RIVAS 1\textsuperscript{st} workshop

WP3: Mitigation measures on track

14th september 2011
 WP3: overview

Partners: ADIF, ATSA, BAM, CEDEX, Chalmers, CSTB, DB, D2S, ER, KUL, Pandrol, RailOne, Sateba, SBB, SNCF, Vibratec

The scope of this WP is to tackle ground vibrations at source by developing and optimising mitigation measures on the track itself. Activities comprise ballasted in-line track, curves, switches and slab track.

The expected reduction of ground vibration for different configurations of tracks and soils, the installation features, the consequences onto the track maintenance, the costs will be provided for each mitigation measure.
WP3: overview

– Task 1: state-of-the-art
– Task 2: mitigation measures for ballasted track
– Task 3: mitigation measures for ballasted curves and switches
– Task 4: mitigation measures for in-line slab track
WP3: task 1

Task 1: State-of-the-art

The compiled document gathers the different mitigation measures on track. It proposes technology assessments of existing vibration mitigation measures and definition of priorities for further work.

Classification: (benefit = positive insertion loss)
Class A: benefit < 5 dB
Class B: benefit 5 – 10 dB
Class C: benefit 10 – 20 dB
Class D: benefit > 20 dB
T1: State-of-the-art

Modification of the super structure:
- Resilient rail fastening system
- Under-sleeper pads (ballasted track)
- Booted sleeper (slab track)
# T1-SoA: Resilient Fastening System

<table>
<thead>
<tr>
<th>Mitigation measure</th>
<th>Test site</th>
<th>Excitation</th>
<th>Costs</th>
<th>Positive insertion loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slab track with VANGUARD baseplates (dynamic vertical stiffness of the order of 10 kN/mm)</td>
<td>Tung Chung line, Hong Kong; Measurement points: close to track</td>
<td>Passenger train, 10 – 13 tonne axle load, 60 km/h</td>
<td>300 EUR/m (baseplates without installation)</td>
<td>31.5 Hz 1/3 octave band and above; benefit: class B</td>
</tr>
<tr>
<td>Slab track ZÜBLIN with resilient BWG fastening system</td>
<td>Mainline, Germany; Measurement points: 8 m beside the middle of the track</td>
<td>ICE, 160 km/h</td>
<td>No information</td>
<td>31.5 Hz 1/3 octave band and above; benefit: class C</td>
</tr>
<tr>
<td>Soft under baseplate pads</td>
<td>Test bench in France, 4 baseplate pads with different stiffness</td>
<td>2 static loads (90 kN/120 kN), dynamic excitation: 8 Hz – 400 Hz</td>
<td>No information</td>
<td>63 Hz/80 Hz 1/3 octave band and above, resonance of the system around 40 Hz; benefit: class B/C</td>
</tr>
</tbody>
</table>
## T1-SoA: under sleeper pads (BT)

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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Ballasted track with B70</td>
<td>Mainline, Germany; Measurement points: 8 m beside the middle of the track</td>
<td>ICE, 160 km/h</td>
<td>90 EUR/m for new lines, 250 EUR/m for upgraded lines (costs for sleeper-dismantling included)</td>
<td>31.5 Hz 1/3 octave band and above; <strong>benefit: class B</strong></td>
</tr>
<tr>
<td>concrete sleeper + sleeper pads</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ballasted track + sleeper pads</td>
<td>Different sites in Switzerland</td>
<td>No information</td>
<td>No information</td>
<td>31.5 Hz 1/3 octave band and above; <strong>benefit: class B/C</strong></td>
</tr>
<tr>
<td>Under sleeper pads</td>
<td><strong>Test bench</strong> in France, 2 different types of sleeper pads</td>
<td>2 static loads (90 kN/120 kN), dynamic excitation: 8 Hz – 400 Hz</td>
<td>No information</td>
<td>63 Hz/80 Hz 1/3 octave band and above, resonance around 40 Hz; <strong>benefit: class B/C</strong></td>
</tr>
</tbody>
</table>
## T1-SoA: booted sleepers (ST)

<table>
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<th>Positive insertion loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>LVT HA</td>
<td>EIFFAGE-RAIL, Germany; Measurement points: 0 m, 8 m, 16 m</td>
<td>Unbalanced mass generator “Dynaq”, 10 Hz – 100 Hz</td>
<td>Only available for test section</td>
<td>40 Hz and above; <strong>benefit: class A, partly B</strong></td>
</tr>
<tr>
<td>HAS</td>
<td>Metro (16 t axle load); Measurement points: 4 m beside the track, both sides</td>
<td>Metro, 30 km/h and 60 km/h</td>
<td>No information</td>
<td>Above 100 Hz compared with a ballasted track as reference; <strong>benefit: class A to B</strong></td>
</tr>
</tbody>
</table>
Ballasted track: modifications of the infrastructure

– Under ballast mats,
– ballasted trough with under ballast mat,
– concrete slab in the ground+soft under ballast mat
## T1-SoA: under ballast mat

