Design of low emissive tracks in terms of ground vibration

Under sleeper pads impact in ballasted and slab track
Under sleeper pads (USP) are used in tracks for several reasons for some years.

- Easy to install
- Compatible to the process in track installation
- USP
- Impact on LCC
- Positive influence on track quality
- Cheap compared to other solutions
Under sleeper pads (USP) are used in tracks for several reasons for some years.

How could the potential for vibration-mitigation effects improved?
From the idea to a new solution in track, a long way with different steps of improvements have to be pass-through.
The first three steps were carried out within RIVAS.
After simulation with parametric studies different configurations were chosen

Criterias for choosing the configuration

- Standard German B 70 sleeper without USP serve as reference
- Influence of different USP stiffness on identical sleepers
- What is the influence of mass on the insertion loss
  - Special aggregates for the concrete were used to double the mass of the B 70 sleeper by compatible sleeper geometries
- Influence of concrete edge on the dynamic behavior
- Influence of different rail pads on the Insertion Loss of the system
- What is the influence of increasing the contact area and...
  - Possible use of more resilient USP with same track deflections
  - Developing of a resiliently supported wide sleeper
Three basic designs of sleepers were investigated:

- **B 70**
  - Weight: 309 kg*
  - * (incl. Fastener + USP)

- **B 90.2**
  - Weight: 605 kg*
  - with heavy aggregates

- **BBS 4**
  - Weight: 577 kg*

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The possible influence of concrete edge stripes should be improved

Sleeper ‘without’ concrete edge stripes

Sleeper with concrete edge stripes
Additionally a special slab track system with resilient layer was improved

WP 3.4: Slab track

GETRAC A3.1 (USP)
In total, 10 different configurations of USP, sleepers, and rail pads were determined.

<table>
<thead>
<tr>
<th>Measuring section ID</th>
<th>Short name</th>
<th>Sleeper</th>
<th>Under sleeper pad (USP)</th>
<th>Rail pad</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Type</td>
<td>weight incl. USP &amp; fastener</td>
<td>type</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[kg]</td>
<td></td>
<td>[N/mm³]</td>
</tr>
<tr>
<td>ME11</td>
<td>BBS3.1 V2</td>
<td>BBS 3.1</td>
<td>577</td>
<td>V-02</td>
</tr>
<tr>
<td>ME12</td>
<td>BBS4 G13</td>
<td>BBS 4</td>
<td>577</td>
<td>G-13</td>
</tr>
<tr>
<td>ME13</td>
<td>BBS4 G15</td>
<td>BBS 4</td>
<td>577</td>
<td>G-15</td>
</tr>
<tr>
<td>ME14</td>
<td>B90.2 G13</td>
<td>B 90.2</td>
<td>605</td>
<td>G-13</td>
</tr>
<tr>
<td>ME15</td>
<td>B90.2 G04</td>
<td>B 90.2</td>
<td>605</td>
<td>G-04</td>
</tr>
<tr>
<td>ME16</td>
<td>B70 G04</td>
<td>B 70</td>
<td>309</td>
<td>G-04</td>
</tr>
<tr>
<td>ME17</td>
<td>B70 G04 NE</td>
<td>B 70</td>
<td>309</td>
<td>G-04</td>
</tr>
<tr>
<td>ME15</td>
<td>B90.2 G04 Zw900b</td>
<td>B 90.2</td>
<td>605</td>
<td>G-04</td>
</tr>
<tr>
<td>ME16</td>
<td>B70 G04 Zw900b</td>
<td>B 70</td>
<td>309</td>
<td>G-04</td>
</tr>
<tr>
<td>ME17</td>
<td>B70 G04 NE Zw900b</td>
<td>B 70</td>
<td>309</td>
<td>G-04</td>
</tr>
</tbody>
</table>
For preparing the homologation a series of lab tests were performed:

- Determination of static bedding modulus of USP on block
- Determination of high frequency bedding modulus
- Bending moments and crack tests of sleepers
- Fatigue tests of USP material
ER provided a testfield with an installation of 7 different configurations of sleepers and USP.
Preperation of testfield and sublayers
Layout of the sleeper configuration, tamping and dynamic stabilization
This test field allows several investigation in 1:1 scale test

- Installation of new configuration outside the technical limitation of commercial tracks
- Vibration measurements with stationary artificial vibration excitation
- Determination of track mobility
- Determination of the impact on lateral track stability (LTR) for a non consolidated track relative to each other
- Determination of track deflection
- Some other practical improvements
For vibration tests a special hydraulic shaker BUTTERFLY® was successfully used.

- Max. dynamic excitation force of BUTTERFLY®

<table>
<thead>
<tr>
<th>Dynamic force amplitude</th>
<th>7500 N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excitation frequency</td>
<td>sweep 5 – 110 Hz</td>
</tr>
<tr>
<td>Unsprung mass</td>
<td>2.3 t steel foundation</td>
</tr>
<tr>
<td></td>
<td>0.35 t shaker</td>
</tr>
<tr>
<td></td>
<td>400 kg oscillating mass</td>
</tr>
<tr>
<td>Static load due to excavator weight</td>
<td>3 bucket positions</td>
</tr>
<tr>
<td></td>
<td>(~ 300, 200, 5 kN)</td>
</tr>
<tr>
<td>Measurement locations</td>
<td>3x 8 m-point</td>
</tr>
<tr>
<td></td>
<td>1x 16 m-point</td>
</tr>
<tr>
<td></td>
<td>1x steel foundation</td>
</tr>
</tbody>
</table>
Measurement layout of the test-rig at Herne test-site (ER)

