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**LÄRM
FORSCHUNG
EISEN
BAHN**
**EXCHANGE of
EXPERTS 2|'22**

New Rail Pads for Simultaneous Noise Reduction and Improved Track Superstructure Protection

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Context and motivation

- The density of the population and the rail network in Switzerland is increasing rapidly.
- Noise levels up to 100 dB when a train passes.
- Rail pads protect the track superstructure (sleeper, ballast) but increase rolling noise.
- Optimum rail pad solutions needed to reduce noise while ensuring protection of the superstructure.



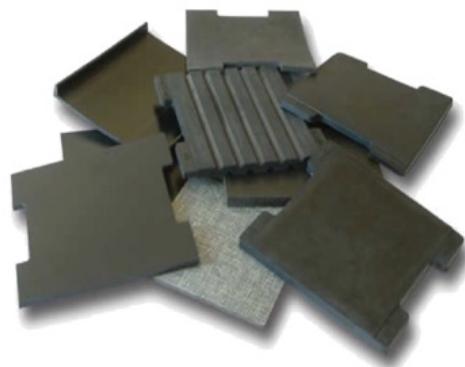


High-damping rail pads for optimum noise reduction and superstructure protection: hypotheses and aims

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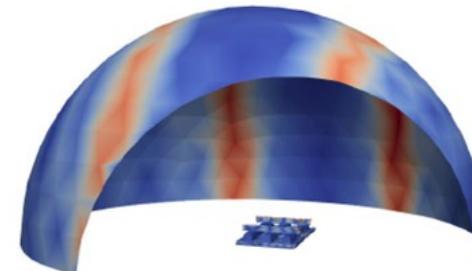
1

Improved acoustic performance and superstructure protection may be achieved using rail pads with *increased damping*.



2

Optimization through detailed *understanding of the relationships between rail pad materials properties, and sound levels at the full track scale.*



3

Prototyping and scale-up for field tests.



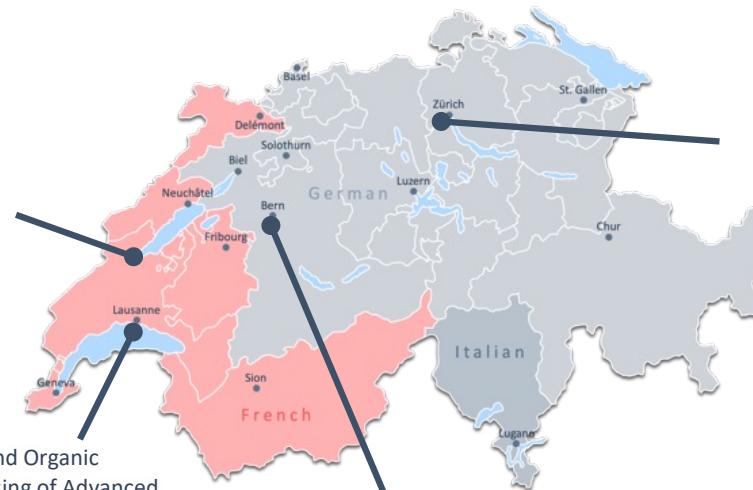


A multidisciplinary team: materials, engineering, railway acoustics, manufacture

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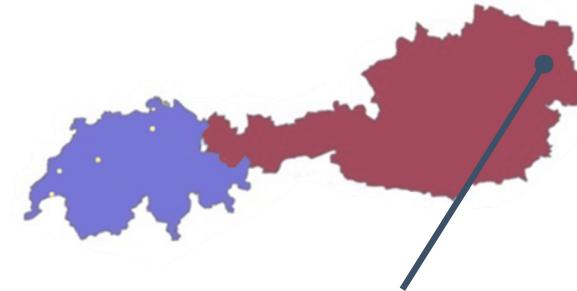
HE^{VD}
IG

Materials Science & Packaging
Technologies (COMATEC)
Institute of Mechanical Design
HEIG-VD, Yverdon



Empa

Abteilung Akustik/Lärmreduzierung, Empa,
Dübendorf



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Semperit Technische Produkte GmbH,
Wimpassing, Austria

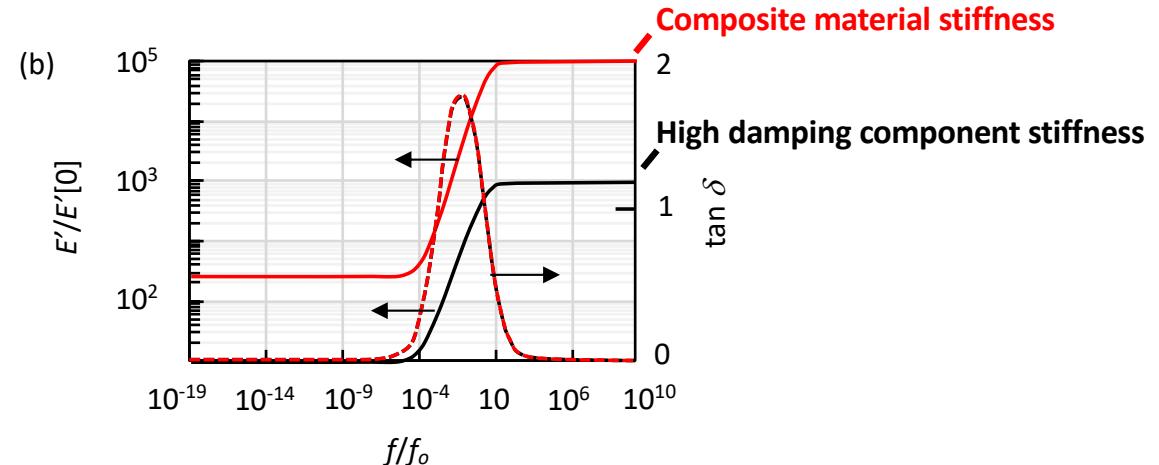
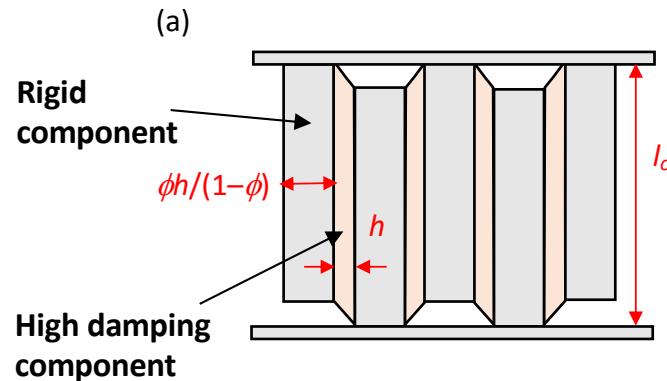
- **5 year Project funded by the Federal Office for the Environment (FOEN) & Federal Office of Transport (FOT) from 9/2017, as part of the Ordinance on Railway Noise Reduction (VLR).**





A Composite Design Approach

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Example of independent control of stiffness and damping in an idealized composite material: the composite has greatly increased stiffness over the whole frequency range, but identical damping ($\tan \delta$) to its high damping component.

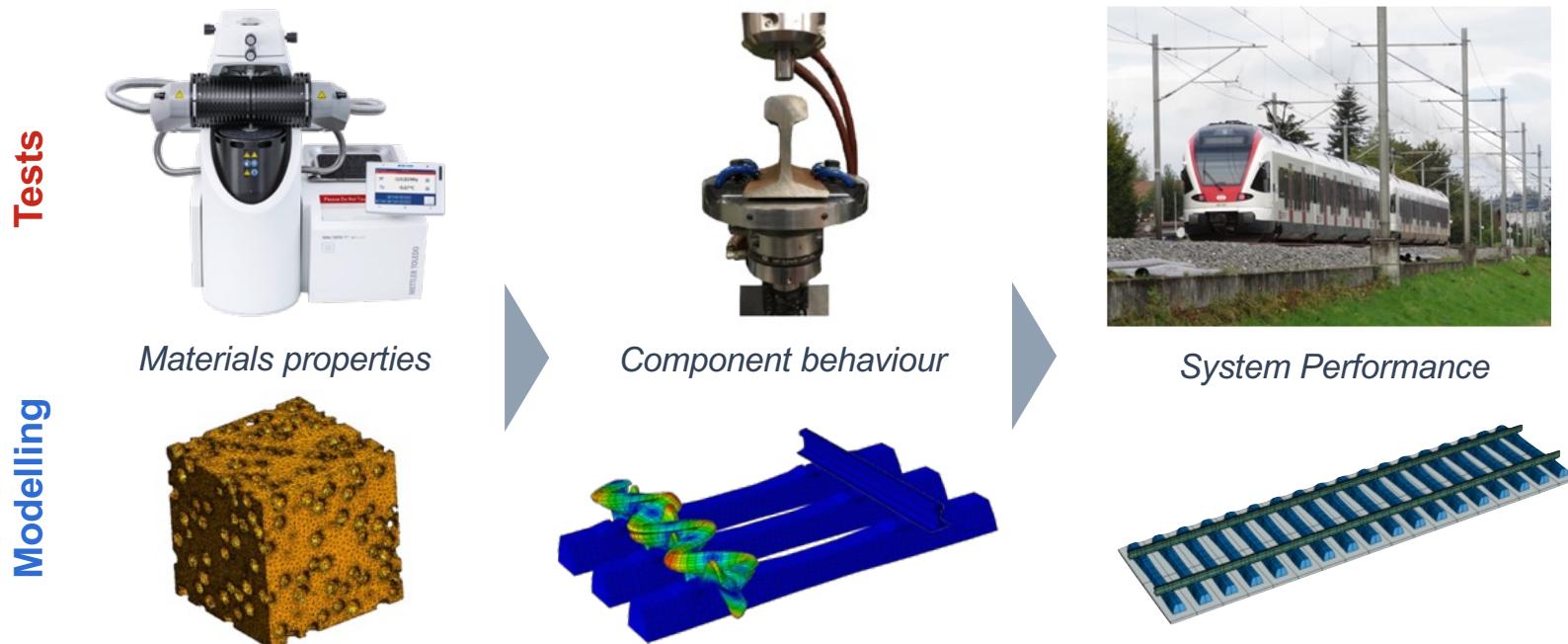
- Composites easily modulable (combinations of stiff and high damping materials) for systematic studies without need to change chemical structure, formulation.
- Unique properties through local strain control.
- May be used to provide design targets for single material rail pads.





