TUNNEL ENGINEERING

Contents

- Tunnel

  Artificial underground passage to by pass obstacles safely without disturbing the over burden
- Open Cut

  Open to sky passage excavated through huge soil mass of obstacle in required directions to connect two roads or railways
- Bridge

  Over-ground construction to cross over obstacles without disturbing the natural way below it

- Tunnels
  - An underground passage for
    - Road or rail traffic
    - Pedestrians
    - Utilities
    - Fresh water or sewer
  - Ratio of length to width is at least 2: 1
  - Must be completely enclosed on all sides along the length

- Types of Tunnels
  - Based on purpose (road, rail, utilities)
  - Based on surrounding material (soft clay vs. hard rock)
  - Submerged tunnels

History of Tunnels Constructed

- Egyptians and Babylonians – 4000 years ago

  length – 910 m ; width – 3600 mm ; height – 4500mm

- Channel Tunnel – linking Britain & France – 1994

  length – 50 km ; undersea component - 39 km
- Consist of 3 parallel bores of 50 km length interconnected every 375 m by cross passages

Economics of Tunneling

- Nature of Soil
- Requirements of fill
- Depth of cut > 18m – tunneling
- Desirable when

1. Rapid transport facilities
2. Avoids acquisition of land
3. Shortest route connection
4. Permits easy gradient & encourages high speed
5. On strategic routes

Selection of Tunnel Alignment

- Depend on Topography of area & points of entrance and exit
- Selection of site of tunnel to be made considering two points

- Alignment Restraints

- Environmental Considerations

Classification of Tunnels

- Based on Alignment

Off- Spur tunnels : Short length tunnels to negotiate minor obstacles

Saddle or base tunnels : tunnels constructed in valleys along natural slope

Slope tunnels : constructed in steep hills for economic and safe operation

Spiral Tunnels : constructed in narrow valleys in form of loops in interior of mountains so as to increase length of tunnel to avoid steep slopes

Classification of Tunnels

- Based on purpose

  Conveyance Tunnels
  Traffic Tunnels

- Based on type of material met with in construction

  Tunnels in Hard Rock
  Tunnels in Soft materials
  Tunnels in Water Bearing Soils

INVESTIGATIONS

- Investigations prior to planning
- Investigations made at time of planning
- Investigations made at time of construction

Investigations prior to planning

- Geological Investigations – relation between bed rock and top soil
- Morphology, Petrology, Stratigraphy
- Electrical Resistivity Methods – positions of weak zones - faults, folds and shear zones

Investigations made at time of planning

- Drilling holes by percussion, rotary percussion and rotary
- Rotary or Rotary Percussion methods – loose soils
- Rotary Drilling – rocky soils
- Spacing – 300-500m ; reduced to 50-100 m in geologically disturbed areas
- Lateral Spacing – 10-15m from C/L of tunnel
- Depth – 20-50 m deeper than proposed invert level of tunnel

- For detailed undisturbed observations, shafts can be excavated
- Shafts – vertical or inclined tunnel excavated to reach and to get information for the area surrounding proposed tunnel and tunnel section
- Section of 3m x 1.5 m to 3 m x 2m
- Minimum depth of excavation
- Temporary and Permanent Shafts

Investigations made at time of construction

- Heading – Part of tunnel cross section excavated for small lengths – can be top, bottom or side excavation- part of c/s

- Drift – Part of tunnel cross- section excavated for entire length of tunnel

- Heading & Drift give info about
- Rock Stratification
- Thickness of layers
- Constituents
- Structure and Texture of rock
- Hardness
- Temperature
- Underground water levels
- Presence of foul gases
- Effect of earthquake and artificial vibrations
- Possibility of land slides and rock falls

