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

Cheap compared to other solutions

Compatible to the process in track installation

USP

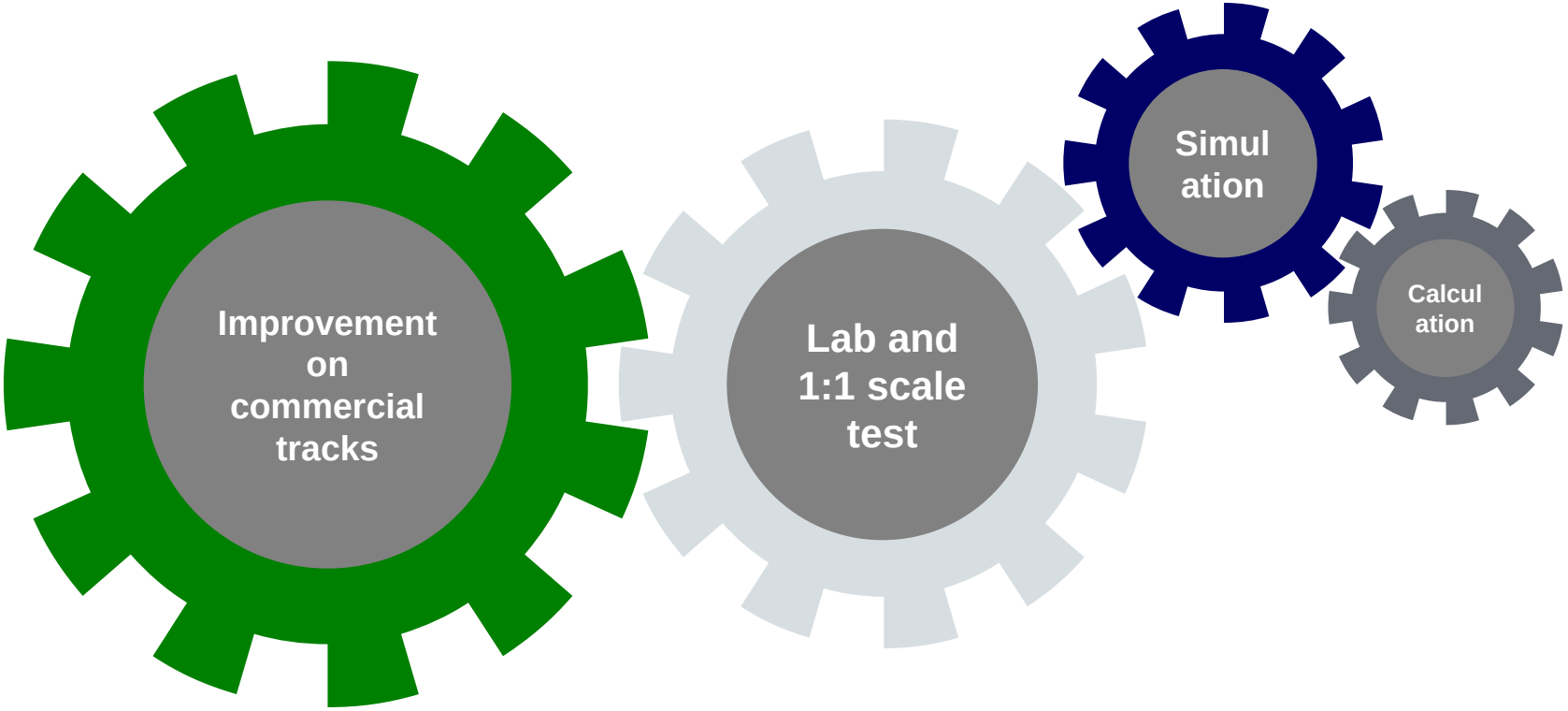
Positive influence on track quality

Impact on LCC

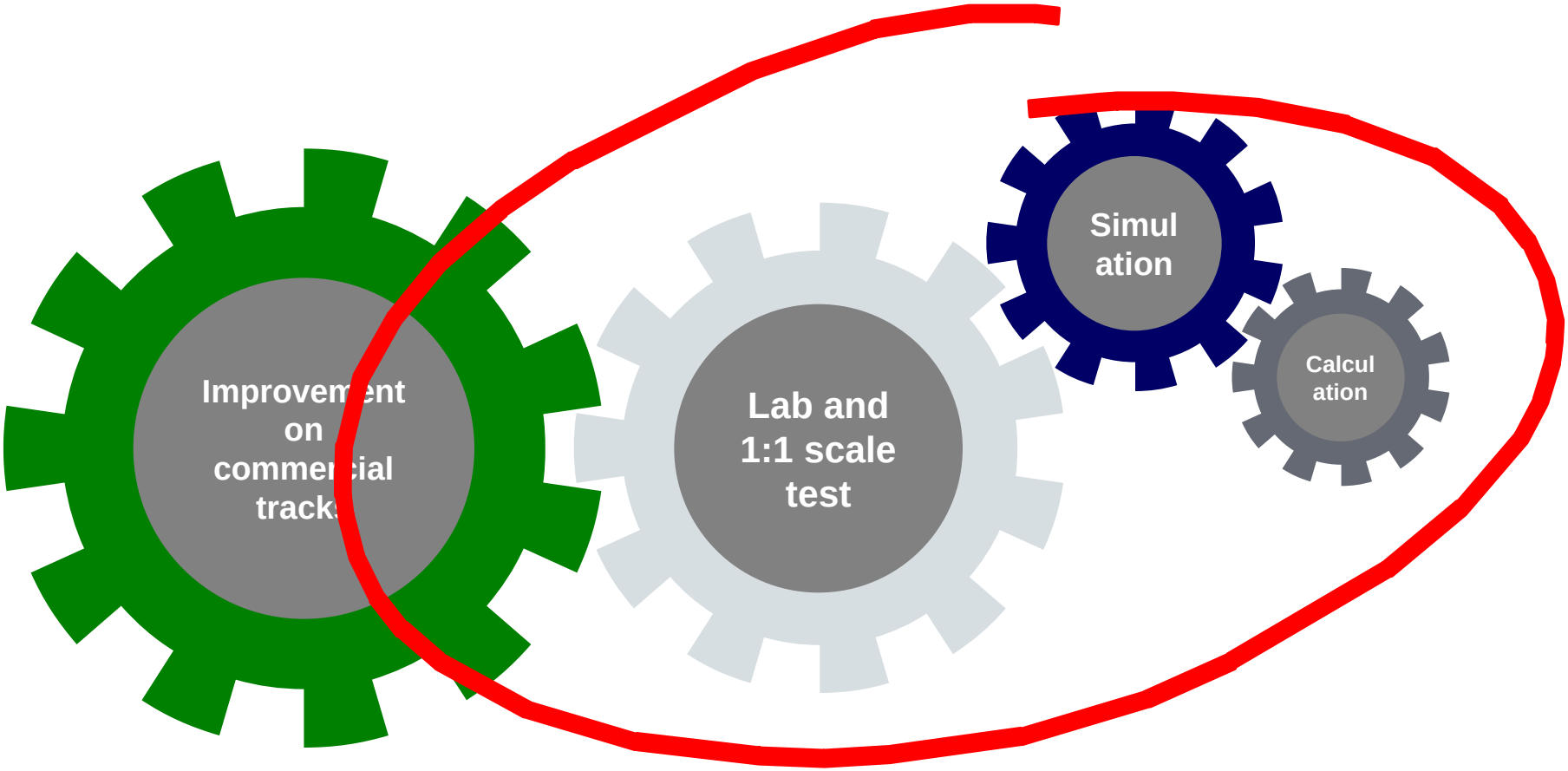
Under sleeper pads (USP) are used in tracks for several reasons for some years

How could the potential for vibration-mitgation effects improved

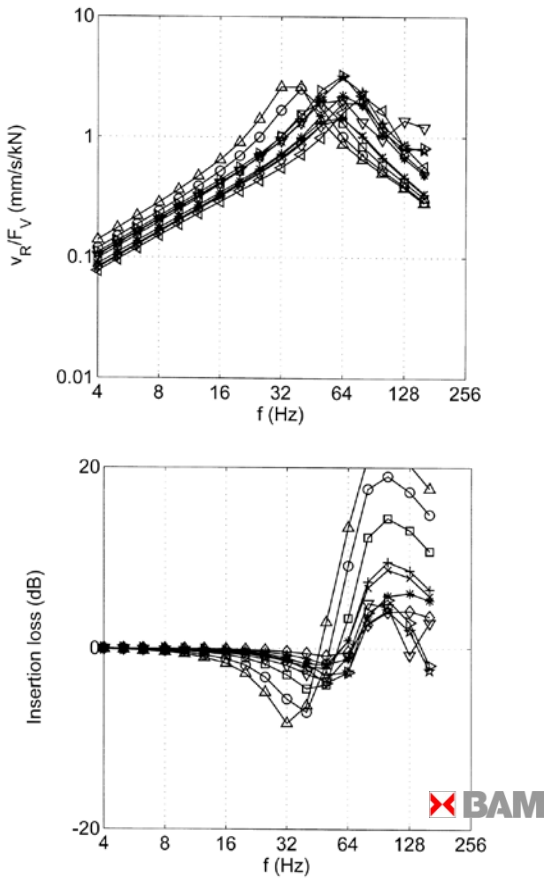
From the idea to a new solution in track, a long way with different steps of improvements have to be pass-through



The first three steps were carried out within RIVAS



After simulation with parametric studies different configurations were chosen



Rail mobilities (v_R/F_V, top) and insertion losses (bottom) of ten tracks in Herne, calculation with approximating values for an axle load, test sections □ ME11 (BBS/V2), ○ ME12(BBS/06), △ ME13 (BBS/03), + ME14 (B90/06), × ME15 (B90/10), ◇ ME16 (B70/10), ✱ ME17 (B70/10no), ▽ ME15* (B90/10/900), ✱ ME16* (B70/10/900), ▷ ME17* (B70/10no/900), ◁ reference track

