The Role of Elasticity in Ballasted Railway Tracks

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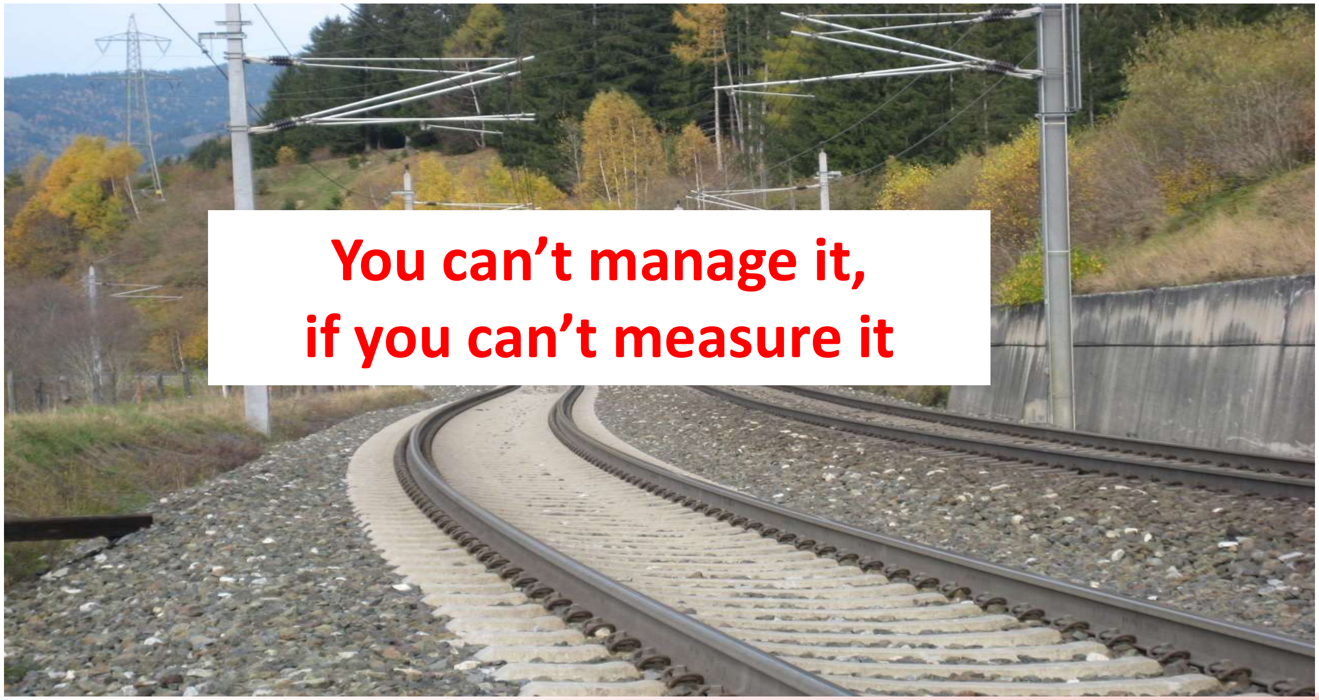
HH WRI Chicago 2021.10.21

Outline

- Load Transfer
- Elastic Behavior
- Ballast
- Subgrade
- Elastic Elements
- UTP (under tie pads)=USP

Ballasted Track

Challenge: Linear Asset



- Rail type
- Fastening
- Ties
- Ballast
- Terrain
- Subgrade
- Drainage
- Civil Structures

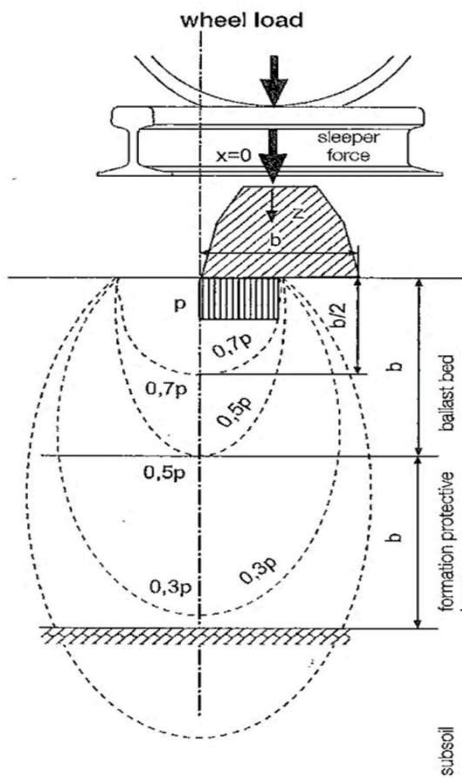
Vertical Deflection Measurement (1968)

Bending curve of the rail S49 (rail with 49 kg/m=32.9 lb/ft) with timber sleepers, measurement points at 65 cm intervals (sleeper spacing)

Sleeper#8
Sleeper#7
Sleeper#6
Sleeper#5
Sleeper#4
Sleeper#3
Sleeper#2
Sleeper#1

Load Transfer

Elastic behavior of the components



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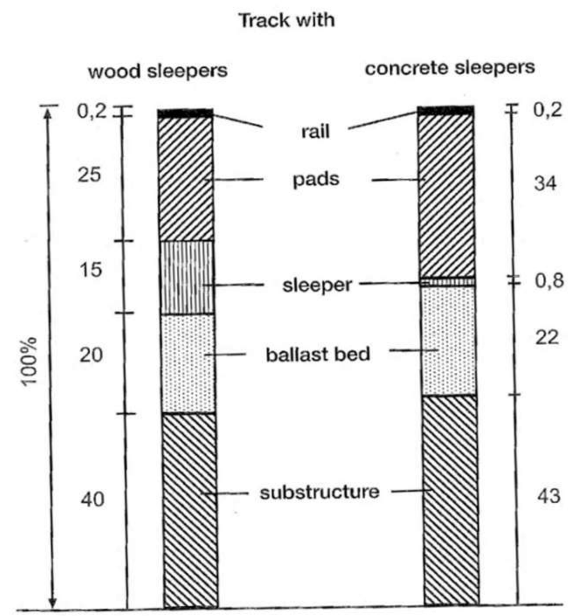
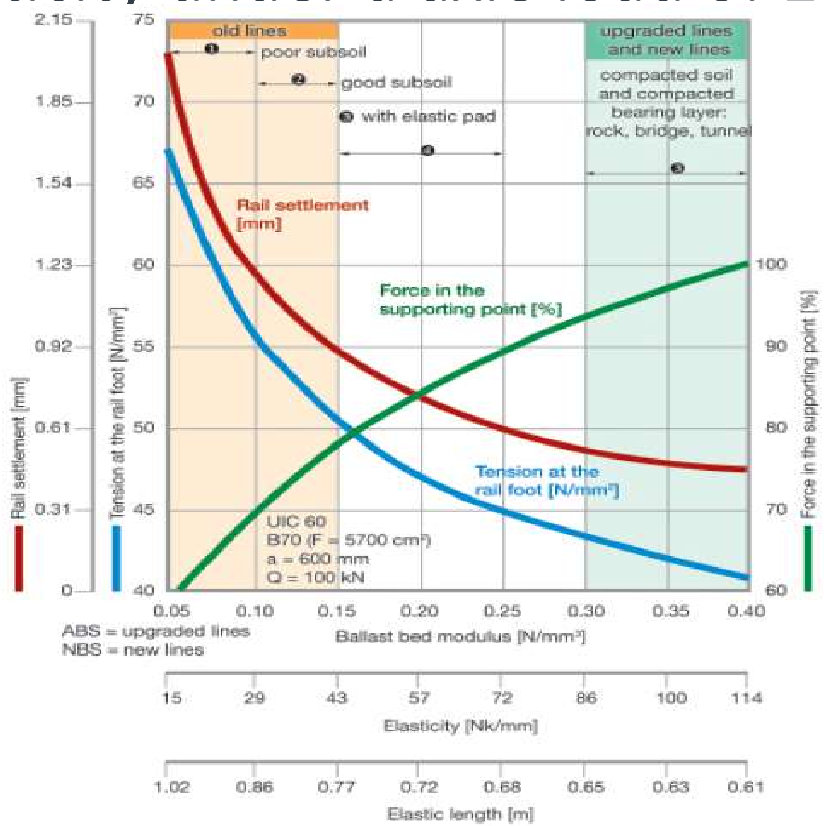


