DI04006071: Railway, Harbour & Tunnel Engineering

Lecture 5.36: Necessity, classification, advantages and disadvantages of Tunnel

GTU Course Instructor

Civil Engineering

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Introduction to Tunneling I

A tunnel is an underground passage constructed for the purpose of transport, conveying water, or laying utilities, typically constructed without disturbing the overlying soil or rock. Tunneling requires substantial preliminary investigations and specialized construction techniques.

Key Points

- Subsurface passageways for roads, railways, and canals.
- Constructed to bypass natural obstacles like mountains or water bodies.
- Provides rapid transit in congested urban areas without disrupting surface life.

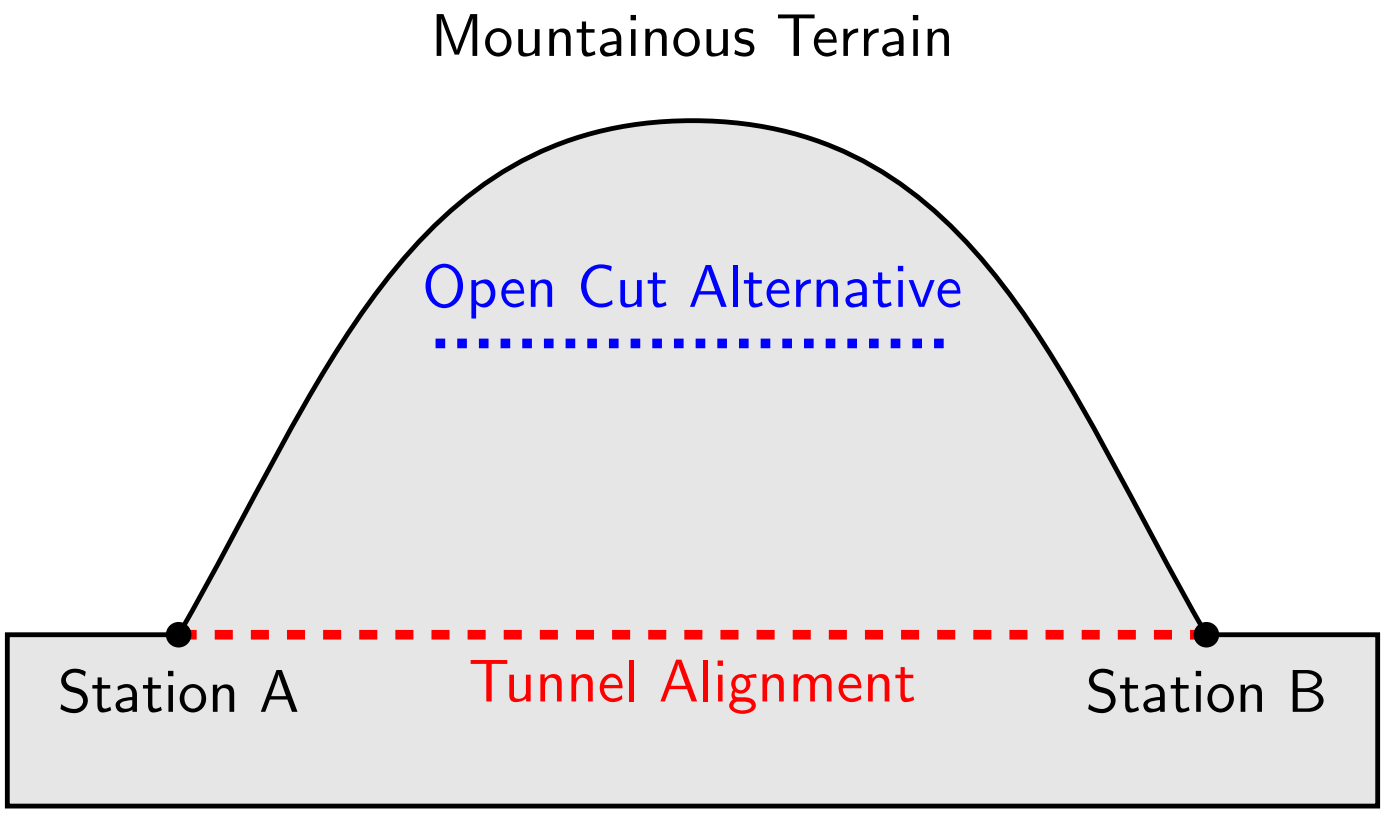
Necessity of Tunnels I

Tunnels are essential in modern civil engineering to provide direct routes through natural and man-made obstacles. They become structurally and economically necessary when open cuts are unfeasible or environmentally destructive.

Key Points

- To connect two points separated by a mountain or hill barrier.
- To provide an underground route for rapid transit systems (metros) in congested cities.
- To cross water bodies like rivers or straits where bridges are impractical.
- To avoid long, circuitous routes around natural obstacles, saving travel time and fuel.

Tunnel vs. Open Cut Profile I



Tunnel vs. Open Cut Profile II

Key Points

- Visual representation of a mountain barrier between two stations.
- The red dashed line shows the direct and efficient tunnel alignment.
- The blue dotted line illustrates the massive excavation required for an open cut.

Advantages of Tunnels I

Tunnels offer significant advantages over surface routes, especially in difficult terrains or densely populated areas. They provide a protected environment that is isolated from surface disturbances.

Key Points

- Shortens the route distance, heavily reducing operation and maintenance costs.
- Avoids the acquisition of highly expensive surface land in urban areas.
- Provides a sheltered route, immune to adverse weather like snow, heavy rain, or landslides.
- Does not disrupt existing surface traffic, utilities, or city life during operation.
- Maintains favorable gradients for railways compared to climbing steep mountain passes.

