Railway Concrete Pavements

Dr.-Ing. Bernhard Lechner

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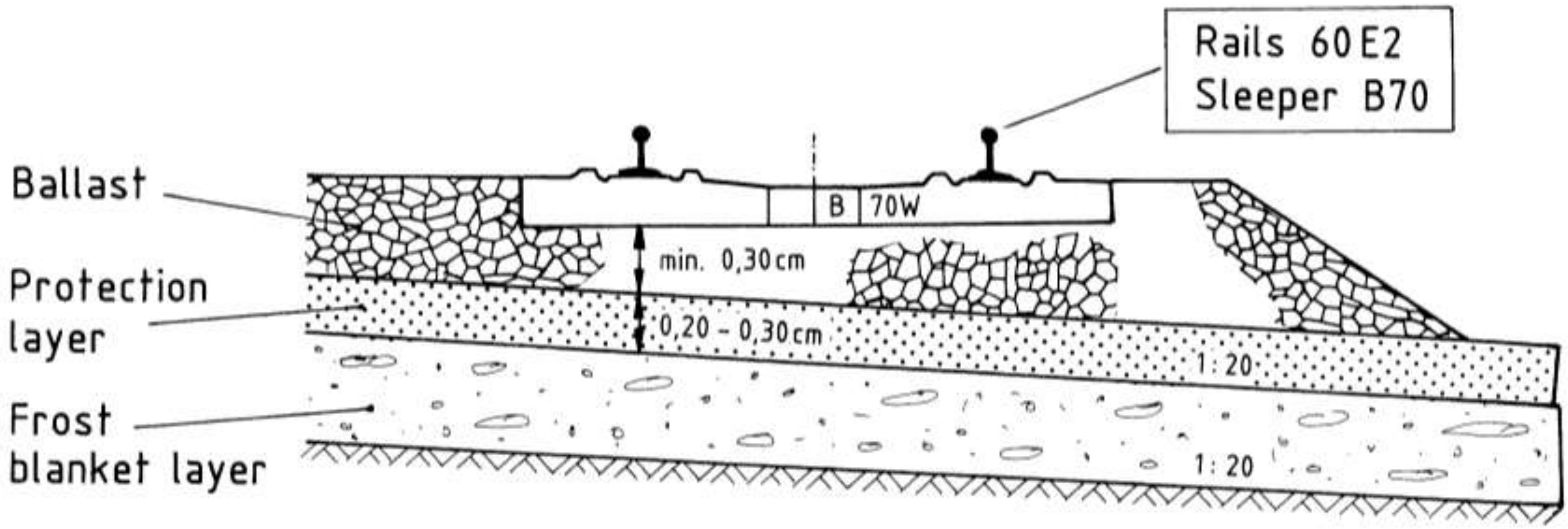
for Concrete Pavements
Florianopolis, November 2011

Continuously Reinforced Concrete Pavement
for ballastless tracks (Nuremberg-Ingolstadt)

High speed line Cologne – Rhine/Main opened 2002

- Introduction “Why ballastless tracks?”
- Concrete Pavements supporting
  Sleeper Panels or Fastening Systems
- Design features and thickness design
- Perspectives and Conclusions

