DI04006071: Railway, Harbour & Tunnel Engineering

Lecture 6.42: Temporary and Permanent Support Systems

GTU Course Instructor

Civil Engineering

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Introduction to Tunnel Support Systems I

Tunnel excavation alters the in-situ stress state of the surrounding rock mass, necessitating support systems to ensure stability. These systems manage the redistribution of stresses and prevent uncontrolled rock mass deformation.

Key Points

- Support systems counter inward displacement of the tunnel perimeter.
- They maintain the structural integrity of the surrounding ground.
- Crucial for the safety of personnel during construction and the operational lifespan of the tunnel.
- Selected based on geological conditions, excavation method, and tunnel dimensions.

Temporary vs. Permanent Supports I

Support systems in tunneling are broadly classified into temporary (primary) and permanent (secondary) supports, each serving distinct roles during different phases of the project.

Key Points

- Temporary Support (Primary): Installed immediately after excavation to stabilize the opening, ensure worker safety, and control short-term ground movement.
- Permanent Support (Secondary): Installed later to provide long-term stability, accommodate ultimate ground loads, and provide a finished interior surface.
- In modern practices like NATM, primary supports often become part of the final composite permanent support structure.

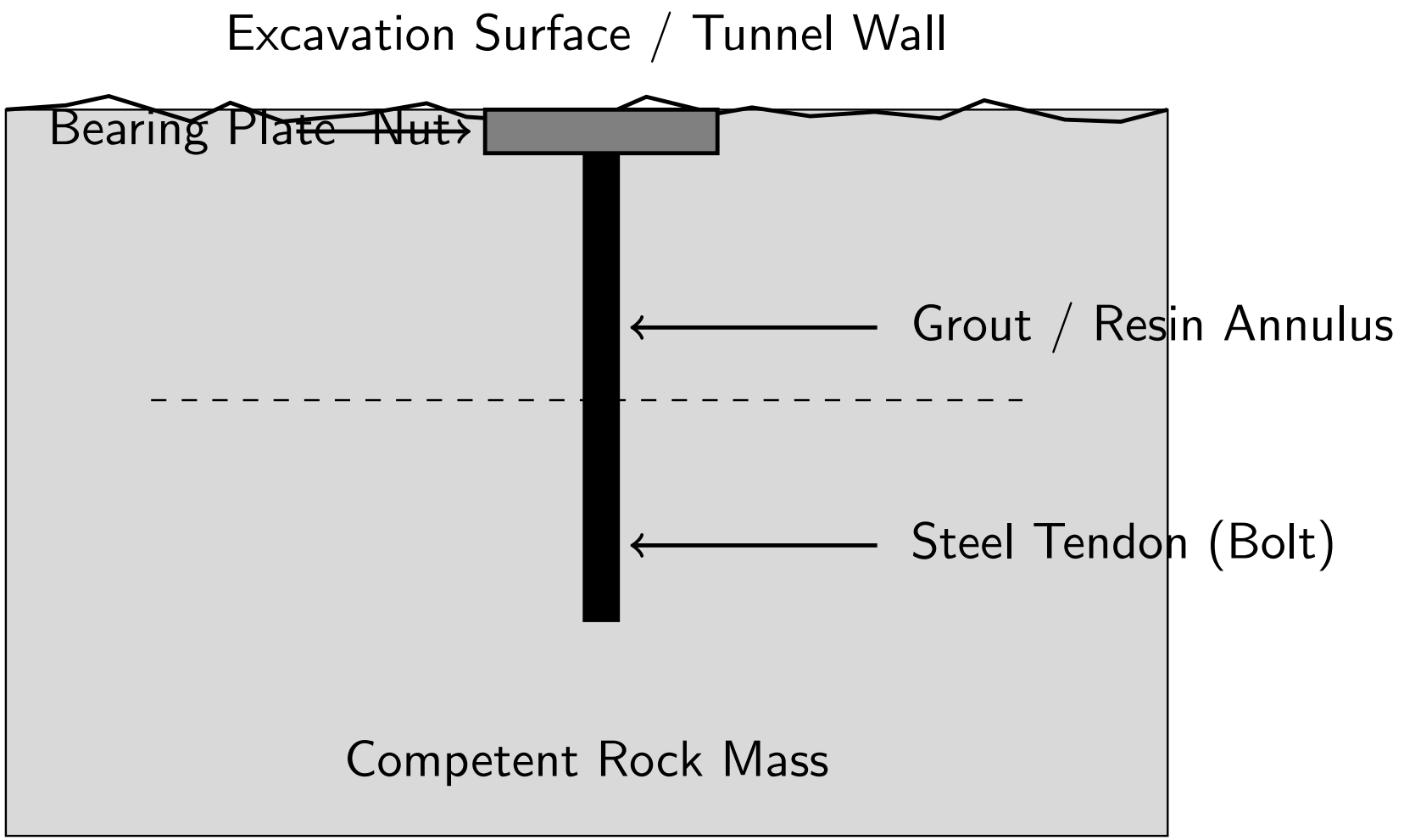
Rock Bolts: Principles and Types I

Rock bolts are reinforcing elements inserted into boreholes in the rock mass to stabilize excavations. They improve the rock's natural strength by tying discrete blocks together or anchoring weak zones to stable rock.

