Experience with USP at the Austrian Federal Railways

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Austrian Federal Railways (ÖBB) - Facts

Republic of Austria:

size: **83.871 km²**

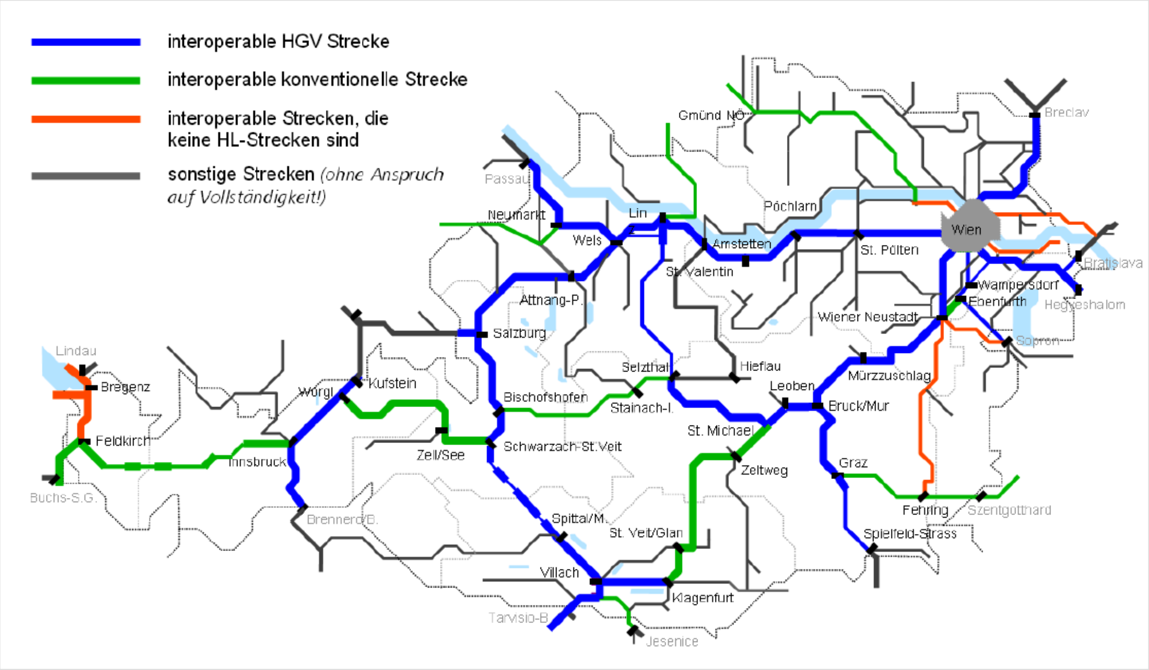
9 provinces

Inhabitants*:* **9,0 Mio.**

Capital: **Vienna (2,0 Mio.)**

ÖBB - Network:

4.859 km line length with
1.250 km dedicated HS – Lines (TEN)
9.708 km total track length,
13.539 S&C (turnouts)
28.075 signals
6.169 bridges and viaducts
248 tunnels and galleries
3.559 railway crossings
1.128 stations



How it all began…

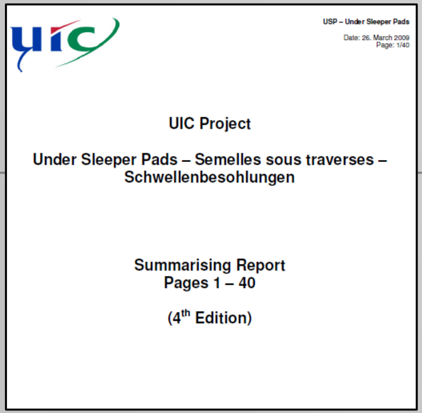
- **1989**: Tests at SNCF laboratory using concrete cubes covered with polyurethane
- **1990**: 1st Project with „Under Sleeper Pads“ (USP) realised by Getzner Company at Metro Oslo
- **1994-1996**: 1st test trials in tracks with USP in Germany and Austria
- **1997**: 1st big project "Öresund" realised by Getzner Company
- **1997**: Research project on USP in Austria – partners: Universities, ÖBB, Getzner Company

  aim: Reduction of vibrations, reduction of corrugation in tight curves and optimization of track position stability

- **2003-2007**: **UIC Project No I/05/U/440** on USP – DB, SBB, Prorail, JBV, Network Rail, OSE, SNCF, PKP, Banverket, CD, HZ, ÖBB
- **2007-2009**: UIC Summarising Report (4 editions) on **"Under Spleeper Pads – Semelles sous traverses – Schwellenbesohlungen"**
- **2019: UIC IRS 70713-1: Railway Application – Track & Structure "Under Sleeper Pads (USP) – Recommendations for Use"**

→ **…up to now, a story of success!**

UIC Project No I/05/U/440


USP – Under Sleeper Pads
Date: 26. March 2009
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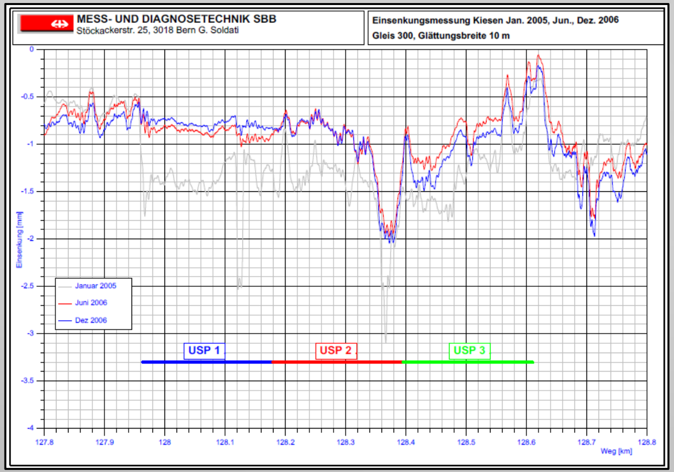
UIC Project

Under Sleeper Pads – Semelles sous traverses – Schwellenbesohlungen

Summarising Report
Pages 1 – 40

(4th Edition)

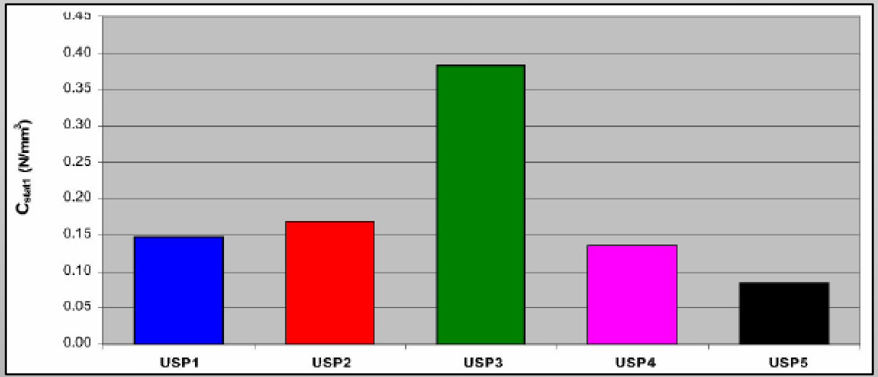
- **WP1**: State of the Art Report
- **WP2**: Theoretical Investigations (track dynamics, track settlements, stresses within sleepers)
- **WP3**: Acoustics and Vibration
- **WP4**: Standardisation of Materials
- **WP5**: Lab measurements (static and dynamic stiffness, fatigue test „Vibrogir“)
- **WP6**: Test track measurements 2006