Criterias for chosing 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

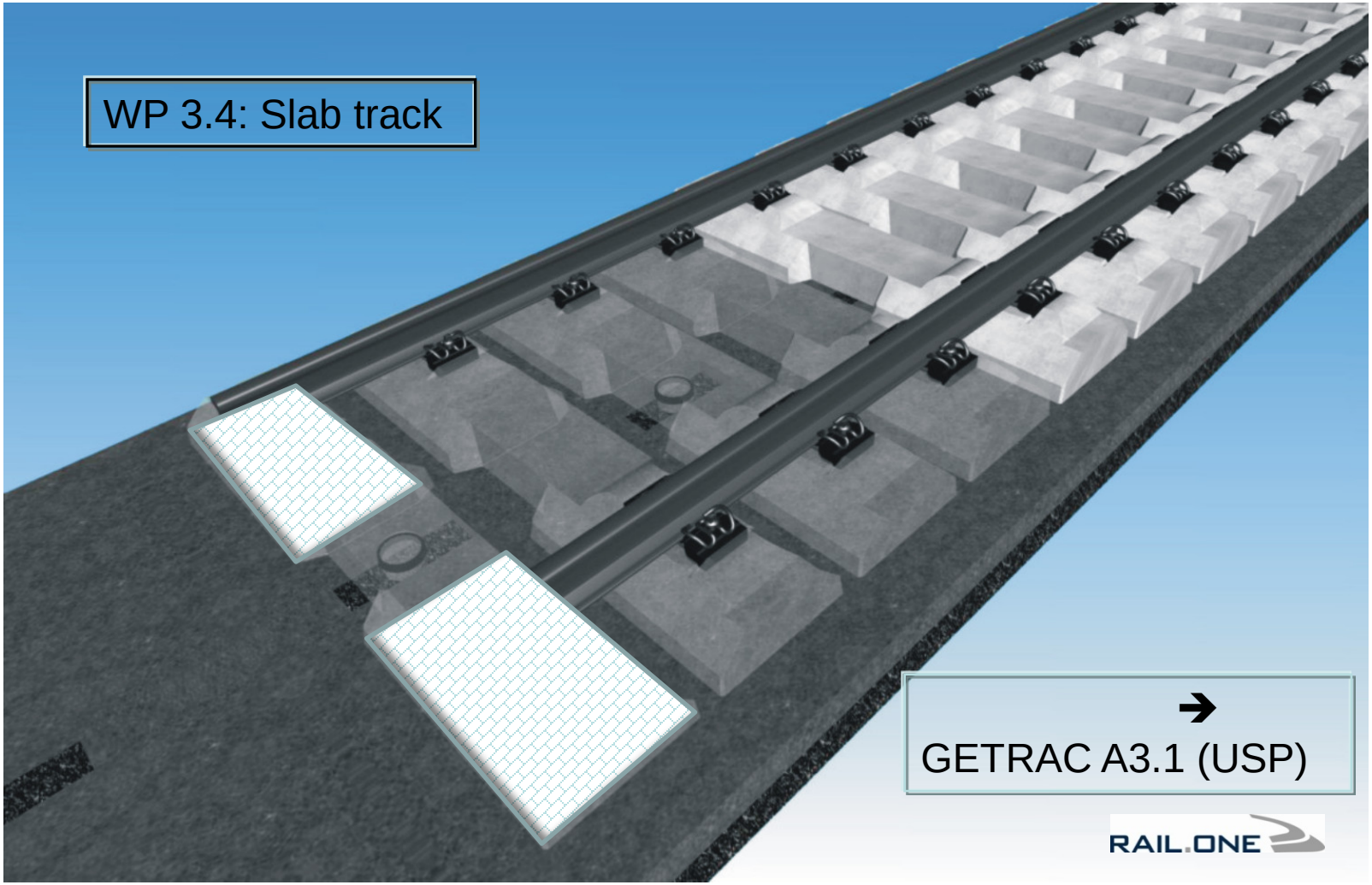
Weight: 577 kg*

The possible influence of concrete edge stripes should be improved

Sleeper ´without´ concrete edge stripes

Sleeper with concrete edge stripes

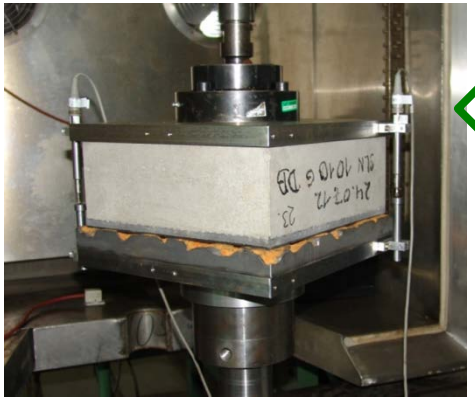
Additionally a special slab track system with resilient layer was improved



In total, 10 different configurations of USP, sleepers, and rail pads were determined

Measuring section ID	Short name	Sleeper		Under sleeper pad (USP)					Rail pad
		Type	weight *incl. USP & fastener*	type	Supply name	Nominal static modulus	Total area	Concrete edge?	
			[kg]			[N/mm³]	[cm²]		
ME11	BBS3.1 V2	BBS 3.1	577	V-02	-	0,08	10,080	With concrete edge	Zw 687a
ME12	BBS4 G13	BBS 4	577	G-13	SLN 0613	0,06	11,820		
ME13	BBS4 G15	BBS 4	577	G-15	SLN 0315	0,03	11,820		
ME14	B90.2 G13	B 90.2	605	G-13	SLN 0613	0,06	7,122		
ME15	B90.2 G04	B 90.2	605	G-04	SLN 1010	0,10	7,122		
ME16	B70 G04	B 70	309	G-04	SLN 1010	0,10	5,900		
ME17	B70 G04 NE	B 70	309	G-04	SLN 1010	0,10	6,391	Without	
ME15	B90.2 G04 Zw900b	B 90.2	605	G-04	SLN 1010	0,10	7,122	With concrete edge	Zw 900b
ME16	B70 G04 Zw900b	B 70	309	G-04	SLN 1010	0,10	5,900		
ME17	B70 G04 NE Zw900b	B 70	309	G-04	SLN 1010	0,10	6,391	Without	

For preparing the homologation a series of lab tests were performed



Determination of static bedding modulus of USP on block

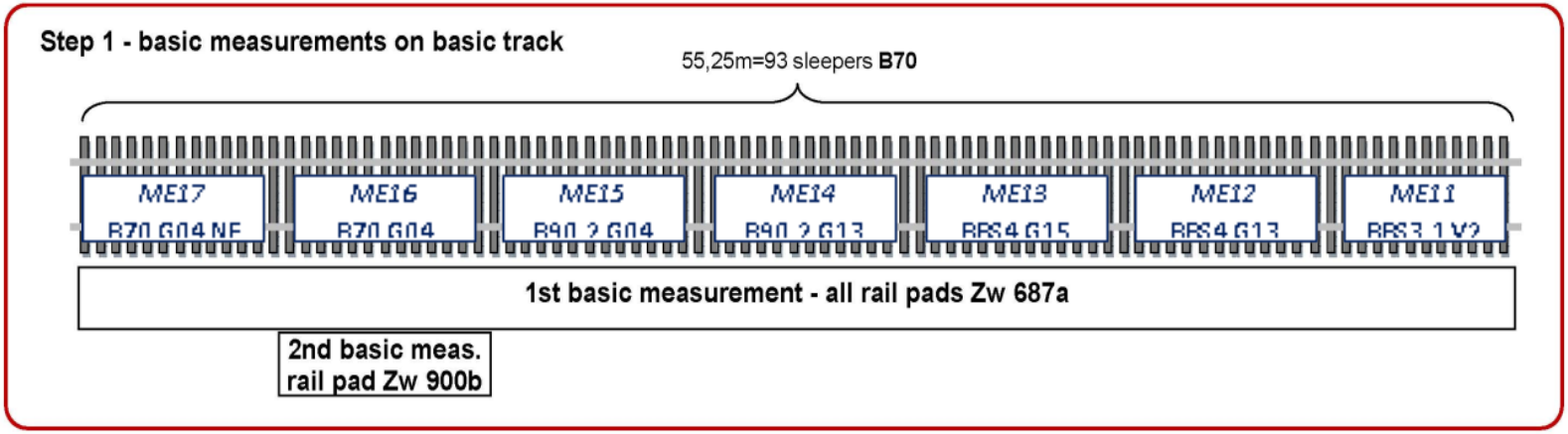
Determination of high frequency bedding modulus

