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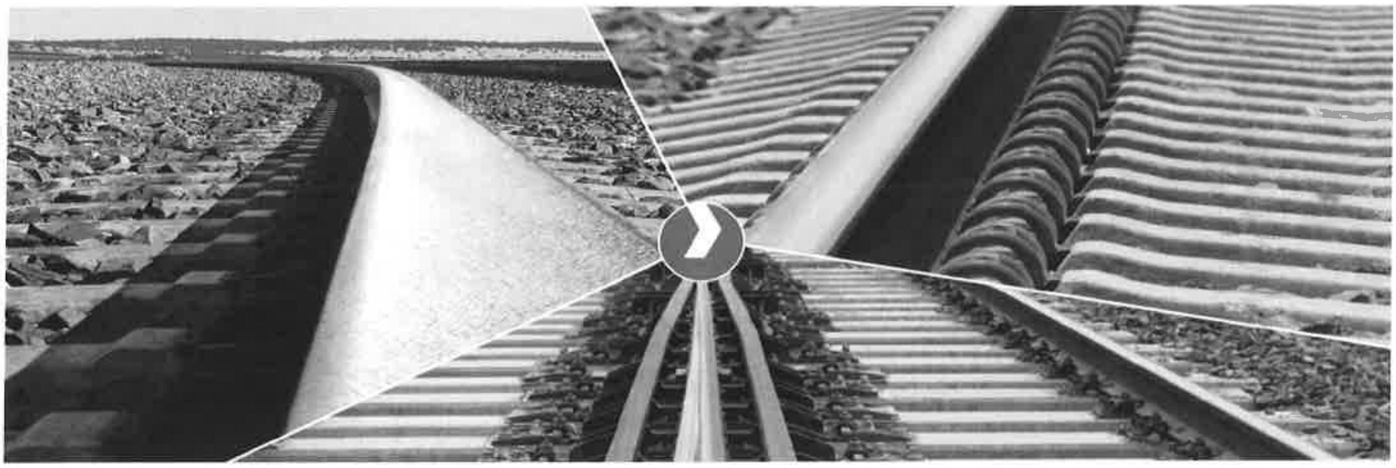
International requirements for Engineered Polymer Sleeper (EPS) based on the development of Vossloh Amalentic

South Korea 25th May 2019



Summary

1. **International Requirements**
   - -American Railway Engineering and Maintenance-of-Way Association **AREMA**
   - -International Organization for Standardization **ISO**
   - -European Standards **EN**

   -Serviceability testing of composite sleepers – **DB AG**

2. **The idea of the material**
3. **Challenge in the development of composite sleepers**
4. **Requirements for the raw material (plastic), the modeling and the production process of the "Vossloh Amalentic sleeper"**
5. **Various test methods, properties and results at a glance**
   - -3 point bending test
   - -Fatigue test of sleepers in ballast–trough according to German Railway requirements
   - -Fatigue test of sleepers in ballast–trough according to AREMA
   - -Determination of temperature influence
   - -Pull out test
   - -Longitudinal test with rail anchors
   - -Fire behavior
   - -Spike lateral restraint test
   - -Fastening System test according to EN
   - -Fastening System test according to AREMA
   - -Lateral resistance

AREMA – Chapter 30 – Ties

190 pages

Design Consideration:

extract

- Single tie lateral push
- Spike / Screw pullout
- Spike lateral restraint
- Tie and Fastener wear / deterioration
- Cooefficient of thermal expansion
- ...

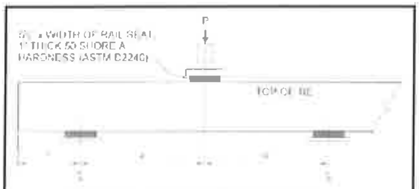


Figure 30-2-1. Rail Seat Positive Bending Test

EN / ISO - Railway applications — Track — Plastic sleepers and bearers

Railway applications — Track — Plastic sleepers and bearers — Part 1: General requirements

Plastic railway sleepers for railway applications (railroad ties) — Part 2: Products testing

Railway applications — Track — Plastic sleepers and bearers — Part 3: Material characteristics

Serviceability testing of plastic sleepers, part of approval requirements

DB NETZE

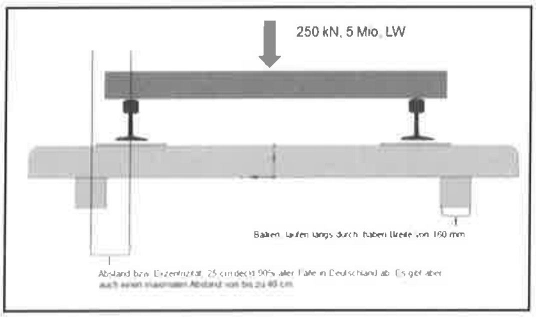
Due to the different types of loading, it is necessary to differentiate between track / turnout sleepers (loading in ballast, negative bending moments due to sleeper riding) and bridge beams (single-span beams).
The usability test consists of two parts:
• Determination of the expansion coefficient in a climate box
• fatigue test with temperature stress ..

