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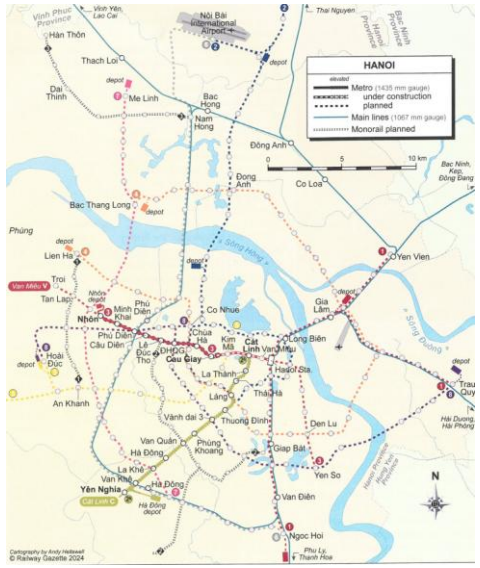
URBAN TRANSPORT SYSTEMS

20.08.2025



URBAN TRANSPORT SYSTEMS

METRO APPLICATION

01 **Fastening Systems for Metro Application**

02 **Slab Track**

03 **Noise and vibration**

04 **Comparison**

05 **300 Mflex7 Fastening Systems for Metro Application**

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01

FASTENING SYSTEM AND METRO REQUIREMENTS

FUNCTION OF RAIL FASTENING SYSTEM

1. Securing the Rails: Ensuring stable and secure fastening of the rails to the sleepers.

2. Load Distribution: Even distribution of loads generated by train traffic across the sleepers.

3. Vibration Damping: Reducing vibrations and noise to minimize sound emissions.

4. Flexibility and Adaptability: Ability to adapt to various track types and environmental conditions.

5. Protection: Functionality under changing weather/climate and environmental conditions to ensure reliability.

METRO SYSTEM

CHALLENGES

- High Acceleration and Braking Forces: High train frequencies activate significant acceleration and braking forces, especially on inclines and declines.

-Tight Curve Radii: Tight curves result in increased lateral forces acting on the rail.

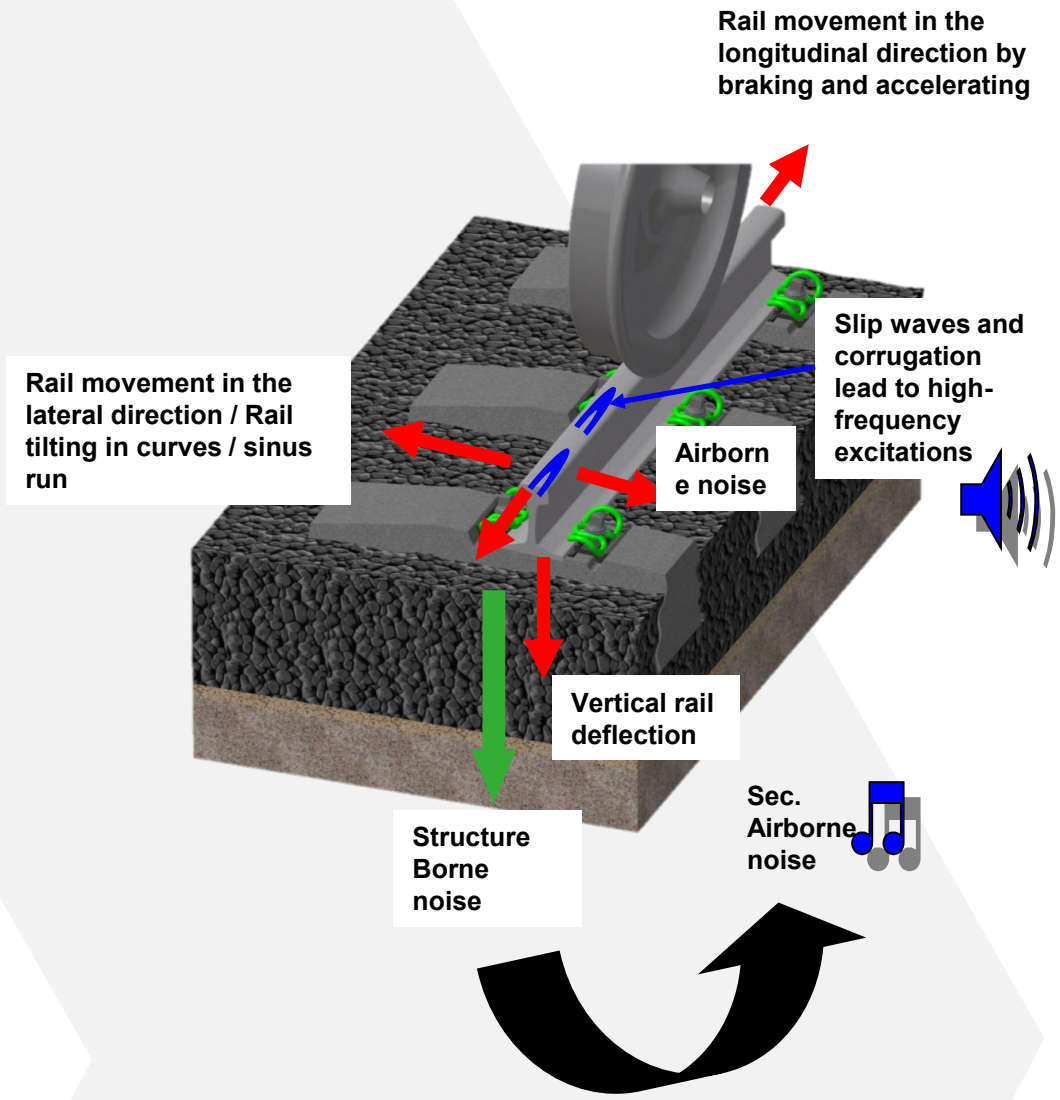
-Varying Alignment Parameters: Different alignment parameters lead to varying loads on the inner and outer rails of curves.

-Corrugation Formation Phenomenon: Corrugation formation can be a common issue, particularly in metro systems

-Sensitive Areas: Proximity to hospitals, churches, historical buildings, residential areas, and other sensitive locations necessitates the use of vibration-reducing systems.

Requirements for Metros are defined in EN resp. ISO

Category B fastening system fastening system designed for urban light rail and some industrial tracks, with a typical axle load of 160 kN, a typical curve radius of 100 m, a typical maximum speed of 140 km/h, a typical rail section of 54E1 and a typical sleeper or support spacing of 600 mm



FASTENING SYSTEMS

TYPICAL PARAMETERS EN 13481-1

UTS – METRO (Cat. A)

Axle load:
10 t

Curve radius:
80 m

Speed:
max. 100 km/h

Rail profile:
40E1

Spacing:
800 mm

Stiffness

UTS – METRO (Cat. B)

Axel load:
16 t

Curve radius:
100 m

Speed:
max. 140 km/h

Rail profile:
54E1

Spacing:
600 mm

Stiffness

CONVENTIONAL (Cat. C)

Axle load:
22.5 t

Curve radius:
400 m

Speed:
max. 250 km/h

Rail profile:
60E1

Spacing:
600 mm

Stiffness

HIGH SPEED (Cat. D)

Axle load:
18 t

Curve radius:
800 m

Speed:
> 200/250 km/h

Rail profile:
60E1

Spacing:
600 mm

Stiffness

HEAVY HAUL (Cat. E)

Axle load:
30 t

Curve radius:
150 m

Speed:
max. 200 km/h

Rail profile:
60E1

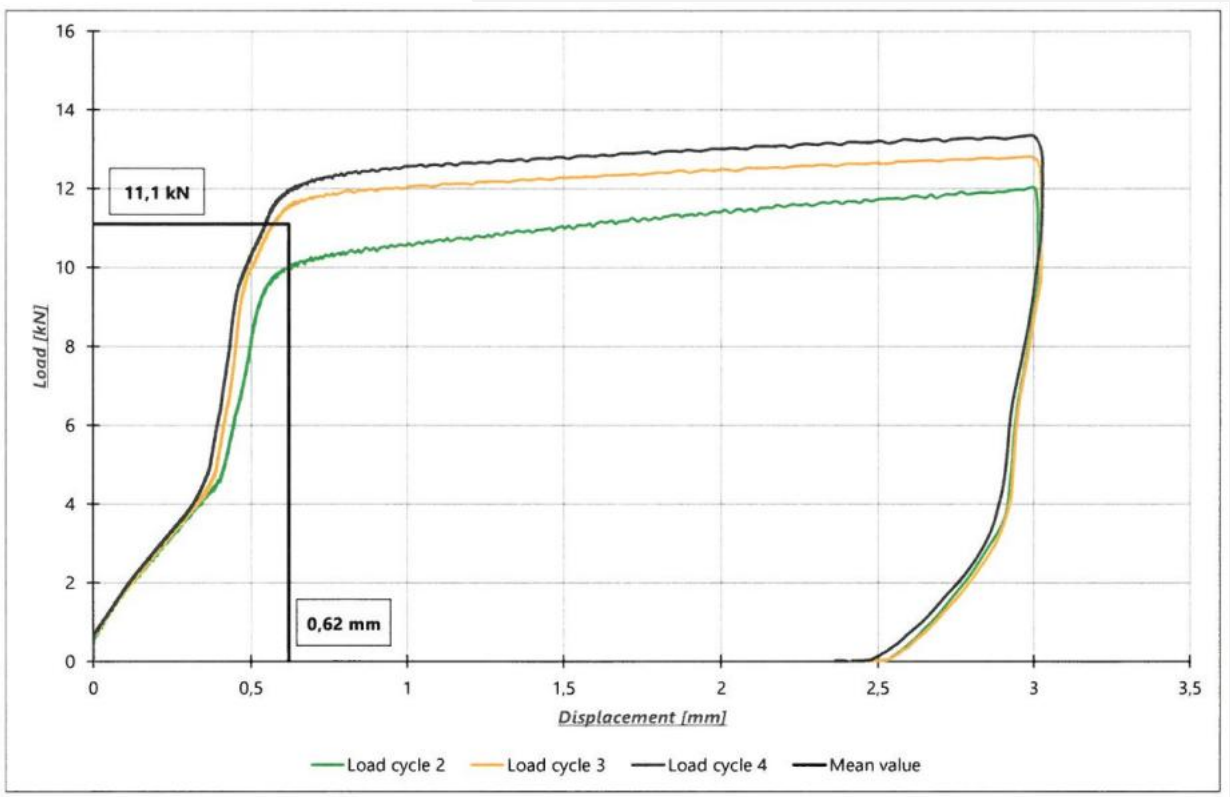
Spacing:
600 mm

Stiffness

LONGITUDINAL FORCES IN THE TRACK

ACCELERATION-BRAKING-INCLINED TRACKS

/ **Secured by high creep resistance of rail due to the fastening system with toe load and friction of pad to the rail**