Rail settlement, rail foot tension and relative supporting force versus ballast bed modulus and elasticity under a axle load of 200 kN = 22.5 ton (US)



Rail 60 E1=132.7 lb

Sleeper spacing = 23.6 in

Wheel load = 11.24 ton(US)

1 N/mm^2 = 145 psi

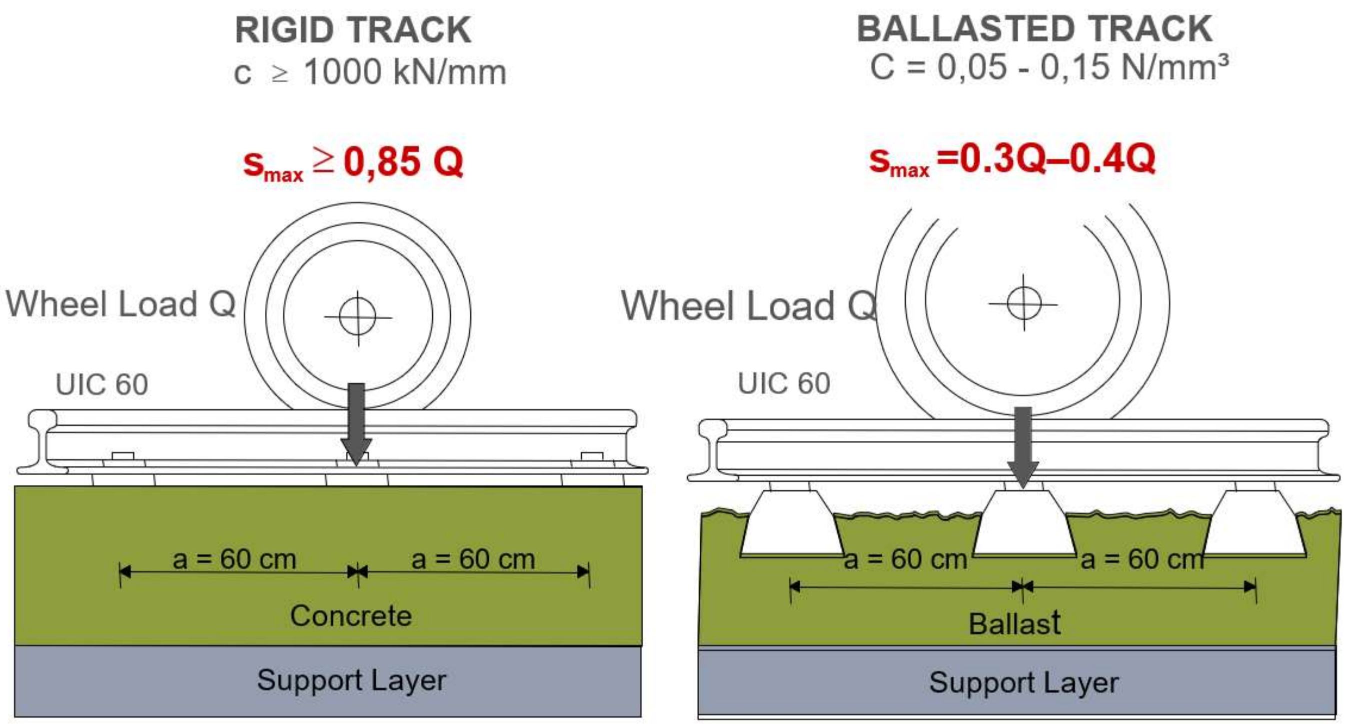
1 N/mm^3 = 271447 lb/in^3

1 kN/mm = 0.01459 lb/ft

1 m= 39.4 in

1 mm= (1/25.4)’’