Testing and modelling at different length scales

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- **Complete tool chain for modelling & experimental analysis of materials properties, components (rail, rail pad, sleeper, fastening system) & system (full track, field tests).**





The “three-sleeper cell”: key link in tool chain

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Tests



Three-sleeper cell

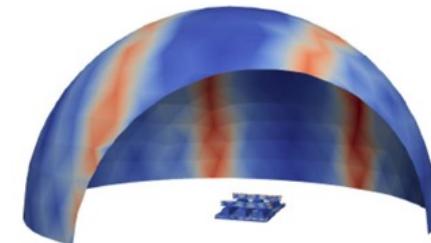
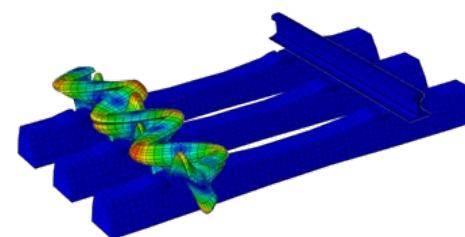
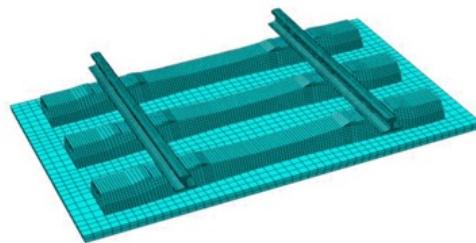


Dynamic response



Acoustic response

Modelling



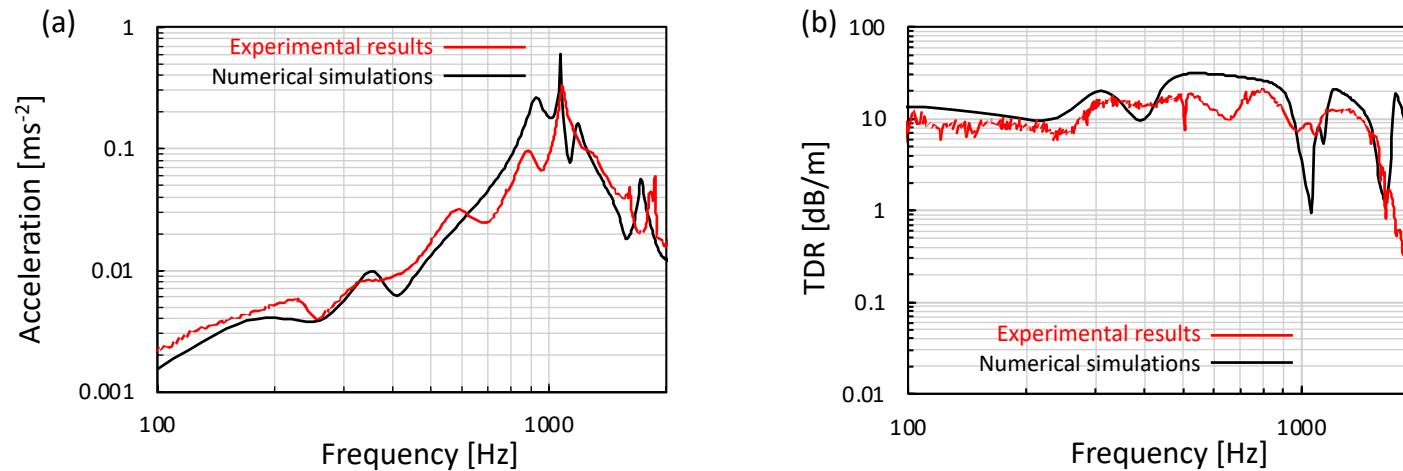
- **Laboratory-scale validation of simulations prior to extension to full track.**
- **First evaluation of the new rail pads: requires only 6 rail pads for a measurement.**





Semi-analytical simulations for rapid screening

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Comparison of semi-analytical model with experimental results from track near Sempach, Switzerland: a) Frequency response, b) TDR.

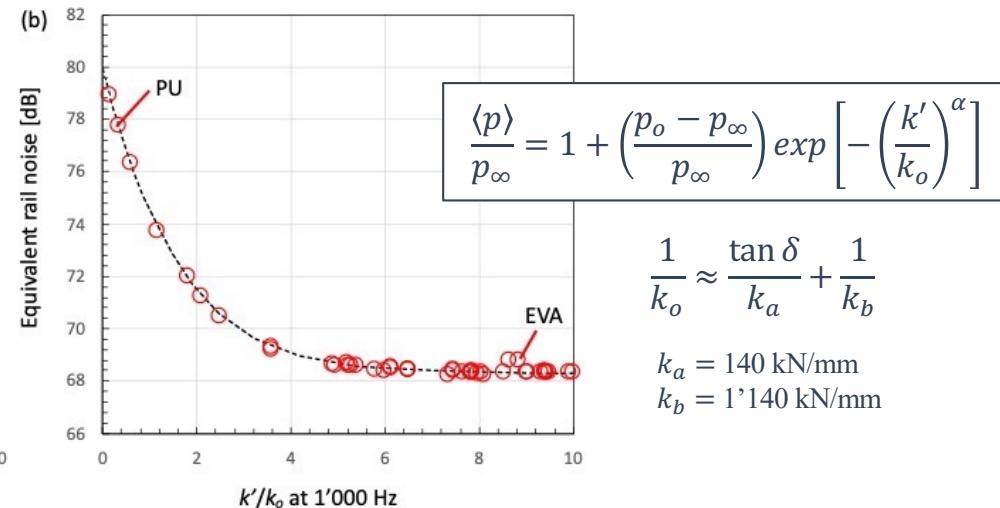
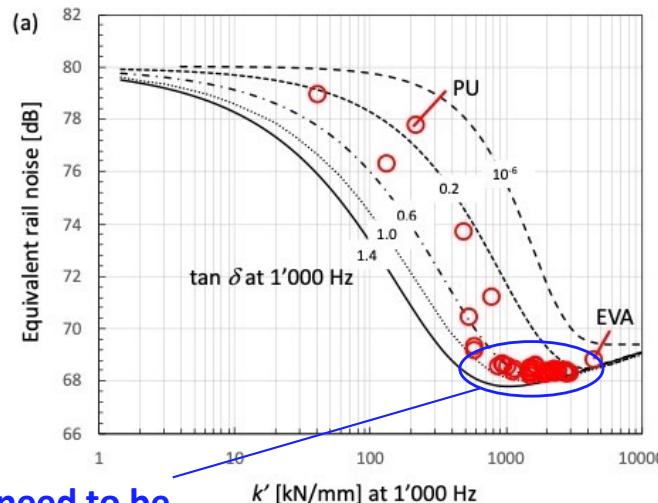
- Numerical/semi-analytical models validated from field tests with reference rail pads.
- Justifies the use of such models for the systematic evaluation of new prototypes.