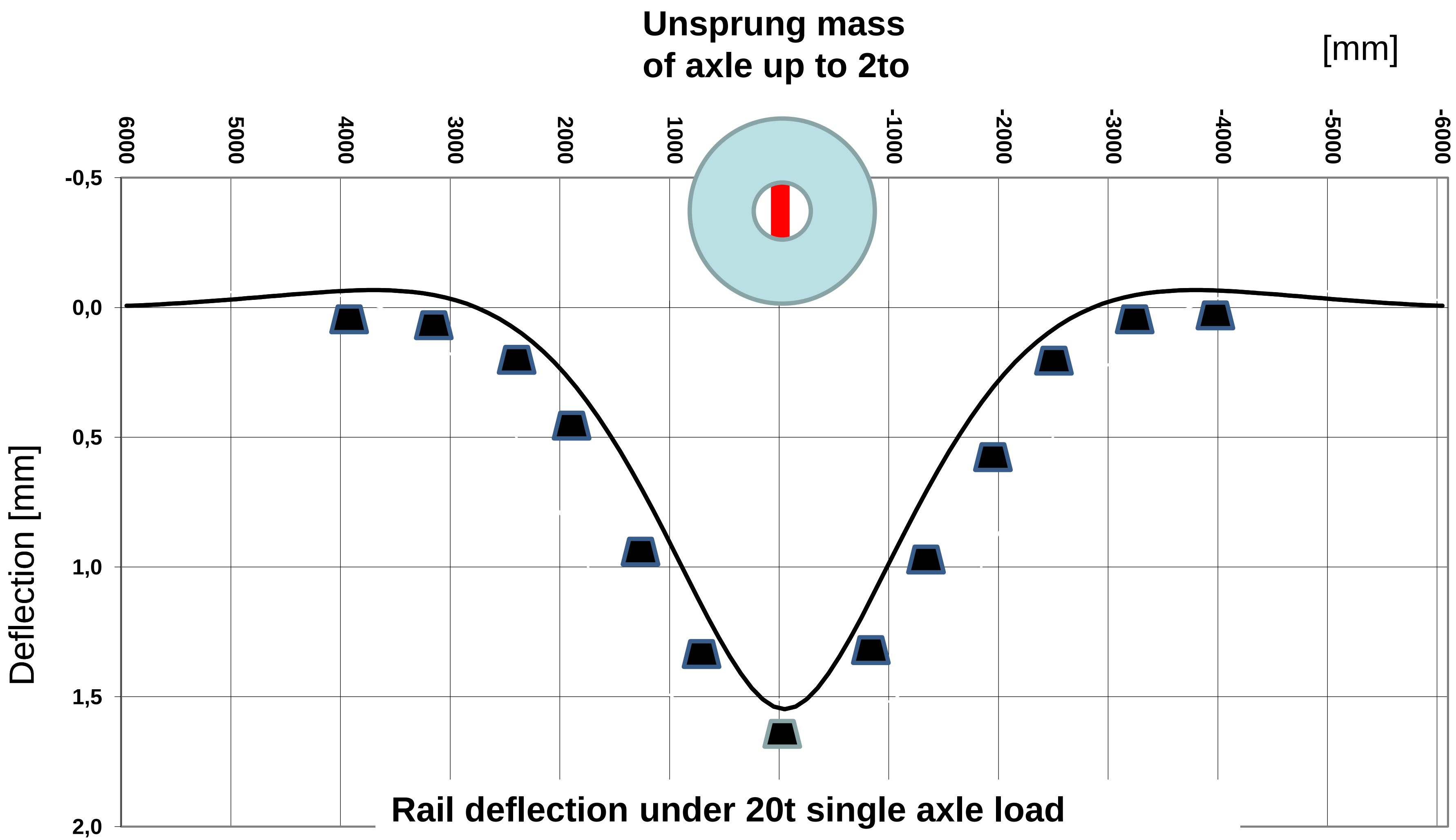
Actual conventional track design



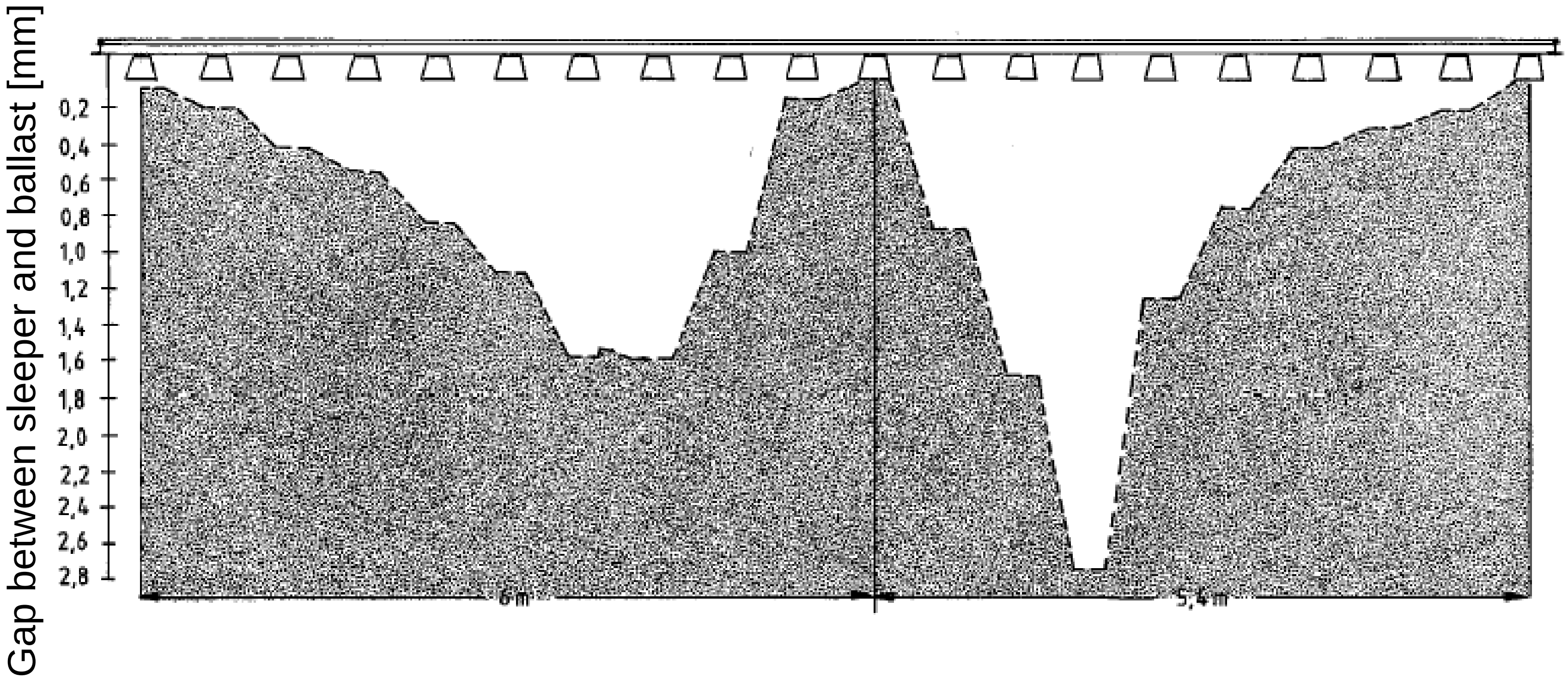
Ballast bed:

High permeability
No rigid fixation of sleeper panel

Load distribution by rail deflection and damping required



Uneven sleeper support („Hanging sleeper“)