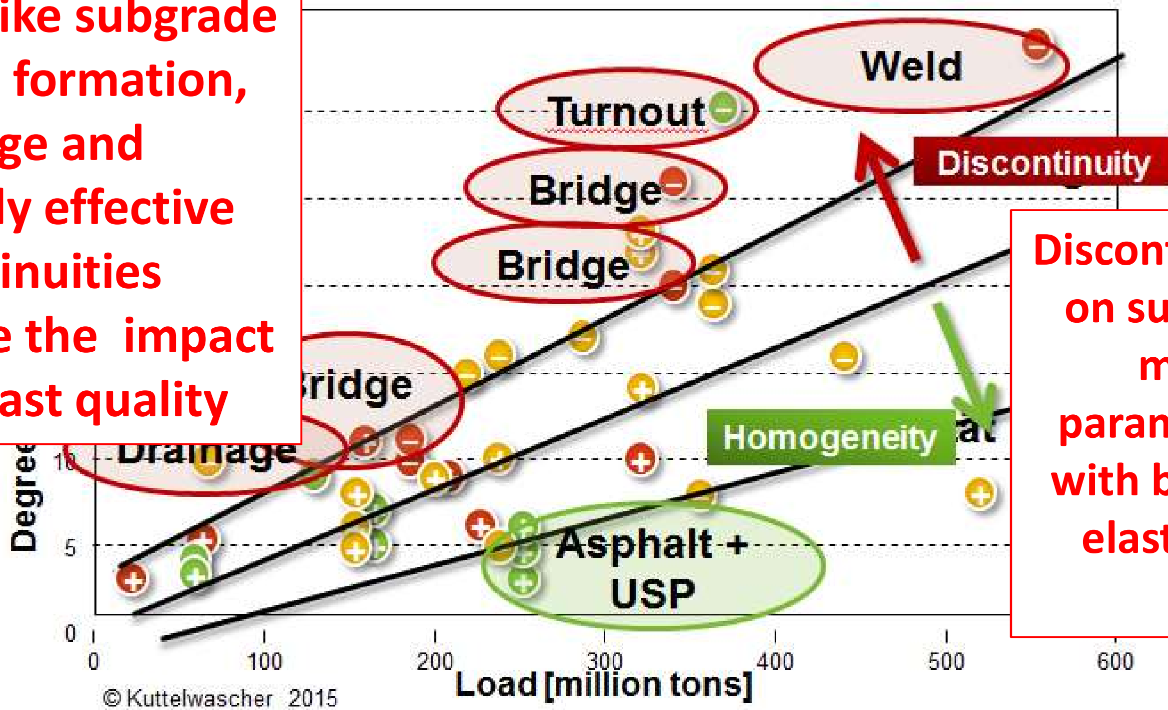
Load Transfer



Rail 60 E1=132.7 lb
Sleeper spacing = 23.6 in
1 N/mm^3 = 271447 lb/in^3
1 kN/mm = 0.01459 lb/ft

Discontinuities accelerate ballast fouling for axle loads 225 kN = 25.3 ton (US)

Constraints like subgrade (bridges…), formation, drainage and dynamically effective discontinuities superimpose the impact of the ballast quality



22.4 mm=0.88 in

Discontinuities in track and on subgrade surface are massive damage parameters, even ballast with best quality without elastic elements is too weak

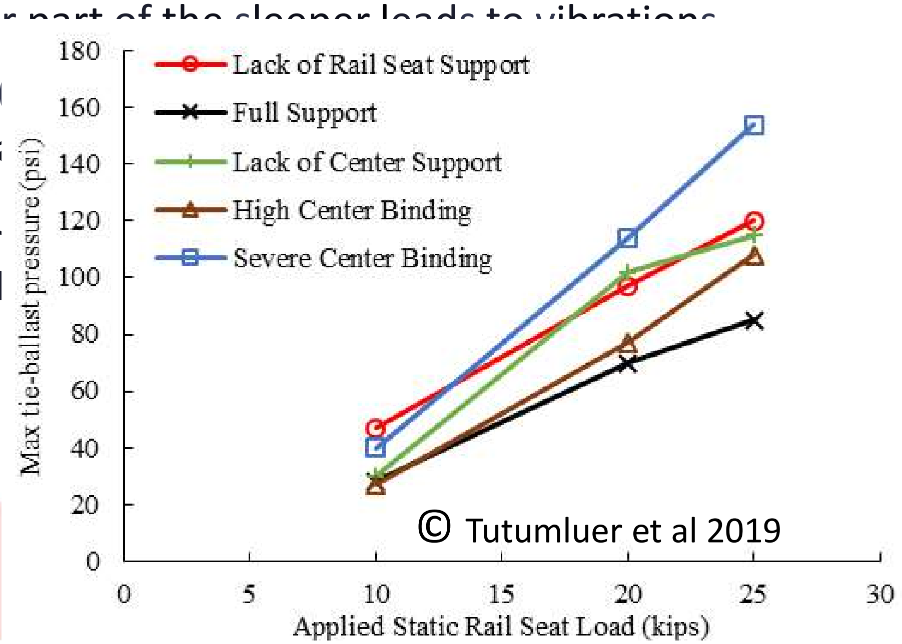
Site Measurements (2011)
4 typical deflection patterns

Type1: Continuous contact
The sleeper has continuous contact to the ballast during the load passage

Type 2: Centre gap
A gap in the center part of the sleeper leads to vibrations

Type 3 :End gaps (
vibrating consider

Type 4: Continuou
The unloaded slee

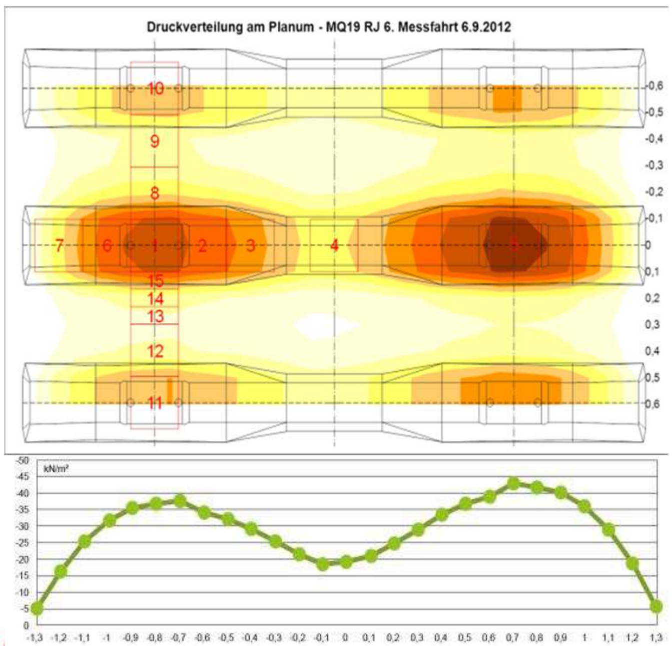


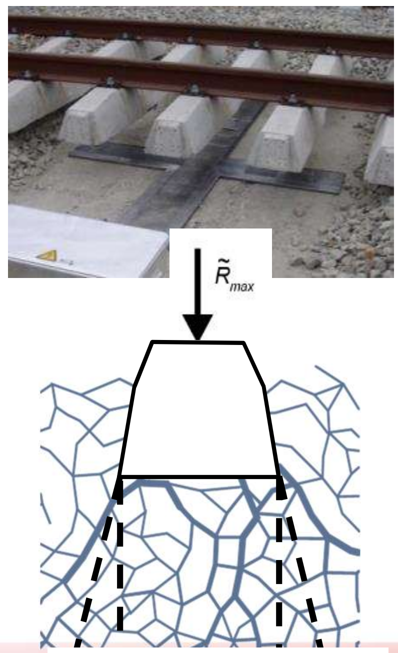
HEAVY HAU ... CTOBER 20 -

Pressure on formation

Railjet 250 kph (155.3 mph)

