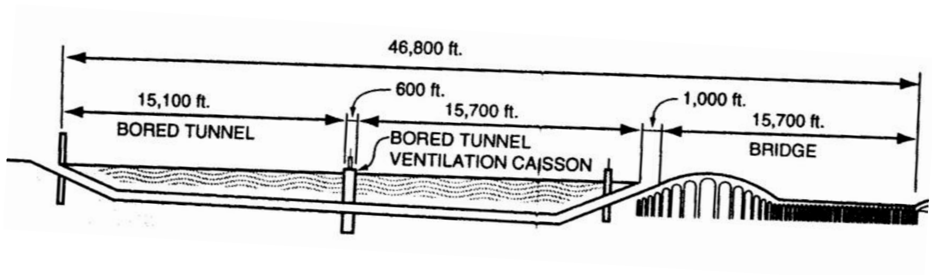
Rock Tunnel Engineering

INTRODUCTION

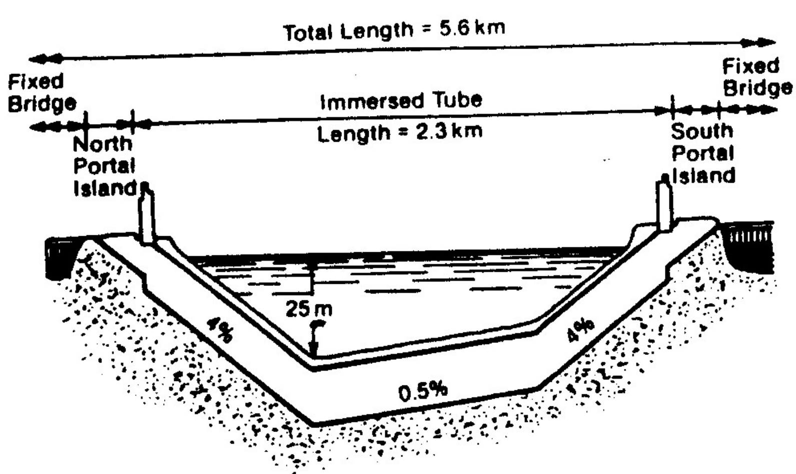
- Tunnel – a hole in the ground to provide for desired movement or as mobility channel.
- Serves as highway, railroad, pedestrian passageway, water conveyance, waste water transport, hydropower generator, utility corridor, storage, etc.
- Tunnel shape: circular, multicurve, horseshoe, arched, flat-roofed.
- Location: under mountain, cities, river, lakes, straits, bays etc.
- Ground: soft ground, mixed face, rock, layered, wet, flowing or squeezing ground.
- Tunnel constructed ; cut and cover method, drilling and blasting, mechanized ; TBM , Roadheader,etc.

Example of Underground tunnel Layout



Trans – Tokyo Bay Tunnel.