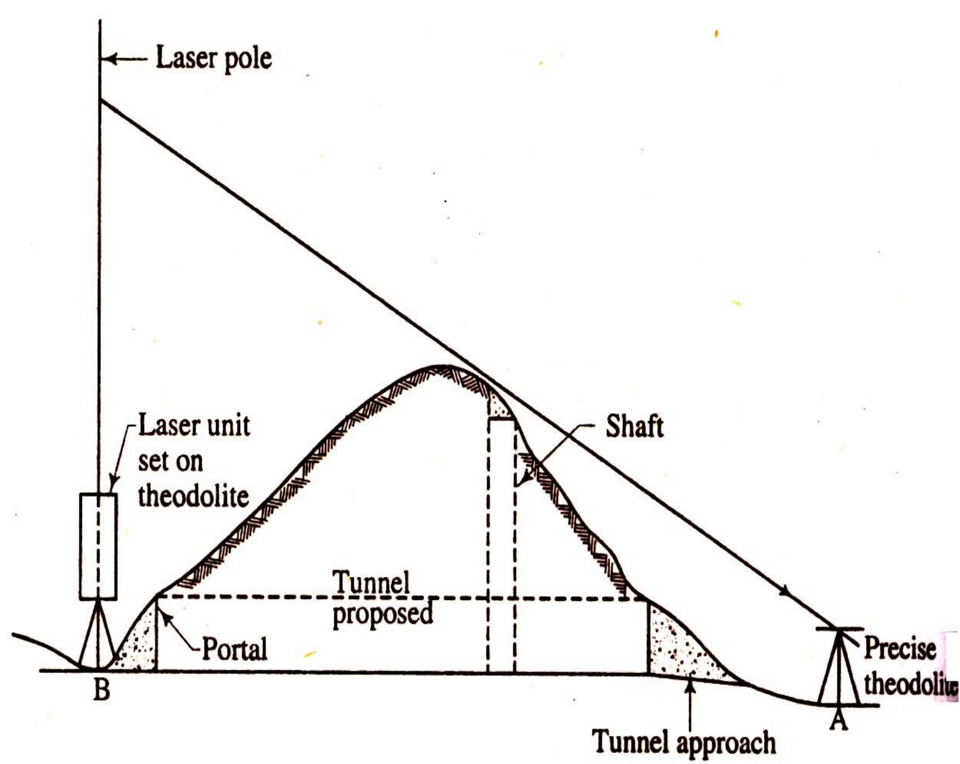
Setting Out of Tunnel

- Setting Out - Making the centre line or alignment of any construction work on ground
- Setting out centre line of tunnel by 4 stages:

- Setting out tunnel on ground surface
- Transfer of Centre line from surface to underground
- Underground setting out
- Underground Leveling

Setting out tunnel on ground surface

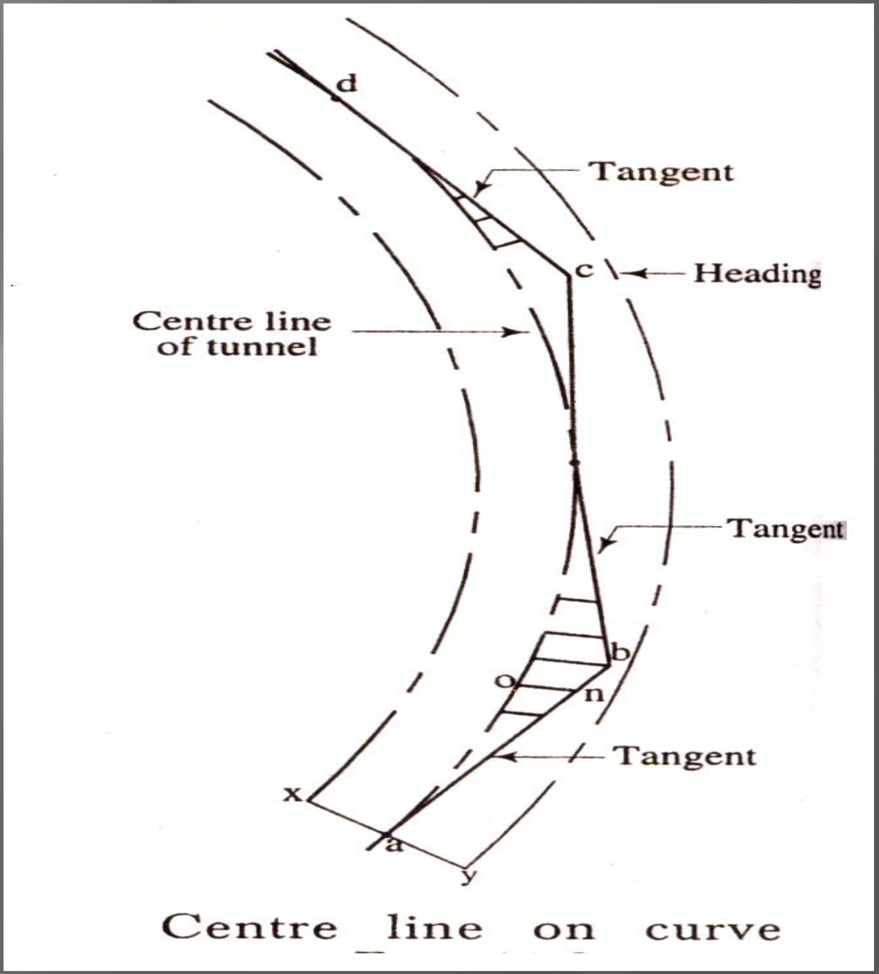
- Running an open traverse between two ends of proposed tunnel