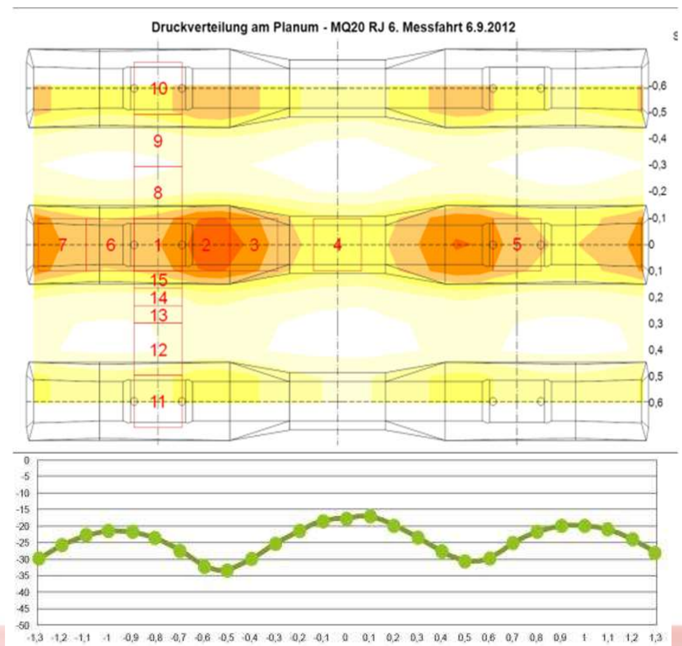
Sleeper 1



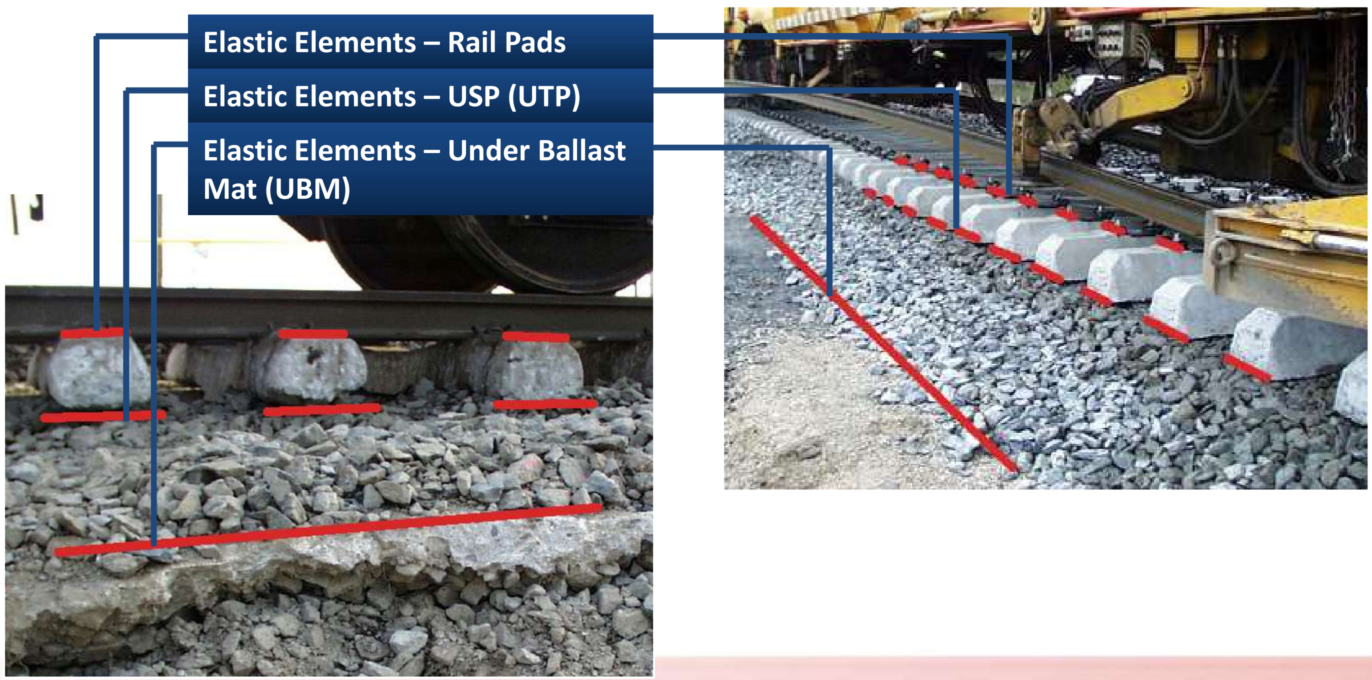


© Kuttelwascher 2014

Sleeper 75

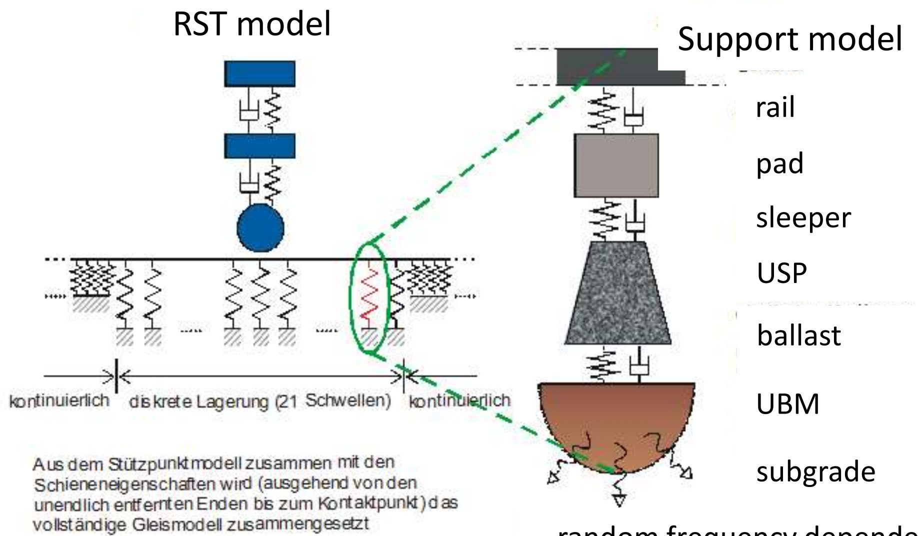


Elastic Elements



iSi Model (Breitsamter)

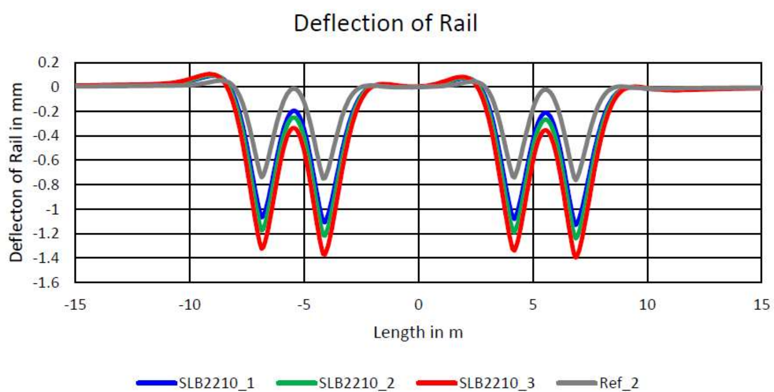
Contents all effects on elastic elements