▶ **Description of Determination of the coefficient of expansion in the climate box (abstract)**

• For the climatic box test, a half sleeper without fastening system is to be tempered for each type (bridge beam, track sleeper, turnout sleeper). The coefficient of expansion must be re-established for a type if the degree of reinforcement of the cross-section is changed.
• Installation of measuring markings for measuring changes in length.
• Temperature range between -20 ° C and + 40 ° C.
• 10 temerature changes (+40 / -20 / +40 ° C).
• The limit temperatures (+40 and -20)...

Bridge beam

▶ **Figure of load description**



▶ **Fatigue test in ballast trough – description in detail**

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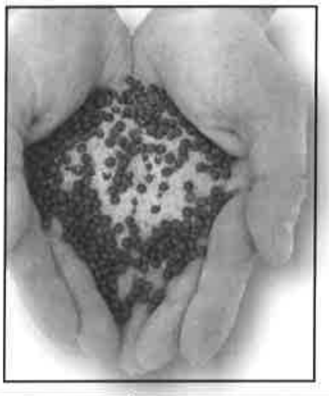
The Idea of the material - AMALENTIC



▶ **Material:**

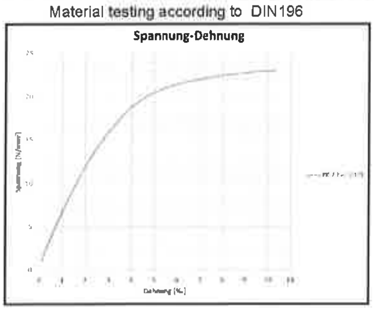
- Innovative material mixture: recycled polymer (high and uniform industrial quality), additives and filler with defined properties
- Additives to ensure the lifetime and quality (UV stabilizer, antioxidants/ process stabilizers and others)

▶ **In General: different mixing ratios**

▶ **Advantages of the material mixture:**

- Isotropic material behavior, no fibers
- High density
- Low thermal expansion coefficient of the sleeper
- Dimensional stability
- Low retardation and plastic deformation

Material testing according to DIN196



▶ **Environmentally friendly due to recycled and recyclable material**

▶ **Approx. 350 internal and external material tests performed**

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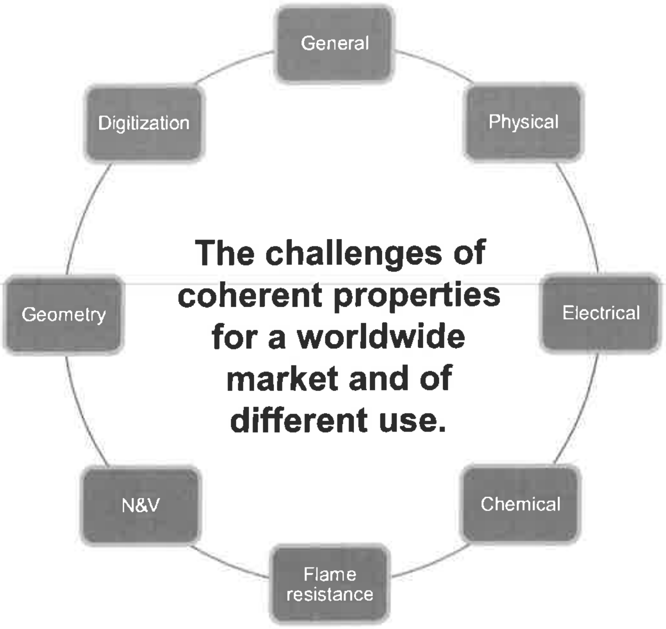
The Challenge

Important properties of polymer sleepers

- ▶ **High pull-out force of the anchoring**
- ▶ **Low deflection / bending of sleepers**
- ▶ **Low thermal expansion coefficient**
- ▶ **Uniform high quality**
- ▶ **High lateral resistance in track**
- ▶ **Long life time, high UV and thermal stability**
- ▶ **Cost effective solution for the client**
- ▶ **...**



More than 150 requirements were identified

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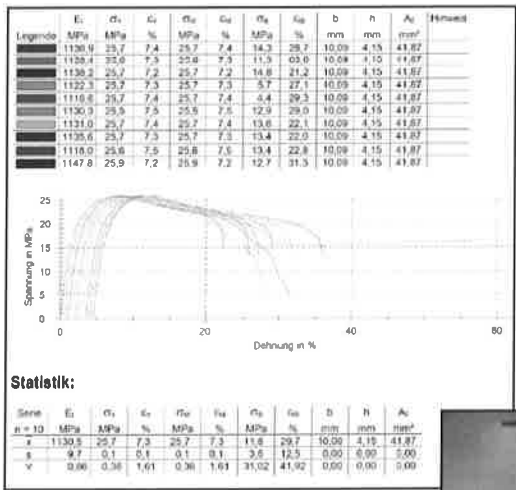
Requirements for the raw material to guarantee uniform high quality

▶ **Minimum requirements for polymer:**

- Melt flow rate
- Tensile modulus
- Tensile stress at yield
- Elongation at rupture
- ...

▶ **Minimum requirements for the filler:**

- Grain size and geometry
- Hardness
- Residual moisture
- ...



