Elastic Solutions for Railway Superstructures

PWI Lunch & Learn 18/02/25

Andy Moore

Core Competence - Vibration Isolation

Elastic Solutions For Railway Superstructure

Contents

- Under Sleeper Pads

- Under Ballast Mats

- Mass Spring System

Why Under Sleeper Pads?


Vibration Isolation
SLN sylodyn by getzner
SLS sylomer by getzner


Ballast Protection
SLB sylomer by getzner

Ballast is the Weakest Component

Ballast Turns to Dust!

Creating Voids Under The Sleepers

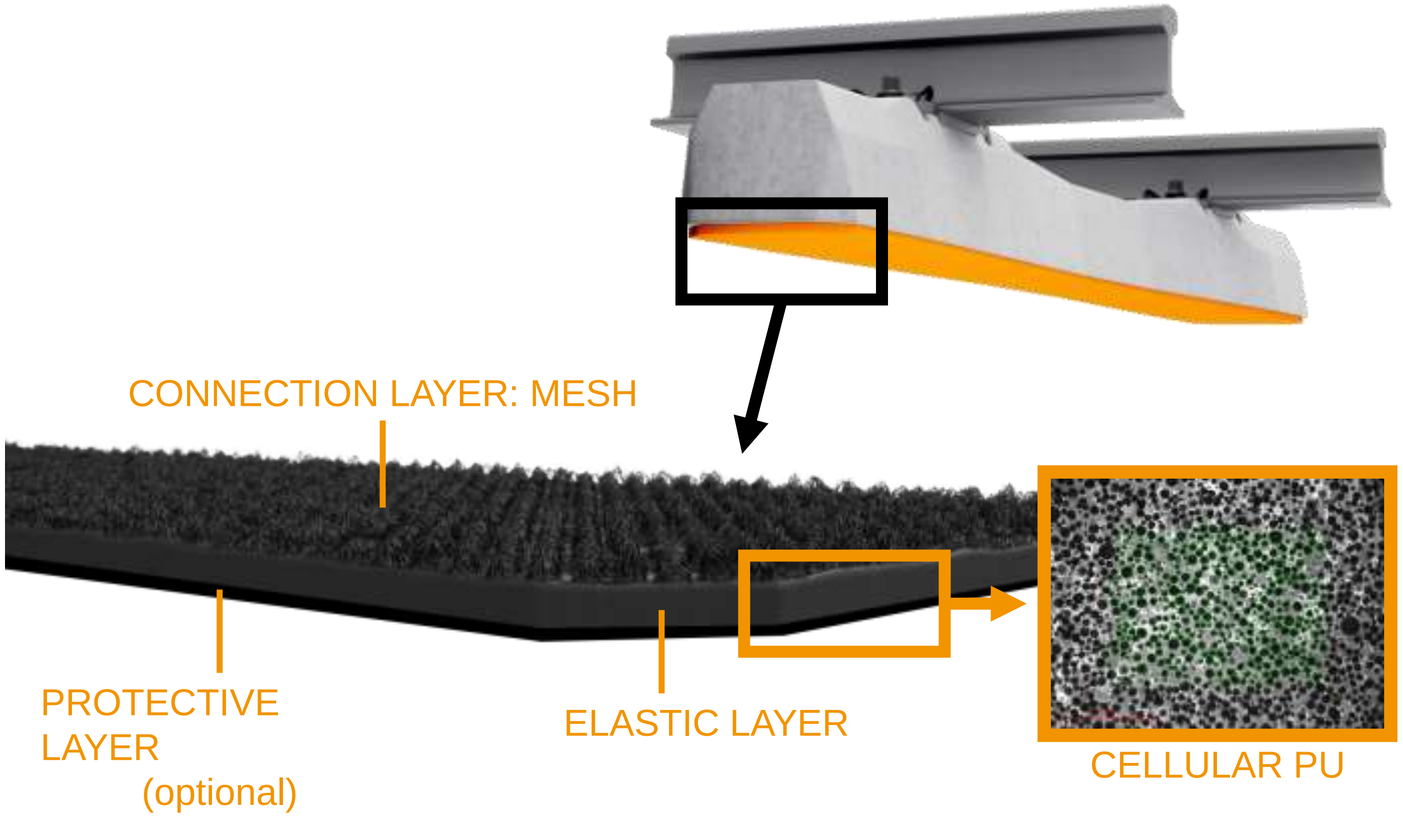
Sleepers Crack

White Spots

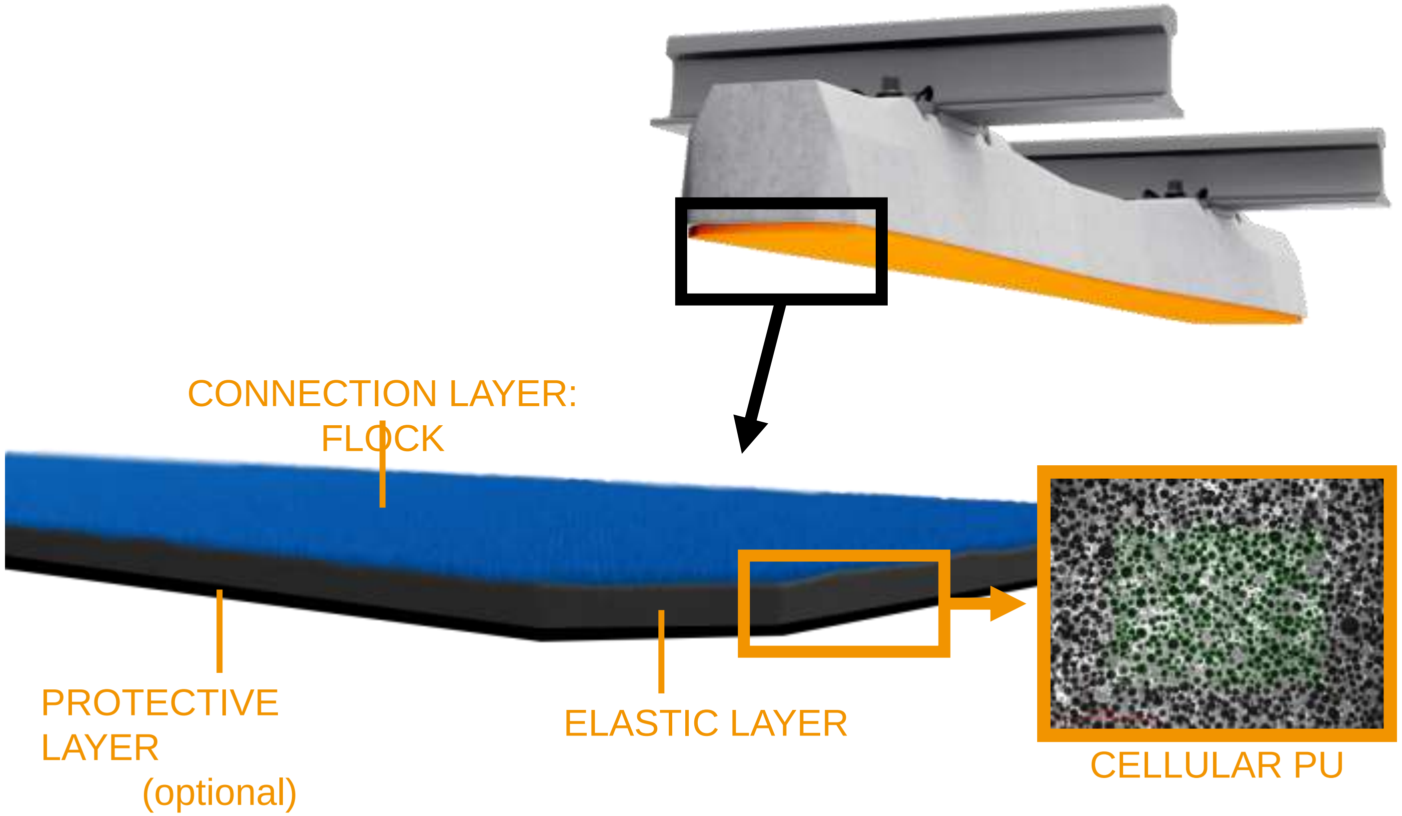
Transition Zones

Poor Track Quality

Elastic Solutions For Ballasted Track
Under Sleeper Pads



Elastic Solutions For Ballasted Track
Under Sleeper Pads



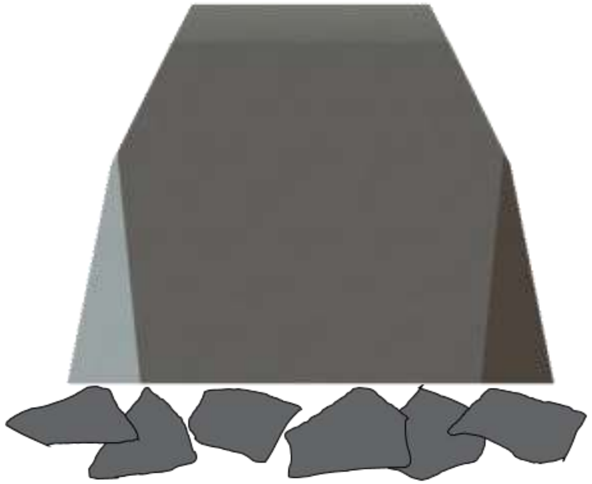
Assembly in the Sleeper Factory

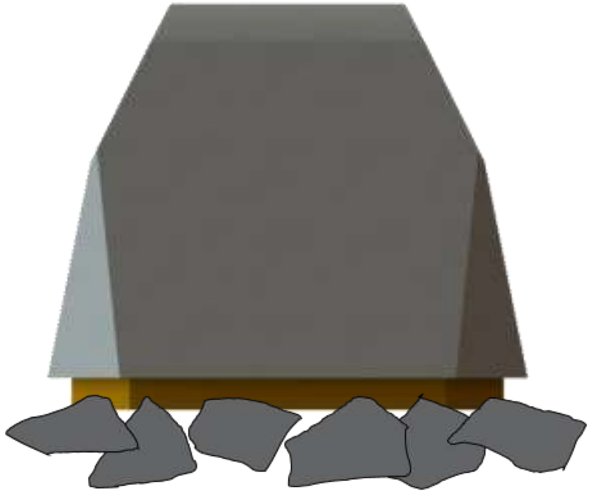
Assembly in the Sleeper Factory

Ballast Embeds

Elastic Solutions for Insulated Rail Joints

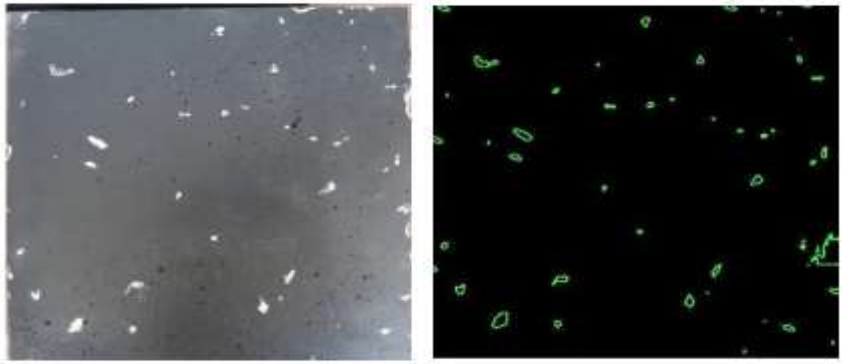
Unpadded vs. Padded Sleepers

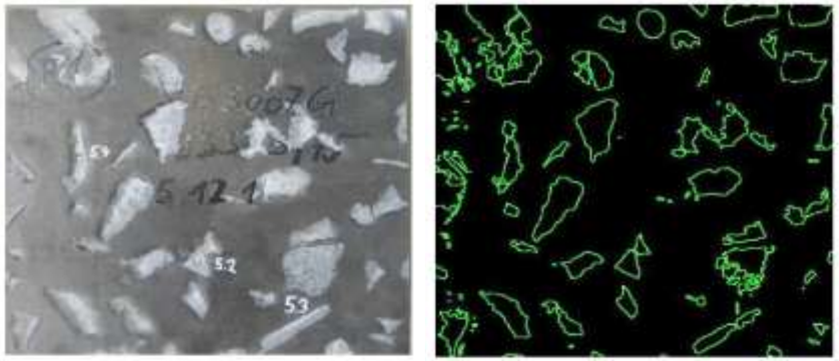




Contact Area: 3 - 5 %

15 - 35 %





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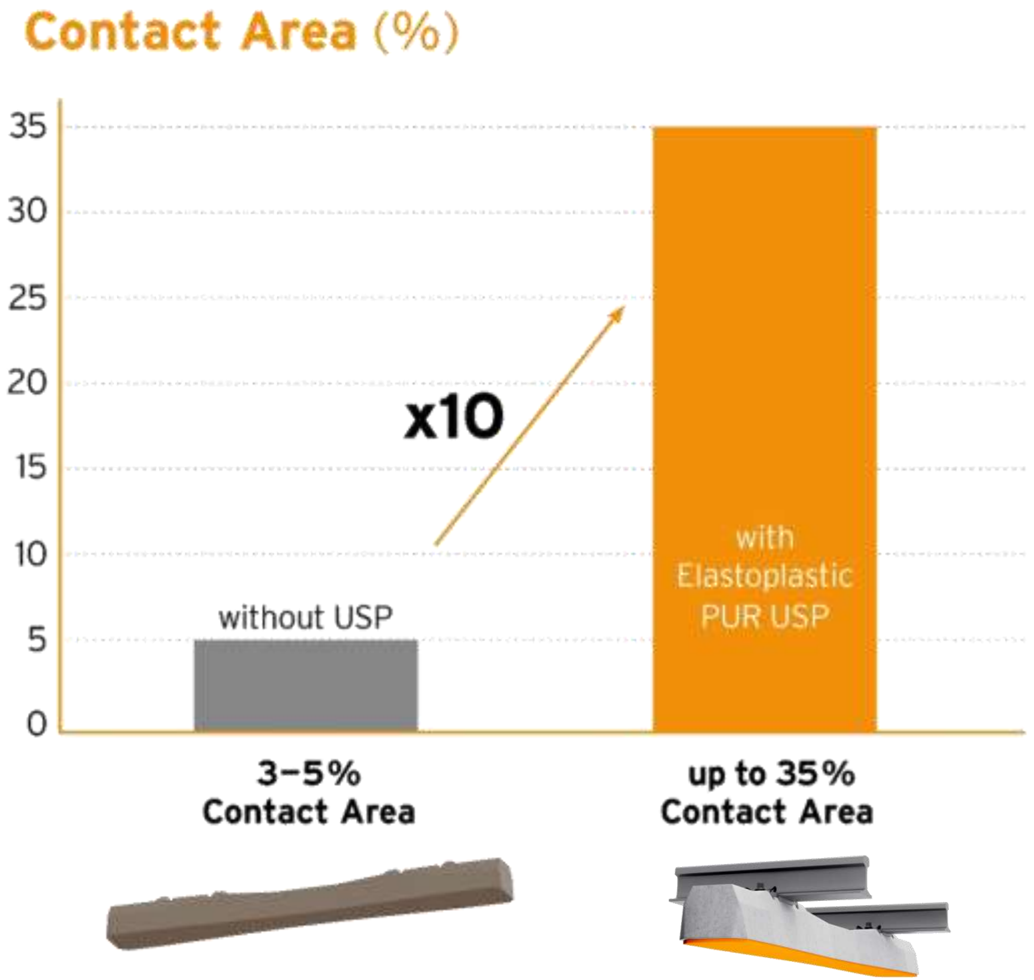
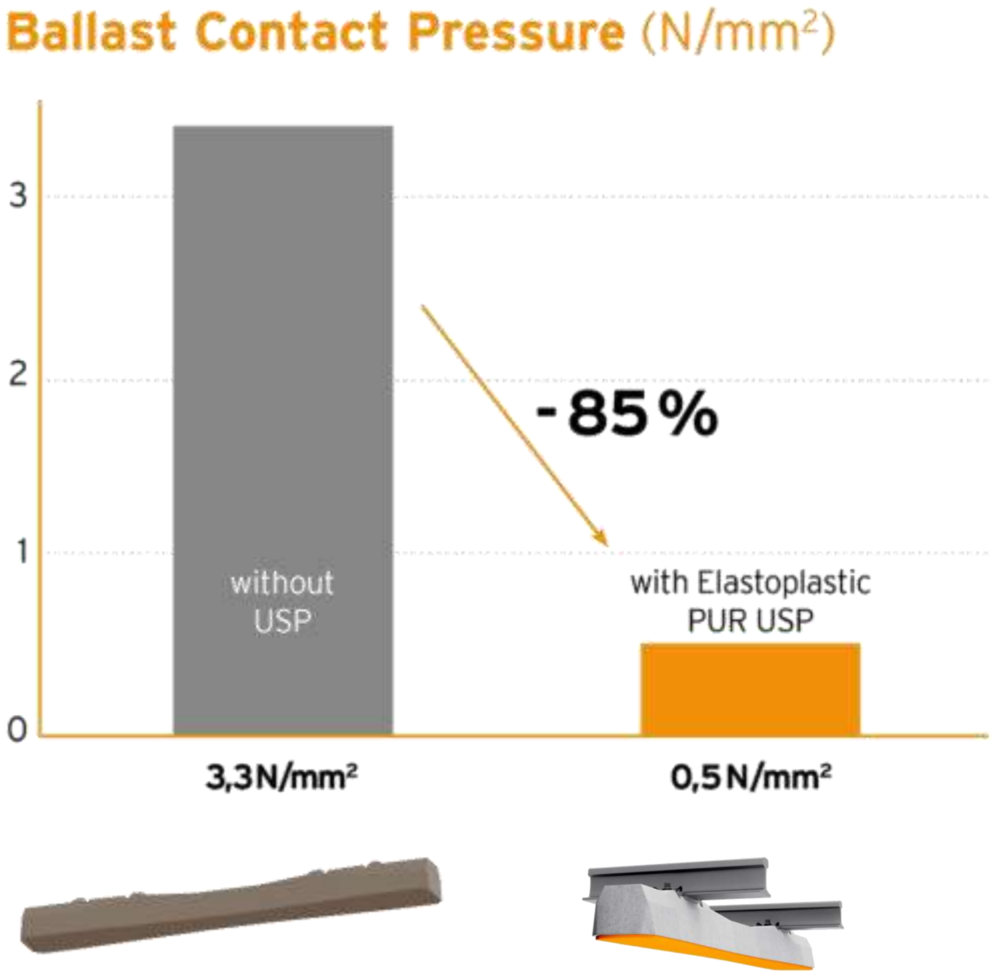
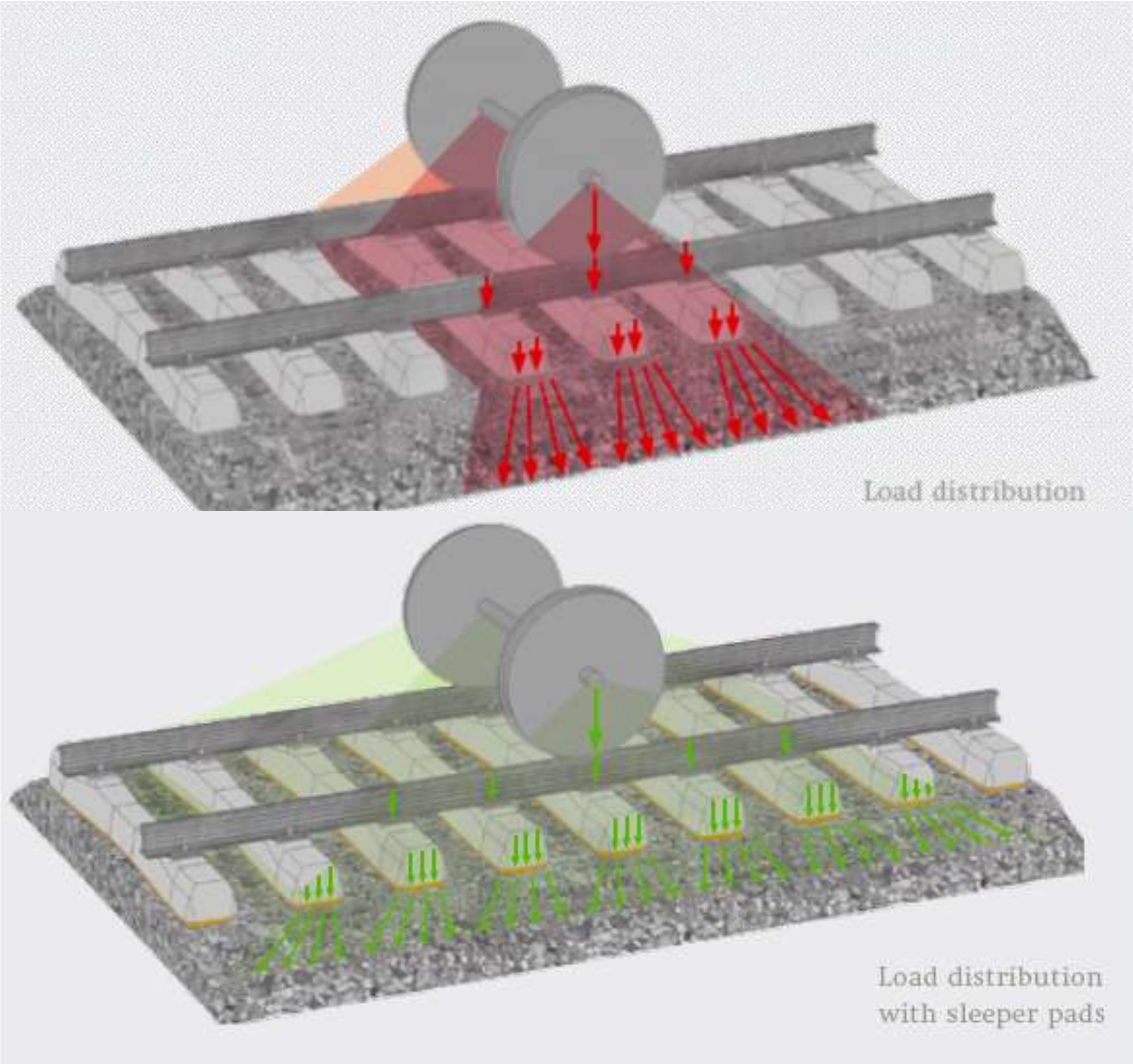