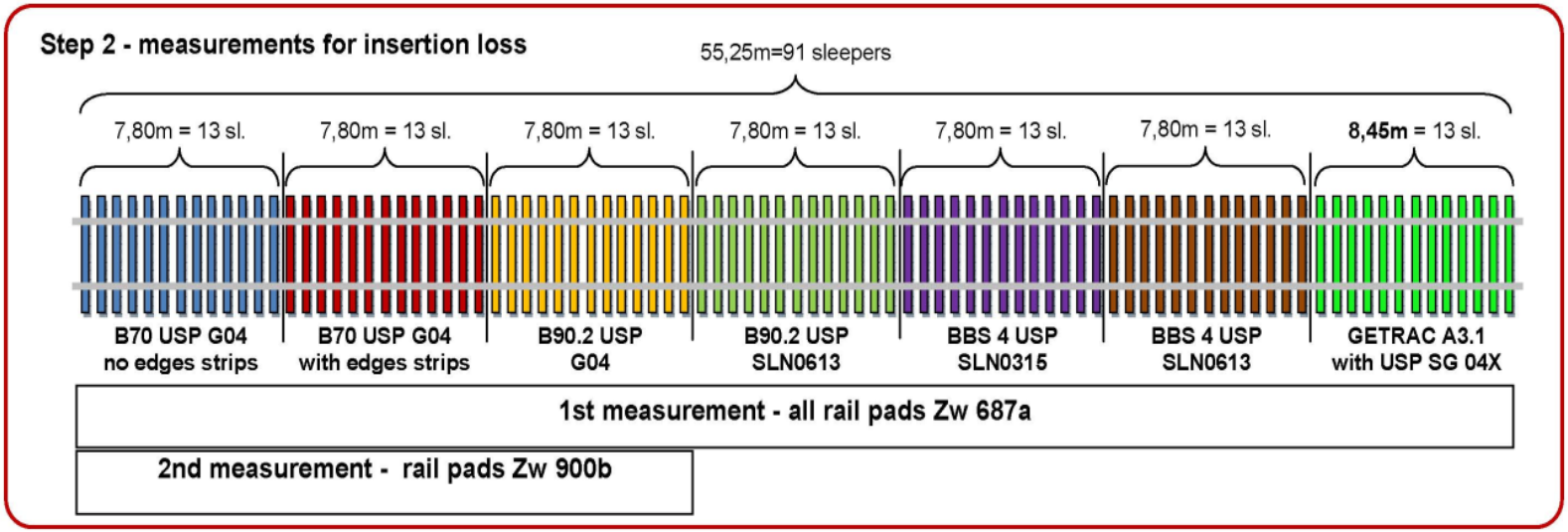
BAM

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

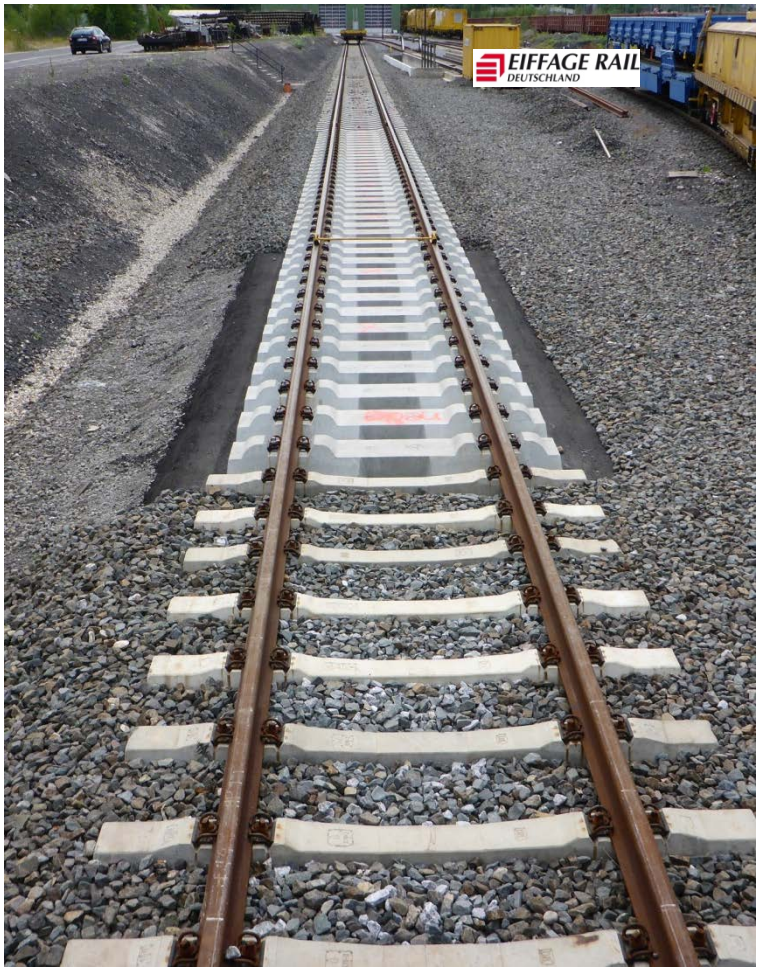




Preperation of testfield and sublayers

Layout of the sleeper configuration, tamping and dynamic stabilization

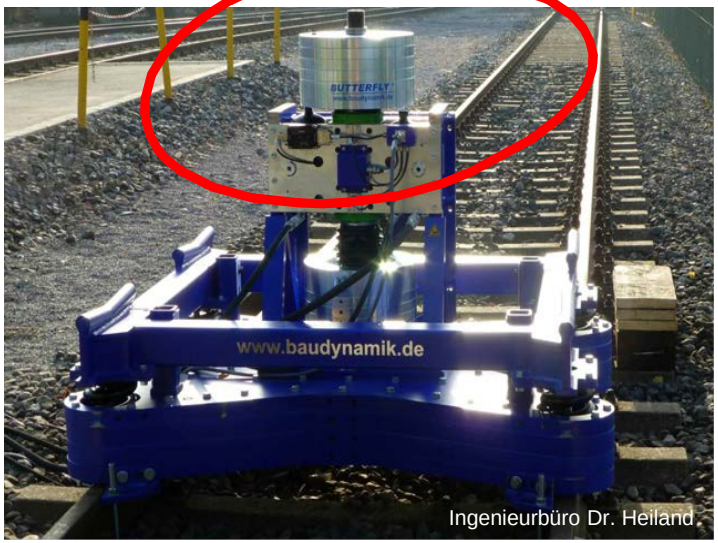
This test field alllows several investigation in 1:1 scale test



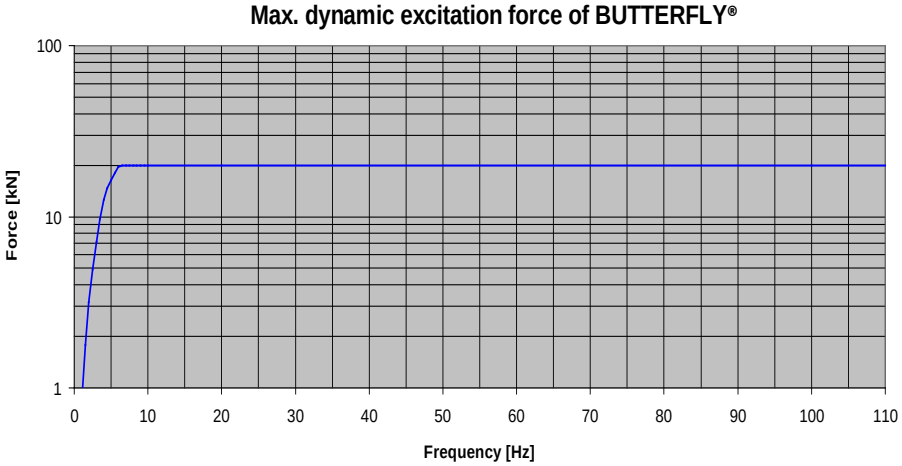
Tests

- 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

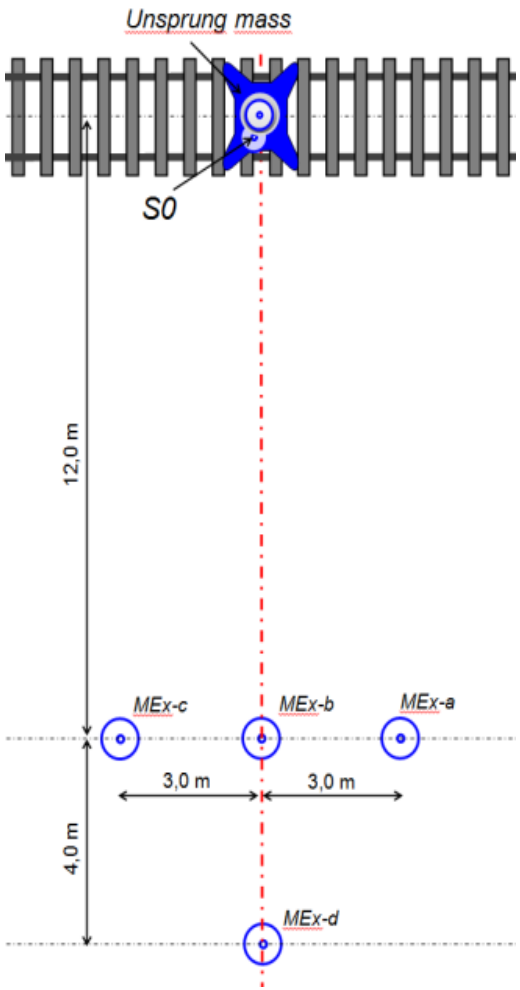


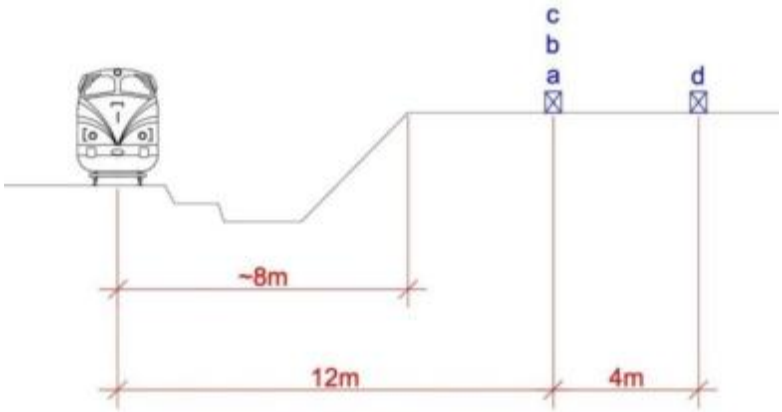
- ✓ Force / Amplitude / Velocity controlled
- ✓ High forces already in low frequency range
- ✓ clear line of force action
- ✓ Direct measurement of the force
- ✓ Mobile / demountable