Legende	E_t MPa	σ_Y MPa	ε_Y %	σ_M MPa	ε_M %	σ_B MPa	ε_B %	b mm	h mm	A_0 mm²	Hinweis
	1130,9	25,7	7,4	25,7	7,4	14,3	29,7	10,09	4,15	41,87	
	1128,4	25,6	7,3	25,6	7,3	11,5	03,0	10,09	4,15	41,87	
	1138,2	25,7	7,2	25,7	7,2	14,8	21,2	10,09	4,15	41,87	
	1122,3	25,7	7,3	25,7	7,3	5,7	27,1	10,09	4,15	41,87	
	1110,6	25,7	7,4	25,7	7,4	4,4	29,3	10,09	4,15	41,87	
	1130,3	25,5	7,5	25,5	7,5	12,9	29,0	10,09	4,15	41,87	
	1131,0	25,7	7,4	25,7	7,4	13,6	22,1	10,09	4,15	41,87	
	1135,6	25,7	7,3	25,7	7,3	13,4	22,0	10,09	4,15	41,87	
	1118,0	25,6	7,5	25,6	7,5	13,4	22,8	10,09	4,15	41,87	
	1147,8	25,9	7,2	25,9	7,2	12,7	31,3	10,09	4,15	41,87	

Statistik:

Serie n = 10	E_t MPa	σ_Y MPa	ε_Y %	σ_M MPa	ε_M %	σ_B MPa	ε_B %	b mm	h mm	A_0 mm²
$\bar{x}$	1130,5	25,7	7,3	25,7	7,3	11,6	29,7	10,09	4,15	41,87
s	9,7	0,1	0,1	0,1	0,1	3,6	12,5	0,00	0,00	0,00
ν	0,86	0,36	1,61	0,36	1,61	31,02	41,92	0,00	0,00	0,00

Further quality parameters

▶ **Material mixture:**

- Determination of optimal mixing ratio and grain size
- Determination of optional bonding agent and ratio for extreme applications
- ...

▶ **Reinforcement:**

- Determination of the optimal type and position of reinforcement
- Grading curve, geometry of filler
- ...

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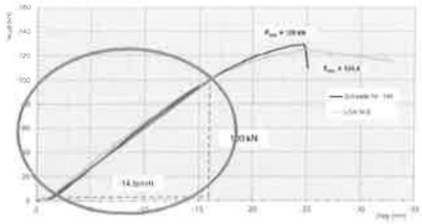
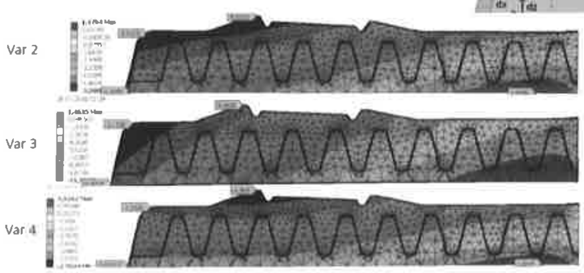
Modeling as part of development



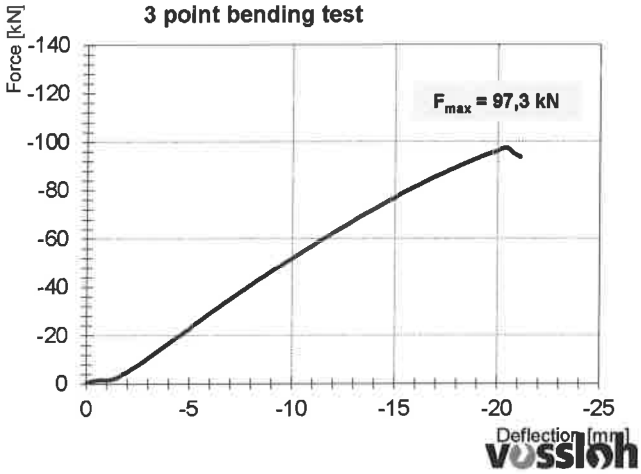
Linear part for the material model

- ▶ **Development of a material model for FEM calculations**
- Static strength
- Influence of the rebar's position to the deformation by production
- Design

- ▶ **Example:**
- Simulation: ~ 100kN ultimate load; 17,5 mm deflection
- Real test: 97,3 kN @ 21mm



Deformation by production



Production Process

Melting and mixing (polymer additives and filler)