PERMANENTLY HIGH TOE LOAD

TENSION CLAMP TO THE RAIL

Sample: M7

Spring arms (first stiffness)

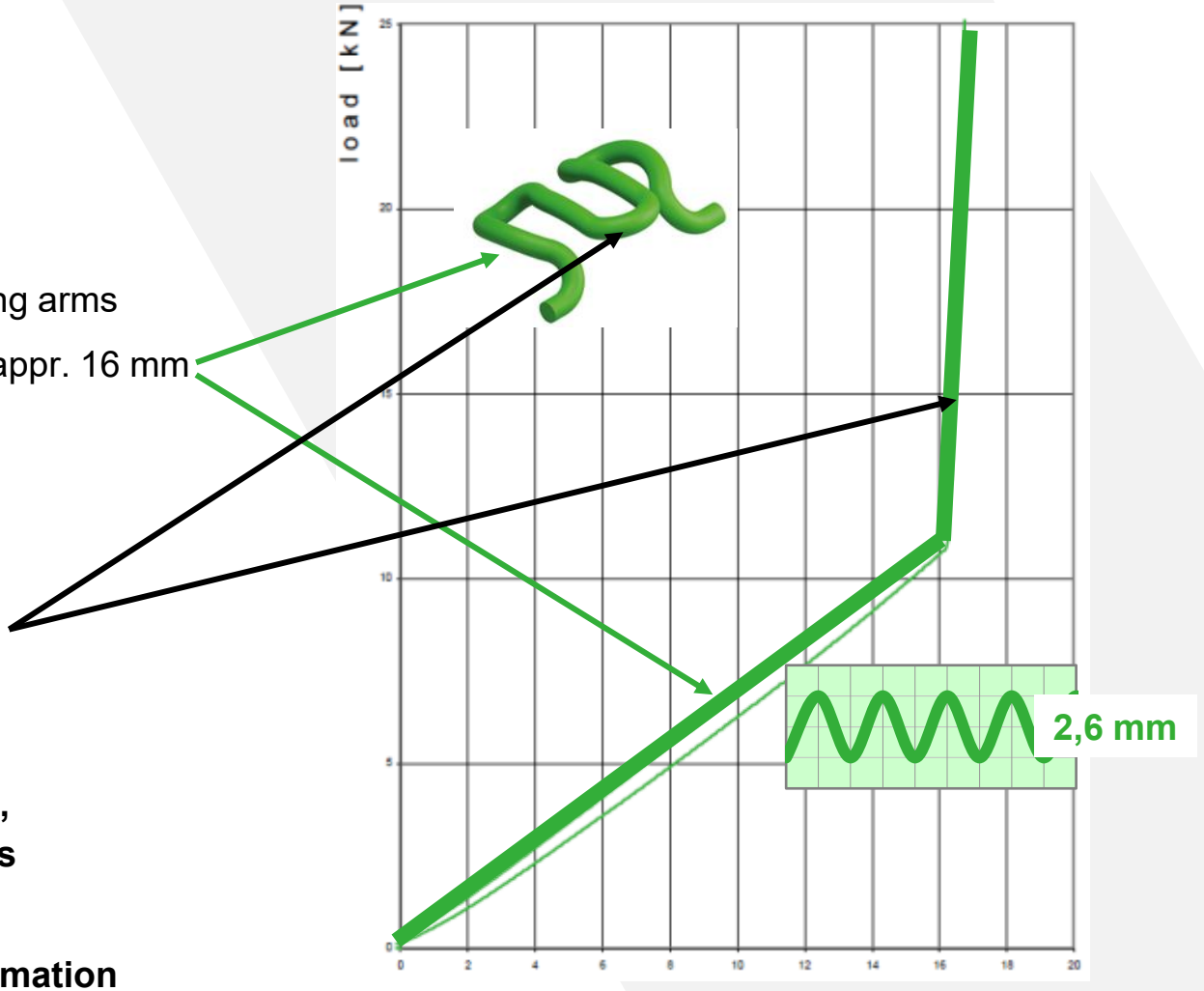
- Two independent working spring arms
- High elastic spring deflection: appr. 16 mm
- High toe load: > 10kN

Middle bend (Second stiffness)

- no twist, no tilting of rail
- no stresses at middle bend

High vertical amplitude 2,6 mm, allows to use highly elastic pads

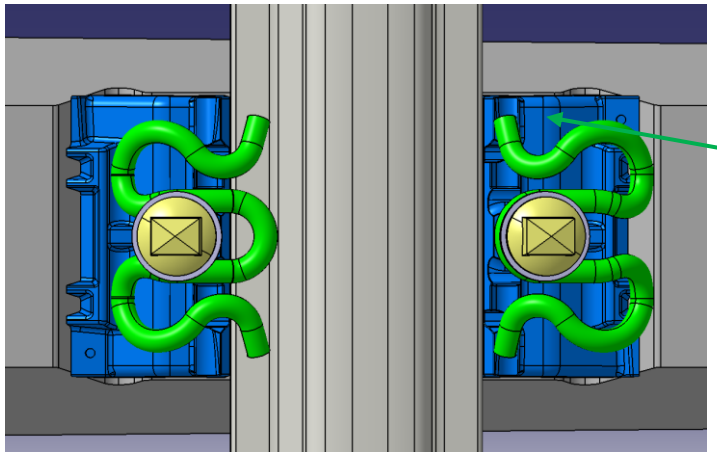
Overstressing and plastic deformation of spring arms is totally avoided



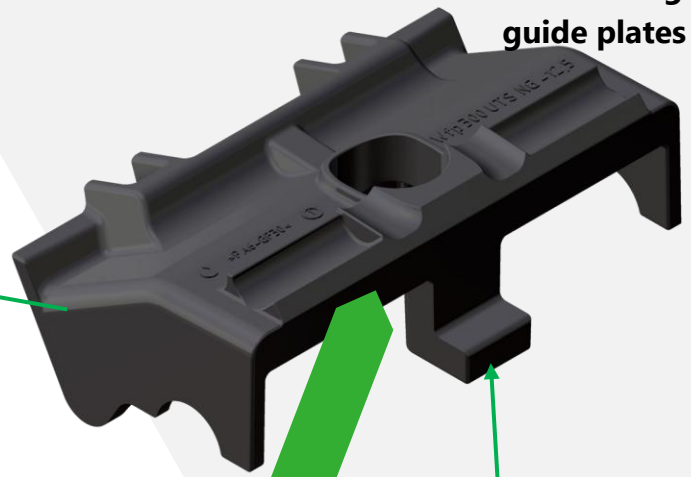
HIGH LATERAL FORCES

IN SMALL CURVE RADIUS

- Have to be transmitted from the rail via guiding plates to the concrete shoulder in the slab



- **Stable Gauge regulation up to ±10mm with guide plates**



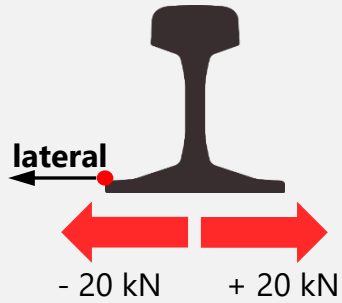
Additional tilting protection

Long contact area from rail to guiding plate

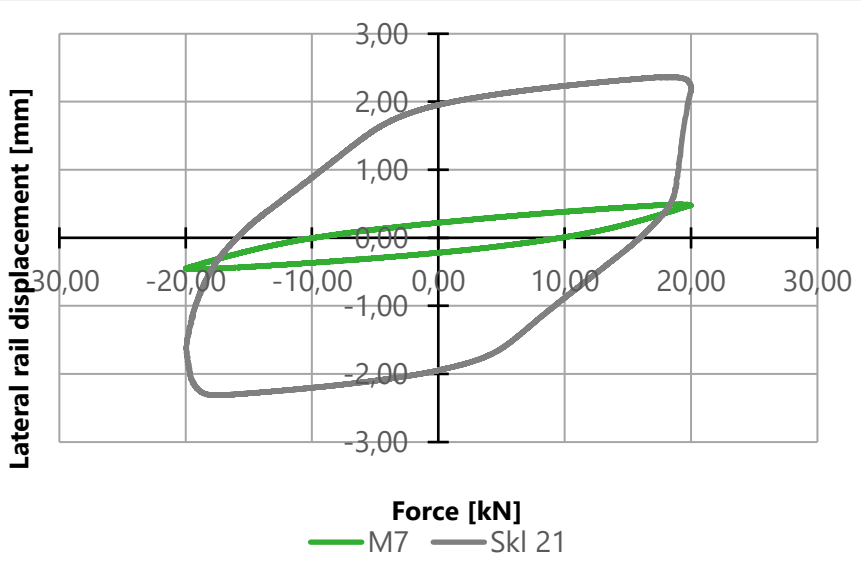
COVERING OF LOADS IN TOUGH CURVES

ADDITIONAL WITH HIGH STIFFNESS OF TENSION CLAMP IN LATERAL DIRECTION

- Significant reduction of rail and tension clamp displacement
- Significant increase of lateral clamp stiffness