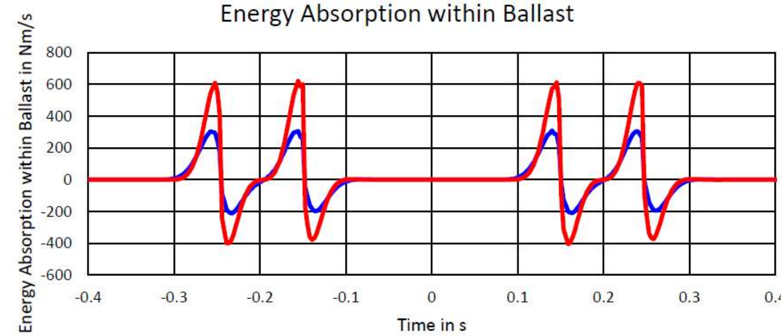


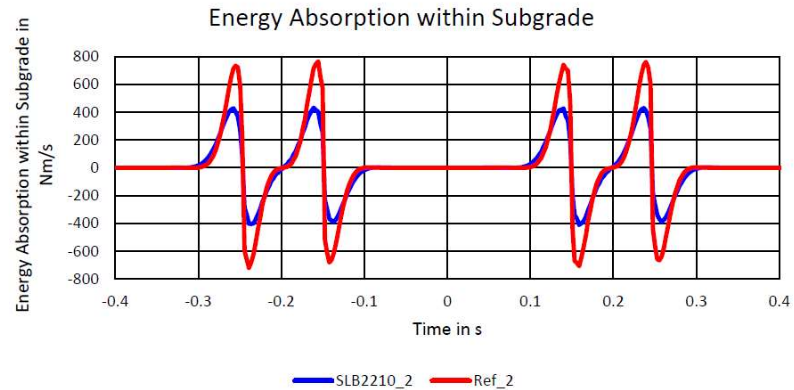
random frequency dependence of all parameters

Freight Traffic

35 t (38,5 ton),100 kph (62 mph), UTP, Rail Pad 400 kN/mm (27409 kips/ft)





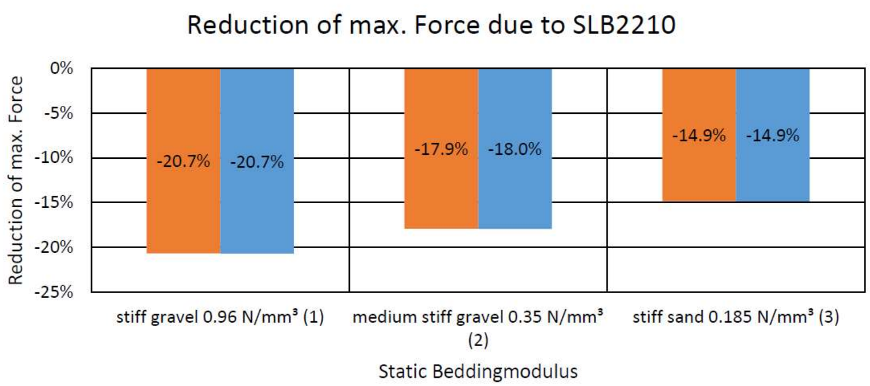


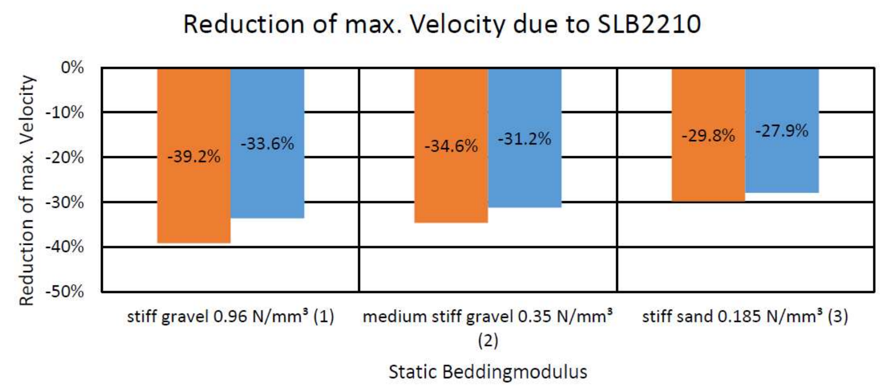
(1) Stiff gravel 0.96 N/mm³ = 3556 lbs/in³
(2) Medium stiff gravel 0.35 N/mm³ = 778 lbs/in³
(3) Stiff sand 0.185 N/mm³ = 685 lbs/in³

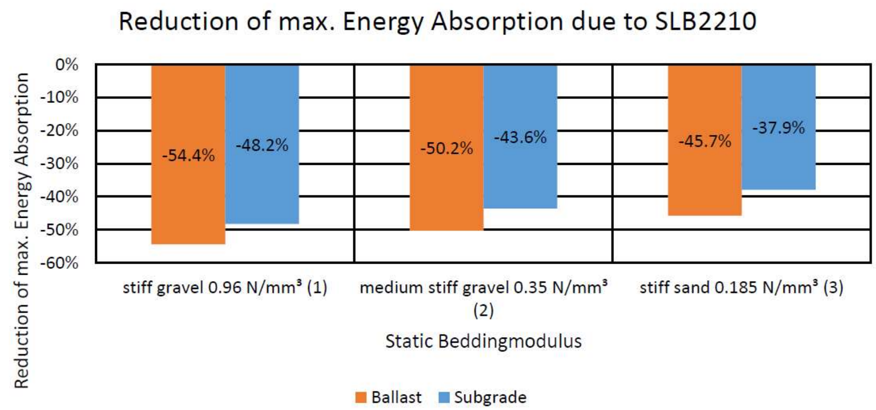
100 Nm/s = 73.75 ft-lb/s = 100 W

Freight Traffic

35 t (38,5 ton),100 kph (62 mph), UTP, Rail Pad 400 kN/mm (27409 kips/ft)







USP Lateral Track Resistance

UIC LTR Project, Site Measurements

NEWS OF THE PROJECT

Results of the 3 Tests:

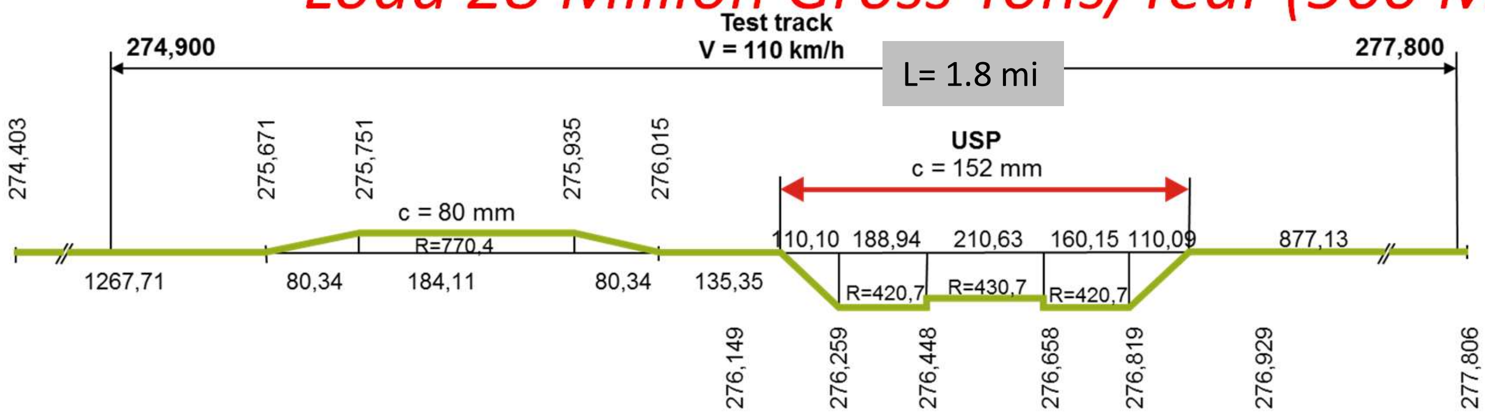
Mittelwert [kN]			without USP (for 2mm)	with USP (for 2mm)	without USP (for 4mm)	with USP (for 4mm)
DB	B91	2013	10,56	12,89	10,57	13,20
SBB		2013	16,22	19,36	23,90	29,35
TU München		2013	10,90	13,60	10,90	13,60
SBB		2015	14,17	18,22	21,77	28,77
TU München		2015	9,90	13,60	10,00	13,80
DB	B07	2016	9,71	12,24	9,13	12,51
SBB		2016	20,89	19,06	25,54	26,16