Ballast Protection for Your Superstructure
Contact Area Explained

Elastic Solutions for Ballasted Track
Under Sleeper Pads



UNPADDED SLEEPERS
few load bearing „shoulders“

PADDED SLEEPERS
more load bearing „shoulders“

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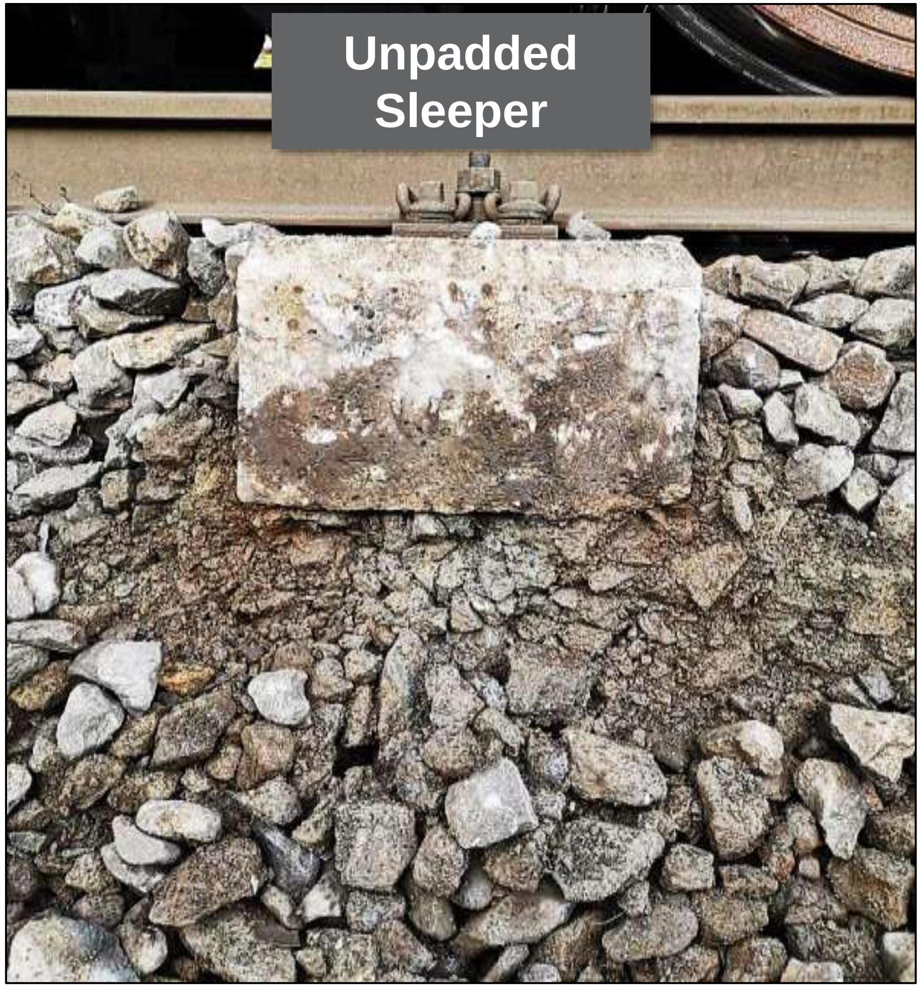
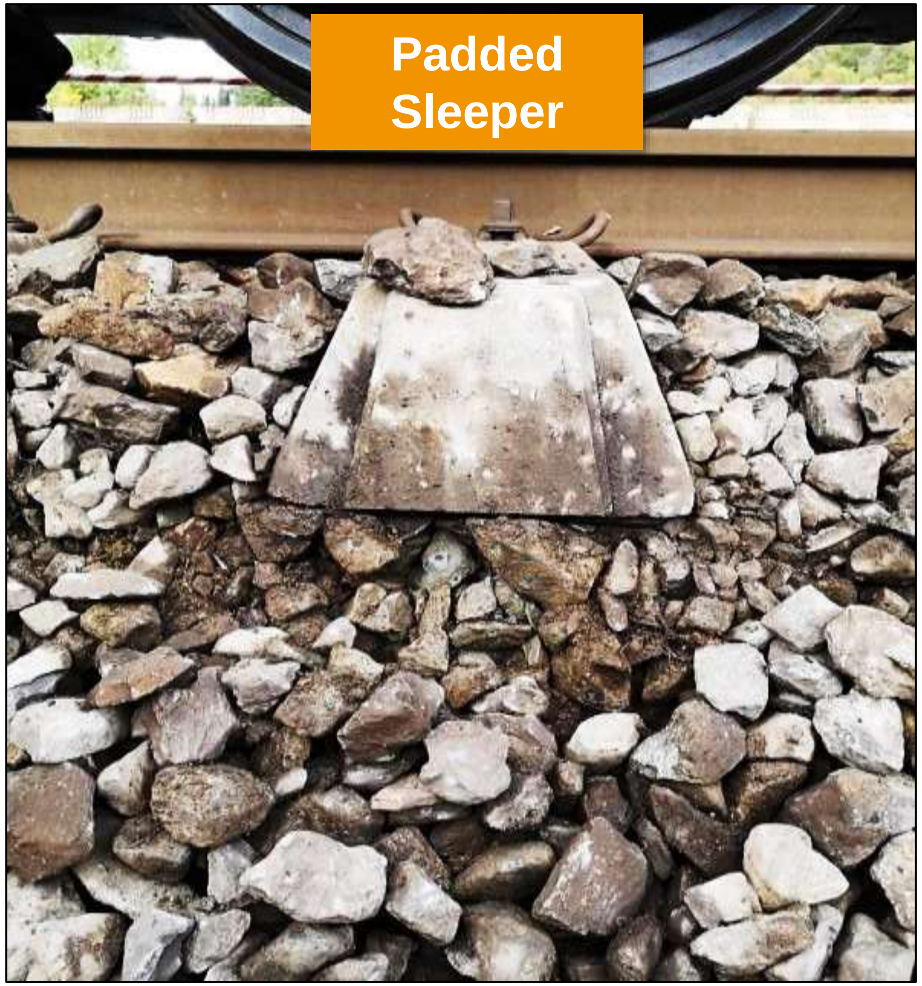
Under Sleeper Pads

Radius = 280m, 100 MGT

State of The Ballast
Unpadded Vs. Padded Sleepers





network of ÖBB, Leoben

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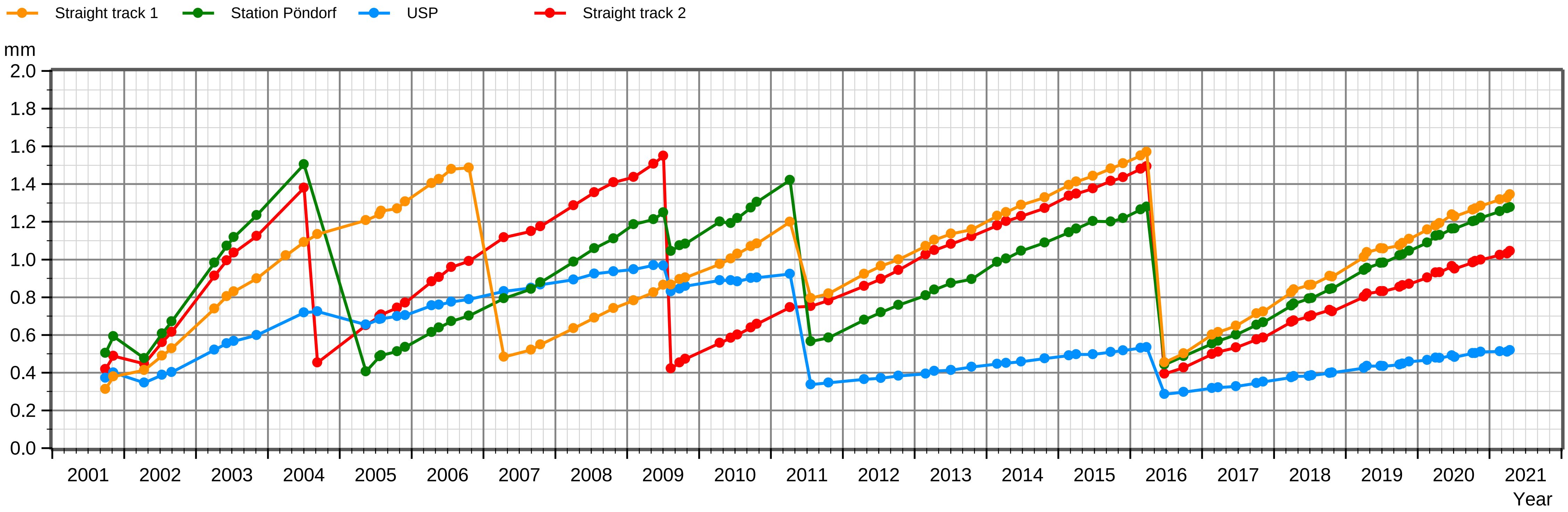
Under Sleeper Pads: General



Deterioration Rate (2011-2016)	
Straight track 1	0,16 mm/year
Station Pöndorf	0,16 mm/year
USP	0,04 mm/year
Straight track 2	0,16 mm/year

Deterioration Rate (2016-2021)	
Straight track 1	0,18 mm/year
Station Pöndorf	0,18 mm/year
USP	0,05 mm/year
Straight track 2	0,13 mm/year

Straight track 1	km 274.900 – km 275.500
Station Pöndorf	km 275,500 – km 276,100
USP	km 276,100 – km 276,950
Straight track 2	km 276,950 – km 277,800

Main-line network of ÖBB, Austria 225 kN axle load, 20 MGT/year

Elastic Solutions For Ballasted Track

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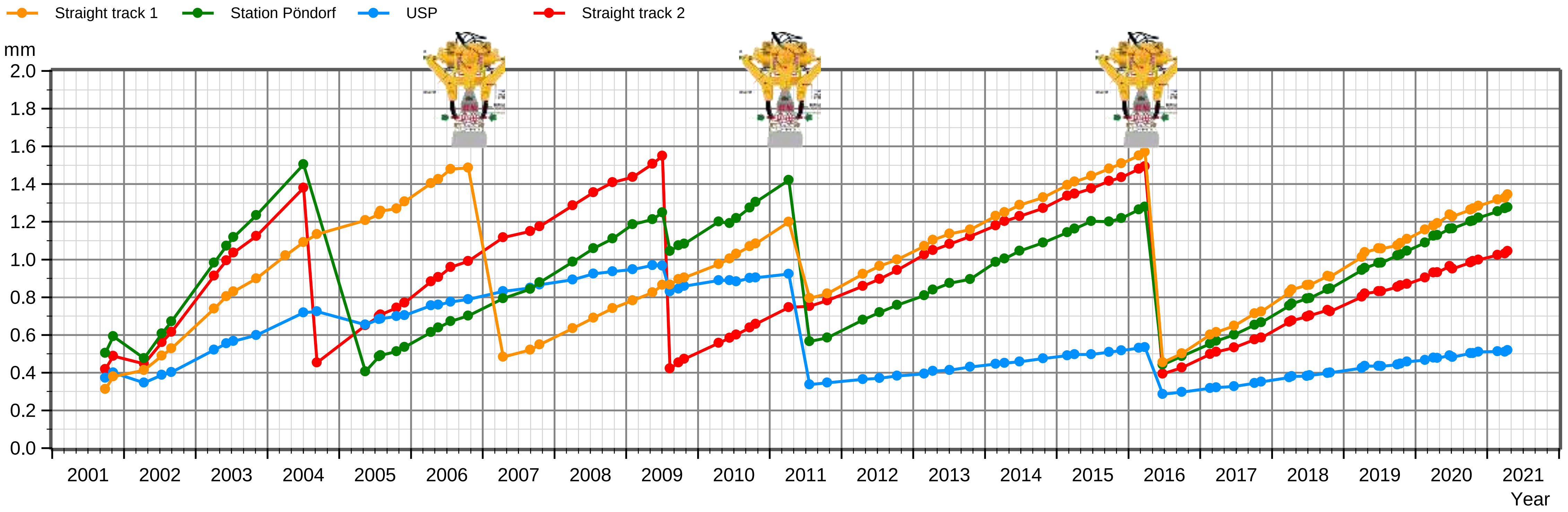

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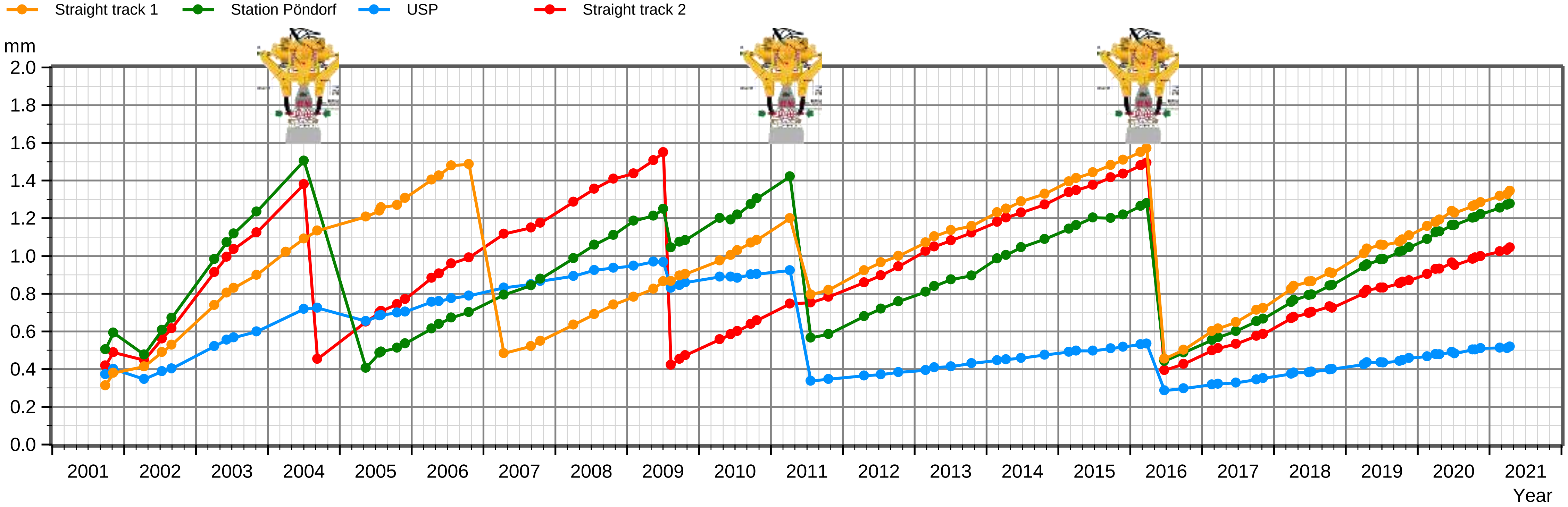

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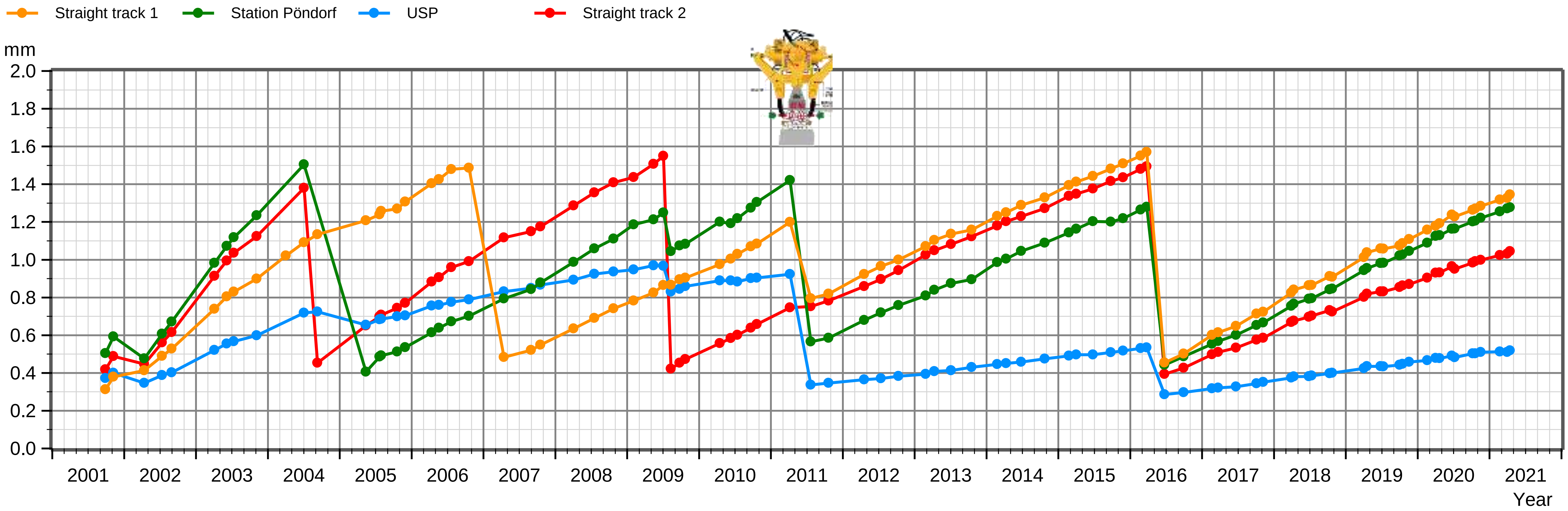

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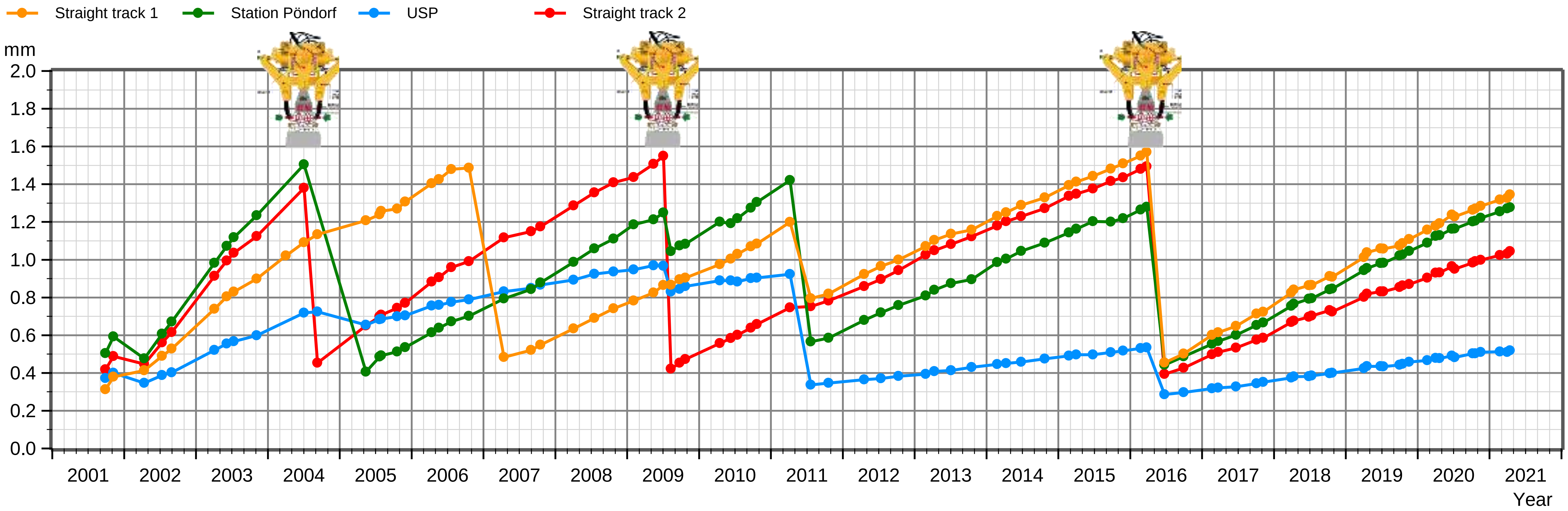

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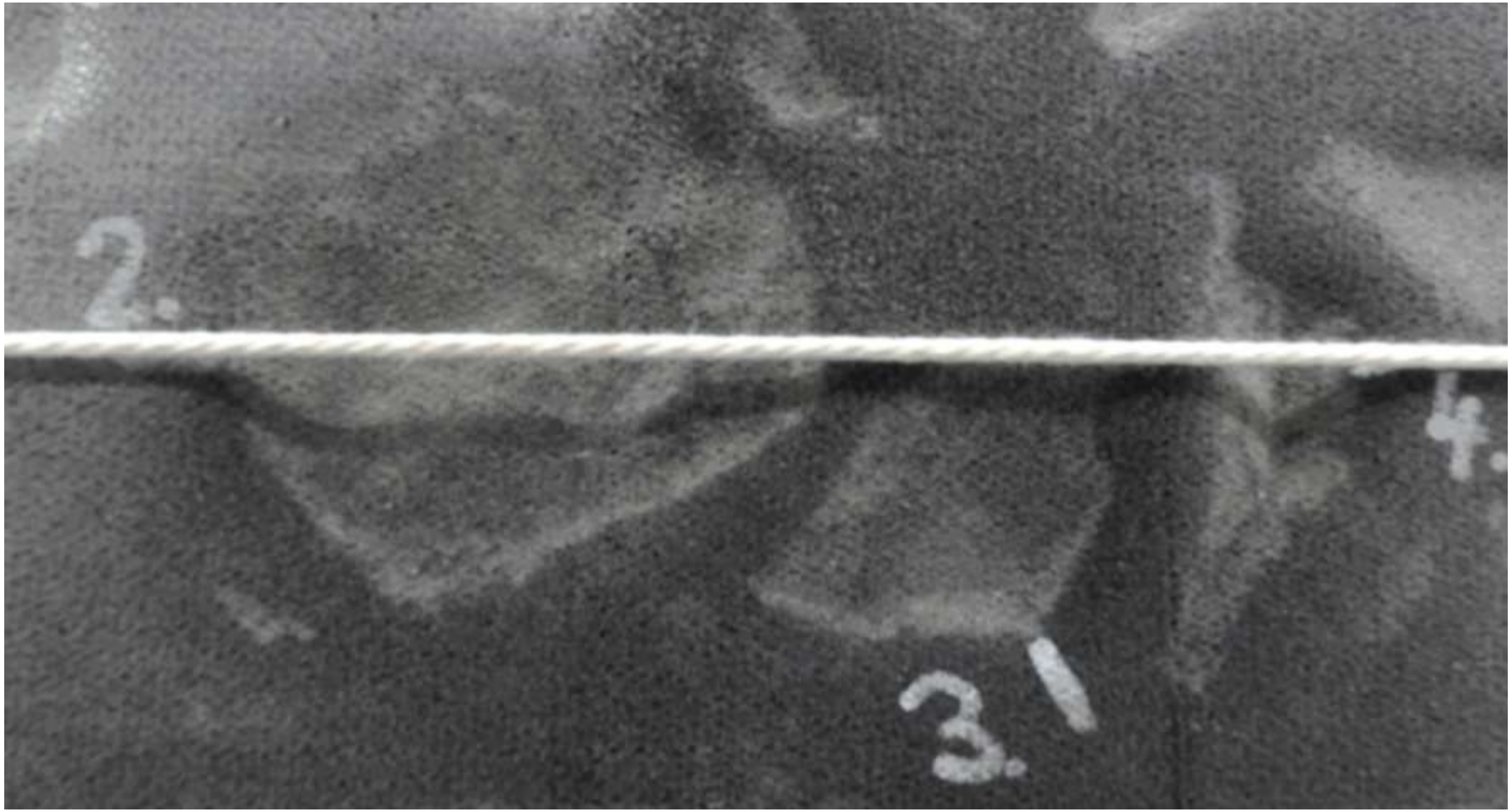
USP - Under Sleeper Pads
Project/References

LCC - Strategy

Evaluation of more than 1500 cross sections in Austria with more than 20 MGT and equipped with Getzner Under Sleeper pad type SLB 3007 G show an increase of the tamping intervals by a factor of 2,75.