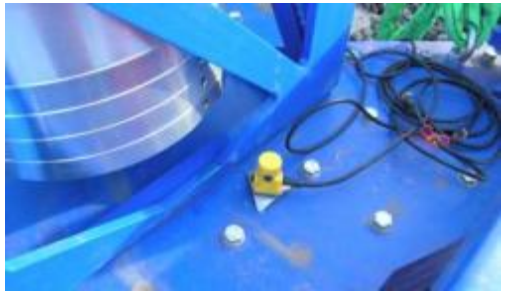
Dynamic force amplitude	7500 N
Excitation frequency	sweep 5 – 110 Hz
Unsprung mass	2,3 t steel foundation 0,35t shaker 400kg oscillating mass
Static load due to excavator weight	3 bucket positions (~ 300, 200, 5kN)
Measurement locations	3x 8 m-point 1x 16m-point 1x steel foundation

Measurement layout of the test-rig at Herne test-site (ER)



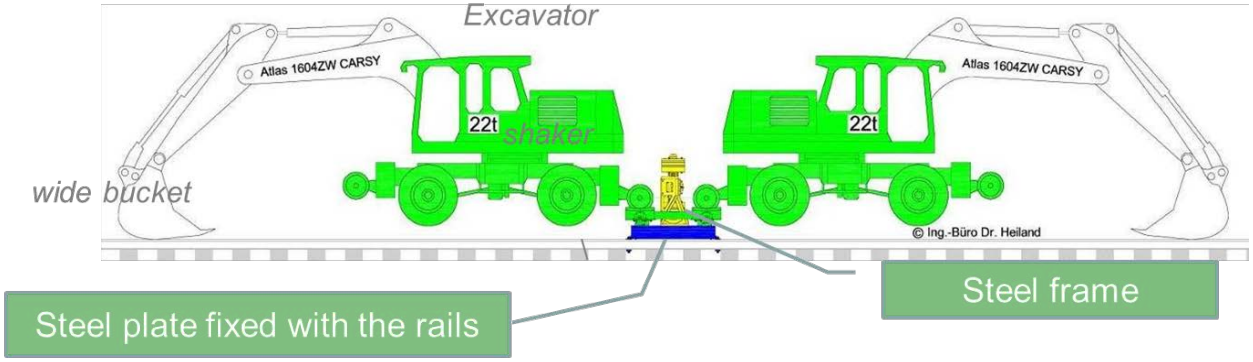


- one measuring point on the unsprung mass (steel foundation of the hydraulic shaker, coupled with the rails)

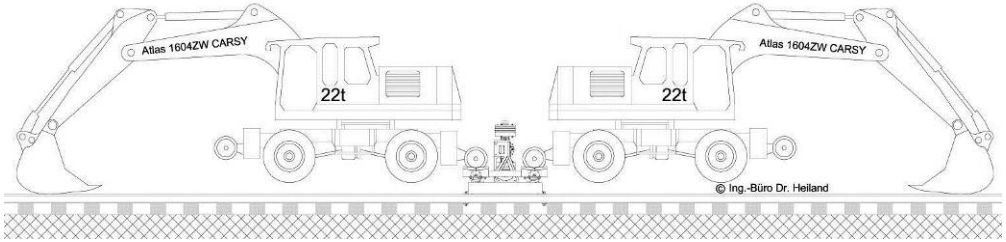
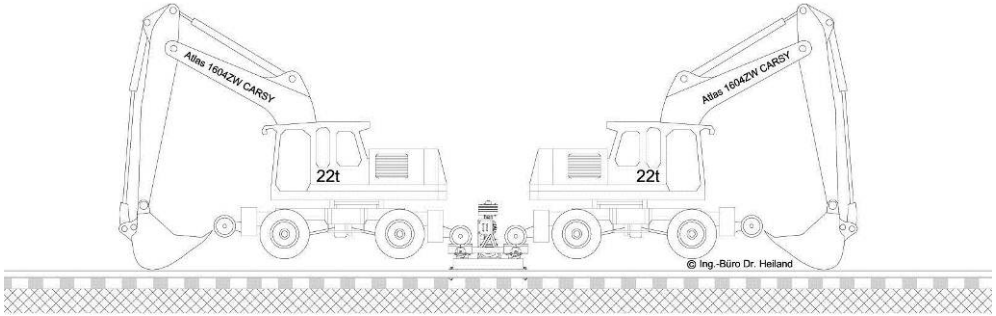
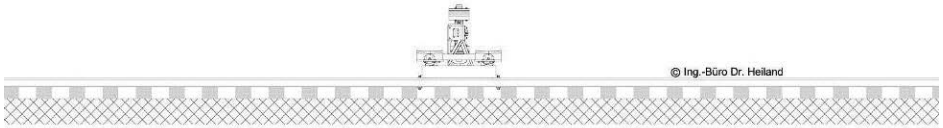


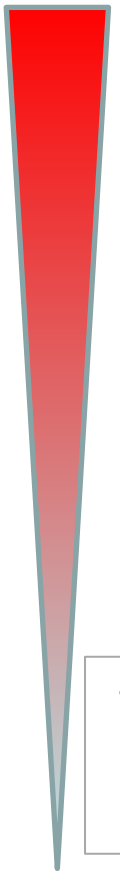
- three points at 12m distance
- one point at 16m distance from the center of the track

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

Load case or Position	**Bucket position**
LC1 ≈ 304 kN	
LC2 ≈ 221 kN	
LC3 (without excavators) ≈ 5 kN	

