DI04006071: Railway, Harbour & Tunnel Engineering

Lecture 5.37: Lecture 37: Shape and Size of Tunnel

GTU Course Instructor

Civil Engineering

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Introduction to Tunnel Geometrics I

The shape and size of a tunnel are critical parameters that directly influence the structural integrity, construction cost, and functional efficiency of the underground structure. The cross-section must be large enough to accommodate the intended traffic or utility, while its shape must optimally resist surrounding ground pressures.

Key Points

- Determines the stress distribution around the excavated opening.
- Affects the method of excavation and type of supporting system required.
- Influences the overall cost, including excavation volume and lining materials.

Factors Influencing Tunnel Shape I

Selecting the appropriate shape for a tunnel is not arbitrary; it requires a careful evaluation of geological, structural, and functional requirements.

Key Points

- Purpose of the tunnel (e.g., railway, highway, sewer, navigation).
- Nature and properties of the soil or rock mass.
- Magnitude and direction of earth and water pressures (horizontal vs. vertical).
- Method of construction (drill and blast, TBM, cut-and-cover).

Comparison of Common Tunnel Shapes I

The following table summarizes the primary tunnel shapes, their typical applications, and their structural characteristics.

Key Points

- | Shape | Application | Advantage | Disadvantage |
- |—|—|—|—|
- | Circular | Sewers, Aqueducts | Maximum resistance to external pressure | Inefficient floor space utilization |
- | Horseshoe | Highways, Railways | Excellent floor space and arching action | Complex formwork for lining |
- | D-Shape (Segmental) | Subways, Navigation | Flat invert is ideal for track laying | Weak against high lateral pressure |
- | Rectangular | Pedestrian, Shallow transit | Easy and economical for cut-and-cover | Poor structural efficiency at depth |

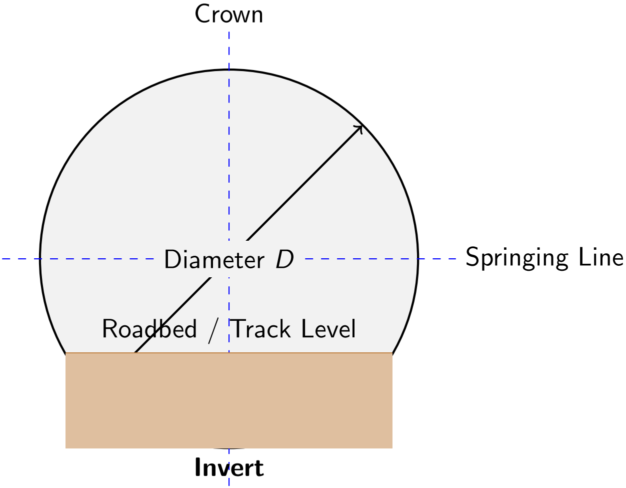
Circular Section I

The circular shape provides the most efficient cross-section for resisting external pressures, as compressive stresses are distributed uniformly around the ring. It is the natural shape formed by Tunnel Boring Machines (TBMs).

Key Points

- Offers the highest structural stability, especially in soft ground or sub-aqueous conditions.
- Provides the maximum cross-sectional area for a given perimeter.
- Significant unused space when used for vehicular or rail traffic, requiring additional fill for the roadbed.

Circular Tunnel Geometry I



Circular Tunnel Geometry II

Key Points

- The theoretical pure circle distributes hoop stresses efficiently.
- Invert requires backfilling to create a flat operational surface.

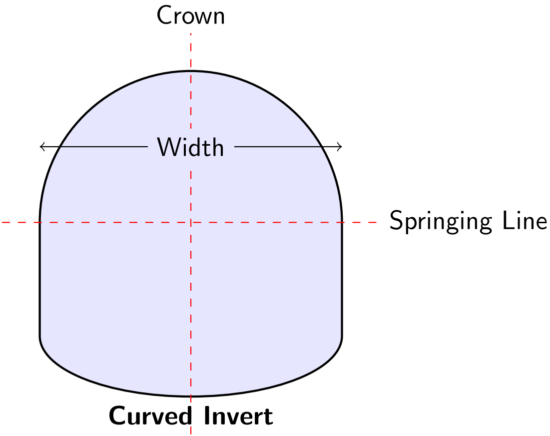
Horseshoe Section I

The horseshoe shape is widely regarded as the most versatile cross-section for highway and railway tunnels in competent rock. It combines the structural benefits of a semi-circular arched roof with the functional benefits of a wider base.

Key Points

- Semi-circular roof efficiently transfers vertical loads to the abutments.
- Curved sidewalls provide resistance against moderate lateral earth pressures.
- Offers a wide floor area, minimizing the need for excessive backfilling compared to circular tunnels.

Horseshoe Tunnel Geometry I



Horseshoe Tunnel Geometry II

Key Points

- Characterized by a semi-circular arch, straight or slightly curved sidewalls, and a dished invert.
- Provides an optimal balance between structural strength and usable clearance.

D-Shape (Segmental) Section I

The D-shape or segmental roof section features a semi-circular arch over straight vertical sidewalls and a flat invert. This profile is traditional in hard rock environments where lateral pressures are minimal.

Key Points

- Flat invert is highly suitable for laying railway tracks or road surfaces immediately.
- Provides maximum vertical clearance at the sidewalls.
- Susceptible to failure at the corners if subjected to high lateral hydrostatic or earth pressures.

Other Shapes: Egg and Rectangular I

Specific project requirements dictate the use of specialized shapes like the egg-shaped or rectangular sections.

Key Points

- **Egg-Shaped:** Narrow at the bottom and wider at the top. Highly effective for sewers carrying varying flows, as it maintains self-cleansing velocity during low discharge.
- **Rectangular:** Commonly used for pedestrian underpasses and shallow urban transit systems constructed via cut-and-cover. Requires strong roof slabs to resist bending moments.
- **Polycentric:** Used in very large underground caverns to adapt to complex stress regimes.

Determining the Size of a Tunnel I

The size of a tunnel is dictated primarily by its functional requirements, known as the 'structure gauge' or 'clearance envelope', with additional allowances for operational necessities.

Key Points

- **Traffic Clearance:** Must accommodate the largest vehicle or train, plus dynamic kinematic envelopes.
- **Ventilation:** Space required for air ducts, jet fans, and emergency smoke extraction.
- **Utilities and Drainage:** Provisions for lighting, signaling cables, walkways, and drainage gutters.
- **Construction Tolerance:** Additional excavation margin to account for lining thickness and geological overbreak.

Summary I

The optimal shape and size of a tunnel represent a balance between structural efficiency, geological conditions, and the intended functional use.

Key Points

- Circular shapes are structurally superior for soft ground but less efficient for traffic.
- Horseshoe and D-shapes provide excellent space utilization for railways and highways.
- Size is strictly governed by clearance gauges, ventilation needs, and lining thickness.
- Careful selection reduces construction costs and ensures long-term stability.