Infrastructure for high speed lines in Japan

Atsushi YOKOYAMA
Director of Japan Railways Group Paris Office
Paris, FRANCE
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✓ Measures for natural hazard

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Japanese Shinkansen Network

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<tr>
<th>Line</th>
<th>Section</th>
<th>Length (mile)</th>
<th>Max. Speed (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tokaido</td>
<td></td>
<td>343.4</td>
<td>168</td>
</tr>
<tr>
<td>Sanyo</td>
<td></td>
<td>400.2</td>
<td>187</td>
</tr>
<tr>
<td>Tohoku</td>
<td></td>
<td>392.6</td>
<td>171</td>
</tr>
<tr>
<td>Joetsu</td>
<td></td>
<td>188.6</td>
<td>150</td>
</tr>
<tr>
<td>Nagano</td>
<td></td>
<td>72.9</td>
<td>162</td>
</tr>
<tr>
<td>Kyushu</td>
<td></td>
<td>85.5</td>
<td>162</td>
</tr>
<tr>
<td></td>
<td><strong>Sub Total</strong></td>
<td><strong>1483.3</strong></td>
<td></td>
</tr>
<tr>
<td>Akita</td>
<td></td>
<td>79.1</td>
<td>81</td>
</tr>
<tr>
<td>Yamagata</td>
<td></td>
<td>92.3</td>
<td>81</td>
</tr>
<tr>
<td></td>
<td><strong>Sub Total</strong></td>
<td><strong>171.4</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>1654.7</strong></td>
<td></td>
</tr>
</tbody>
</table>

*Length: mileage in revenue service

- Converted from narrow gauge to standard gauge

*The Tokaido Shinkansen (1964) is shown in green, the Sanyo Shinkansen (1972, 75) is shown in blue, the Tohoku Shinkansen (1982, 85, 91, 2002) is shown in purple, the Joetsu Shinkansen (1982) is shown in orange, the Nagano Shinkansen (1992, 99) is shown in red, the Kyushu Shinkansen (2004) is shown in yellow, the Akita Shinkansen (1997) is shown in black, and the Yamagata Shinkansen (1997) is shown in pink.*
Facts

- Shinkansen has strong points:
  - Safe
  - Faster
  - Punctual, Reliable
  - No fatal accidents in 45 years
  - 300km/h (Sanyo Shinkansen)
  - Average delay time per train:
    0.6min (Tokaido, 2008, 323 trains/day)
  - 15 trains/hour at maximum
  - Environmental friendly
    - Less energy consumption, Low noise,…

“Average delay time”: total “delay time” of all trains/total train number, and the “delay time” is counted if it is more than 1 minute.

Data between 1999-2006
<table>
<thead>
<tr>
<th>Line name</th>
<th>Tokaido</th>
<th>Sanyo</th>
<th>Tohoku</th>
<th>Hokuriku</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section of line</td>
<td>Tokyo - Shin-Osaka</td>
<td>Okayama - Hakata</td>
<td>Omiya - Morioka</td>
<td>Takasaki - Nagano</td>
</tr>
<tr>
<td>Year opened</td>
<td>1964</td>
<td>1975</td>
<td>1982</td>
<td>1997</td>
</tr>
<tr>
<td>Maximum speed (mph) initial/present</td>
<td>130/168</td>
<td>130/186</td>
<td>130/171</td>
<td>162/162</td>
</tr>
<tr>
<td>Track gauge (mm)</td>
<td>1435</td>
<td>1435</td>
<td>1435</td>
<td>1435</td>
</tr>
<tr>
<td>Permissible axle weight (t)</td>
<td>16</td>
<td>16</td>
<td>17</td>
<td>16</td>
</tr>
<tr>
<td>Dominant Track type</td>
<td>Ballast</td>
<td>Slab</td>
<td>Slab</td>
<td>Slab</td>
</tr>
<tr>
<td>Distance between centers of main tracks (m)</td>
<td>4.2</td>
<td>4.3</td>
<td>4.3</td>
<td>4.3</td>
</tr>
<tr>
<td>Minimum curve radius (m)</td>
<td>2500</td>
<td>4000</td>
<td>4000</td>
<td>4000</td>
</tr>
<tr>
<td>Maximum designed cant (mm)</td>
<td>200</td>
<td>200</td>
<td>180</td>
<td>200</td>
</tr>
<tr>
<td>Cross section area of tunnel (m²)</td>
<td>60.5</td>
<td>63.4</td>
<td>63.4</td>
<td>63.4</td>
</tr>
<tr>
<td>Maximum gradient (if needed)</td>
<td>1.5% (2%)</td>
<td>1.5% (2%)</td>
<td>1.2% (1.5%)</td>
<td>1.5% (3.5%)</td>
</tr>
<tr>
<td>Electrical power supply</td>
<td>AC25KV 60Hz</td>
<td>AC25KV 60Hz</td>
<td>AC25KV 50Hz</td>
<td>AC25KV 50/60Hz</td>
</tr>
<tr>
<td>Signal type</td>
<td>Digital ATC</td>
<td>ATC</td>
<td>Digital ATC</td>
<td>ATC</td>
</tr>
</tbody>
</table>
Proportion of structures