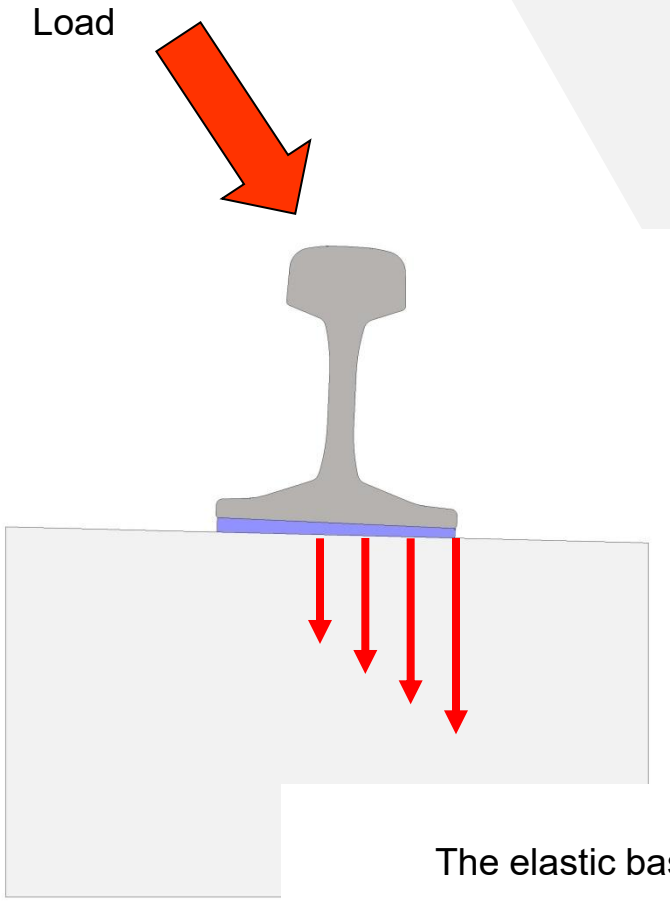


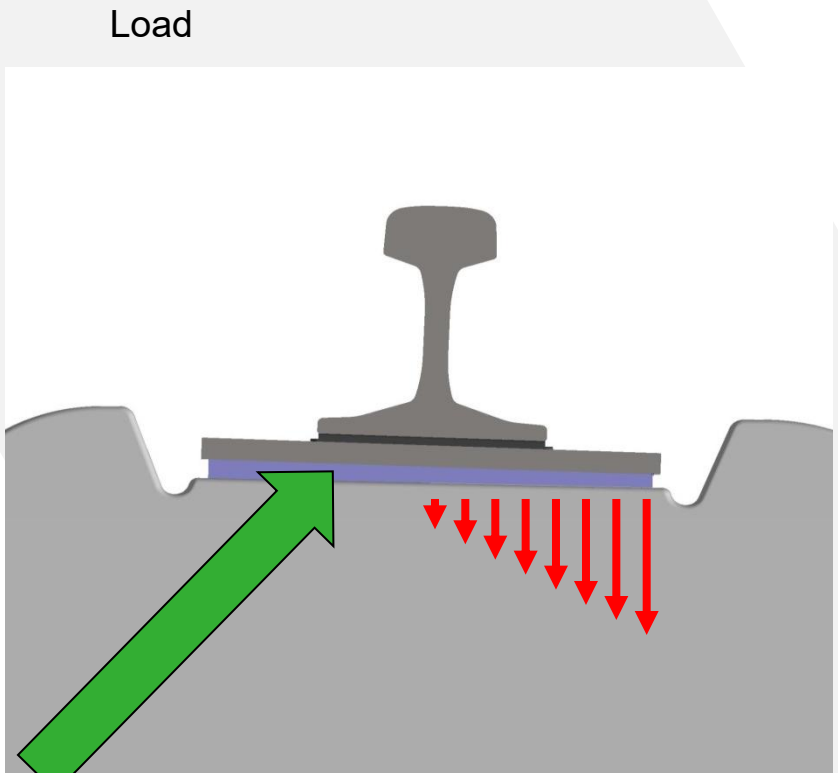
Clamp	M7	SKL 21	Diff. (%)
Force	+/- 20 kN		
Rail displacement	0.95 mm	4.67 mm	**- 79.7 %**
Spring arm displacement	0.80 mm	2.81 mm	**- 71.5 %**
Slip of clamp	**15.8 %**	**39.8 %**	
Clamp stiffness	50.0 kN/mm	14.2 kN/mm	**+ 252 %**



TILTING REDUCTION OF RAIL IN CURVE

CONTACT AREA OF RAIL



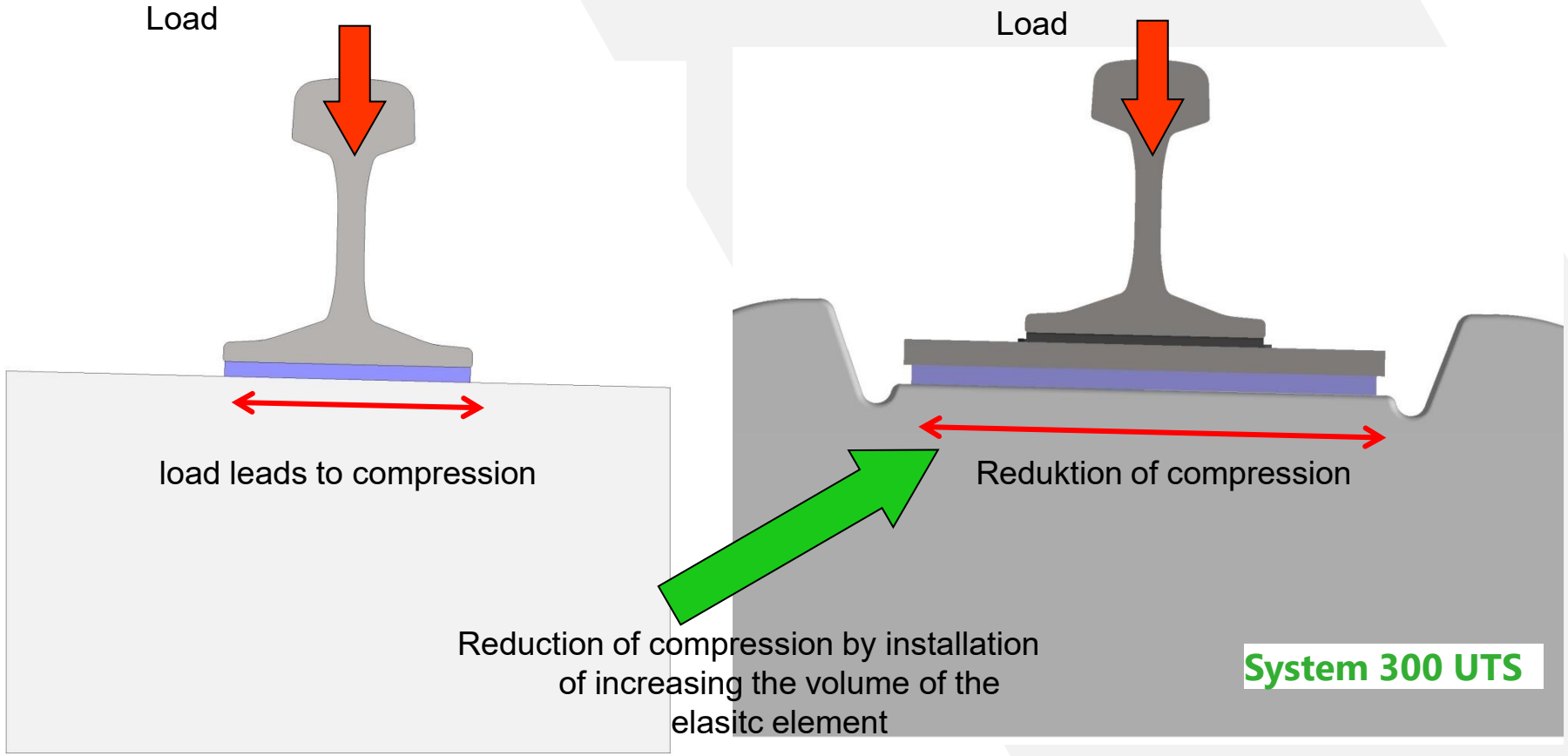


The elastic base plate pad Zwp in combination with the load distribution plate Grp resp. are reducing rail tilting responsible for gauge widening in tough curves

ELASTICITY

ELASTICITY

Enlarged elastic base plate pad guarantees
the necessary elasticity for the rail system