Setting out tunnel on ground surface

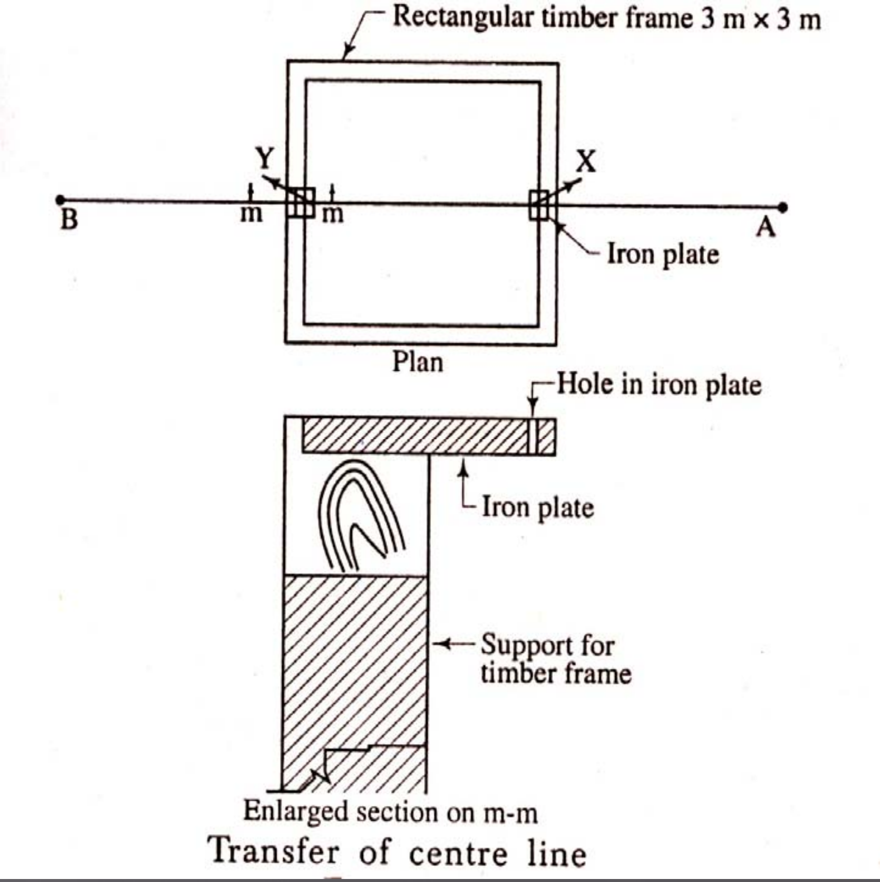
Curved Alignment

- Heading consist of short tangent to curve alignment
- Offsets measured from these tangents