Proof of concept, noise reduction design space

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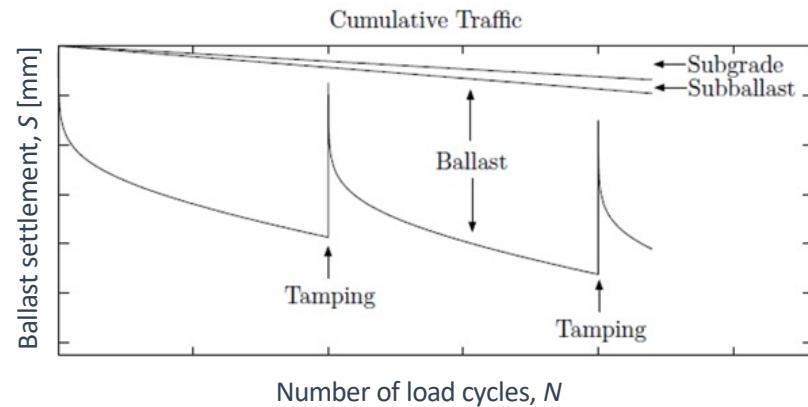
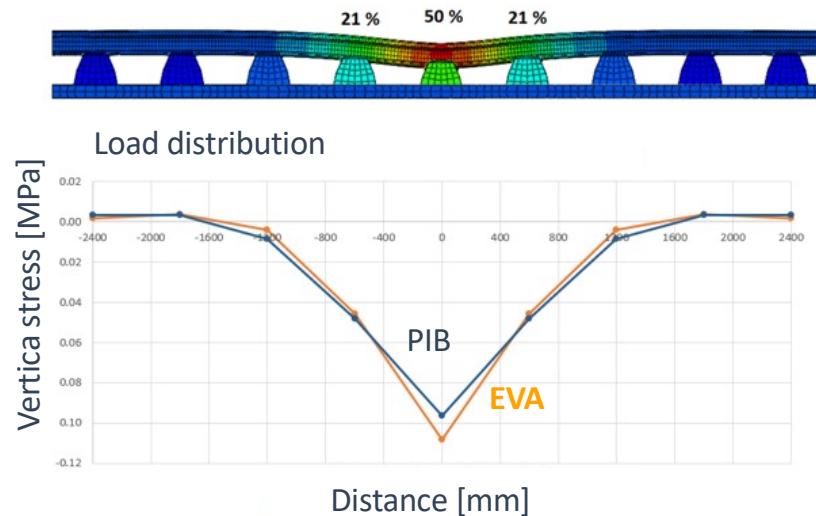
- a) Average sound pressure from 200–2'000 Hz, $\langle p \rangle$, from semi-analytical model as a function of dynamic stiffness, k' , for various damping factors, $\tan \delta$.
- b) Predictions for various composite rail pads plotted as a function of k'/k_o : damping is effective!





Track protection: ballast settlement rates

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Thom, N.H., Oakley, J.: Predicting Differential Settlement in a Railway Track bed, Railway Foundations. Birmingham, UK, 2006.

$$S = [\log_{10}(N) - 2.4]^2 \left(\frac{\sigma}{160} \right) \left(\frac{47}{K_s} \right)$$

where σ is the von Mises stress in the ballast obtained from the simulations and K_s is the stiffness of the ballast

- Calculation of load distributions (9 sleeper simulation) and estimated settlement rates.





Performance indicators: "Ballast index" and "Acoustic index"

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"Ballast index", I_b

Value of N that gives the same value of settlement as the reference rail pads after $N = 2,000,000$ cycles, normalized by 2,000,000. **$I_b > 1$ indicates better ballast protection than for reference rail pads (hard EVA).**

$$\text{"Acoustic index", } I_a = \frac{\langle p_{EVA} \rangle}{\langle p \rangle}$$

where $\langle p \rangle$ is the mean rail sound pressure predicted by semi-analytical simulations between 200 Hz and 2'000 Hz and $\langle p_{EVA} \rangle$ is the corresponding value for the reference rail pad (hard EVA). **$I_b > 1$ indicates better acoustic behaviour than for the reference rail pads (hard EVA).**



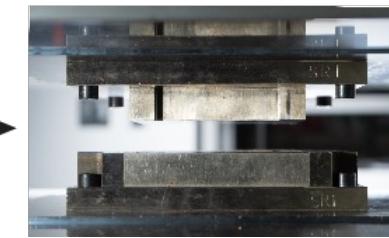
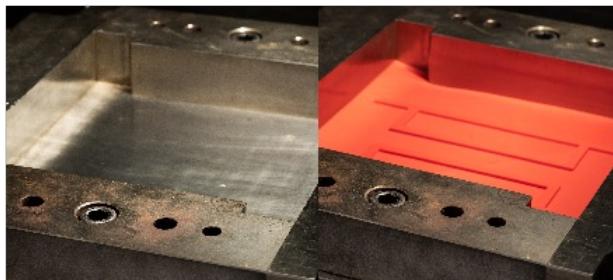


Production of experimental EVA/PIB rail pads

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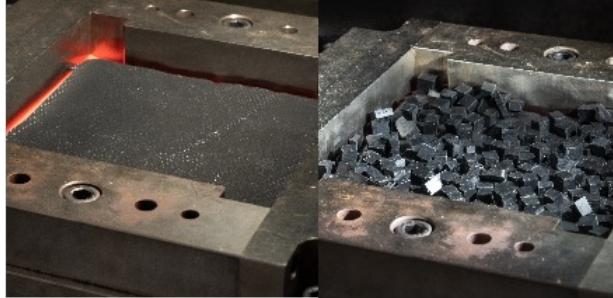
Ethylene vinyl acetate copolymer
(EVA) in granular form



Compression moulding,
crosslinking (1 hour)



Uncrosslinked PIB sheets



Stacking of sheets on 3D printed template

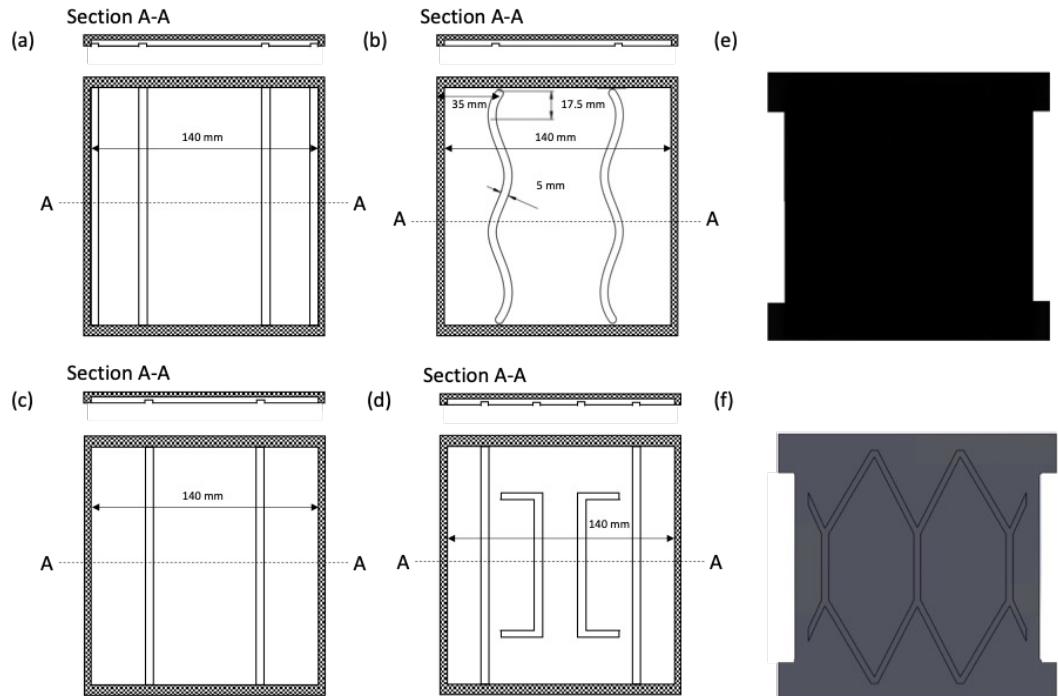


Composite rail pad

- Composite rail pads produced in-house: EVA + high damping polyisobutylene-based rubber (PIB).
- Additive manufacturing of templates enables rapid production of new prototypes.



1st gen. composites: EVA/PIB



Grooved EVA/PIB composite rail pad designs retained for standardized testing and further development. (The shaded regions represent the EVA in each case.)

- a) 60 % PIB with four straight surface grooves (static stiffness = 477 kN/mm, $\tan \delta$ at 1'000 Hz = 0.63, groove width = 5 mm, groove depth = 2 mm).
- b) 60 % PIB with two undulating surface grooves (static stiffness = 472 kN/mm, $\tan \delta$ at 1'000 Hz = 0.72, groove width = 5 mm, groove depth = 2 mm).
- c) 60 % PIB with two straight surface grooves (static stiffness = 440 kN/mm, $\tan \delta$ at 1'000 Hz = 0.56, groove width = 5 mm, groove depth = 2 mm).
- d) 60 % PIB with a more complex groove pattern (static stiffness = 281 kN/mm, $\tan \delta$ at 1'000 Hz = 0.54, groove width = 5 mm, groove depth = 2 mm).
- e) Actual rail pad produced using a 3D printed template for the grooves, including the overhang to prevent rail pad slippage according to the standard SBB specifications.
- f) Optimized groove design generated by a neural network.