↓

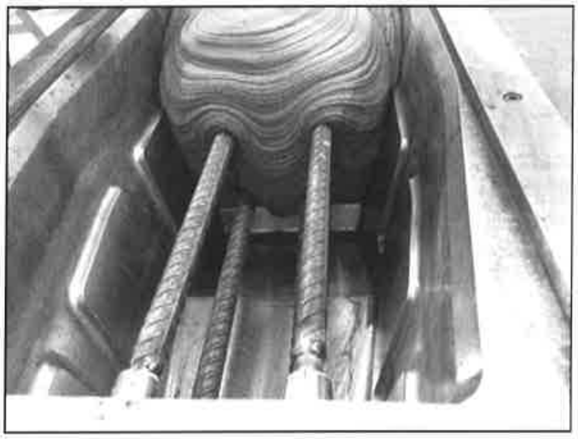
Positioning of the rebar's and filling

↓

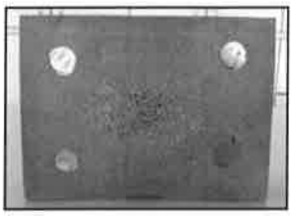
Pressing and cooling

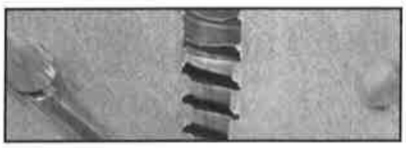
↓

Demoulding

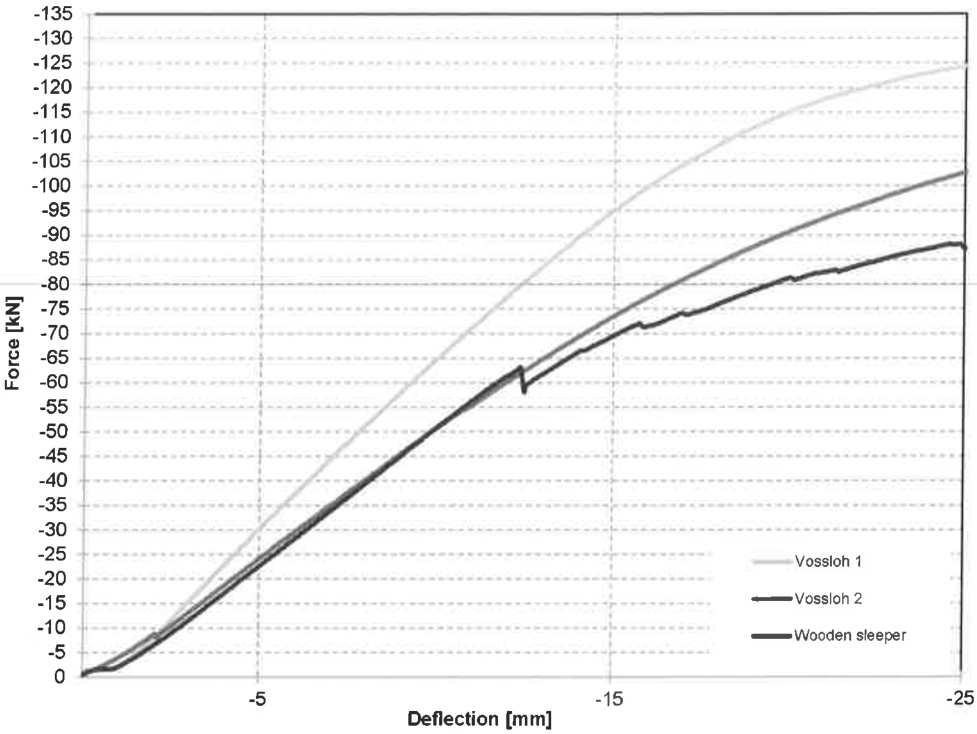


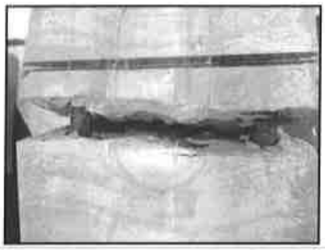
Filling proses





3 point bending test - Negative bending moment





Local necking of the rebar due to the good bond between rebar and polymer

- Stiffness and deflection can be adjusted

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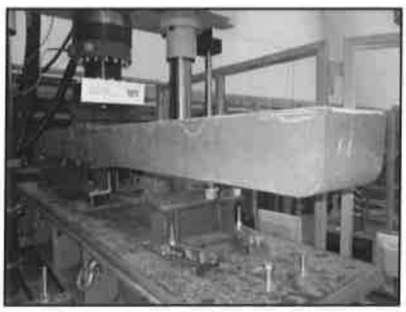
Serviceability testing of composite sleepers

- **Serviceability of DB Netze** DB NETZE **(Betriebstauglichkeitsuntersuchung)**
- **Fatigue test in ballast trough**
  Number of specimens: 2 sleepers in the same experiment.
  Track sleepers: 2 pieces a 2,60m
  • Installation of 40cm new ballast in 2 layers a 20cm. Every gravel layer has to be compacted.
  • After compacting the ballast, clear a layer of ballast in the middle of the sleeper with a length of 500 mm in the longitudinal axis of the sleeper.
  • 5 million load cycles between 10 kN and 375 kN (takes into account dynamic surcharges). Load frequency between 1 - 10 Hz.

Vossloh Test Center



3 point bending test at Technical University Munich

Before the DSV, the modulus of elasticity in a three-point bending test based on DIN EN 13230-2 for the center test is to be determined by means of a force-deflection diagram.

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Fatigue test based on American axle loads 36,5 t

▶ **conditions:**

- One sleeper in ballast
- Temperature measurement in the sleeper core
- Strain gauge measurement (center and rail seat)

▶ **Load levels:**

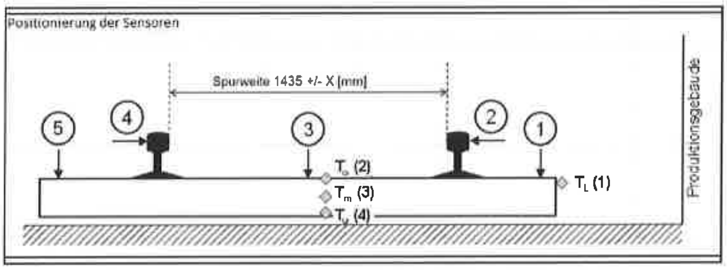
- 20 – 250 kN (Hollow area in middle of the sleeper, no contact to the ballast)
- 20 – 250 kN (middle of the sleeper under packed → to simulate sleeper riding and increasing center bending stress
- 20 – 250 kN Sleeper riding
- 20 – 375 kN Sleeper riding