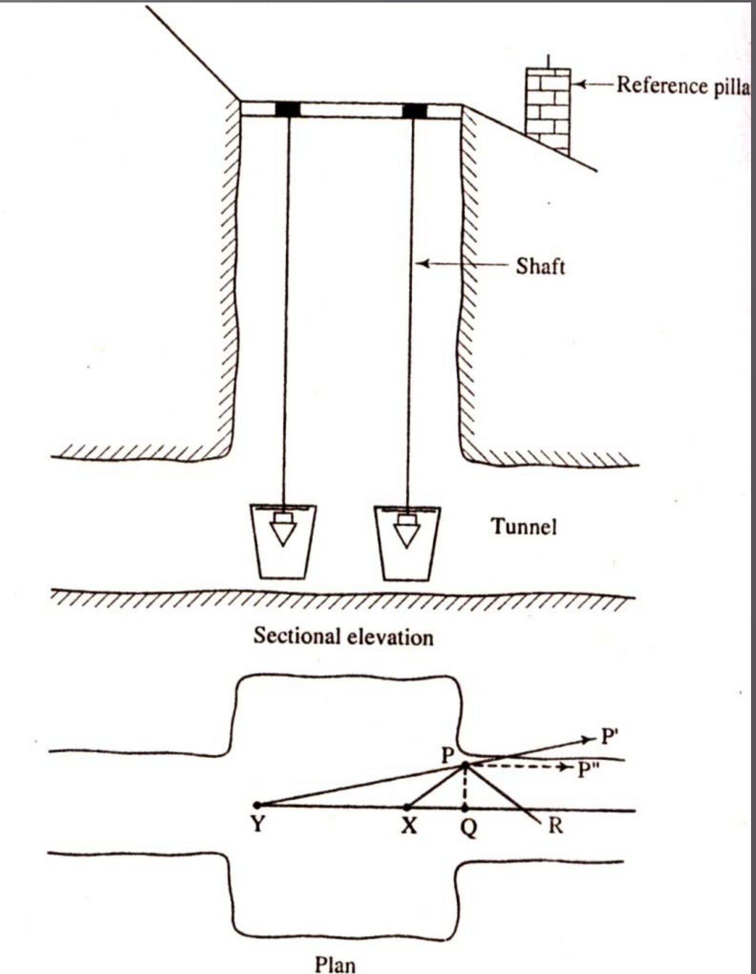
Transfer of Centre line from surface to underground

- Underground shafts – interval of 500 m along transverse lines
- Rectangular Horizontal frame set at proposed location along AB
- On two sides of the frame, iron plates are fixed and screwed down & holes are drilled along A and B at X & Y
- Plumb bobs are suspended to define vertical lines



Transfer of Centre line from surface to underground

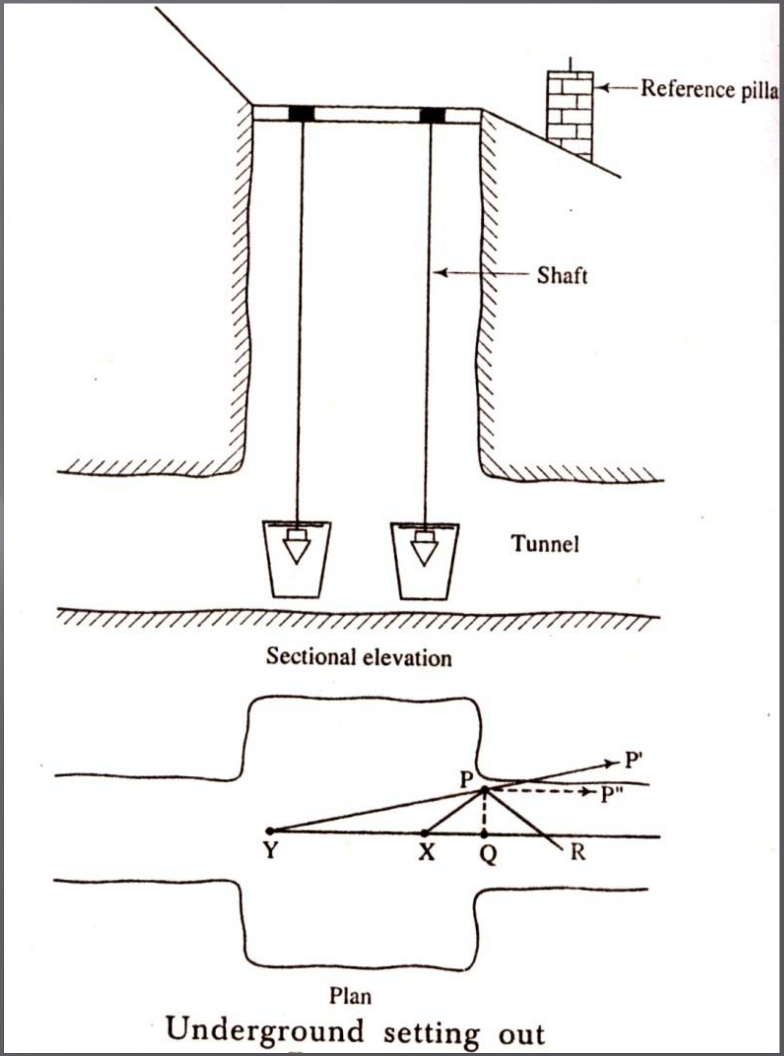
- Set up theodolite at P
- Measure PX, PY & XY
- Mark R at random
- Measure angles YPR& XPR , YPX & PYX
- YXP- Weisbach Triangle
- Sin PYX = (XP/XY) Sin XPY
- PQ= YP Sin PYX
- Set theodolite on P and take back sight on Y. Adjust line of collimation along PP′
- Turn telescope by angle PYX so that line of sight is brought to PP″. Mark PP″.
- Measure PQ perpendicular to PP″ to get C/L extended up to Q.