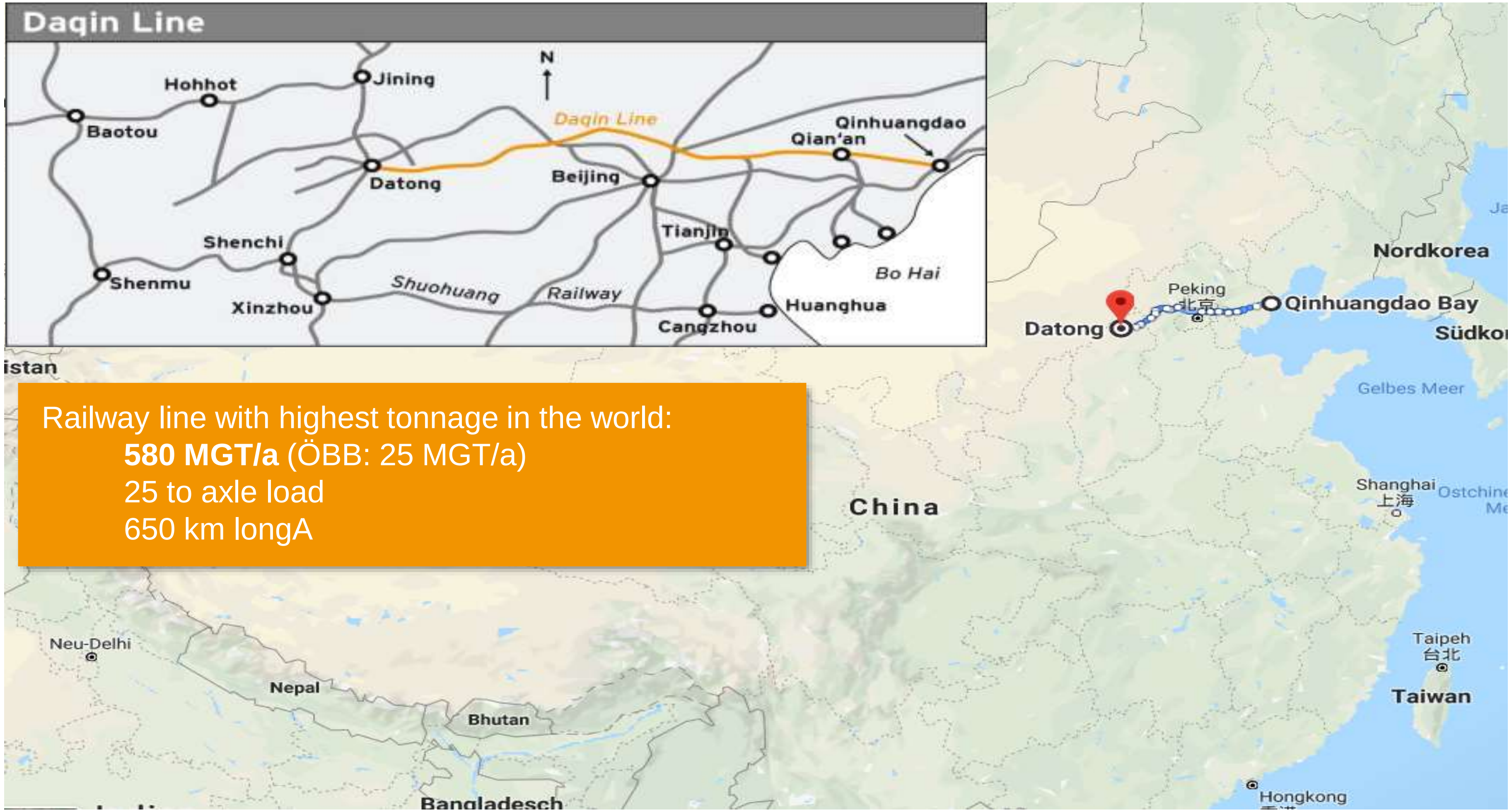
Elasto-plastic Behaviour



Reference DaQin Coal Line – Section with USP

Elastic Solutions for Ballasted Track

Under Sleeper Pads: Reference DaQin Coal Line



Railway line with highest tonnage in the world:

- **580 MGT/a** (ÖBB: 25 MGT/a)
- 25 to axle load
- 650 km longA

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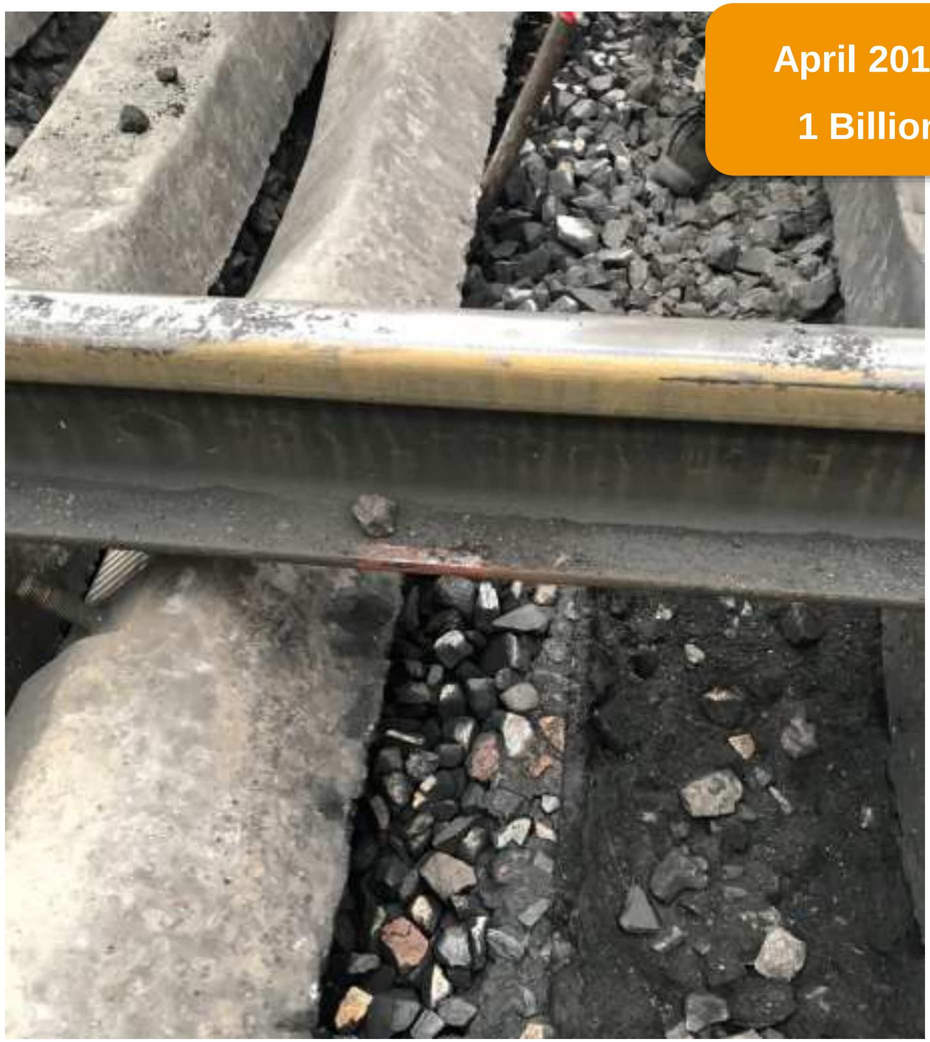
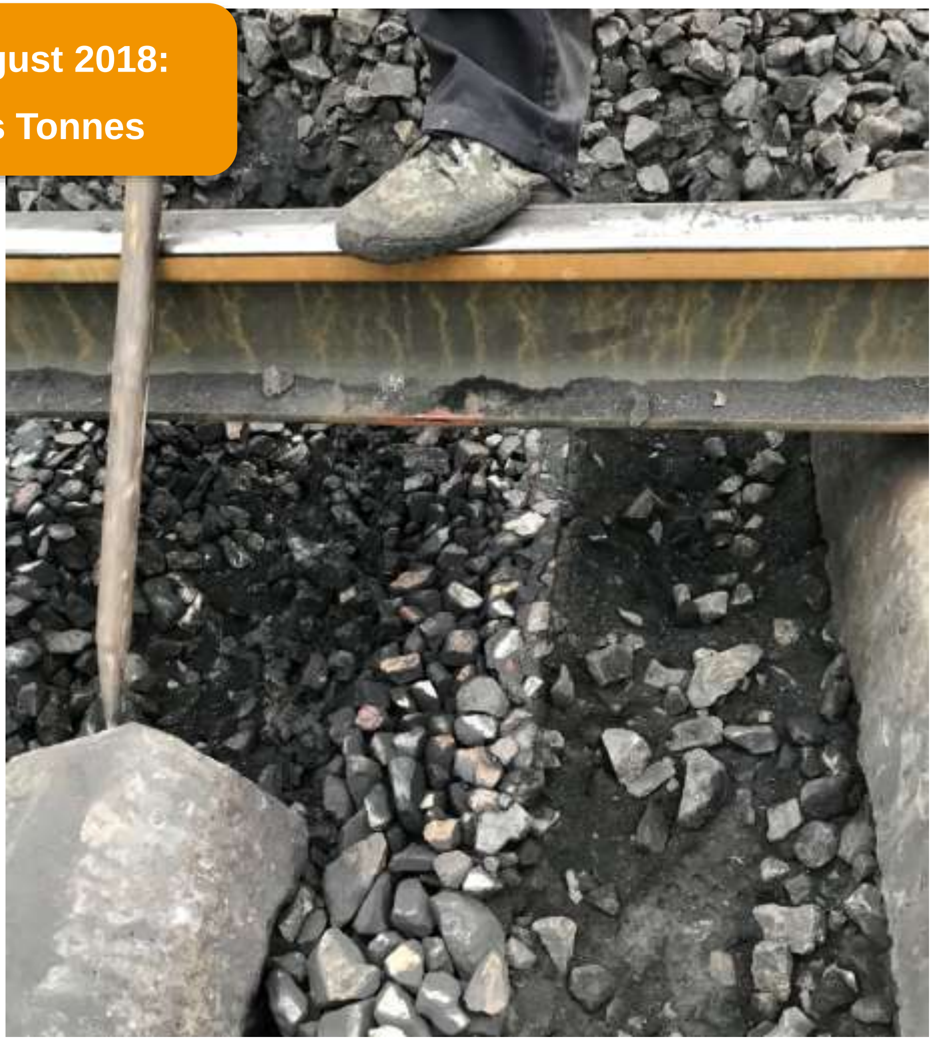
Under Sleeper Pads: Reference DaQin Coal Line

April 2016 – August 2018:

1 Billion Gross Tonnes





Elastic Solutions for Ballasted Track

Under Sleeper Pads: Reference DaQin Coal Line

中国铁路太原局集团有限公司工务部

弹性轨枕使用报告

我局于 2015 年、2016 年结合集中施工分别在大秦重车线延庆-下庄 K296+700-K298+160、空车线下庄-延庆 K283+720-K285+013 两段铺设了弹性轨枕，枕下弹性垫由
格士纳公司提供，并在太原

主要铺设情况如下：

序号	线路及里程	弹性产品	数量	[illegible]
1	大秦上行方向（空车） K283+720-K285+013	[illegible]	2300	[illegible]
2	大秦下行方向（重车） K296+700-K298+160	[illegible]	2500	[illegible]

大秦重车线延庆-下庄 K296+700-K298 在 2016 年 4 月上线试铺弹性轨枕 1.46Km，该地段处于长大下坡道，最大坡度 12‰，包含曲线 1 条 R=700m、L=760.49m，三座桥梁共计 375.9m，三座隧道共计 277m。上线 36 个月以来累计通过总重达到 17.4 亿吨（年运量 4.5 亿吨），历经 5 次集中修均未进行大机捣固，目前该地段无轨枕失效；道床无坍白空吊；无翻浆冒泥（大秦重车线目前每半年集中修捣固一次）。设备质量优良率始终 100%，水平和高低平均公里无不良扣分，TQI 值 7.42，设备质量、状态一直保持在较高水平。

大秦空车线下庄-延庆 K283+720-K285+013 在 2015 年 10 月上线试铺弹性轨枕 1.293Km，包含三座桥梁，一座隧道以及两条曲线，42 个月以来累计通过总重达到 4.64 亿吨，历经 6 次集中修均未进行大机捣固，但设备质量优良率始终 100%，水平和高低平均公里无不良扣分，TQI 值 6.41，轨道线路几何形位始终保持在良好状态。

量、维修投入和产生
性轨枕后，枕下弹性
钢轨、轨枕及道床的
砟粉化和道床板结、
缓道床的累积变形，
、设备质量大幅提升，
用工投入大大减少；从而达到延长轨道维护周期，减少轨道养护维修工作量的应用目的。

我局对弹性轨枕的使用效果非常满意。

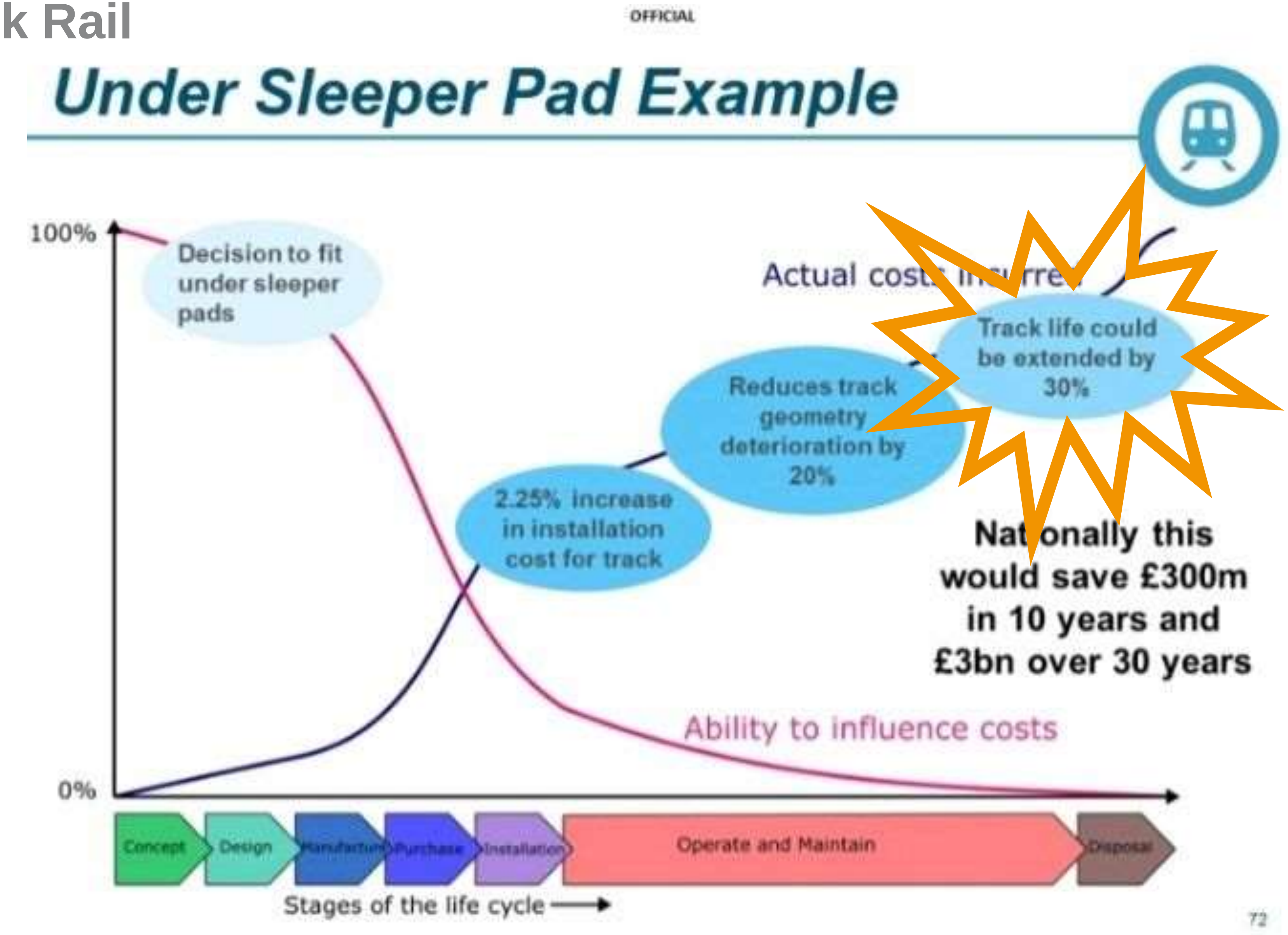
中国铁路太原局集团有限公司工务部

2019年4月10日

—2—

Official reference letter: “in the unpadded section tamping was performed 5 times, **in the padded section not once. The track geometry and quality remain excellent to date.”**

Network Rail



Network Rail Standard

5.8.1 Under-sleeper pads

Under-sleeper pads shall be specified on all category 1A, 1 and 2 track.

Where under-sleeper pads are not specified, the variation justification should be supported with a whole life cost analysis and consider any forecast future tonnage increases.

***NOTE 1**: Design checks should be applied in accordance with NR/L2/TRK/4239.*

***NOTE 2**: It may also be appropriate to consider the use of under-sleeper pads in track category 3,4 or 5 if there are heavy axle loadings.*

Under-sleeper pads used for ballast protection on plain line shall have a bedding modulus C static of equal to or greater than 0.30N/mm^3.

Under-sleeper pads used for noise and vibration reduction shall have a bedding modulus C static of between 0.04N/mm^3 to 0.12N/mm^3.

***NOTE 3**: bedding modulus C static is defined in BS EN 16730*

Where mitigation measures are required to reduce noise and vibration impact, a site history analysis or noise & vibration study shall be conducted.