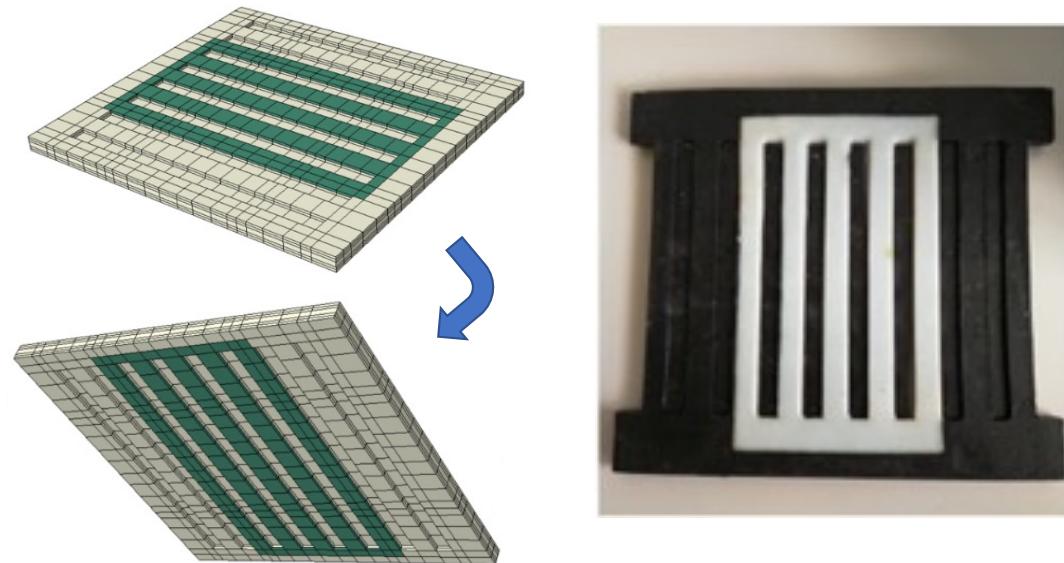




2nd gen. composites: Hytrel/SemperSilent™

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Hytrel (white)/SemperSilent™ (black) composite design: top view showing one of the grooved Hytrel inserts, the other being embedded in the bottom surface at 90 ° to the top plate, as shown schematically (left).



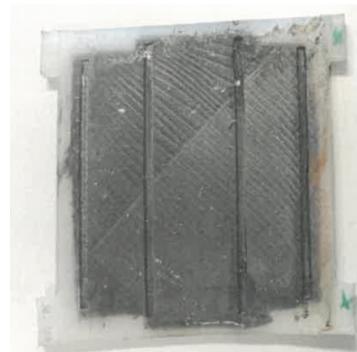
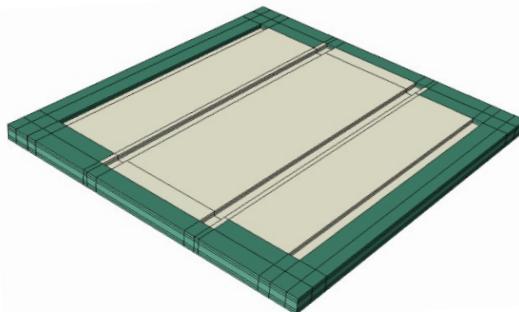
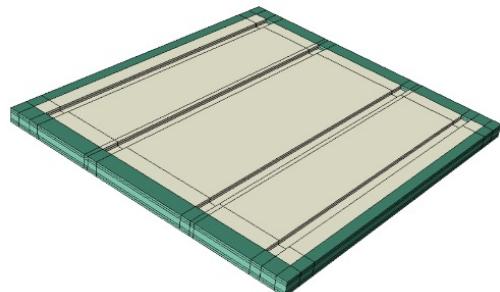
- EVA replaced by hard polyester elastomer (Hytrel™, from DuPont), and PIB replaced by Semperit high damping rubber “SemperSilent™”.
- Compatible with industrial process, improved performance *in silico* and in three-sleeper cell.



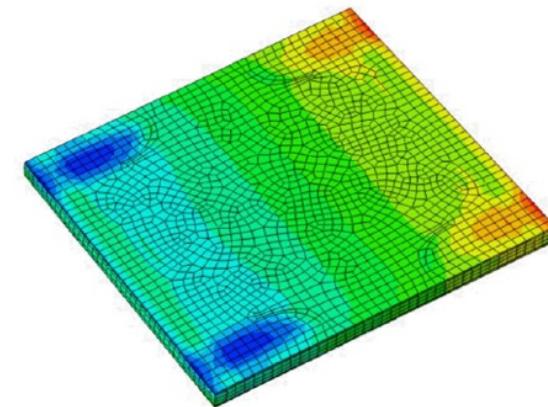


Optimization for homologation

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- Determination of maximum permissible stresses from compression tests.
- Geometric optimization to limit local stress concentrations and avoid fatigue damage in standard tests.





SEMPERSILENT™ PAD DEVELOPMENT FOR SBB TEST SECTION “NOTWILL”

September 6, 2022

EPFL: EXCHANGE OF EXPERTS – rail pads

H. Miessbacher

SEMPERIT S



Agenda

Facts & Figures Semperit Group

Overview Semperit railway business

SemperSilent™ Pad: Feasability study elastic material & design

Product testing

Production of samples for test section

Conclusion and outlook



Semperit at a glance

International group

which develops, produces and sells highly specialized products made of polymers in the Industrial and Medical Sectors

Leading market position

with strong brands in the Industrial and Medical Sectors for more than
198 years

EUR **1.1821** m revenue
EUR **361.8** m operating EBITDA

Balanced portfolio



Semperflex



Sempertrans



Semperform



Semperseal



Sempermed

Employees **6,948**



16 production sites

worldwide



Strong global R&D team:

- 9 R&D locations
- More than 240 FTE in R&D
- Around 300 active patents



History:

1824 Company founded

1890 Company listed on the Vienna stock exchange

1986 Tyre business sold since then growth in core businesses

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Worldwide presence: Semperit as a global player





Semperit railway business – one stop shop made in EU fastening components



DOWELS

Semperit offers different types of dowels such as HDPE, PA and replacement dowels to support all dowel systems. Our dowels are known for their good temperature and acid resistance, and from market feedback, long service lives.

RAIL PADS

Rail pads distribute the load, reduce vibration and noise, and protect the sleeper and the ballast. No matter what type of rail pads our customers need – extruded or moulded, rubber or plastic – we have the solution for all requirements.

GUIDE ANGLE PLATES AND INSULATORS

We offer different types of guide angle plates and insulators for various applications and manufacturers. Our products feature high load-bearing capacity and outstanding stability.





SemperSilent® Pad: Customer requirements SBB

1. Noise reduction on track:
-1dB(A) compared to EVA pad 687
2. Pad dimensions according ZW687
(UIC60 rail + type W fastening)
3. Minimum rail pad stiffness:
200kN/mm according EN13481-2-
Class C
4. Relevant performance tests
according EN13481-2-Class C

