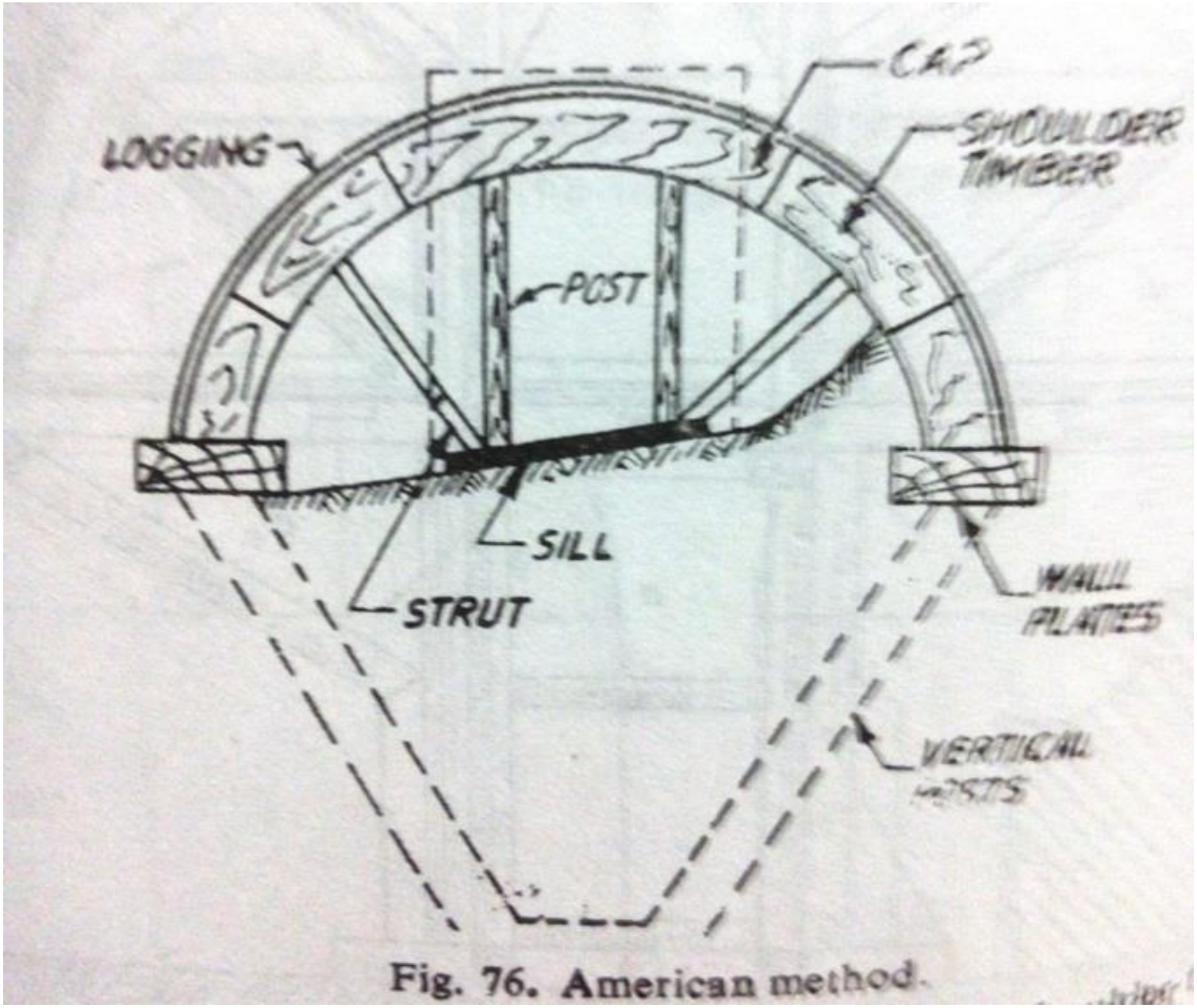


Fig. 76. American method.

❖LINING PLATE METHOD

- IT IS PRESENTED STEEL PLATES ,PLAIN OR CORRUGATED ARE USED TO SUPPORT THE SOIL DURING EXCAVATION.

- THE SIZE OF PLATES ARE 0.9 X 0.4 WITH FLANGE OF .05 MTR.

- THE PLATES ARE BOLTED TO EACH OTHER THROUGH HOLES IN FLANGE.

- **SEQUENCE OF OPERATION** :
- A HOLE OF 0.4 Mt. DEPTH IS CUT AT CROWN AND LINER PLATE " a" IS INSERTED.

- EXCAVATED SIDES AND PLACE “b” AND “c” PLATES
- NOW TWO WOODEN WALL PLATES OF SIZE ABOUT 20 CM. X 5 CM. AND PLACED ON EACH SIDE OF THE BENCH
- JACKS ARE REMOVED
- THE BENCH IS THEN CLEARED AND THE WALL PLATES ARE UNDER PINNED AT BOTTOM.

