



Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Bundesamt für Umwelt BAFU

Bundesamt für Verkehr BAV

LÄRM
FORSCHUNG
EISEN
BAHN
EXCHANGE of
EXPERTS 2|'22

optimized soft rail pads

Dr. Christian Czolbe, Yves Kohler, PROSE AG



Optimized rail pads

- Research Project goals
- Process
- Requirements LCC / Noise (Advantages stiff / soft pads)
- Laboratory tests (low- / highfrequency)
- Homologation
- Field tests SOB / BLS
- Results





Project idea



- Development of **high damping rail pads**, which fulfil the technical requirements for infrastructure and reducing the railway noise.
- Noise reduction compared to tracks with soft rail pads **1 – 3 dB(A)**
- Individual shapes to apply to the relevant rail types in Switzerland (UIC60 und UIC54 profiles)





State of the art

Stat. Stiffness	≥ 700 kN/mm	ca. 100 kN/mm
range of spring	ca. 50 μm	ca. 350 μm
mounting rail/sleeper	strong fixing = higher mechanical damping	weak fixing = low mechanical damping
Plus	high rail damping = low rolling noise	low displacement of sleepers = low friction at the ballast, low wear
Minus	high displacement of sleepers = high friction at the ballast, higher wear	low rail damping = 3 dB higher rolling noise
temperature impact	low	high

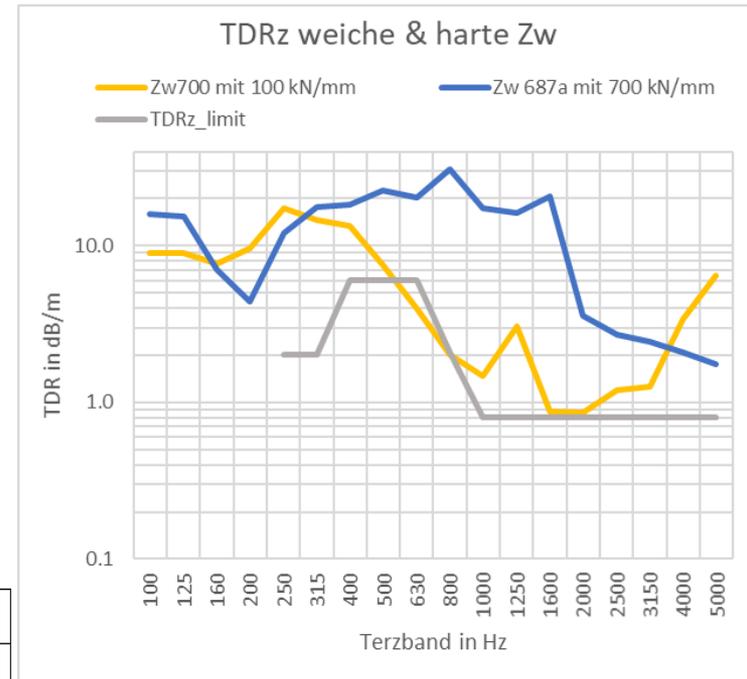




State of the Art

- Dynamic and static stiffness of rail pads
- Vibration damping and temperature behavior
- Laboratory tests according to EN 13146 standards
- Environmental stability behavior

source: PROSE test 2015 in Kerzers, BLS



MQ0: stiff Zw687a with 700 kN/mm
 MQ1: stiff Zw687a with 700 kN/mm
 MQ2: soft Zw700 with 100 kN/mm
 MQ0 to MQ1 adjacent sites within 120m of track

Zug-Art	Anz.	Mittelwerte [dB(A)]			Pegel-Differenz [dB(A)] (positive Werte: Pegelzunahme gegenüber MQ0)	
		MQ1	MQ0	MQ2	Differenz_1-0	Differenz_2-0
Lötschberger	14	75.3	75.1	78.7	0.2	3.6
EW3 mit Re420/Re465	15	79.7	79.8	82.1	-0.1	2.3
Güterzüge	1	84.5	84.2	87.2	0.3	3.0
Nina	1	75.7	75.9	78.7	-0.2	2.8

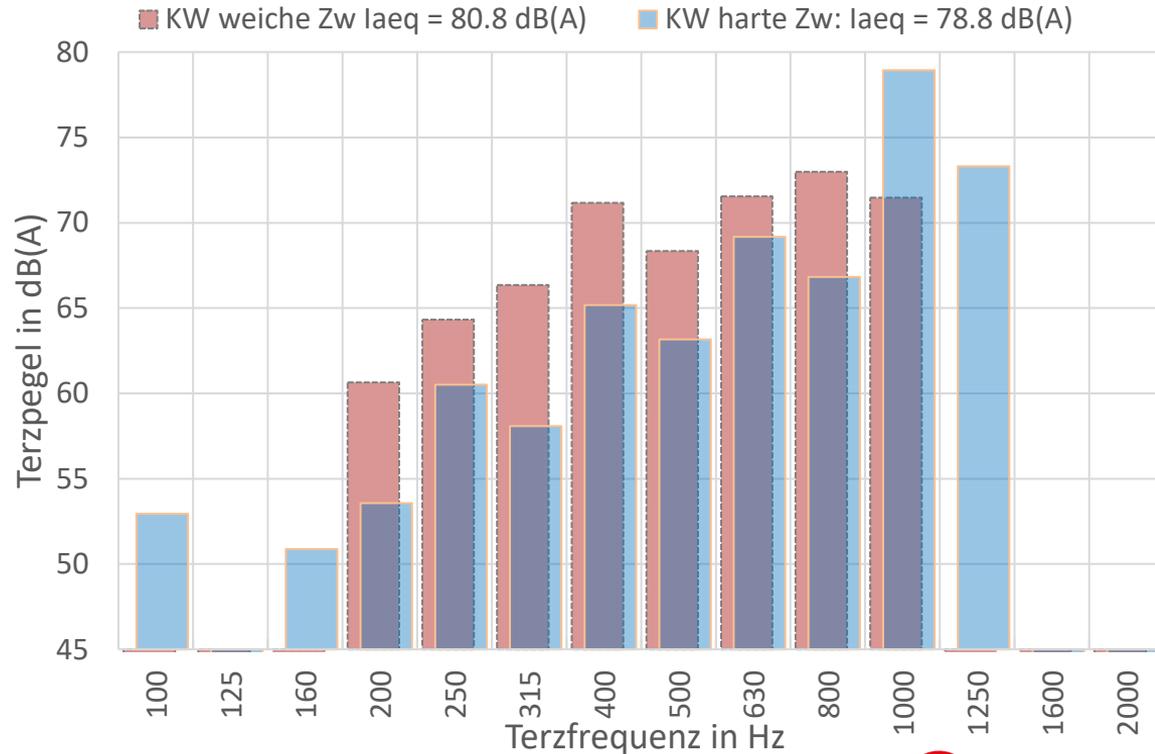


Preparing Investigations

Source separation

Rail noise measurements
at two test sites
tank cars at 80 km/h
November 2017 in Kerzers

Sound intensity measurements



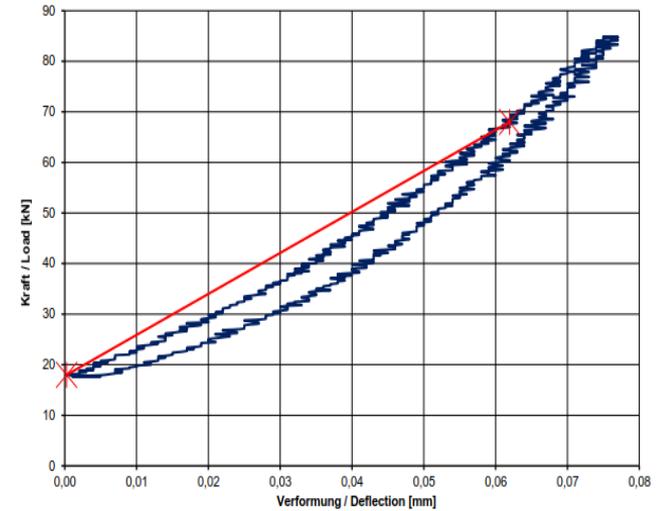


Material design

- Selection of Polymeres
- Material tests
- Parts testing

Laboratory tests:

- Technische Universität München
- Assessment of static stiffness
- Assessment of dynamic stiffness between 5 and 30 Hz
- Environmental conditions -10, 10, RT23 and 40 °C



Auswertung / Evaluation	
Auswertung zwischen Evaluation between	Verformungen Deflections
$F_{SP1} = 18,0 \text{ kN}$	$d_{pA1} = 0,00 \text{ mm}$
$F_{SP2} = 68,0 \text{ kN}$	$d_{pA2} = 0,06 \text{ mm}$
$k_{pA} = 810,7 \text{ kN/mm}$	





Material design

Temperatur dependance:

- Nominal stiffness at room temperature RT = 23°C
- Summer = high temperatures = softer
- Winter = low temperatures = stiffer

Frequency dependance:

- Nominal stiffness at static load
- On rising frequency stiffness increases too

Probe 5 was prototype of BATEGU, which has shown less dependent on temperature and frequency within the investigated specimen.

Ermittlung der Steifigkeit gemäß DIN EN 13146-9						
Temperatur	Proben Nr.	statisch/ [kN/mm]	dynamisch [kN/mm]			
			5 Hz	10 Hz	20 Hz	30 Hz
RT (23 °C)	1	810,7	970,7	1071	1143	1189
	2	88,0	96,0	97,0	96,7	*)
	3	83,4	91,2	92,7	95,1	*)
	4	110,1	118,5	119,3	120,7	128,6
	5	197,8	227,5	232,3	241,9	273,2
	6	242,5	363,1	372,5	416,4	423,5
-10 °C	1	822,4	996,8	1019	1059	1037
	2	98,2	106,2	109,2	116,2	133,6
	3	92,3	109,2	113,8	118,1	134,2
	4	118,2	109,0	148,7	153,1	163,6
	5	177,7	317,0	422,3	491,9	529,0
	6	401,8	628,1	713,0	780,7	781,2
+10 °C	1	777,5	747,4	776,4	839,2	823,8
	2	93,5	99,0	107,3	101,7	*)
	3	88,8	94,6	97,3	99,0	*)
	4	111,6	122,7	127,3	128,8	132,2
	5	178,3	227,5	247,7	258,1	275,0
	6	273,7	412,5	447,2	456,2	497,8
+40 °C	1	629,2	661,5	691,7	703,0	711,2
	2	89,7	96,8	97,2	98,1	*)
	3	81,3	87,7	89,5	90,1	*)
	4	101,7	111,5	111,4	113,5	*)
	5	179,6	219,7	224,1	238,5	242,4
	6	175,0	223,0	223,1	224,7	218,9

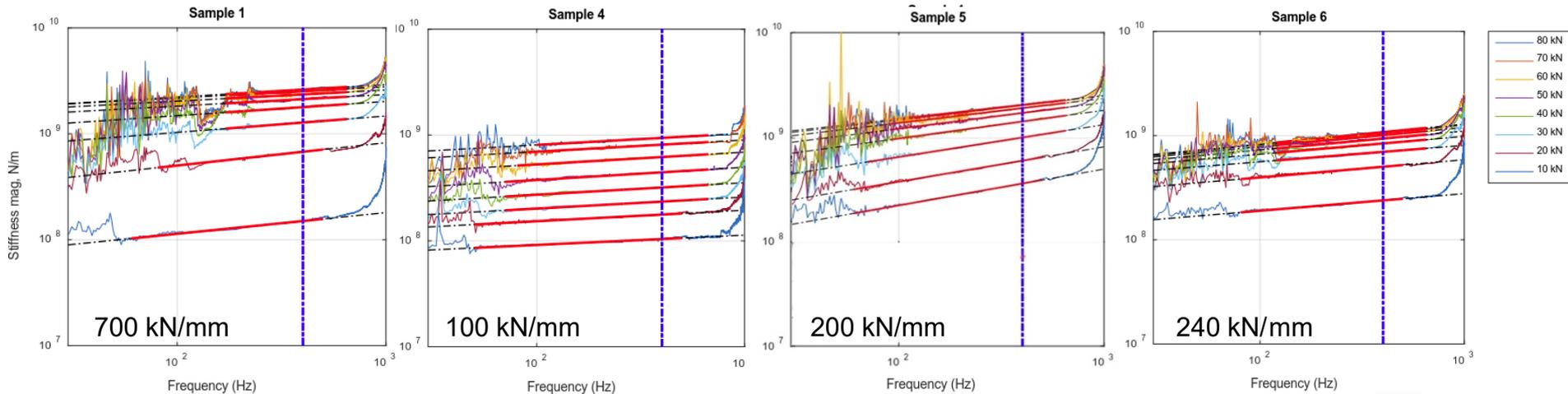
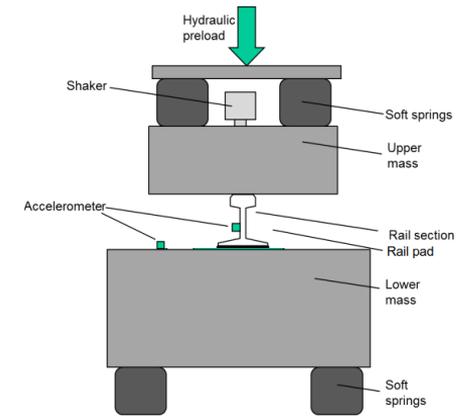




Material design

High frequency dynamic tests

- University Southampton UK
- Stiffness and loss factor between 50 and 1000 Hz
- Tests at different pre-loads 10 to 80 kN





Material design

High frequency dynamic stiffness and loss factors

Table 1 Effect of preload on pad stiffness (at 400 Hz), MN/m

	Pad 1	Pad 2	Pad 3	Pad 4	Pad 5	Pad 6
10 kN	150	135	113	104	370	239
20 kN	676	260	198	177	610	502
30 kN	1278	346	262	235	1012	697
40 kN	1787	437	363	319	1437	841
50 kN	2124	587	512	444	1733	936
60 kN	2354	735	688	619	1924	1010
70 kN	2522	908	878	811	2051	1063
80 kN	2617	991	985	939	2073	1081

Table 2 Figure 4 Effect of preload on the pad loss factors (at 400 Hz)

	Pad 1	Pad 2	Pad 3	Pad 4	Pad 5	Pad 6
10 kN	0.22	0.14	0.13	0.13	0.49	0.17
20 kN	0.15	0.12	0.12	0.12	0.45	0.15
30 kN	0.12	0.11	0.12	0.12	0.38	0.14
40 kN	0.10	0.11	0.11	0.11	0.31	0.13
50 kN	0.09	0.10	0.10	0.10	0.26	0.13
60 kN	0.08	0.09	0.09	0.09	0.24	0.13
70 kN	0.08	0.09	0.08	0.08	0.22	0.12
80 kN	0.07	0.08	0.07	0.07	0.21	0.12