Underground setting out

Underground Setting out

- Set theodolite at Q
- Take back sight on X and transit by 180 ^{0}
- Mark 1″ at 10 m from Q
- Change face and mark 1′
- If 1″ & 1′are same, YXQ1 is extended C/L of tunnel
- Else midpoint of 1″ & 1′ is the extended C/L of tunnel



Underground Leveling

- Reduced Levels of X & Y are found
- Plumb bobs are suspended through X and Y to touch marked points X & Y on invert level of tunnel
- Plumb bob with wire is spread on ground for comparison with steel tape (say 8 m)
- From RL of X, subtract 8 m to get RL of point X on invert
- Taking this level as BM, leveling is performed underground

EXCAVATION

- Drilling of Holes

  Percussions Drills – Jack hammer, Tripod, Drifter, Churn

  Abrasion Drills – Shot, Diamond

  Fusion Piercing

  Special Drills – Implosion, Explosion

BLASTING

- Types of Explosives

  Straight Dynamites

  Ammonia Dynamites

  Ammonia - Gelatine

  Semi – Gelatine

  Blasting Agents

  Slurries or water jets
- Theory of Blasting

  Impact, Abrasion, Thermally Induced Spalling, Fusion and Vaporization, Chemical Reaction

SHAPE OF TUNNELS

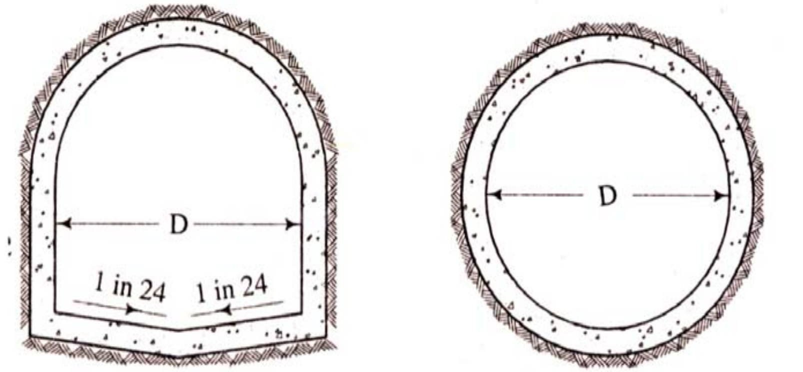
- Resist pressure exerted by unsupported walls of the tunnel excavation
- Design to be done in such a way that it suits the site conditions and functional requirements