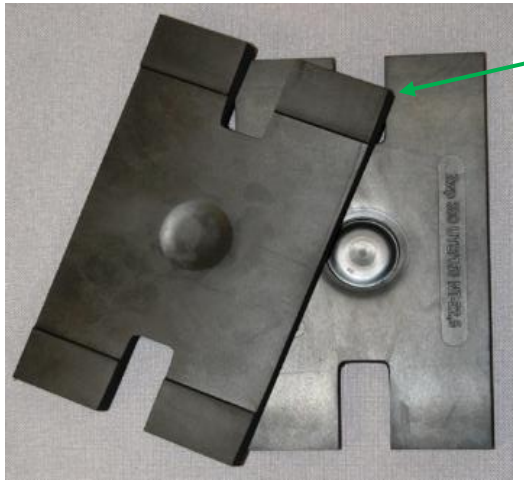


ELASTIC BASE PLATE PADS

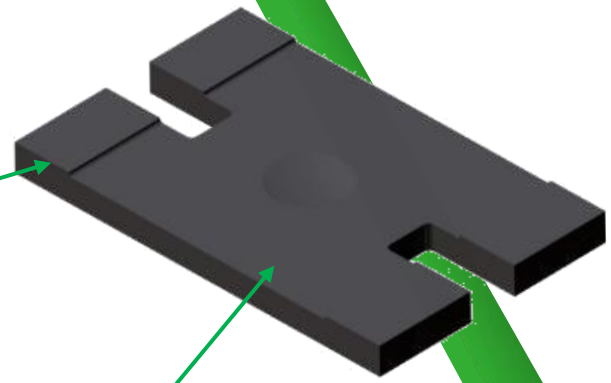
HIGH EFFICIENCY *CLOSED CELL GUARANTEES ELASTICITY*

- Optimized by FEM- simulation
- Improved track stability with the use **of anti-tilting-version**
  - closed cell structure
    - Outside boundaries strengthened
    - Regular stiffness area
    - Center very soft load distribution
    - spring curve characteristic with *cellentic*
    - Stiffness 15 – 30 kN/mm (15- 30 kN/mm)

Magnification of microcellular structure



reinforced area

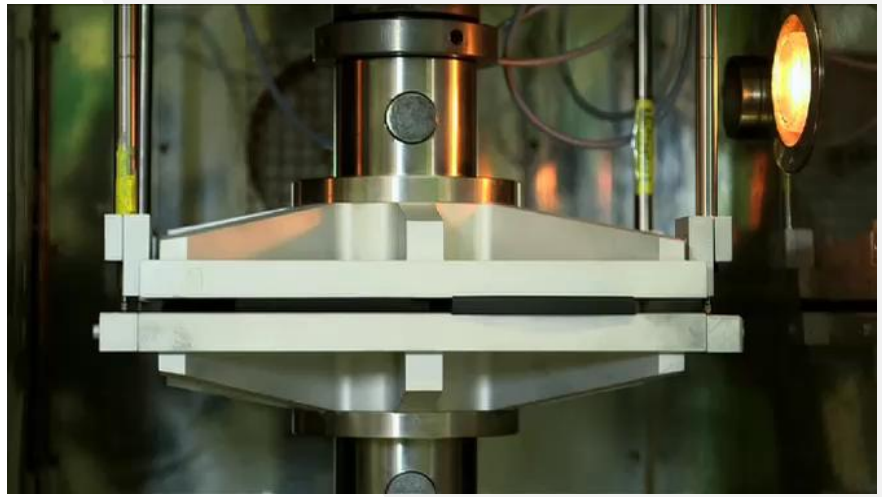


Zwp **300 UTS**

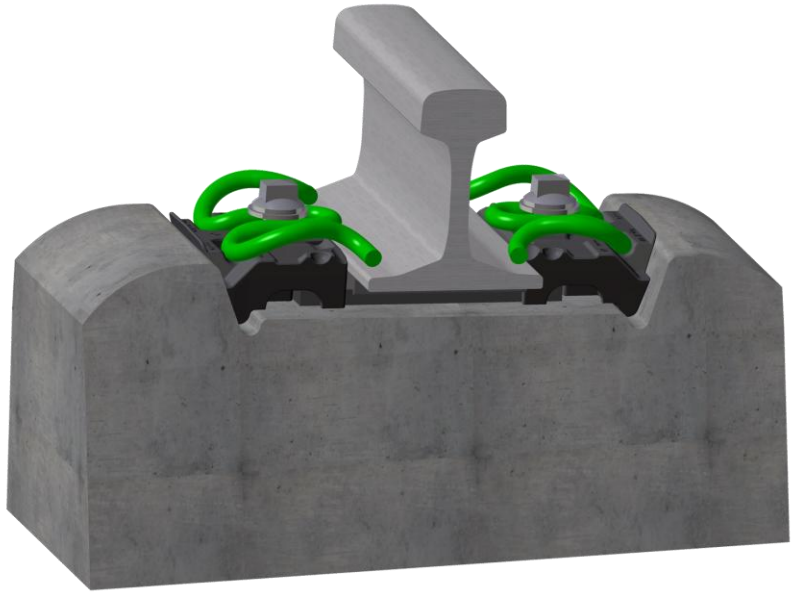
ELASTIC BASE PLATE PADS

OPTIMIZED SOLUTION

Rail pads under constant load testing: Various materials deform to differing degrees under enormous pressure, e.g. when the train passes over them.



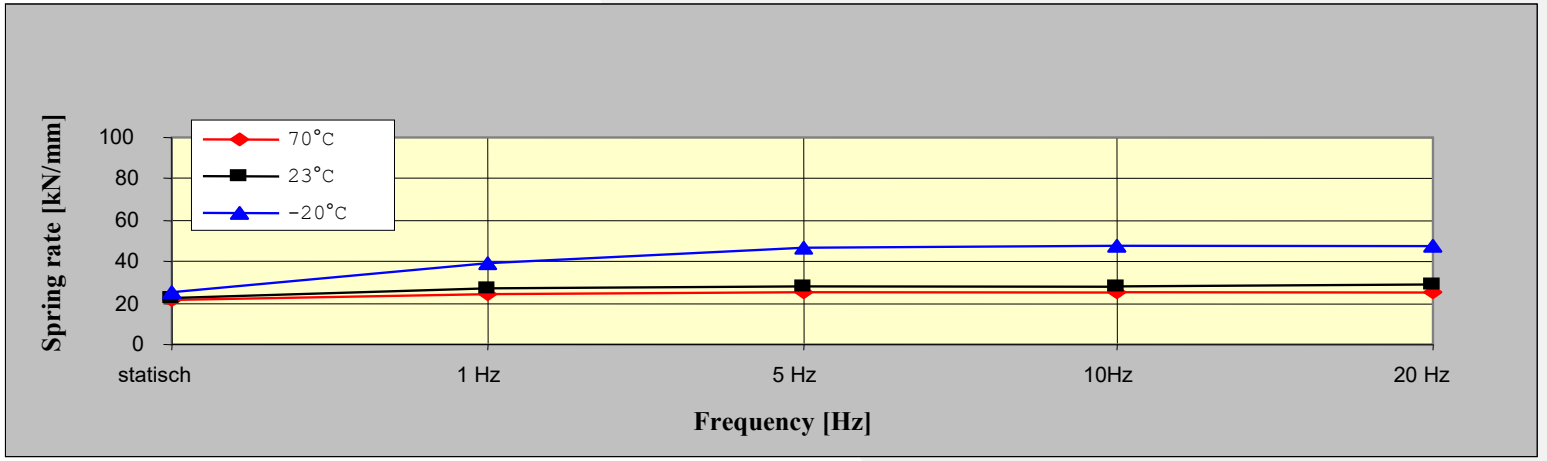
- The *micro cellular* components **reduce vibrations caused by track and wheel unevenness**.
- Thanks to its defined porosity, the *cellentic* pad can **work within its own structure** and will hardly deform under load.
- Rail pads and intermediate plates **allow rail deflection** and can therefore **optimally distribute occurring vertical forces**.



