Mixed Traffic and High Speed

Michael Steidl
Mixed Traffic
Challenge

The challenge of mixed traffic is to find a compromise between the high speeds of passenger trains and the high axle loads and low speed of freight trains.

Different Geometry Parameters would apply for sole freight trains or sole passenger trains.

Fast Passenger Trains are slowed down by the Freight Trains in front of them.
Mixed Traffic
Geometry

A part of the line routing and layout is the superelevation which is defined by the following equations

Centrifugal acceleration: \[ a_r = \frac{V^2}{3.6^2 \cdot R} \]
whereas \( v \) = speed and \( R \) = curve radius

Excess centrifugal acceleration: \[ a_q = \frac{V^2}{13 \cdot R} - \frac{u}{153} \]
whereas \( u \) = superelevation
Mixed Traffic Geometry

If the superelevation is fully balancing the centrifugal acceleration then the superelevation is as follows:

\[ u_D = \frac{118 V^2}{R} \]

Superelevation deficiency \( u_f = u_D - u \)

is the value of the superelevation being too low to balance the centrifugal acceleration.

Superelevation excess \( u_U = u - u_D \)

is the value of the superelevation being too high and causing movement of the car to the inner side of the curve.
Mixed Traffic
Geometry

German Railways allows a superelevation of 6.3” (160mm) on ballast track and 6.7” (170mm) on slab track. If other parameters need to be chosen a special permit needs to be requested.

Additional rules apply where a regular superelevation

$$\text{reg}_u = \frac{7.1 \cdot v^2}{R}$$

is calculated. This superelevation needs to be chosen when most trains are not reaching the allowable speed in that section.

The allowable max. speed can be calculated as follows:

$$\text{zul}_v = \sqrt{\frac{R}{118} \cdot (u + \text{zul}_u)}$$
Mixed Traffic Geometry

From Technical University of Munich; Lehrstuhl fuer Verkehrswegebau
Example: Cologne – Rhine / Main
Mixed Traffic
High Speed Line Cologne – Rhine/Main

The High Speed Line Cologne – Rhine/Main was opened in 2001. The track is designed for and operated with high speed trains with speeds up to 205mph.

The min curve radius is 2 miles (3,320 m) and the max. superelevation is 7” (180mm). The max. grade is 4%.

Mixed traffic was considered at the beginning of the planning, but the line is now operated solely with high speed trains.

Separating slow trains and high speed trains was stipulated in the “Netz 21” Strategy of German Railways.
Mixed Traffic
High Speed Line Cologne – Rhine/Main

- Bundling of new railway line and existing expressway reduces the land usage and improves the acceptance by residents
- High values for cant and cant deficiency are essential for small radii—consequently slab track is required
- Exceptional horizontal and vertical alignment on Cologne-Frankfurt

Source: RAIL.ONE
Mixed Traffic Example:
Hannover – Wuerzburg
Mixed Traffic
High Speed Line Hannover - Wuerzburg

The High Speed Line Hannover – Wuerzburg was finally opened in 1991. The ballasted track is designed for and operated with high speed trains with speeds up to 174mph (280km/h) during the day. Freight trains are running at 100mph (160km/h) during the night.

The min curve radius is 3.16 miles (5,100 m) and the max. superelevation is 3.15” (80mm). The max. grade is 1.25%
Mixed Traffic
High Speed Line Hannover - Wuerzburg

“Überleitstellen” are used where the fast trains can pass slower freight trains. These are installed every 3.1 to 4.3 miles (5 to 7 Kilometers) and about every 12.4 miles (20km) is a kind of depot.
Alignment parameters of international high-speed lines