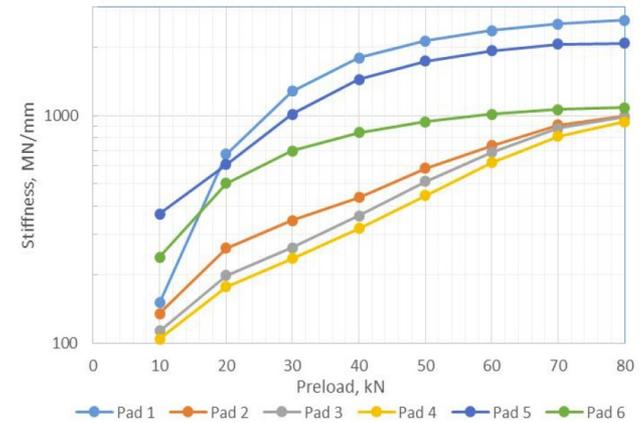


Figure 3 Effect of preload on pad stiffness (at 400 Hz), MN/m

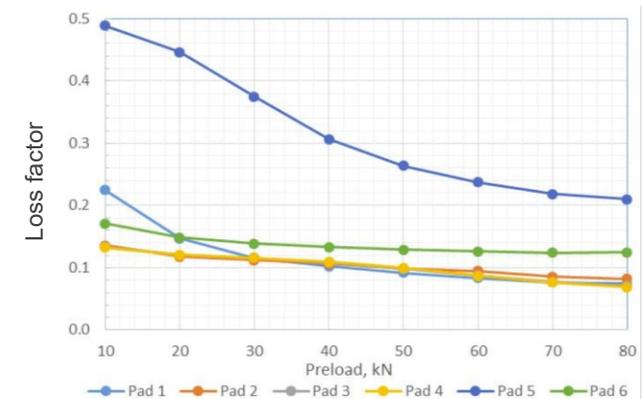


Figure 5 Effect of preload on the pad loss factors (at 400 Hz)





Material design

The material of **PROSE/BATEGU** rail pad shows a **very good sustainability, resistance against weather, UV rays and ozon.**

The following laboratory tests were carried out

- ISO 1431-1 Resistance to ozone cracking
- ISO 812 Determination of low-temperature brittleness
- ISO 132 Determination of flex cracking and crack growth (De Mattia)
- DIN 53508 artificial aging
- ISO 1817-1 Determination of the effect of liquids

DBS 918 235, Elastische Zwischenlagen und Zwischenplatten (Punkt 4.8.9 Alterungsbeständigkeit)

- The rail pad meets the requirements of „Railway Industry Substance List“ (RISL) of UNIFE, state of 08.02.2019





Material design

Conclusions

- At two laboratory tests the basic behavior, temperatur dependance and high-frequency dynamic properties was determined
- Main parameter to effect the rail noise is the TDR at tracks without vehicle load: 10-20 kN pre-load

Pad 5 (Prototyp BATEGU):

- Static stiffness is at 200 kN/mm
- Shows a good temperatur sustainability
- Shows at high frequency dynamic tests (airborne acoustic domain) about the highest loss factors compared to Zw687a of factor 4





Effect evaluation

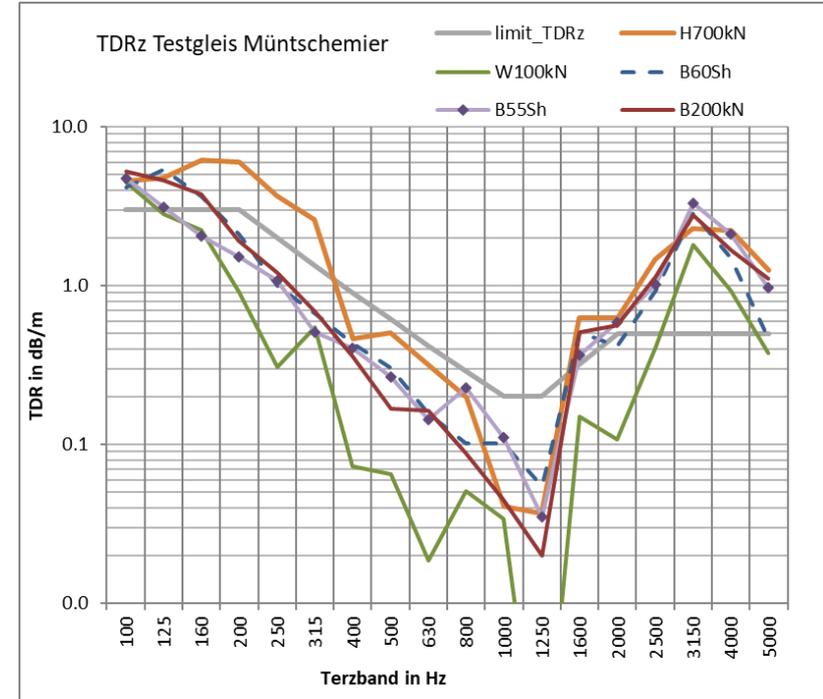
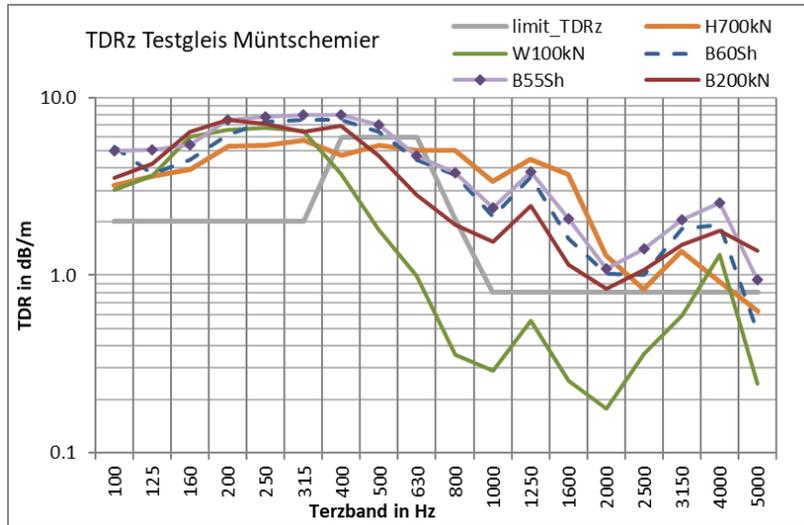
- TDR tests on the test rig in Müntschemier 12-2018
- Reference: **ZW687a-stiff** and **Zw700-soft** rail pads
- Straight track BLS Kerzers - Ins
- Curved track SOB Wollerau

Test rig provides:
Safe test environment
TDR comparison





Effect evaluation





Effect evaluation

Ri	Terz	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	
	limit TL	2.0	2.0	2.0	2.0	2.0	2.0	6.0	6.0	6.0	2.1	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Z	WL	4.8	4.5	5.9	6.5	6.3	6.2	4.4	2.2	1.5	0.8	1.0	0.3	0.2	0.0	0.1	0.1	0.9	0.5	
Z	B60L	5.6	4.0	4.5	6.6	7.8	7.8	7.7	6.6	4.5	3.7	2.1	3.6	1.8	1.1	1.1	1.8	1.9	0.5	
Z	WR	3.0	3.5	6.1	6.6	6.8	6.6	3.8	1.8	1.0	0.4	0.3	0.6	0.3	0.2	0.4	0.6	1.3	0.2	
Z	B55R	4.5	4.2	4.9	6.7	7.7	8.0	8.0	7.0	4.6	3.7	1.7	3.2	2.2	1.2	1.2	1.7	1.9	0.3	
Z	HL	4.7	3.8	4.6	6.4	6.3	6.0	5.4	5.2	5.5	5.2	3.8	4.0	3.5	2.3	0.9	1.5	0.7	0.6	
	limit TL	3.0	3.0	3.0	3.0	2.0	1.4	0.9	0.6	0.4	0.3	0.2	0.2	0.3	0.5	0.5	0.5	0.5	0.5	
Y	WL	3.1	4.7	2.8	1.4	0.9	0.1	0.2	0.3	0.1	0.3	0.2	0.2	0.3	0.2	0.3	1.5	0.9	0.6	
Y	B60L	4.0	5.3	3.8	2.1	1.5	0.5	0.5	0.7	0.1	0.2	0.1	0.1	0.4	0.6	1.3	2.9	1.5	0.5	
Y	WR	4.8	2.9	2.3	0.9	0.3	0.5	0.1	0.1	0.1	0.2	0.0	0.1	0.2	0.2	0.2	1.8	0.9	0.4	
Y	B55R	4.8	3.3	2.1	1.5	1.1	0.5	0.4	0.3	0.1	0.2	0.1	0.0	0.4	0.6	1.0	2.8	1.4	0.8	
Y	HL	3.6	4.6	5.0	5.4	5.3	3.9	1.6	1.1	0.8	0.6	0.3	0.1	0.6	1.1	1.1	1.1	2.9	0.9	





Effect evaluation

Fatigue resistance of the **BATEGU rail pad** (UIC54 und UIC60) has been successfully tested according to EN 13481-2 at accredited laboratories

The tests include the static stiffness of the fastening system, longitudinal rail push-pull-resistance, torque resistance, rail fixing force and one long term vibration test with 3 Mio. loads. All test results with prototype **BATEGU rail pads** regarding the long term tests are within the requirements of the related standard.