Disadvantages of Tunnels I

Despite their profound benefits, tunnels present unique engineering challenges and entail high initial investments. The construction is inherently risky and requires highly skilled labor alongside sophisticated machinery.

Disadvantages of Tunnels II

Key Points

- Extremely high initial capital cost of surveying, design, and construction.
- Construction requires specialized equipment (e.g., TBMs) and highly trained workforce.
- Significant time required for completion compared to laying surface routes.
- Ventilation, drainage, and lighting during and after construction require complex systems.
- High risk of occupational accidents due to roof collapse, water ingress, or noxious gases.

Comparison: Tunnel vs. Open Cut I

A comparative analysis evaluating whether to construct a tunnel or an open cut for passing through a geographical obstacle. Generally, tunnels become more economical than open cuts when the depth of excavation exceeds 20 meters.

Comparison: Tunnel vs. Open Cut II

Key Points

- | Feature | Tunnel | Open Cut |
- | — | — | — |
- | **Initial Cost** | Very high | Lower (for shallow depths) |
- | **Maintenance Cost** | Low | High (due to slope stabilization) |
- | **Environmental Impact**| Minimal surface disruption | High surface disruption |
- | **Weather Effect** | Immune to weather | Susceptible to landslides/snow |
- | **Depth Suitability** | Economical for depth $>$ 20m | Economical for depth $<$ 20m |

Classification Based on Purpose I

Tunnels are broadly classified based on the fundamental purpose they serve. The intended purpose heavily dictates their cross-sectional design, alignment, and internal finishing.

Key Points

- **Traffic Tunnels:** Designed for railways, highways, metros, and pedestrian walkways.
- **Hydropower Tunnels:** Convey water from reservoirs to turbine powerhouses under high pressure.
- **Public Utility Tunnels:** Used for safely routing utility lines like power cables, water supply, and sewage.
- **Navigation Tunnels:** Constructed to allow passage of ships and canal boats through terrain.

Classification Based on Alignment & Material I

The geological strata through which a tunnel passes, along with its specific alignment configuration, determine the excavation methods and support systems required.