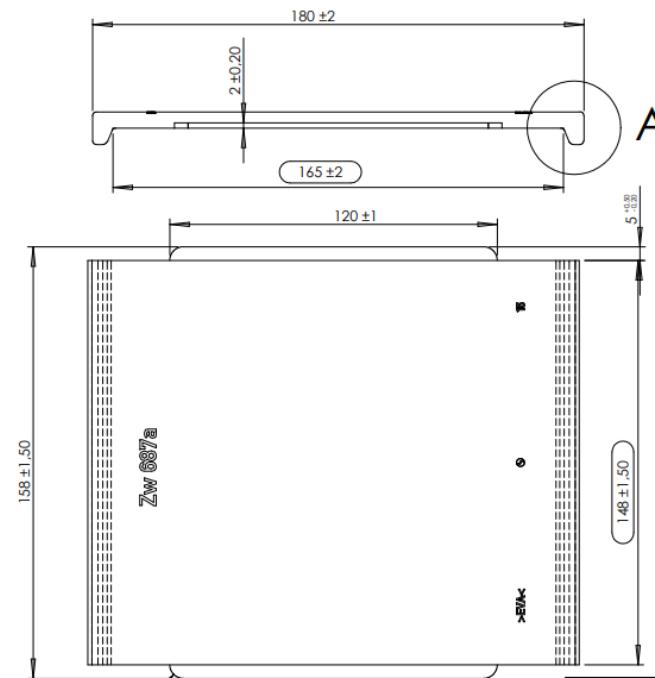
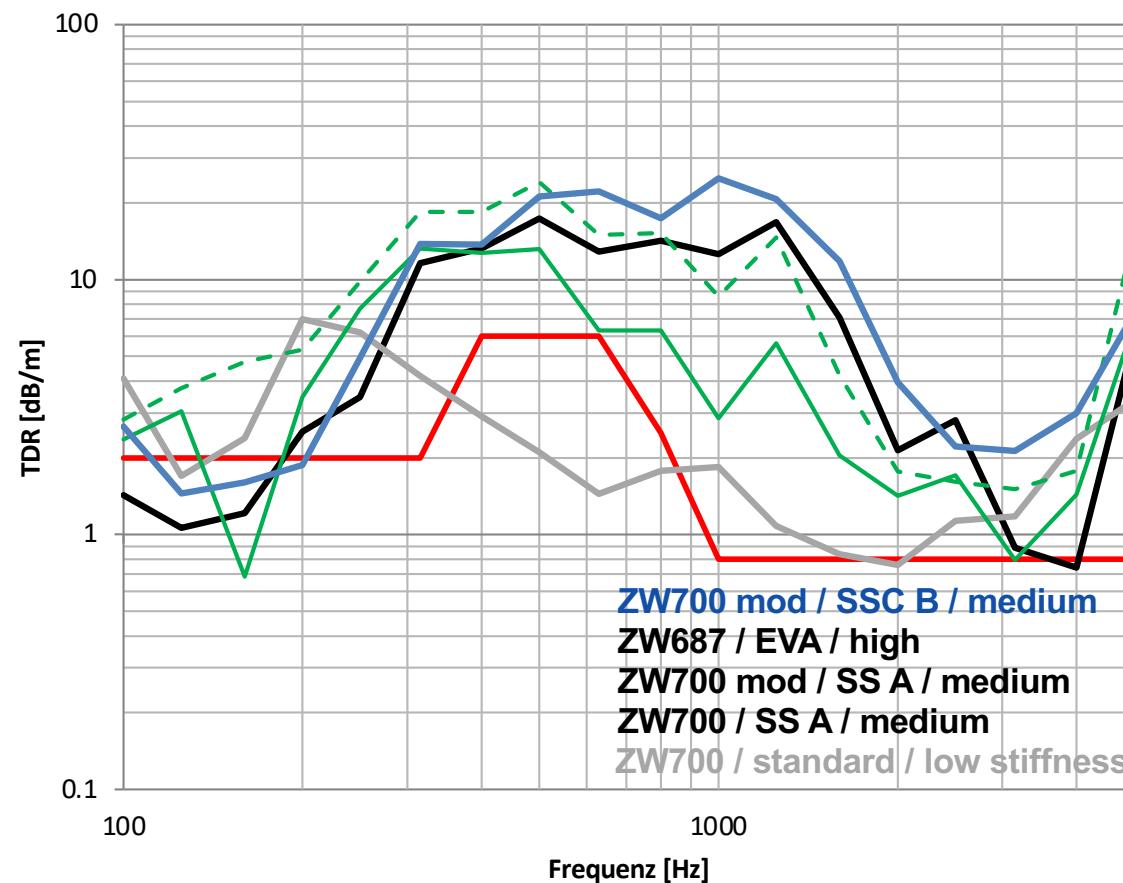


Tabelle 1 — Befestigungskategorie-Kriterien

Kategorie	Maximale Auslegungsachslast kN	Minimaler Gleisbogenhalbmesser m
A	130	40
B	180	80
C	260	150
D	260	400
E	350	150

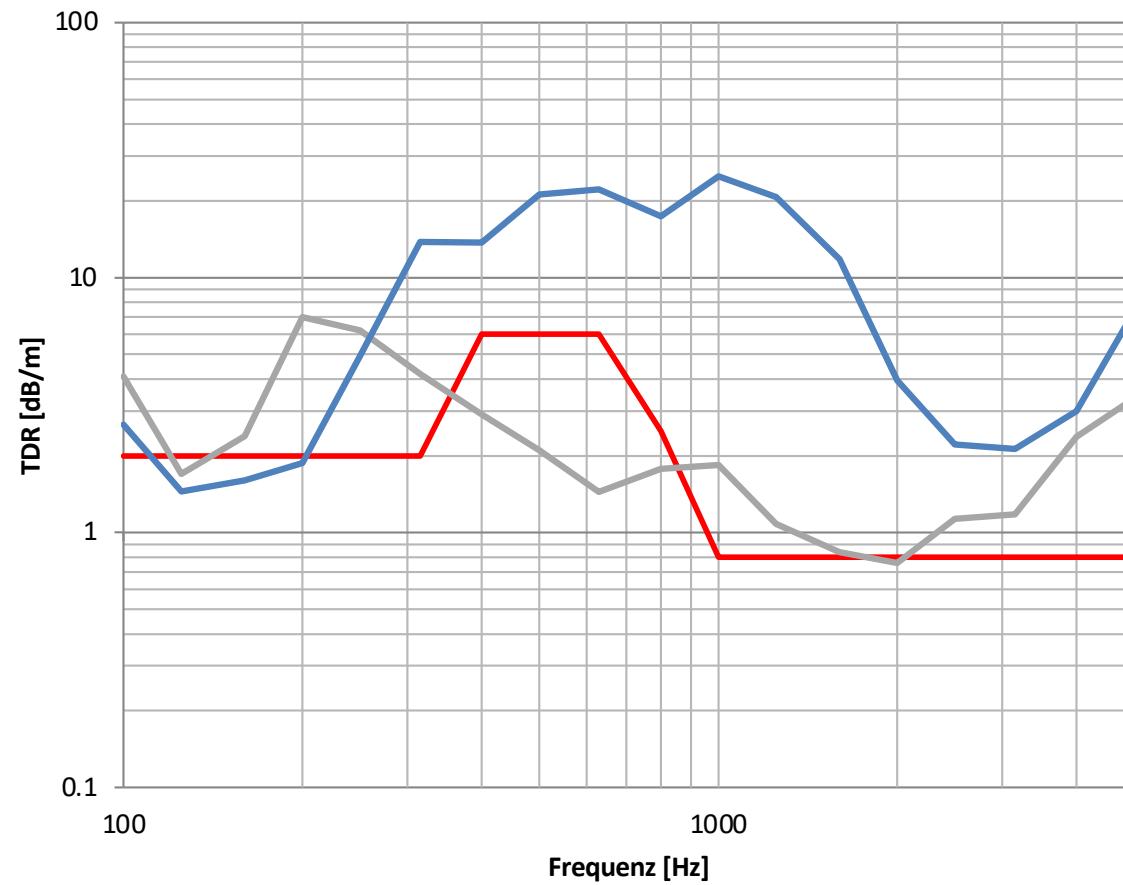


SemperSilent® Pad: Feasibility study elastic materials and design Vertical track decay rate acc. EN15461 @ Semperit W14 test bench