All components of the fastening systems are optimally attuned to each other

ELASTICITY ON SLAB TRACK

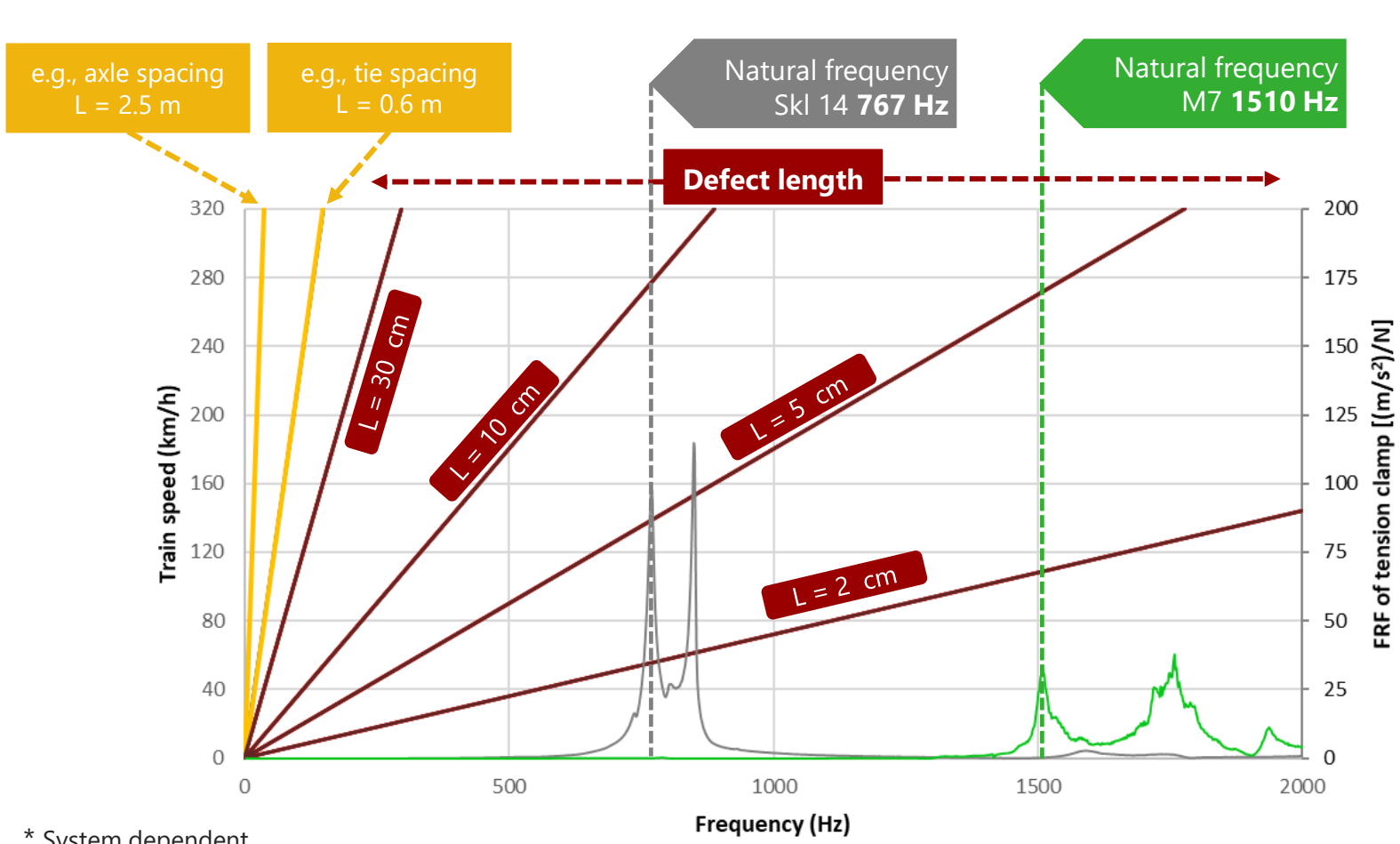
ELASTIC BASE PLATE PADS – CONSTANT ELASTICITY AT DIFERENT FREQUENCIES AND TEMPERATURES



		Frequency [Hz]				
		Static	**1 Hz**	**5 Hz**	**10 Hz**	**20 Hz**
Temperature [°C]	**+ 70 °C**	22.1 kN/mm	24.1 kN/mm	24.9 kN/mm	25.2 kN/mm	25.6 kN/mm
	+ 23 °C	23.0 kN/mm	26.9 kN/mm	27.9 kN/mm	28.5 kN/mm	29.3 kN/mm
	- 20 °C	24.8 kN/mm	39.7 kN/mm	46.3 kN/mm	47.3 kN/mm	48.0 kN/mm

HIGHER NATURAL FREQUENCY ENSURES BETTER SAFETY

RAIL FAILURES LIKE CORRUGATION AND OTHERS



* System dependent

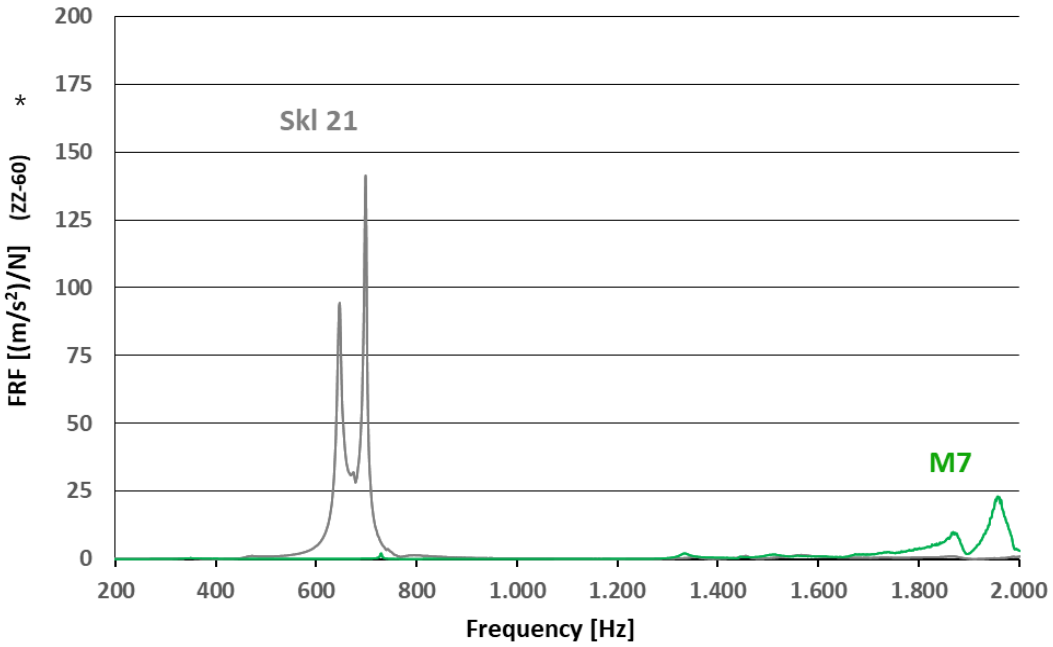
* M7 is resistant to high frequency loading (e.g. rail defects as corrugation)

DETERMINING THE NATURAL FREQUENCY

USING THE LABORATORY TEST WITH IMPACT HAMMER

Advantages of M Clamps:

- Significantly higher natural frequency
- Significantly smaller frequency response



* System dependent

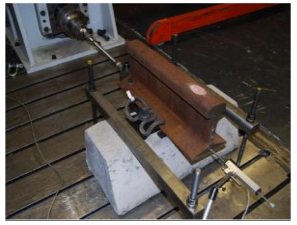
Frequency mode	M7	Skl 21	Difference *
1. Natural frequency	1870 Hz	647 Hz	+ 1223 Hz
2. Natural frequency	1960 Hz	698 Hz	+ 1262 Hz
Frequency response	20.5	141.0	- 85.5 %

QUALIFICATION OF FASTENING SYSTEM

TESTING

Acc. to the application and EN, ISO, AREMA, Gost, DBS or other national and project specifications

Creep resistance

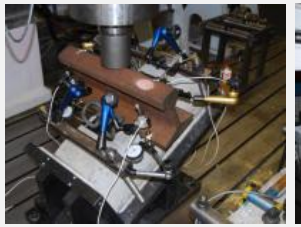


Vertical stiffness

Toe load

Torque moment test

Fatigue test



Electrical resistance

Fatique test under special environmental condition

Fatigue test in ballast trough

Fatigue test of elastic comp. ballast trough

02

SLAB TRACK

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CHARACTERISTIC OF SLAB TRACK SYSTEMS

WHY BALLASTLESS TRACK?

Advantages of the slab track

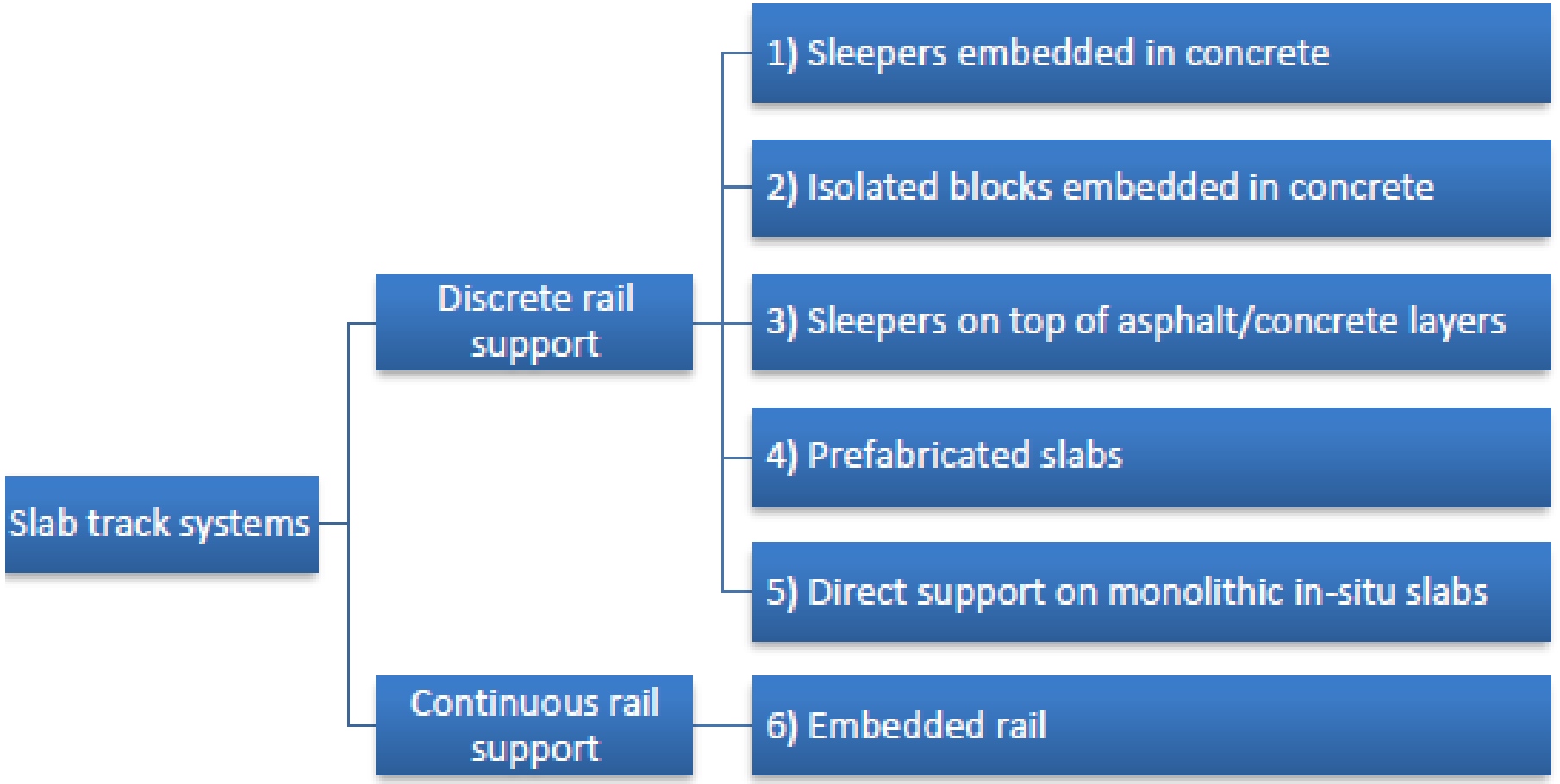
- hardly any maintenance effort – optimum for Metro application with less track closure time
- higher track availability
- no vegetation control on the track
- homogeneous elasticity and lower dynamic forces
- permanently high track quality in contrast to the ballasted track
- Precast elements allows a fast installation
- high resistance to transverse and longitudinal displacement (track displacement and track buckling are excluded)
- lower construction height (e.g. in tunnels)
- larger superelevation's and higher superelevation deficiencies possible, thus smaller track radii possible

