Effect of rail fastening system on railway noise and vibration in general, and on high speed rail systems in particular
Railway Noise: Some case studies of different problems with different solutions

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Pandrol Rail Fastenings
Technical Development Director

Investing Today for a Brighter Tomorrow
Content

- Introduction
  - Principles
- Case studies
  - Ground Vibration
  - Airborne Noise
  - Structural Vibration
- Summary

2006 APTA RAIL CONFERENCE
Investing Today for a Brighter Tomorrow
Introduction

Directly transmitted noise
From vehicle, wheels, rails, pantographs etc.

Secondary Noise
Results from vibration of structures

Vibration
Transmitted through ground
Introduction

Ground borne vibration

Airborne noise

Structural vibration

LH Vibration (dB re 5e-8 m/s)

RH Sound (dB A)

Frequency (Hz)
Modelling
Principle I - Theory

Reducing track stiffness

Reduced slab vibration

Frequency (Hz)

Invert Vibration (dB ref 5e-8 m/s)

IWRN8 Buxton 2004

50 kN/mm
30 kN/mm
15 kN/mm
5 kN/mm
Principle I - Theory

IWRN8 Buxton 2004

Attenuation (dB)

Slope 14 dB / decade

Log stiffness (kN/mm/m/rail)
Principle I - Measurement

IWRN7 Portland 2001

Vibration level (dB)

Log stiffness (kN/mm/m/rail)

Theory
Attenuation
Measurement
Ground borne vibration
Ground borne vibration
Guangzhou Metro, China
Guangzhou Metro, China

At surface 13m above rail level

Acceleration (dB re:1e-6m/s²)

Frequency (Hz)

10 20 30 40 50 60 70 80

10 20 30 40 50 60 70 80

12/3/2010
Guangzhou Metro, China

Existing Fastening – 52kN/mm

图 1 广州地铁 1 号线线路单动弹性扣件系统
Guangzhou Metro, China

Pandrol Panguard – 5 kN/mm

图 2 标准潘得路先锋扣件系统
Guangzhou Metro, China
Guangzhou Metro, China

![Graph showing acceleration (dB re:1e-6m/s²) vs. frequency (Hz) with lines for Before and After.]
<table>
<thead>
<tr>
<th>Fitted with Pandrol Panguard</th>
<th>Slab 52 kN/mm</th>
<th>13 m</th>
<th>5.2 dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guangzhou GZM Pandrol</td>
<td>Slab 100 kN/mm</td>
<td>20 m</td>
<td>6.9 dB</td>
</tr>
<tr>
<td>London LU Pandrol LU</td>
<td>Slab 150 kN/mm</td>
<td>5 m</td>
<td>12.0 dB</td>
</tr>
<tr>
<td>Milan ATM CONVURT Pandrol</td>
<td>Ballast 20 kN/mm</td>
<td>22 m</td>
<td>12.6 dB</td>
</tr>
<tr>
<td>Boston MBTA Pandrol</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Principle II - Theory

Silent Track - TWINS

Decay Rate (dB/m)

Vibration travels further along rail

Reducing track stiffness

Frequency (Hz)

- 75 kN/mm
- 120 kN/mm
- 200 kN/mm
Principle II - Measurement

Decay Rate (dB/m) vs Frequency (Hz)

- Hard Pad
- Soft Pad

WCRR Edinburgh 2003
Airborne noise
Airborne noise
Allerød, Denmark
Allerød, Denmark
### Allerød, Denmark

<table>
<thead>
<tr>
<th>Silent Track Data</th>
<th>Dynamic Stiffness</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>kN/mm</strong></td>
<td><strong>F\text{ stat} = 20\ kN</strong>&lt;br&gt;<strong>X\text{ dyn} = 5\mu m at 100Hz</strong></td>
</tr>
<tr>
<td>Temperature</td>
<td>0°C</td>
</tr>
<tr>
<td><strong>Studded EVA Pad</strong></td>
<td>620</td>
</tr>
</tbody>
</table>
Secondary Noise
Secondary Noise
Arsta Bridge, Stockholm
Arsta Bridge, Stockholm

Graph showing sound pressure level (dBA) against frequency (Hz) for different types of bridges.

- Steel Bridge
- Concrete Bridge
- Modelled - steel
- Modelled - after
- Modelled – steel bridge component

Frequency (Hz) range: 100 to 5000
Sound Pressure Level (dBA) range: 40 to 80
Arsta Bridge, Stockholm

Existing Fastening
Arsta Bridge, Stockholm

Pandrol Vipa SP – 20 kN/mm
Arsta Bridge, Stockholm
# Secondary Noise

<table>
<thead>
<tr>
<th>Fitted with Pandrol Vipa SP</th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsta Bridge *, Stockholm Pandrol</td>
<td>Open</td>
<td>Bearers</td>
<td>1 dBA</td>
</tr>
<tr>
<td>Nidelv Bridge *, Trondheim Brekke &amp; Strand</td>
<td>Closed</td>
<td>Closed</td>
<td>Bearers Plate</td>
</tr>
<tr>
<td>Gavignot Bridge, Paris SNCF</td>
<td>Open</td>
<td>Plate</td>
<td>4-6 dBA</td>
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</tbody>
</table>