The **BATEGU/PROSE rail pad** has passed the tests required to components in the «rail fastening system» and can be applied in the track.





Rail pads on the track

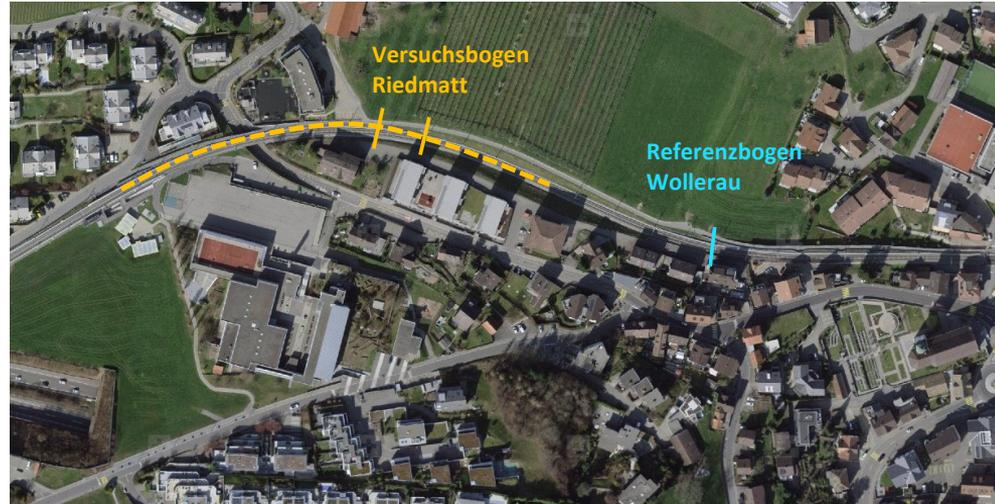




Field Tests SOB in Wollerau

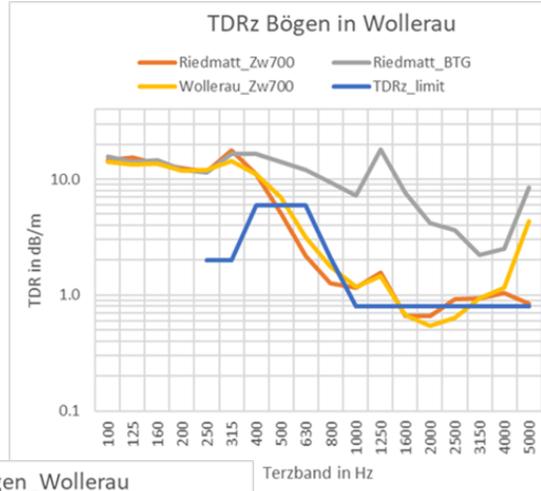
BATEGU on UIC54 rails at curves

- Installation on 200m track
- Microphones placed on both track sides
- in 7.5m distance acc. ISO 3095
- in 3.0m distance
- Pre-Test 4.10.2019
- Effect-Test 31.10.2019
- Control-Test TDR / RR April 2021

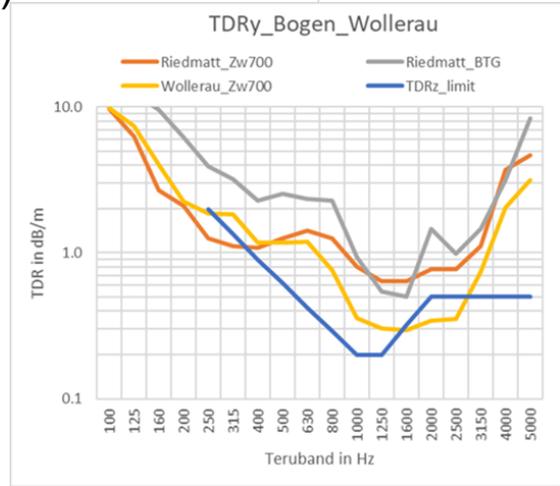


Field Tests SOB in Wollerau

- **Pass-by level @60 km/h LpAeq,T**
- Sound level reduction in curve **BATEGU** acc. to ISO 3095 microphone positions: **5 dB**
- Pass-by level **BATEGU** curved track ~ 76 dB(A)

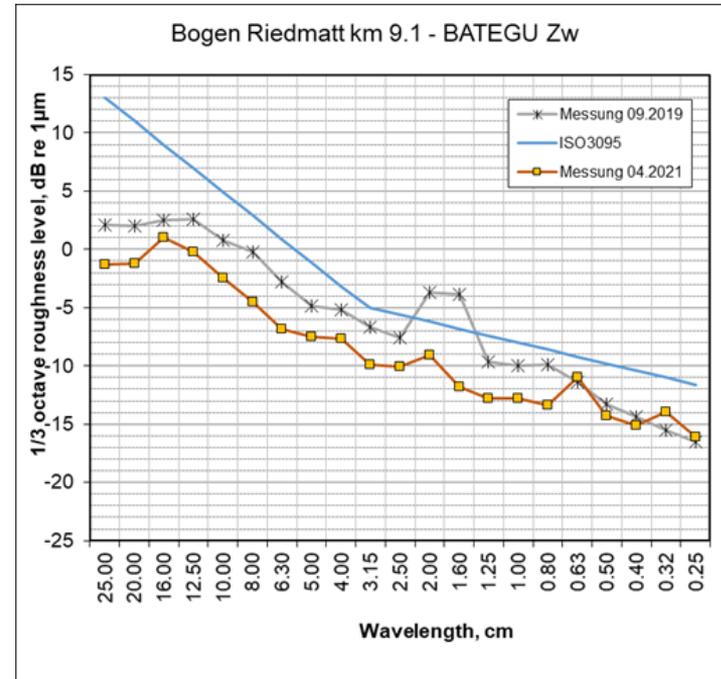
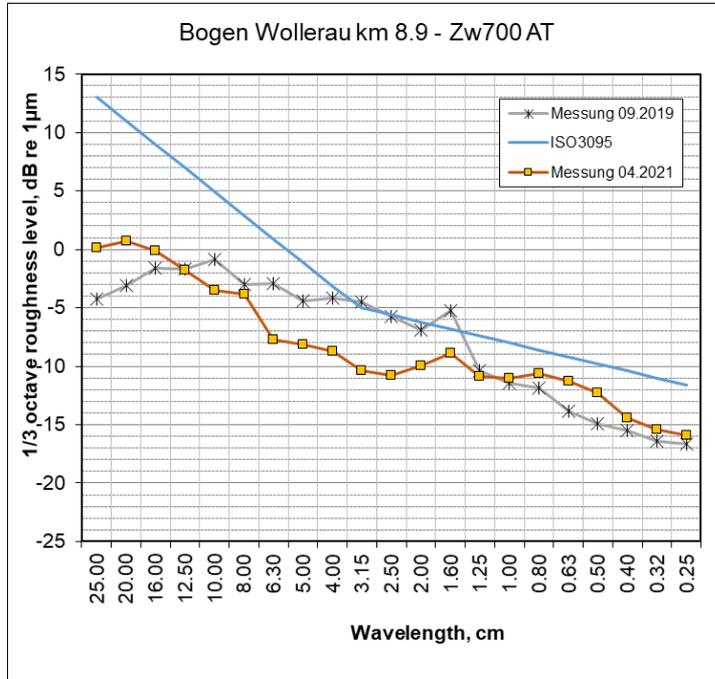