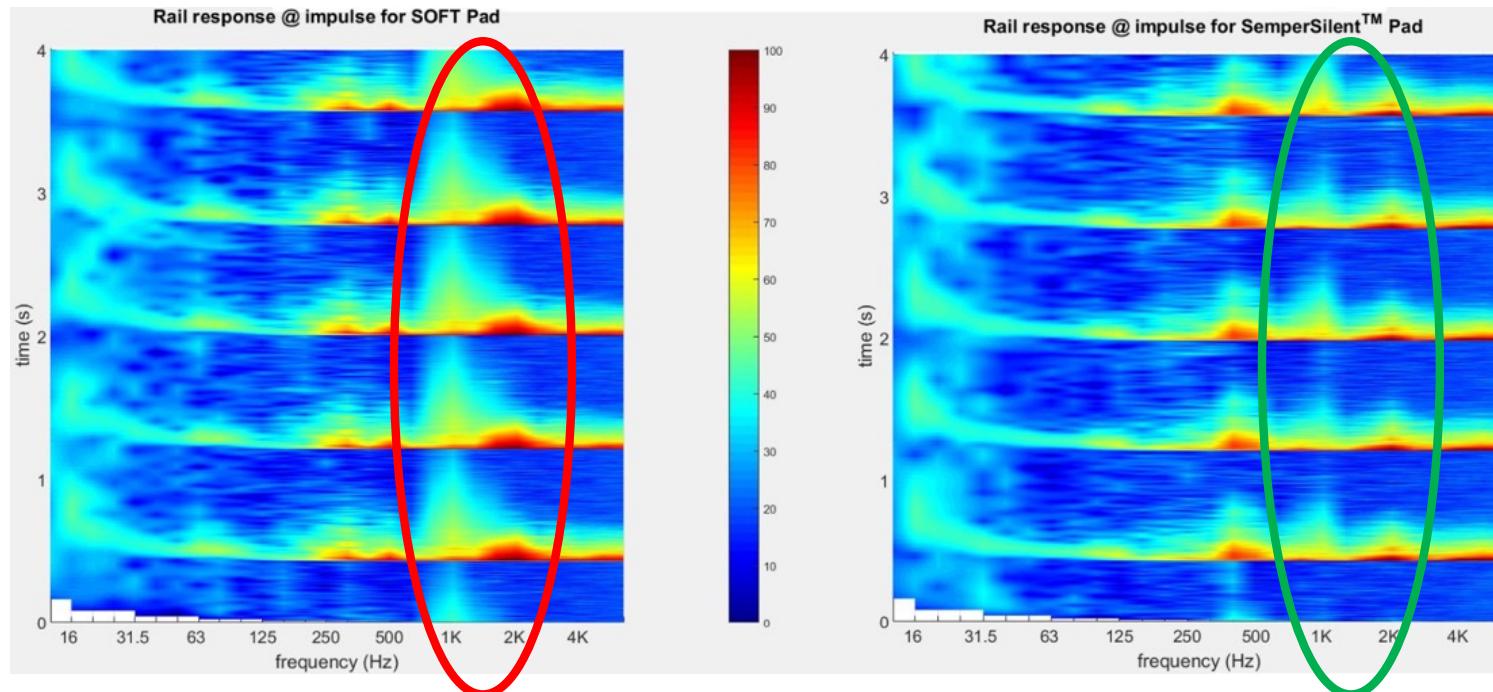


SemperSilent® Pad: Product testing TDR - acoustic comparison





SemperSilent® Pad: Product testing TDR - acoustic comparison





SemperSilent® Pad: Product testing acc. UIC864 and EN13481-2-C

Test (Unit)	UIC864-5
Tensile strength (N/mm ²) ISO 37 Type 2	>12
Elongation at break (%) ISO 37 Type 2	>250
hardness (Shore A) ISO 48-4	>65
kSP static stiffness (kN/mm) EN13146-9-C	>200
specific volume resistance (Ωcm) DIN IEC 60093	≥10 ⁸

- Product test according UIC864-5



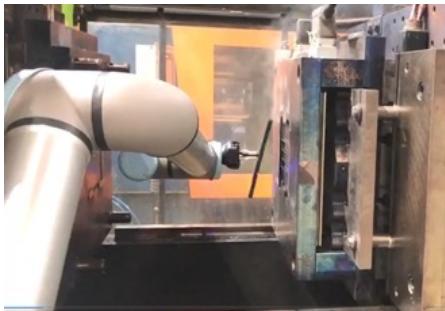
Test setup for repeated load test according to DIN EN 13146-4

- Changes after repeated load test (3 Mio cycles):
- kSP and kFLP 5/10/20Hz < 15%
- kSA ≤ 25%
- longitudinal creep resistance ≤20%; F > 9kN
- The rail pad and guide angle plate showed no damage that would impair its function after repeated load test

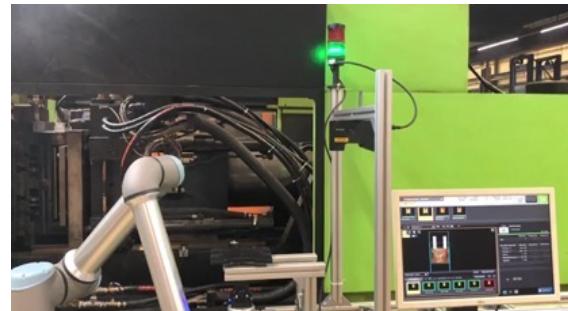




SemperSilent® Pad: Production of samples for test section Notwill



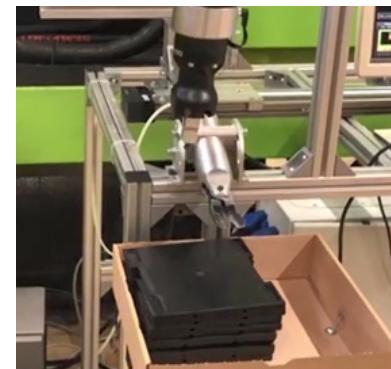
Removal of component



Handover and inspection with an optical inspection unit



Removal of the sprue



Defined storage of the pad



SemperSilent® Pad: Summary and outlook

1. The choice of material and the rail pad design was done according to the customer requirements. The newly developed pad corresponds to the requirements of EN13481-2 Class C and UIC864-5.
2. It was shown that with a suitable choice of material and a well-balanced product design, the track decay rate of elastic rail pads can be brought at least to the level of hard EVA pads.
3. Based on the development results, the new rail pads were released by SBB and installed in "Notwill" test section. Pass-by measurements were carried out by EMPA.
4. Previous experiences show that the advance "rail singing" effect on the track, which annoys the residents but is usually not measured, is also reduced with these type of rail pads.



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ENJOY THE SILENCE
WITH OUR SEMPERSILENT™
NOISE-REDUCTION RAIL PAD



Visit our test station at **Hall 26, Booth 890** to hear the difference



Summary of prototype performance indices

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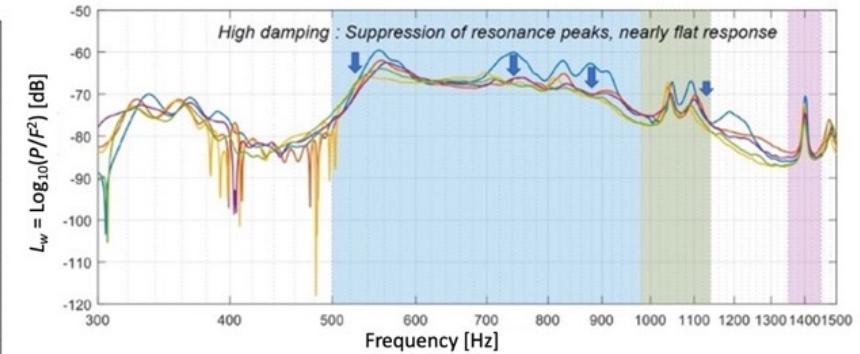
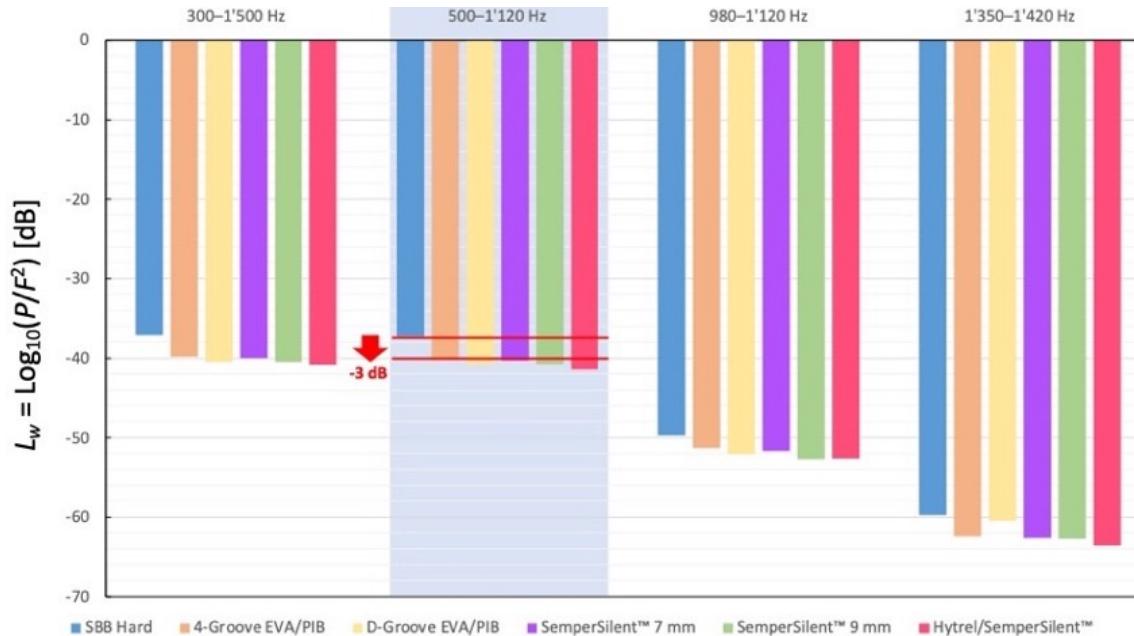
	$20\log_{10} I_a$	I_b	I_b^{HF}
4-groove EVA/PIB	3.01	1.10	1.52
Hytrel [©] /SemperSilent [™]	4.52	1.34	1.72
SemperSilent [™]	4.32	1.13	1.32





Experimental results from 3-sleeper cell

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Comparison of the normalized logarithmic average sound power levels

- D-Groove and 4-Groove EVA/PIB composite prototypes
- 9 and 7 mm SemperSilent™ single material prototypes
- Hytrel/SemperSilent™ composite prototype

- Excellent acoustic performance for all prototypes (> 3 dB noise reduction over reference rail pads).
- Corresponding continuous spectra illustrate the effect of damping on the resonance peaks.