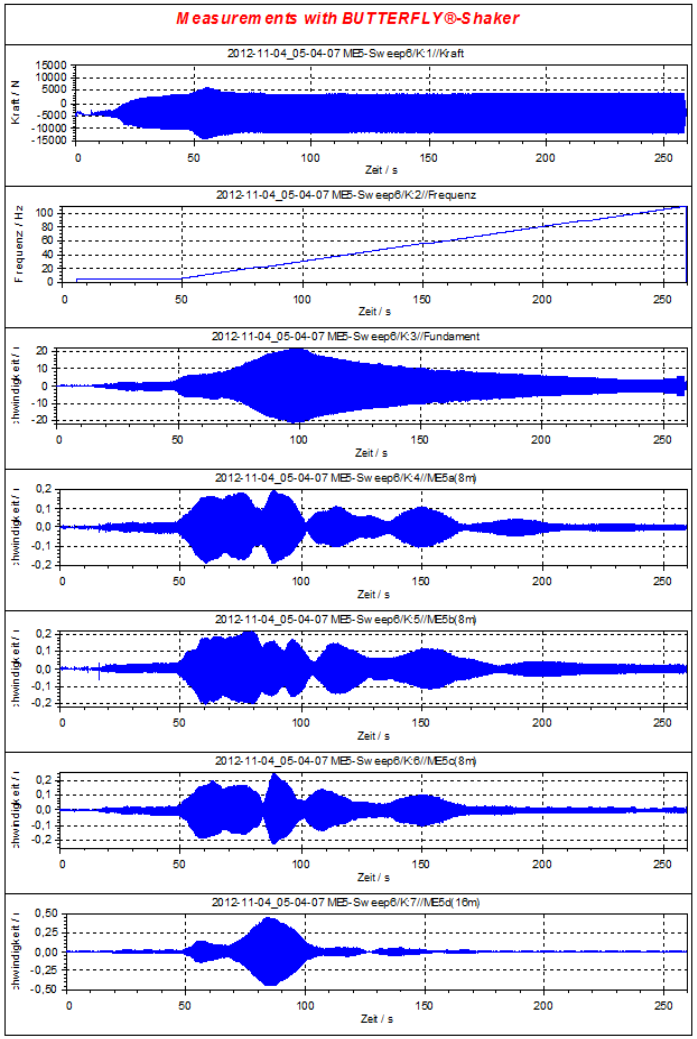


Max 320 kN

F_{sprung} = static load

The static load corresponds to the deflection of the springs

Example for time history of force, frequency and velocities of sensors



force

frequency

Velocity at fundation

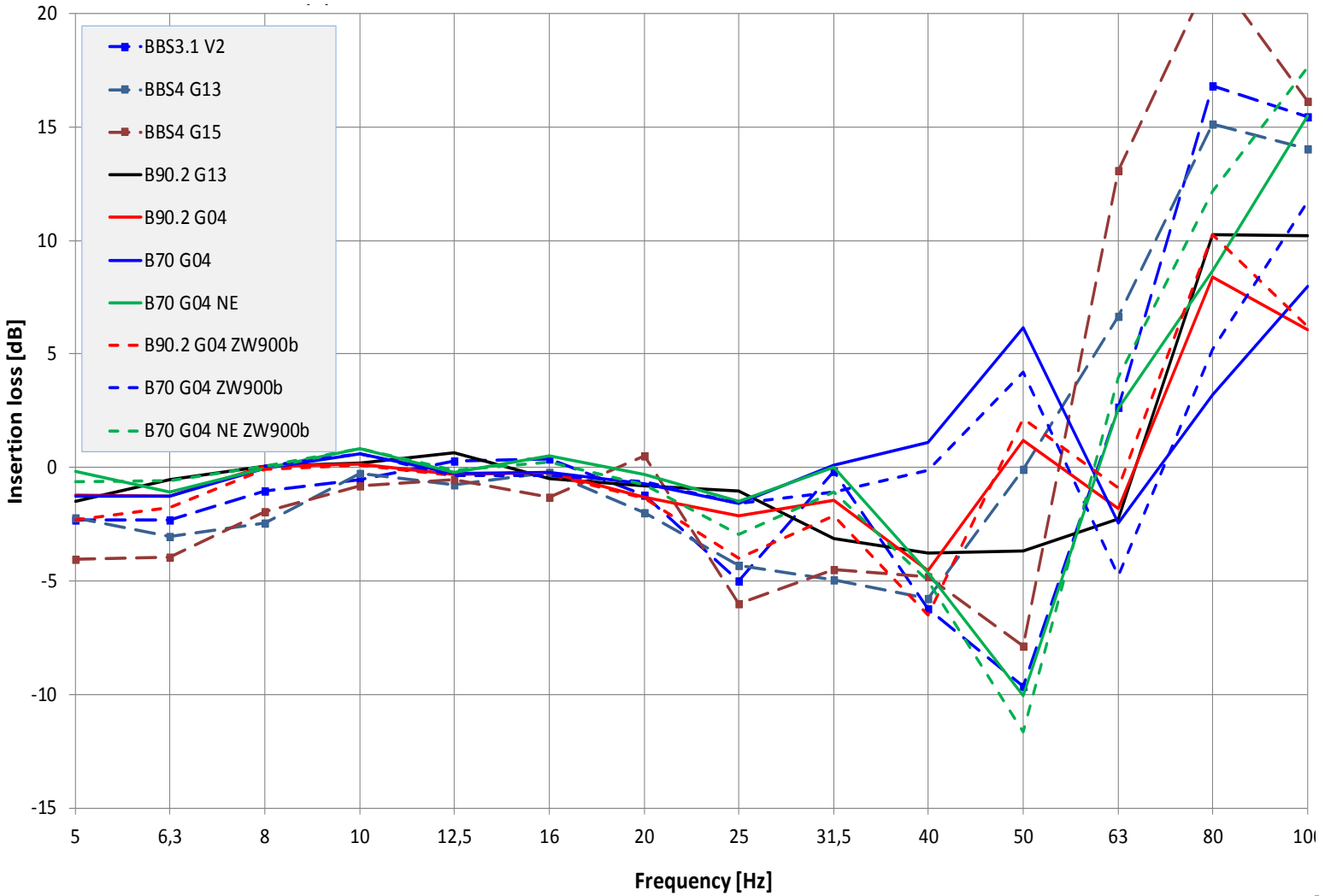
Velocity 8m, a

Velocitiy 8m, b

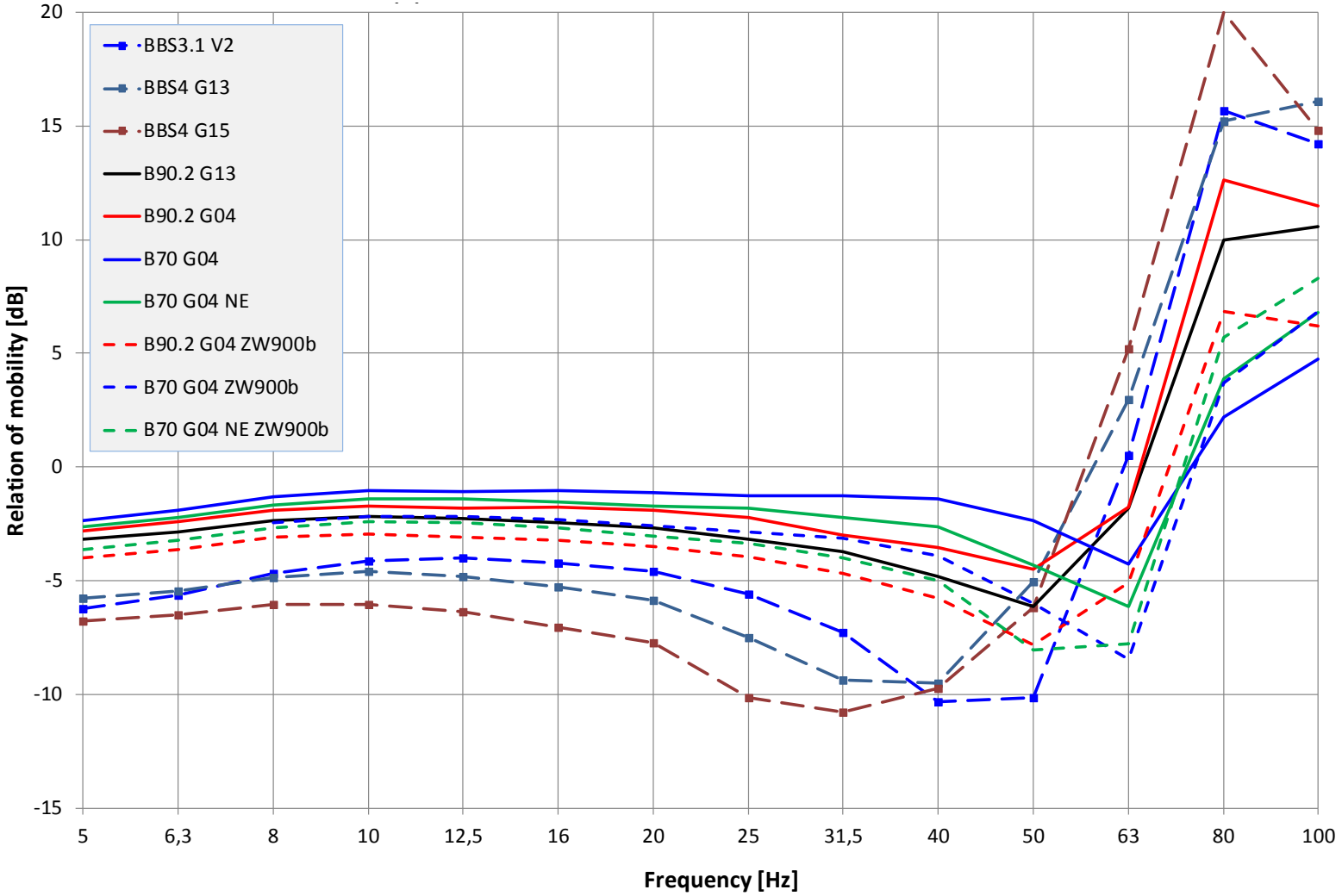
Velocity, 8m, c

Velocity, 16 m

The Insertion loss at Load Case 2 (LC2) for all investigated track systems



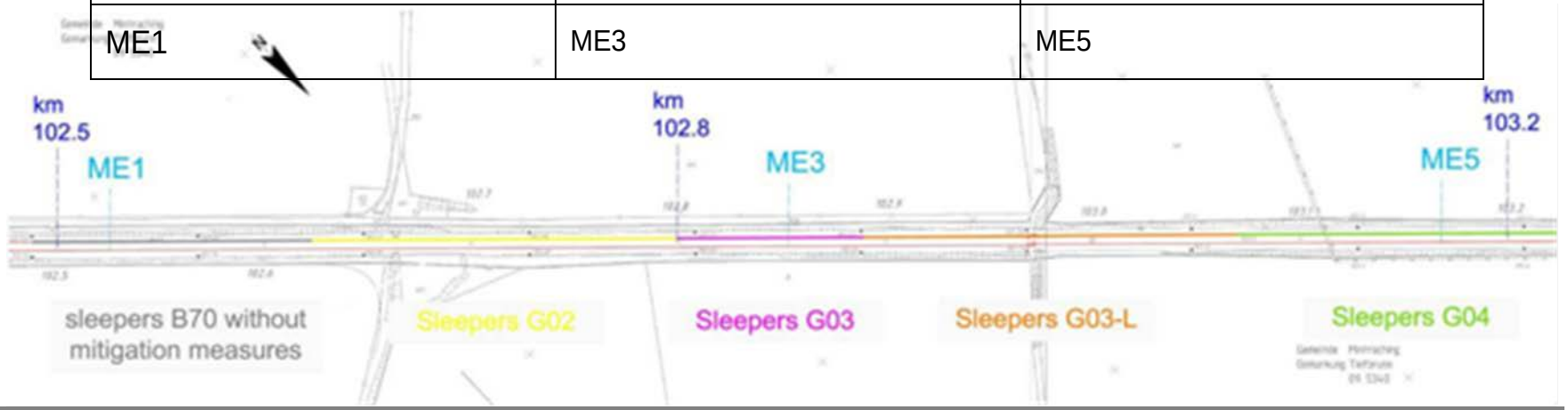
Relation of unsprung mass mobility at Load Case 2 (LC2) for all investigated track systems



To compare the IL with artificial source and with natural train excitation an existing track near Regensburg could be used

