TUNNEL ENGINEERING
Contents

- Tunnels & their Classification
- Selection of tunnel alignment
- Investigations for Tunneling
- Excavation for Tunnels
- Shape of Tunnels
- Tunneling in Soft Soils & Hard Rocks
- **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 – 4500 mm

- 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 $> 18$ m – 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
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
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
Running an open traverse between two ends of proposed tunnel
- 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.
- Set theodolite at Q
- Take back sight on X and transit by 180°
- 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
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
Drilling of Holes

Percussions Drills – Jack hammer, Tripod, Drifter, Churn

Abrasion Drills – Shot, Diamond

Fusion Piercing

Special Drills – Implosion, Explosion
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
- 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
D or Segmental Roof Section

Suitable for sub-ways or navigation tunnels
Additional Floor Space and flat floor for moving equipment
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
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
SHAPES 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
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
Tunnel Shielding Method
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
Influencing Factors

- Type of rock
  - Igneous
  - Sedimentary
  - Metamorphic

- Rock Hardness

- Rock Brittleness

- Extent of existing fractures and planes of weakness
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