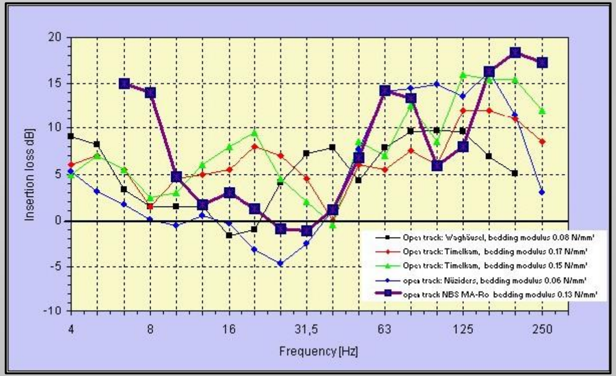


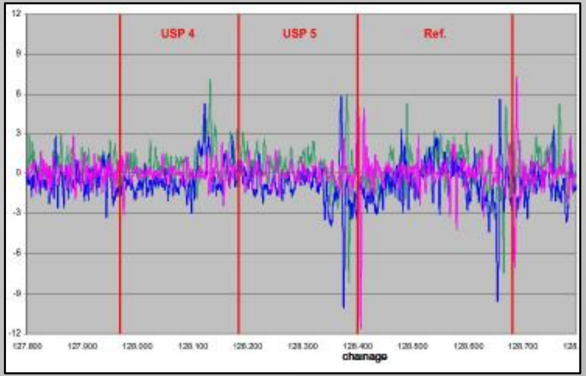
UIC Project No I/05/U/440

Observed benefits of USP:

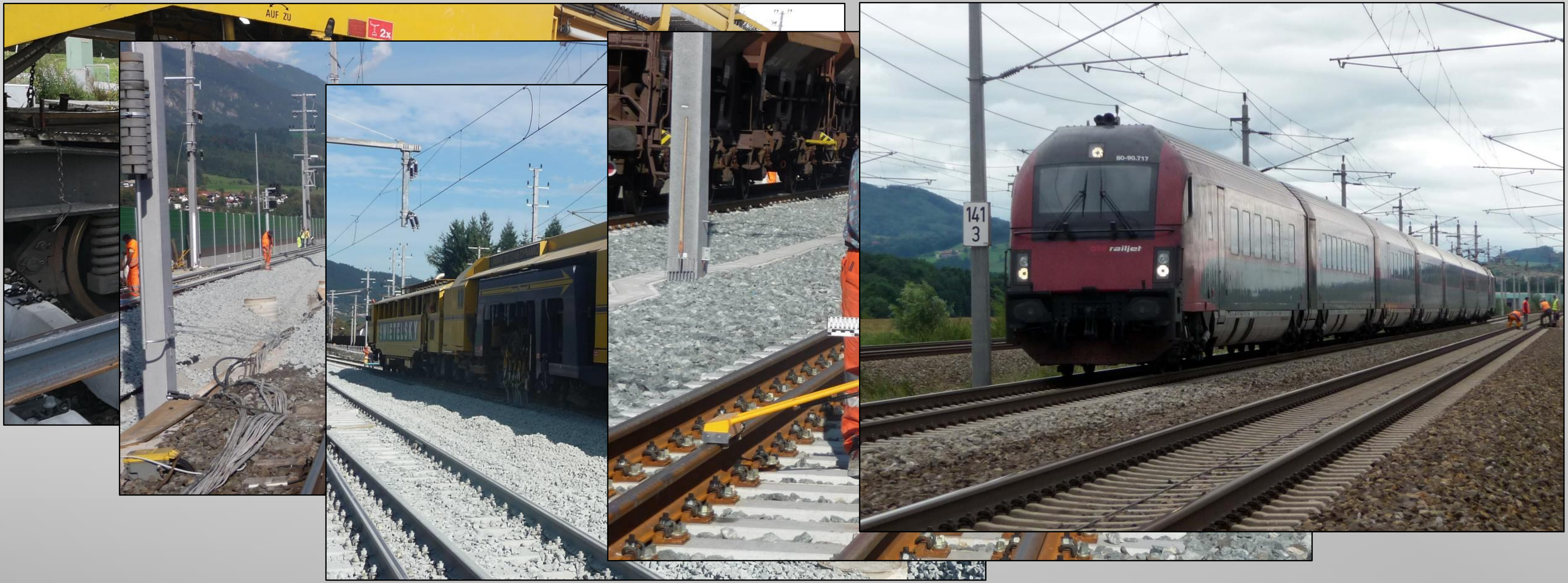
- Compensation for localised differences in track stiffness: E. g. transitions between different construction types, between embankment and bridges and at level-crossings
- Reduction of high-frequency vibrations and structure-borne noise: USP being used as an alternative to under ballast mats (UBM) in the frequency range above 40 – 50 Hz
- Reduction of on-track machine maintenance: The track geometry is stable over a longer period of time and therefore a longer interval between tamping is possible







New track laying – how it starts.....



...what can become of it in the course of time...

...and it`s all a problem of elasticity in the track...

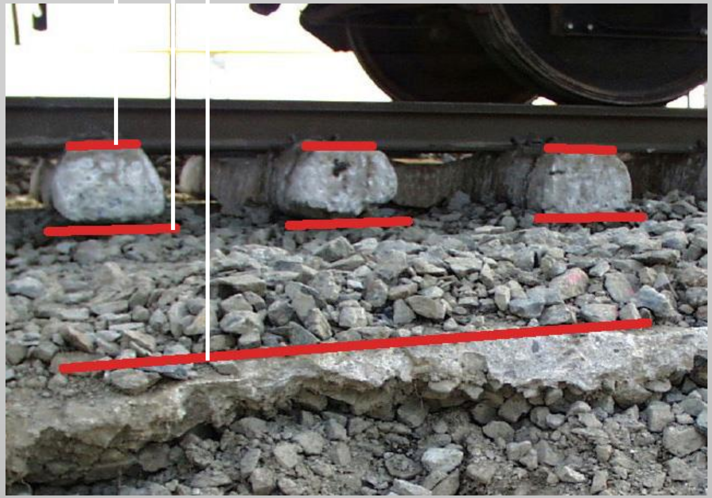
Conducting **causal research**, you very often and very quickly come to an **essential parameter** in the track system as the main reason for many subsequent developments: The **elasticity in the track!**
Elasticity is decisive for the development of the later track geometry position, but also for the development of the superstructure components in terms of wear and overstressing.