-This optimizes the route with savings or avoidance of engineering structures (bridges, tunnels), thus potentially significantly more economical overall

- no risk of track distortion as with the classic ballasted track, use of the linear eddy current brake possible
- no flying ballast
- easier track cleaning (tilting in the track)
- surface drainage possible

SLAB TRACK SYSTEMS

CONSTRUCTION TYPES



SLAB TRACK SYSTEMS

NON-BALLASTED TRACK - EXCERPT

different construction types

On Bi-Block Sleeper

On Pre-fabricated Slab

METRO PROJECT

EXAMPLE

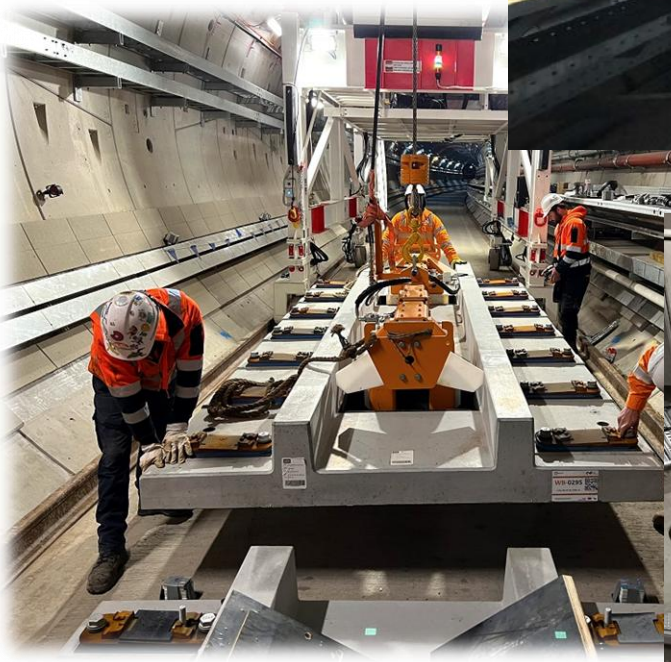
Overview

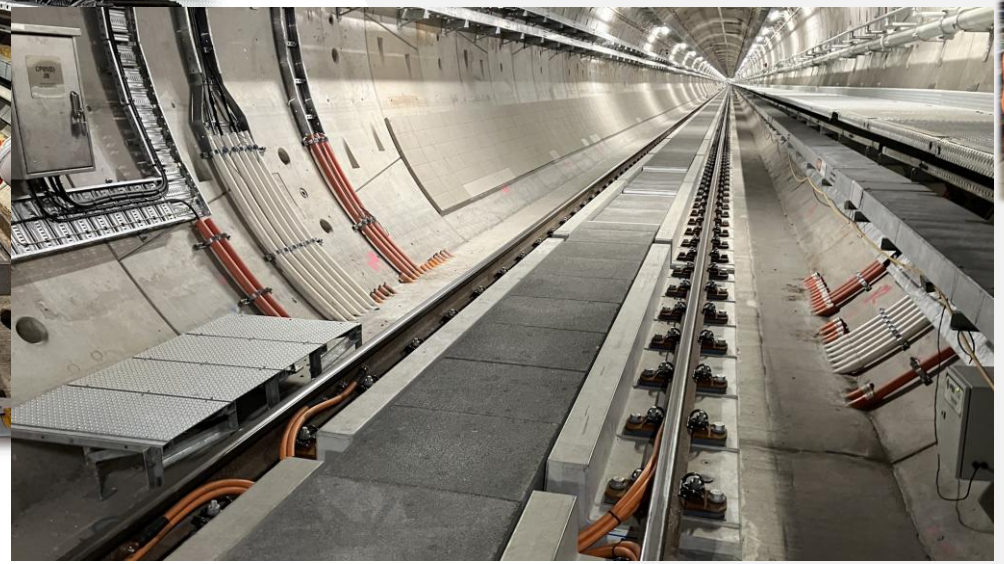
- Melbourne’s largest project with slab track (ballastless track)
- Underground twin tunnels 9.5km (19km track)
- Construction early works started 2016
- Cross Yarra Partnership awarded "tunnel and stations" public-private partnership in December 2017

- Track design completed early 2021, construction started late 2022 and completed early 2023

METRO PROJECT

TRACK INSTALLATION

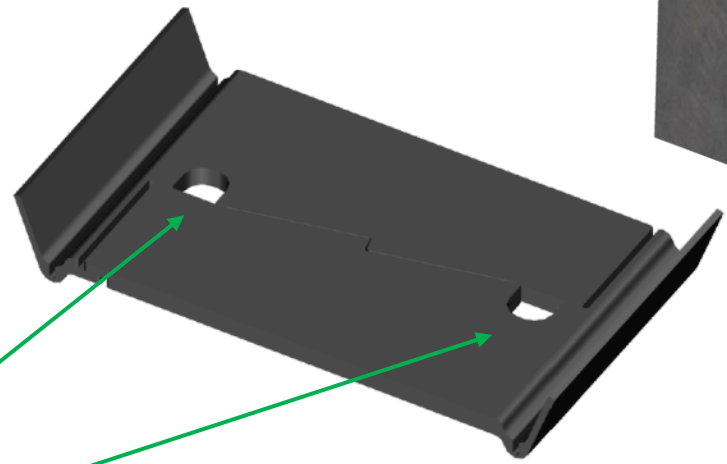




HEIGHT REGULATION FOR SLAB TRACK FASTENING

HEIGHT ADJUSTMENT STACKING

- Optimized blade shaped HAP design
- HAPs with frustration-free design & less complexity
- Improved for maximum elasticity performance & load distribution
  - **>10% improved** support for elastic pad
  - Higher stability



New design concept:

- Only one simple execution
- Slot (Airgap) is covered after installation

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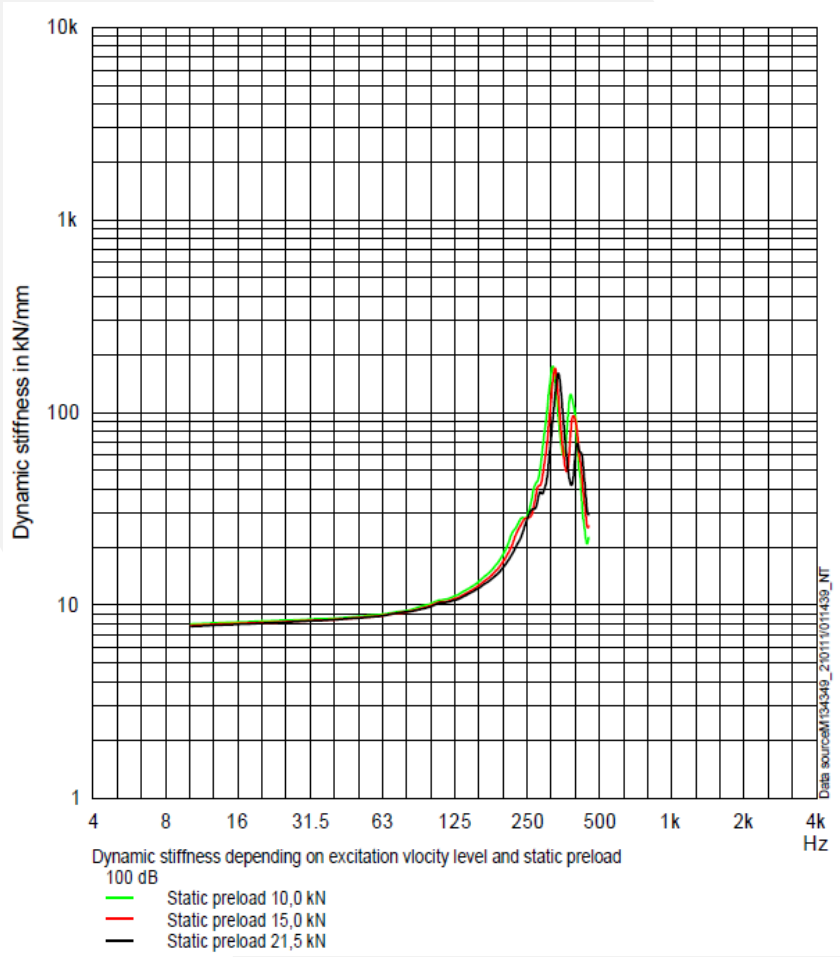
03 NOISE AND VIBRATION