Key Points

- Mechanically Anchored Bolts: Utilize an expansion shell at the end of the bolt to grip the rock.
- Fully Grouted Bolts (Resin or Cement): The annulus between the bolt and borehole is fully filled with grout, providing load transfer along the entire length.
- Friction Bolts (Split Sets, Swellex): Rely on frictional resistance between the bolt and borehole wall.
- Key functions include rock reinforcement, suspension of detached blocks, and building a structural rock arch.

Mechanism of Rock Bolting I



Mechanism of Rock Bolting II

Key Points

- The diagram illustrates a fully grouted rock bolt installed in a tunnel wall.
- The bearing plate provides immediate surface support and tensioning capability.
- Grout or resin transfers stress from the rock to the high-tensile steel tendon.
- Bolts anchor potentially unstable near-surface rock to the deeper, competent rock mass.

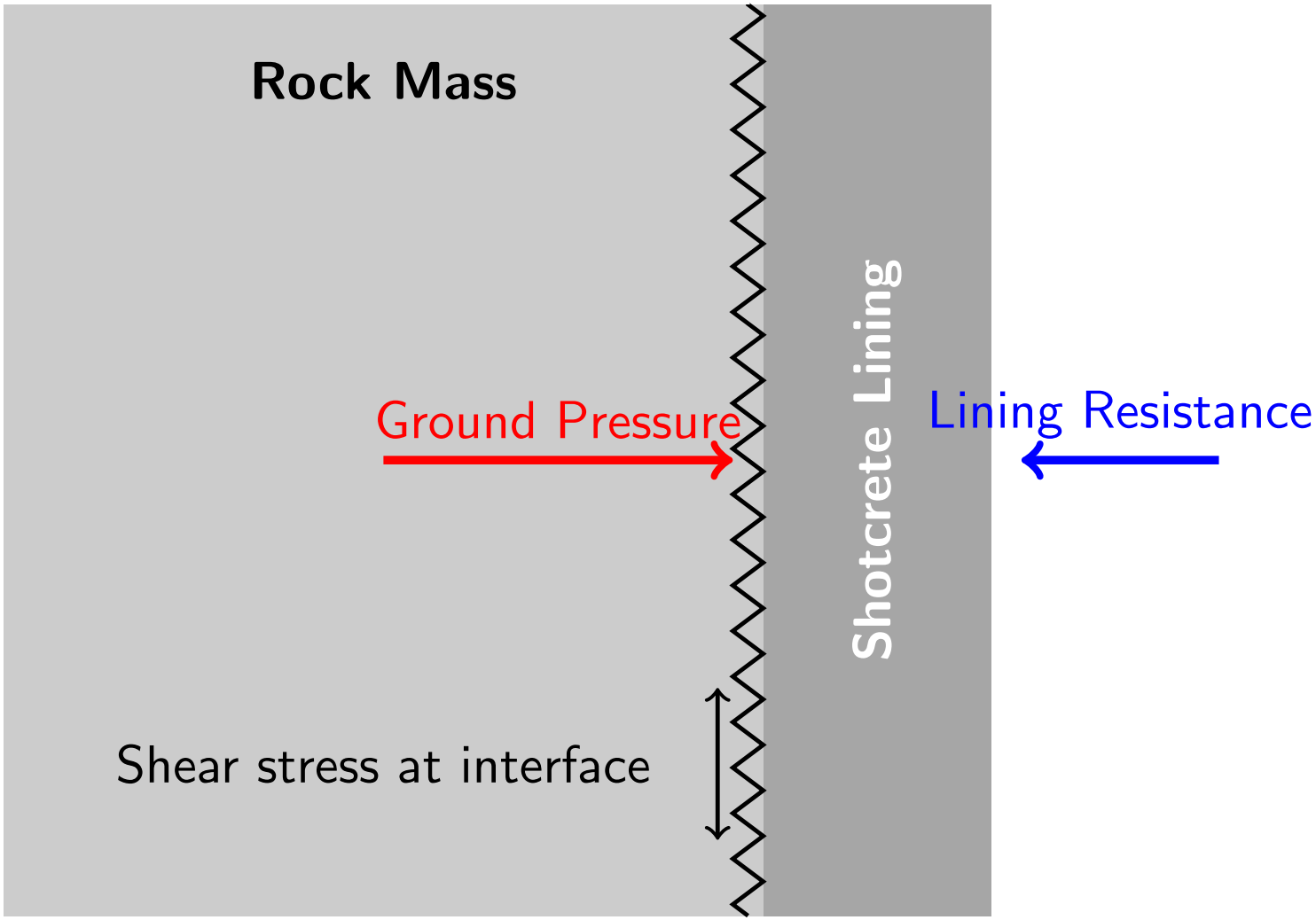
Shotcrete (Sprayed Concrete) I

Shotcrete is concrete or mortar conveyed through a hose and pneumatically projected at high velocity onto a surface. It provides immediate, continuous surface support and seals the rock mass.

Key Points

- Dry-Mix Shotcrete: Dry ingredients are mixed with water at the nozzle. Generates more dust and rebound.
- Wet-Mix Shotcrete: Pre-mixed concrete is pumped to the nozzle where compressed air is introduced. Offers better quality control and less rebound.
- Can be reinforced with steel mesh or steel/synthetic fibers to improve ductility, toughness, and energy absorption.
- Rapid strength gain is achieved using chemical accelerators.

Shotcrete-Rock Interaction I



Shotcrete-Rock Interaction II

Key Points

- Shotcrete creates a stiff, semi-rigid shell closely conforming to the excavation profile.
- It prevents loosening of rock blocks and restricts immediate deformation.
- Adhesion to the rock surface allows shear stress transfer between the ground and lining.
- Acts compositely with rock bolts to form a reinforced arch around the tunnel.

Steel Arches and Ribs I

Steel sets (arches or ribs) are passive support elements fabricated from rolled steel sections (like H-beams or I-beams). They are used primarily in heavily squeezing ground or fault zones where immediate, high-capacity support is required.

Key Points

- Installed in sequence as excavation advances, blocked against the rock with timber or concrete.
- Can handle significant immediate loads, preventing total collapse in poor ground.
- Yielding steel arches incorporate sliding joints (e.g., TH profiles) to accommodate large rock deformations without buckling.