		Vorbeifahrpegel LpAeq,Tp			
		Versuchsbogen		Vergleichsbogen	
		Riedmatt		Wollerau	
		7.5m	7.5m	7.5m	
		M1a	M4i	Mittel	
Zugart	Abschnitt	n	dB(A)	dB(A)	dB(A)
Flirt 4T	Zw700A T vor	6	79.3	82.8	Zw700A T 87.2
Flirt 8T	Zw700A T vor	3	80.0	83.3	Zw700A T 84.2
Flirt 4T	Bategu nach	6	74.9	77.7	Zw700A T 86.7
Flirt 8T	Bategu nach	3	75.2	78.0	Zw700A T 83.9
Flirt 4T	nach-vor		-4.4	-5.1	-0.6
Flirt 8T	nach-vor		-4.8	-5.3	-0.4



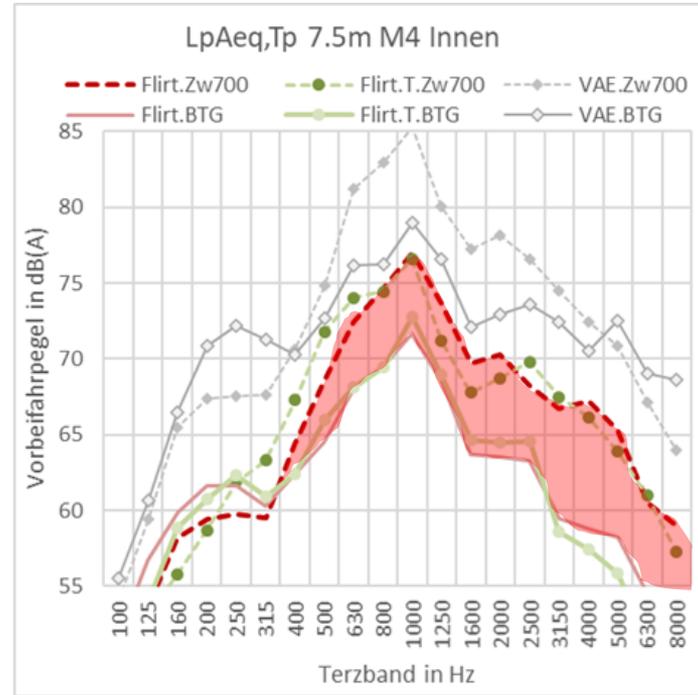
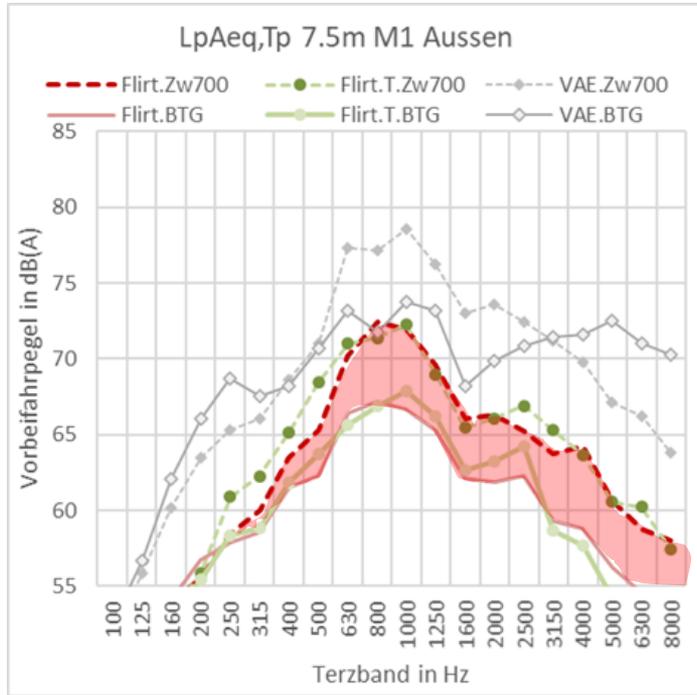
Field Tests SOB in Wollerau

rail roughness development



Field Tests SOB in Wollerau

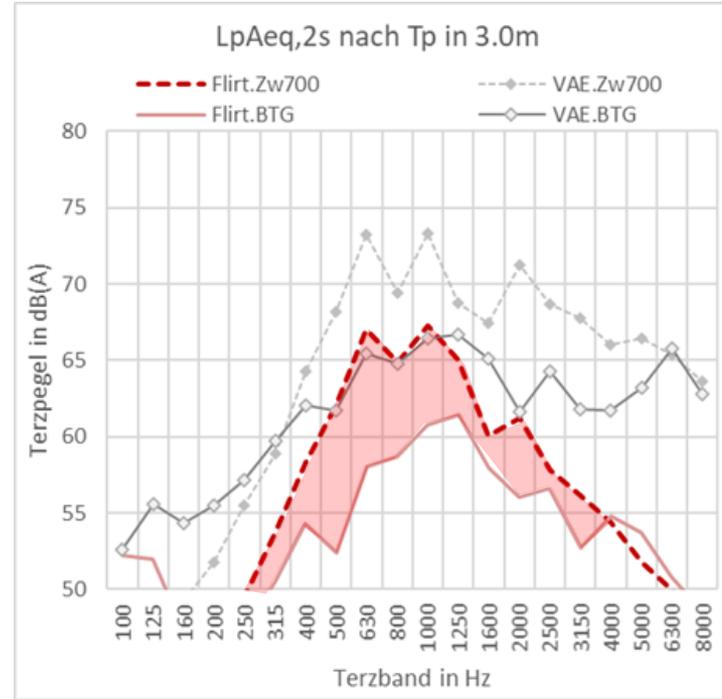
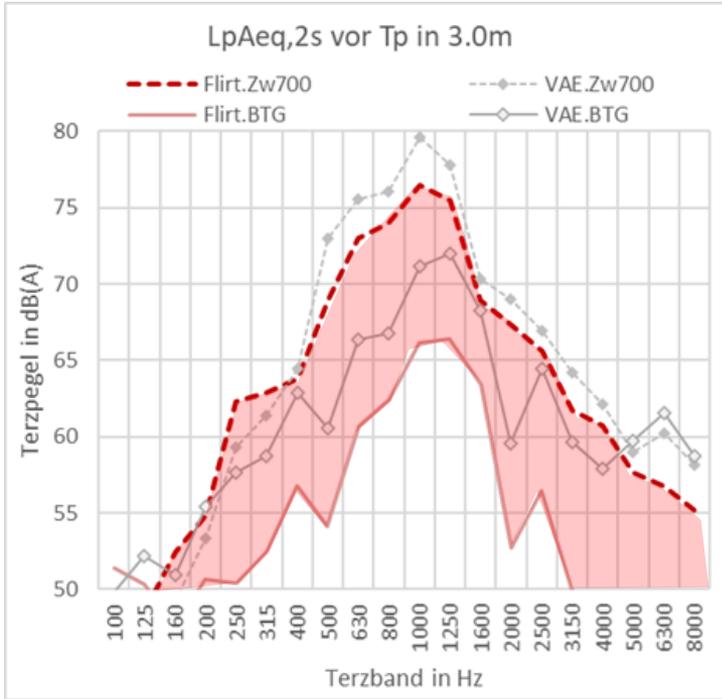
Pass-by level at 7.5m distance to the track center