- Level crossing is avoided.
- Concrete structure is dominant after Sanyo Shinkansen
- Proportion of tunnel is large

Data: Excerpted from “Shinkansen”, Sankaido, 2003
Structures on Shinkansen

- **Tunnel**
  - (Hokuriku Shinkansen)

- **Bridge**
  - (Tohoku Shinkansen)

- **Viaduct**
  - (Tohoku Shinkansen)

- **Earth Structure**
  - (Kyushu Shinkansen)
Viaduct
Tunnel
Track Structure (Slab Track)

On a bridge
  (Kyushu Shinkansen)

In a tunnel
  (Kyushu Shinkansen)
Design concepts of slab track

In 1965, the former Japanese National Railways (JNR) started to develop “New Track Structures”.

The design concepts were:

1. The construction cost shall be less than twice as much as that of ballasted track.
2. Elasticity and lateral/vertical strength shall be greater than those of ballasted track.
3. A construction rate shall be at least 200 m/day.
4. Track irregularities due to substructure deterioration shall be within the allowable range. (+/-50 mm vertically, +/-10 mm laterally)
Structure of slab track
Rail fastening device type-8

- Spring clip
- Anchor bolt
- Insulation plate
- Tie plate
- Rail pad
- Insert
Conventional type of slab track

(a) For open section
(b) For tunnel section
Frame-shaped Slab Track
Comparison of maintenance work cost

Ballasted track

Slab track

Costs 1/3

1000 USD/Year/mile

1USD=94JPY

Average

Maintenance cost (million yen/year/km)

2003  2004  2005  2006  Average

Ballasted track

Fastening
Leveling
Lining
Overall leveling
CA-mortar

1/3

17

34

51
Comparison of total cost ballasted track vs slab track
### Track structure of JR East

<table>
<thead>
<tr>
<th>Line name</th>
<th>Line length</th>
<th>Segment</th>
<th>Slab</th>
<th>Ballast</th>
<th>Resiliently supported track</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tohoku Shinkansen</td>
<td>377.4</td>
<td>Slab</td>
<td>315.5</td>
<td>30.8</td>
<td>29.0</td>
<td>2.1</td>
</tr>
<tr>
<td>Joetsu Shinkansen</td>
<td>167.5</td>
<td>Ballast</td>
<td>151.2</td>
<td>9.0</td>
<td>7.3</td>
<td>0.1</td>
</tr>
<tr>
<td>Hokuriku Shinkansen</td>
<td>71.8</td>
<td>Resiliently</td>
<td>62.4</td>
<td>9.1</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>616.6</strong></td>
<td><strong>Others</strong></td>
<td><strong>529.1</strong></td>
<td><strong>48.9</strong></td>
<td><strong>36.4</strong></td>
<td><strong>2.2</strong></td>
</tr>
<tr>
<td><strong>Ratio</strong></td>
<td></td>
<td></td>
<td><strong>85.8%</strong></td>
<td><strong>7.9%</strong></td>
<td><strong>5.9%</strong></td>
<td><strong>0.4%</strong></td>
</tr>
</tbody>
</table>

Slab track

Resiliently supported track
Riding Quality Management: Overview

**Inspections**
- Electric and track inspection car (Train oscillation and track irregularity inspections)
- Operational trains (Train oscillation inspections)

**Planning**
- Track maintenance technology center
  - Inspection data
  - Facilities data
  - Work records
  - Work estimates
  - Planning support
- Track management company
  - Inspection data
  - Facilities data
  - Work records

**Maintenance work**
- Decision making of repair plans etc.
- Maintenance work volume calculation & work planning

Central server
- Inspection data
- Facilities data
- Work records
- Work estimates
- Planning support
Riding quality management: Management criteria

Management of long wavelength track irregularities

10m-chord track irregularity management
⇒ 40m-chord track irregularity management

Short wavelength maintenance
Before maintenance
After maintenance

Long wavelength maintenance
Before maintenance
After maintenance

Planned line
Status of riding quality management: Track conditions

Reduction of permitted management value

Trends in 40m-chord track irregularities
Riding quality management: Car body oscillation acceleration

Trends in car body oscillation acceleration (Tohoku Shinkansen, per 10km[6.2mile] on one trip)
Inspection train for infrastructure maintenance

Maintenance train for inspecting track and electrical facilities ("Dr. Yellow" and "East-i")

- Inspection by running at the same speed of commercial train.
- Run about every 10 days.