Network Rail Regions and Routes

Network Rail USP usage by area 2023/2024

Route	Total	USP Volume	Non USP Volume	% of USP
Anglia	7,196	896	6,300	12.5%
Central	17,586	6,226	11,360	35.4%
East Coast	16,114	280	15,834	1.7%
East Midlands	27,121	8,232	18,889	30.4%
Kent	14,728	2,520	12,208	17.1%
North & East	44,010	25,599	18,411	58.2%
North West	28,141	26,447	1,694	94.0%
Scotland	39,984	33,376	6,608	83.5%
Sussex	10,968	2,296	8,672	20.9%
Wales & Borders	26,160	-	26,160	0.0%
Wessex	28,558	8,904	19,654	31.2%
West Coast Mainline South	58,163	28,047	30,116	48.2%
Western	45,405	-	45,405	0.0%
	364,134	142,823	221,311	39.2%

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Lateral Track Resistance with USP

Track Buckling

Lateral Resistance of Railway Track

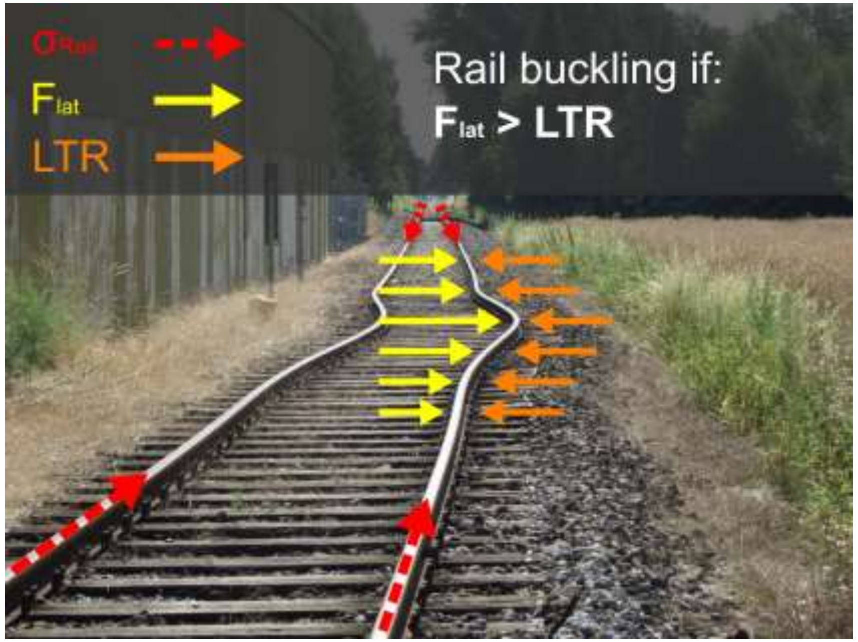
- “Lateral resistance of the ballast is one of the most important factors to prevent the expansion and track buckling. According to the tests results, from the summation of the track lateral resistance it is known that the proportion of the ballast, rails and fastenings from the total lateral resistance are 65%, 25% and 10%, respectively.”

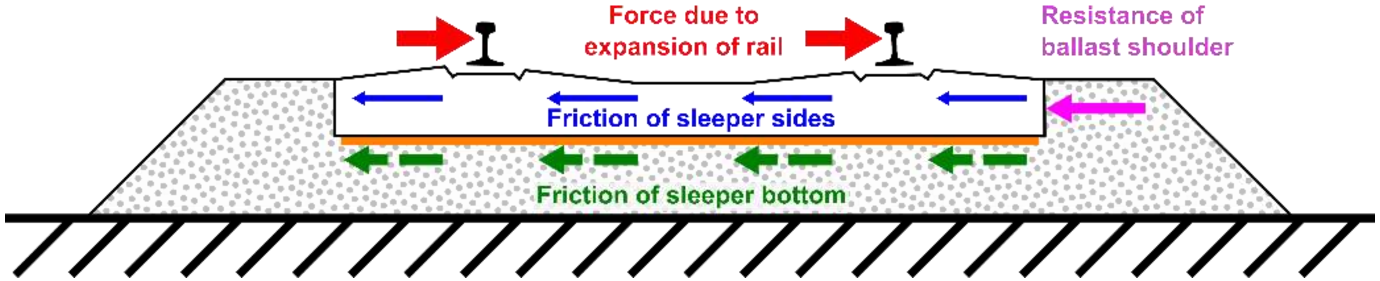
- Jabbar Ali Zakeri from Chapter 13 “Lateral Resistance of Railway Track” of “Relaibility and Safety in Railway”

Component	Lateral Track Resistance
Ballast	65%
Rails	25%
Fastenings	10%

Lateral Track Resistance (LTR)

- Sleeper Bottom
- Ballast Shoulder
- Sleeper Sides



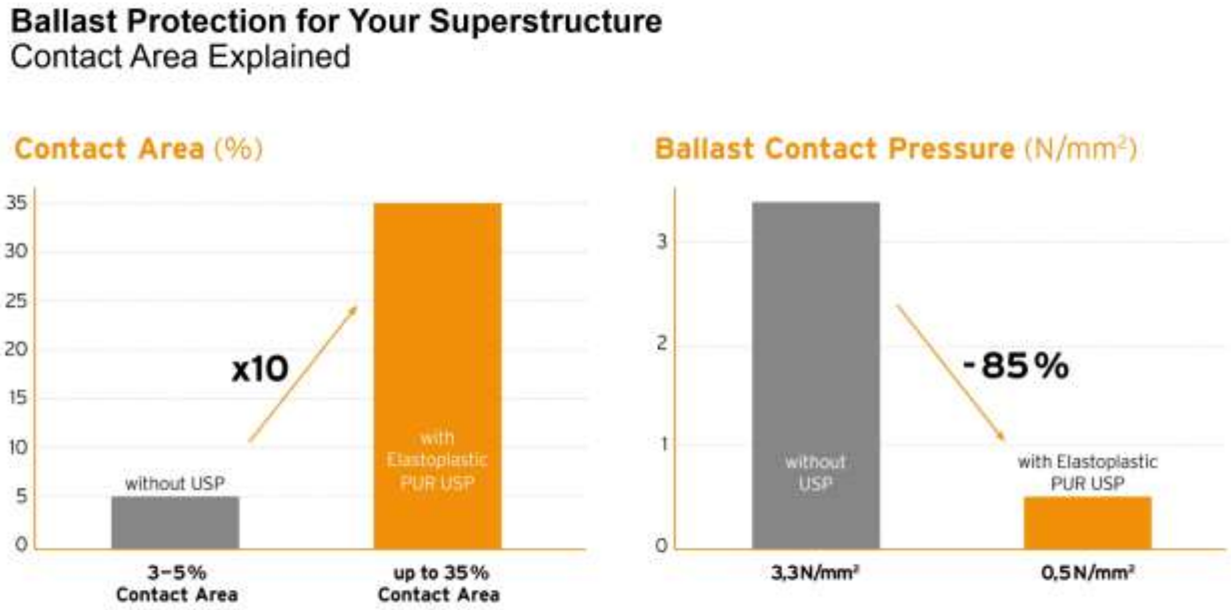


Shares LTR	Iliev	Lichtberger
Sleeper bottom	45 - 50 %	45 - 50 %
Ballast shoulder	16 - 20 %	35 - 40 %
Sleeper sides	21 - 30 %	10 - 15 %

Lateral Track Resistance

The “Play-Doh Principle”

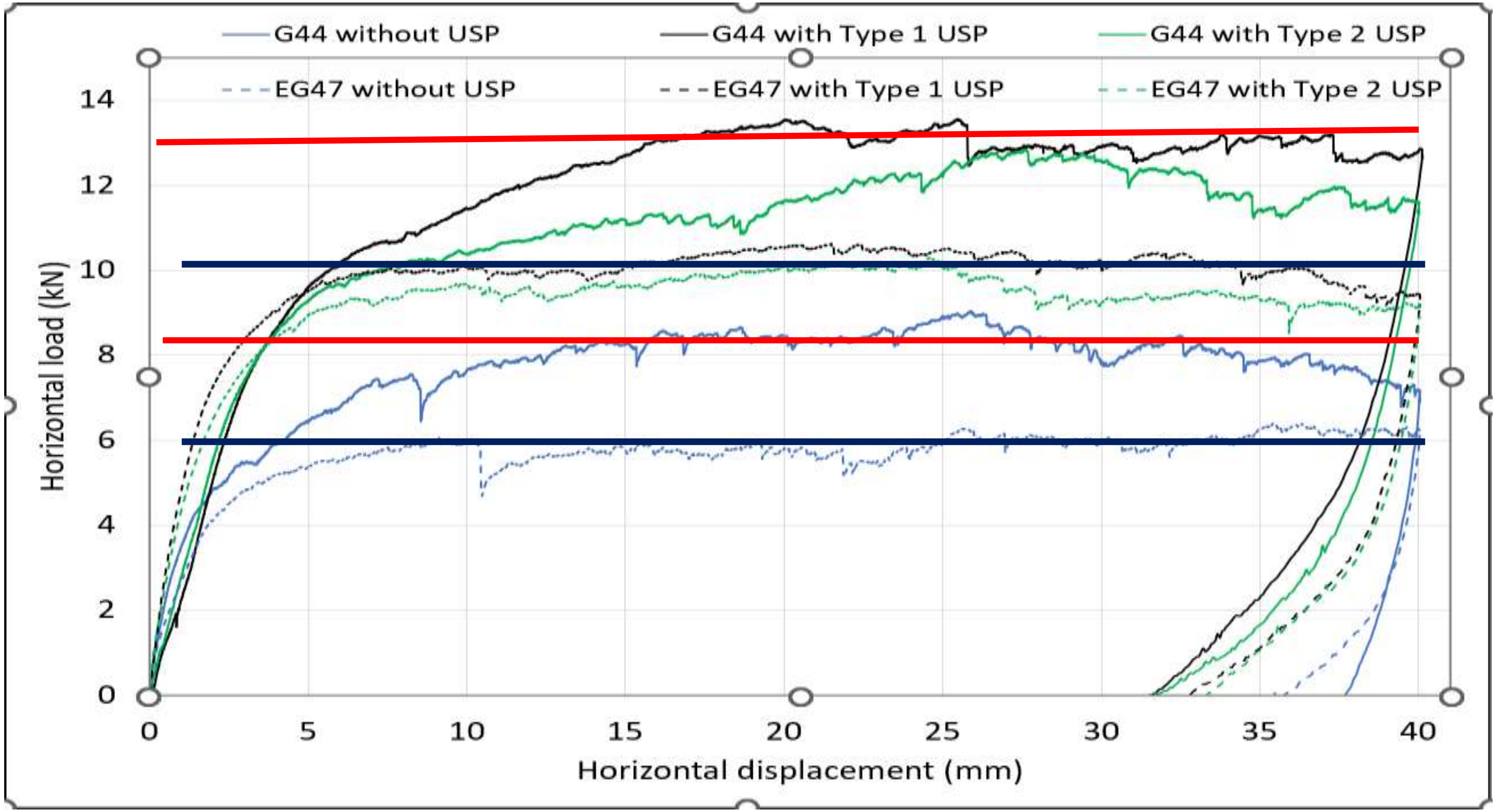
Increased Contact Area



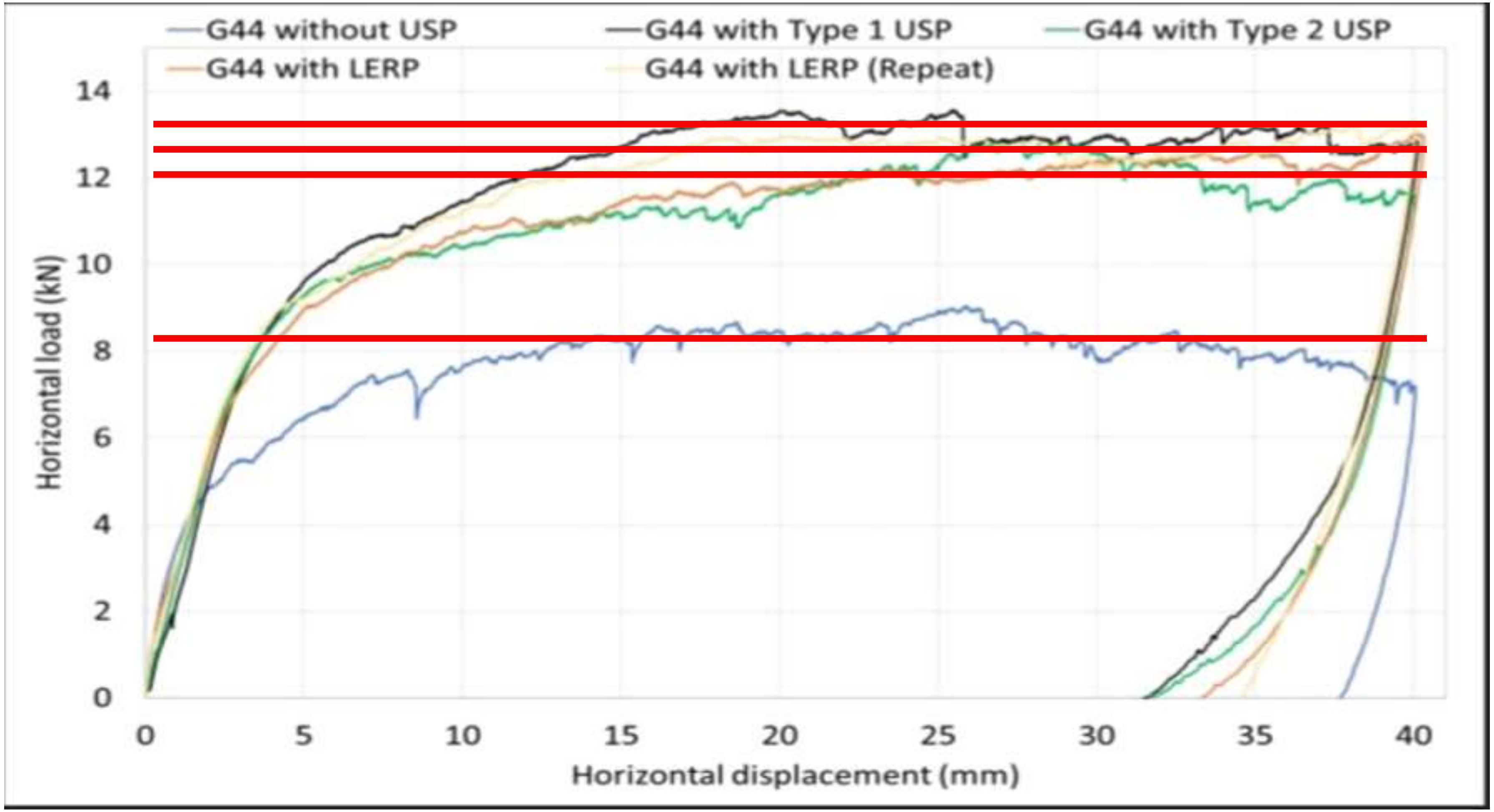
Lateral Track Resistance

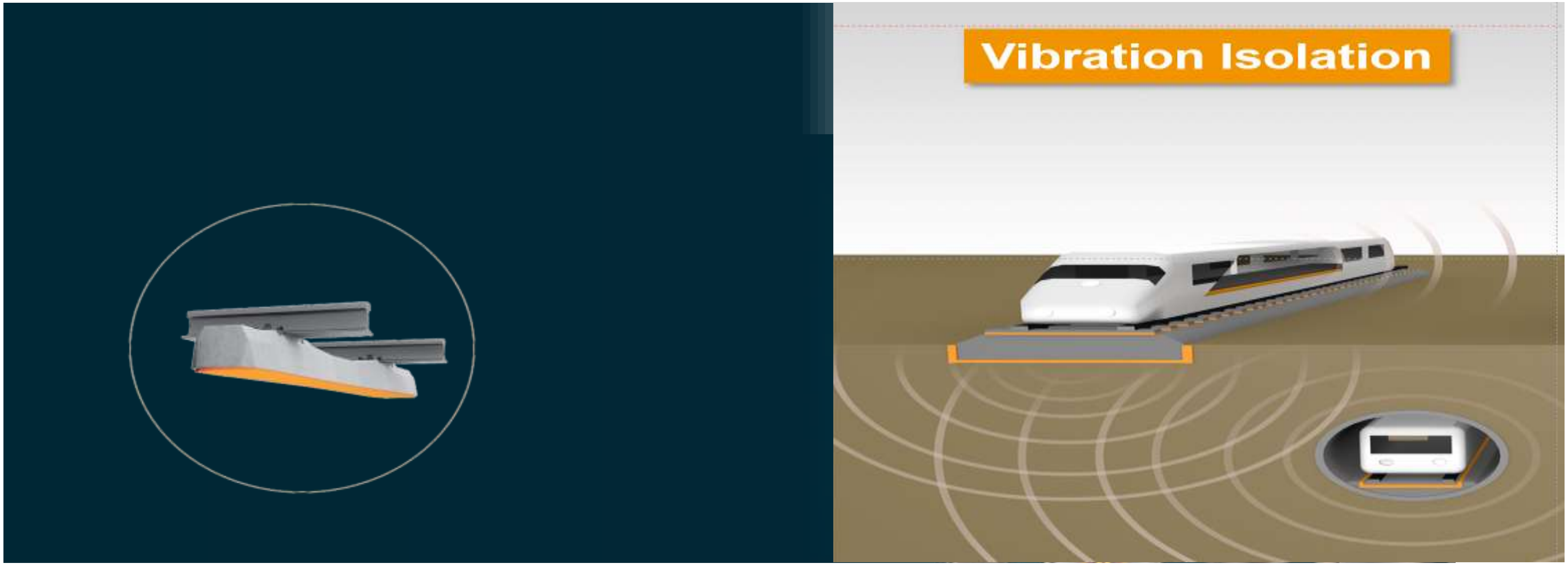
LTR Tests at Southampton University

LTR Test Results



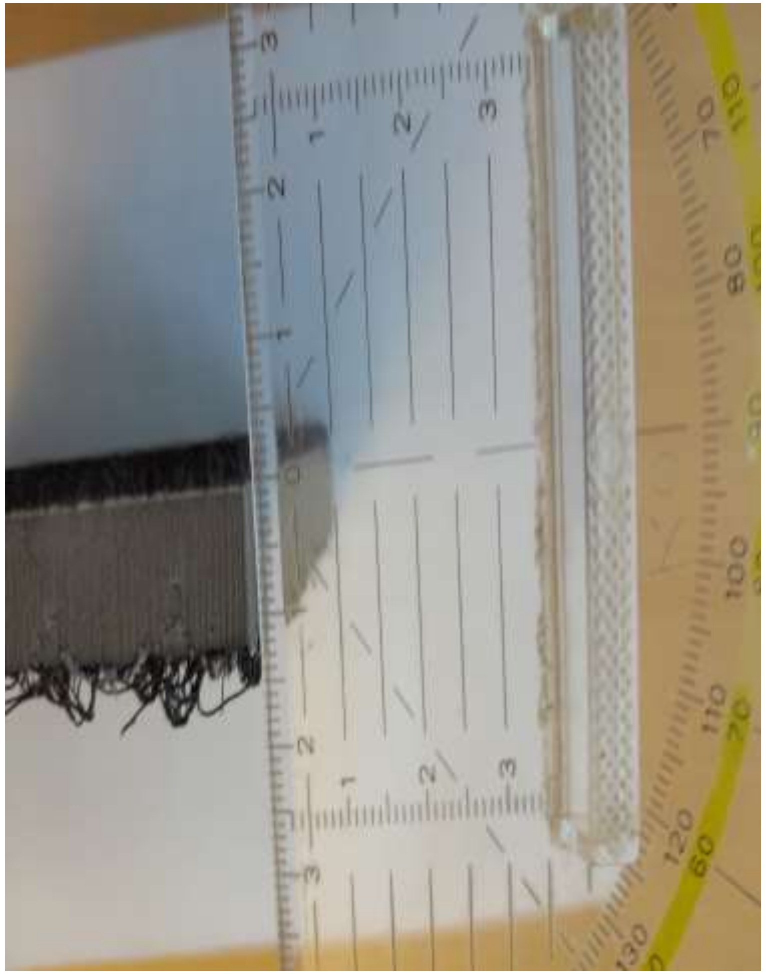
USP’s instead of LERP’s





Vibration Isolation With USP

USP for Vibration Mitigation



Case Study: Elastic USP for Kraków Airport Link, Poland

Research Unit
Institute Bridges and Railways
Department of Civil Engineering
Wroclaw University of Technology

Wrocław University of Science and Technology

Report No. 1 / 2017

Measurement Results of Vibration Isolation Performance
Getzner Under Sleeper Pads SLS1308 at Kraków Łobzów

TASK	Measurements of Vibration Mitigation of concrete sleepers with Under Sleeper Pads (USP)
DESCRIPTION	This report is made in accordance with the free field investigations with USP from Getzner Werkstoffe GmbH
DATE OF MEASUREMENTS	14th September 2016
TEST SITE / LOCATION	Line No. 118 Nearby Station Kraków Łobzów / Poland
REPORT DATE	15th August 2017
REPORT BY	Dr. Ewelina Kwiatkowska, Dr. J. Grosel, DI M. Hein, Dr. H. Loy
APPLICATION PICTURE	

Measurement Report Wroclaw University of Technology 1 / 21

USP for Vibration Mitigation

The following figure shows the measurement sections at Line No. 118:

Fig. 1: Measurement Sections at line No. 118 without and with USP

USP for Vibration Mitigation

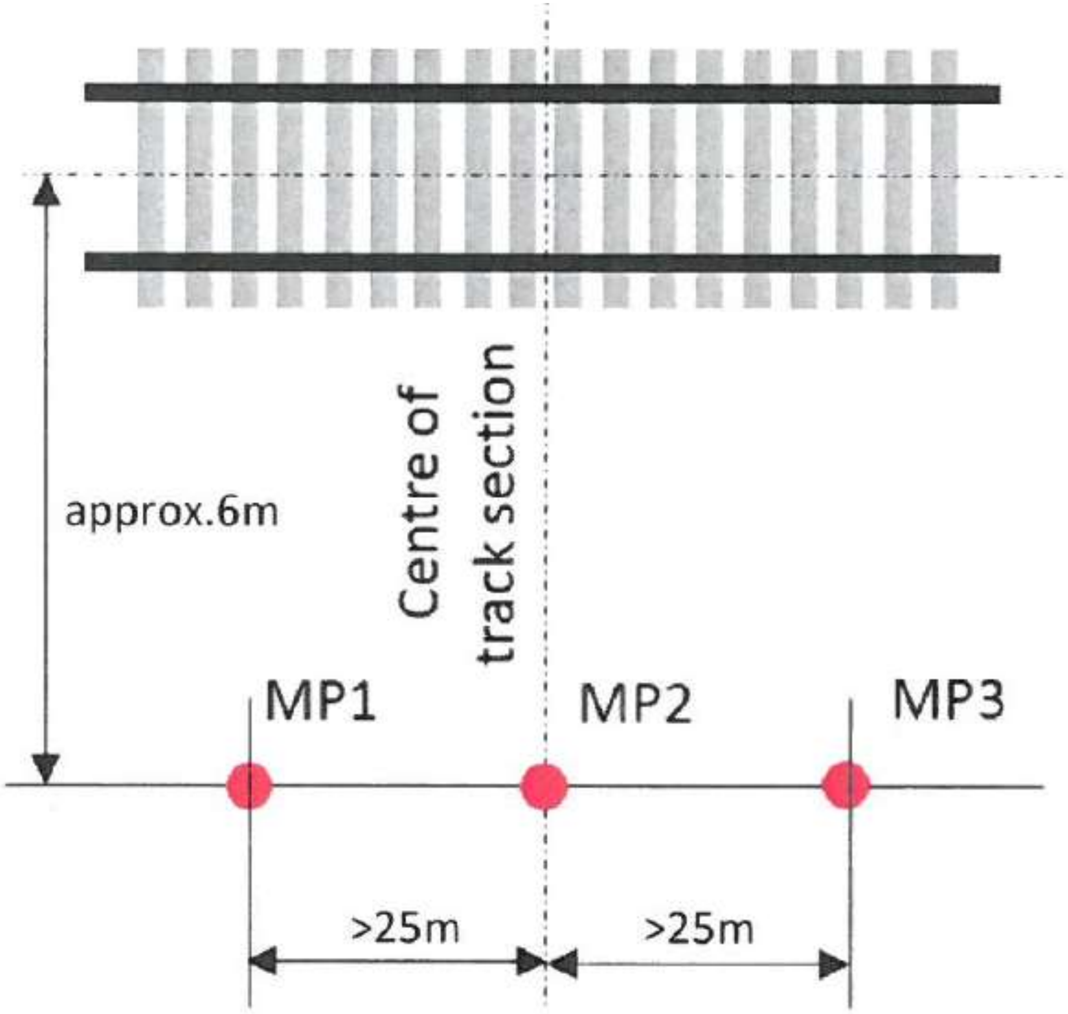
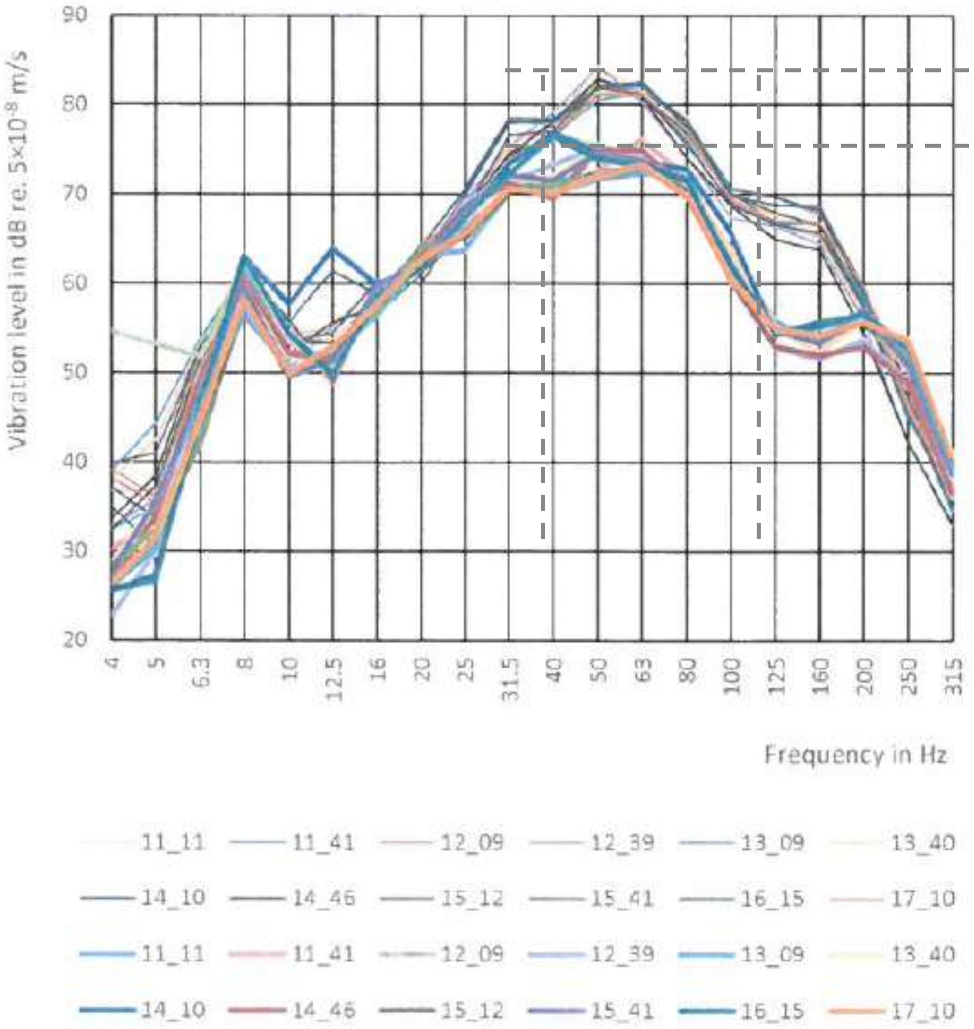


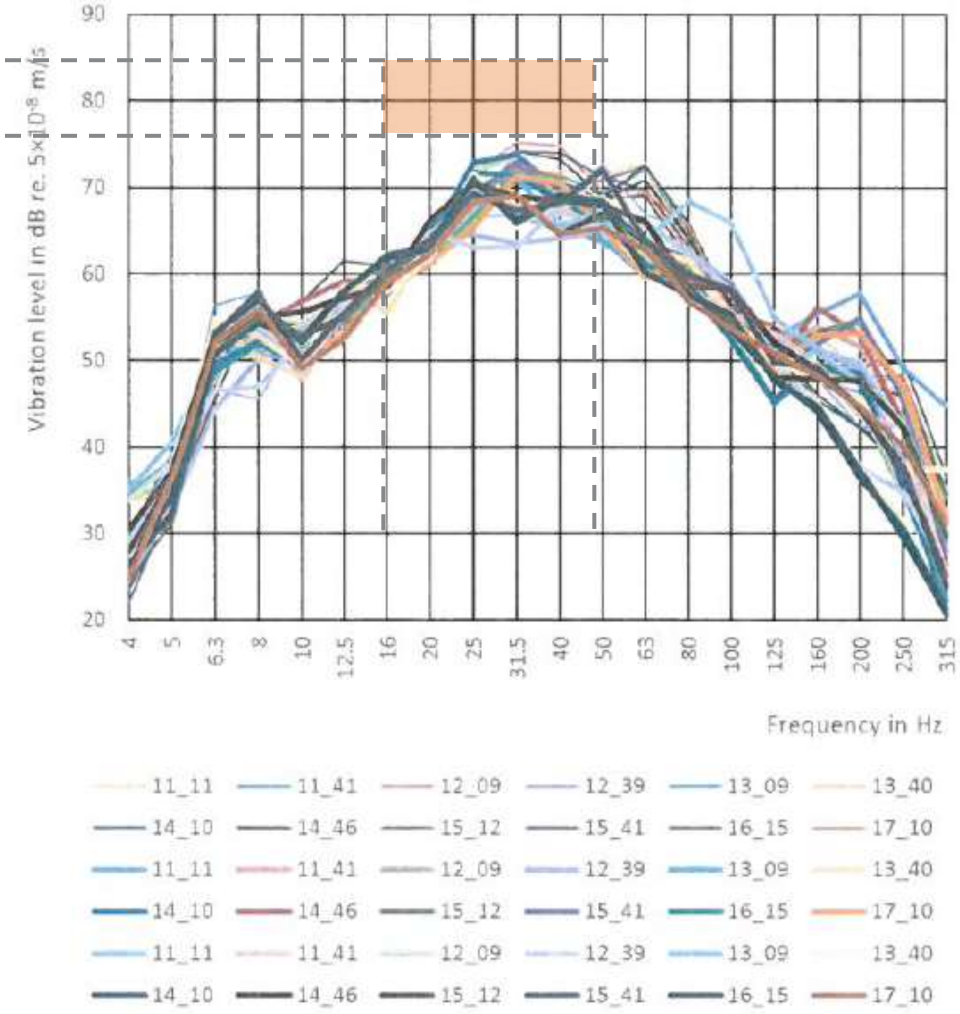
Fig. 2: Vibration measurement points within each section

USP for Vibration Mitigation

Vibration level of the track without USP

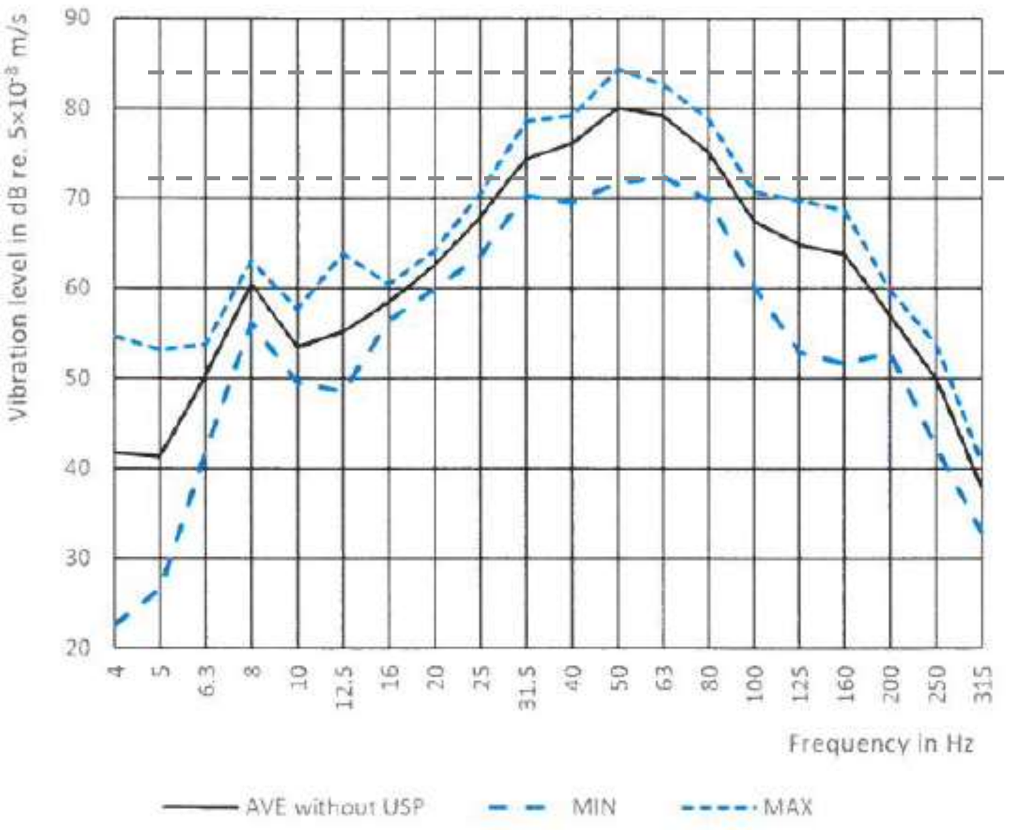


Vibration level for the track with USP

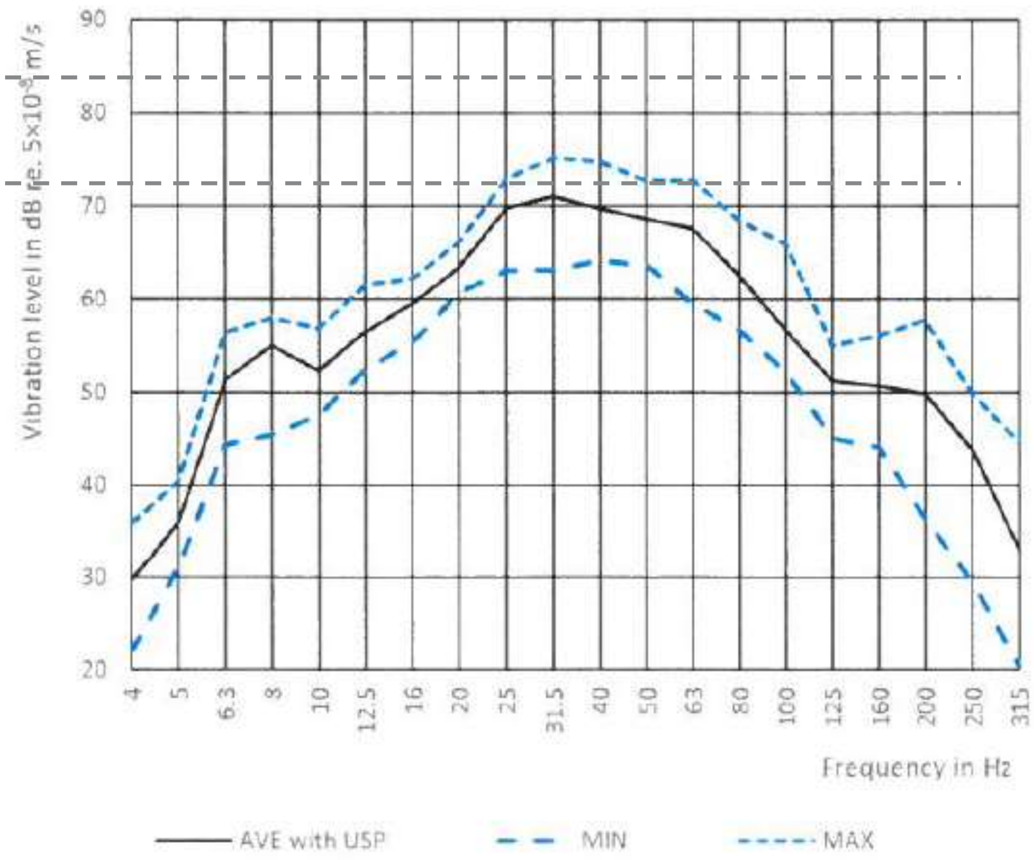


USP for Vibration Mitigation

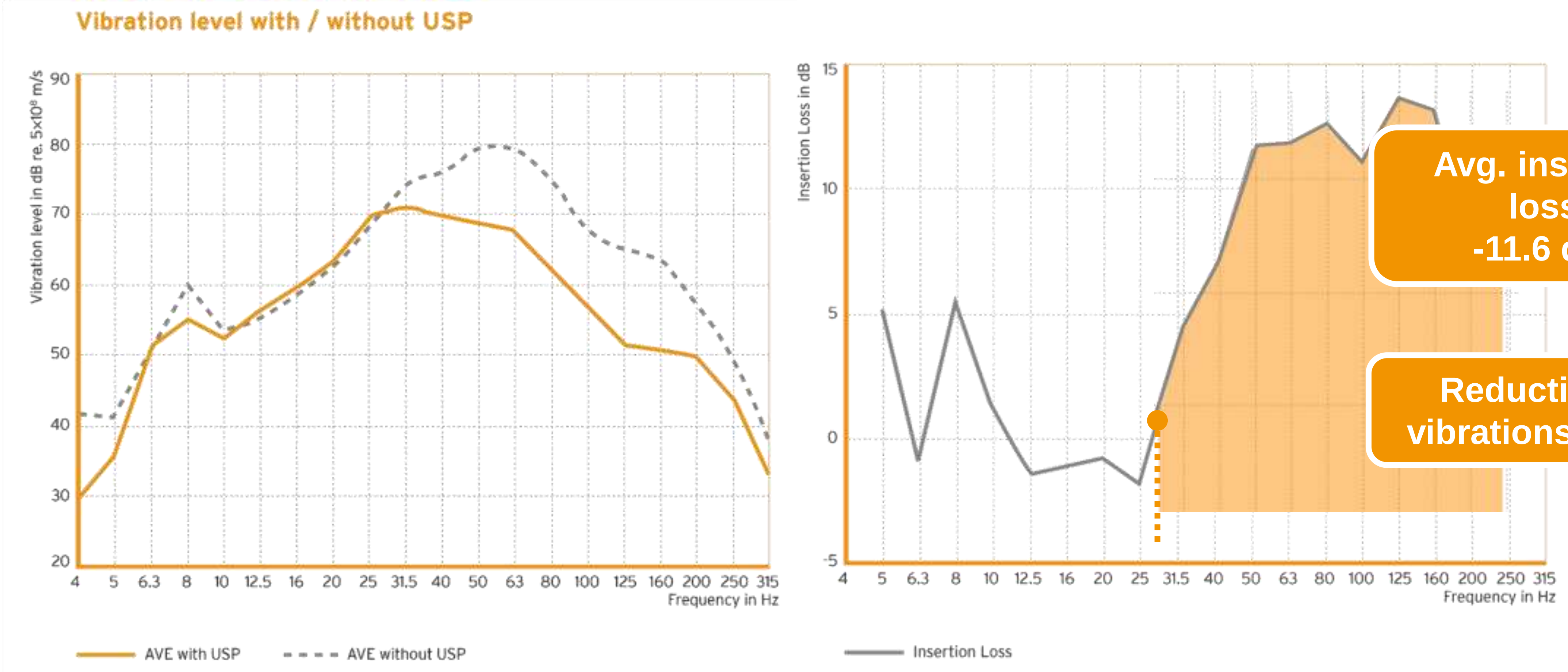
Average Maximum and Minimum Vibration Level
Without USP



Average Maximum and Minimum Vibration Level
With USP

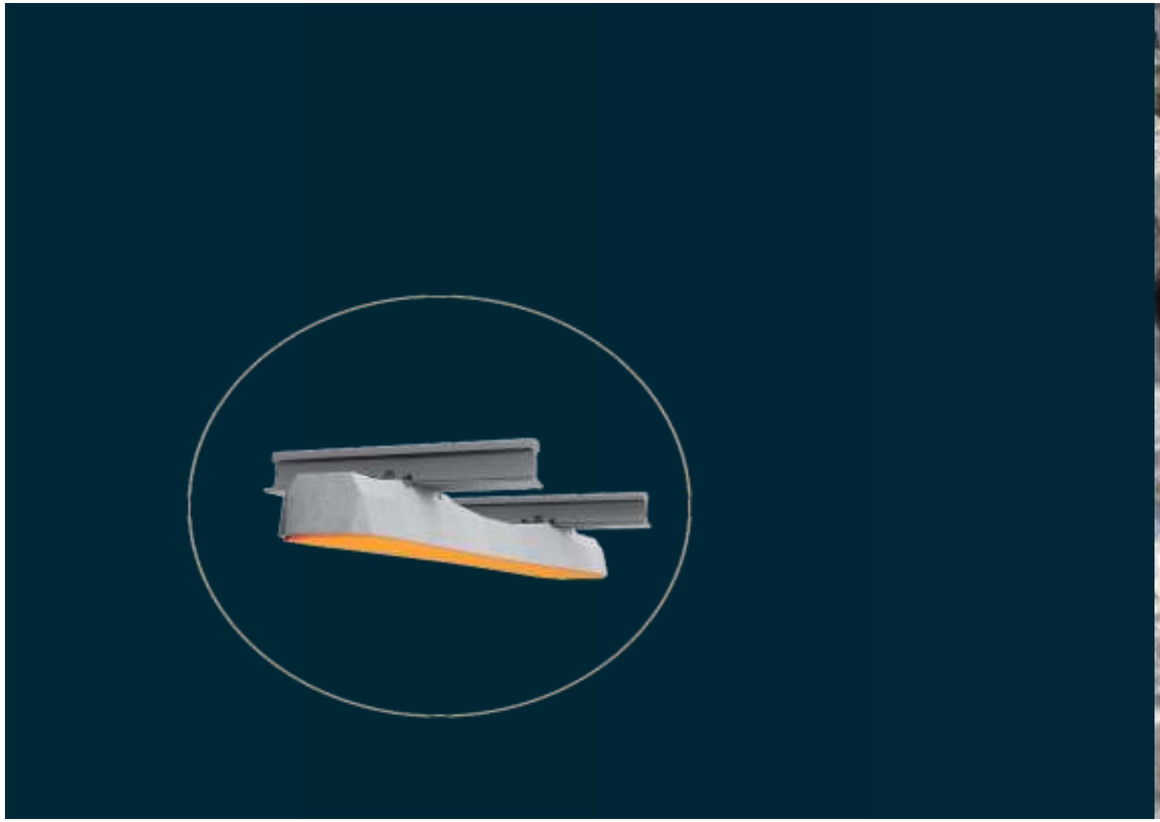


Kraków Airport Link: Vibration Reduction with USP Sylomer® SLS 1308



Avg. insertion loss: -11.6 dBv

Reduction of vibrations: -74 %



Shallow Ballast Height with USP

USP- Under Sleeper Pads

ÖBB test track Markersdorf

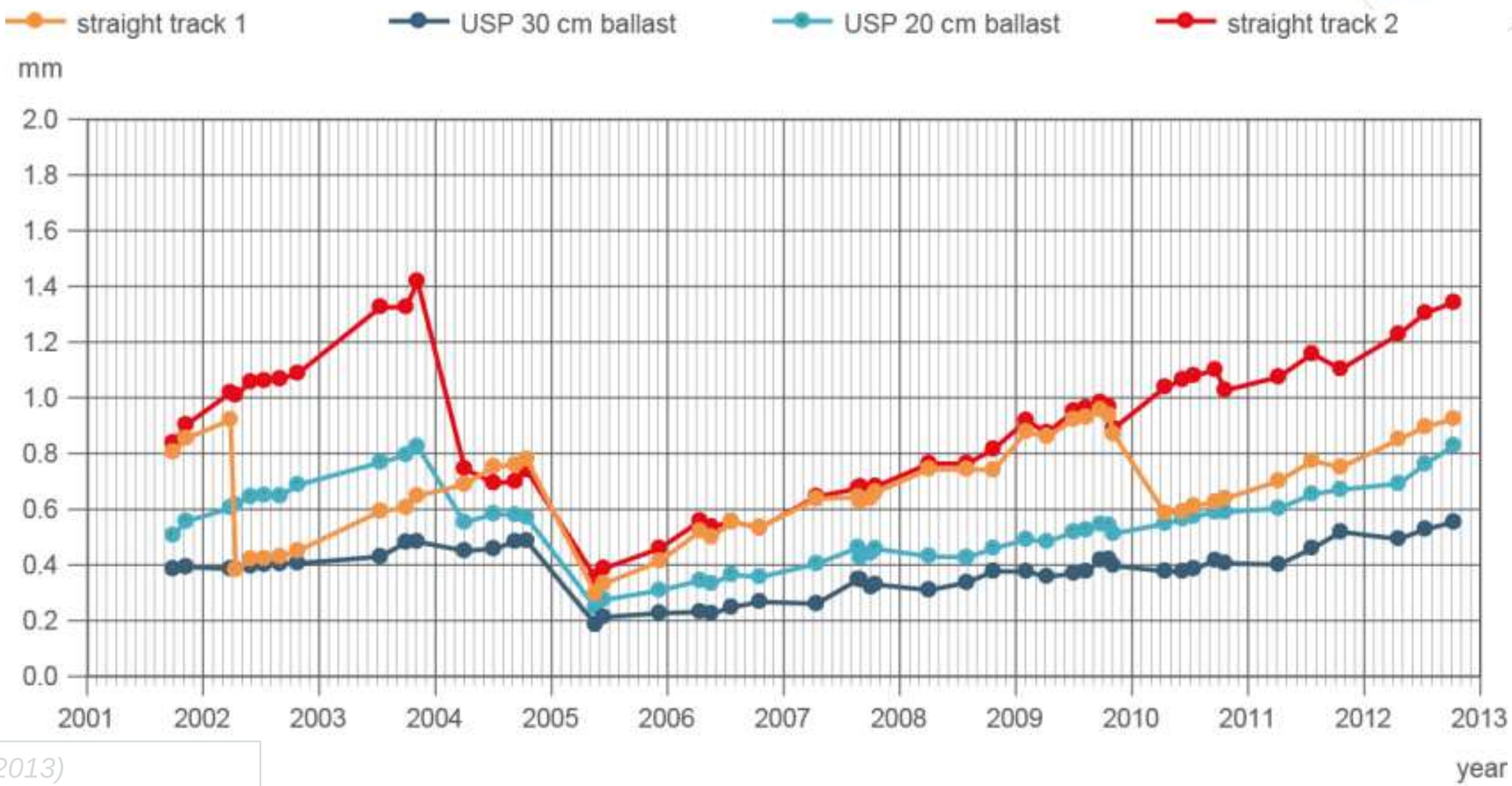
ÖBB test track Markersdorf

The test trials has been done on following four track sections at Markersdorf

1) Straight track 1 – 300 mm ballast without USP
2) USP 30 cm – 300 mm ballast with USP
3) USP 20 cm – 200 mm ballast with USP
4) Straight track 2 – 300 mm ballast without USP