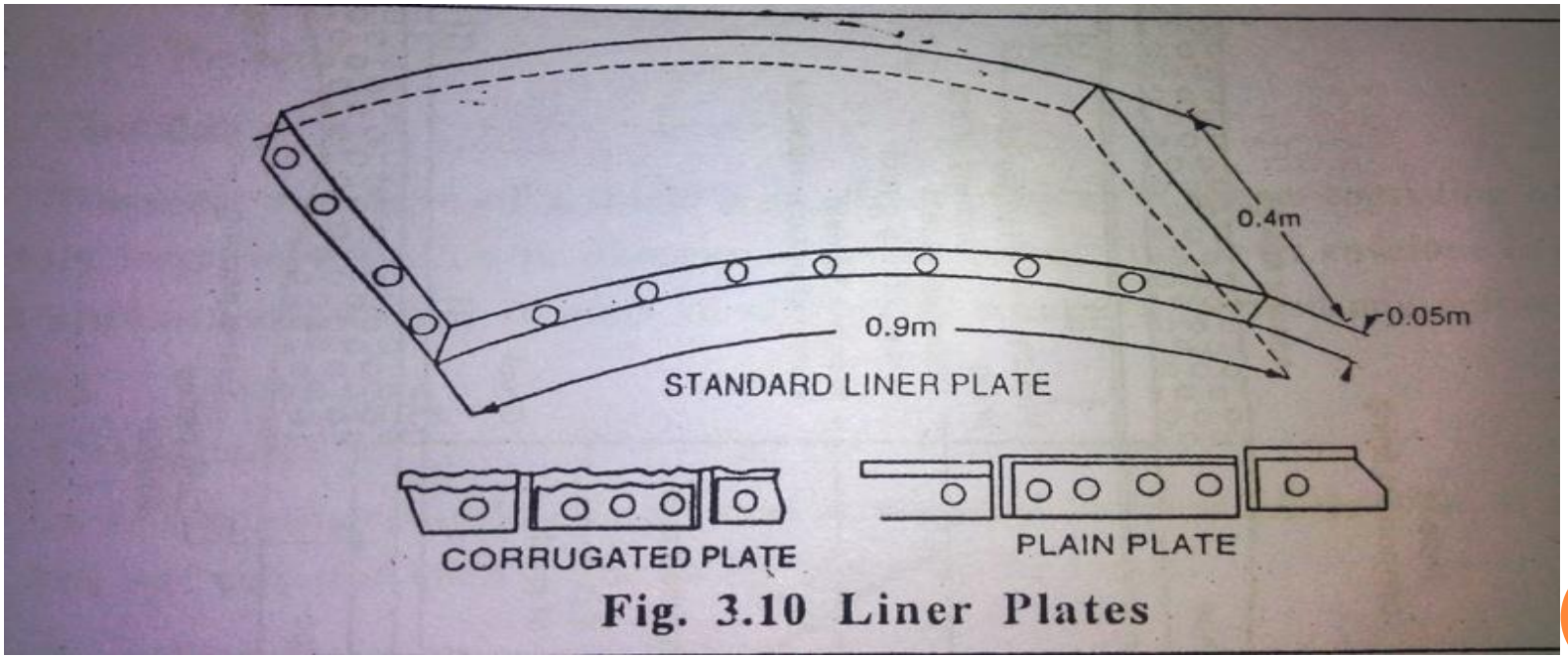


Fig. 3.10 Liner Plates

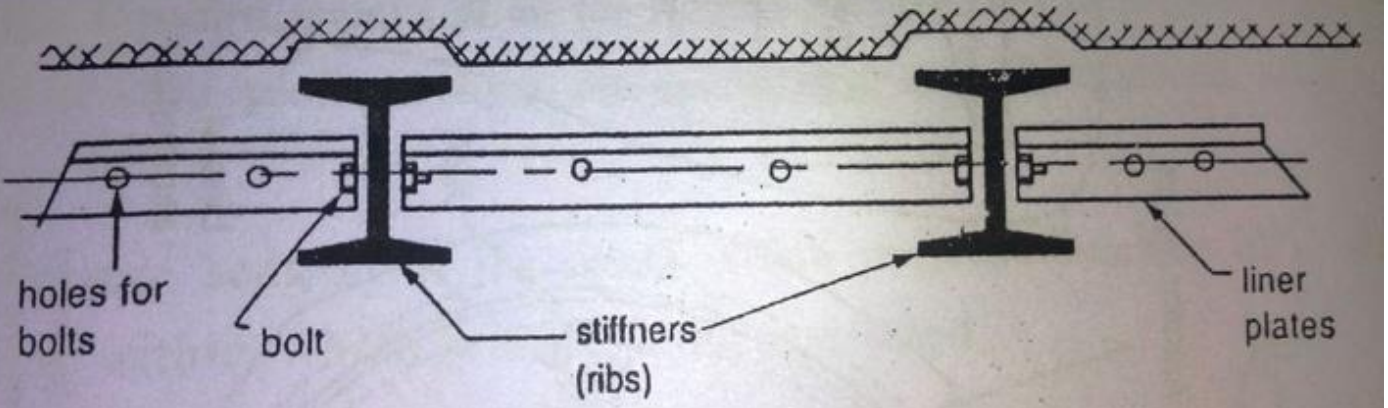


Fig. 3.11 Liner plates with stiffners

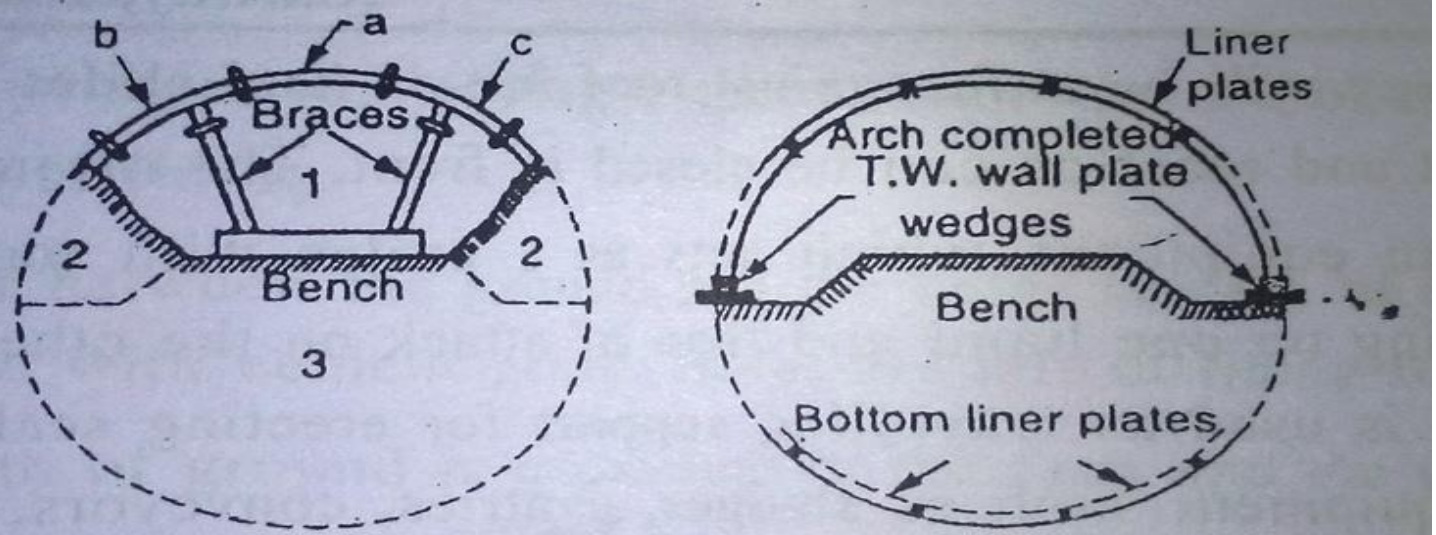


Fig. 3.12 Tunnelling with liner plate

- **LINEAR PLATE WITH STIFFNERES** :
  - FOR STRENTHEN THE PLATE “I” OR “T” SECTION RIB IS USED AS STIFFNERS.

- **MERITES** :
  - LIGHTER, ECONOMICAL
  - ERECTED WITH UNSKILLED LABOUR
  - FIRE PROOF
  - REQUIRE LESS NUMBER OF JOINTES

❖SHEILD METHOD

- IT IS USED FOR DRIVING A TUNNEL THROUGH WATER BEARING STRATA.
- IT IS AN EQUIPMENT WHICH ACTS AS A BRIDGE WITH ROOF FOR WORKERS.
- IT OPEN AT ONE END OR BOTH END.
- IT CONSIST SLEDGES , CONVEYORES ETC.

➢ **LENGTH OF SHEILD** :

1. STORAGE REQUIRED
2. PROBLEMES OF CHANGING DIRECTION

- **SHAPE OF SHIELD** :
  - RESISTANCE OF MOTION :

CONTECT AREA OF THE SHAPE

  - CROSS SECTION AREA / UNIT PERIMETER

FOR CIRCULAR AND SQURE=D/4

- RESISTANCE TO PRESSURE CAUSED BY SURROUNDING SOIL :

CIRULAR IS BEST

- PERMISSION FOR ROTATION OF SHEILD ABOUT ITS OWN AXIS :