SHAPE OF TUNNELS

- **D or Segmental Roof Section**

  Suitable for sub-ways or navigation tunnels

  Additional Floor Space and flat floor for moving equipment



(a) `D' Section (b) Circular section

SHAPE OF TUNNELS

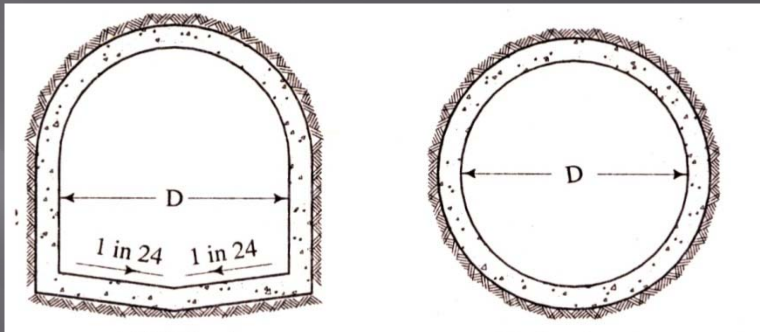
- Circular Section

  To withstand heavy internal or external radial pressures

  Best theoretical section for resisting forces

  Greatest C/s Area for least perimeter

  Sewers and water carrying purposes



(a) `D' Section

(b) Circular section

SHAPE OF TUNNELS

- Rectangular Section

  Suitable for hard rocks

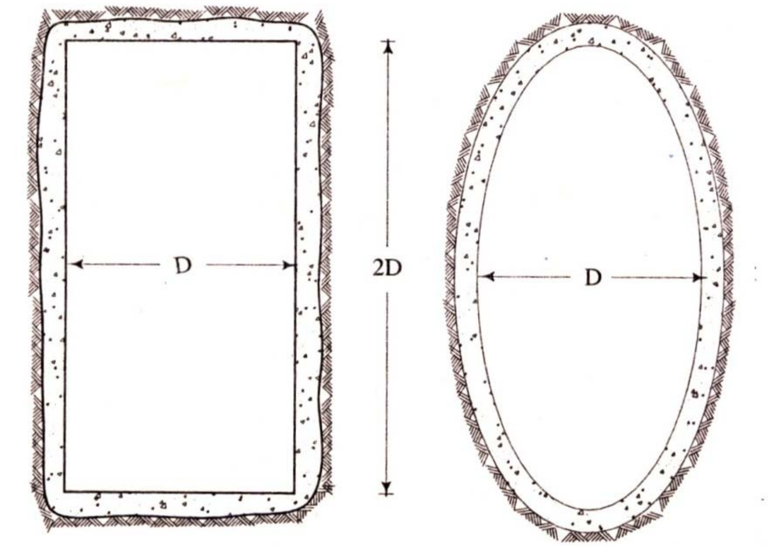
  Adopted for pedestrian traffic

  Costly & difficult to construct

- Egg shaped Section

  Carrying sewage

  Effective in resisting external and internal pressures



(c) Rectangular section (d) Egg - shaped section

SHAPE OF TUNNELS

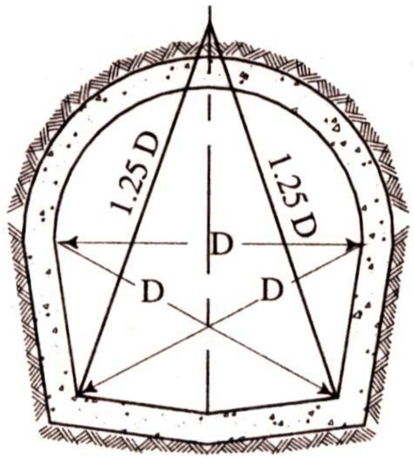
- Horse – shoe Section

  Semi-circular roof with arched sides and curved invert

  Best shape for traffic purposes

  Most suitable for soft rocks and carrying water or sewage

  Most widely used for highway and railway tunnels



(e) Horse - shoe section

Shapes for tunnel cross-sections

SIZE OF TUNNEL

- Determined from utility aspect
  - Road tunnels – No. of traffic lanes
  - Railway tunnels – Gauge & No. of tracks

Thickness of lining
Provision for drainage facilities
Clear opening required for traffic
Nature of traffic

SOIL CLASSIFICATION

- Hard Rock or fully self- supporting

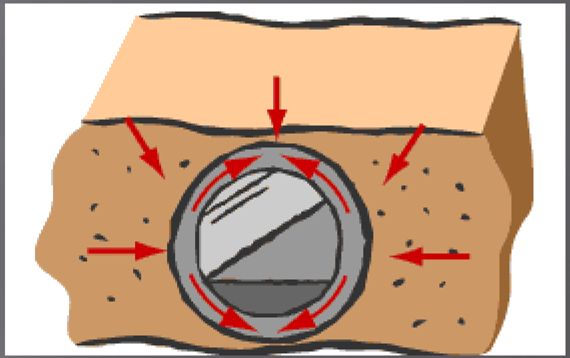
- Soft Soils – requiring temporary supports during and after construction