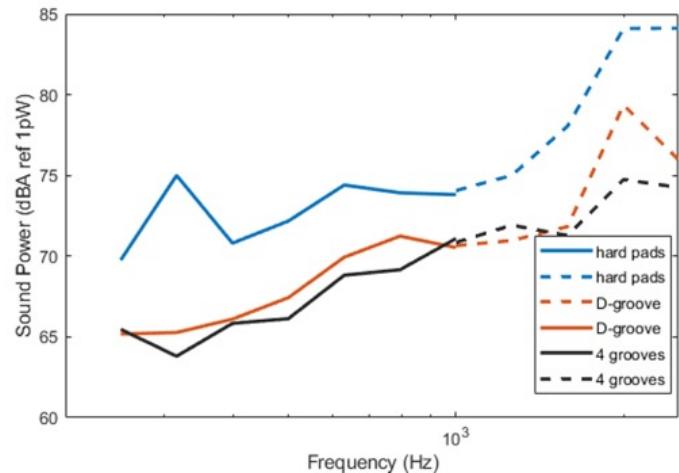




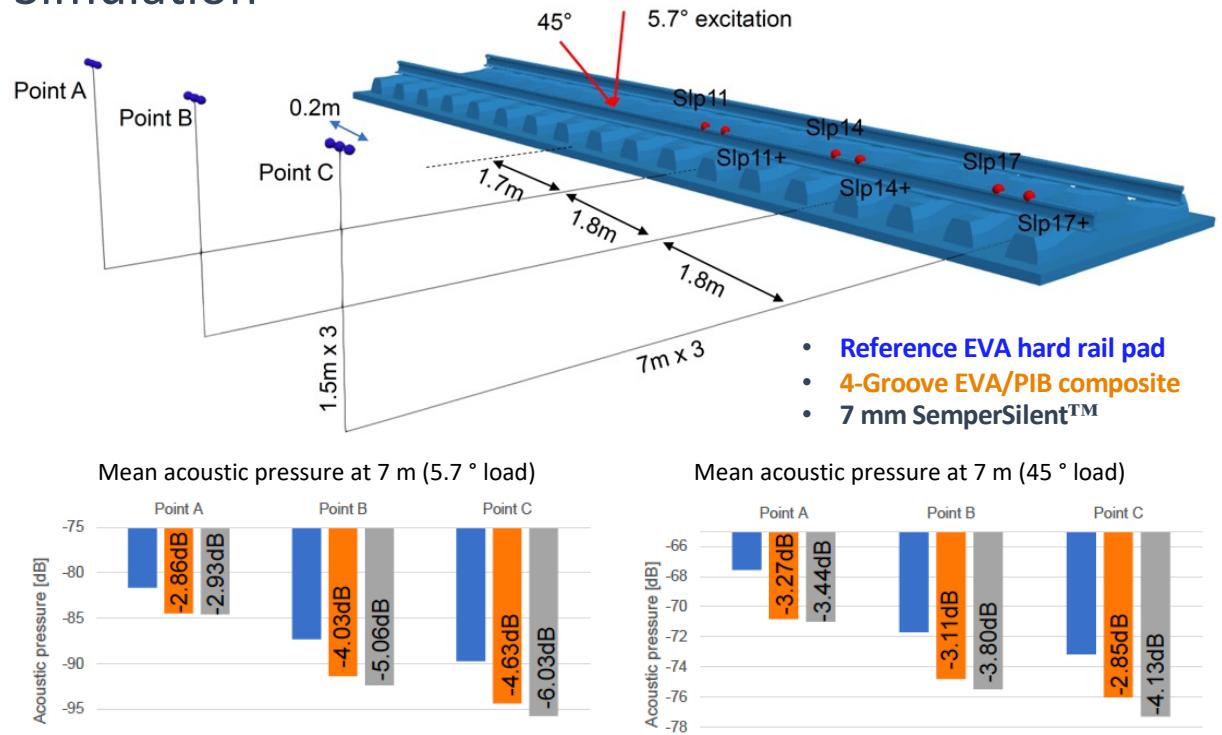
Experimental/model results at track scale

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Experiment (TU Munich)



Simulation



- Strong correlation with results from 3-sleeper cell.
- “Sound” basis for field tests.

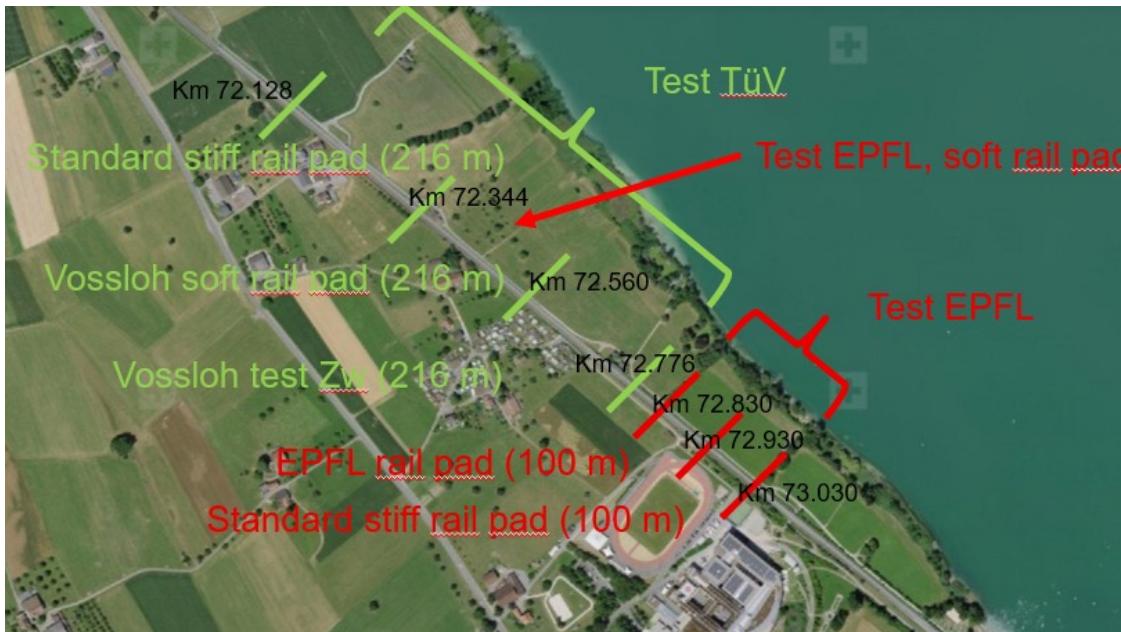




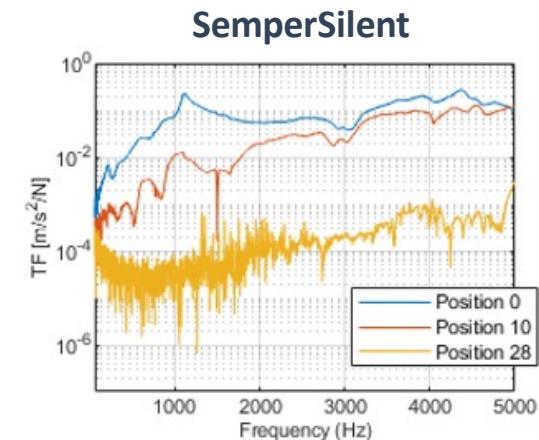
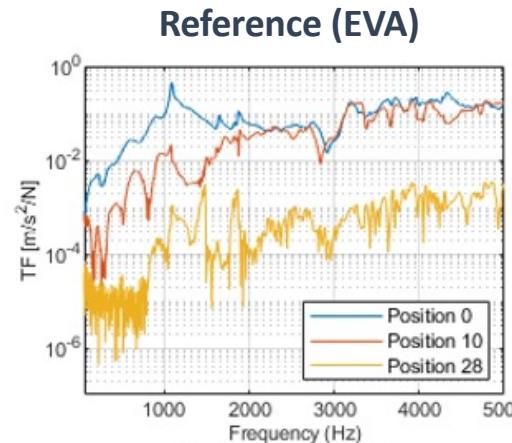
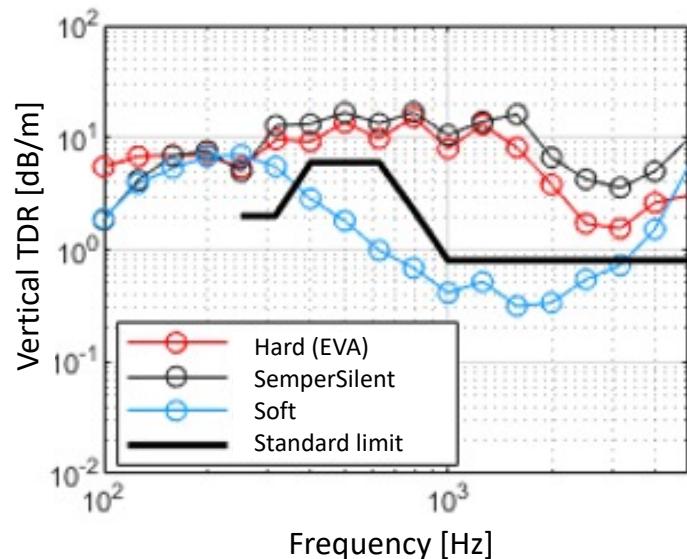
Field tests