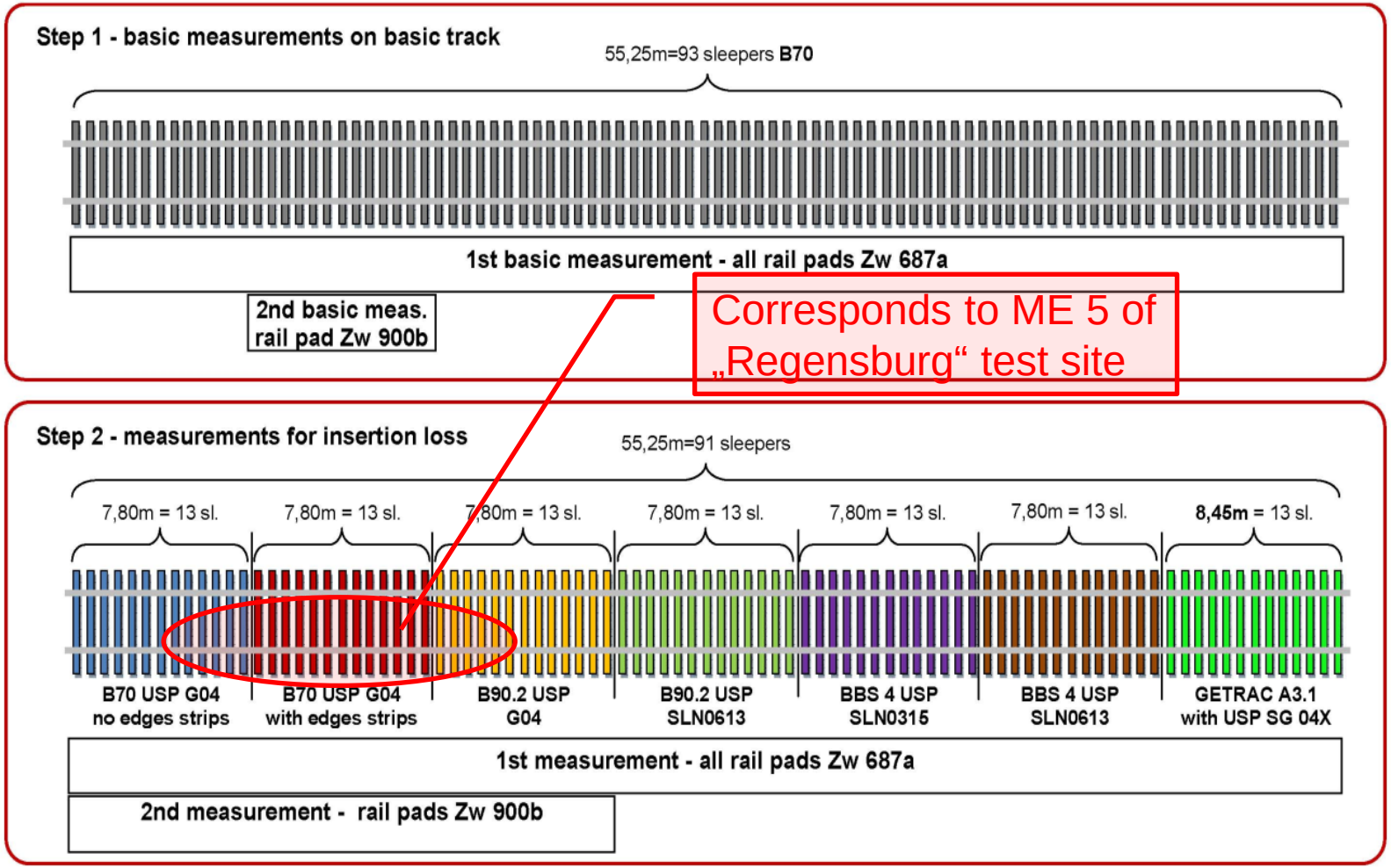
A track installation with several sections of track with USP served as reference site

		
ME1	ME3	ME5

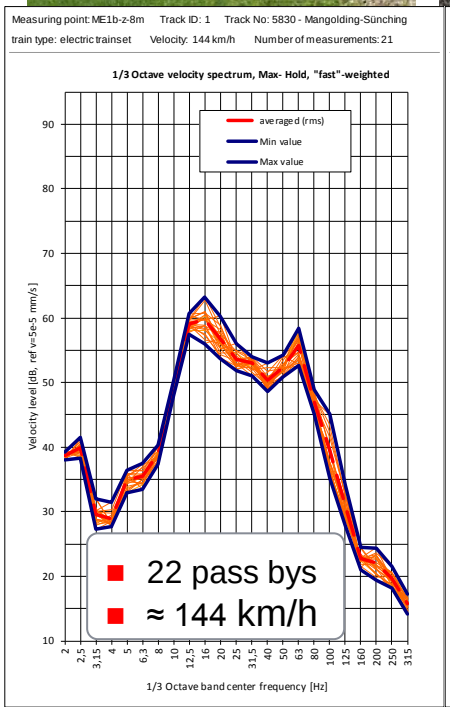


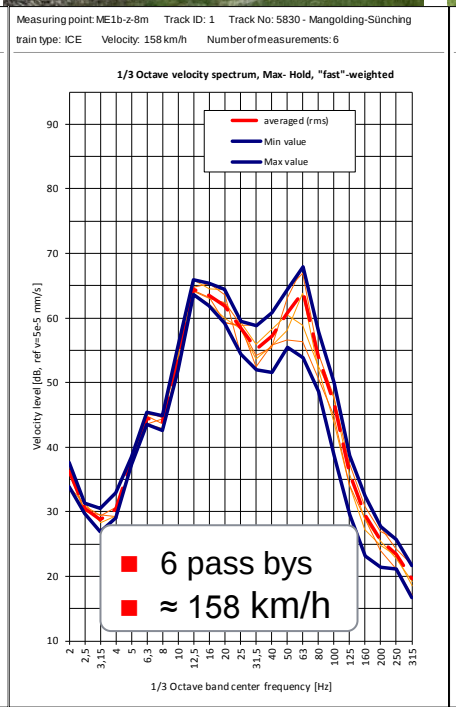
The reference section ME 1 and the section and ME 5 with USP have the identical track configuration as the track sections at the Eiffage Rail test rig

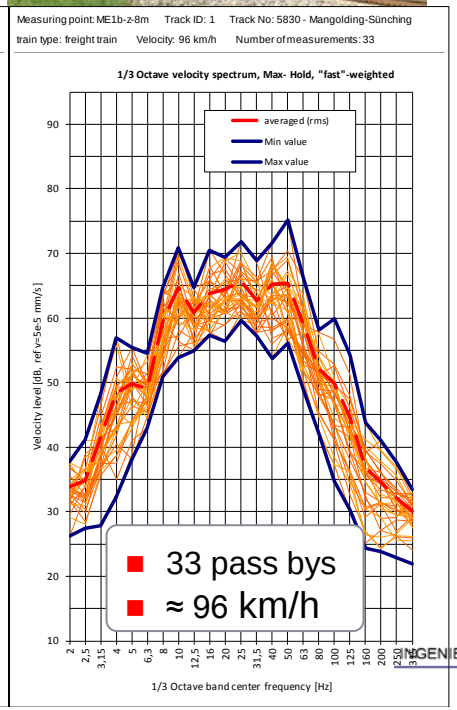
The reference situation and one of the track sections have the same configuration as the real track at Regensburg



Three different train categories could be investigated



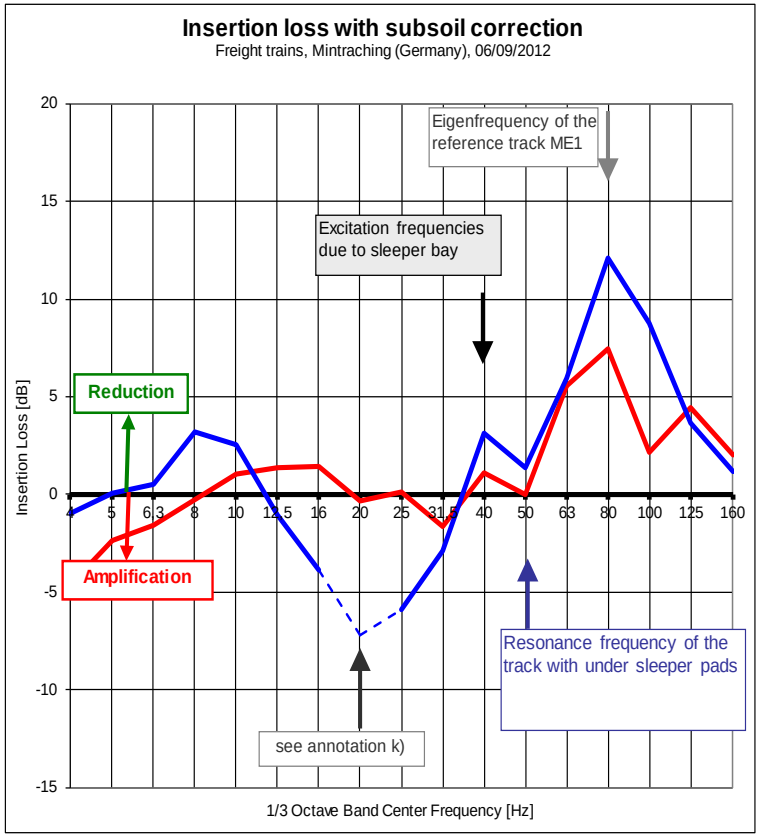




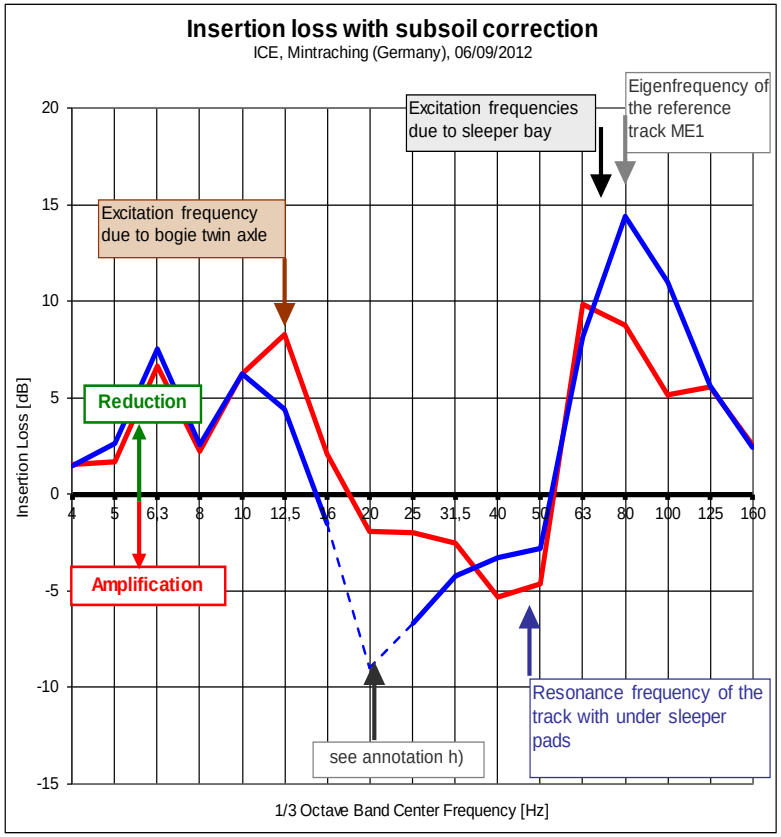
INGENIEURBÜRO DR. HEILAND

Insertion Loss of train pass by of freight trains compared to ICE trains

IL of train pass-bys (Freight trains)