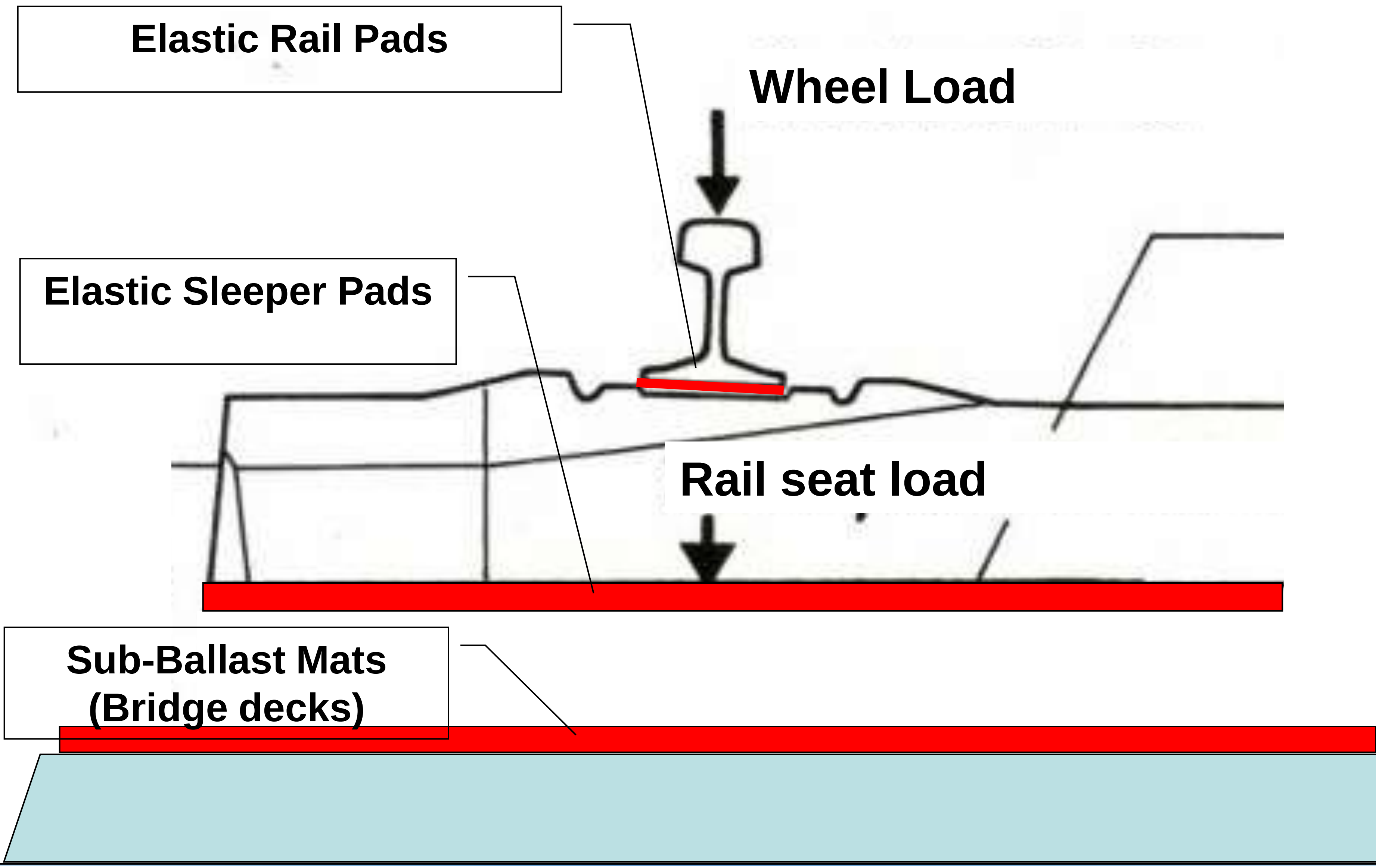


„White spots“

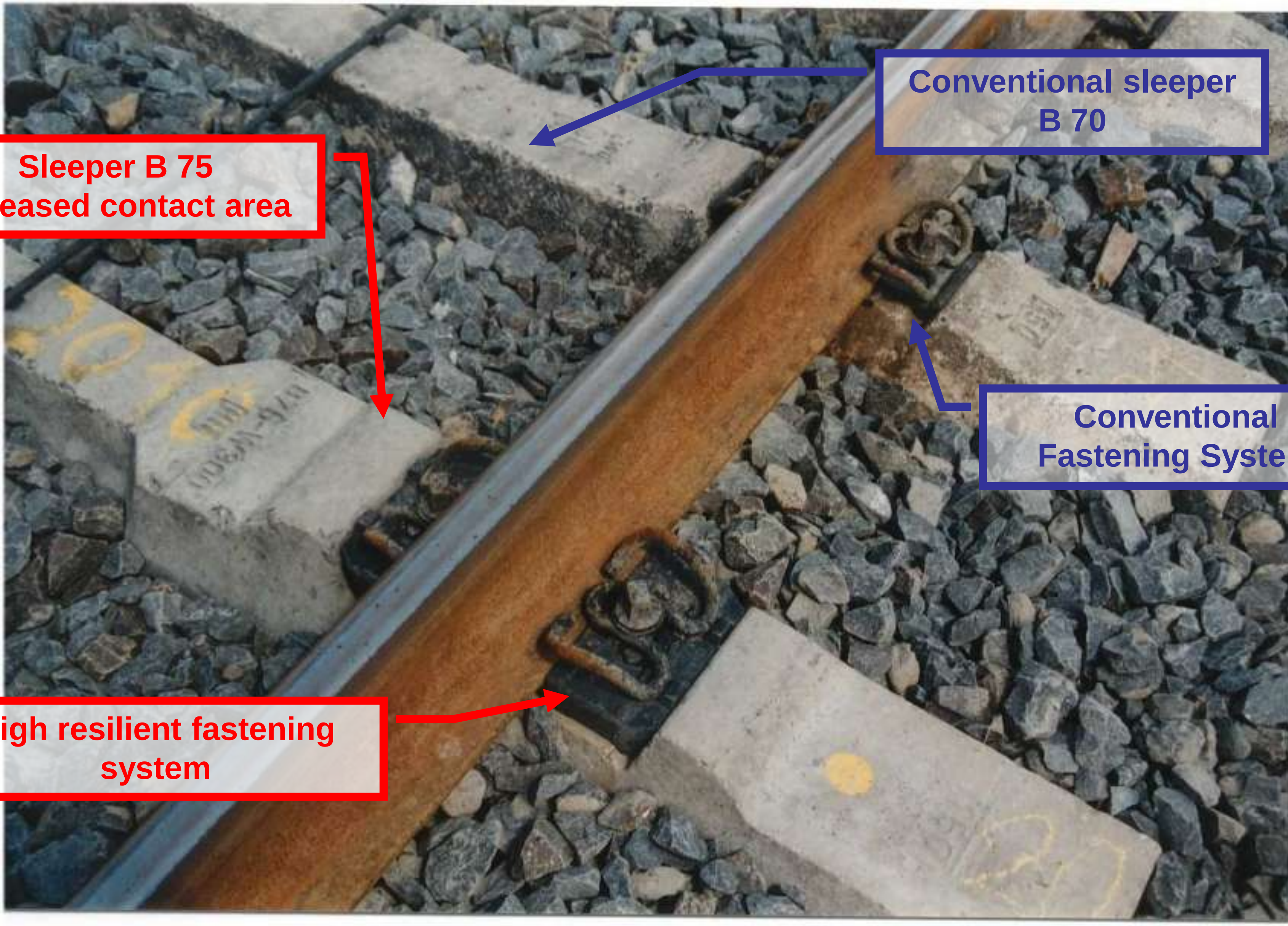
Improving conventional ballasted tracks by

- **Reduction of dynamic rail seat loads:**
  Additional load distribution and damping
  by introduction of elastic components (e.g. fastening systems)

- **Reduction of ratio rail seat load vs. ballast stress:**
  Wide base sleepers



Elastic Rail Pads
Wheel Load
Elastic Sleeper Pads
Rail seat load
Sub-Ballast Mats
(Bridge decks)


Sleeper B 75
increased contact area
Conventional sleeper
B 70
Conventional
Fastening System
High resilient fastening
system

Resistance against track buckling

Control of high longitudinal compressive forces in continuously welded rail during summertime.

Cologne – Rhine/Main 2002

V_{max} = 300 km/h

R_{reg} = 3350m

$Cant_{max}$ 170mm

$Grade_{max}$ 40 %o

Costs ballasted vs. ballasted track

Tracks on earthworks:

Improved Ballasted track superstructure (including protection layer)