Classification of Soft soils

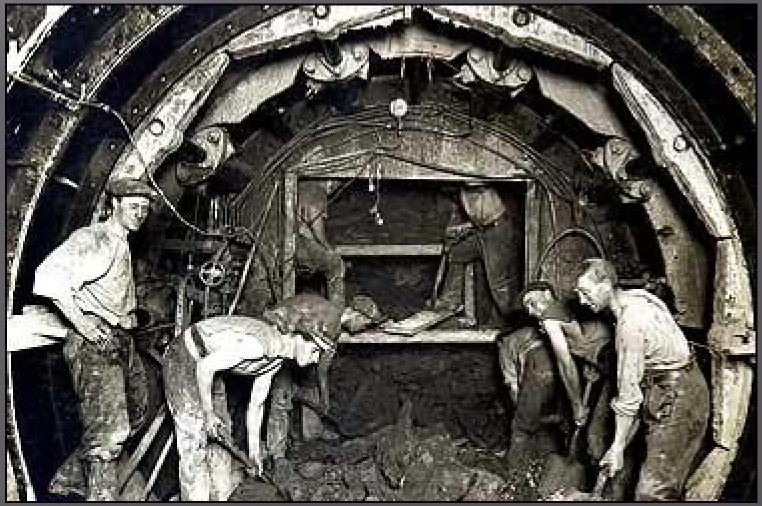
- Running ground – needing instant support all around- Water Bearing sands and cohesion-less soils
- Soft ground - instant support for roof like soft clay
- Firm ground – roof will stand for a few minutes and sides for a much longer period- Firm clay and dry earth
- Self supporting ground – soil stands supported for a short period and for short lengths of 1200 mm to 5000 mm – sandstones , cemented stones

Tunneling in Soft Soils

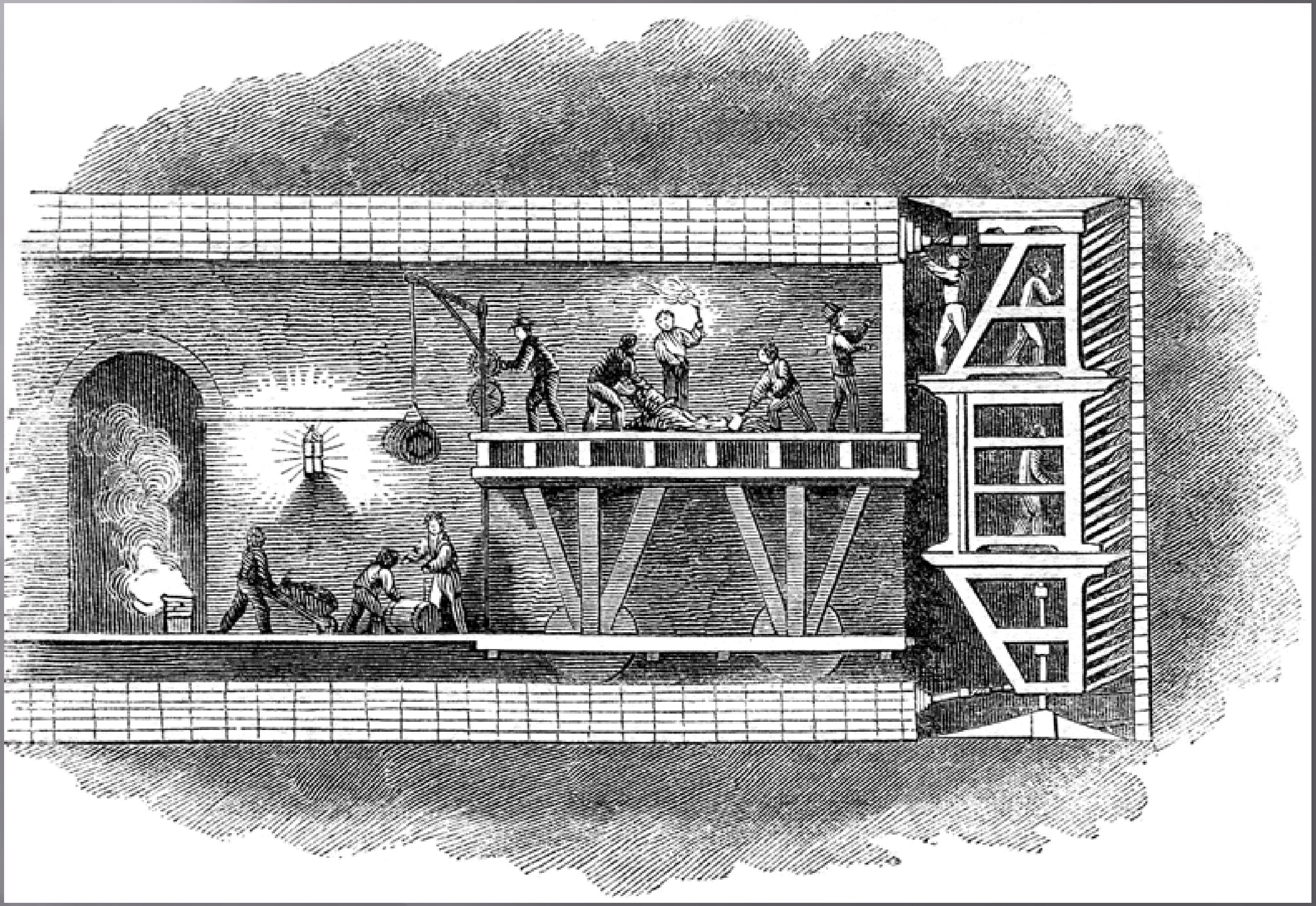
- Challenges
  - Preventing soil movements
  - Soil pressure
  - Water seepage