Field Tests SOB

rail noise before and after pass-by



Field Tests BLS in Kerzers

Single track

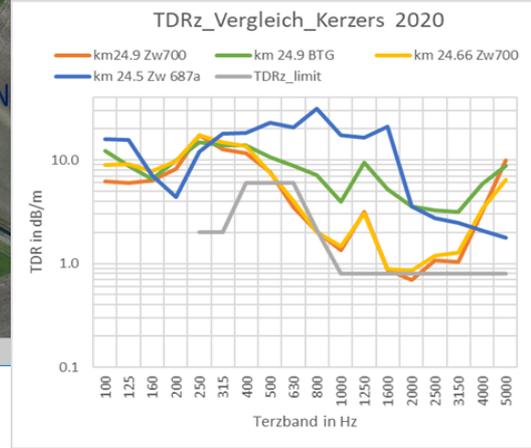
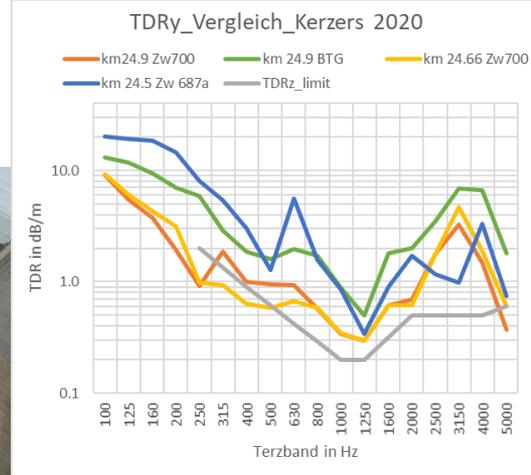
Tests acc. to ISO 3095

Pre-Test 12.2019

Effect-Test 03.2020

Effect-Test 06.2020

C-Test TDR / RR 02.2021





Field Tests BLS in Kerzers sound level

before – after
installation of
rail pads

		pass-by level	km 24.9			km 24.66			km 24.5		
		Temperatur 10 °C	Zw700, soft			Zw700 soft			Zw687a hard		
			LpAeq, Tp 7.5m			LpAeq, Tp 7.5m			LpAeq, Tp 7.5m		
			South	North	Median	South	North	Median	South	North	Median
Date	n		dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)
12_2019	6	EWIII 120 km/h	82.4	82.0	82.2	82.4	82.2	82.3	81.2	81.0	81.1
12_2019	6	Nina 3T 120 km/h	79.2	79.7	79.5	79.3	80.3	79.8	78.9	79.5	79.2
			Umbau Zw BATEGU			Zw700 weich			Zw687a hart		
03_2020	6	EWIII 120 km/h	79.3	79.6	79.4	82.0	82.8	82.4	80.2	80.9	80.6
03_2020	6	Nina 3T 120 km/h	77.6	77.5	77.5	80.7	81.3	81.0	78.6	79.2	78.9
		Differenz EWIII	-3.1	-2.5	-2.8	-0.4	0.6	0.1	-1.0	0.0	-0.5
		Differenz Nina 3T	-1.6	-2.3	-2.0	1.4	1.0	1.2	-0.3	-0.3	-0.3

track1 – track2
Parallel operation

6	Differenz EWIII	-2.7	-3.2	-3.0				-1.9	-1.8	-1.9
6	Differenz Nina 3T	-3.1	-3.9	-3.5				-2.1	-2.1	-2.1

Noise Reduction = $(L_{\text{Test, before}} - L_{\text{Ref., before}}) - (L_{\text{Test, after}} - L_{\text{Ref., after}})$ according to DB AG

6	Differenz EWIII	2.8	3.1	2.9
6	Differenz Nina 3T	3.1	3.3	3.2



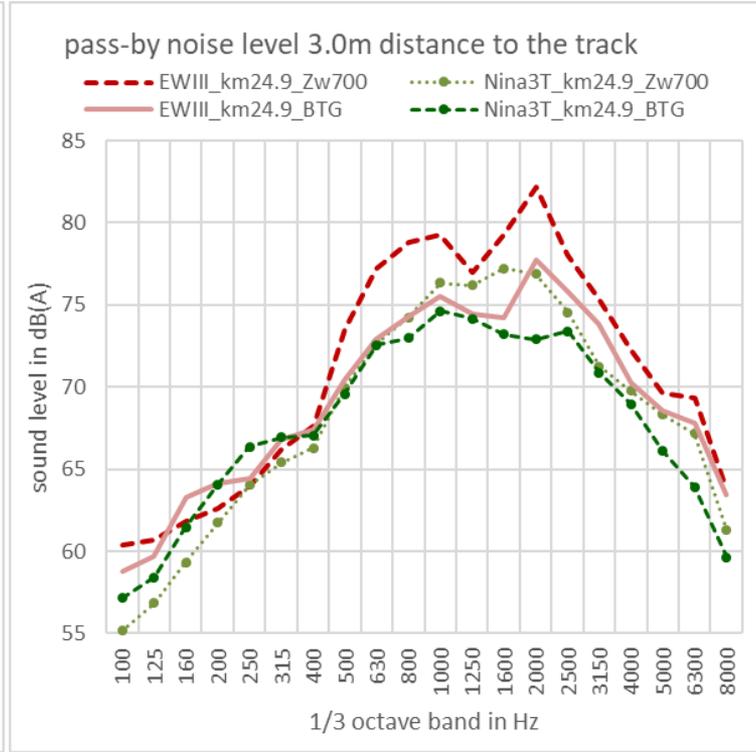
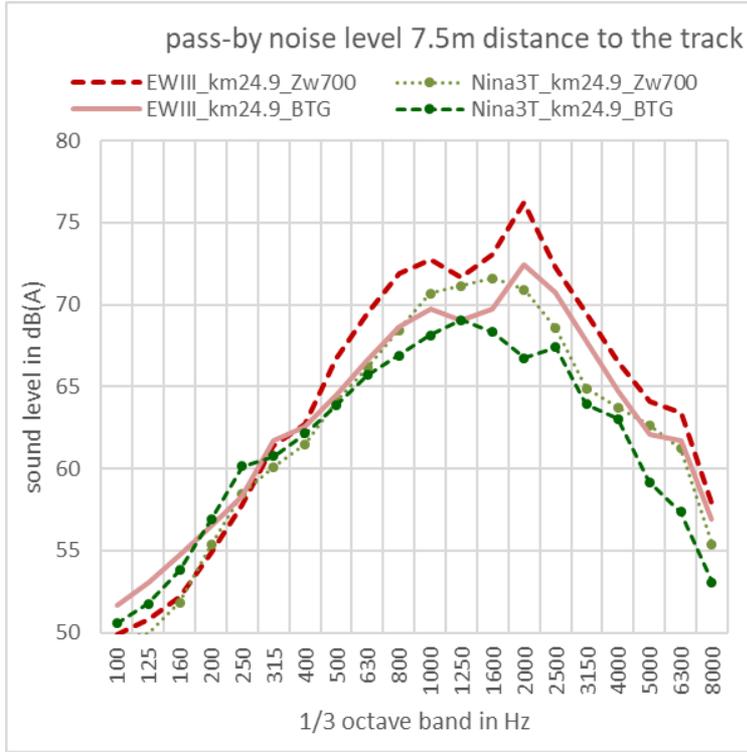
Field Tests BLS in Kerzers



		km 24.9			km 24.66			km 24.5			
		Zw700 -> BTG			Zw700 weich			Zw687a hart			
		LpAeq, Tp 7.5m			LpAeq, Tp 7.5m			LpAeq, Tp 7.5m			
		Süd	Nord	Median	Süd	Nord	Median	Süd	Nord	Median	
Datum	Anzahl	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	dB(A)	
06_2020	12	EWIII 120 km/h	78.4	77.5	77.9	82.0	82.6	82.3	79.5	79.6	79.6
06_2020	16	Nina 3T 120 km/h	78.2	77.6	77.9	82.0	82.7	82.4	80.0	79.7	79.9
06_2020	5	Nina 6T 120 km/h	84.3	83.5	83.9	87.7	88.4	88.0	85.1	85.1	85.1
06_2020	1	Güterzug1 100 km/h	82.7	82.3	82.5	86.5	86.6	86.5	84.4	84.0	84.2
06_2020	1	Güterzug2 100 km/h	91.1	90.0	90.6	94.9	94.5	94.7	92.4	91.8	92.1
		delta Zw700 EWIII	-3.6	-5.1	-4.4	-	-	-	-2.4	-3.0	-2.7
		delta Zw700 Nina 3T	-3.8	-5.1	-4.5	-	-	-	-2.0	-3.0	-2.5
		delta Zw700 Nina 6T	-3.3	-4.9	-4.1	-	-	-	-2.6	-3.3	-2.9
		delta Zw700 GZ1	-3.8	-4.3	-4.1	-	-	-	-2.1	-2.5	-2.3
		delta Zw700 GZ2	-3.7	-4.5	-4.1	-	-	-	-2.4	-2.7	-2.5