CIRCULAR IS PREFERABLE

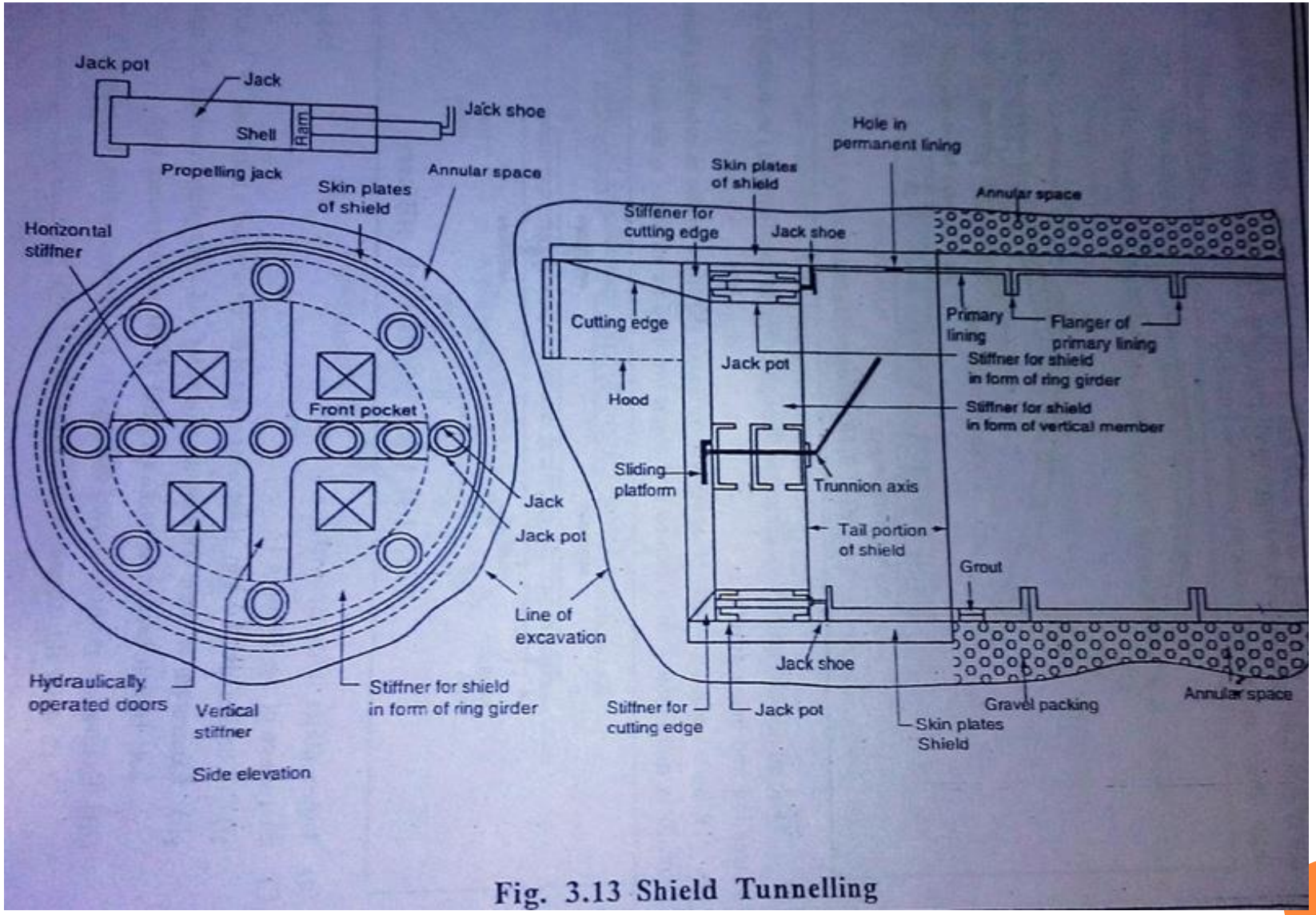


Fig. 3.13 Shield Tunnelling

- **COMPONENTES OF SHIELD :**

1. THE SKIN
2. CUTTING EDGE
3. PROPELLING JACKE
4. THE HOOD
5. THE TAIL
6. PART HOLES

- **SEQUENCE OF OPERATION :**
  - THE GROUND IS EXCAVATED AHEAD OF THE SHEILD OF .45 TO .75 meter.
  - THE SHEILD IS JACKED FORWARDE.

- **PRIMARY LINING** :
  - IT IS THE NAME GIVEN TO THE HEAVY CAST IRON LINING USED IN CONJUCTION WITH THE SHIELD.

- **SECONDARY LINING** :
  - 5 TO 7 cm. CONCRETE IS PLACED OVER THE FLANGE OF IRON.

- **MERITS** :
  - FULL DIMENSION AVAILABLE
  - SPEEDY
  - MOVING WITH CONSTANT SUPPORT TO THE ADVANCED TUNNEL.