2 mm = 2/25.4’’
4 mm=0.1575 in

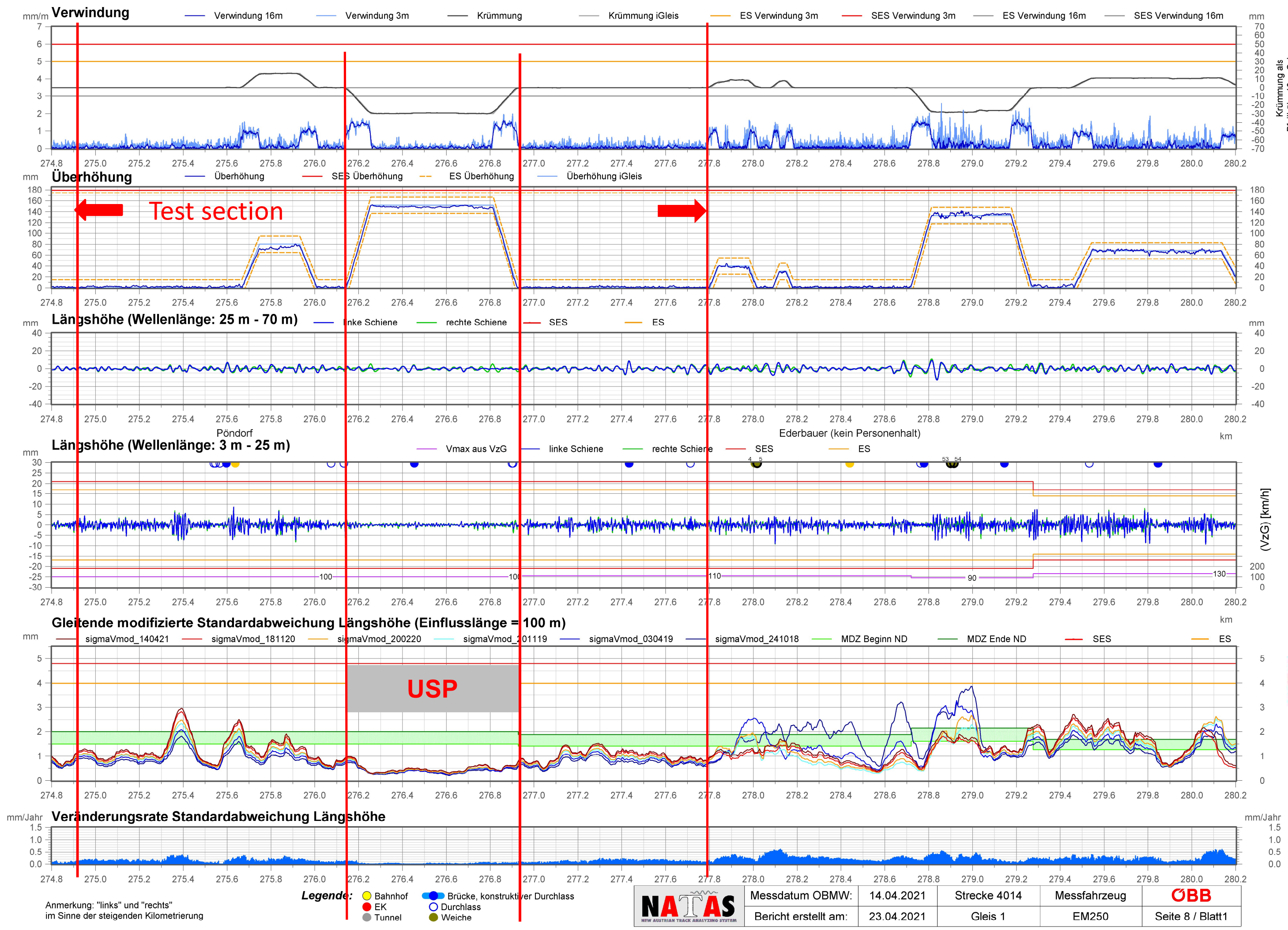
Nota: USP of B91: SLB3007G (GETZNER)
USP of B07: SLB2210G (GETZNER)

USP – Frankenmarkt

Load 28 Million Gross Tons/Year (560 MGT)



Conversion:
110 kph=68 mph
420.7 m= 4.15 °
770.4 m= 2.27°
152 mm= 6 in.
80 mm= 3.14 in
1000 m= 1093.6 yd=
0.62 mi=3281 ft