TESTING HIGH FREQUENCY STIFFNESS OF FASTENING SYSTEM

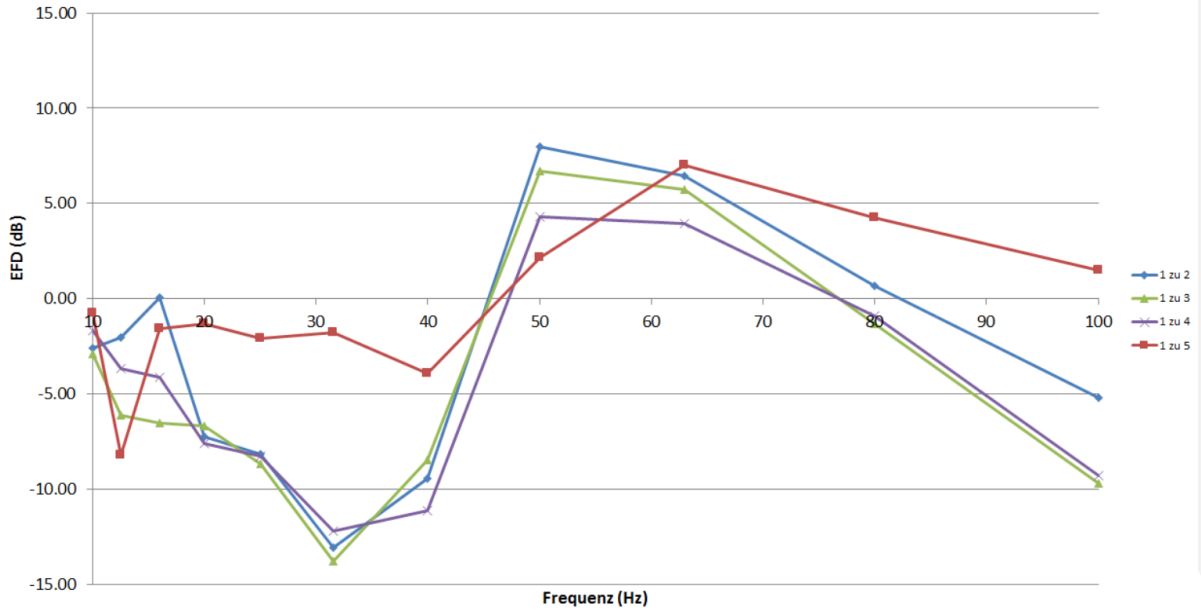
URBAN TRANSPORT CONFIGURATION – MELBOURNE -DETERMINATION OF HIGH DYNAMIC SYSTEM STIFFNESS

Track fastening	Standard Attenuation	High Attenuation	Very high Attenuation *
Minimum Static Stiffness Kstat	21 kN/mm	6.5 kN/mm	41kN/mm
Maximum Dynamic Stiffness Kdyn	28 kN/mm	8.5 kN/mm	55kN/mm



INSERTION LOSS MEASUREMENT

URBAN TRANSPORT CONFIGURATION – MELBOURNE -DETERMINATION OF HIGH DYNAMIC SYSTEM STIFFNESS



System	Static Stiffness [kN/mm]	Natural frequency [Hz]
1. Reference System: 336V (110 kN/mm)	109,1	> 50
2. System 336V (8 kN/mm)	8,2	approx. 40
3. System 336V (10 kN/mm)	8,5	approx. 40
4. System 336V (15 kN/mm)	10,3	approx. 40
5. System DFF 336NG (10 kN/mm)	10,2	approx. 40

SIMULATION OF INSERTION LOSS

URBAN TRANSPORT CONFIGURATION – MODEL FOR CALCULATION ISI

Using a software system called ISI, Vossloh calculated the Insertion loss of it´s System 336 series for different track types.
The evaluation is based on DIN-standard-in-preparation DIN V 45673-4 "Mechanical vibration – Resilient elements used in railway tracks – Part 4: Analytical evaluation of insertion loss of mounted track systems".

Exemplary Parameters Vehicle Model	
Speed	Vmax = 80 km/h
Length	21m
Wheel-to-wheel distance	2.300mm
Wheel diameter	800mm
load / wheel = 7,5 to	75% mass railcar body = 5.625 kg 10% bogie mass = 750 kg 15% unsprung mass = 1880 kg

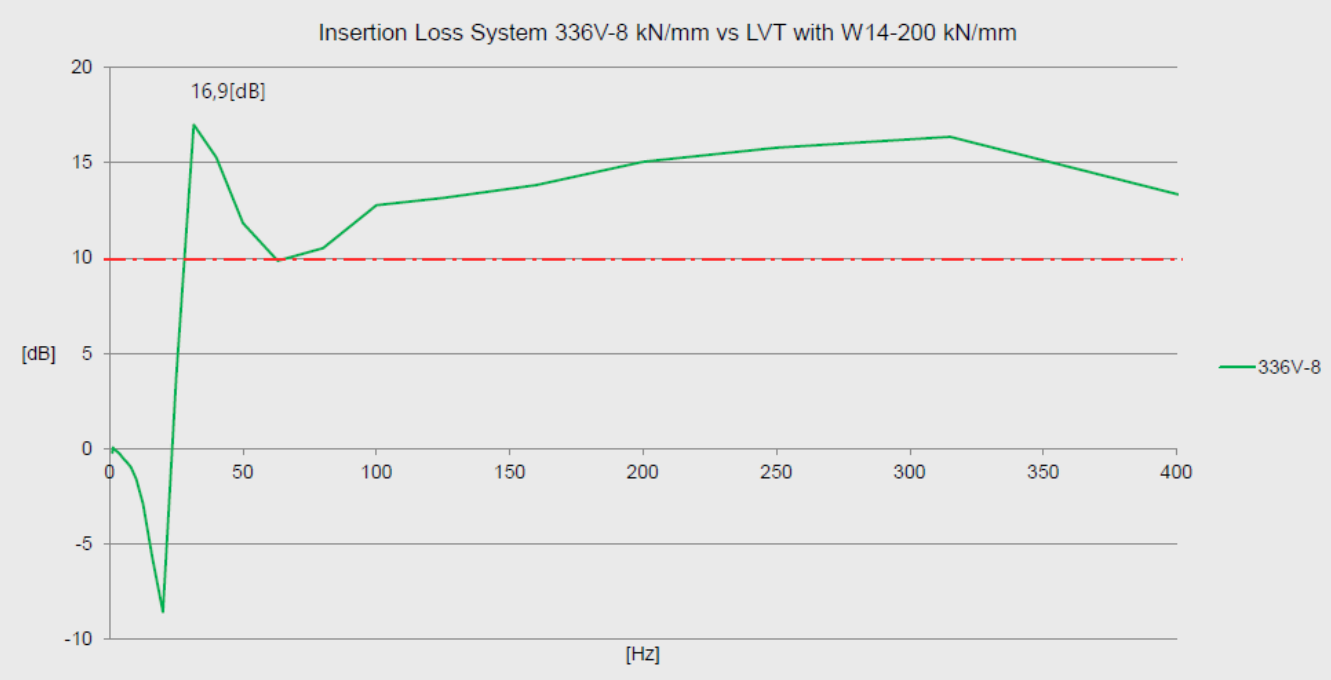
Base Plate	336V- 8 kN/mm
Type	Slab track, support-point spacing: 750 mm
Subsoil	stiff rock

Assumptions according car suspension	
Primary Stiffness	0,972 kN/mm
Primary Damping	12000 Ns/m
Secondary Stiffness	0,352 kN/mm
Secondary Damping	10000 Ns/m

Reference	LVT Standard
Reference Rail Pad	200 kN/mm

SIMULATION OF INSERTION LOSS

URBAN TRANSPORT CONFIGURATION – MODEL FOR CALCULATION ISI



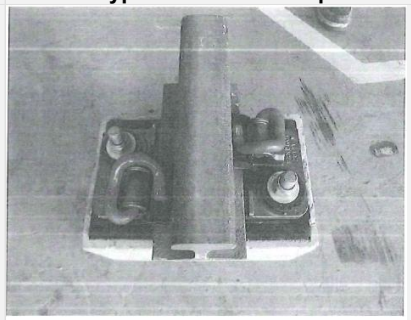
Reference	System	Insertion loss [dB]
W14 200 kN/mm Zw + LVT	336V/ Zwp 8 kN/mm	16,9
	336V/ Zwp 12 kN/mm	10,2
	336V/ Zwp 12,5 kN/mm	9,9
	336V/ Zwp 13 kN/mm	9,7
	336V/ Zwp 14 kN/mm	9,2
	336V/ Zwp 15 kN/mm	8,7