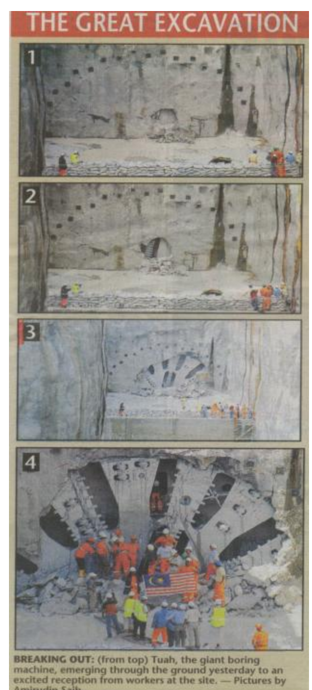
Example of Underground tunnel Layout



Hampton Roads Bridge-Tunnel,Virginia.1957

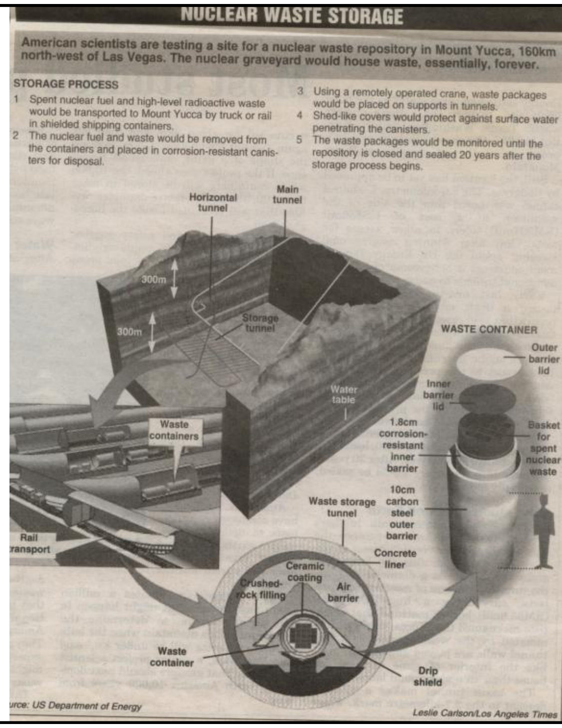
Example of Underground tunnel Layout

Smart Tunnel-Tunnel Boring Machine

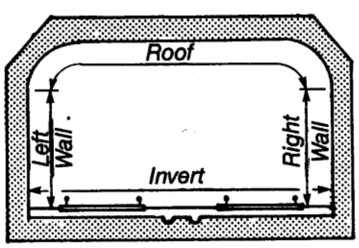


Underground Nuclear

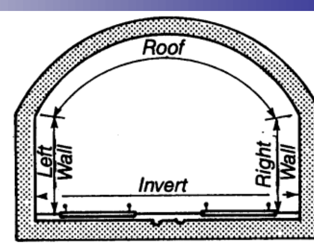
waste storage



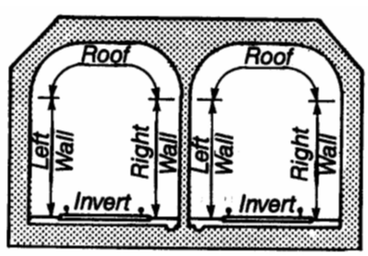
TYPICAL TUNNEL GEOMETRY



Typical box tunnel, single cell

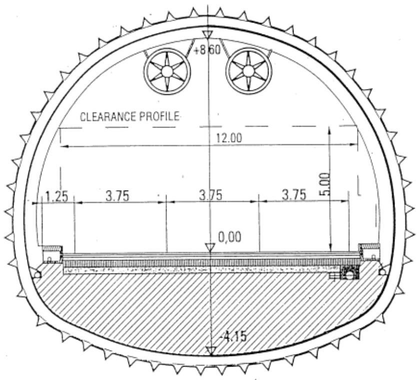


Typical arch roof tunnel, single cell

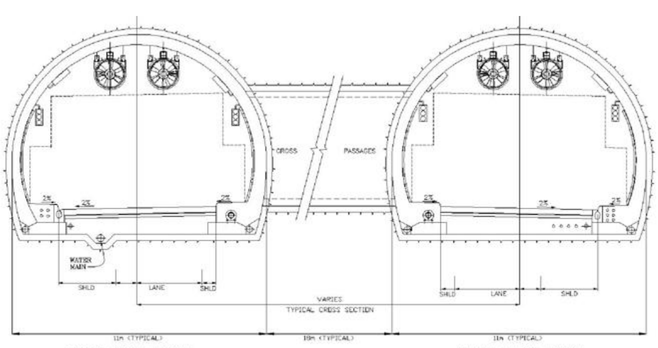


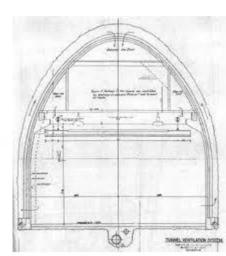
Typical box tunnel, double cell

TYPICAL TUNNEL GEOMETRY



TYPICAL TUNNEL GEOMETRY





Geotechnical Investigations Challenges

- Vast uncertainty in all underground projects.
- The cost and feasibility of the project is dominated by geology.
- Every feature of geologic investigation is more demanding than foundation engineering projects.
- The regional geology must be known.
- Engineering properties drastic change with a wide range of conditions eg time, season, rate and direction of loading etc.
- Groundwater is the most difficult condition/parameter to predict and the most troublesome.
- It is guaranteed that the actual stratigraphy, groundwater flow and behaviour encountered during construction will be compared with the geotechnical team's prediction.