- Techniques
  - Cut and Cover
    - Supporting Beams
    - Roof lining
  - Tunnel Shields



Tunneling in Soft Soils



Tunnel Shielding Method

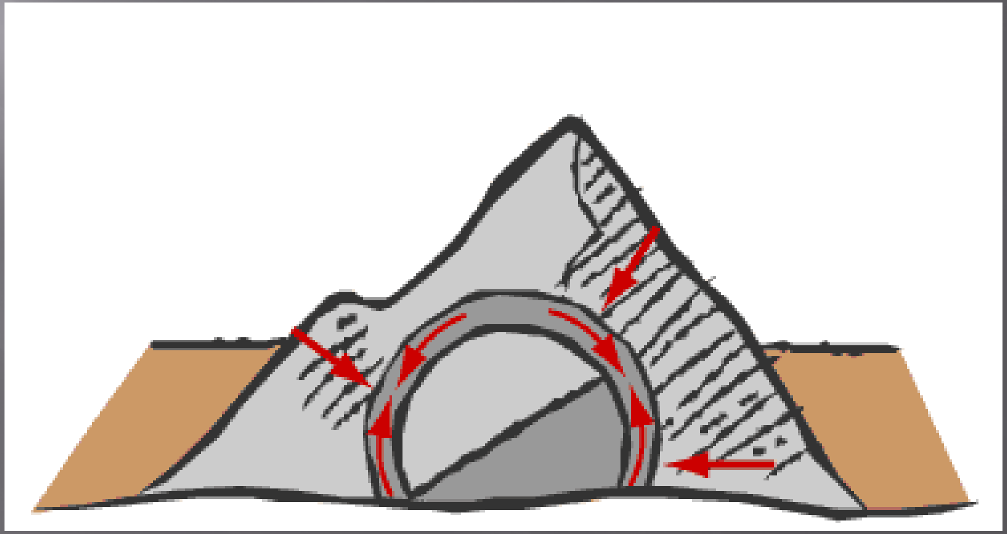
Tunneling in Soft Soils

- Tunnel Shielding
  - a protective structure used in the excavation of tunnels through soil that is too soft or fluid to remain stable during the time it takes to line the tunnel
  - developed by Sir Marc Isambard Brunel to excavate the Thames Tunnel beginning in 1825
  - Types of Shield Tunneling
    - Manual
    - Tunnel Boring Machine (TBM)
      - Front end: Rotating cutting wheel
      - Middle portion: Soil dispensing mechanism via slurry
      - Rear portion: Precast concrete sections placement mechanism

Tunneling in Soft Soils

Tunneling in Hard Rocks

- Influencing Factors
  - Type of rock
    - Igneous
    - Sedimentary
    - Metamorphic
  - Rock Hardness
  - Rock Brittleness
  - Extent of existing fractures and planes of weakness



Tunneling in Hard Rocks

- Tunneling Methods
  - Heating and quenching (old technique)
  - Drilling
    - Percussion drills (penetrate rock by impact action alone)
    - Rotary drills (cut by turning a bit under pressure against the rock face)
    - Rotary-Percussion drills (combine rotary and percussion action)
  - Blasting
    - Primary blasting vs Secondary blasting
    - Explosives
      - Dynamite (expensive)
      - Ammonium Nitrate (cheaper but not good in water logged areas)
      - Slurries (mixture of explosives, gel and water)
  - Tunnel Boring Machine (TBM)

THANK YOU