- Often combined with lagging and backfilling to distribute rock loads evenly.

Lattice Girders I

Lattice girders are lightweight, three-dimensional spatial structures made of steel rebars. They are increasingly preferred over solid steel ribs in modern tunneling methods like NATM.

Key Points

- Constructed typically of three primary reinforcing bars connected by diagonal lacing.
- They offer low resistance to shotcrete application, reducing shadow zones and rebound.
- Act as templates for excavation profiling and thickness control of the shotcrete layer.
- Fully embedded in shotcrete, they form a composite, reinforced concrete support structure.

Comparison of Support Systems I

A comparative overview of the primary tunnel support elements, highlighting their structural characteristics, typical applications, and relative costs.

Key Points

- | Feature | Shotcrete | Rock Bolts | Steel Arches | Lattice Girders |
- | :— | :— | :— | :— | :— |
- | **Action Type** | Surface Seal / Arch | Reinforcement | Heavy Passive Support | Composite (w/ Shotcrete) |
- | **Flexibility** | High (Conforms) | High | Low (Rigid) | Moderate |
- | **Application Speed** | Fast | Moderate | Slow | Fast |
- | **Ground Type** | Most ground types | Blocky/Jointed Rock | Squeezing/Faults | Most (NATM style) |
- | **Cost** | Low to Medium | Low | High | Medium |

Integrated Support (NATM Approach) I

The New Austrian Tunneling Method (NATM) or Sequential Excavation Method (SEM) relies on integrating various support elements to mobilize the inherent strength of the rock mass.

Key Points

- Instead of heavy, rigid linings, NATM uses a combination of shotcrete, rock bolts, and lattice girders.
- Support is applied dynamically based on continuous monitoring of tunnel deformations.
- The surrounding ground is transformed from a loading element into a load-bearing structural ring.
- Ensures safety while optimizing the cost and material usage for support systems.

Summary I

Effective tunnel design relies heavily on the appropriate selection and integration of temporary and permanent support systems to ensure stability.

Key Points

- Temporary supports (primary lining) stabilize the tunnel during construction.
- Rock bolts reinforce the rock mass internally, preventing block falls and delamination.
- Shotcrete provides immediate surface sealing and structural continuity.
- Steel arches and lattice girders provide robust support in challenging geological conditions.
- Modern techniques favor composite, flexible systems over rigid, massive supports.