- one measuring point on the unsprung mass (steel foundation of the hydraulic shaker, coupled with the rails)

- three points at 12m distance
- one point at 16m distance from the center of the track
Two „flying“ excavators serve as a simulation for the dead load.
By variation of the bucket position three different Load cases (LC) could be investigated

<table>
<thead>
<tr>
<th>Load case or Position</th>
<th>Bucket position</th>
</tr>
</thead>
<tbody>
<tr>
<td>LC1 ( \approx 304 \text{ kN} )</td>
<td>![Diagram of bucket position LC1]</td>
</tr>
<tr>
<td>LC2 ( \approx 221 \text{ kN} )</td>
<td>![Diagram of bucket position LC2]</td>
</tr>
<tr>
<td>LC3 (without excavators) ( \approx 5 \text{ kN} )</td>
<td>![Diagram of bucket position LC3]</td>
</tr>
</tbody>
</table>

\[ F_{\text{sprung}} = \text{static load} \]

The static load corresponds to the deflection of the springs.

Max 320 kN
Example for time history of force, frequency and velocities of sensors

- Force
- Frequency
- Velocity at foundation
- Velocity 8m, a
- Velocity 8m, b
- Velocity, 8m, c
- Velocity, 16 m
The Insertion loss at Load Case 2 (LC2) for all investigated track systems

- BBS3.1 V2
- BBS4 G13
- BBS4 G15
- B90.2 G13
- B90.2 G04
- B70 G04
- B70 G04 NE
- B90.2 G04 ZW900b
- B70 G04 ZW900b
- B70 G04 NE ZW900b

Frequency [Hz]

Insertion loss [dB]
Relation of unsprung mass mobility at Load Case 2 (LC2) for all investigated track systems

![Graph showing the relation of mobility (in dB) vs. frequency (in Hz) for various track systems.](image)
To compare the IL with artificial source and with natural train excitation an existing track near Regensburg could be used.
A track installation with several sections of track with USP served as reference site.

The reference section ME 1 and the section and ME 5 with USP have the identical track configuration as the track sections at the Eiffage Rail test rig.
The reference situation and one of the track sections have the same configuration as the real track at Regensburg.

Corresponds to ME 5 of „Regensburg“ test site.
Three different train categories could be investigated

- Electric trainset: Velocity: 144 km/h, Number of measurements: 21
- ICE: Velocity: 158 km/h, Number of measurements: 6
- Freight train: Velocity: 96 km/h, Number of measurements: 33

- 22 pass bys, ≈ 144 km/h
- 6 pass bys, ≈ 158 km/h
- 33 pass bys, ≈ 96 km/h
Insertion Loss of train pass by of freight trains compared to ICE trains

IL of train pass-bys (Freight trains)

IL of train pass-bys (ICE Train-sets)

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Insertion loss under artificial and natural train excitation (freight trains)

IL with BUTTERFLY® excitation and different load positions

IL of train pass-bys (freight trains)
Insertion loss under artificial and natural train excitation (rail car)

IL with BUTTERFLY® excitation and different load positions

IL of train pass-bys (rail car with about 144 km/h)

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Insertion loss under artificial and natural train excitation (ICE Train-sets)

IL with BUTTERFLY® excitation and different load positions

Insertion loss with subsoil correction (8m)
BUTTERFLY® sweep tests, Mintraching (Germany), 04/11/2012

IL of train pass-bys (ICE Trainsets)

Excitation frequencies due to sleeper bay
Excitation frequency due to bogie twin axle
Eigenfrequency of the track with under sleeper pads
Resonance frequency of the track with under sleeper pads

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To improve the impact of USP on track-stability, the LTR was determined.
The measured deflection line under 20 to Axle-load shows some minor supported areas.
Conclusions I

- The test with stationary artificial excitation is suitable to show the dynamic characteristics of a track, but...
- It shows not all effects of USP (e.g. minimizing the dynamic forces by a better load deflection line or by better track qualities by avoiding hanging sleepers ...) and the effects of parametric excitations in particular for lower frequency ranges
- Therefore the vibration mitigation effect is underestimated with these tests in particular at lower frequencies
- The wide sleepers present an high additional potential for ground vibration mitigation combined with soft USP, further investigation in commercial track would be recommended to get results on a consolidated track by train pass-by measurements
Conclusions II

- The production of new developed heavy sleepers with special aggregates as well for wide sleepers was approved and all necessary tests as a prerequisite for homologation were successfully fulfilled.
- The minor measured mitigation effect for the heavy sleeper type B90.2 was lower than expected by simulations, to understand this effect a real track installation is recommended.
- The effect of application of very soft USPs have been confirmed as well by simulation as by measurements, the track compliance may compromise the application from track deflection of view.
- All tested combination of sleepers and USP show no negative effect on lateral track resistance (LTR) but instead an improvement.
- The improved slab-track solution shows a good mitigation potential.
Thank you all Partners and subcontractors for their contributions!

References:
All presented results are fully described in the project-deliverables. Most of them are public. Please refer to the project web-site for further information: [http://rivas-project.eu/index.php?id=9](http://rivas-project.eu/index.php?id=9)

- D1.10: Description of test procedures based on laboratory tests and field tests including validation
- D3.2: Results of the parameter studies and prioritisation for prototype construction for ballasted track
- D3.3: Results of the parameter studies and prioritisation for prototype construction for slab track
- D3.7: Results of laboratory tests for ballasted track mitigation measures
- D3.9: Results of laboratory tests of slab track mitigation measures
- D3.14: Results of field test of slab track mitigation measures
- D3.15: Results of field test for ballasted track mitigation measures