❖COMPRESSED AIR METHOD

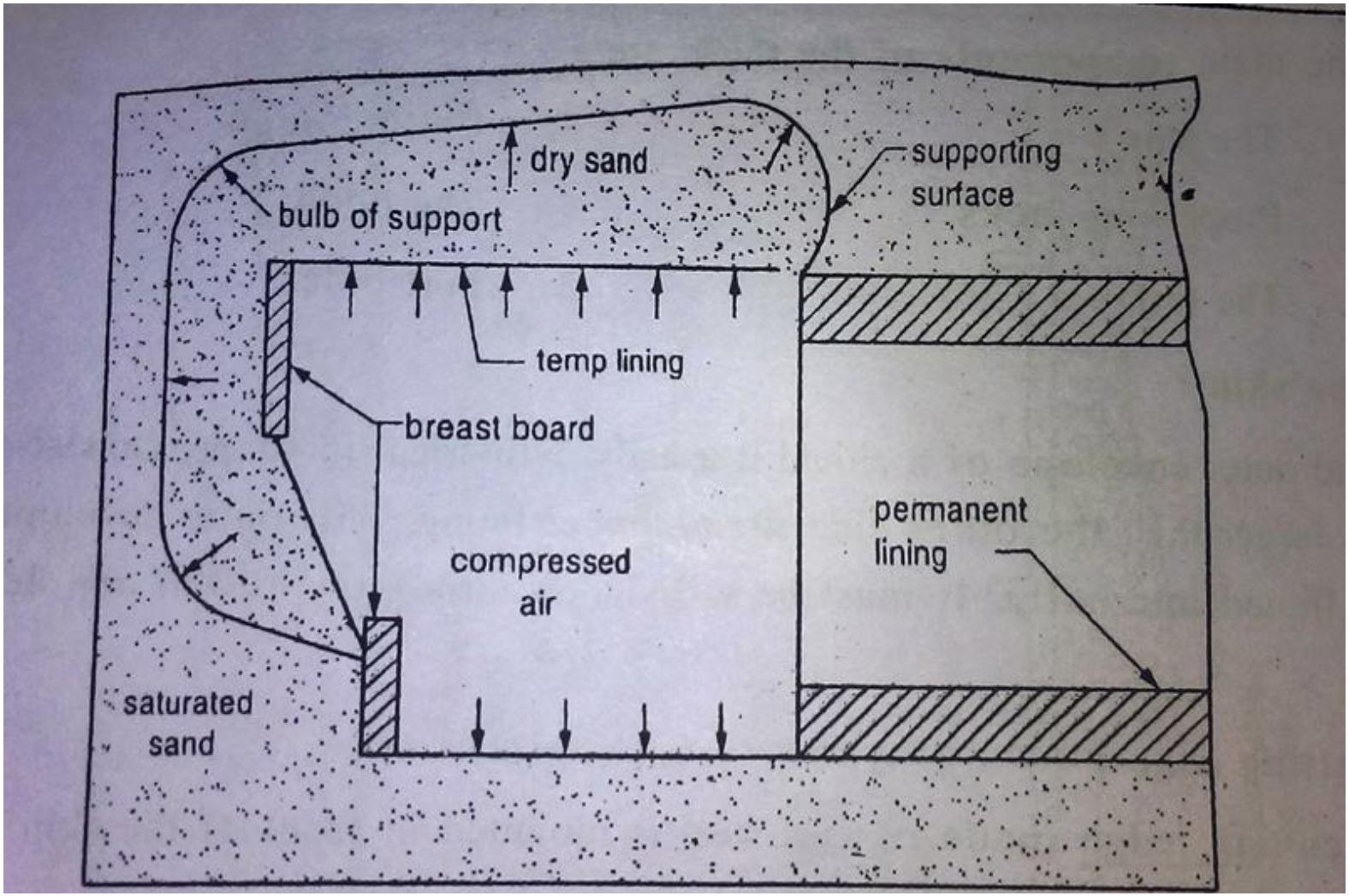
- USED OF COMPRESSED AIR
- USED IN SOFT GROUND

- **COMPRESSED AIR TUNNELING IN CLAY** :
- NO TIMBERING IS REQUIRED INSIDE THE TUNNEL

- PRESSURE REQUIRED INSIDE THE TUNNEL IS
  P = WH. ;0 W=WIEGHT OF SOIL

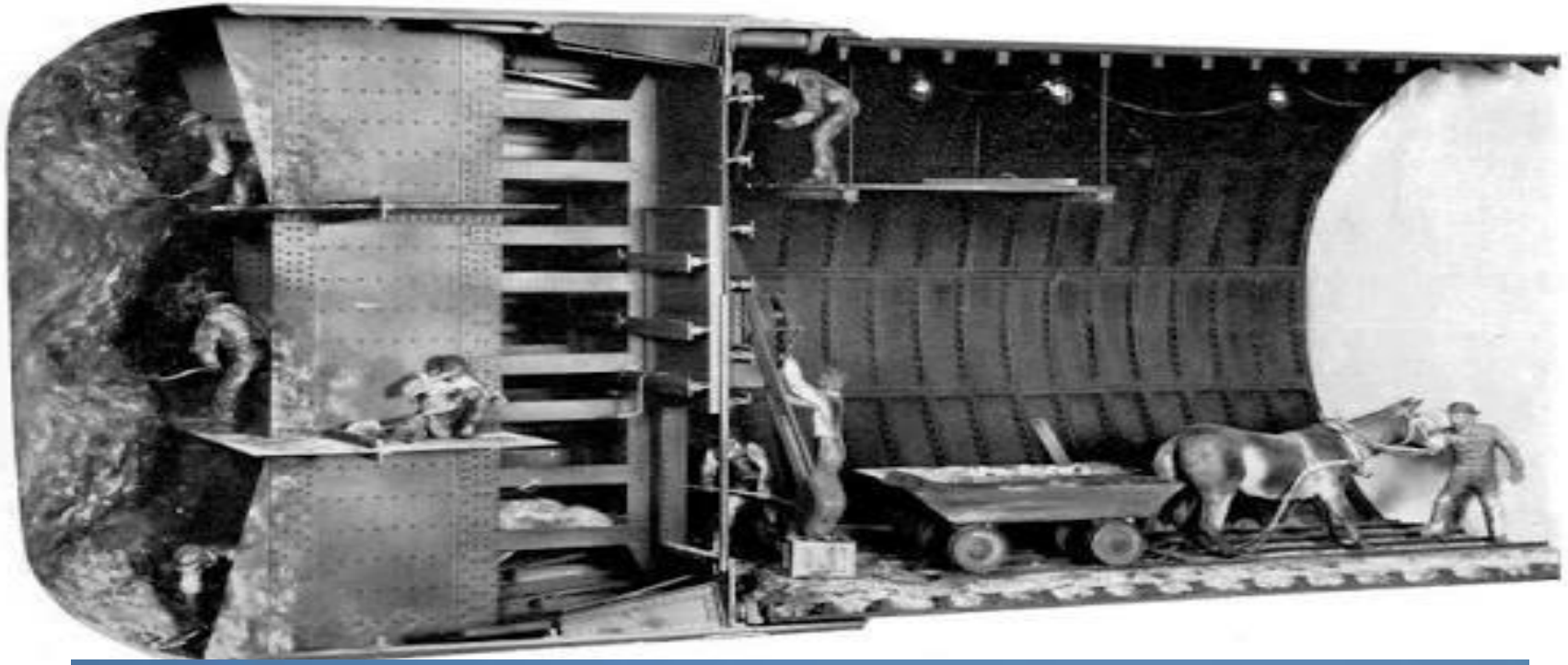
- **IN SILT** :
- DRY THE SILT,RESULTING IN CRACKING
- CHANGE IN PRESSURE REQUIRED