* New rail installed
## Summary (i)

<table>
<thead>
<tr>
<th></th>
<th>Ground Borne Vibration</th>
<th>Airborne Noise</th>
<th>Secondary Noise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>Low</td>
<td>High</td>
<td>Medium</td>
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<tr>
<td>Research</td>
<td>CONVURT</td>
<td>Silent Track</td>
<td>ISVR</td>
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<tr>
<td>Effect</td>
<td>5-15 dB</td>
<td>0-3 dBA</td>
<td>0-10 dBA</td>
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</table>
## Summary (ii)

<table>
<thead>
<tr>
<th>Ground Borne Vibration</th>
<th>Airborne Noise</th>
<th>Secondary Noise</th>
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</thead>
<tbody>
<tr>
<td>Effect of Fastener</td>
<td>Attenuate</td>
<td>Distribute</td>
</tr>
<tr>
<td>Fastener Stiffness</td>
<td>LOW</td>
<td>HIGH</td>
</tr>
<tr>
<td></td>
<td>MEDIUM</td>
<td>Rail noise</td>
</tr>
<tr>
<td></td>
<td>Rail deflection</td>
<td>Track damage</td>
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</table>
## Summary (iii)

<table>
<thead>
<tr>
<th>Pandrol Fastener</th>
<th>Ground Borne Vibration</th>
<th>Airborne Noise</th>
<th>Secondary Noise</th>
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</thead>
<tbody>
<tr>
<td>PANGUARD</td>
<td>RAILPAD</td>
<td>VIPA</td>
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</table>
End
Noise & vibration on high speed routes – effect of track
**Simple mathematics**

\[ 2 + 2 = ? \]

\[ 2 + 3 = ? \]

<table>
<thead>
<tr>
<th>Sources N</th>
<th>Amplitude A</th>
<th>Power ( \propto N \times A^2 )</th>
<th>dB (A*100)</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.000</td>
<td>1</td>
<td>40</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>1.414</td>
<td>2</td>
<td>43</td>
<td>+3</td>
</tr>
<tr>
<td>1</td>
<td>2.000</td>
<td>4</td>
<td>46</td>
<td>+6</td>
</tr>
<tr>
<td>1</td>
<td>3.162</td>
<td>10</td>
<td>50</td>
<td>+10</td>
</tr>
<tr>
<td>2</td>
<td>1.000</td>
<td>2</td>
<td>43</td>
<td>+3</td>
</tr>
<tr>
<td>4</td>
<td>1.000</td>
<td>4</td>
<td>46</td>
<td>+6</td>
</tr>
</tbody>
</table>

1 dB difference: not noticeable

3 dB difference: just noticeable

10 dB difference: apparent doubling of strength
Pass-by noise from high-speed trains

Fig. 1. Time history of TGV-duplex pass-bys.
Pass-by noise from high-speed trains

Rolling noise generation
Rolling noise components – TWINS prediction

![Graph showing the components of rolling noise for a freight wheel at 100 km/h on track with medium stiffness pads.](image)

**Fig. 2** Components of rolling noise for a freight wheel at 100 km/h on track with medium stiffness pads [8]
**Noise spectrum vs speed**

Fig. 4. One-third octave band spectra of the relative contributions of the different vehicles.
Belgium SNCB Brussels - Lille

350 km/hr

*A Wang & S J Cox: Effects of railpad stiffness on rail roughness growth and wayside noise levels on high speed track (2003)*
Wayside noise measurements vs speed and pad type

Rail roughness - high-speed trains

FIGURE A2  Roughness measured at test sites in NOEMIE along with various limit values (from [A1])
Rail roughness - high-speed trains

$$\lambda = f.$$
Pass-by air borne noise from high-speed trains

- **Speed range over which fastening system is influential**
- **30 log_{10}V**
- **60 log_{10}V ??**

- **Traction**
- **Rolling**
- **Aerodynamic**
Pass-by noise from high-speed trains - recap


Fig. 1. Time history of TGV-duplex pass-bys.
In-car noise on high-speed trains – effect of track form

Sound Pressure Level (dB(A) ref. 2x10^{-5}Pa)

1/3 Octave Band Centre Frequency (Hz)

- Total at grade
- Total in tunnel
- in tunnel, slab
- at grade, ballasted

Pandrol measurements: 2010
Rolling HIGH SPEED - VIBRATION
St Pancras Station (2007)
CTRL London Terminus
Vibration from high-speed trains on ballast – effect of speed
Vibration from high-speed trains on ballast – effect of speed

Rail seat acceleration vs speed

Vibration from high-speed trains on ballast – effect of rail pad

Rail seat acceleration vs pad

<table>
<thead>
<tr>
<th>Pad Type</th>
<th>Rail Acceleration (m/s²)</th>
<th>Sleeper Deflection (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard pad</td>
<td>150.9</td>
<td>0.088</td>
</tr>
<tr>
<td>Soft pad</td>
<td>145.75</td>
<td>0.894</td>
</tr>
</tbody>
</table>
Vibration from high-speed trains – effect of track form