The Ballastless Track Technology
For China High-Speed Line

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May 4th 2011
Contents

1. Application of Ballastless Track in China
2. Technical Features of Ballastless Track of HSL
3. Design of Ballastless Track
4. Interface Technology of Ballastless Track
5. Fastening System
6. CWR and Turnouts
7. Conclusion
1.1 Application

- Until now, ballastless track has been used in several High-speed lines which have put into operation recently such as Beijing-Tianjin, Wuhan-Guangzhou, Zhengzhou-Xi’an, Shanghai-Nanjing, Guangzhou-Zhuhai, Shanghai-Hangzhou, and the mileage is more than 2,100km.

- Ballastless track has also been used in Beijing-Shanghai, Haerbin-Dalian, Beijing-Wuhan HSL which will be open soon. The mileage under construction is more than 2,500km.
1. Application of Ballastless Track in China

1.2 Application

High speed lines with ballastless track covered most area of China which have different climates and complex geological conditions.

Ballastless track has also been laid on subgrade, bridge and tunnel on a large scale.
1. Application of Ballastless Track in China

1.3 Projects

(1) Beijing-Tianjin HSL 120km; 2008.8 open, 30min arrival.

(2) Wuhan-Guangzhou HSL 1069km; 2009.12 open, 3h arrival.

(3) Zhengzhou-Xi’an HSL 505km; 2010.2 open; It was the first time in the world that ballastless track was laid in the collapsed loess area successfully.

(4) Shanghai-Nanjing/Shanghai-Hangzhou HSL 300km/169km; opened in 2010, soft soil area, ballastless track used.

(5) Haerbin-Dalian HSL 904km; will open soon; very cold region, lowest temp. -39.9°C; ballastless track used.

(6) Lanzhou-Urumchi second line 1775km; under construction; cold, big temperature difference, sandstorm, strong sunshine, dry, salty soil; lowest temperature -21.7°C ~ -41.5°C.
1. 1.4 Technical Difficulties Solved

(1) Different kind of ballastless track adapt to different climate and infrastructure.

(2) Compatibility between ballastless track and track circuit.

(3) Settlement after work completion on soft soil, carst and collapsed soil is effectively controlled in order to lay ballastless track.

(4) Large-span bridge deformation is under control, satisfy the conditions of ballastless track laying.

(5) Unification of survey control network, construction control network and maintenance control network. implements the concept of “One control network for three engineering stages”.
2. Technical Features of Ballastless Track

- **Ballastless track tech.**
  - **Design tech.**
    - Structure design
    - Interface design of ballastless track system
    - Technical requirements of construction, material performance and maintenance, etc.
  - **Construction tech.**
    - Engineering survey tech.
    - Engineering material tech.
    - Manufacturing tech.
    - Laying tech.
  - **Inspection & maintenance tech.**
    - Inspection and evaluation
    - Repair tech.
    - Quick renewal tech. (in particular cases)
2. Technical Features of Ballastless Track

2.1 Structural type of Ballastless track

- Precast slab track
- Cast-in-situ concrete type track
2. Technical Features of Ballastless Track

2.2 Technical features of precast slab track

- Layer-built structure, which is “precast slab + mortar filling layer + cast-in-situ support foundation”.

- Accordingly, “from bottom to top” construction method is adopted.

- Improve construction efficiency, guarantee the quality of concrete structure.

- Reduce the influence of environment and weather.
2. Technical Features of Ballastless Track

2.2 Technical features of precast slab track

Application

Ballastless track in Southwest China
2.2 Technical features of precast slab track

- Different ways of slab position restriction

- Different fine-adjusting methods for track geometry
2. Technical Features of Ballastless Track

2.3 Technical features of cast-in-situ ballastless track

- Longitudinal continuous concrete bed structure is generally adopted on subgrade and tunnel sections.

- Longitudinal discrete concrete bed structure is adopted on bridges. Intermediate layer is installed to keep concrete bed and support foundation separate.
3. Design of ballastless track system

3.1 The design principle of ballastless track system

Design principle:
- Enough strength and stability
  → High safety
- Reasonable design scheme of manufacturing, laying and fine-adjusting of track system
  → Good Smoothness
- Reasonable structure types and durable engineering material
  → Low maintenance
3. Design of ballastless track system

3.2 Design philosophy of ballastless track

Schematic diagram

- Design method analysis
  - allowable stress, limit states method
- Train load
- Temperature/gradient
- Foundation deformation
- Temporary load
- Parameters/limits for calculation

Key factors:
- Train load
  - Beam-plate theory
- Foundation deformation
- Temperature
- Environment

- Rein. design
- Dynamic evaluation
- Stiffness design
- Construction process design

Parameters/limits for calculation:
- Track stiffness and matching design
- Durability/Crack control
- Temperature stress
- Calculation method of train load
  - Beam-beam
  - Beam-plate
  - Beam-solid element
- Calculating method of foundation deformation
- Temporary load
- Environment
- Train load
- Temperature/gradient
- Foundation deformation

Test & verify of design theory:
- Test of parameter
- Compatibility of Interface design
- Economic evaluation method
- Dynamics evaluation method

Economics

Test of parameter:
- Rein. design
- Static evaluation
- Beam-plate
- Beam-solid element
- Stiffness design
- Construction process design
- Environment

Schematic diagram
3. Design of ballastless track system

3.2 design theory

a. Train load:

FEM model of Beam-plate based on elastic foundation
3. Design of ballastless track system

3.2 design theory

b. Calculation of temperature stress

**Axial force:**

Discrete slab:

\[ P_i = \frac{(f_d + f_k)L}{2} + \frac{k_s \alpha_t L_s \Delta T}{2} \]