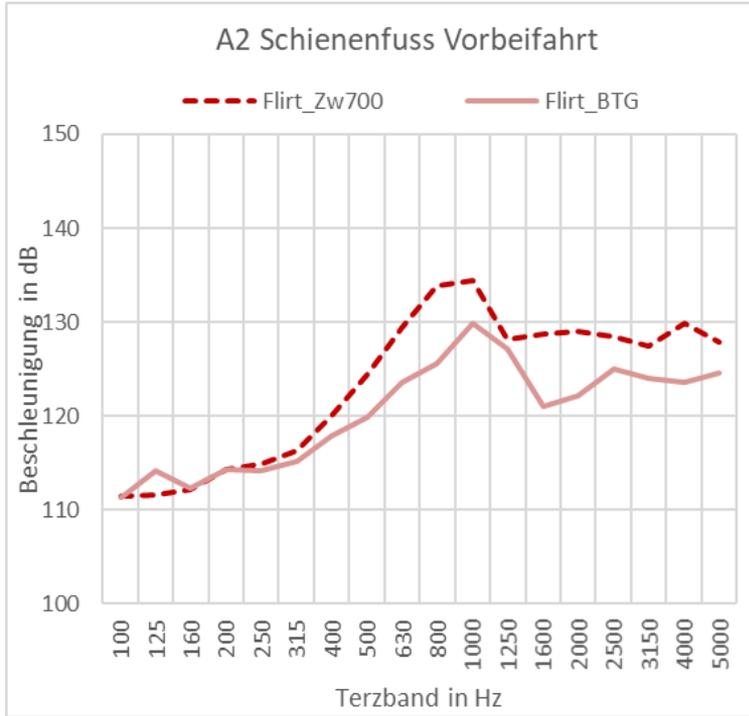


Field Tests BLS in Kerzers

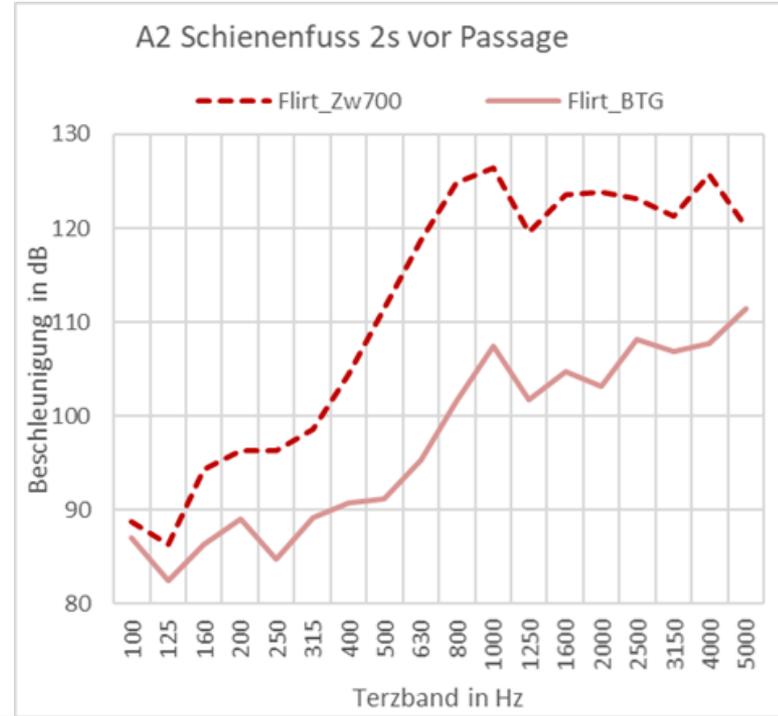


Field Tests BLS in Kerzers

Rail foot vibrations during train pass-by

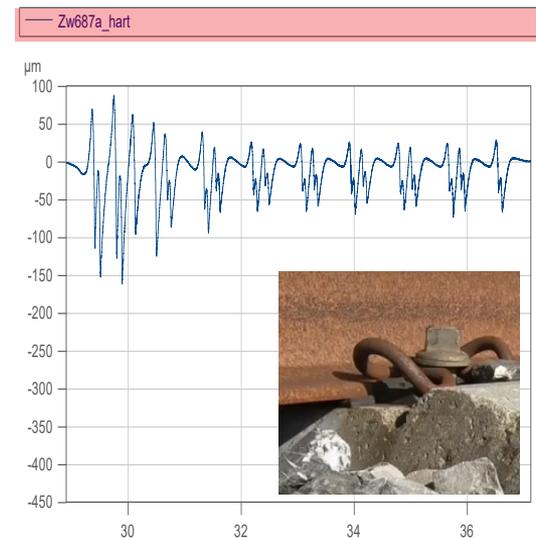
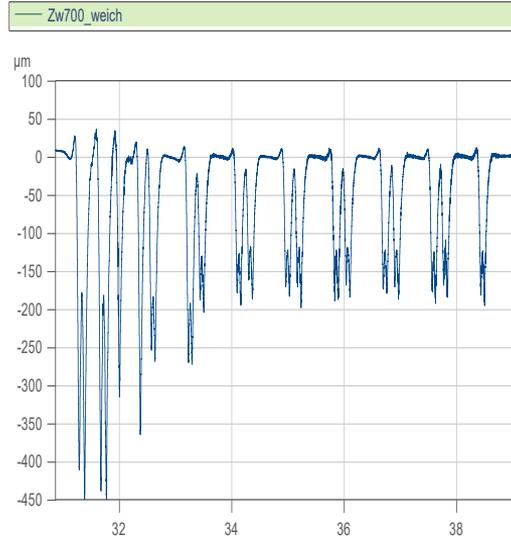
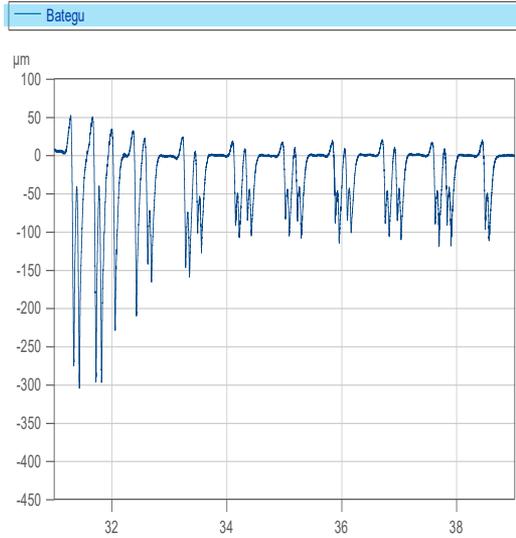


train approaches 2 seconds before pass-by



Field Tests BLS in Kerzers

Rail displacements
in relation to the sleeper



		Schieneneneinsenkung	km 24.9			km 24.66			km 24.5		
			BTG			Zw700 weich			Zw687a hart		
			LpAeq, Tp 7.5m			LpAeq, Tp 7.5m			LpAeq, Tp 7.5m		
			Lok	Wagen	Prozent	Lok	Wagen	Prozent	Lok	Wagen	Prozent
Datum	Uhrzeit		µm	µm	%	µm	µm		µm	µm	%
06_2020	08.26	GZ mit 100 km/h	300	120	66	440	200	100	150	60	33
06_2020	09.12	EWIII mit 120 km/h	280	110	67	400	180	100	140	60	34