<table>
<thead>
<tr>
<th>Line</th>
<th>Opening</th>
<th>Length [km]</th>
<th>Traffic</th>
<th>max V [km/h]</th>
<th>max cant [mm]</th>
<th>max cant deficiency [mm]</th>
<th>min R [m]</th>
<th>max gradient [%o]</th>
<th>Min vertical curves [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tokaido-Shinkansen</td>
<td>JR 1964</td>
<td>515</td>
<td>Dedicated Passenger</td>
<td>220</td>
<td>180</td>
<td>60 (100)</td>
<td>2500</td>
<td>20</td>
<td>10000</td>
</tr>
<tr>
<td>Sanyo-Shinkansen</td>
<td>JR 1972/75</td>
<td>161+393</td>
<td>Passenger</td>
<td>260 &lt;230&gt;</td>
<td>180 (200)</td>
<td>30 (50)</td>
<td>4000</td>
<td>15</td>
<td>15000</td>
</tr>
<tr>
<td>Nuovo Diretissima (Rom Florenz)</td>
<td>FS 1977</td>
<td>236</td>
<td>Mixed Traffic Passenger+ Freight</td>
<td>250 &lt;200&gt;</td>
<td>125</td>
<td>120</td>
<td>3000</td>
<td>8,5</td>
<td>20000</td>
</tr>
<tr>
<td>Tohuku Shinkansen</td>
<td>JR 1982</td>
<td>496</td>
<td>Passenger</td>
<td>260 &lt;240&gt;</td>
<td>155</td>
<td>45</td>
<td>4000</td>
<td>15</td>
<td>15000</td>
</tr>
<tr>
<td>Joetsu Shinkansen</td>
<td>JR 1982</td>
<td>270</td>
<td>Passenger</td>
<td>260 &lt;210&gt;</td>
<td>155</td>
<td>45</td>
<td>4000</td>
<td>15</td>
<td>15000</td>
</tr>
<tr>
<td>TGV-Sudost Paris - Lyon</td>
<td>SNCF 1983</td>
<td>388</td>
<td>Passenger</td>
<td>270</td>
<td>180 (200)</td>
<td>35 (130)</td>
<td>4000</td>
<td>35 (130)</td>
<td>25000 (16000)</td>
</tr>
<tr>
<td>NBS M/S Mannheim Stuttgart</td>
<td>DB 1987/91</td>
<td>99</td>
<td>Mixed Traffic. Passenger + Freight</td>
<td>250</td>
<td>45 (85)</td>
<td>60</td>
<td>7000 (5100)</td>
<td>12,5</td>
<td>25000</td>
</tr>
<tr>
<td>NBS H/W Süd Fulda- Würzburg</td>
<td>DB 1988</td>
<td>83</td>
<td>Mixed . Rz + Gz</td>
<td>250</td>
<td>45 (85)</td>
<td>60</td>
<td>7000 (5100)</td>
<td>12,5</td>
<td>25000</td>
</tr>
<tr>
<td>TGV-Atlantik</td>
<td>SNCF 1990</td>
<td>278</td>
<td>Passenger Rz</td>
<td>300</td>
<td>150 (180)</td>
<td>27 (86)</td>
<td>6000</td>
<td>25 (86)</td>
<td>16000 (12000)</td>
</tr>
<tr>
<td>NBS H/W Nord+Mitte Fulda Würzburg</td>
<td>DB 1991</td>
<td>244</td>
<td>Mixed</td>
<td>250</td>
<td>45 (90)</td>
<td>60</td>
<td>7000 (5100)</td>
<td>12,5</td>
<td>25000</td>
</tr>
<tr>
<td>NBS Frankfurt/Main - Köln</td>
<td>DB 2002</td>
<td>177</td>
<td>Passenger</td>
<td>330 (300)</td>
<td>170 (190)</td>
<td>190 (190)</td>
<td>3350</td>
<td>40</td>
<td>11500</td>
</tr>
<tr>
<td>HSL-Zuid</td>
<td></td>
<td>90</td>
<td>Passenger</td>
<td>300</td>
<td>180</td>
<td>100</td>
<td>4000</td>
<td>25</td>
<td>12000</td>
</tr>
</tbody>
</table>

Source: RAIL.ONE
Fasteners for Mixed Traffic on ballasted track
Mixed Traffic and High Speed
Requirements for fasteners

Mixing freight trains with high speed trains requires also a compromise regarding the fastening systems.

Passenger Tracks require a soft pad to ensure riding comfort.

Freight tracks need to be able to endure the high loads.
Required Elasticity of Fastening Systems

Generally a low static stiffness is favored due to:

- Higher passenger comfort
- Damping of vibrations / impact loads
- Protection of the rolling stock
- Reduction of secondary deflection
- Reduction of pressure to ballast

Difference between vertical deflection $y$ and secondary deflection $\delta$ should not be more than 3-4%. Otherwise, this can lead to:

- Increasing of corrugation
- Increasing of structure borne noise
- Increasing of secondary air borne noise
Stiffnesses of different rail pads and deflection of track
**Requirements for stiffness of elastic components according to DBS 918 235 (German Railways Standard)**

<table>
<thead>
<tr>
<th>Testing temperature</th>
<th>Nominal static stiffness</th>
<th>Stiffening factor</th>
<th>Testing frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15 ( \leq c_{\text{nom,stat}} \leq 200 ) kN/mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>30 ( \leq c_{\text{nom,stat}} \leq 200 ) kN/mm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>High speed</th>
<th>regular*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower limit</td>
<td>Upper limit</td>
<td>Lower limit</td>
</tr>
</tbody>
</table>

<p>| | | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>50 °C</td>
<td>1,0</td>
<td>1,5</td>
<td>1,0</td>
<td>2,2</td>
<td>10 Hz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23 °C (RT)</td>
<td>1,0</td>
<td>1,5</td>
<td>1,0</td>
<td>2,2</td>
<td>5, 10, 20, 30 Hz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 °C; -10 °C</td>
<td>1,0</td>
<td>2,0</td>
<td>1,0</td>
<td>5,0</td>
<td>10 Hz</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Determination of elasticity at different temperatures
- Determination of elasticity static and dynamic at different frequencies
Elastic Performance of Base plate pad

Stiffness of Base plate pad 300

-10 °C
±0 °C
+50
Room Temperature RT

Elastic Performance of Base plate pad

Stiffness of Base plate pad 300

-10 °C
±0 °C
+50
Room Temperature RT
The Tension Clamp Skl14/Skl21
Load - Deflection Diagram

► Long and flat spring deflection of the independent working outer spring arms
  - The flatter the deflection curve the lower the toe load loss is after settlements

► Secondary stiffness through middle bend
  - Rail rollover protection
  - Use of additional anti rail rollover component not required

► Overstressing and plastic deformation of spring arms avoided, which ensures a permanent toe load
Fatigue Limit of Skl 21 (0.1“/2.5mm)
Testing Device for Fatigue Test

A soft pad – especially when used with heavy freight trains requires a very high fatigue limit of the clip.

0.1”/2.5 mm for Skl21

0.1” (2.5 mm) (Skl21) movement in assembled position for at least 5 Mio. load cycles

High Fatigue Limit allows for high elastic pads (Static stiffness down to $c_{stat\,18-68kN} = 35 \text{ kN/mm}$)
THANKS!