▶ **Additional covered with dry ice**

- Surface temperature of the sleeper -20°C

Bottom side - After 7.7 Mio cycles

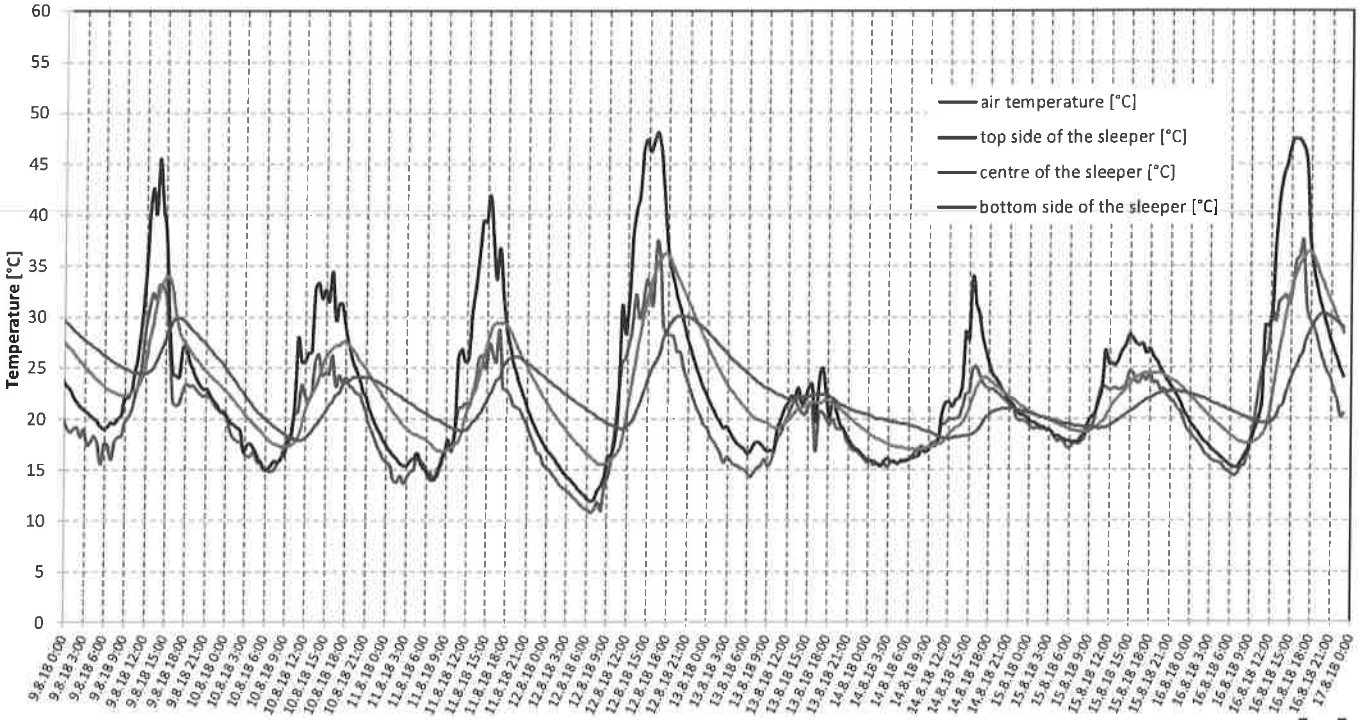
Outdoor test to determinate the influence of the temperature



▶ **Measuring campaign in midsummer 2018**

- **Reference measurement at 7:00 am (12 °C air temperature)**
- **Measurements at 7:30, 13:00 and 16:30**

Outdoor test to determinate the influence of the temperature



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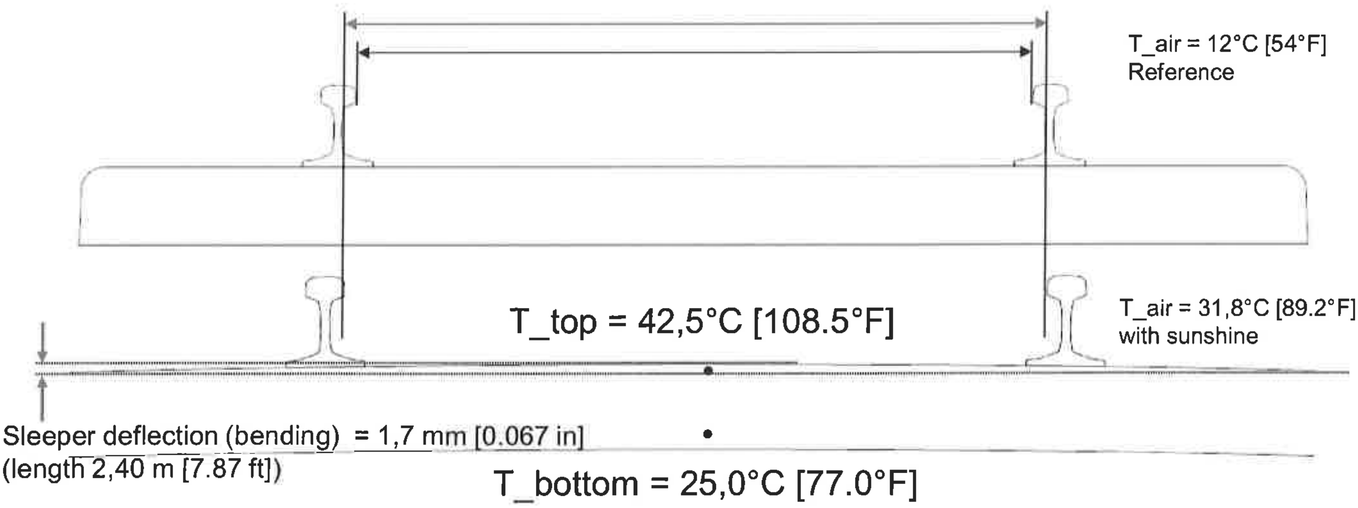
Outdoor test to determinate the influence of the temperature