To improve **load distribution** and thus minimize **ballast** and **substructure stresses**, it is possible to insert **elastic elements** at various points on the track body:

Elastic Elements – Rail Pads

Elastic Elements – USP

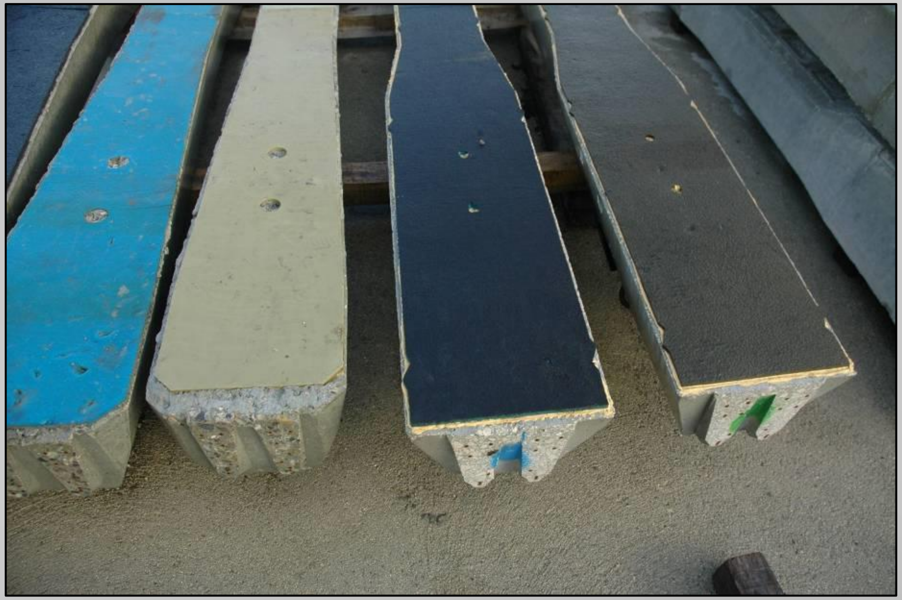
Elastic Elements – Under Ballast Mats



Under Sleeper Pads (USP)

USP is the term used to describe **elastic layers that are attached** to the **bottom of the (concrete) sleeper**.

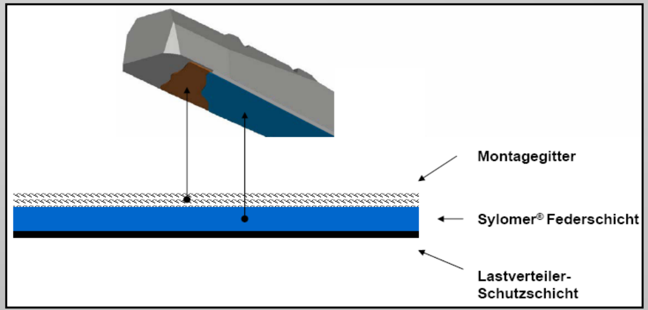
This has a positive effect on the dynamic behavior of the track in the ballast bed and increases the overall track position quality.



Under Sleeper Pads (USP)

Materials used for USP:
- **Polyurethane**
- **Rubber**
- **Ethylene vinyl acetate (EVA/EVAC)**

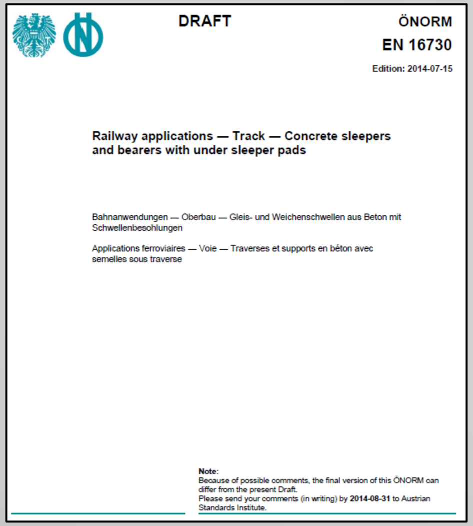
Application of USP:
- **coating** by spraying or painting
- **gluing** to hardened concrete
- **inserting** directly into unset concrete (during production)
- assembling with an **interlocking layer** (e. g. extruded knobs, wire mesh, geomembrane, fine-grained gravel)



Under Sleeper Pads (USP)

Technical Specifications: - **EN 16730** Concrete sleepers and bearers with USP

- **IRS 70713-1** Under Sleeper Pads (USP)-Recommendation for Use



DRAFT

ÖNORM
EN 16730

Edition: 2014-07-15

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

Bahnanwendungen — Oberbau — Gleis- und Weichenschwellen aus Beton mit Schwellenbesohlungen

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

Note:
Because of possible comments, the final version of this ÖNORM can differ from the present Draft.
Please send your comments (in writing) by **2014-08-31** to Austrian Standards Institute.

Content of EN 16730:

- Requirements for qualification and routine tests of USP
- Data to be supplied by the manufacturer
- Rules for the use of sleepers and bearers with USP
- Quality Control
- Marking, labelling and packaging
- Annex: Test procedures for stiffness measurement of USP
  Test procedures for fatigue behaviour with USP applied
  Test procedures for bond strength by pull-out
  Test procedures for effect of severe environmental conditions
  ……………………

Under Sleeper Pads (USP)

Classification: (from **UIC IRS 70713-1** Under Sleeper Pads - Recommendation for Use)

The following table gives a rough classification of the USP- **static bedding modulus**:

USP-type	**Static bedding modulus C_{stat}**
Stiff	0.25 N/mm³ ≤ $\mathbf{C_{stat}}$ < 0.35 N/mm³
Medium	0.15 N/mm³ ≤ $\mathbf{C_{stat}}$ < 0.25 N/mm³
Soft	0.10 N/mm³ ≤ $\mathbf{C_{stat}}$ < 0.15 N/mm³
Very soft (not part of this leaflet)	$\mathbf{C_{stat}}$ < 0.10 N/mm³

Field of application: (from **UIC IRS 70713-1** USP - Recommendation for Use)

Fields of application of USP	**USP-type**		
	Soft	**Medium**	**Stiff**
Improvement of track quality (2.3)			
S&C (2.3)			
Transition Zones (2.4)			
Zones with reduced ballast thickness (2.5)			
Reduction of long pitch corrugation (2.6			
Reduction of ground-borne vibrations (2.7)			

Economic Evaluation of USP

In 2012, the **Technical University of Graz (Prof. Veit)** has lauched an economic evaluation of USP **based on LCC**.

The total costs under the LCC methodology include the costs of initial construction, ongoing maintenance costs, operational hindrances and the disposal costs at the end of service life of the asset.

Result:
Even with a very conservative approach, the **Internal Rate of Return** for USP at radii of **500 m** shows **high economic efficiency!**

Recommendation for ÖBB:
Every concrete sleeper should be equipped with USP, inde-pendently from the transport volume on the line…