Field Tests BLS in Kerzers

Ground vibrations

Measuring points in 6m distance to the track center x, y, z accelerations

Calculation of KB rms/max values according ISO 2631-1 1997

Erschütterungen		BTG				weiche Zw				harte Zw			
6m von der Gleismitte		wk / wd		wm		wk / wd		wm		wk / wd		wm	
		KBrms	KBmax	KBrms	KBmax	KBrms	KBmax	KBrms	KBmax	KBrms	KBmax	KBrms	KBmax
Zug	n	mm/s ²	mm/s ²	mm/s	mm/s	mm/s ²	mm/s ²	mm/s	mm/s	mm/s ²	mm/s ²	mm/s	mm/s
EWIII	15	17.1	35.3	0.1	0.2	24.2	60.1	0.1	0.4	50.5	113.5	0.3	0.7
Nina3T	11	13.3	26.6	0.1	0.2	25.0	52.9	0.1	0.3	54.4	123.8	0.3	0.8
Nina6T	3	18.1	41.4	0.1	0.4	22.9	50.0	0.1	0.3	60.3	143.1	0.4	0.9
GZ	1	23.6	68.9	0.1	0.3	22.0	53.6	0.1	0.4	52.3	138.9	0.3	0.6
Mittelwert		18.0	43.0	0.1	0.3	23.5	54.1	0.1	0.4	54.4	129.8	0.3	0.8
Prozent zur harten Zw		33	33	33	34	43	42	40	45	100	100	100	100



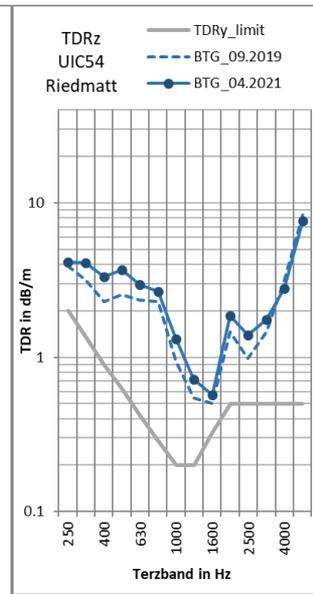
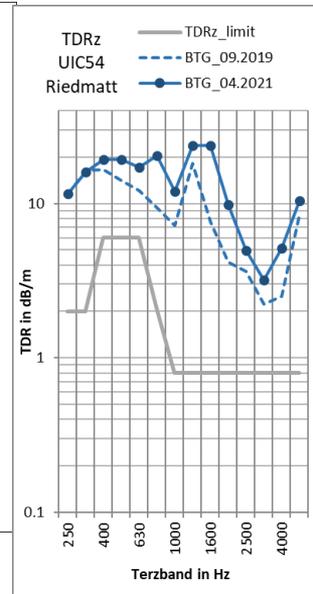
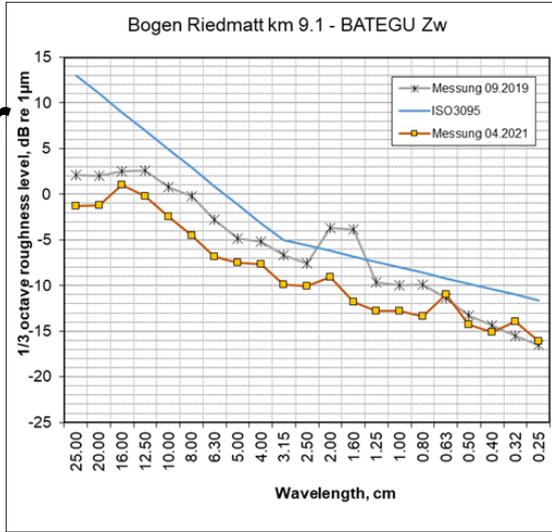


Field Tests control after 1 year

Rail roughness &

TDR UIC54 Wollerau SOB

TDR UIC60 Kerzers BLS

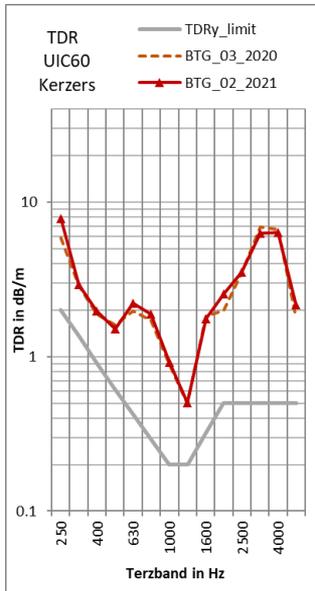
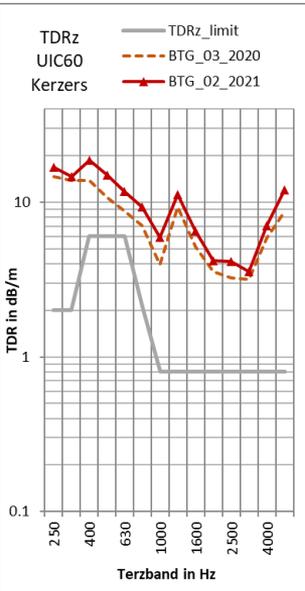


Pass-by levels Kerzers BLS

results during type tests 25.02.2021			BATEGU	Zw687a	Getzner
tests			km 24.9	km 24.56	km 24.44
n	type	km/h	LpAeq,Tp dB(A)		
6	Regio train EWIII	120	80.7	82.4	82.5
3	Regio train Nina3T	120	78.8	80.7	80.6
1	freight train	100	80.5	82.0	81.4
3	tank wagon	80	77.1	80.4	80.4
2	tank wagon	120	83.8	86.9	86.4

BATEGU vs. Zw687a
1.7 dB less railway noise

No changes of relevant parameters after 1 year!



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

optimierte Zwischenlage PROSE / BATEGU

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



Conclusions Effects



- On curved tracks with UIC54 rails in Wollerau SOB the pass-by levels with **BATEGU rail pads** appear about **5 dB** lower compared to **Zw700AT soft rail pads**.
- On straight tracks with UIC60 rails in Kerzers BLS the pass-by levels with **BATEGU rail pads** appear about **3 - 4 dB** lower compared to **Zw700 soft rail pads** and of **1.5 dB** lower compared to **Zw687a stiff rail pads**.
- The **dynamic shock forces** into the track superstructure measured as rail displacement **will be reduced about 66%** compared to **stiff rail pads** and about **20%** compared to **Zw700 soft rail pads**
- Measured at 6m distance to the **BATEGU** track the **ground vibrations** appear to be about **33% lower** compared to the track section with **Zw687a stiff pads**.

Link to the project report:

<https://www.aramis.admin.ch/Texte/?ProjectID=40241>





Conclusions



- The rail pads **BATEGU** passed the required laboratory tests for track components „rail fastening systems“ and can be applied to the track.
- Using high damping soft rail pads will reduce shock forces to the track superstructure which lead to **extended maintenance intervalls** and **LCC reduction**
- Soft rail pads can be connected to **low rail roughness** and **rail corrugation growth**
- **Sustainability:** After one year of operation no relevant changes of the noise and vibration reduction effects, roughness changes and TDR on the tracks with **BATEGU** rail pads are seen
- On a track section between Vevey-Gilamont **BATEGU** rail pads have been installed in 09.2021, now three sections with **BATEGU** rail pads still exist for investigations and as sample

High damping soft rail pads of **BATEGU/PROSE** are ready for the future tracks.