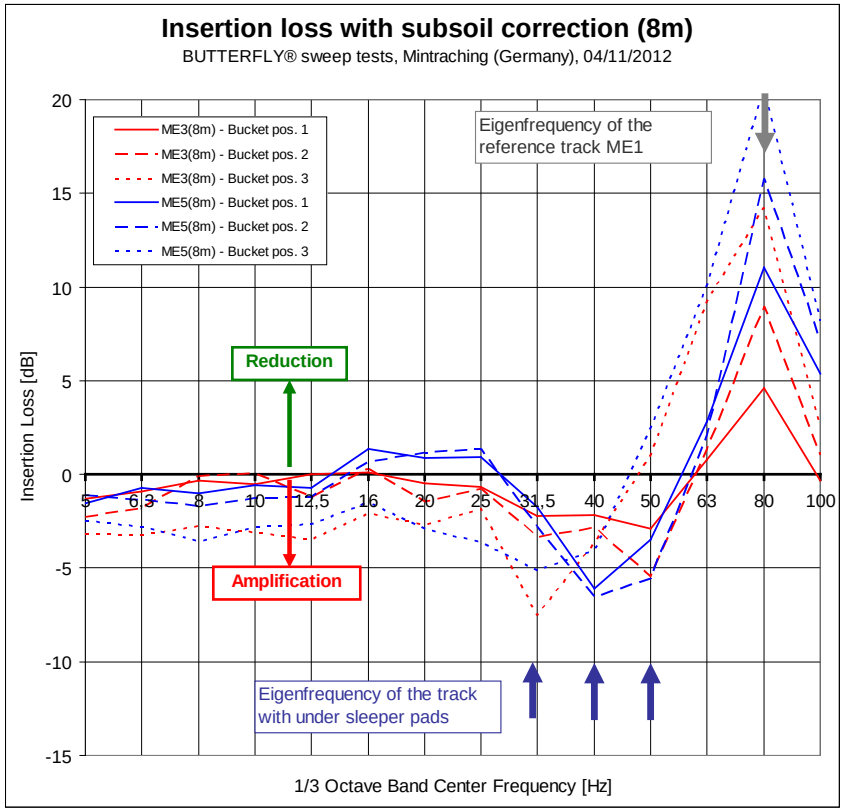


IL of train pass-bys (ICE Train-sets)

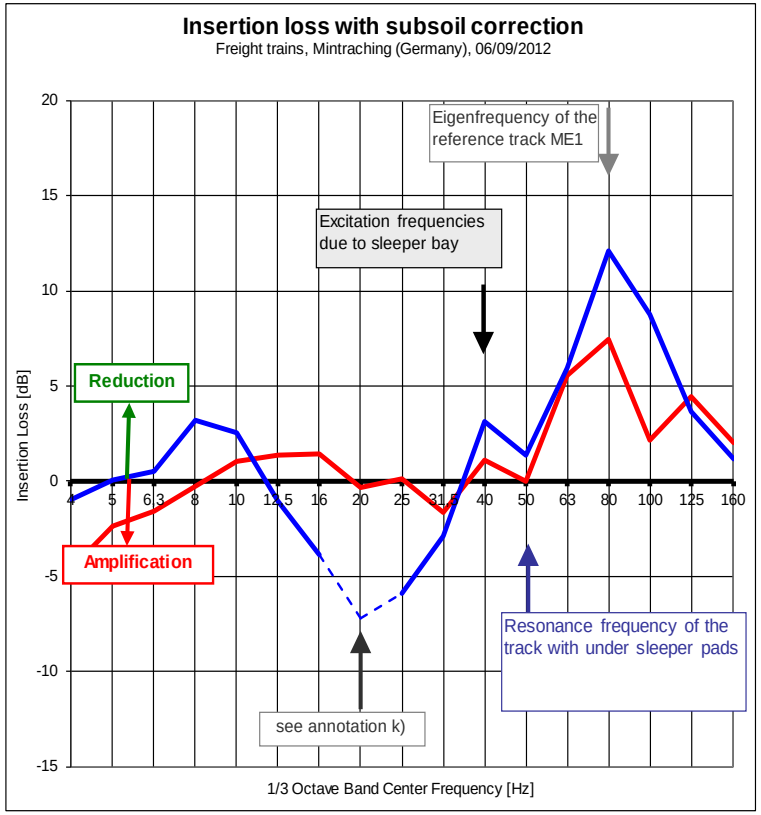


Insertion loss under artificial and natural train excitation (freight trains)

IL with BUTTERFLY® excitation and different load positions

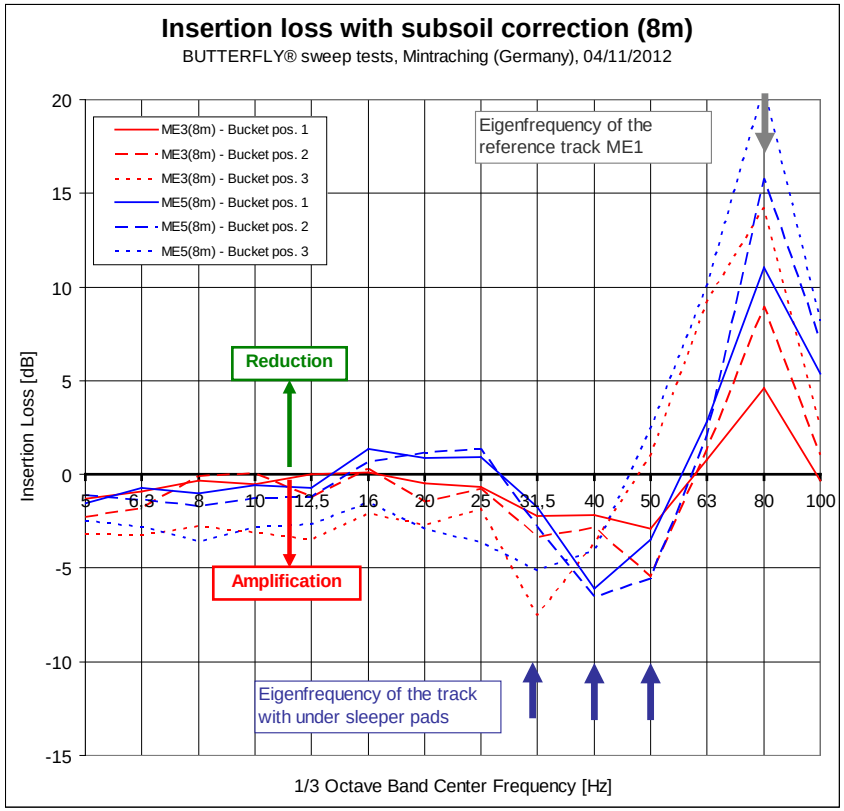


IL of train pass-bys (freight trains)

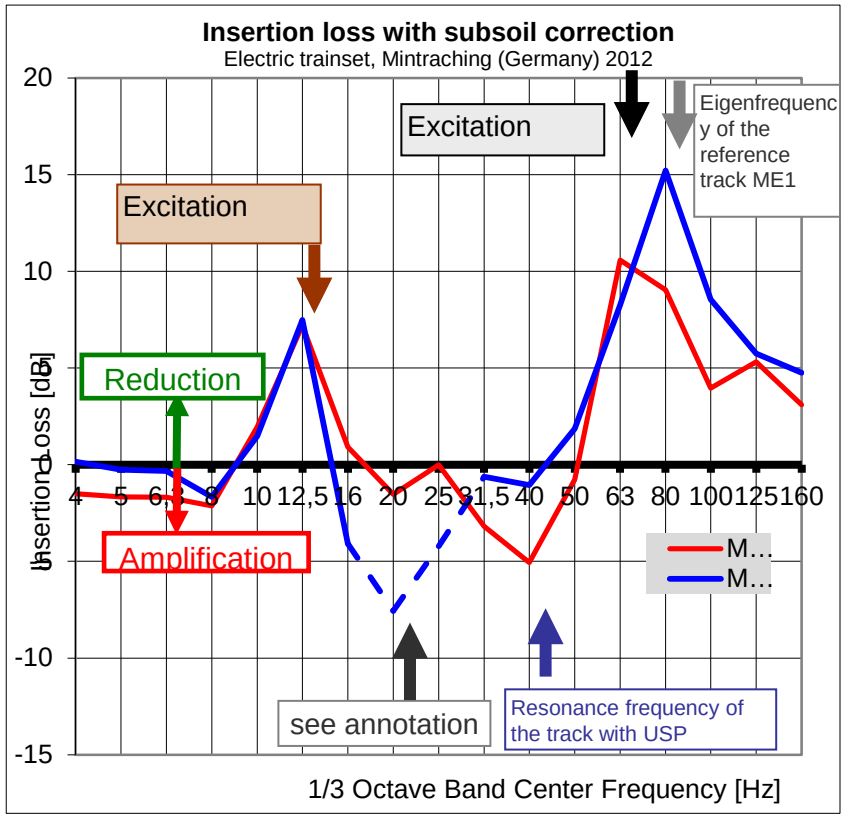


Insertion loss under artificial and natural train excitation (rail car)