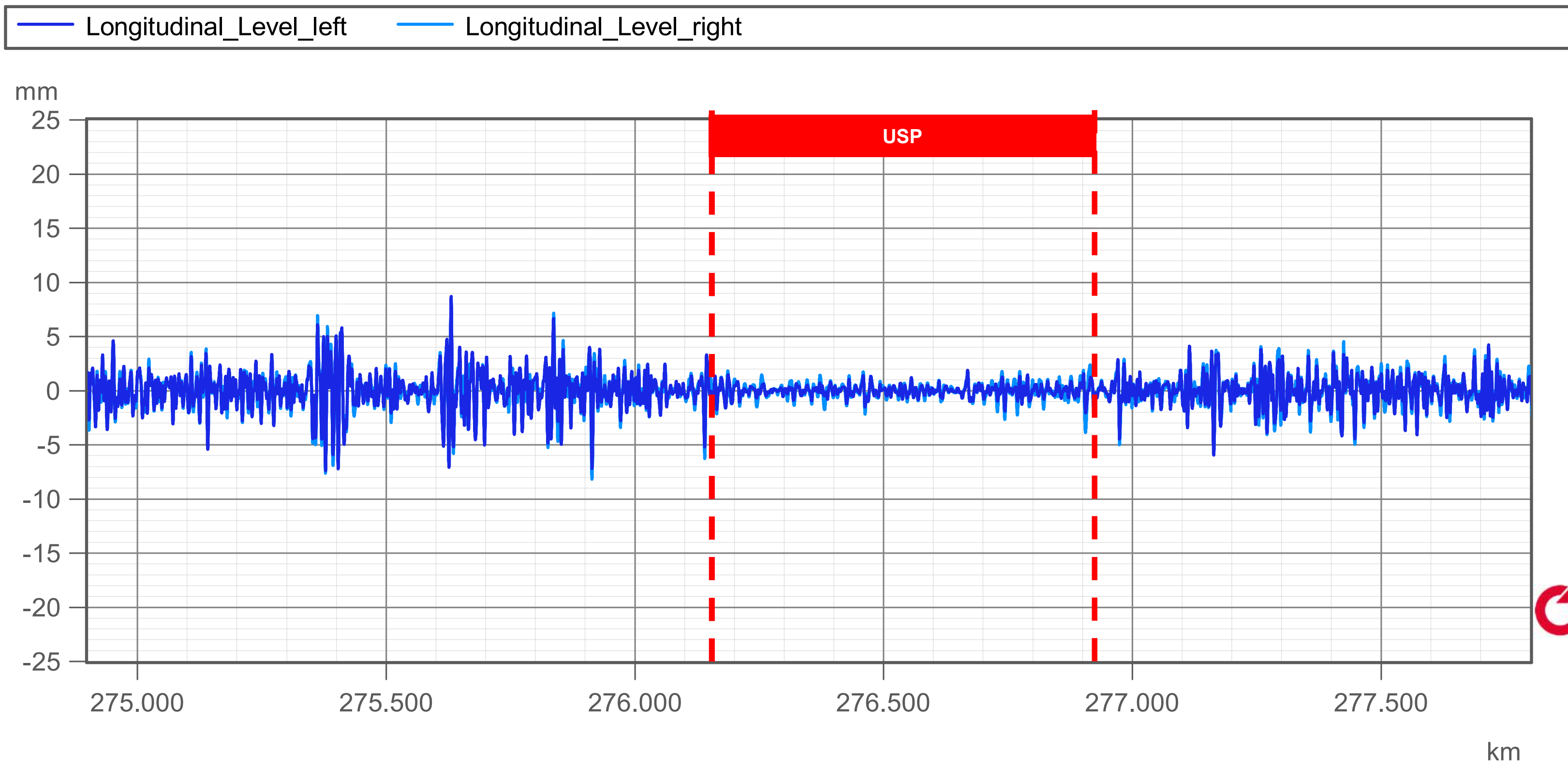


ÖBB INFRA

2021

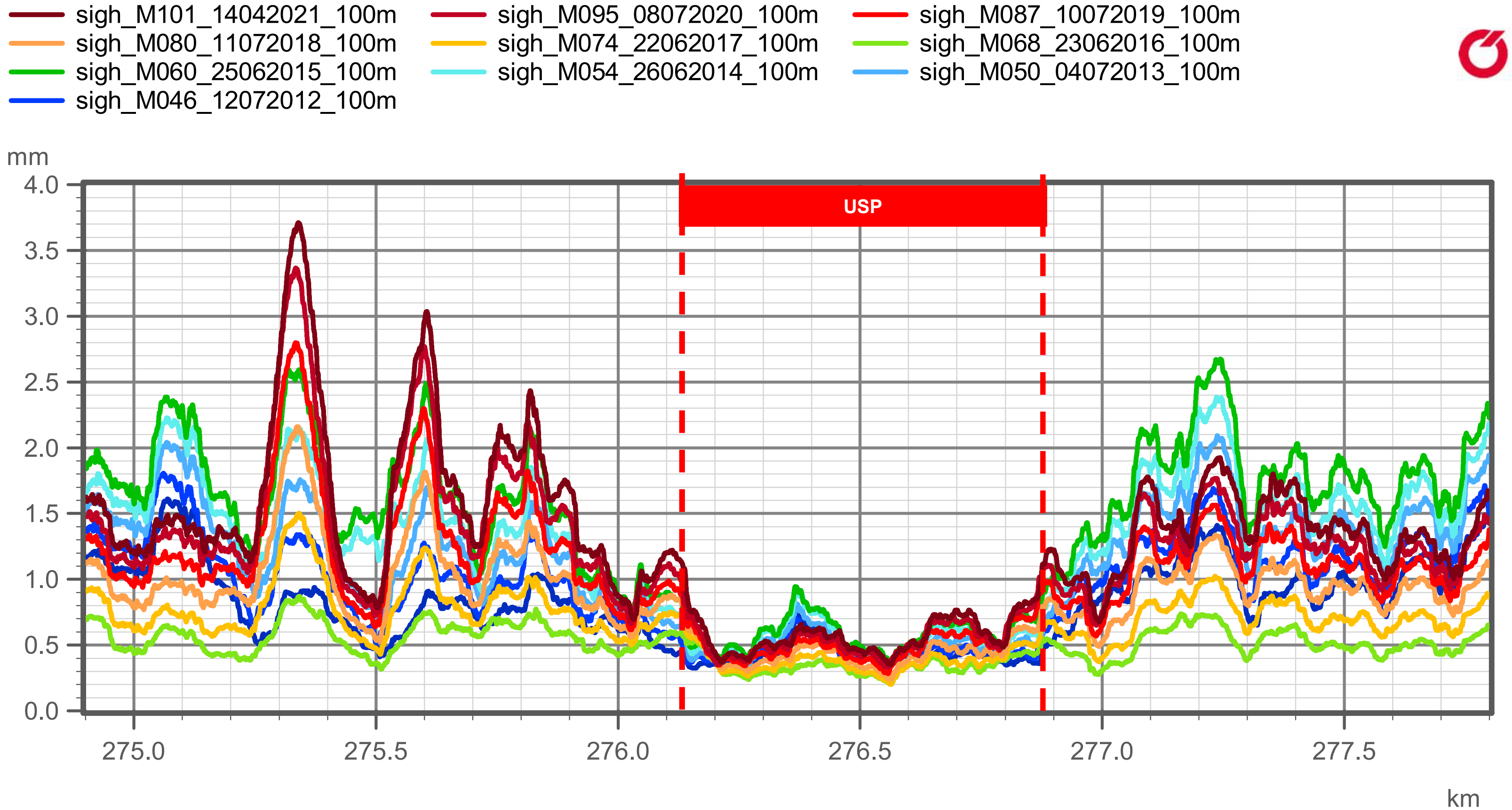
Frankenmarkt, 4014 Track 1

Longitudinal Level, Record 14-04-2021



Frankenmarkt, 4014 Track 1

Standard Deviation Longitudinal Level



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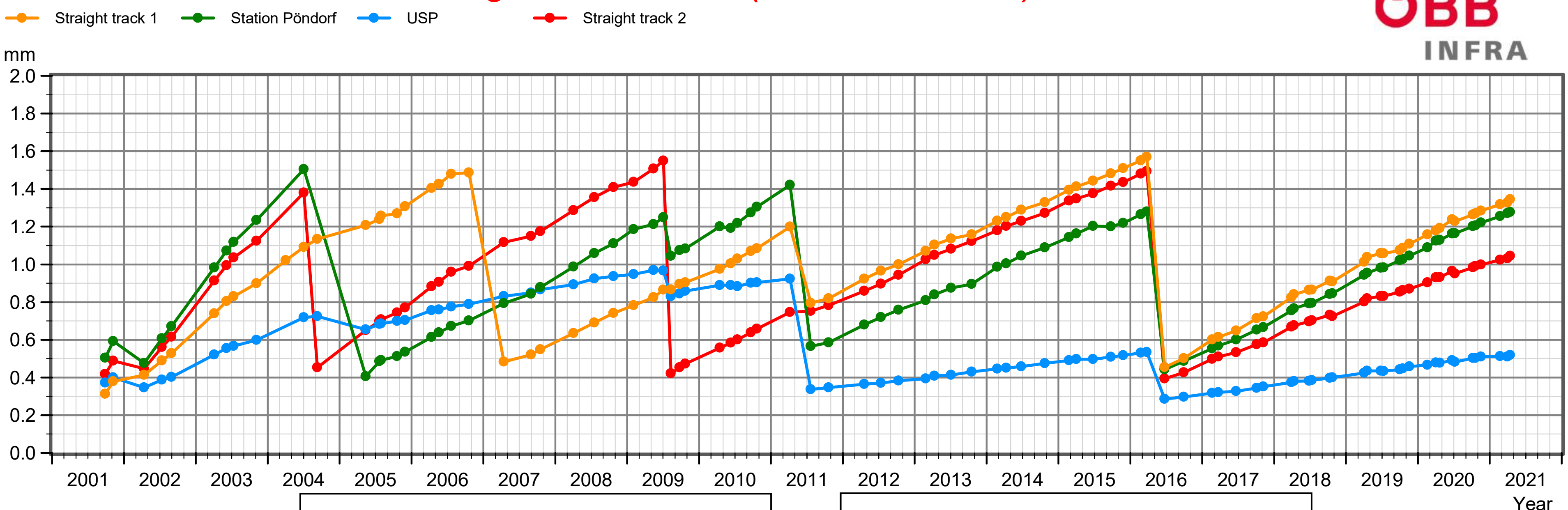
Frankenmarkt, 4014 Track 1

Standard Deviation Longitudinal Level (1 mm=0.04 in.)



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

ARTC 13 pts USP 2016 – 2018

axle load 32 t, 240 MGT/y

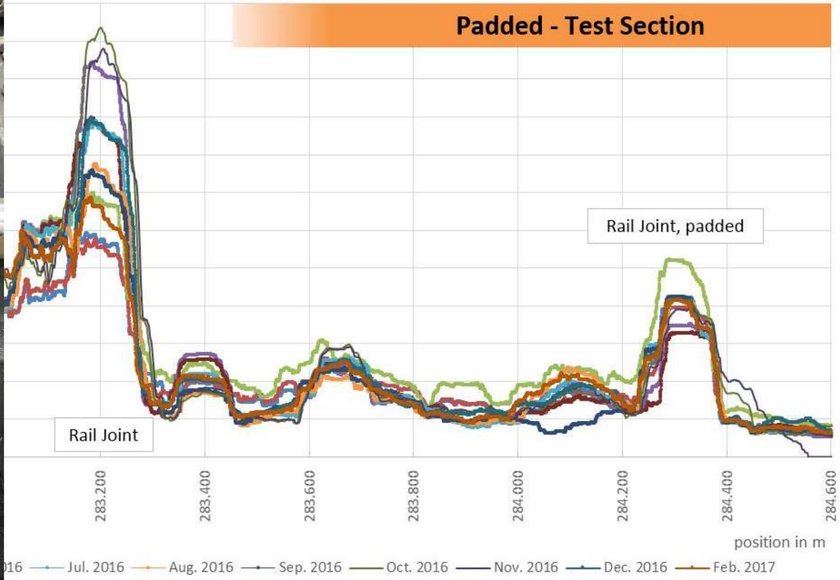
	410	414	413A	402B	403A
Ave tamping frequency (month)	6.5	4.3	5	3.8	3.8
Ave. xing build ups frequency (month)	0	15	15	8	8
Ave xing replacement frequency (month)	0	10	7.5	23	11.5

Turnout No.

- 410 pts tamped less frequent than other turnouts
- Note: 410 Pts. some time tamped because of close proximity to other turnouts – not included in calculation

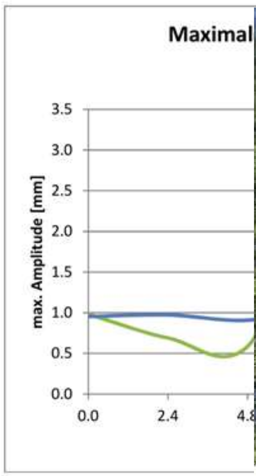
Da-Quin Coal Line (China)