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</tr>
</thead>
<tbody>
<tr>
<td>Ballasted track with under sleeper mat</td>
<td>Mainlines in Switzerland, Germany and other European countries</td>
<td>Trains (no further information)</td>
<td>25 EUR/m² – 90 EUR/m² (Germany)</td>
<td>40 Hz 1/3 octave band and above, <strong>benefit: class B/C</strong></td>
</tr>
</tbody>
</table>
## T1-SoA: ballasted trough

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</tr>
</thead>
<tbody>
<tr>
<td>Ballasted trough with under sleeper mat for ballast protection</td>
<td>Mainline, Germany; Measurement points: 4 m and 12 m beside the middle of the track</td>
<td>Suburban trains (ET 420), 60 km/h and 120 km/h</td>
<td>1.200 EUR/m (higher for short troughs or poor ground conditions)</td>
<td>16 – 31,5 Hz and above 63 Hz 1/3 octave band, no negative insertion loss even at about 40 Hz 1/3 octave; <strong>benefit: class B</strong></td>
</tr>
</tbody>
</table>

**Suburban trains (ET 420), 60 km/h and 120 km/h**

**Mainline, Germany; Measurement points: 4 m and 12 m beside the middle of the track**

**Ballasted trough with under sleeper mat for ballast protection**

**1.200 EUR/m (higher for short troughs or poor ground conditions)**

**16 – 31,5 Hz and above 63 Hz 1/3 octave band, no negative insertion loss even at about 40 Hz 1/3 octave; benefit: class B**
## T1-SoA: slab in the ground

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>Concrete slab in the ground (without/with under ballast mat)</td>
<td>Mainline, Germany; Measurement points: 8 m beside the middle of the track</td>
<td>Suburban and freight trains, 40 km/h</td>
<td>Not available</td>
<td>Without under ballast mat: close to 0, with soft under ballast mat: 8 Hz 1/3 octave band and above with resonances at 16 Hz and 31.5 Hz; <strong>benefit: class B, partly C</strong></td>
</tr>
</tbody>
</table>
T1: State-of-the-Art

Slab track: modification of the infrastructure

- Asphalt layer
- Continuously supported track
- "Lawn-track" with longitudinal sleepers
<table>
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</tr>
</thead>
<tbody>
<tr>
<td>GETRAC</td>
<td>Test-field EIFFAGE-RAIL, Germany Measurement points: 0 m, 8 m, 16 m</td>
<td>Unbalanced mass generator &quot;Dynaq&quot;, 10 Hz – 100 Hz</td>
<td>Only available for test section</td>
<td>40/50 Hz and above (results depending on the load and the distance of the measurement points from the track, for some measurements negative insertion loss at about 100 Hz); benefit: class A, partly B</td>
</tr>
<tr>
<td>SATO</td>
<td>Mainline, Germany Measurement points: 8 m beside the middle of the track</td>
<td>ICE, 160 km/h</td>
<td>No information</td>
<td>Mostly positive effect from 40 Hz to 160 Hz 1/3 octave band (benefit: class A to B); negative insertion loss below 40 Hz and from 160 Hz to 315 Hz</td>
</tr>
</tbody>
</table>
### T1-SoA: Continuously supported track

<table>
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<th>Positive insertion loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>INFUNDO</td>
<td>Mainline, Germany; Measurement points: 8 m beside the middle of the track</td>
<td>Suburban trains, 120 km/h</td>
<td>Not available</td>
<td>63 Hz to 250 Hz 1/3 octave band (benefit: class B to C) and some positive effects from 8 Hz to 16 Hz 1/3 octave band (benefit: class A/B);</td>
</tr>
</tbody>
</table>
## T1-SoA: "Lawn-track" with longitudinal sleepers

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<tr>
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<th>Excitation</th>
<th>Costs</th>
<th>Positive insertion loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Lawn-track&quot;</td>
<td>Mainline, Germany; Measurement points: 8 m beside the track</td>
<td>ICE, 160 km/h</td>
<td>Not available</td>
<td>20 Hz to 100 Hz and above 160 Hz 1/3 octave band; <strong>benefit:</strong> mostly class A</td>
</tr>
</tbody>
</table>

**Benefit:**
- Mostly class A

**Excitation Test site Mitigation measure**

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**Image:** Lawn-track setup with longitudinal sleepers.

**Diagram:** "Lawn-track" with longitudinal sleepers diagram showing the track setup and measurement points.
T1: State-of-the-Art

- Mitigation measures presented below have been tested by at least one of the WP3 partners, most of them need further investigations.

