

DI04006071: Railway, Harbour & Tunnel Engineering

Lecture 1.4: Design and Construction of Slab Track

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Civil Engineering

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Introduction to Slab Track Systems I

Slab track, or non-ballasted track, replaces the traditional elastic ballast layer with a rigid concrete or asphalt structure. This provides superior geometric stability, which is essential for high-speed rail (HSR) operations and heavily utilized urban transit networks where maintenance windows are extremely limited.

Key Points

- Eliminates the need for traditional ballast
- Provides high lateral and longitudinal stability
- Significantly reduces maintenance requirements over the lifecycle
- Ideal for tunnels, viaducts, and earthworks with low settlement

Ballasted vs. Slab Track Comparison I

While traditional ballasted tracks offer lower initial construction costs and easier subgrade settlement correction, slab tracks provide long-term economic benefits through reduced maintenance, improved track availability, and enhanced safety at high speeds. The rigid nature of slab tracks requires stringent subgrade preparation to prevent differential settlement.

Key Points

- Initial cost: Ballasted is lower, Slab track is higher
- Maintenance frequency: Ballasted is high, Slab track is very low
- Design life: Ballasted ~20-30 years, Slab track ~50-60 years
- Structural height: Slab track has a reduced structural height

Characteristics of Track Structures I

A comparative summary of key engineering parameters between traditional ballasted tracks and modern slab track systems for high-speed applications.

Key Points

- Parameter | Ballasted Track | Slab Track
- Elasticity | Provided by ballast and pad | Provided by highly elastic fastening systems
- Acoustic performance | Good absorption | Requires additional sound-absorbing materials
- Weight | Heavy | Lighter structural load on bridges
- Track geometry retention | Poor over time | Excellent long-term stability

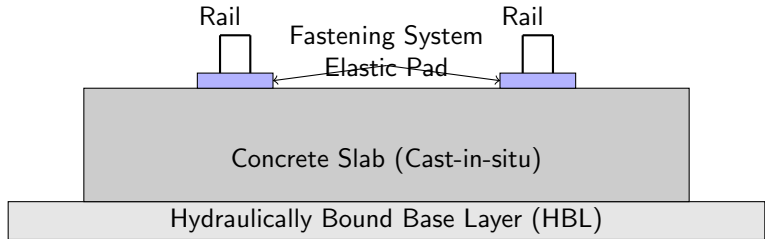
Primary Types of Slab Track Systems I

Slab track technologies can be broadly categorized into several structural concepts, including continuous poured-in-place concrete slabs, precast concrete slab systems, and independent block systems embedded in a concrete or asphalt layer. Each system offers distinct advantages in terms of constructability, curing time, and long-term performance.

Key Points

- Cast-in-situ systems (e.g., Rheda 2000, Zublin)
- Precast slab systems (e.g., Bögl, Shinkansen slab)
- Direct fastening systems (commonly used in tunnels and on viaducts)
- Embedded rail systems for specific urban applications

Cross-Section of Cast-in-Situ Slab Track I



Key Points

- Sub-base layer ensures uniform load distribution
- Cast-in-situ concrete slab incorporates reinforcement steel
- Elastic fastening systems compensate for the loss of ballast elasticity
- Twin-block sleepers may be embedded within the continuous slab

Design Principles: Elasticity and Load Distribution I

In a slab track system, the structural elasticity traditionally provided by the ballast must be replaced by highly engineered elastic components. This is typically achieved through resilient rail pads, baseplate pads, and sometimes sleeper boots. The design must optimize the track stiffness to distribute wheel loads safely to the subgrade while minimizing vehicle-track interaction forces.

Key Points

- Target track stiffness is typically between 20 and 60 kN/mm
- Vertical deflection is controlled to prevent excessive rail bending stresses
- Dynamic load amplification factors must be accounted for at high speeds
- Transition zones between ballasted and slab track require gradual stiffness variations

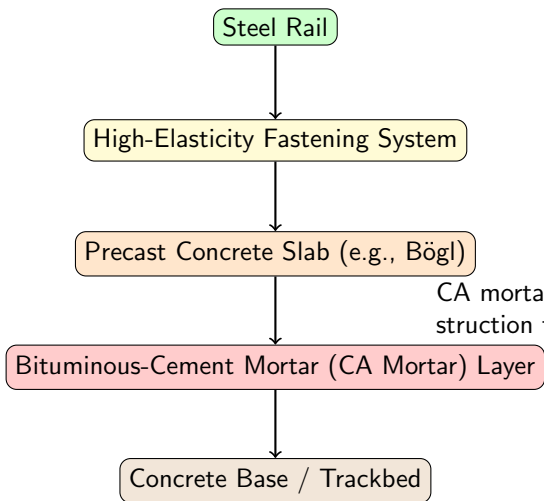
Subgrade and Earthwork Requirements I

The most critical vulnerability of slab track is its inability to easily accommodate differential subgrade settlement. Consequently, the supporting earthworks must meet extremely stringent settlement criteria. High-quality fill materials, rigorous compaction, and sometimes deep soil mixing or piling are required to achieve the necessary foundation stiffness and stability.

Key Points

- Maximum allowable residual settlement is typically limited to 15-20 mm
- Transition structures are mandatory at bridge abutments and tunnel portals
- Frost protection layers are essential in cold climates to prevent heave
- Hydraulically bound layers (HBL) provide a stable working platform and spread loads

Precast Slab Track System Component Hierarchy I



CA mortar provides adjustment for construction tolerances and uniform support

Precast Slab Track System Component Hierarchy II

Key Points

- Rails are mounted on pre-manufactured concrete panels
- Quality control is maximized through factory production of slabs
- CA (Cement-Asphalt) mortar acts as a leveling and damping layer
- Rapid installation process suitable for long continuous viaducts

Construction Methodologies I

The construction of slab track is a highly mechanized and precision-driven process. For precast systems, specialized gantry cranes place the slabs, followed by the injection of grouting material. For cast-in-situ systems, slip-form pavers or specialized rail-mounted concrete trains are utilized. Top-down construction is often used, where rails are suspended to exact geometry before the concrete is poured around the supports.

Key Points

- Top-down construction ensures millimeter-level geometric accuracy
- Logistics of concrete supply and placement are critical on long sections
- Curing times dictate the scheduling of subsequent track laying activities
- Stringent surveying using total stations and 3D machine control is mandatory

Vibration and Noise Mitigation I

The high acoustic reflectivity of concrete and the rigid nature of slab tracks can lead to increased airborne noise and ground-borne vibration compared to ballasted tracks. Mitigation strategies are essential, particularly in urban environments and tunnels. These include the use of floating slab tracks (FST), highly resilient rail fasteners, and sound-absorbing panels.

Key Points

- Floating slab track systems use discrete or continuous elastomeric bearings
- Reduces ground-borne vibration transmission to adjacent structures by up to 20 dB
- Sound-absorbing materials (e.g., porous concrete, synthetic mats) are placed between rails
- Rail dampers can reduce rolling noise generation

Summary and Future Trends I

Slab track systems represent the state-of-the-art in railway infrastructure for high-speed and dense urban networks, offering unparalleled geometric stability and drastically reduced maintenance. While the initial capital expenditure is high, the lifecycle cost benefits are substantial. Future developments focus on modularity, improved damping materials, and automated construction techniques.

Key Points

- Slab track is essential for safe and comfortable high-speed operations
- Stringent foundation requirements dictate overall project feasibility
- Transition zones require careful engineering to manage stiffness changes
- Ongoing innovations aim to reduce installation costs and improve acoustic performance