Gauge change = 1,3 mm [0.05 in] (thermal expansion + deflection)



Measurement results TU-Munich (only thermal expansion):
Gauge change of ~1,1 mm [0.043 in] at ΔT = 30 K [54°F]

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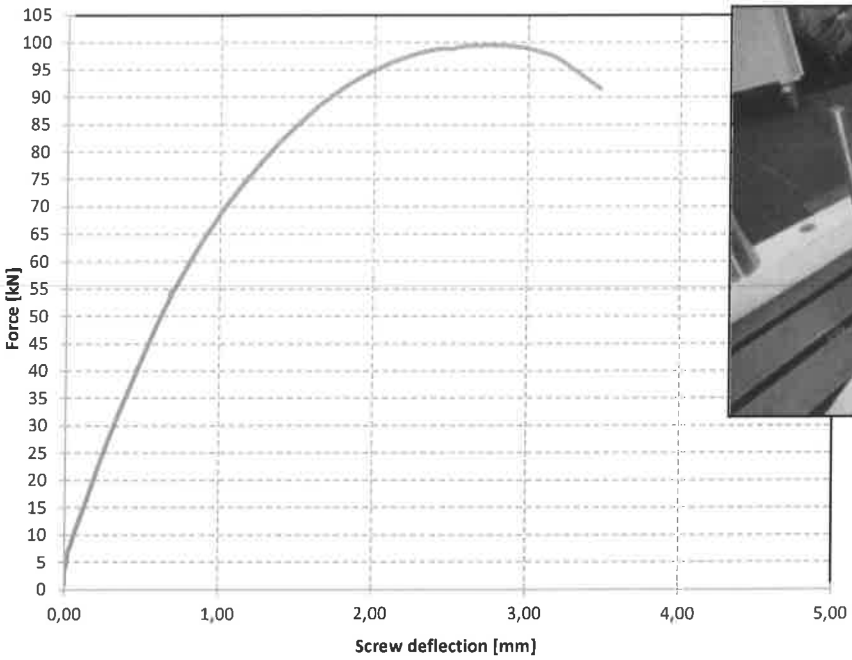
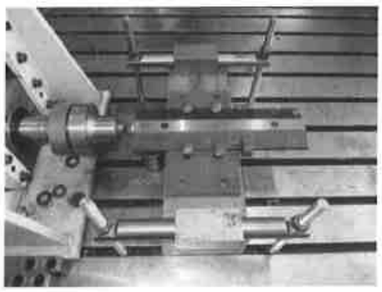
Pull out test

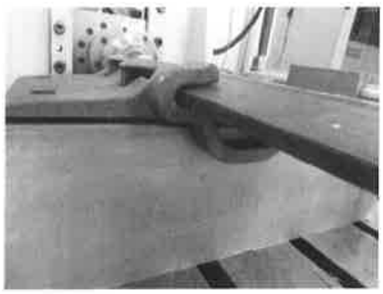


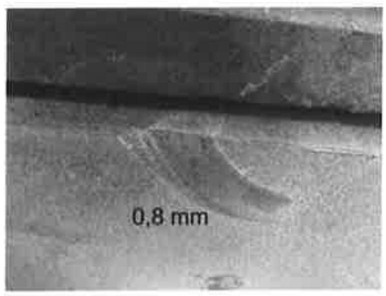
Longitudinal fatigue test with rail anchor

- **Static load test:**
  - 26 kN
- **Fatigue test:**
  - 1-16kN
  - Frequency 4Hz

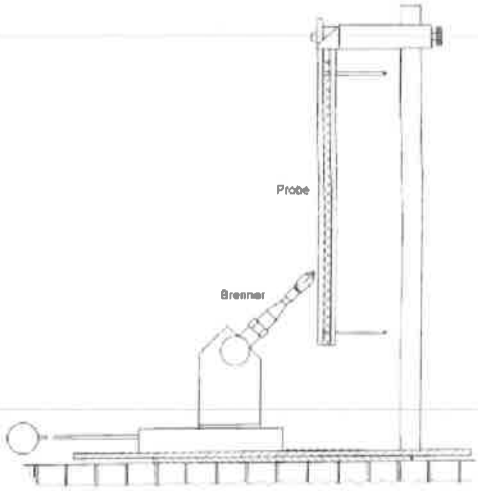
- **Slightly marks after 1 million load cycles**