- Many others are in the scope of the WP3 and could be investigated such as:
  - Wide-sleeper track + under sleeper pad
  - Combination of slab in the ground + under sleeper pads
  - Combination of asphalt layer + booted sleepers

- for example, but also new designed track such as the BBest from Balfour Beaty and the Corus Two Layers Steel Slab Track (presented below within the task 3)
WP3: task 2 & Task 4

Task 2: in-line ballasted track
Development of vibration mitigation measures based on optimization of rail fastening systems and sleeper / ballast interaction
Steps:
– Parametric study
– Optimization of the components characteristics that depends on in-site parameters via a numerical approach
– In-site installation of mitigation measures
– Guidelines

Task 4: slab track
Classification of existing slab track systems with respect to emission of ground vibrations and development of mitigation measures with focus on the sleeper/slab interface
Steps:
- Classification of slab track
- Parametric study
- Numerical optimization of a mitigation measure
- In-site installation of mitigation measures
- Guidelines
T2 & T4 / upstream phase

- Characterisation of test site dynamic behaviour
  - Parameters identification for parametric study and numerical optimisation process

- Track stiffness concept
  - How to measure it?
  - Parameter identification for numerical study: is track stiffness a good input to identify them?
T2 & T4 / track stiffness

Measurement tools used and compared within Innotrack

Geophysical methods

> **Seismic methods:** observation of seismic waves propagation (bulk density & modulus of elasticity of the soil)
> **Resistivity / tomography:** measurement of electric resistivity of the rocks (water content & soil grain size)
> **Geological Radar (GPR):** electro magnetic waves transmitted and reflected from geological boundaries
> **Gravimetry (+ levelling):** observation of changes in soil gravity

Track stiffness measurement methods

> **RSMV:** track loading vehicle made of a freight wagon, equipped with hydraulics and vibrating masses. The vertical track stiffness is calculated continuously from measured axle box forces and accelerations.

> **Penetrometer Panda coupled with endoscope:** investigates Granular material resistance and material behaviour variability of the track structure. It consists in driving calibrated cone through the soil and recording the data which represent the cone resistance with the depth.

Sampling methods

> **Resonant Column tests** and **large scale triaxial tests:** From soil sampling and in-situ density estimation, a lab characterization of the soil is done
T2 & T4 / track stiffness

Stiffness assessment: Rolling Stiffness Measurement Vehicle (RSMV)

> The RSMV: TLV (Track Loading Vehicle) made of a rebuilt two axle freight wagon, equipped with hydraulics and two vibrating masses.

> With the concept of exciting discrete sinusoidal frequencies, the vertical track stiffness is calculated continuously from measured axle box forces and accelerations.
Is track stiffness a good input to identify track dynamic parameters?
->crossed data analysis
T2 & T4 / upstream phase

- Identification of problematic sites
  -> Innotrack Database
  - Is track stiffness a relevant global indicator for the track propensity to propagate vibration?
  - How to efficiently use Innotrack results /database?
T2 & T4 / upstream phase

Is track stiffness a relevant global indicator for the track propensity to propagate vibration?

Q. to Alexander Smekal, from TV
identifying the relevant parameters and techniques, and building a multi-parameters assessment method.

> 15 investigated sites in 5 European countries

> 5 existing and developed measurement techniques have been used for investigations
T2 & T4 / Innotrack Database

Example from the database (crossed data analysis)
T2 & T4 / Innotrack Database

Example from the database (crossed data analysis)
Example from the database (crossed data analysis)
T2 & T4 / downstream phase

- Measurement of the impact of mitigation measures on ground vibration -> WP1.2 protocol
- Impact of mitigation measures on maintenance?
  - How to quantify this impact?
  - What is the most damageable with the insertion of:
    - a new designed URP
    - a USP
    - a ballast mat
WP3: task 3

Task 3: curve and switch
Assessment of the potential of under sleeper pads as vibration mitigation measure for curves
Better understanding of the phenomena causing ground vibrations by switches and subsequent design of efficient mitigation measures
WP3: task 3

• Curves:
  -> USP as mitigation measures for curves
    – Impact on track static behaviour?
    – Impact on rolling stock behaviour?
  -> to be measured within RIVAS (SBB)
  – Impact on maintenance?
WP3: task 3

• Switches
  – To characterize in-site the ground vibrations induced by switches
  – To combine the numerical approach developed in Chalmers that allows to estimate the wheel/rail interaction force when RS runs over a switch to a software that simulates GV propagation in free-field
  – To propose mitigation measures for switches configuration

  – Are new designed track such as Balfour beaty (BBest) and Corus a good option? How to handle, in such installation, the transition zone issue?
WP3: New designed track opportunities

Balfour Beaty Slab Track: BBEST

- **Low maintenance** slab track
- **Continuous support of the rail**
- **Modified rail section**
- Accommodation of both soft subgrades and high axle loads

A test track has been installed in Germany
WP3: New designed track opportunities

Corus Two Layers Steel Slab Track

- **Low maintenance track** support system
- Low construction time (≈ ballasted track)
- Continuous rail support
- Potential recycling of old ballast as infill material
- High initial cost implies no installation in plain line, but for critical track segments:
  - Improvement of poor formation/instability.
  - Critical track locations: S&C example
    - Logistic advantages
    - Significant reduction in future maintenance needs

A test track has been installed in Scunthorpe (UK)
Thank you for your attention!