USP load 1.05 billion GT (28 month)



LLT interval extended by min. 4

Breathing in tight curves

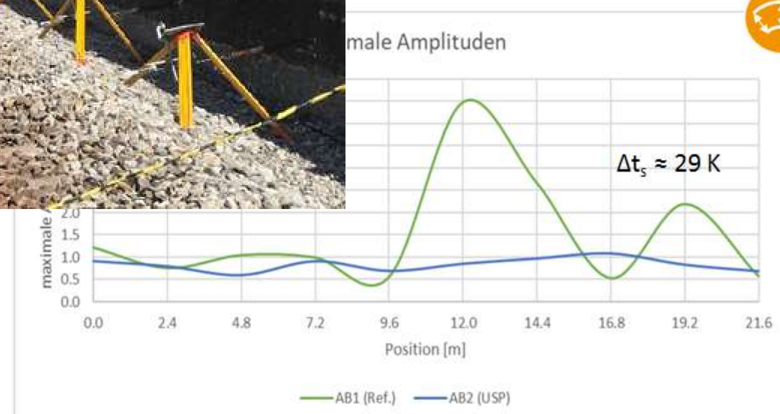


m = 7.18 (6.53)°

n = 7.45 (7.03)°

1m=3.28 ft

1mm=1/25.4 in



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Δt
33K=91.4F
29K=84.2F
1m=3.28 ft

R_{ref} = 240 (242) m=7.3(7.24)°

R_{USP} = 237 (250) m=7.39(7.0)°

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UTP (USP) *Standards*

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 16730

June 2016

ICS 93.100

English Version

Railway applications - Track - Concrete sleepers and bearers with under sleeper pads

Applications ferroviaires - Voie - Traverses et supports en béton avec semelles sous traverse

Bahnanwendungen - Oberbau - Gleis- und Weichenschwellen aus Beton mit Schwellensohlen

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"Under Sleeper Pads (USP) - Recommendations for Use"

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