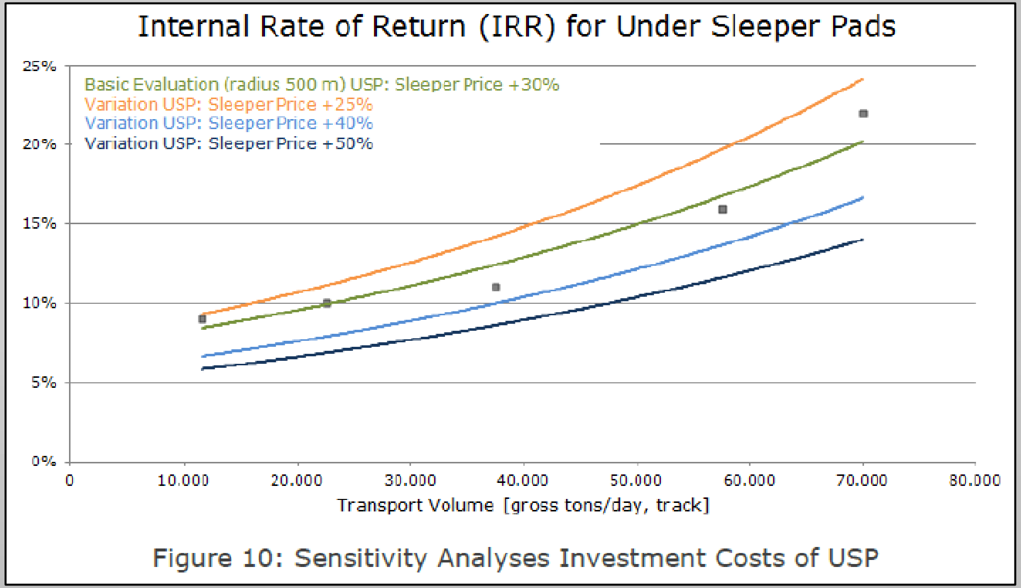
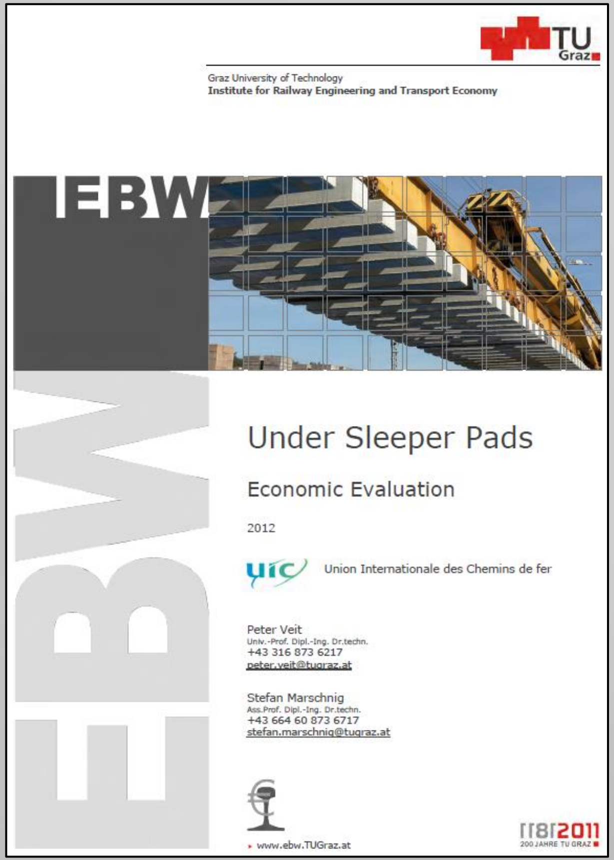


Figure 10: Sensitivity Analyses Investment Costs of USP



Experience with USP in the ÖBB network

In the period **1997 - 2007** numerous istallations of **concrete sleepers with USP** took place in the network of ÖBB-Infrastruktur AG:

- **Fully covered**
- **Partly covered**
- **Conical shaped USP**

} No major differences investigated!

The evaluation of the track geometry position was carried out with ÖBB-track recording car "EM 250" and the parameter "Mean value from the standard deviation longitudinal level".

Experience with USP in the ÖBB network

Test installation of USP in the period **1997 – 2007:**

1. Frankenmarkt **2001** (Route Vienna – Salzburg): 21 Mio GT/Jahr = **350 Mio GT**
2. Markersdorf **2001** (Route Vienna – Salzburg): 25 Mio GT/Jahr = **425 Mio GT**
3. Angern – Dürnkrut **2007** (Route Vienna – Hohenau): 11,7 Mio GT/Jahr = **130 Mio GT**
4. Landl – Hieflau **1997** (Route Amstetten – Hieflau):6,2 Mio GT/Jahr = **130 Mio GT**
5. Neumarkt - Friesach **2007** (Route Vienna – Villach): 12 Mio GT/Jahr = **135 Mio GT**
6. Hallwang - Kasern **2003** (Route Vienna – Salzburg): 28,5 Mio GT/Jahr = **430 Mio GT**
7. Hallwang - Kasern **2004** (Route Vienna – Salzburg): 28 Mio GT/Jahr = **400 Mio GT**

Experience with USP in the ÖBB network

Test installation of USP in the period **1997 – 2007**

7 4014 – Hallwang - Kasern Gl.2: **28 Mio GT/Jahr = 400 Mio GT,** installed 2004

19a	no USP	km303,334 – km304,810
K1	USP	km305,940 – km309,195
K1	no USP	km310,897 – km312,162

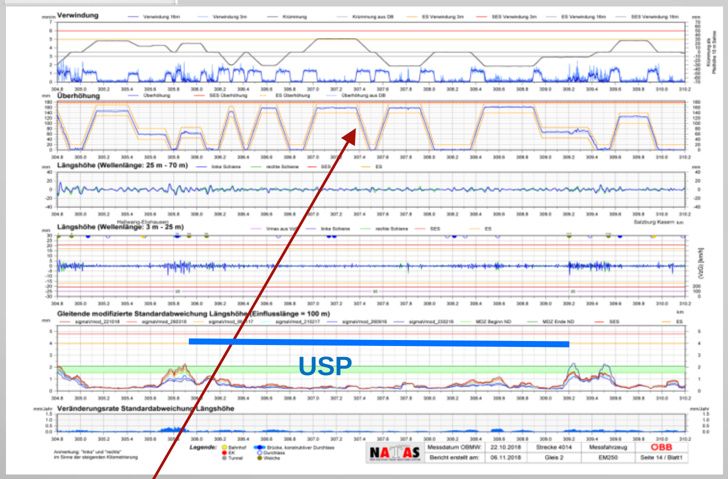
Rail profile 60E1,
Concrete Sleeper with USP
V = 95 km/h
Radii between 400m–600m
Rail pad: K_{sp} = 100 kN/mm

Experience with USP in the ÖBB network

Test installation of USP in the period **1997 – 2007**

1 **4014 – Hallwang - Kasern Gl.2**: **28 Mio GT/Jahr = 400 Mio GT,** installed 2004