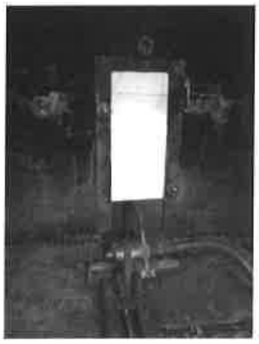




Fire behavior



Fire behavior test



▶ **Fire behavior e.g. according to DIN 53 438**

- Criterion: time until the fire reaches the measuring point
- Classification in K classes K1-K3
- K1: fire does not reach the measuring point
- K2/ K3: fire reaches the measuring point in less or over 20 seconds

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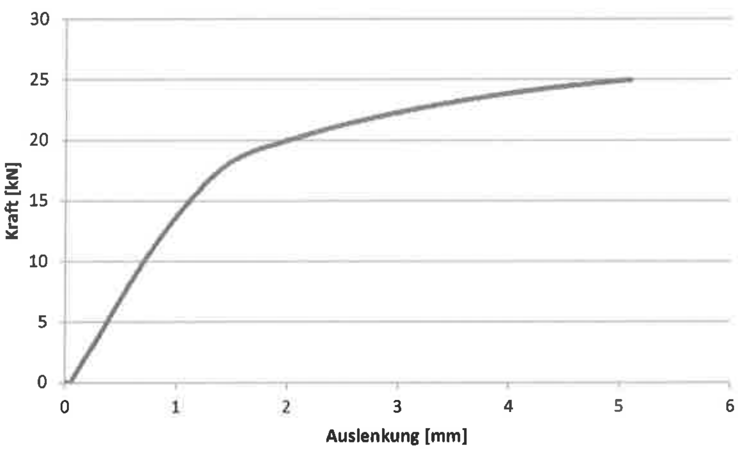
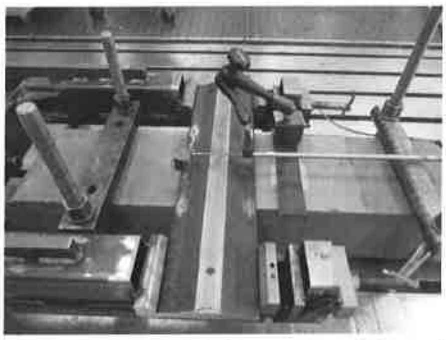
Spike lateral restraint

▶ **Determination of the static load for a 5.1 mm deflection of the spike.**

- Loading speed: 5,1mm/min
- Max. test load: 25kN
- Bore diameter and depth: Ø 12 mm / 130mm





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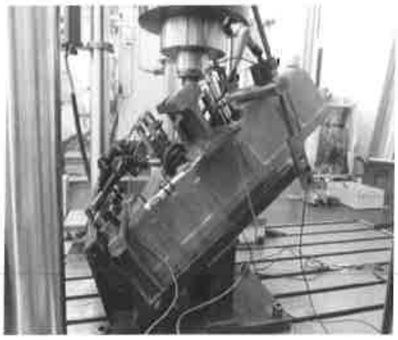
Fastening systems test for track with heavy axle loads

▶ **Fastening: W30HH; 160kN stiffness**

▶ **Test conditions:**

- Load: 108 kN (category E)
- Frequency: 4 Hz
- Angle: 40°, head reduction: X = 75 mm; 3 Mio. Cycles



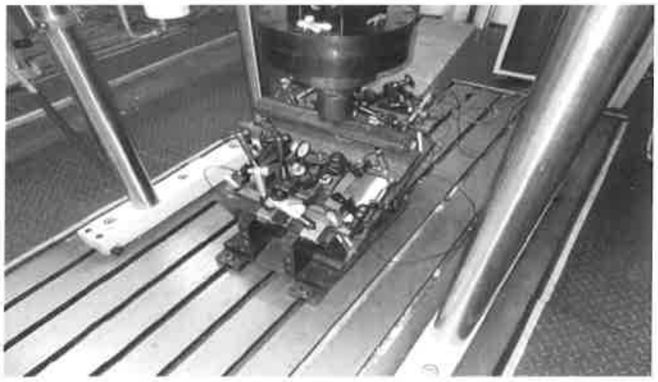
	displacement before execution of test [mm]		displacement after execution of test [mm]	
	static	dynamic	static	dynamic
rail head, horizontal				
permanent	0.00	0.30	0.40	0.53
elastic	0.99	0.87	0.85	0.68
rail foot, vertical, field side				
permanent	0.00	0.33	0.70	0.70
elastic	0.53	0.35	0.32	0.30
rail foot, vertical, gauge side				
permanent	0.00	0.07	0.05	0.09
elastic	0.38	0.21	0.19	0.13
rail foot, lateral				
permanent	0.00	1.14	1.52	1.65
elastic	1.10	0.79	0.72	0.55

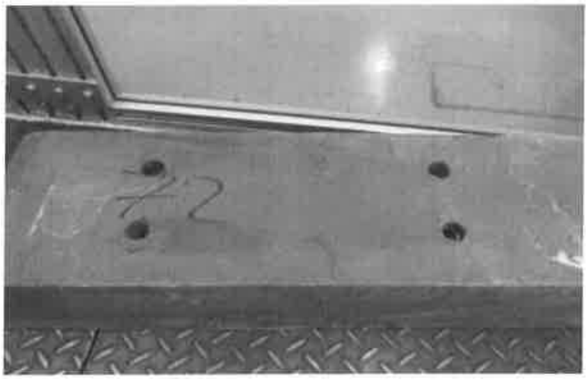
▶ **Additional 1 million load cycles with increased ambient temperature (50°C rail temperature)**