Rock Classification

- Physical rock description- rock types, Intact strength, weathering state, Discontinuities.
- Rock mass classification system; RQD (core loss –indicate a weakness in the rock),RMR, Q-system.

PRINCIPLE OF TUNNEL STABILIZATION AND DESIGN

- The most important part of design to stabilize ground movement, not to carry ground load.
- The most important part of tunnel lining is the ground that surrounds it.
- The most important component of the ground is the groundwater.
- Most important element of lining construction is to secure full, continuous contact between the lining and the ground.

PRINCIPLE OF TUNNEL STABILIZATION AND DESIGN

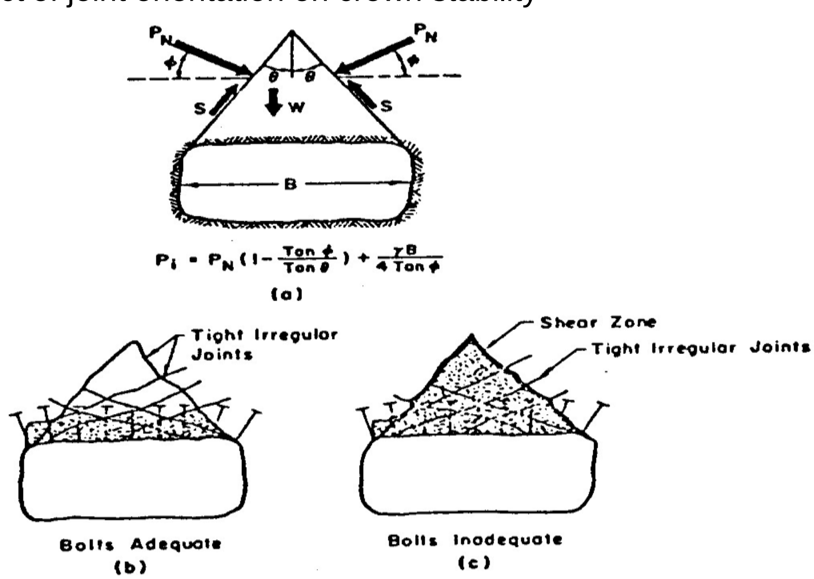
- The most efficient tunnel stabilization and lining system is one that mobilizes the strength of the ground by permitting controlled ground deformation.
- Selection of type of lining depends on excavation methods that suited ground characteristics, of which ‘ stand-up’ time is most significant. It affects the magnitudes of ground deformation and lining loads
- Axial stiffness of the lining permits it to distribute non-uniform ground loads by mobilizing passive pressure from surrounding ground, thereby modify ground deformation.
- Flexural stiffness of lining is inefficient in modifying ground deformation