<u>Track</u>	<u>Speed</u>
Track renewal 2018	$V_{\max} = 160 \text{ km/h}$
B91 Sleepers	
Rail grinding in March 2021	
(tamping over 330 m in 2022 in direction of Sempach)	
Identical rail roughness in test and reference sections	
<u>Installation</u>	
March 17/18, 2022	
Organized by VU (Verfügbarkeit und Unterhalt)	



Selected track measurements



Position 0: excitation point; position 10: 1.5 m away (over a sleeper); position 28: 39.6 m away.

- Vertical TDR measurements confirm laboratory results: significantly better performance with high-damping rail pads.
- Vertical point mobility reduced for high-damping rail pads: *suppression of resonances*.

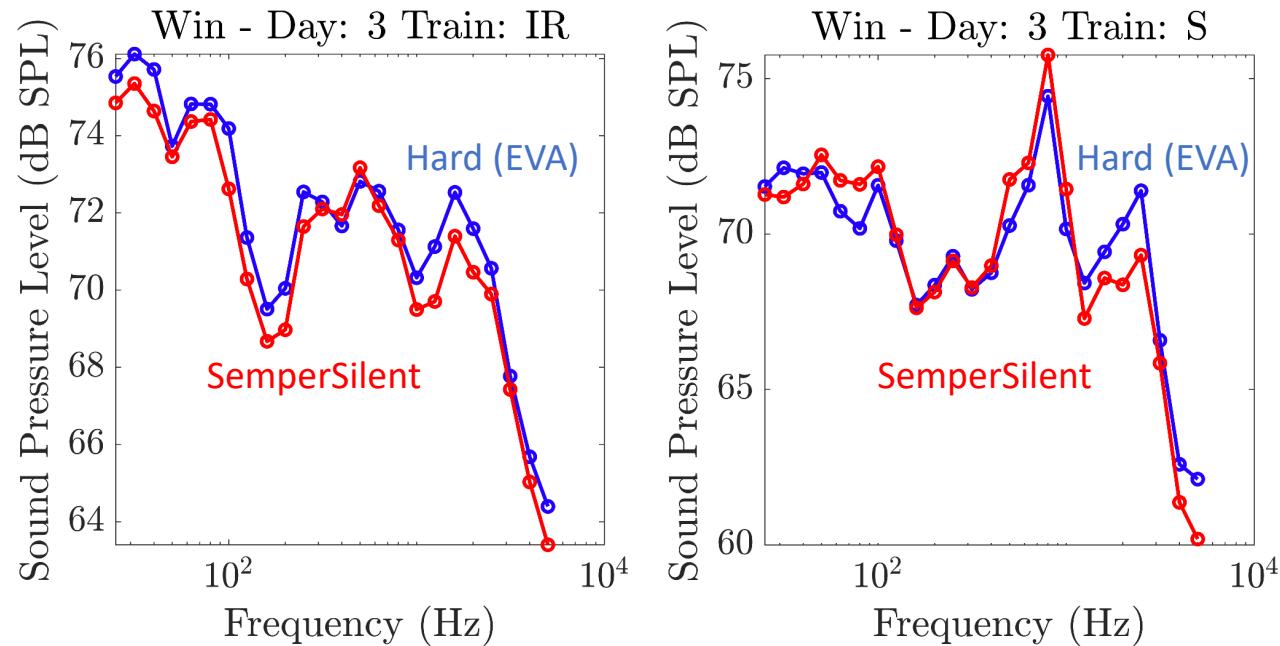




Noise reduction* from individual train types

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* Microphone position from ISO 3095:2013, horizontal position 7.5 m from track axis and vertical position 1.2 m above the plane of the railway head, no A-weighting.



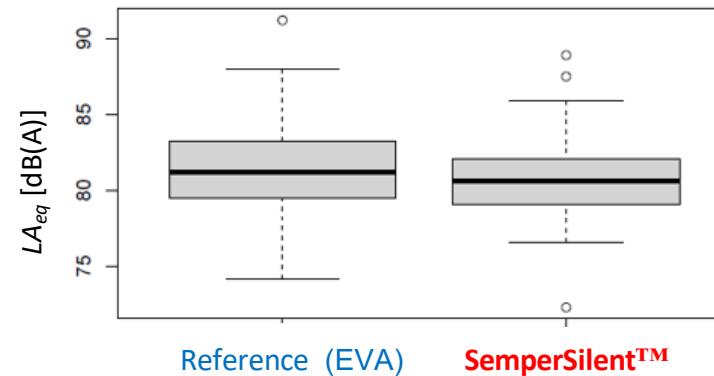
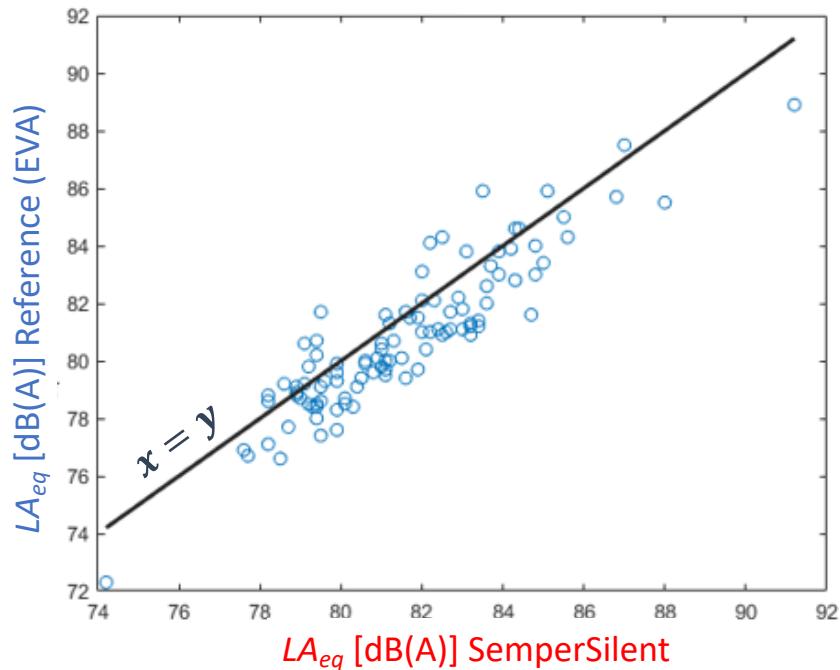
- **Track-side acoustic measurements under standard conditions: consistent measurable reductions in sound pressure, but absolute noise levels highly dependent on type of traffic.**





Statistical analysis of 101 trains pass-by events

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- LA_{eq} for individual trains for SemperSilent™ rail pads (y-axis) vs. LA_{eq} for same trains and reference pads (x-axis). Points below $x = y$ correspond to reduced noise for high-damping rail pads.
- Statistically significant global noise reduction by $0.73 \pm 0.11 \text{ dB(A)}$ (Student's t-test, $p < 0.0001$)





Conclusion and outlook

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- High-damping composite rail pad design concepts brought to fruition through systematic testing, and use of validated analytical and numerical simulation tools to extrapolate laboratory-scale measurements to train pass-by on real rail tracks.
- Results confirmed by field tests: statistically significant reduction in noise for representative Swiss rail traffic by 0.73 dB(A) when reference hard rail pads replaced by high-damping single-material prototype, "SemperSilent™", meeting our design criteria.
- Composite rail pads show increased design flexibility and significant scope for further optimization
- All prototypes show much lower static stiffness than the reference rail pads, implying improved superstructure protection, quantified in terms of a ballast index based on an empirical model for sedimentation rates, and sleeper stresses calculated using numerical simulations, supported by field measurements of the stress transfer functions associated with the various track components.

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Materials Science and Technology

HE
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Confédération suisse
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Confederaziun svizra

SBB CFF FFS

Exchange of Experts 2|'22
September 6th, 2022

Güterverkehr auf der Schiene.
Mit Forschung und Investitionshilfe des Bundes.