Key Points

- **Saddle & Spiral Tunnels:** Saddle tunnels pass through natural valleys; spiral tunnels loop inside mountains to gain elevation.
- **Tunnels in Hard Rock:** Require blasting and minimal initial support (e.g., Granite, Gneiss).
- **Tunnels in Soft Rock:** Can be excavated using mechanized roadheaders without blasting (e.g., Shale, Sandstone).
- **Tunnels in Soft Soil:** Require immediate support and tunneling shields (e.g., Clay, Silt).
- **Subaqueous Tunnels:** Constructed beneath water bodies using immersed tubes or compressed air techniques.

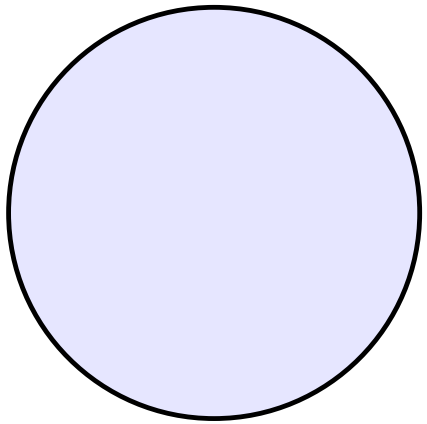
Classification Based on Cross-Section I

The cross-sectional shape of a tunnel is meticulously chosen based on internal clearance needs, external rock or soil pressure, and the specific utility of the tunnel.

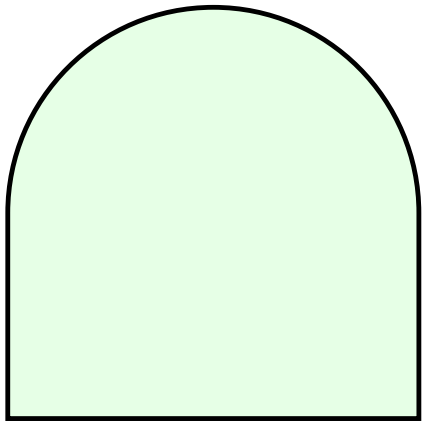
Key Points

- **Circular Section:** Offers maximum resistance to external pressure, ideal for soft ground and aqueducts.
- **D-Shape (Segmental):** Most suitable for subways and navigation due to its flat invert and arched roof.
- **Horseshoe Section:** Commonly used for highway and railway tunnels in semi-solid rock masses.
- **Rectangular Section:** Often adopted for pedestrian subways and cut-and-cover shallow urban tunnels.

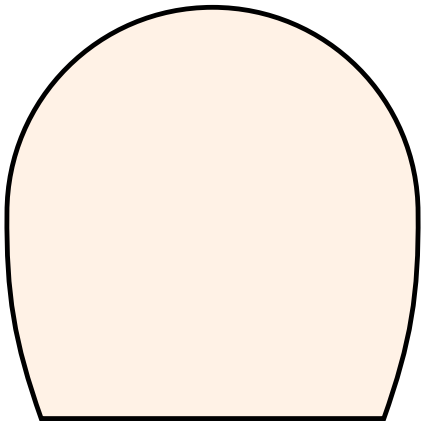
Standard Tunnel Cross-Sections I



Circular Section



D-Shape Section



Horseshoe Section

Standard Tunnel Cross-Sections II

Key Points

- Circular: Best for bearing high external radial pressures (e.g., sewers, soft soils).
- D-Shape: Provides a flat base for tracks or roads with good head clearance.
- Horseshoe: Combines the structural benefits of arch action and a wider operational floor base.

Summary I

Tunnels are critical infrastructural elements that conquer geographical barriers to optimize transit systems and utilities. While highly capital-intensive and risky to construct, their long-term benefits in urban planning and mountainous terrain are unmatched.

Summary II

Key Points

- Tunnels are necessary for minimizing route length and bypassing insurmountable obstacles.
- Key advantages include weather immunity, improved gradients, and reduced surface congestion.
- Major disadvantages involve immense capital costs, construction risks, and ongoing ventilation needs.
- Classification is based on their purpose, geological material, alignment, and cross-section.
- Proper selection of tunnel shape is vital for enduring structural stability and optimal functional use.