The results of all four sections were compared to check the performance of USP with standard and reduced ballast cushion

Testtrack reduced ballast depth Markersdorf



Rates of change (2005 – 2013)

Straight track 1	**0,15 mm/year**
USP 30 cm ballast	**0,05 mm/year**
USP 20 cm ballast	**0,08 mm/year**
Straight track 2	**0,14 mm/year**

Conclusion from OeBB

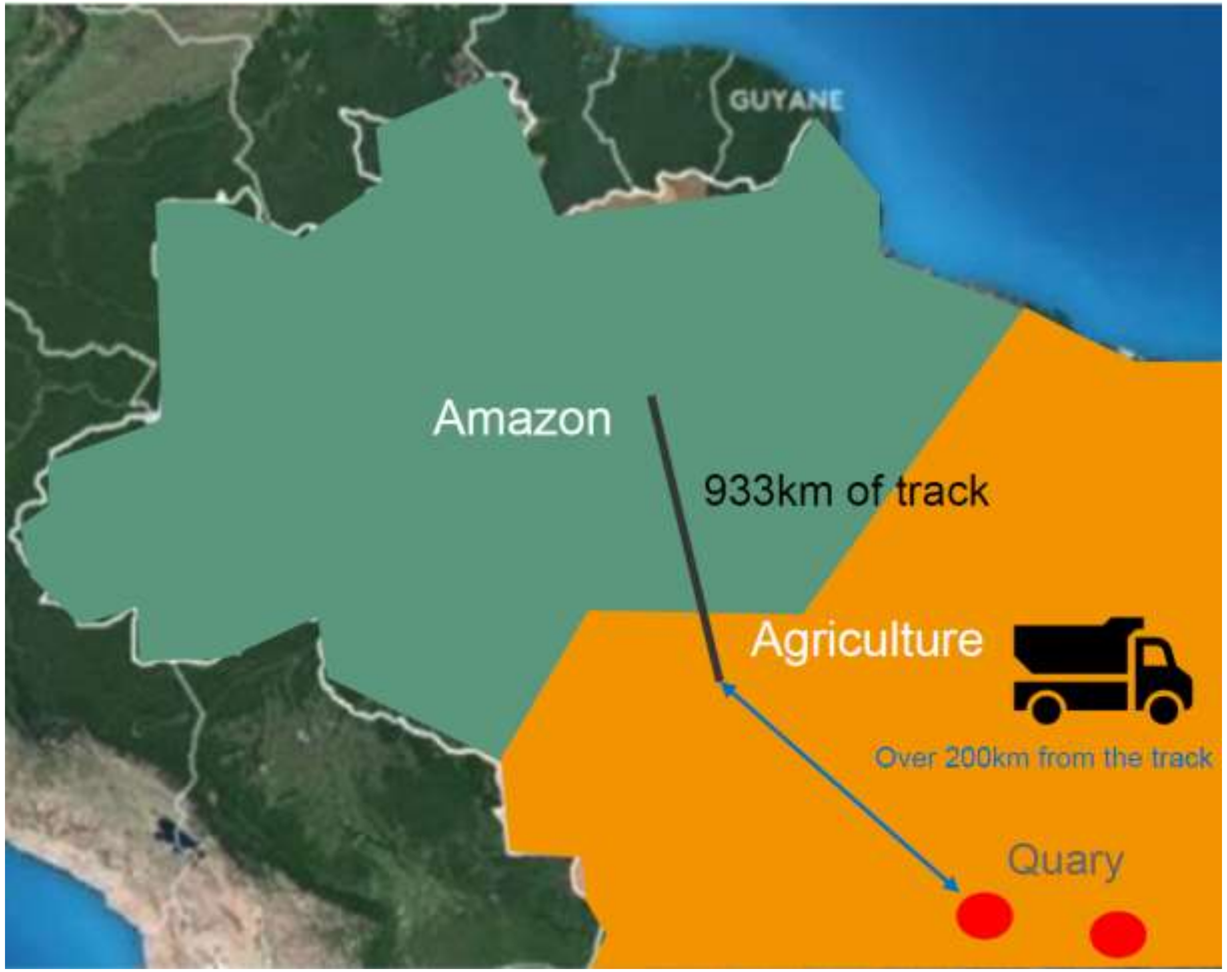
In year 2005, machine tamping has done to bring the initial track quality of all four sections at same level.

Thereafter, the track settlement in USP sections with 200mm ballast cushion is considerably lower than the straight track sections without USP but with 300 mm ballast cushion.

Average track settlement from year 2005 to 2013

Straight track 1 – 300 mm ballast without USP	0,15 mm/year
USP 30 cm – 300 mm ballast with USP	0,05 mm/year
USP 20 cm – 200 mm ballast with USP	0,08 mm/year
Straight track 2 – 300 mm ballast without USP	0,14 mm/year

Reduced Ballast Height - Ballast as the driver – Distance – Ferrogrão Project.



Under Sleeper Pad Considerations

- Contact Area Increased by up to Ten Times
- 85% Less Ballast Contact Pressure
- 60% Less Maintenance – Greater Track Availability – Cost Savings
- 30% Extension of the Lifetime of the Track – Cost Savings
- 100% Greater Load Distribution
- Greater Lateral Track Resistance (Cheaper Alternative to LERPS)
- Reduced Ballast Height Possible – 200mm instead of 300mm
- Reduction in Whole Life Cycle Costs
- Reduction in Whole Life Cycle Carbon Footprint
- Less Maintenance = Less Boots on Ballast
- Less Maintenance = Greater track availability – 24 hour railway
- Smoother Transitions
- Noise and Vibration Mitigation

- Under Sleeper Pads should be considered to be part of minimum viable product.

getzner
engineering a quiet future

Under Ballast Mats

Bridge Protection Mat

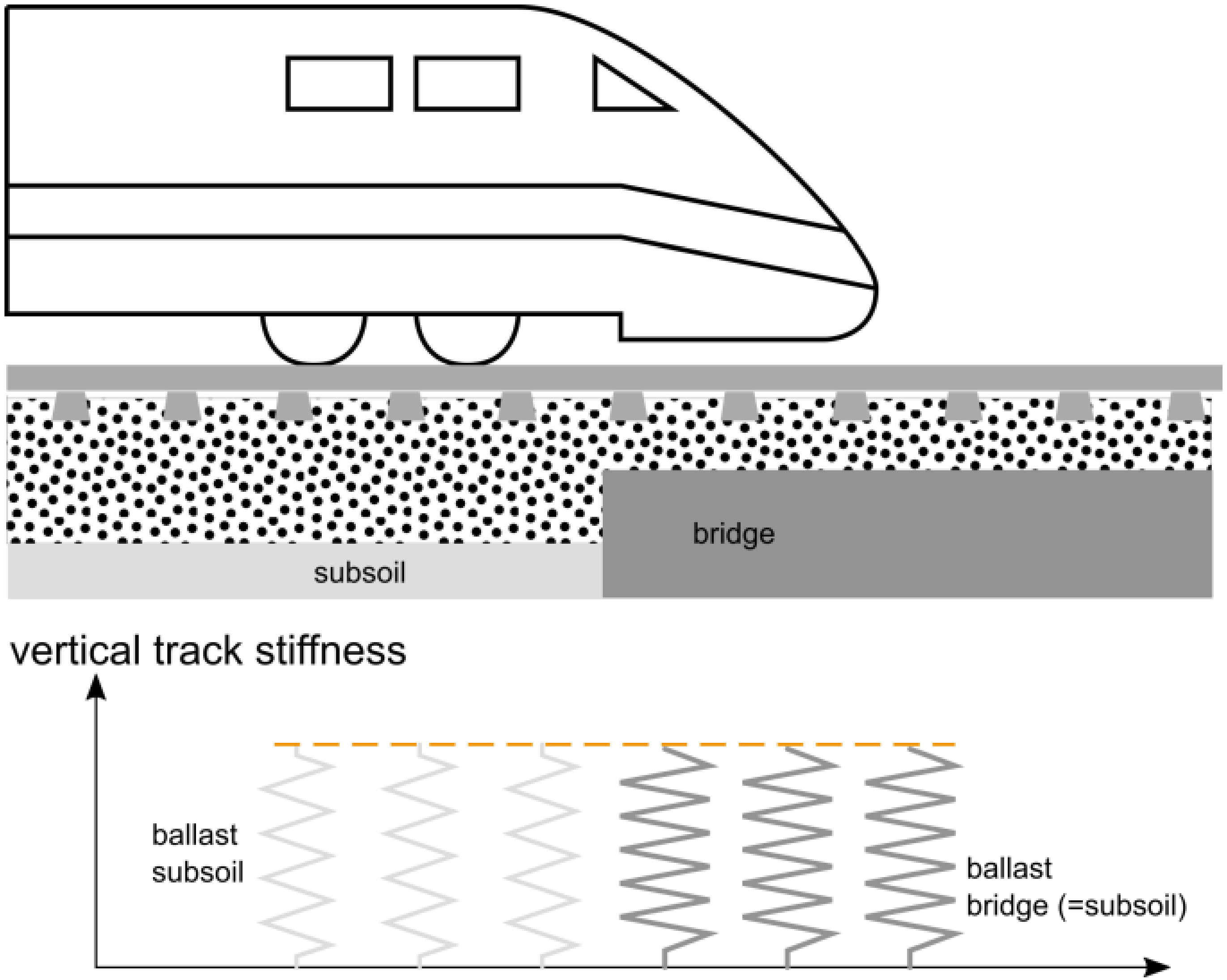
- Ballast Crushes Against Bridge deck

- Damage to Waterproofing Layer

- Damage to Bridge Deck

Bridge Protection Mat

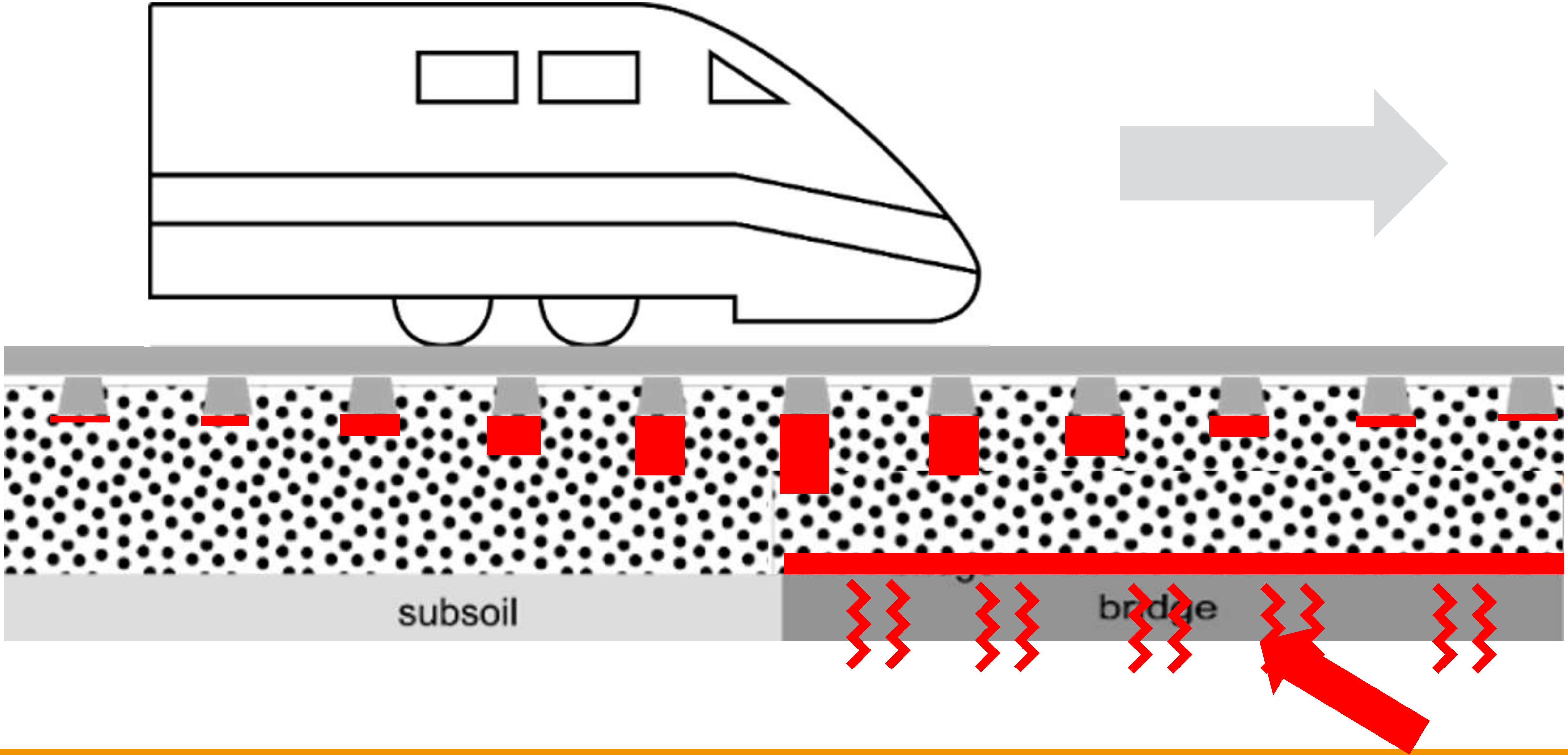
Change in Track Stiffness



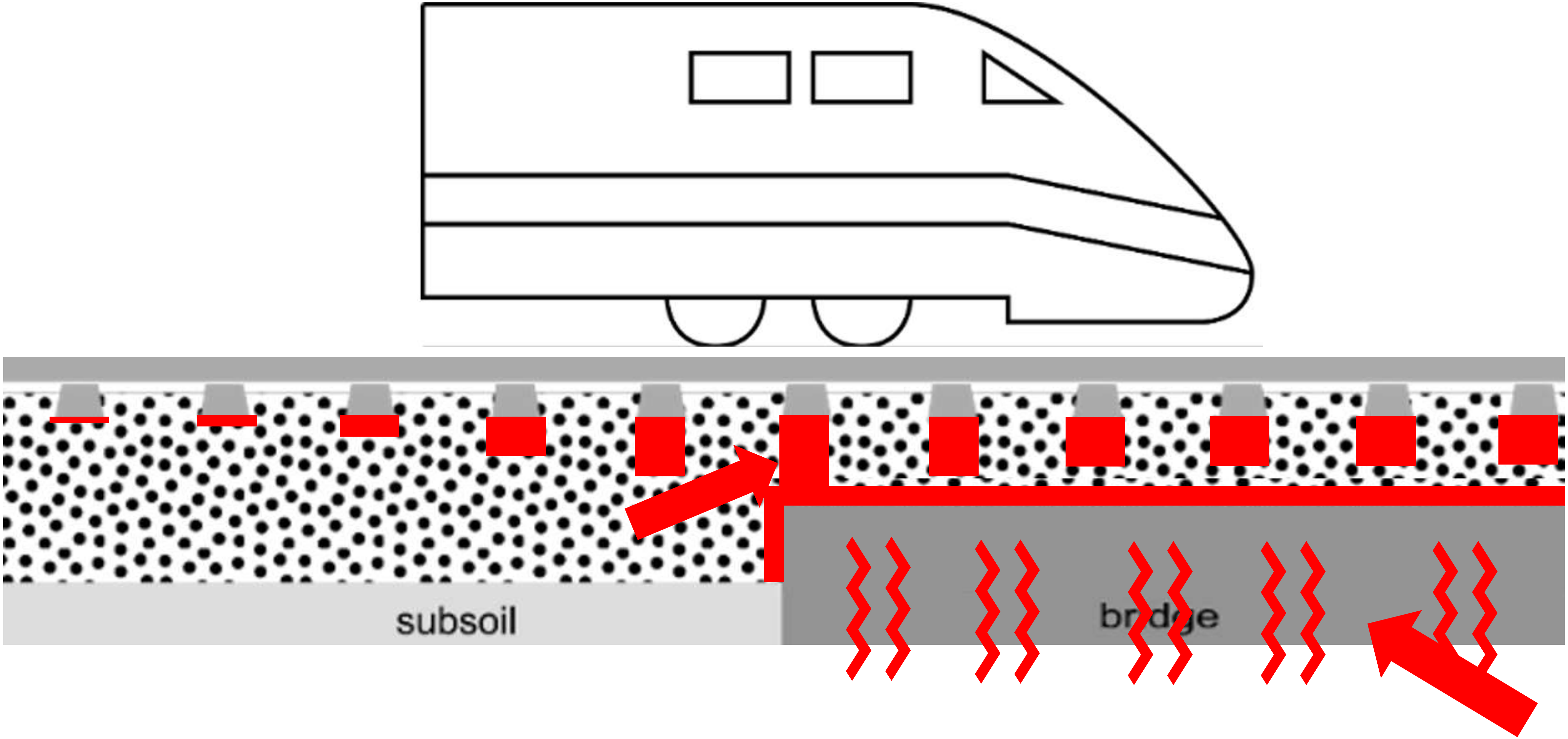
Any area where a change in superstructure design occurs

→ sudden change in vertical track stiffness

Change in Track Stiffness



Change in Track Stiffness



Outcome of Sudden Changes in Track Stiffness

- Ballast is Destroyed

- Hanging Sleepers

- Sleepers Crack

- Damage to fastenings

- Passenger Discomfort

- Closing Tracks for Maintenance

- Time and Money

Outcome of Sudden Changes in Track Stiffness

- Disturbing Vibrations

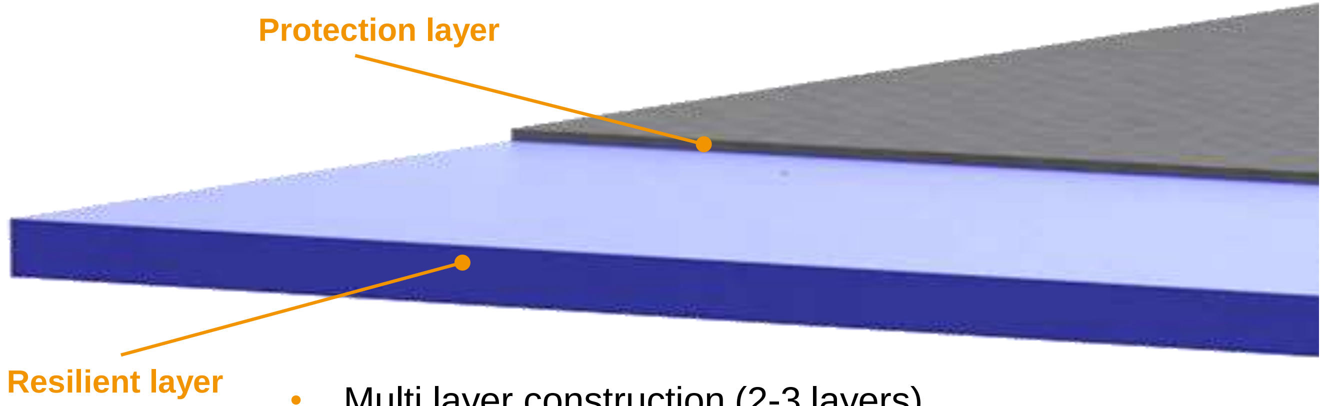
- Damage to Structures

- Noise Pollution

Railway Bridges

- The most important structures on railway lines
- High costs
- Limit the availability of a track