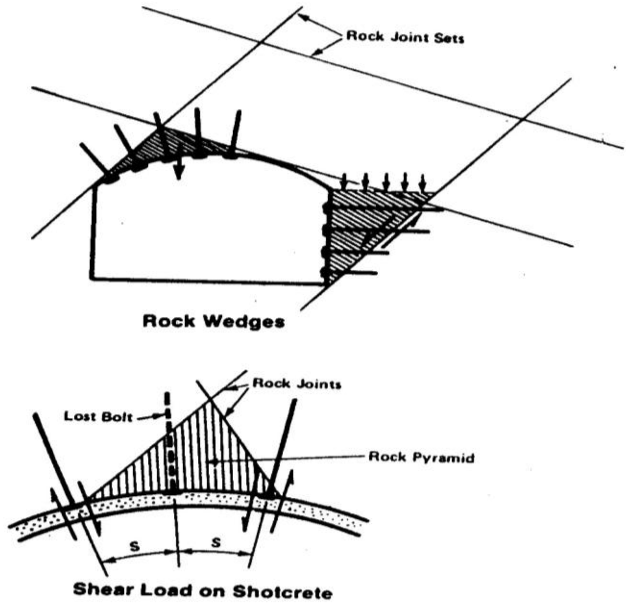
PRINCIPLE OF TUNNEL STABILIZATION AND DESIGN

- Multistage lining can absorb large flexural deformation and redistribution of ground stresses
- Dimension of lining are controlled by water sealing, constructability, facility usage rather than ground load
- Load and pressures vary along the length of tunnel owing to variations in geology and construction proficiency
- The largest loads on the lining may come from construction processes