NATAS EM 250 track recording car



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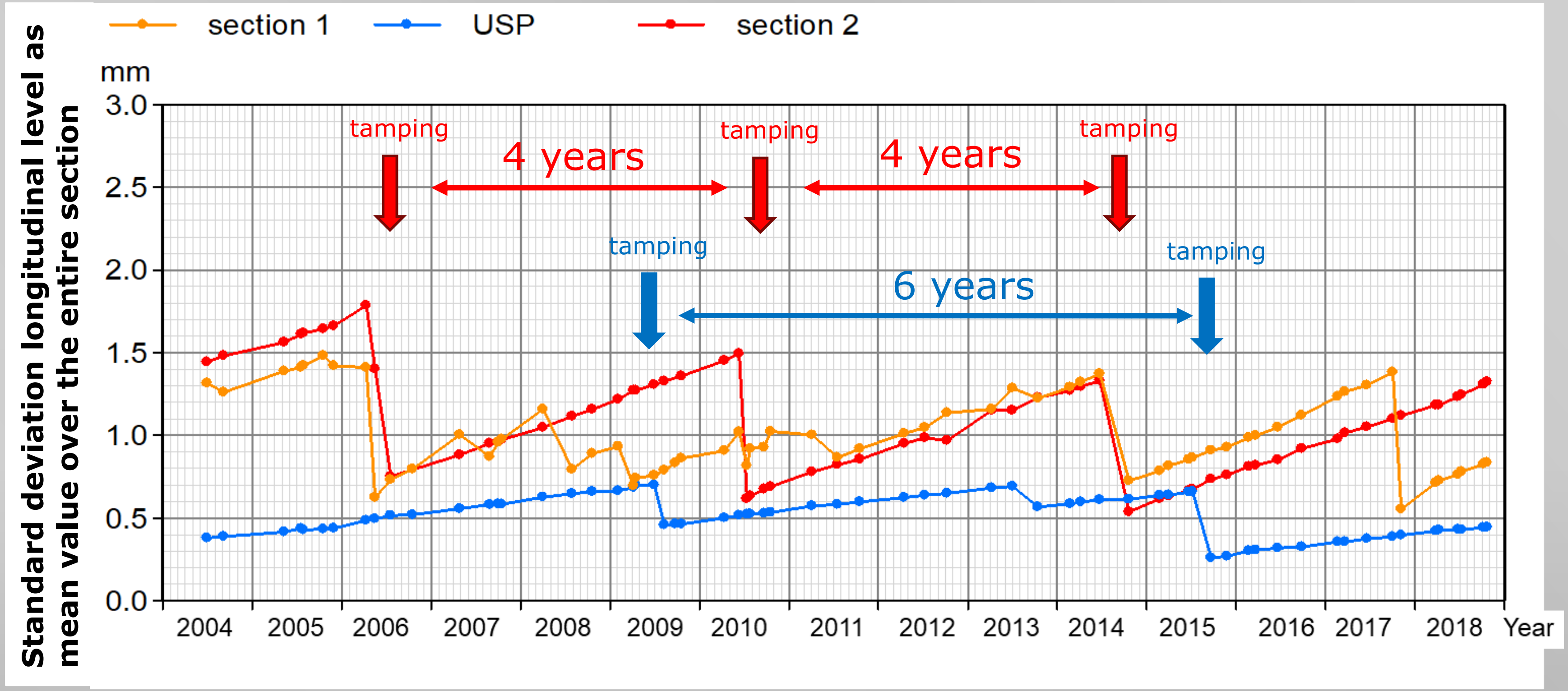
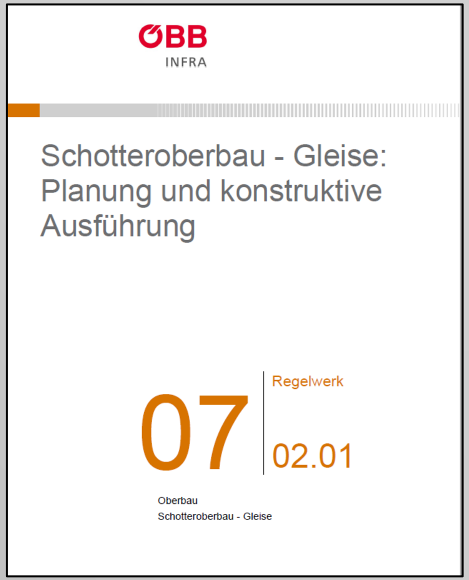


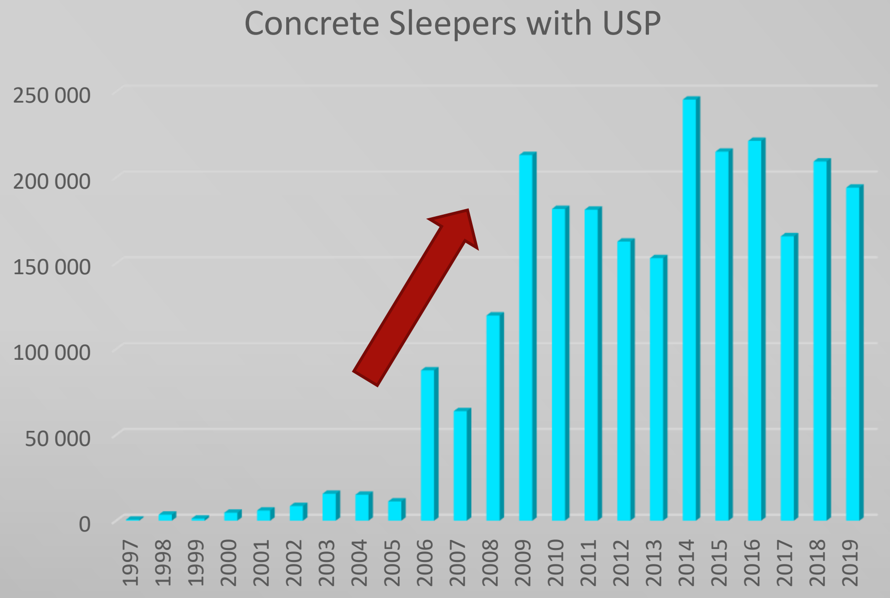
Application of USP at ÖBB network



ÖBB-Regulation 07.02.01: *applicable **since 2007***

- All tracks with **concrete sleepers** and > **30.000 gross tons** per day and track → around 200.000 pieces/year
- **Specific applications** in ground born vibration sensitive areas → only a few!
- All **S&C with concrete bearers** (around 150 - 250 / year)

ÖBB-statistics:



Installation capacity:

1997 – 2022: **1950 km tracks**

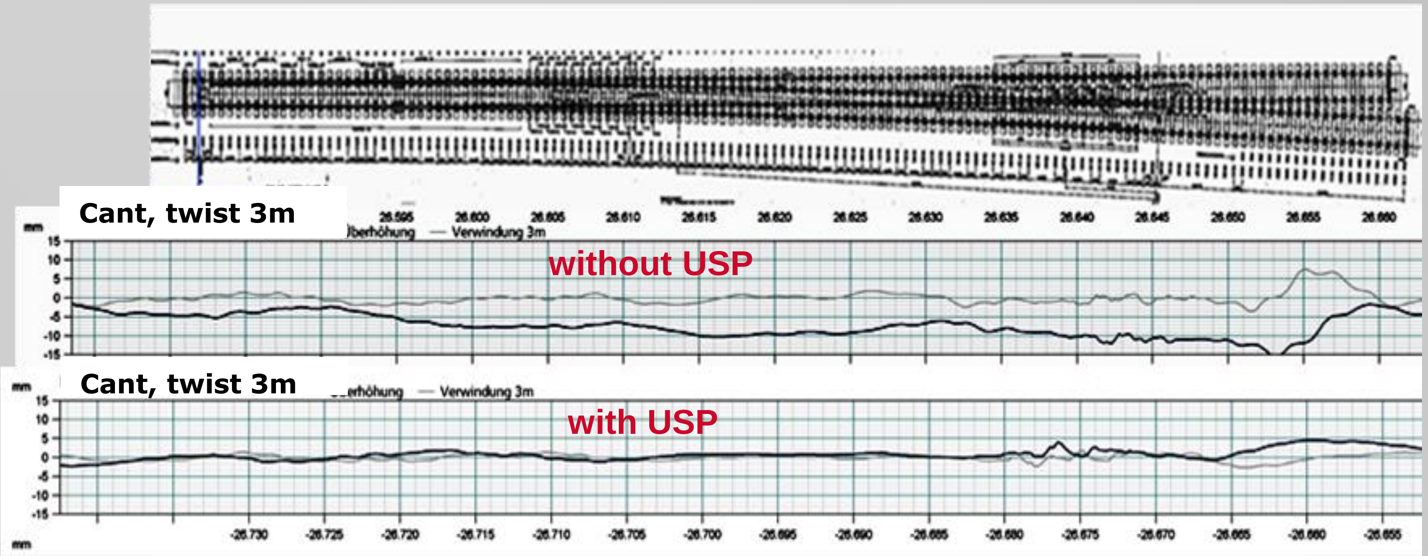
2002 – 2022: **1800 S&C**

Application of USP at ÖBB network

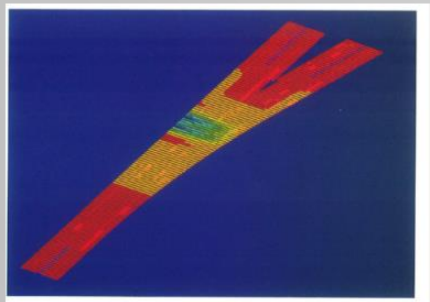
Concrete bearers with USP in S&C

Problem: bending and inclining of turnouts from its beginning to the end

EW 1200-1:18,5



Optimizing USP-stiffness:
FE-model-calculations result in a constant settlement at different bedding conditions throughout the turnout.

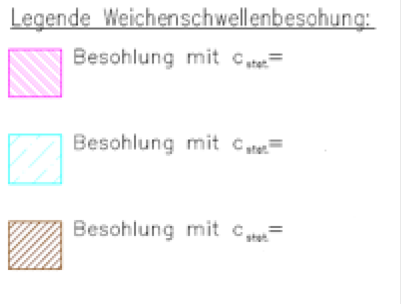


FE-Modell zur Optimierung der Weichenbesohlung bei Getzner Werkstoffe

The reduction of the ballast bed stresses and better elasticity → **better track geometry**, **reduced maintenance actions and costs.**

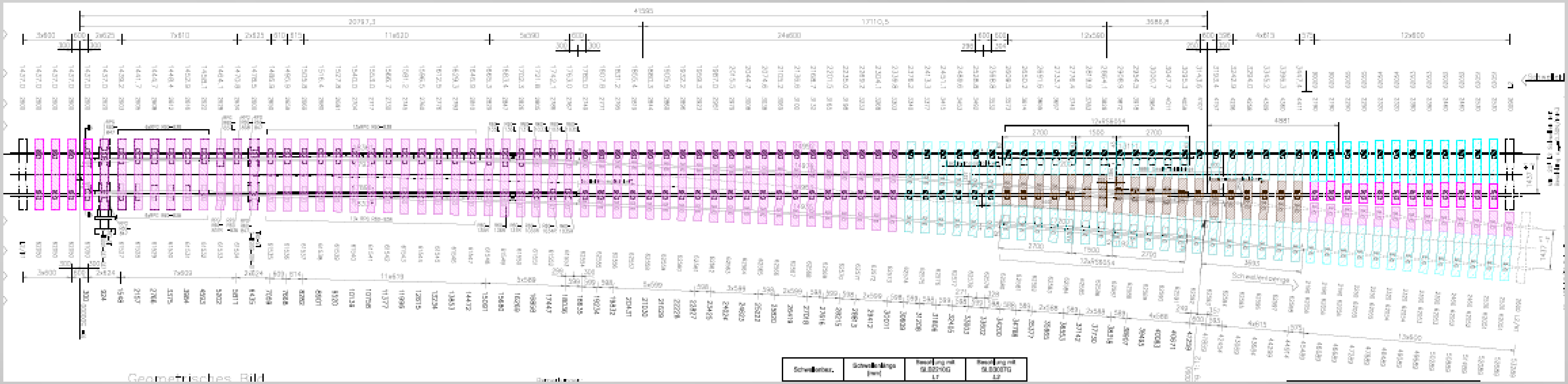
➡ **USP: reduced settlements and better track durability!**

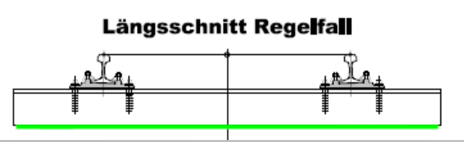
Application of USP at ÖBB network

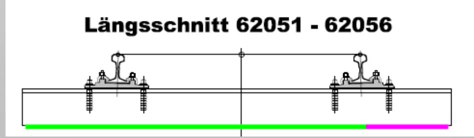


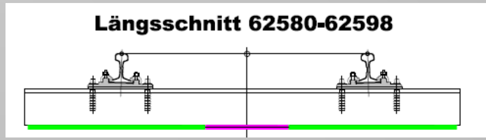
Concrete bearers with USP in S&C

Optimizing USP-stiffness: 3 different elasticities









Why Under Sleeper Pads (USP) ?

Main goal for ÖBB: Prevention of ballast damage - ensuring long-term ballast protection in tracks with concrete sleepers

Insufficient elasticity in the superstructure (stiff ballast bed, concrete sleepers) in combination with stiff subgrade conditions leads to high sleeper-ballast forces and premature ballast wear → **fine ballast abrasion** ("white spots") occurs

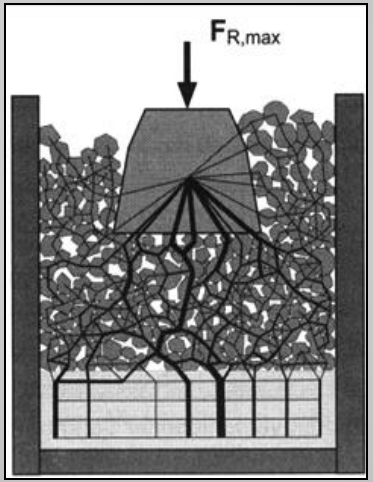
- Water impermeable ballast abrasion → „Wet spots“ occur
- loss of stable ballast compaction
- rapid deterioration of the track geometry
- stress-induced transverse cracks in the sleeper
- Shortening of tamping intervals
- life span of the track decreases...

Why Under Sleeper Pads (USP) ?

Main goal for ÖBB: Prevention of ballast damage

Ballast contact area on the bottom of conventional concrete sleepers: **approx. 5-6%.**

USPs **significantly increase** the contact area by pressing ballast stones into the elastic layer: **up to approx. 25%.**

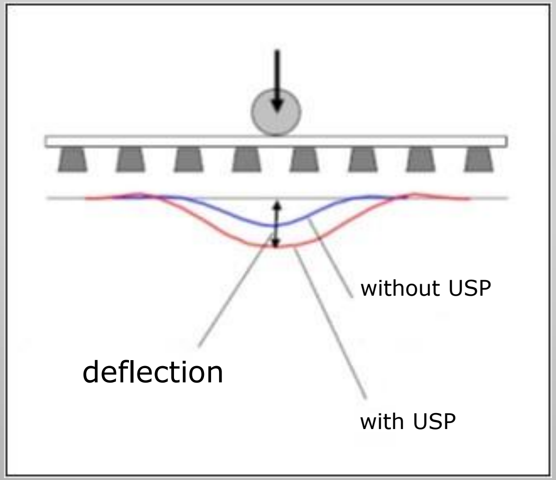


More "force paths" are formed, reducing local ballast stresses →
More uniform transfer of dynamic train traffic loads is made possible

Why Under Sleeper Pads (USP) ?