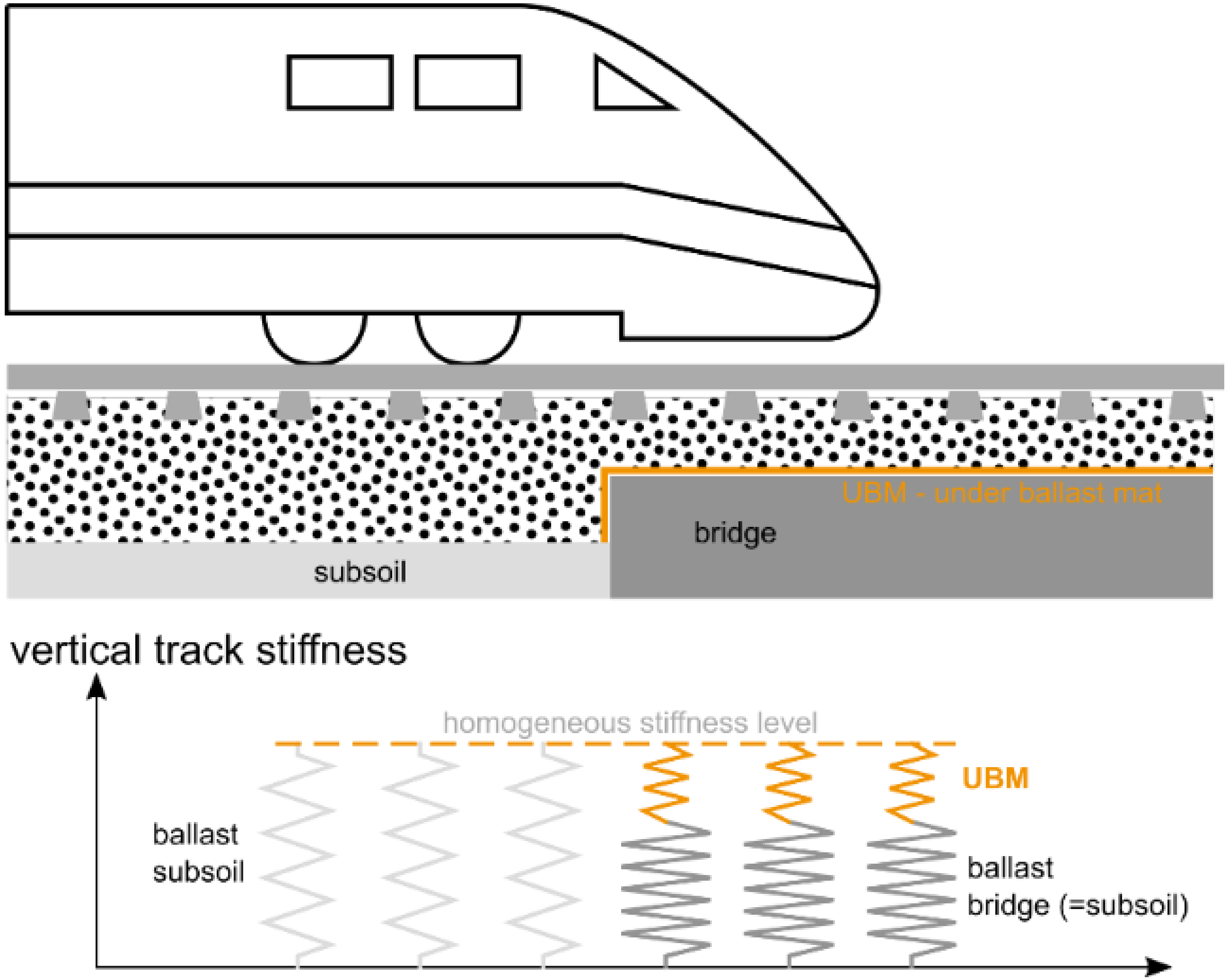
Under Ballast Mats to The Rescue



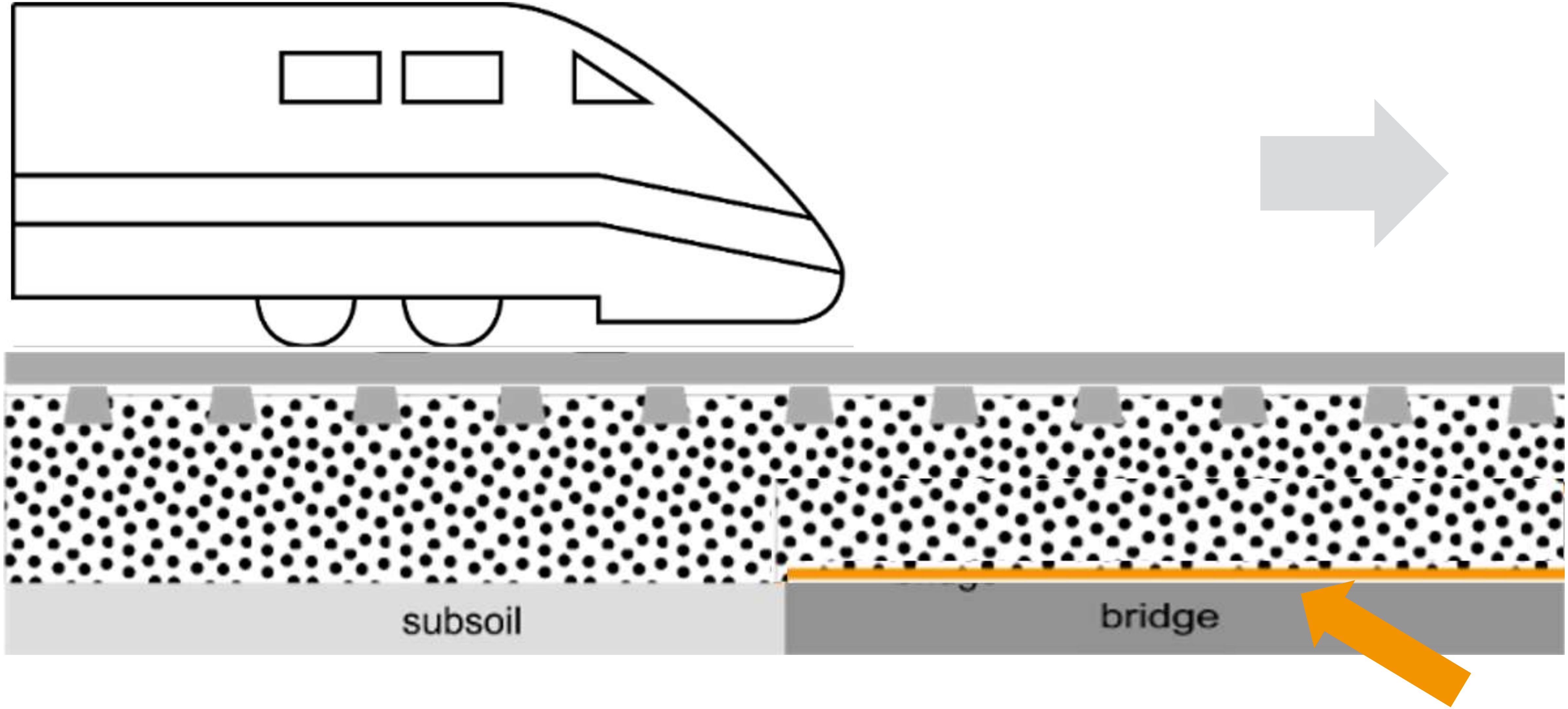
- Multi layer construction (2-3 layers)
- Various stiffnesses and thicknesses possible
- For all static stiffnesses different dynamic values
- No special geometric shapes necessary to enable the elasticity

Adaption of Track Stiffness

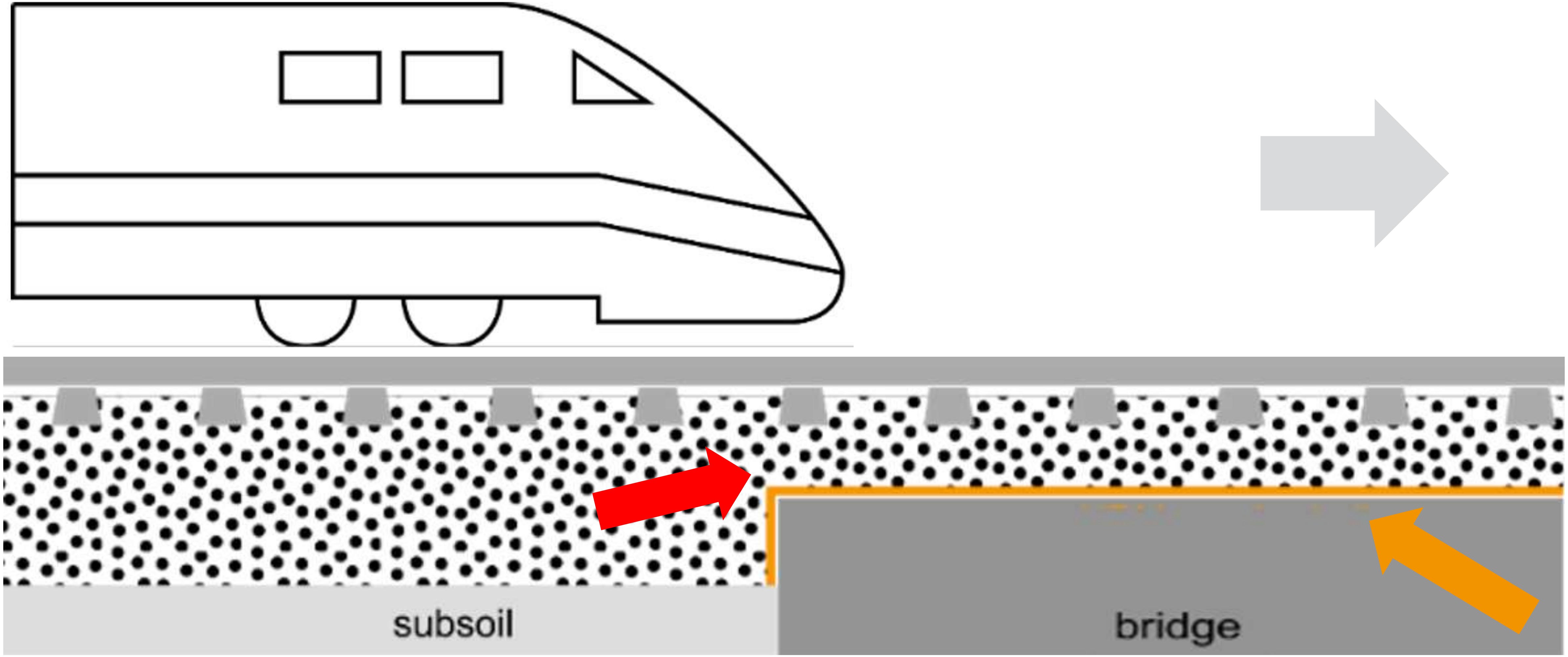
- Compensation of the track stiffness change by using under ballast mats
- Avoiding “hot spots”
- Avoiding the negative impacts



Adding Elasticity in Stiffer Areas of Track



Replacing The Missing Elasticity



Under Ballast Mats
Product Overview

- Area of application according to guideline of DB: TL 918 071
- Choice of UBM type according to project specific requirements

Urban transport

APPLICATION AREA	C_{stat}	PRODUCT NAME	THICKNESS mm	WEIGHT kg/m²
Urban Rail/Subways ≤ 130 kN axle load	C_{stat} = 0.007 N/mm³ v ≤ 100 km/h	Sylomer® A 728	28	6.0
	C_{stat} = 0.01 N/mm³ v ≤ 100 km/h	Sylomer® B 119 Sylomer® B 123 Sylomer® B 135 Sylodyn® BN 140	19 23 33 40	4.25 5.8 9.5 11.0
Light Rail lines ≤ 160 kN axle load	C_{stat} = 0.02 N/mm³ v ≤ 120 km/h	Sylomer® C 219 Sylodyn® CN 225 Sylodyn® CN 235	19 25 35	5.3 6.4 10.0
Side mats urban transp.	C_{stat} = 0.01 N/mm³	Sylomer® SM 119	19	4.3

Main line

APPLICATION AREA	C_{stat}	PRODUCT NAME	THICKNESS mm	WEIGHT kg/m²
≤ 250 kN axle load	C_{stat} = 0.03 N/mm³ v ≤ 120 km/h	Sylomer® D 319 Sylodyn® DN 319 Sylodyn® DN 325 Sylodyn® DN 335	19 19 25 35	5.8 4.4 7.1 11.2
	C_{stat} = 0.06 N/mm³ v ≤ 200 km/h	Sylomer® D 619 Sylodyn® DN 619	18 19	5.7 6.2
	C_{stat} = 0.10 N/mm³ v ≥ 200 km/h	Sylomer® D 1019 Sylodyn® DN 1019	18 18	6.5 6.3
	C_{stat} = 0.15 N/mm³ v ≥ 200 km/h	Sylomer® D 1519	18	8.0
Side mats main lines	C_{stat} = 0.03 N/mm³	Sylomer® SM 319	19	5.0

Under Ballast Mat Overview

Product Overview

Easy to Install

Easy to Install

Easy to Install

Easy to Install

Getzner UBM Can Easily
Be Connected By welding

Easy to Install

Easy to Install

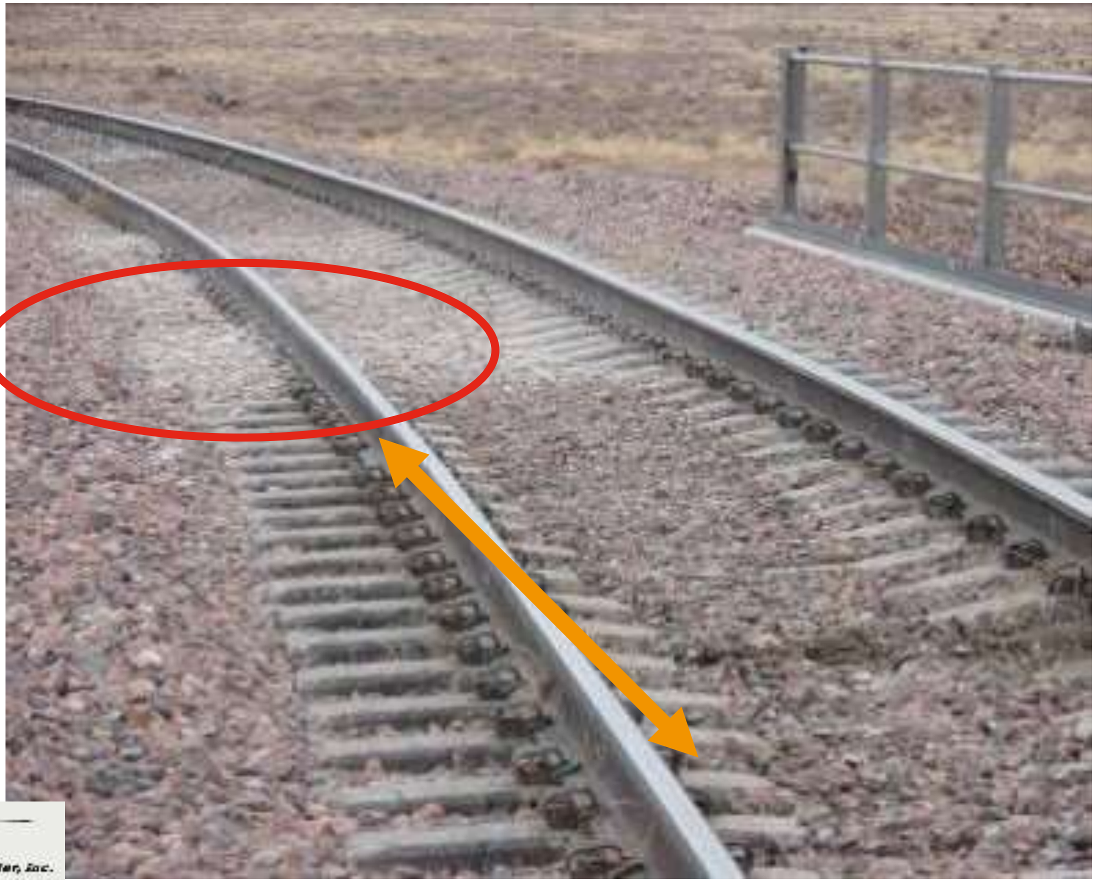
Easy to Install

Adds Defined Elasticity

High contact area due to the elasticity/plasticity of the material

Reduced ballast stress

Under Ballast Mats
Applications: Track Defects

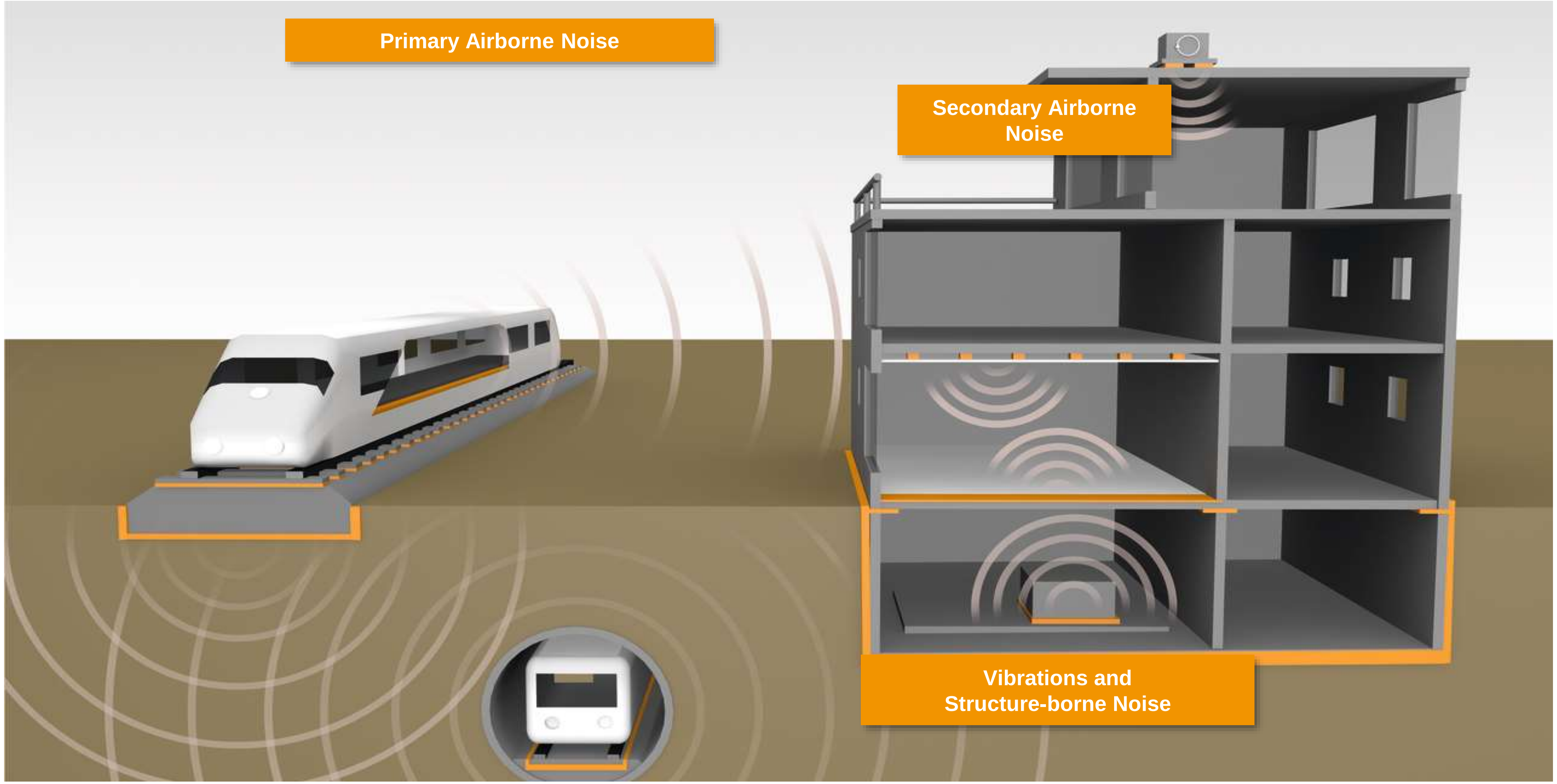


Visual Inspection After 50 MGT

Section with under ballast mat in perfect condition

Ballast heavily deteriorated (section without UBM)