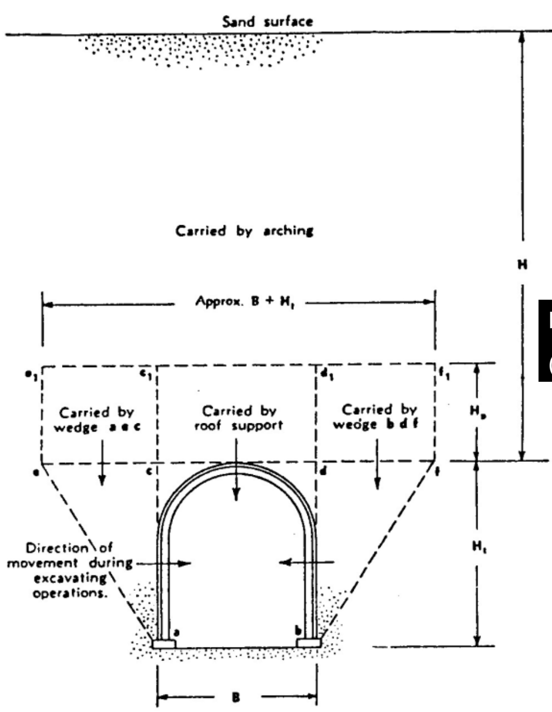
MECHANISM OF FAILURE AND LOAD ANALYSIS

Effect of joint orientation on crown stability

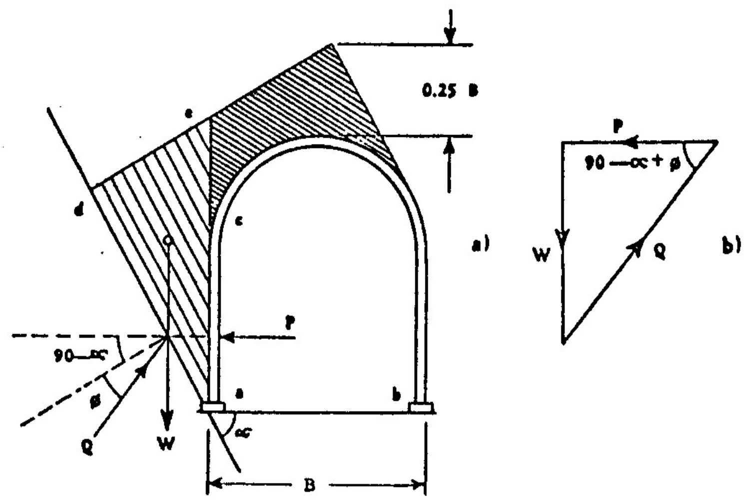




Tunnel Load Analysis

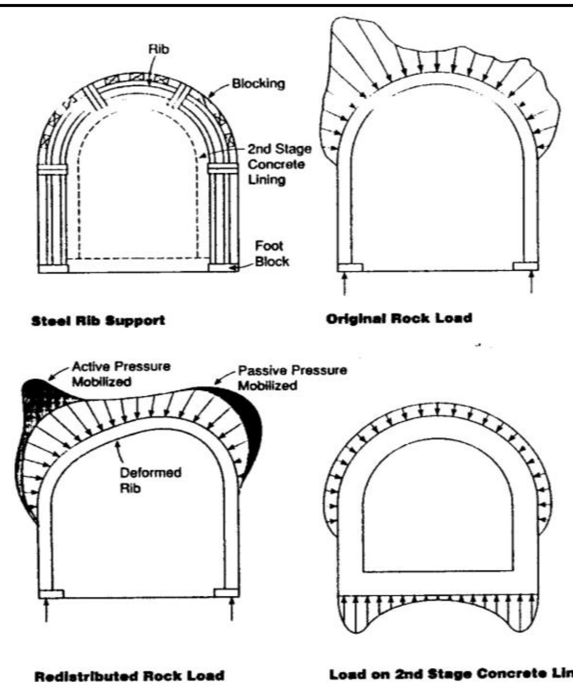


Loading on tunnel support
(Terzaghi,1964)



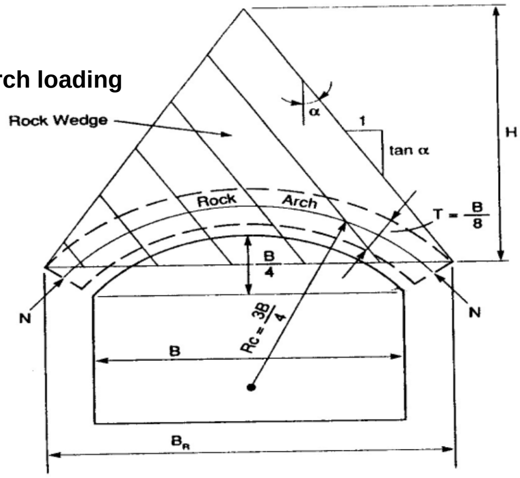
Forces acting on tunnel; support in inclined strata .(Terzaghi,1964)

E3 : Load on 2-stag lining system



Load Analysis

- Reinforced rock arch loading



Width of rock wedge = $B_R = [B + 2\left(\frac{4}{5} \cdot \frac{B}{4}\right)] = \frac{7}{5} B$

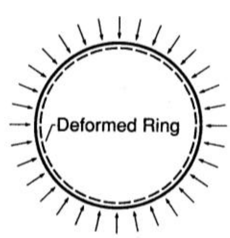
Height of rock wedge = $H = \frac{B_R}{2} \cdot \tan\alpha = \frac{7}{10} B \tan\alpha$

Assume average rock arch load = $p = \frac{\gamma H}{2} = \frac{7}{20} \gamma B \tan\alpha$

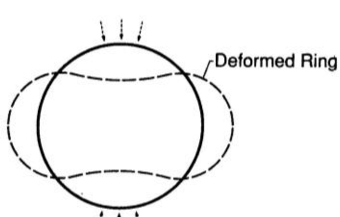
Thrust/ft = $N = pR_c = \frac{21}{80} \gamma B^2 \tan\alpha \cong \frac{\gamma B^2 \tan\alpha}{4}$

Arch compression $\sigma c = \frac{N}{T} \cong 2 \gamma B \tan\alpha$

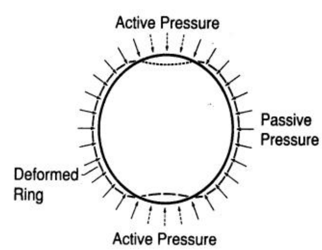
Circular Tunnel : deformation characteristics & behaviour of flexible rings