Continuous slab:

\[ P_{t1} = E_c \alpha_t \Delta TA \]

\[ P_{t2} = f_t A \]
3. Design of ballastless track system

3.2 design theory

Calculation of warping stress (temperature gradient) (analysis or FEM method)

\[ \sigma_t = \frac{E_c \beta_h \alpha_t \Delta T}{2} \]
3. Design of ballastless track system

3.2 design theory

c. Deformation of foundation (analysis method)

\[ M = EI \kappa \]

Uneven settlement of subgrade
3. Design of ballastless track system

3.2 Design theory

c. Deformation of foundation (analysis method)

\[ M = EI \kappa \]

Influence of beam flexure on ballastless track
### 3. Design of ballastless track system

#### 3.3 classification of loads

<table>
<thead>
<tr>
<th>classification</th>
<th>load</th>
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<tbody>
<tr>
<td>Main force</td>
<td>Dead load</td>
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<td>Additional load</td>
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<td></td>
<td>Structure weight</td>
<td></td>
<td>Brake/traction force</td>
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<td></td>
<td>Shrinkage and creep of concrete</td>
<td></td>
<td>Uneven settlement of Sub.</td>
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<td>Special load</td>
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<td></td>
<td>Vertical force</td>
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<td>Construction temp. force</td>
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<td></td>
<td>Lateral force</td>
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<td></td>
<td>Temperature force</td>
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<tr>
<td></td>
<td>Flexure of bridge</td>
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<td>Live load</td>
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3. Design of ballastless track system

3.4 dynamic evaluation of ballastless track

train-track-foundation dynamic module
3. Design of ballastless track system

3.4 dynamic evaluation of ballastless track

Evaluation index:

a. Safety index:
   derailment coefficient, rate of wheel load reduction

b. Comfort index:
   Carbody acceleration

c. Dynamic response index:
   vertical force, lateral force, acceleration, and so on.
4. Interface tech. of ballastless track

4.1 Interface with engineering structure

- Settlement and deflection of engineering structure
- Elevation and Flatness of engineering structure
- Design requirement of embedded parts
- Drainage system design
4. Interface tech. of ballastless track

4.2 Interface with signal system

The compatibility with the track circuit

Integrated earthing System

Installation of signal device on track
5. Fastening System for ballastless Track

5.1 Technical Requirements and Key Technologies

Technical Requirements:

① Ability to keep track gauge
② Resistance to rail climbing
③ Damping performance
④ Insulation performance
⑤ Number of Components and maintenance work
⑥ Evenness
⑦ Capacity of adjusting vertical/lateral position of rails
⑧ Versatility
⑨ Uniformization of track stiffness in turnout area
5. Fastening System for ballastless Track

5.1 Technical Requirements and Key Technologies

Key Technologies:

① Selection of a reasonable fastening stiffness

② Improvement in insulation performance

③ Toe load lost and fatigue life of clips

④ Uniformization of track stiffness in turnout area
5. Fastening System for ballastless Track

5.2 Fastening system in China

Fig 1: WJ-7
5. Fastening System for ballastless Track

5.2 Fastening system in China

Fig 2: WJ-8
5. Fastening System for ballastless Track

5.2 fastening systems in China

Fig 3: fastening system in turnout
5. Fastening System for ballastless Track

5.3 The Application in High-Speed Railway

WJ-7 fastenings
5. Fastening Systems for ballastless Track

5.3 The Application in High-Speed Railway

WJ-8 fastenings
5. Fastening Systems for ballastless Track

5.3 The Application in High-Speed Railway
In China, high speed railway CWR is based on ballastless track, long-span bridge, elevated station and other key techniques, so it results in a series of technical difficulties:

a. CWR on long-span bridge of high speed railway

b. CWR turnouts on bridge of high speed railway

c. CWR laying technology: rail welding base, 500m long rail transportation, flash butt welding in the field.
6. CWR Design Technologies of HSL

Application:

- CWR on bridge, ballastless track, Weinan, Zhengzhou-Xi’an High-speed line.
- Features:
  1. Interaction between CWR and bridge (trackbed bonded with bridge).
  2. Ballastless track, design speed 350km/h.
  3. Rail temperature: \( T_{max} = 62.2^\circ C, \ T_{min} = -16.7^\circ C. \)
  4. CWR was laid on continuous beam bridge which thermal span is 736m.
  5. Two directional EJ which designed by CARS was used for HSL.
  6. WJ-8 fastening system which designed by CARS was used on long-span bridge for HSL.
6. CWR Design Technologies of HSL

EJ layout:
Two directional EJ for HSL, 5 places, 10 sets, maximum speed 390km/h.
6. CWR Design Technologies of HSL

EJ for HSL
Turnout for non-ballast track laid on continuous beam bridge which largest span is 56m.
6. CWR Design Technologies of HSL

Turnout technology

High-speed series turnouts (No.18, 42, 62) have been developed and used in HSL lines in China.

Following problems need to be solved in the design, manufacture, laying, acceptance and application of high speed turnout:

- **Optimum plane shape** and suitable requirements on different straight and side passing speeds
- **Wheel/rail interaction** in turnout area that ensures safety and stability of train operation
- Reasonable **rail stiffness** in turnout area that ensures riding comfort of train operation
- Turnout structure adaptable to **CWR** (continuous welded rail)
- Optimized design of switching between long switch rail and flexible elastic point rail
- Transport, assembly and laying technologies can ensure high accuracy of turnout.
A complete set of ballastless track technical standards of HSL has formed in China. These standards are able to adapt to different climates, environments and foundations.

- **Design code**
- **Technical standards for prefabricated parts and engineering materials**
- **Operation rules of construction**
- **Quality acceptance criteria and inspecting methods**

We are willing to share China’s ballastless track technology with other countries and achieve sustainable development of High-Speed Railway.
Thank you for your kind attention

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