IL with BUTTERFLY® excitation and different load positions

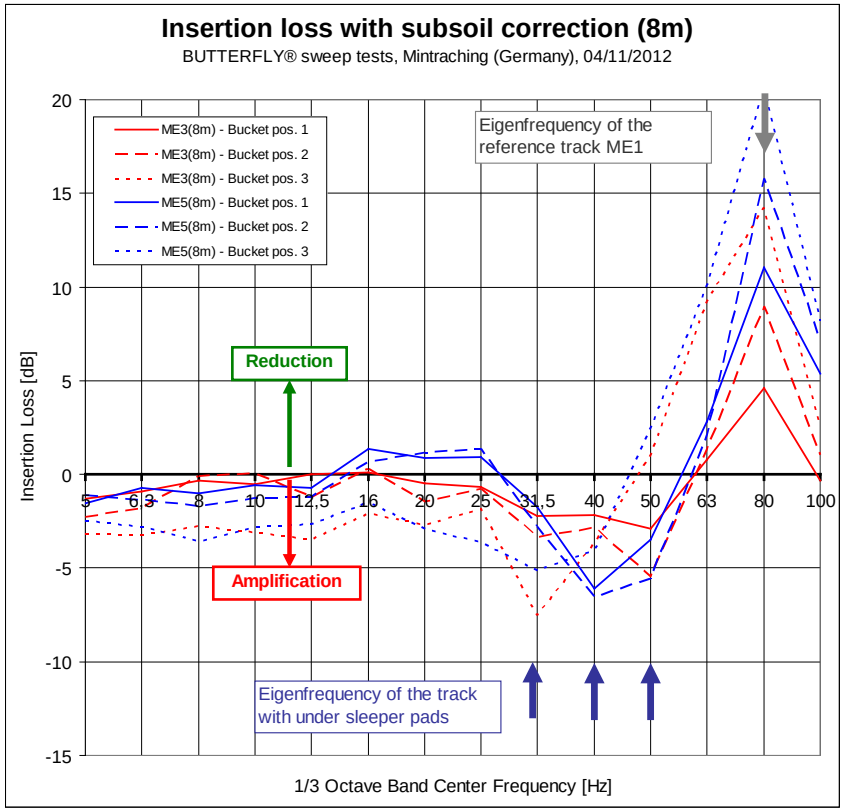


IL of train pass-bys (rail car with about 144 km/h)

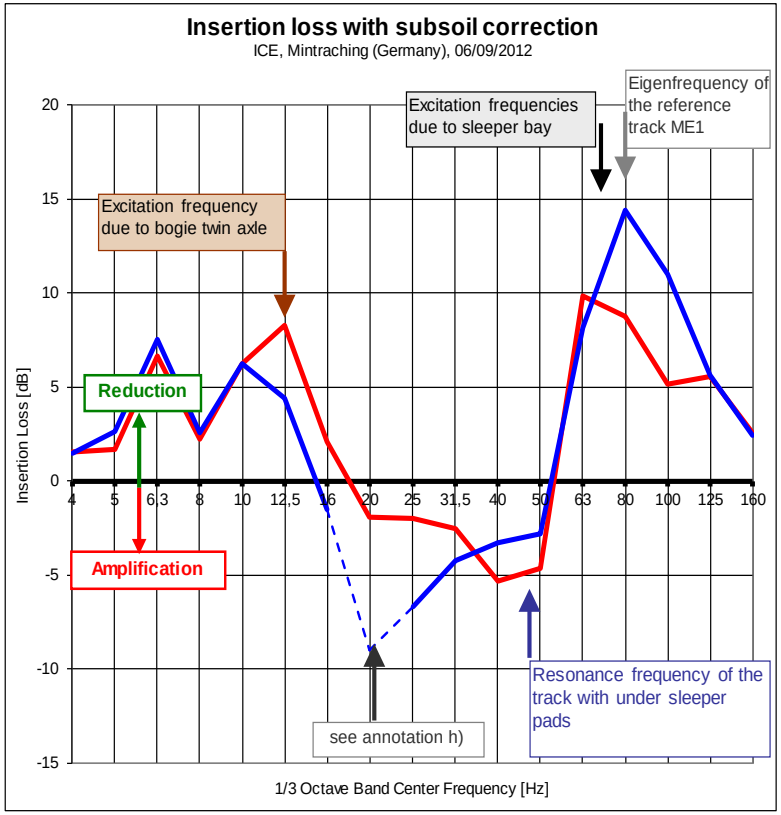


Insertion loss under artificial and natural train excitation (ICE Train-sets)

IL with BUTTERFLY® excitation and different load positions



IL of train pass-bys (ICE Trainsets)

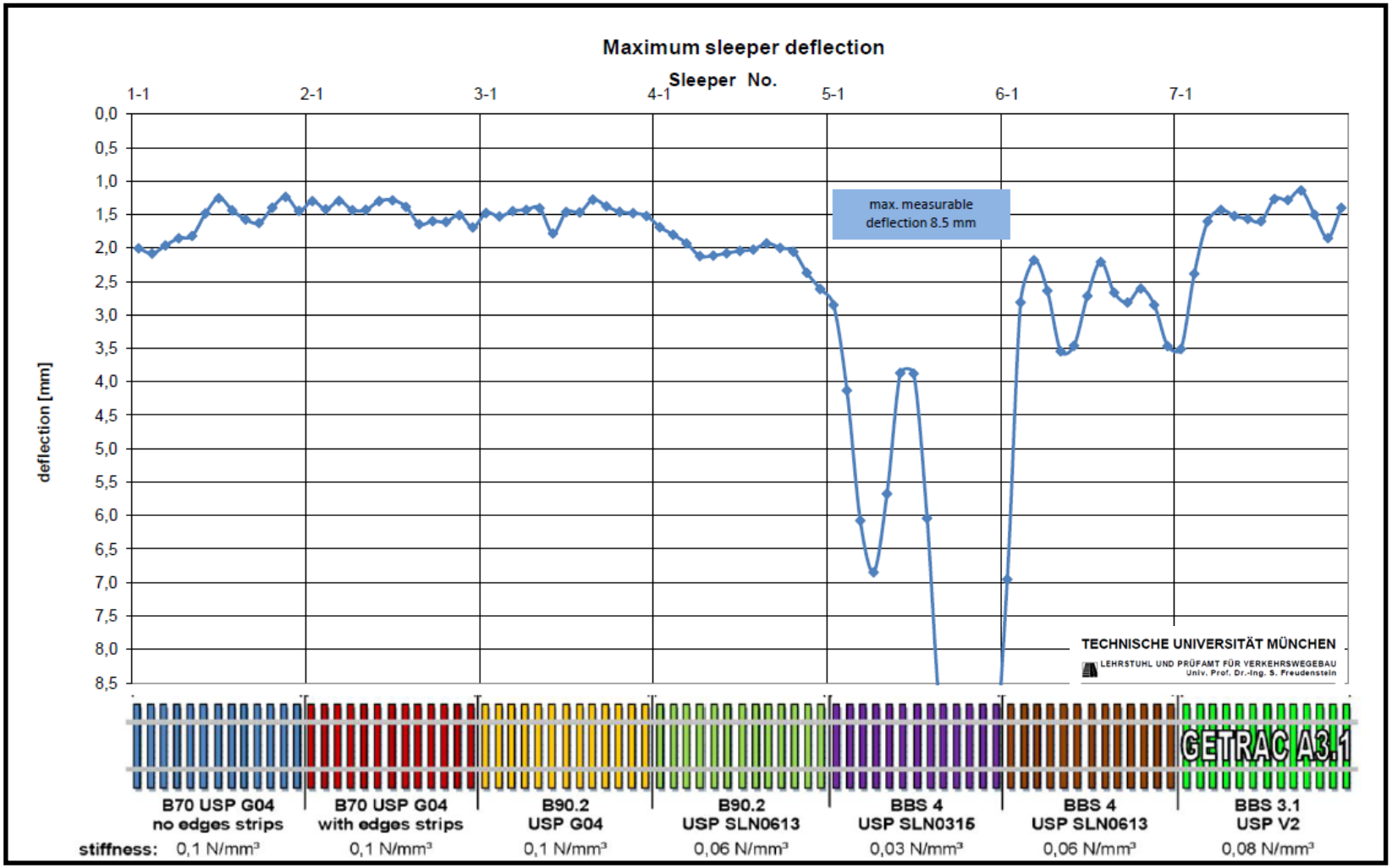


To improve the impact of USP on track-stability, the LTR was determined

#	Sleeper/USP type	Sec. ME	# of sleeper each section	Force @lateral displace-ment [kN]	Lateral track resistance w [N/mm]	Mean value w' [N/mm]	Stand. deviat. s [N/mm]	Remark
1	B70, no USP	-	-	4.9	8.2	8.1	0.4	Standard ballast track with B70
2	B70, no USP		-	4.6	7.6			
3	B70, no USP		-	5.2	8.6			
4	B70 G04 NE	17	2	6.2	10.3	11.1	0.6	
5	B70 G04 NE		5	6.6	10.9			
6	B70 G04 NE		9	7.0	11.6			
7	B70 G04 NE		12	7.0	11.7			
8	B70 G04	16	2	6.1	10.2	10.3	0.0	
9	B70 G04		5	6.2	10.3			
10	B70 G04		9	6.2	10.3			
11	B70 G04		12	6.4	10.7			
12	B90.2 G04	15	2	10.7	17.8	17.8	1.0	
13	B90.2 G04		5	11.3	18.9			
14	B90.2 G04		9	10.9	18.2			
15	B90.2 G04		12	9.8	16.3			
16	B90.2 G13	14	2	9.9	16.5	16.5	0.2	
17	B90.2 G13		5	10.1	16.8			
18	B90.2 G13		9	9.7	16.2			
19	BBS 4 G15	13	2	12.1	20.1	18.8	1.4	Numbers in brackets all values, others witho. single values (hang. Sleepers)
20	BBS 4 G15		5	7.2	(12.0)			
21	BBS 4 G15		9	10.4	17.4	(15.7)	(3.2)	
22	BBS 4 G15		12	7.9	(13.2)			
23	BBS 4 G13	12	2	14.2	23.6	23.2	2.1	Numbers in brackets all values; otherw. single values out of range not taken into account
24	BBS 4 G13		5	13.6	22.7			
25	BBS 4 G13		8	9,1	(15,2)	(18.3)	(5.1)	
26	BBS 4 G13		11	6,9	(11,5)			

All sections with USP show higher LTR (lateral track resistance) then the standard section without USP

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 refere to the project web-site for further information: 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