Other goals for ÖBB: Better Track geometry

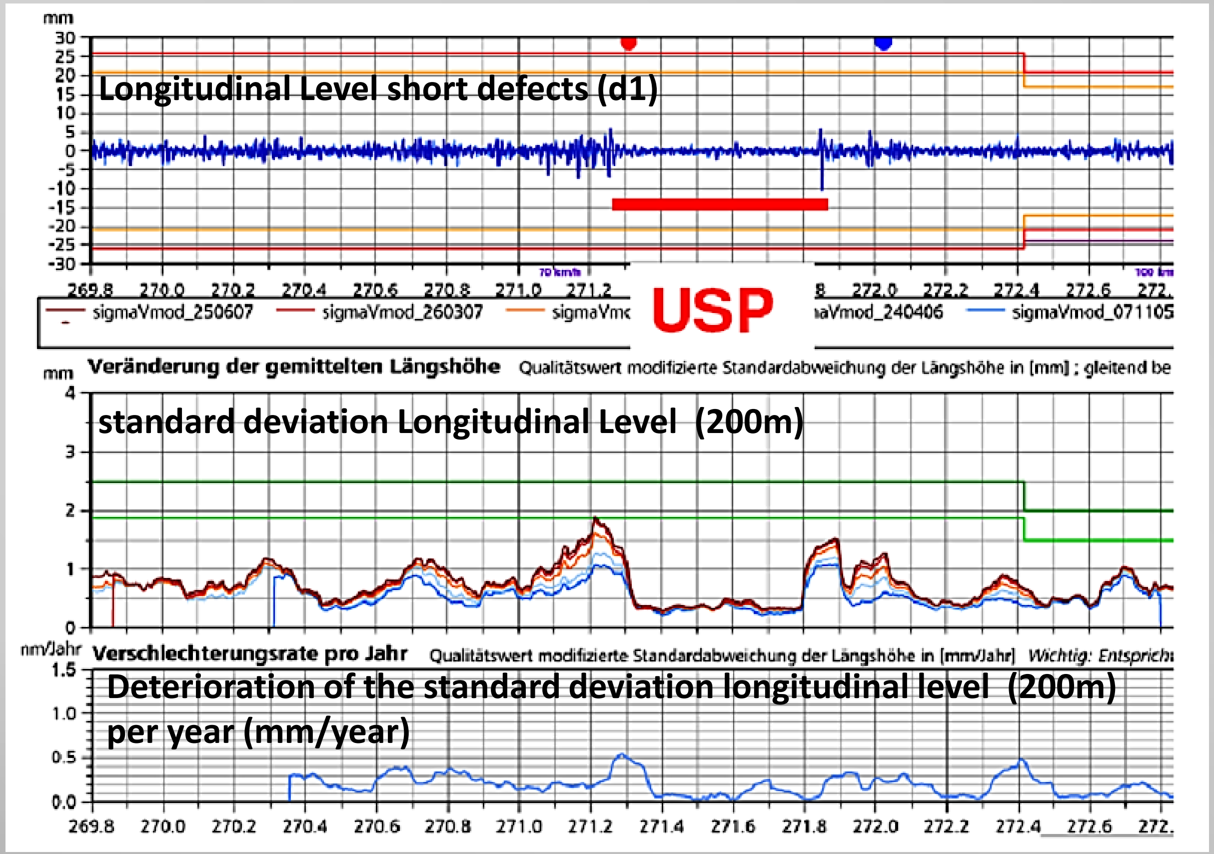
Existing lines: problem of track settlement due to fine-grained soils and inadequate drainage



- Increase of elasticity in the track
- Distribution of the wheel load over a longer track length ("rail as a support”)
- Greater rail deflection: lower stresses on sleepers and ballast, increase in rail stresses, higher vertical accelerations.

Why Under Sleeper Pads (USP) ?

Other goals for ÖBB: Better track geometry – reduction of track deflection



Track measurement at Scheifling, Southern Route

Measuring chart of 5 runs with the track recording car EM 250 between 11/2005 and 06/2007

➡ No change in the track geometry, where USP were mounted

- lower forces and settlements in the subgrade (40%-70% of sections without USP)
- longer tamping intervals
- the softer the USP, the lower the long-term subgrade settlements

Why Under Sleeper Pads (USP) ?

Other goals for ÖBB: Reduction of corrugation in narrow curves

Narrow curves with concrete sleepers and stiff rail pads tend to develop **corrugation** quicker than thus with USP and soft rail pads.

- Early wear of the rail pads
- Short rail grinding cycles
- High stresses on the rail fastenings
- Service life of the sleeper decreases
- High noise emission

By selecting proper superstructure components, corrugation can be significantly delayed and rail grinding intervals stretched:

- Head hardened 60kg rails
- Soft rail pads (k_{sp} = 60 kN/mm)
- Fastenings (Skl) with greater holding down force and
- Adequate USP

→ **Increased service life of the track !**

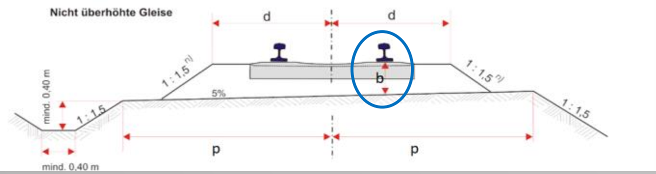
Why Under Sleeper Pads (USP) ?

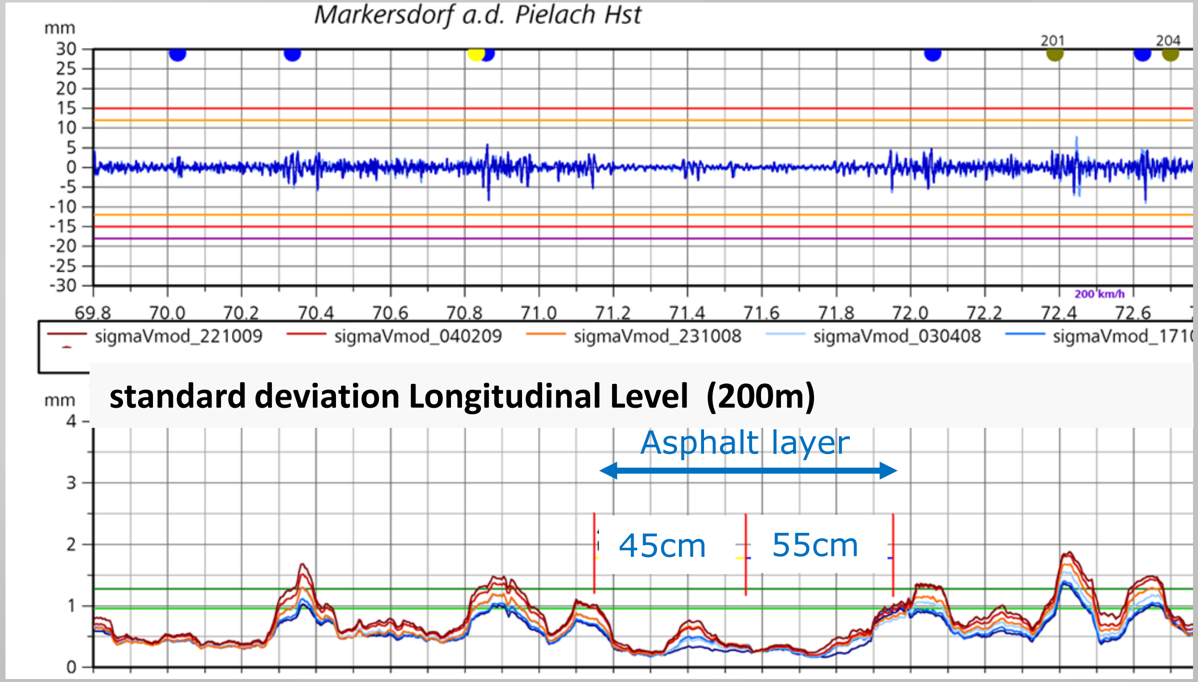
Other goals for ÖBB: Reduction of ballast bed thickness