Fatigue test fastening system

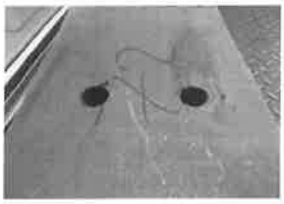
▶ **Conditions (AREMA):**

- α: 20°
- Test load: 133,5 kN (load level 1 for 2 Mio. cycles
  163 kN (load level 2 for 1 Mio. cycles





Surface after fatigue test none permanent deformation

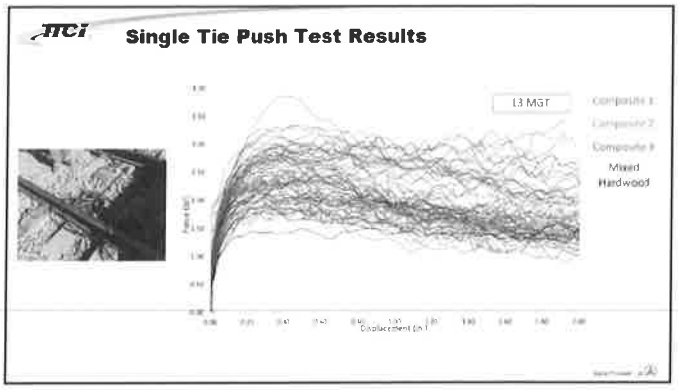


Gauge side after fatigue test

Field side after fatigue test

Lateral resistance

Requirement from AREMA: 11,1kN (2500lbf)
Measured after 0,1 MGT



Testing under laboratory conditions

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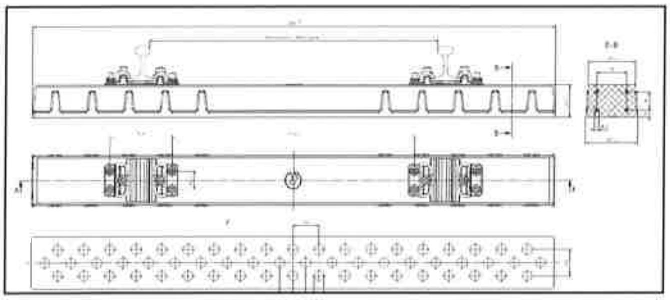
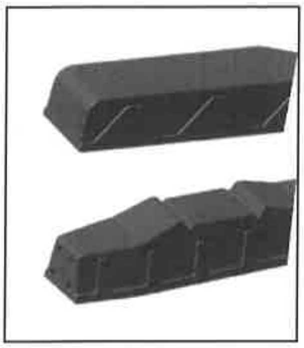
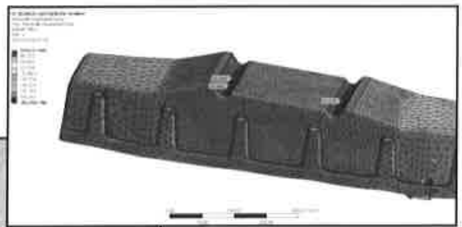
Design

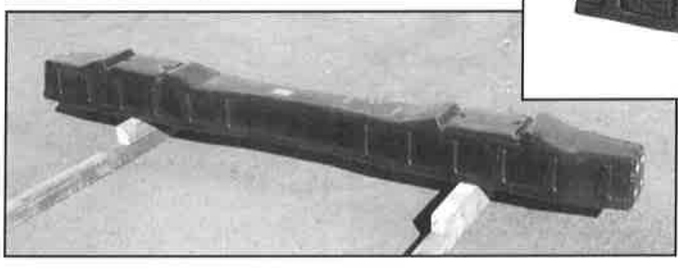


Profiling of the bottom side



Lateral profiling





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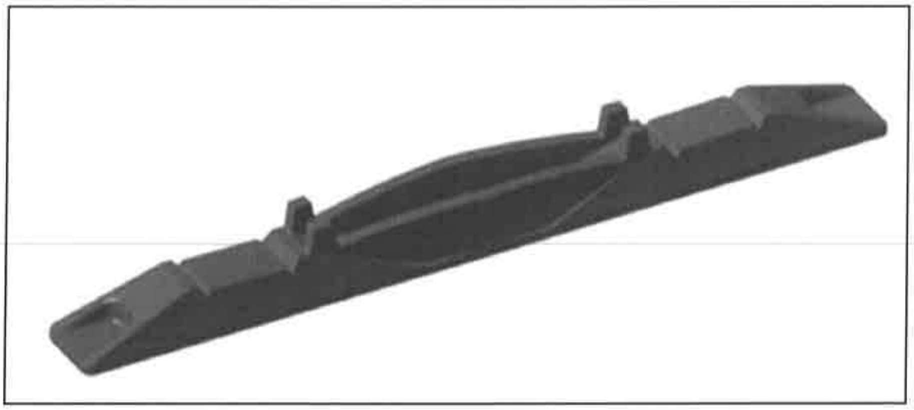
Questions



- Winfried Bösterling
  Executive Vice President Innovation and R&D
  Vossloh Fastening Systems GmbH
  e-mail: winfried.boesterling@vossloh.com

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