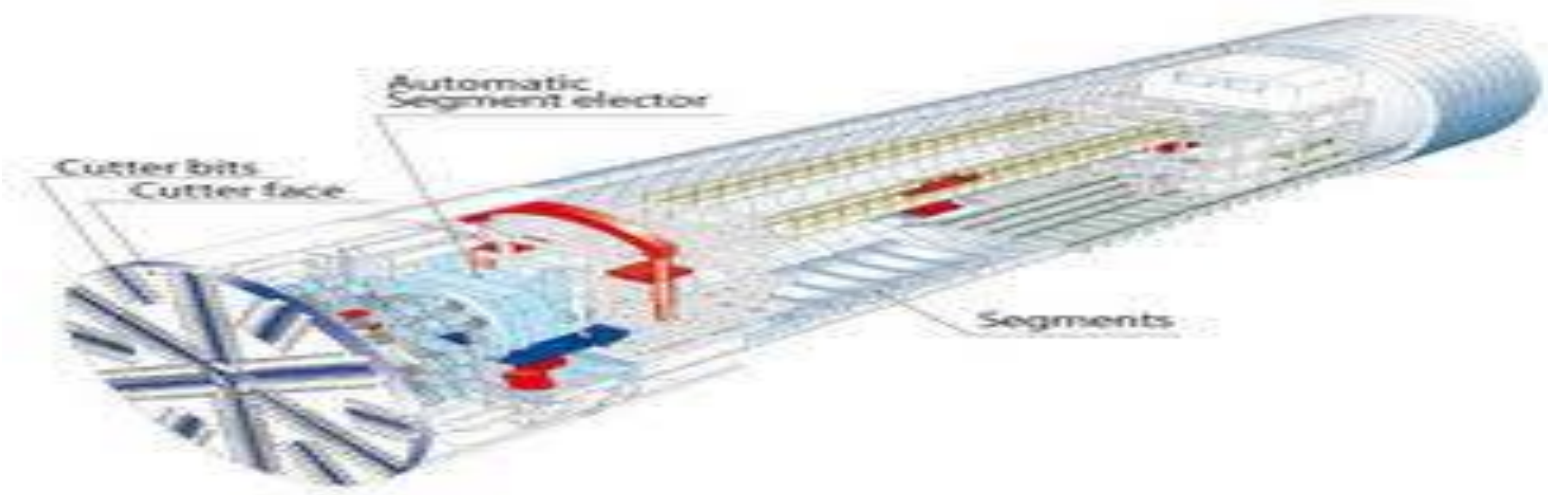
- **IN SAND** :
  - IT PENETRATES A CENTER DISTANCE AND EQUILLIBRIUM IS REACHED
  - THE BULB OF GROUND BENEATH THE MATERIAL IS ALL THAT REQUIRES THE TEMPORARY LINING SUPPORT.

