DI04006071: Railway, Harbour & Tunnel Engineering

Lecture 1.6: High Speed Rail Engineering: Infrastructure (Part 2)

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Civil Engineering

July 23, 2026

Introduction to HSR Infrastructure I

High Speed Rail (HSR) represents a paradigm shift in civil engineering, where the interaction between the moving train and the infrastructure becomes highly dynamic. The infrastructure must endure unprecedented loads, vibrations, and aerodynamic forces.

Key Points

- Speeds exceeding 250 km/h drastically increase dynamic amplification.
- Track geometry must be maintained to millimeter precision.
- Infrastructure requires massive rigidity to prevent resonance.
- Environmental factors like noise and micro-pressure waves become critical.

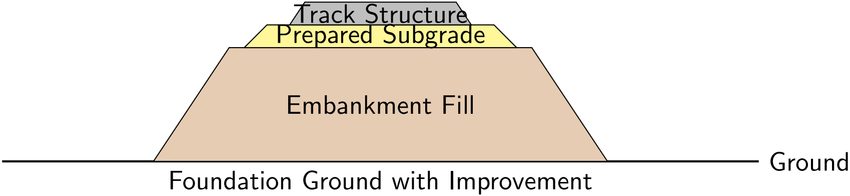
Bullet Train Development & Loading I

The development of bullet trains focuses on minimizing aerodynamic drag and controlling wheel-rail interaction forces. The high operational speeds impart severe dynamic vertical and transverse loads onto the track structure and substructure.

Key Points

- Streamlined nose designs reduce aerodynamic drag and tunnel boom.
- Articulated bogies and active suspension systems distribute loads.
- Increased braking forces require higher longitudinal rail restraint.
- Axle loads are generally lower, but dynamic impact factors are much higher.

HSR Earthwork Cross-Section I



Key Points

- Strict layered compaction to ensure uniform stiffness.
- The prepared subgrade layer dissipates dynamic stresses.
- Transition zones are critical between earthworks and rigid structures.

Earthwork Settlement Control I

In high-speed rail, post-construction settlement of earthworks must be strictly limited to prevent track deformation. Excessive settlement leads to poor ride comfort and potential derailment risks at speeds over 300 km/h.

Key Points

- Post-construction settlement is typically restricted to less than 15 mm.
- Ground improvement techniques (e.g., stone columns, piling) are mandatory.
- Rigorous compaction control using continuous compaction control (CCC) systems.
- Pre-loading and extended rest periods are often used before track laying.

Conventional vs. HSR Infrastructure I

Parameter	Conventional Rail	High Speed Rail
Max Speed	< 160 km/h	> 250 km/h
Minimum Curve Radius	~ 500 m	> 4000 m
Maximum Gradient	Up to 3%	Typically < 1.5%
Settlement Limits	Modest tolerance	Strict (< 15 mm)
Substructure Rigidity	Normal requirements	Exceptionally high

Key Points

- HSR requires much larger curve radii to maintain passenger comfort.
- Gradient restrictions limit routing options, leading to more tunnels and viaducts.
- The demand for structural rigidity drives up material and construction costs.

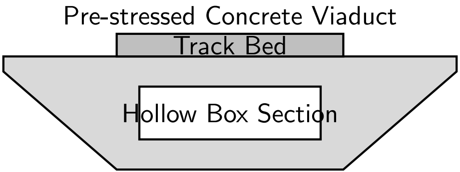
HSR Bridges & Viaducts Design I

Bridges and viaducts on HSR lines account for a significant portion of the total length. Their design is dictated by strict deflection limits to ensure track stability and to prevent resonance with the regular axle spacing of the high-speed trains.

Key Points

- High flexural and torsional rigidity are paramount.
- Train-bridge dynamic interaction analysis is a mandatory design step.
- Continuous welded rail (CWR) on bridges requires careful rail-structure interaction analysis.
- Avoidance of resonant frequencies matching the train's dominant excitation frequencies.

Viaduct Box Girder Section I



Key Points

- Pre-stressed concrete box girders offer excellent torsional stiffness.
- The hollow section reduces dead weight while maintaining aerodynamic stability.
- Standardized spans (e.g., 30m, 40m) are preferred for rapid construction.

Viaduct Construction Methodology I

Given the sheer length of elevated structures required for HSR, advanced, highly mechanized construction methods are deployed to ensure speed, safety, and strict quality control of precast elements.

Key Points

- Full-Span Launching Method (FSLM) is commonly used for rapid deployment.
- Pre-cast yards employ match-casting to ensure perfect alignment.
- Launching gantries handle bridge segments weighing up to 1000 tons.
- Span-by-span construction minimizes disruption to ground-level activities.

HSR Tunnels: Aerodynamic Effects I

When a high-speed train enters a tunnel, it acts like a piston, generating complex aerodynamic pressure waves. These phenomena pose significant challenges to passenger comfort and environmental noise regulations.

Key Points

- Micro-pressure waves propagate through the tunnel at the speed of sound.
- Upon exiting, they create a loud sonic boom known as 'Tunnel Boom'.
- Aural discomfort (ear popping) occurs due to rapid pressure transients inside the cabin.
- Larger tunnel cross-sections are required specifically to mitigate these effects.

Tunnel Portals and Cross-Sections I

To counteract aerodynamic shocks, HSR tunnel infrastructure employs specialized designs, particularly at the entrance and exit portals, to gently dissipate the pressure waves before they steepen.

Key Points

- Flared, hood-shaped portals are installed at tunnel entrances.
- Venting shafts may be incorporated to relieve air pressure.
- The aerodynamic blockage ratio dictates a much larger excavated diameter than conventional tunnels.
- Invert struts and robust linings are essential to withstand cyclic aerodynamic loading.

Summary I

High-Speed Rail infrastructure demands a radical departure from conventional railway engineering, characterized by an absolute necessity for stiffness, precision, and aerodynamic optimization across all civil structures.

Key Points

- Stringent settlement tolerances govern earthwork design and construction.
- Bridges and viaducts prioritize dynamic stability and torsional rigidity.
- Tunnel engineering for HSR is uniquely driven by aerodynamic wave phenomena.
- Seamless integration between train systems and civil infrastructure is vital for safety.