Noise and Vibration Mitigation



Case Study – Long Term Behaviour - Munich

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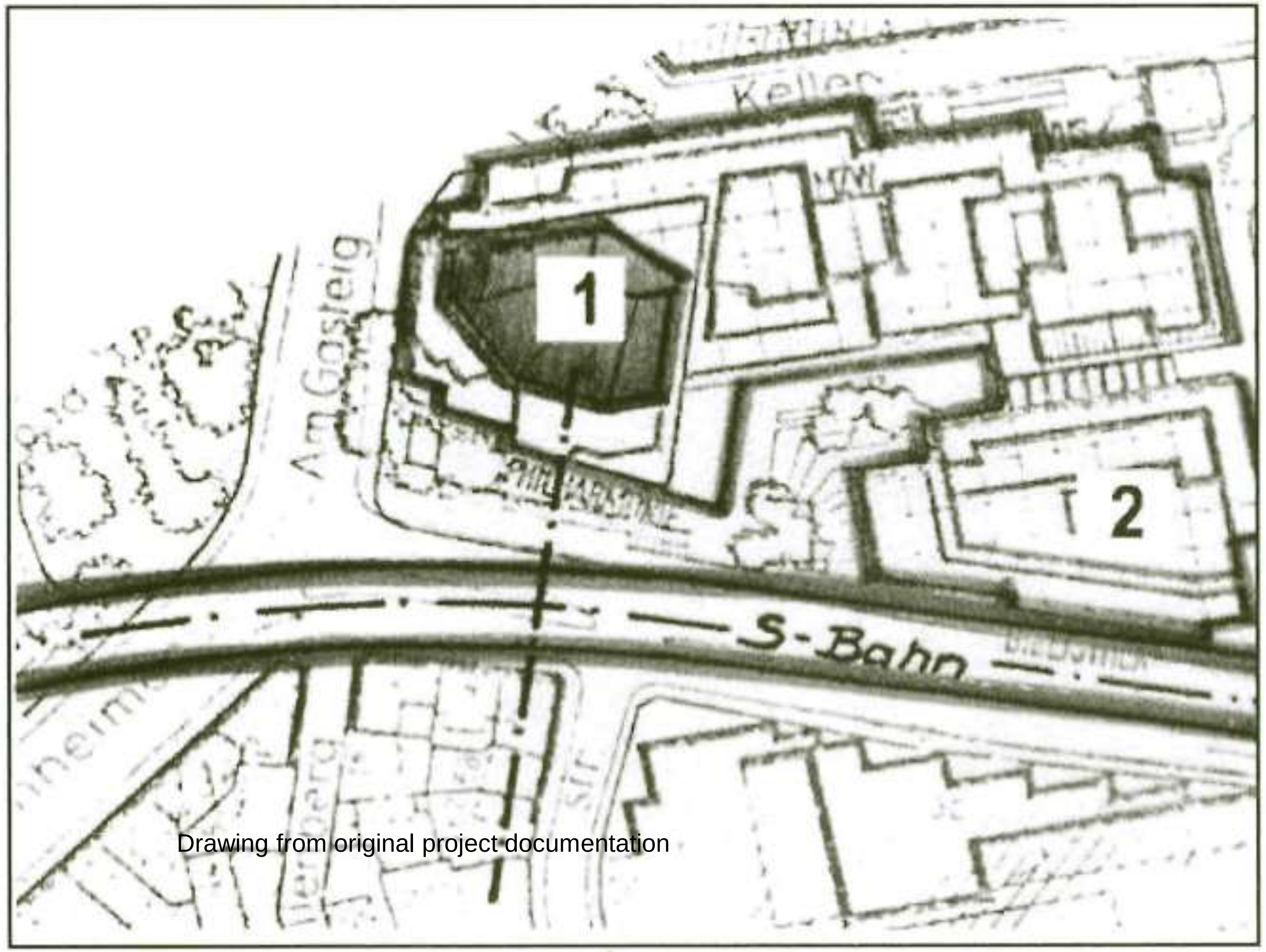
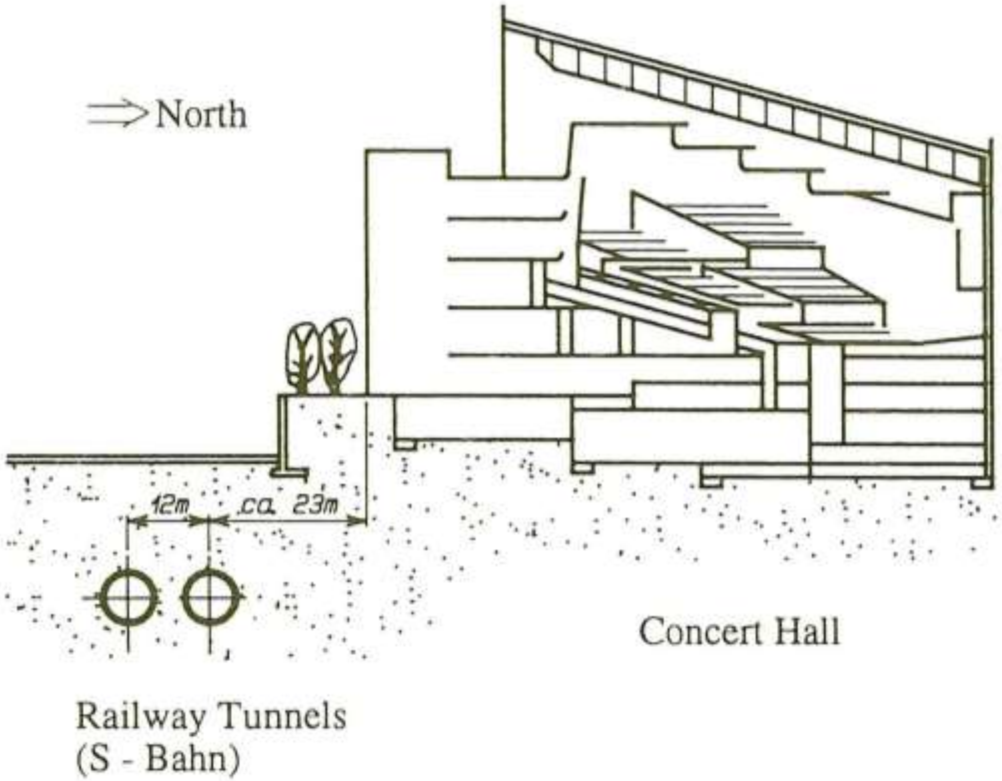
Case Study – Long Term Behaviour - Munich



Drawing from original project documentation

Case Study – Long Term Behaviour - Munich



Drawing from original project documentation

Case Study – Long Term Behaviour - Munich

- UBM completely under water
- Ballast depth: 18 cm
- Accumulated load since installation:
  1 400 000 000 load tons

Case Study – Long Term Behaviour - Munich

- Removal of mats in 2012
- Mats submerged in water

Under Ballast Mats
References: Munich (DE)

Results: Comparison of Values

	1983
	0,0083 N/mm³
	0,0388 N/mm³

After 29 Years: C_{stat} still Inside Original Specification

After 29 Years: C_{dyn} still Inside Original Specification

Under Ballast Mats
References: General Info

- Till now more than **5.000.000 m²** installed UBM; in tracks with different speeds, axle loads, geological conditions and track types (tunnels, bridges, viaducts, stations)
- Products are **qualified by independent test institutes** (Technical University of Munich, Müller BBM GmbH, Construction Technology Laboratories in Chicago, EMPA Zurich)
- **Qualified supplier for the many railway companies** (e.g. DB, SNCF, GIF, ÖBB, SBB, Trafikverket, Japanese Railways, Bane Denmark)

Benefit of the Getzner UBM for Bridge Deck Protection

Technology leader Getzner

- High performance products
- Long time proven references
- Wide experience
- Providing customized solutions and services

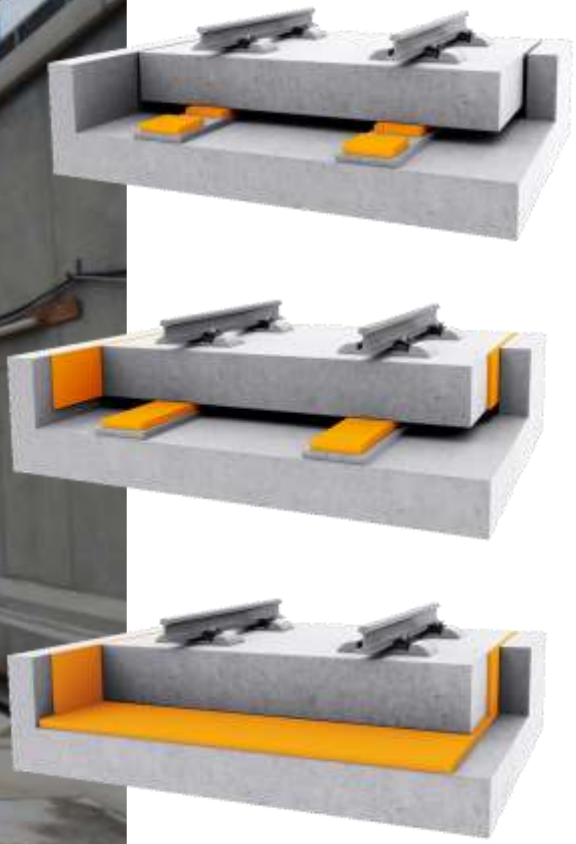
UBM installation

- Quick product installation
- Easy application of the ballast due to the drivability on the mats
- Possibility of pre-installation

Economic system solution

- Reduced components deterioration
- Less maintenance work
- High availability of the track
- Minimal life cycle costs

Mass-spring Systems (MFS)



Full Surface Mass-spring Systems - Installation Steps

Project: Samedan, Switzerland

Full Surface Mass-spring Systems - Installation Steps

Project: Samedan, Switzerland

Full Surface Mass-spring Systems - Installation

Project: Gmunden, Austria

Project: Cuenca, Ecuador

Strip Mass-spring Systems - Installation Steps

Project: Metro Sao Paulo, Brazil

Strip Mass-spring Systems - Installation Steps

Project: San Sebastian, Spain, 14 Hz

Strip Mass-spring Systems - Installation Steps

Project: Munich, Germany

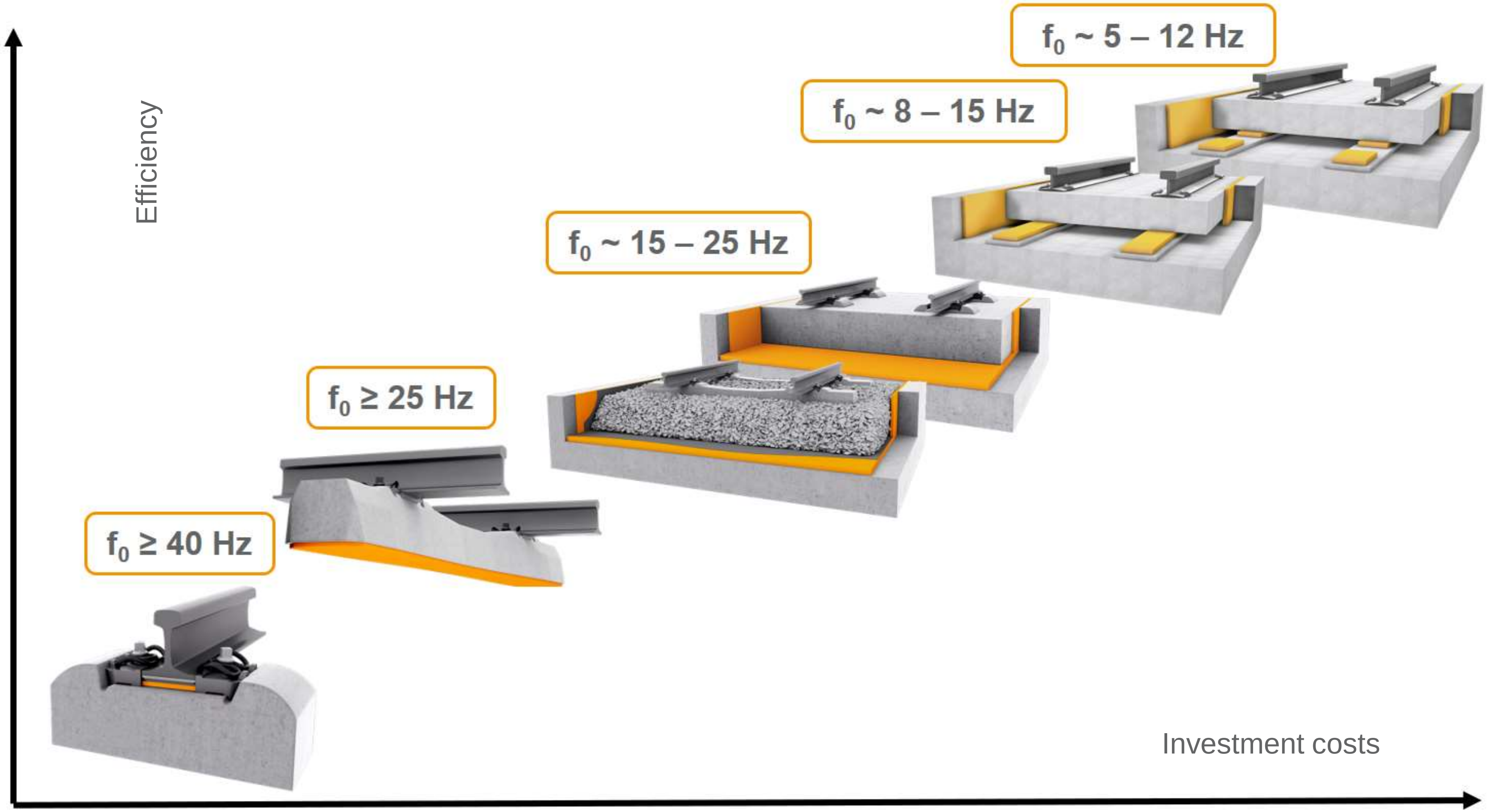
Discrete Mass-Spring Systems

Discrete Mass-spring Systems

Project: San Fernando, Spain, < 7 Hz

Project: Lainzer Tunnel, Austria

Noise and Vibration Control in Railway Systems
Obtainable Natural Frequencies

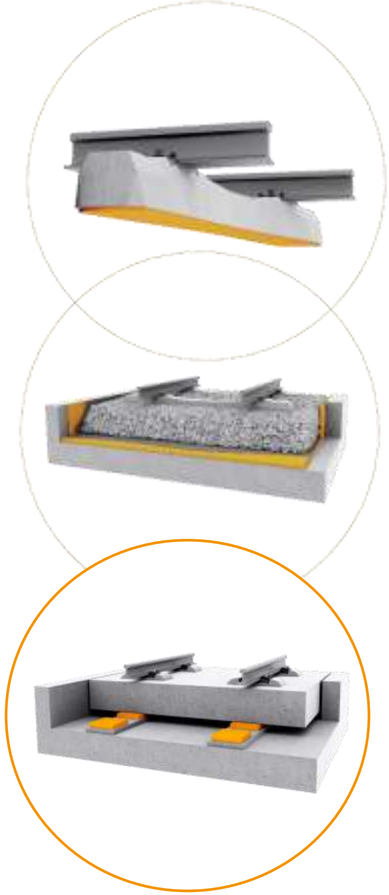


Elastic Solutions for Modern Railway Superstructure

Conclusion

standard railway superstructure

PUR elasticity



more sustainable & more silent superstructure

Thank You For Listening

?

Andy.Moore@Getzner.com

getzner
engineering a quiet future

At Getzner, sustainability is a lot more than just a buzz word.

Our products are built to last!

Our Production:

We generate electricity using natural energy sources and emit no harmful emissions into the environment

100% of our power consumption is powered by our inhouse hydroelectric power plants.

90% of the process waste heat from production equipment is used for heating and cooling our headquarters.

Our Railway Solutions:

Extend the lifetime of the track by at least 30%

Decrease the amount of maintenance required by 60%

Retain their material properties without any loss in performance.

Can be reused or recycled, feeding them back into the production cycle.

Over 50 years experience of supplying certified products, equates to a more environmentally friendly and sustainable future

Thank You For Listening

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Andy.Moore@Getzner.com

Getzner Werkstoffe
Business Units

Railway

Construction

Industry

- Andy.Moore@Getzner.com

How can polyurethane be sustainable?

Table 4. Maintenance demands in the life cycle and service life for tracks with 30 000–45 000 gt day^{-1}, straight section, rail steel grade R 260.

	Maintenance demands in the life cycle	Service life
Wooden sleepers, Rail profile 54E2	Tamping 6× Grinding 1×	35 years
Concrete sleepers, Rail profile 60E1	Tamping 6× Grinding 1×	36 years
Concrete sleepers with under sleeper pads, Rail profile 60E1	Tamping 4× Grinding 2×	50 years

Elongation of system life cycle

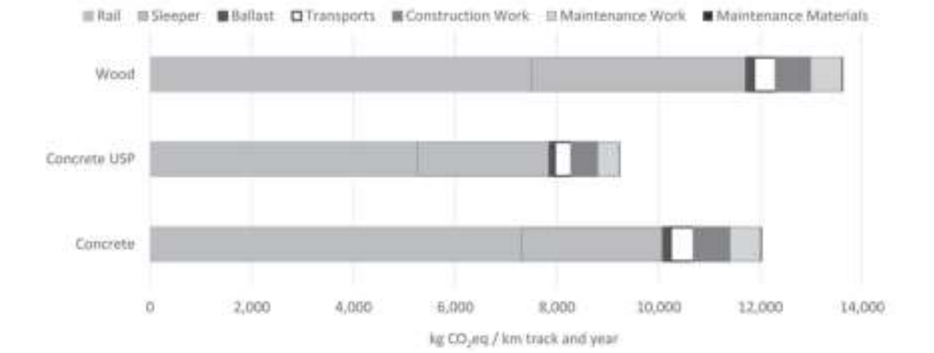


Figure 4. GHG emissions per km of track and year for straight sections, with a traffic load of between 30 000 and 45 000 gt day^{-1}.

Reduction of CO_2

\+ Reduction of noise & vibration

Source: Landgraf, M. & Horvath, A. (2021). Embodied greenhouse gas assessment of railway infrastructure: the case of Austria. Environmental Research: Infrastructure and Sustainability, 1(2), 025008.

Getzner Circular Technologies
Production of recycled polyurethane

- In-house research on mechanical & chemical recycling for production & post-consumer waste
- First products made of recycling material are already in the portfolio, more will follow

Granulate products

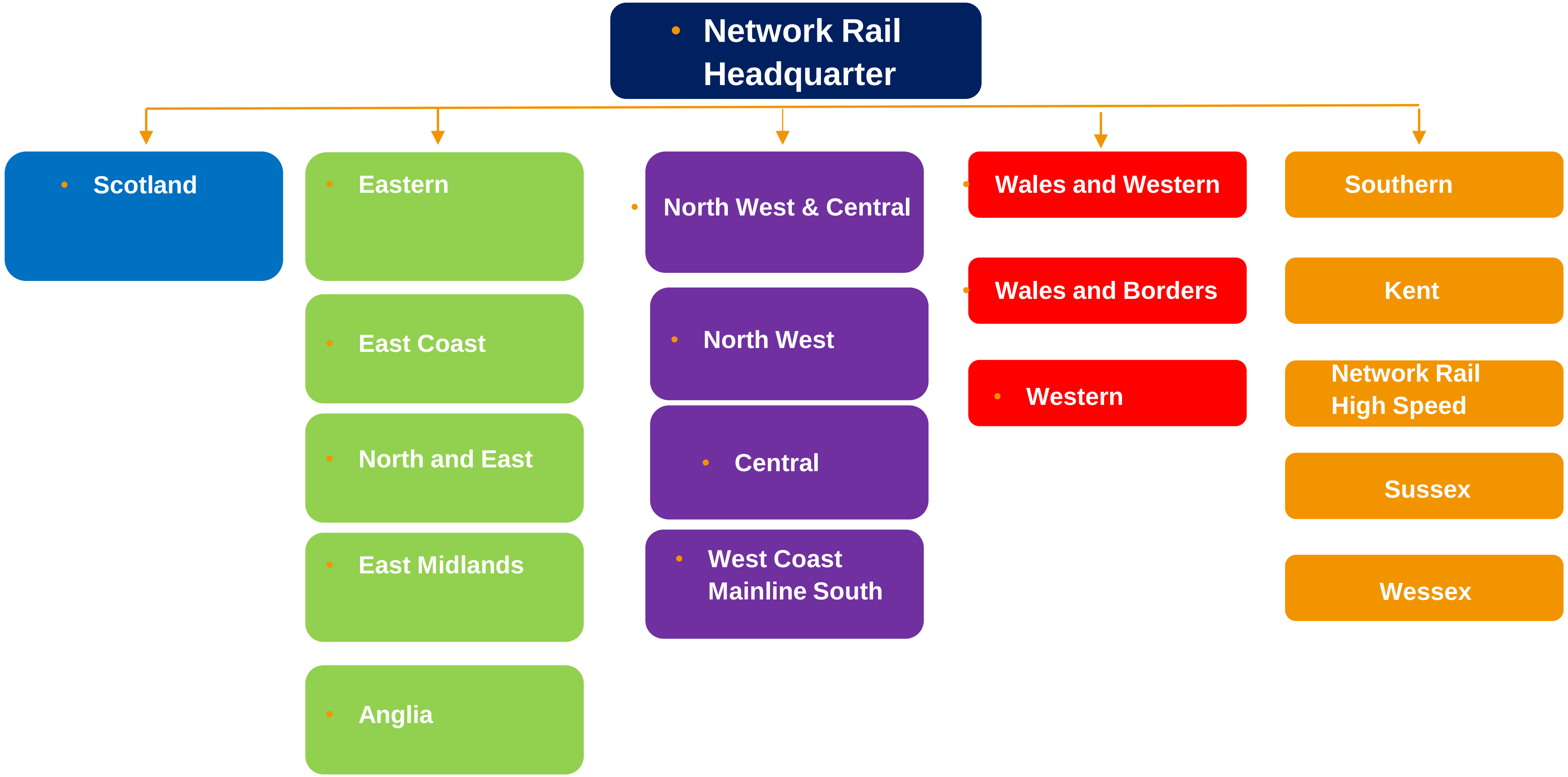
Recycled raw materials

Network Rail Structure

- Network Rail Headquarter
  - Scotland
  - Eastern
    - East Coast
    - North and East
    - East Midlands
    - Anglia
  - North West & Central
    - North West
    - Central
    - West Coast Mainline South
  - Wales and Western
    - Wales and Borders
    - Western
  - Southern
    - Kent
    - Network Rail High Speed
    - Sussex
    - Wessex

- Headquarters – Milton Keynes
- 5 Regions
- 14 Routes

Network Rail Structure



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