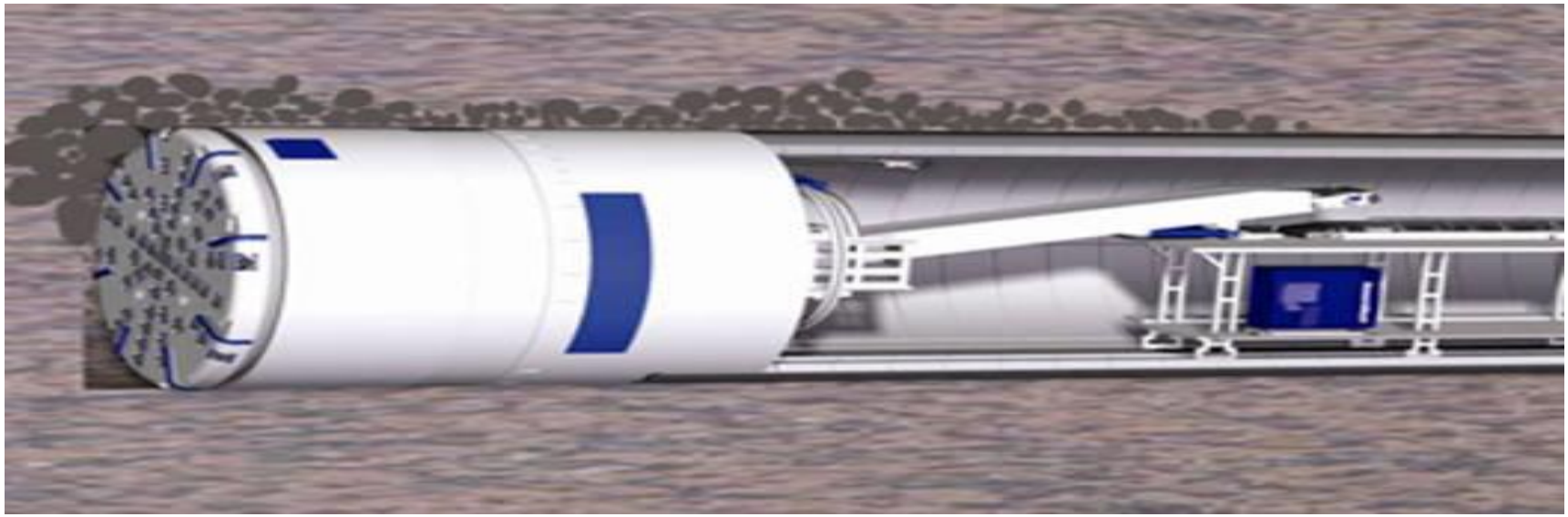

dry sand
supporting surface
bulb of support
temp lining
breast board
permanent lining
compressed air
saturated sand

- **EQUIPMENTES FOR COMPRESSED AIR TUNNELING :**
  - AIR LOCK & ACCESSORIES
  - BULK HEAD TO FIX AIR LOCK
  - BLOW LINE
  - AIR COMPRESSOR
  - GAS TRAPES

- **DURATION OF WORK IN COMPRESSED AIR FOR LABOURES :**
  - P = 12.5 Pa ;8 hr(BREAK 0.5 hr)
  - P= 14 TO 21 Pa; 4 hr (BREAK 2hr)




Automatic
Segment elector
Cutter bits
Cutter face
Segments



THANK YOU

Tunnel Engineering

Tunnel Engineering

Our points of discussion are,

- Lighting in tunnel
- Ventilation in tunnel
- Dust control
- Drainage of tunnel
- Safety measure in tunnel construction

Lighting

Why lighting is required?

- Various operations and activities in tunneling work can not be effectively and satisfactory carried out, if there is poor light in a tunnel.

- also for safety purpose

Good lighting is essential on the following place:-

- Where work in progress
- drilling and mucking zones
- Bottom of shafts
- Pumping stations
- Etc.

Types of tunnel lights:-

1. Lanterns and lamp burning oil

- Used in survey work and during the use of instruments.
- Carried in hand and burning gasoline is used to get light from them.

2. Coal gas lighting

- Coal gas is taken in a pipe from a gas plant and it is then burnt.
- Light------brilliant--------Steady
- Explosion take place-------if there is any leakage in gas pipe

3. Acetylene gas lighting

- Acetylene gas is used to produce light in tunnel. Acetylene lamp.
- Not common at present.(This method)

Acetylene gas is too dangerous..

- 4. electric lighting

Popular source at present

Steady and brilliant light

Do not consume oxygen

Absence of smoke

Wires and lamps are easily put and removed

Spacing of lights:-

- Spacing of lighting should be such that whole tunnel is uniformly lighted.

↓

Difference in the intensity of light ------ outside & inside

↓

Darkening effect is to be filled by some one else who is entering in the tunnel.

- Desirable → put more lights of small wattage .

- If few lights of large wattage is used

Formation of dangerous dark spot------due to more variation of intensity in outside and inside the tunnel.

- Spacing of light along the tunnel depends upon

- Tunnel dimension
- Size of light source
- Rock condition:-limestone(light color)
  lesser no. of light
  Required.

Lights is mounted

- Either at directly on the whole or in recesses in wall at suitable heights.

Ventilation in tunnel:-

What is ventilation?

- Ventilation means technique of providing fresh air inside the tunnel during and after construction.

Why ventilation is required?

- To furnish fresh air for the workers
- To remove obnoxious gases and fumes produced by explosives.
- To remove the dust caused by drilling, blasting and mucking operation.
- To reduce the temperature.

Requirements of a ventilating system:-

- Fumes and smokes must be clear as early as so that work can be resumed after blasting.
- It must prevent accumulation of fumes along the tunnel.
- Workers can do their job safely and comfortably.

- During working ,each worker should be supplied with a minimum of 8.4 cu.m. (300 cu.ft.) of fresh air per minute constantly in working area.

This depends upon various factor…

Method of ventilation:-

- Tunnel ventilation can be carried out by the following methods:-

1. Natural ventilation
2. Mechanical ventilation

1. **Natural ventilation:**

- Due to temperature difference inside and outside the tunnel.
- Achieved by providing shafts at suitable interval.

- Suitability:-
- When diameter of tunnel is large but length is small.
- When tunnel orientation is along wind direction.