A comparison of the track geometry quality of conventional concrete sleeper tracks with **concrete sleepers + USP** shows that in very good subgrade conditions (e. g. bituminous supporting layers) a **reduction of the ballast bed thickness** by **up to 10 cm** is possible without early track deterioration

Savings potential:

~ 0,5 t of ballast per m track

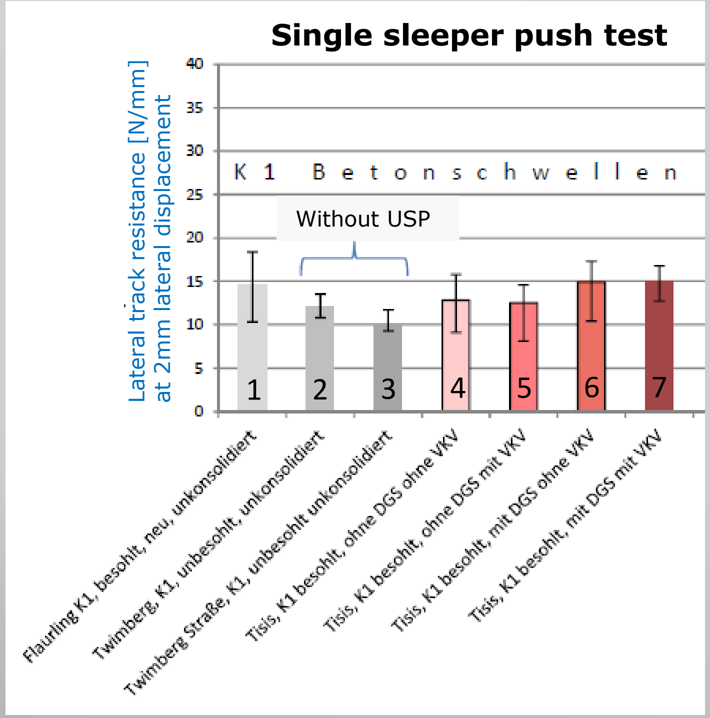




Why Under Sleeper Pads (USP) ?

Other goals for ÖBB: Increase lateral track stability

Measurements of the sleeper-ballast resistance of the track in Austria have shown, that **concrete sleepers with USP** may **increase the lateral track stability** by **up to 10%.**



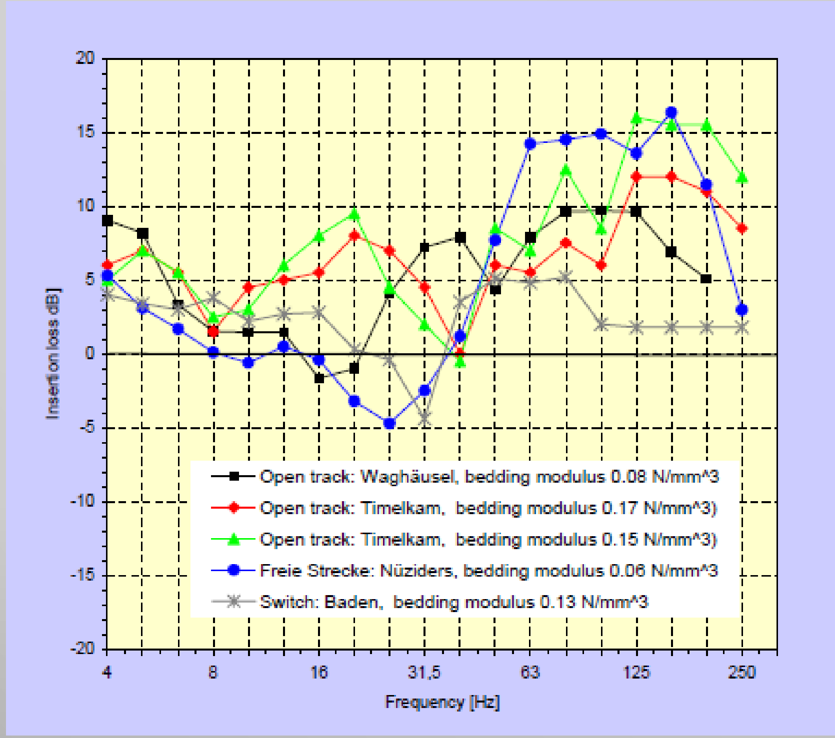
Various SSPT performed by University of Innsbruck:

1. Concrete sleeper with USP, unconsolidated
2. Concrete sleeper without USP, unconsolidated
3. Concrete sleeper without USP, unconsolidated
4. Concrete sleeper with USP, unconsolidated
5. Concrete sleeper with USP + Sleeper End Consolidators
6. Concrete sleeper with USP + Dynamic Track Stabiliser (DTS)
7. Concrete sleeper with USP + DTS + Sleeper End Consolidators

Why Under Sleeper Pads (USP) ?

Other goals for ÖBB: Reduction of noise and vibrations

Not many tracks with **concrete sleepers and "soft" USP** to reduce vibrations have been performed at ÖBB so far.



Results from UIC Projekt 2009:

- Reduction of vibrations and structure-borne noise by **up to 30%.**
- Reduction occurs from a frequency of **above 50 Hz**
- Insertion loss is **~ 8 - 15 dB**
- Resonance frequency: **25 - 40 Hz** → Amplification of vibrations!
- The resonant frequency changes with the modulus of subgrade reaction of the USPs.
- A direct dependence between modulus of subgrade reaction and structure-borne noise reduction cannot be determined

Tracks with USPs **presumably** have a **minimally higher value** for primary airborne noise than standard tracks….

Summary and conclusions:

After more than 20 years of experience in the application of Under Sleeper Pads in Austria, I can state with conviction that USP has raised track and S&C construction to a new level. It is by far the greatest innovation of the last 50 years in track!

Main advantages:

- **Better load distribution** due to larger ballast contact areas (5 % → 25 %)
- **Protection** of the **ballast bed** (less grain fragmentation)
- Improved **track geometry quality**
- **Extension of tamping cycles** (factor 1.5 - 5)
- Possibility to **reduce ballast bed thickness** (5-10 cm)
- **Reduction of corrugation** in narrow curve radii
- **Reduction of structure-borne noise and vibrations** (~30%)
- **Cost-effective alternative** to Under Ballast Mats (UBM)

Thank`s for listening!!!

I am waiting for your Questions