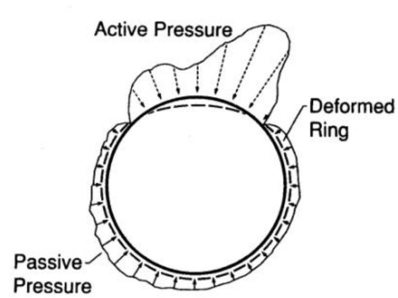
a) Unconfined ring -Uniform radial load



b) Unconfined ring - concentrated load

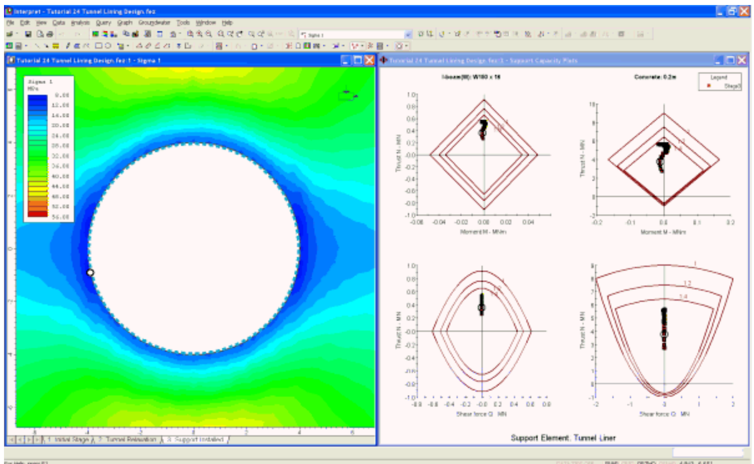


c) Partially confined ring - concentrated load



d) Fully confined ring- random load

Example of analysis using numerical simulation method



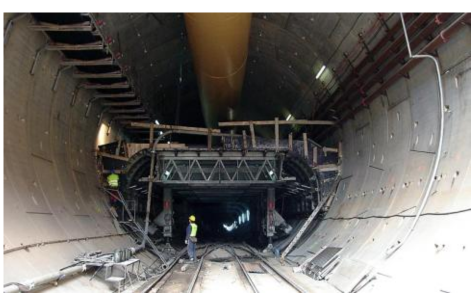
TUNNEL LINING

- Unlined rock- massive and stable rock formation
- Rock reinforcement systems – sound rock but have structural defects (rock joints)eq: rock reinforcement to knit the rock mass together so that it is self-supporting short bolt, untensioned steel dowels, tensioned steel bolt,
- Dowel or bolts provide temporary stabilization
- Shot-crete; stabilization of rock tunnels excavated by drill-and-blast methods. Shot-crete provide early support in rock with limited ‘stand-up’ time.
- Ribbed system- timber, steel H-section in poor rock condition
- Segmental lining- soft ground tunnel
- Poured concrete –poured-in-place concrete in wet- ground, water leakage, water proofing membrane

Ground-structure interaction – characteristics of lining behaviour

- Tunnel lining behaviour is a 4D problem
- During construction, ground conditions at the tunnel heading involve both transverse arching and longitudinal arching or cantilevering from unexcavated face.
- All ground properties are time-dependent, The timing of lining installation is an important variable.

EXAMPLE OF LINING



Steel Fiber Reinforced Concrete Precast Tunnel Segments

•Tunnel segments are precast and packaged in a precasting facility before delivery and placement on site. Steel fiber reinforced concrete is cast or pumped directly inside the formworks.

•With respect to design load conditions, it is possible to use 100% fiber reinforced concrete in precast tunnel segments.

Fiber reinforced concrete can be applied to precast concrete construction with excellent results and several key advantages:

•Better aesthetic quality of the product
•Higher mechanical strength in terms of toughness, flexural and shear stress
•Faster industrialized production process through the partial or total elimination of steel reinforcement cages
•Improved damage resistance during transportation and placing
•Reduced concrete thickness as no reinforcement cover depth is required
•Improved durability in aggressive environments