Ex. East-i

Track Maintenance: Recording image in front view
Power Supply: Measuring distance between wires
Signal: ATC inspection
Telecommunication: Measuring Train Radio Equipment

Track Maintenance:
- Measuring wheel weight & lateral pressure
- Measuring Axle-box accelerometer
- Rail longitudinal level
- Rail condition monitoring
- Recording tracks image

Power supply & Signal:
- Catenary irregularities, Wearing-out, Height
- Monitoring Power collection condition
- Pantograph observing Canopy
- Feeder circuit inspection
- Measuring Train ID detecting device
Infrastructure maintenance

- Safety for maintenance work
  - Dividing time slot to operation hours and maintenance service hours

<table>
<thead>
<tr>
<th>train operation hours</th>
<th>maintenance service hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>6:00</td>
<td>0:00</td>
</tr>
<tr>
<td>12:00</td>
<td>6:00</td>
</tr>
</tbody>
</table>

- Operating Sweeping car after maintenance work time
  
  Sweeping car confirms safety after the maintenance work almost everyday.

Ex. JR East case

Sweeping car with obstacle detection system

Special searchlight

Computer image processing

Obstacle
Operation control system

Systematization of train and crew planning, train operation control and maintenance and management of rolling stock, track, electricity, signal and communication

Ex. New Comprehensive Shinkansen System (COSMOS) for JR East
Earthquake damage for Shinkansen

Niigata Chuetsu Earthquake

October 23, 2004
Magnitude 6.8
Depth of epicenter: 13 km

- First case of derailment of high-speed train by earthquake
- Speed was approx. 125 mph
- 8 cars were derailed in 10 cars
- 154 passengers, no casualties
In 1995, the South Hyogo Earthquake (max. 8.91 gal) caused damage to bridge columns at Sanyo Shinkansen. Measures taken included:

- Pillars were strengthened by the Steel jacket method and Rib-bar (RB) method, among others.
- The design criterion was improved.

These measures were verified as effective at the Niigata Chuetsu Earthquake!

For tunnels, new measures included:

- Application of Backfill grouting method and Rock bolt method for tunnels destroyed by the earthquake.
- Use of the rock bolt method.

Deformation of tunnels and collapse of concrete surfaces were also addressed.
Earthquake observation system and early earthquake detection network

Ex. JR East case

- Seismometers along tracks
- Seismometers along coastline

Seismometers

Signals to stop electric power supply after earthquake detection

Sections to cut electric power supply

Power outage activates emergency brake of the train within 2.58 sec.
Protection from snow damage of infrastructure and train

- Sprinkler
- Snow fall detection equipment
- Snow shelter
- Snow depth meter
- Ballast screen installation to avoid ballast scattering by snow fallen from trains
Other safety and environmental issues

Measures for cross wind
- JR dispatchers have measurements of anemometer network
- Train decreases its speed or stops according to the wind speed if the wind speed exceeds threshold values

Measures for noise
- Reduction of tunnel micro pressure wave
  Tunnel micro pressure wave is a sonic boom radiated from the tunnel exit when a high speed train enters the tunnel
- Noise barrier for the reduction of line side noise
Signaling system

- Safety system is designed to:
  - Reduce human errors
  - Assure safety by automated system
  - Apply fail-safe concept

- ATC in-cab signaling system
  - (Conventional) ATC
    Ground system determines speed limit on each track section and transfers signal to the train. On-board system automatically reduce the speed according to the signal.

- Digital ATC
  - Digital ATC has been developed from conventional ATC system
    - to increase the capacity of lines
    - to improve riding comfort
    by generating continuous braking curve
  - Digital ATC is being introduced to all lines
Power supply system

- Power Company
- Sub Station
- Sub Sectioning Post
- Sectioning Post
- AT Feeding
- Auto transfer
- Change over section
- Contact wire
- Rail or AT protective wire

AC25kV50Hz (eastern Japan area)
AC25kV60Hz (western Japan area)

Trains can run with the least power cut

Regenerative brake can be used
AT feeding system is advantageous in
- less inductive obstruction
- larger distance between substations
but disadvantageous in
- the cost of the contact line system
Power supply system: Catenary

Wave propagation speed must be fast enough = lighter weight and higher tension
Design parameters
  Speed, Capacity, Strength against vibration
  Avoiding breakage, Low maintenance
Heavier compound catenary system

Lighter weight and high tension
Low train traffic capacity
- introduced to newly extended lines

CS catenary system
Thank you very much for your attention.