2. **Mechanical ventilation:-**

- Achieved by one or more electric motor driven fans which may blow fresh air into a tunnel or exhaust the dust and foul air from tunnel.
- Mechanical ventilation provided by,

- Blowing (Blower fan mounted in one or more input shafts)
- Exhausting
- Combination of blowing and exhausting (Reverse fan is to be used)

Dust control in tunnel:-

- In drilling ,blasting ,loading and hauling muck operation

- Dust accumulates in the air in tunnel

- Excessive concentration causes serious health hazard. Ex. ‘silicosis’

- Methods of Dust controlling:-

For to minimize dust accumulation.

1. Wet drilling.

- Modern drilling machines carry arrangements by which water could be used to wet and this prevents dust flying to a considerable extent.
- Quantity of water forced into the hole will depend on the speed of the operation and the class of drill used in the process.
- Give fairly good results and widely used in practice.-------completely dust proof condition is not possible.

2. Use of vacuum hood.

- Where use of water may be undesirable or impracticable , a hood is fitted around the drill steel at rock face, which is connected to a exhaust pipe.

- Through which the drilled rock dust is sucked and removed safely out of the tunnel.

3. Use of respirators

- Well designed respirators worn by the miners offer the best and most up-to-date protection against dust inhalation.

- This method which is becoming increasingly popular in modern tunneling practice.

Drainage in tunnel:-

- Definition:-
- 'Drainage of tunnel' means controlling of water during and after the construction of the tunnel.

Mainly Water comes from two source

1. Wash water—used for washing drill holes.
2. Ground/sub soil water

- The quantity of water obtained from the first source can be easily determined.

- But the calculation of quantity of water obtained from the second source requires careful investigation.

Drainage system:-

temporary drainage system

-open ditch drainage System
-pumping System

permanent drainage

- central drain system
-corrugated sheet roof with side drains
- single side drain system

A. Temporary drainage system:-

- This system is employed during the construction of a tunnel.
- It can be either open ditch drainage system or drainage by pumping.

(1) Open ditch drainage system:-

- Simplest method
- Water may be moved in open ditches with proper slopes.

- Path of water moving

Open ditch--------portals and shafts ------ pumped out

Disadvantages:-

- Consume valuable working space.
- It may not be practicable if proper drainage is not available for self drainage.
- Pools of water may be formed if ditches get blocked with muck or debris.

so

in modern tunneling, **pumping system** is preferred.

(2) Pumping system:-

- In this system, quantity of water that accumulates is collected in sump well and pumped out of the tunnel.
- For long tunnel, it may be necessary to have more than one sump well.
- Usually sumps are located at regular interval of 300 mm to 500 mm , a series of pump at each sump , will pick up the water and pumps back to next sump.

- The diameter of pipe line varies from 5 cm to 25cm depending upon amount of water.

B. Permanent drainage system:-

- The permanent drainage system is provided in the completed tunnel section, to save the pavements and railway track.

- Types:-

1. Central drain system.
2. Corrugated sheet proof with side drains.
3. Single side drain system.

1. Central drain system:-

- This system is suitable when the water coming through roofs and the side walls of the tunnel is sufficiently low.

- This is constructed longitudinally sloping towards the portals or shafts from where they could be pumped out by suitable pump.

2. Corrugated sheet roof with side drains:-

- This system is suitable when seepage is small and comes down from the tunnel roof.
- The seepage water is allowed to flow over a temporary pitched roof of corrugated sheets, shedding the water into the side drains.
- Expensive(iron shed are subjected to corrosion.)

3. Single side drain system:-

- This system is adopted where, the quantity of water entering the tunnel is small.
- This method is adopted in case of tunnels carrying a single lane highway or railway track.
- For drainage of water a single side drain of sufficient capacity is provided.

Safety in tunnel construction:-

- Tunneling being an underground operation, is a hazardous one and measure to protect the workers against accidents, are essential.

Causes of accidents:-

1. Limited working space .
2. Inadequate lighting.
3. Handling of explosives.
4. Unseen weakness in rock.
5. Pressure of equipment for loading and, hauling etc.
6. Working f heavy machines above ground.

- **Safety measures:**

- Majority of accidents occur due to rock falls. Proper design of timbers and supports, prevents accidents due to rock fall.
- The floor of tunnel should be kept clean and water should not be allowed to stand in pools.
- The walls and roof of the tunnel shall be frequently inspected.

- Many accidents occur due to poor lighting and so all the jobs should be kept well lighted.
- All machines and tools must be kept in tip top condition.
- Unwanted machines and construction materials should not be stored in tunnel.
- All light and power lines should be properly installed and well insulated.
- Pipes and other material should not obstruct the movement and should be brought to the site as needed.

- Safety rules and regulation should be framed and taught to every worker.
- Safety rules must be strictly followed without any violation.
- Fire fighting service must be always kept ready.
- Doctors should be available at all times at the site.
- Steel helmet, protective clothing, rubber gloves etc. Must be put on by every worker as required by regulations.

- Shaft openings should be fully protected to prevent both man and material from falling into the hole.
- No unauthorized person should be permitted to enter the tunnel.Authorized visitors should be equipped with safety helmets and accompanied by a guide.

Thank you…….