03

COMPARISON

FASTENING SYSTEMS 1/2

COMPARISON

Track System	Slab track		
Fastening System	**Vossloh 300 MFlex (300 UTS)**		**Pandrol Type 22028 with E`clip 2007**
		**additional explanation**	
		300 Mflex is specially designed for slab track. Highly elastic big base plate pad guarantee the necessary elasticity in the slab track permanently. Rail deflection is targeted for 1,0 - 1,5 mm	Origin is an indirect FS and the elasticity is limited with simple rail pad and due to fatique limit of clip
Gauge	1435 mm and all other regular gauges	Gauge is prefabricated with precast slab or sleeper	Gauge have to be mounted in situ. Accuracy have to be guaranteed with time consuming installation and special equipment. Similiar for inclination of rail
Rail section	60 / 54 and others		
System References	precast slabs, sleepers (monoblock/twin blocks) embedded in situ concrete, single concrete blocks	Accuracy in gauge and inclination for rail is guaranteed with high quality precast products	for in situ installation. Reference quantities unknown
Standards	EN 13481-5 resp. ISO XXX,		
Type of fastening system	direct to the rail seat without ribbed base plates		indirect with kind of ribbed base plates
Insulator between tension clamp and rail	not necessary	fully insulated by rail pad, dowel and angle guide plate	have to be used, which have to be maintained due to higher pressure between clip and rail (could be squezzed)
Transfer of lateral loads from rail to fastening system to the slab	the fastening system laying in a rail seat, where the guide plate have a large contact surface to the sleeper which transfer the lateral loads without loading of anchoring devices.		high loading of anchor bolts in bending and shearing stress
Inclination of rail	set in the rail seat in concrete; 1:40; 1:20 or other	with accuracy due to precast products	accuracy must be achieved with installation

FASTENING SYSTEMS 2/2

COMPARISON

Quality of gauge	very high, but the rail seat/shoulders a perfectionally produced in the concrete factory.		
Axle load	10t - 17t for UTS		
Speed	≤160km/h for UTS;		
Longitudinal resistance	≥ 7kN UTS; according standard, typically approx. > 10 kN per fastening point		
Special application with lower resistance	> 0 - ≤ 7 kN	with dfferent tension clamp	
Toe load	approx. 18 - 20 kN		approx. 14 - 16 kN
Fatigue limit of clamp	3.0mm	Due to the large volume base plate pad in thickness and area, as well as the high fatigue strength of the tension clamp, a wide variety of elasticities can be installed depending on requirements. A load load distribution plate: divides foces to the elastic base plate pad with low stress and acts against rail tilting. This distribution plate enlarged also the small rail foot.	E`clip: approx. 1,0 mm, thats limit the use of softer pads. If, then the rail deflection exceeded the fatique limit of clip and leads to an early breakage
Natural frequency	Resonance challenges: M7 tension clamp with elevated natural frequency (ca. 1500Hz) resists frequencies in the track coming from rail failures and unround wheels which can cause broken tension clamps. Higher resistance against hunting motion.		
Stiffness (elasticity of fastening system)	22.5 kN/mm as standard execution for UTS		
Vibration reduction	via high elastic pads up to 13 kN/mm		
Gauge regulation	plus / minus 12 mm	with different prefabricated angel guide plates	
Height regulation	-4/+76mm (106mm possible)	with height regualion plates and rail pads in steps of 1 mm	height regualtion leads to higher bending stress to the anchor bolts and limited the regualations
Handling	less single components for easier handling		complex
Installation	simple with standard screwing devices		different tools necessary
Pre assembling	standard on the sleeper, that delivered to construction site as a whole system; no loss of components, no handling of components at site		not possible
Installation of rail	easy shift from pre-assembly into assembly position of tension clamp		complete assembly of E`clip
Neutralisation of rail	simple loosening of tension clamp		complete dismantling of E`clip
Plastic deformation of tension clamp	due to the middle of tension clamp, which act over the rail foot, the rail tilting and therefore the plastic deformation is limited. Secondary stiffness of middle bend.		with E`clip higher risk of plastic deformation
Overloading of highly elastic base plate pad	the small nose (thinner than the elastic base plate pad) act as a overloading limitation for the elastic pad		
Contact point of clip / tension clamp to the rail	2 outer spring, which acting independant from each other. 2 contact point to the rail with approx. 4-5kN loading		one single contact with higher pressure. 7-8 kN loading
Corrosion protection	Vossloh protect coating with highest corrosion resistance level for tension clamp. Hot dipped galvanization for sleeper screws		

vossloh
enabling green mobility

05

300 UTS - MFLEX 7 DIRECT FIXATION FOR SLAB TRACK

FASTENING SYSTEM 300 MFLEX 7

URBAN TRANSPORT CONFIGURATION

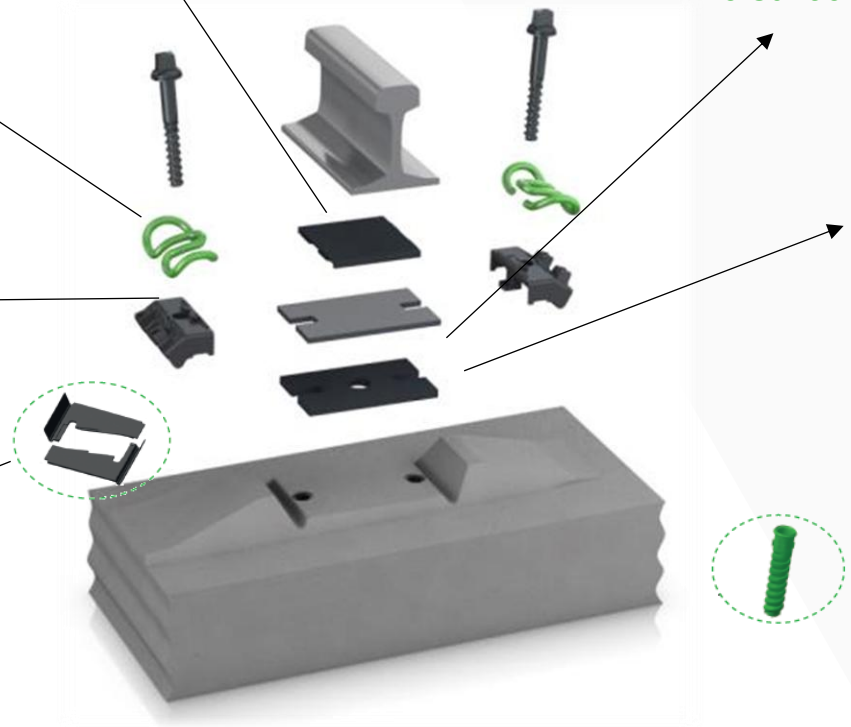
/ Rail pad
for a second elasticity
and insulation

/ M7
provides safety
By its tilting protection,
& rail creep resistance

/ Steel plate ensures an optimum distribution of load

Angle guide plates
Stable rail guiding
and enables gauge regulation

Foamed pad for less vibration -
Vibrations and structure-borne noise are minimised, stable rail deflection

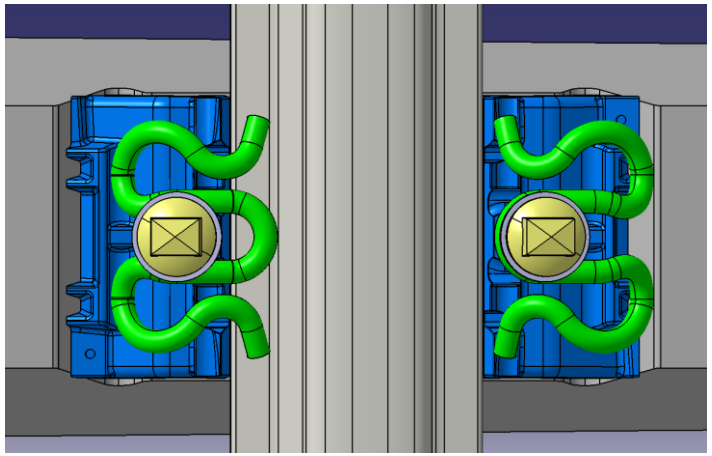


/ By using adjustment plates,
the height of the system can be regulated without

/ Securely clamped with
the screw-dowel
combination *NG*
Decreases the load on
the slab track

BEST PREPARED FOR ALL REQUIREMENTS

300MFLEX 7 FOR URBAN TRAFFIC



- **Completely integrated and standardized, designed to work in full coordination with all components**
- **Noise & vibration**: Intermediate plates are made of *foamed material*
- **Easy to install**: Pre-assembly & exchangeability of all fastening components
- **Track control**: Regulation concept (lateral, vertical & gauge) to correcting subsidence areas
- **Low maintenance**: Reduced wear because of microcellular pads, durable components & system interplay
- **Elasticity: adjustable stiffness**

The individual solution for slab track

The system 300 Mflex 7 has been further developed on the basis of the system 300 especially for urban transport. It is a cost-efficient solution for contoured track plates as well as also for pre-fabricated concrete plinths and due to its modular design it can be configured individually.

300 MFLEX

PREASSEMBLY AND EXCHANGEABILITY FEATURES

- All parts of the fastening system can be preassembled
  - At the construction site, it will only be required to lay the rail and clamp it
    - Fastening components cannot get lost
      - Can be assembled on sleepers, bearing plates and concrete bases
        - For welding of the rail, no fastening elements have to be removed from the support point
          - All components, including dowels, can be replaced

300 MFLEX 7 FOR SLAB TRACK

ECONOMIC FASTENING SOLUTION FOR YOUR SAFE TRACK

User benefits

- Part of the Vossloh 300 Series with more than **18.800 km experience**
- Innovative, **compact design reduces** transportation **costs**
- Simplified **handling** in track & sleeper production
- Ensuring long-term **track availability & safety** of the track

Features

- Highest available **Natural Frequency** by using M7 tension clamp (approx. 2x higher than typical frequency in the track)
- M7 with outside bended spring arms for safer track laying, reduced rail movements and damage to the rail head surface
- **High fatigue** strengths ≥ 2.6 mm offers possibility of increasing the elasticity of the Slab Track
- Advanced **Anti Tilting** features (Zwp, Wfp, M7)
- **Premium coating** *Vossloh Protect* strengthens clamps for highest corrosion protection