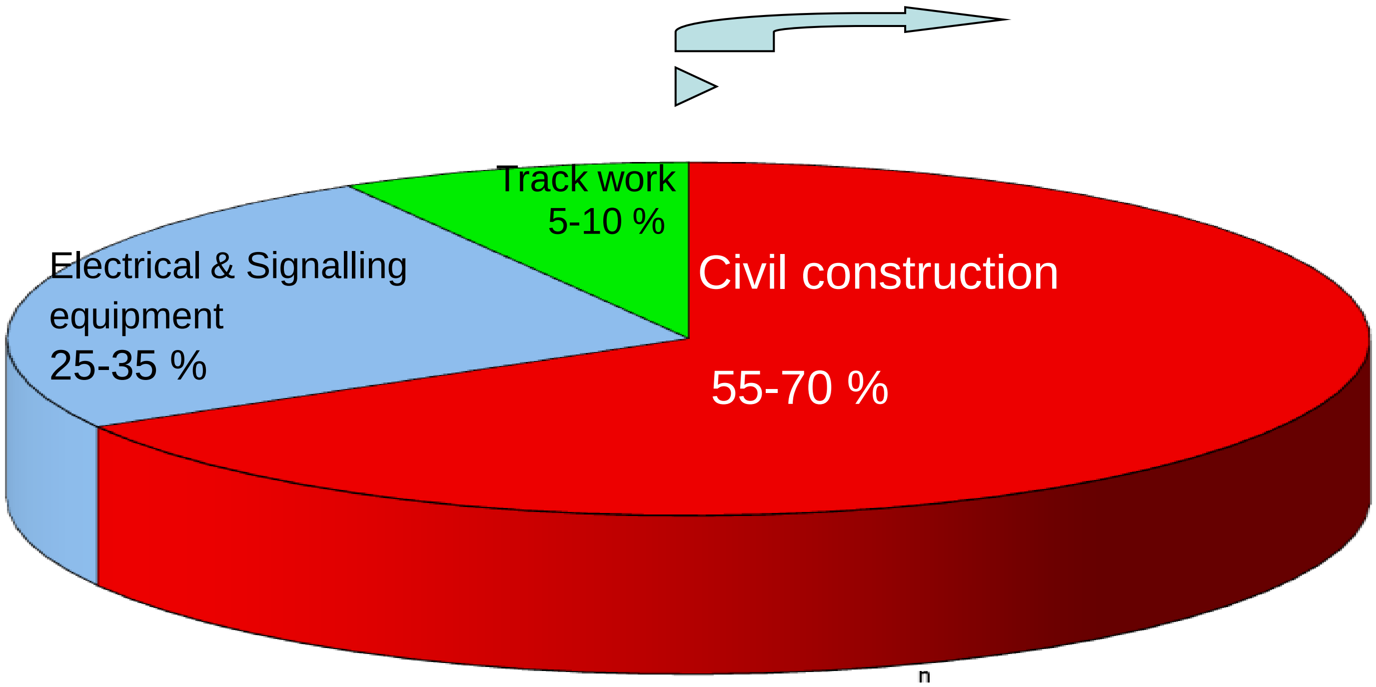
Initial costs: 450-500 T€   Annual maintenance costs: 3.55 T€

Ballastless track superstructure (including base layer and noise absorbers)

Initial costs: 550-700T€   Annual maintenance costs 0.25T€

Total cost for the new construction of a railway line (without rolling stock)

1 % reduction of civil cost 10 % compensation of track cost



Conclusion: High leverage of reducing civil construction cost by use of alignment advantages of slab track superstructure for PDL's

Ballastless tracks

State-of-the-art solutions for high speed lines

Main characteristics:

- Low maintenance
- High availability (→ 100%)
- Increased service life Designed service life 60 years
- Low structural height
- High lateral track resistance which allows future speed increases in combination with tilting technology and/or usage of eddy current brakes (contactless braking system)
- No problems with “flying” ballast stones at high speed

Eddy current brake

- **Introduction “Why ballastless tracks?”**
- **Concrete Pavements supporting**
  Sleeper Panels or Fastening Systems
- **Design features and thickness design**
- **Perspectives and Conclusions**

GENERAL SYSTEMS OF BALLASTLESS TRACKS

DISCRETE RAIL SEATS

OR CONTINUOUSLY EMBEDDED RAIL

ON CONCRETE SLAB

(CRCP)

PRE-CAST SLABS ON TREATED BASE

Ref: Max Bögl GmbH

SLEEPER PANEL ON CONCRETE PAVEMENT (fixed or monolithic)

OR ASPHALT PAVEMENT (fixed)

Ref: Pfleiderer track systems

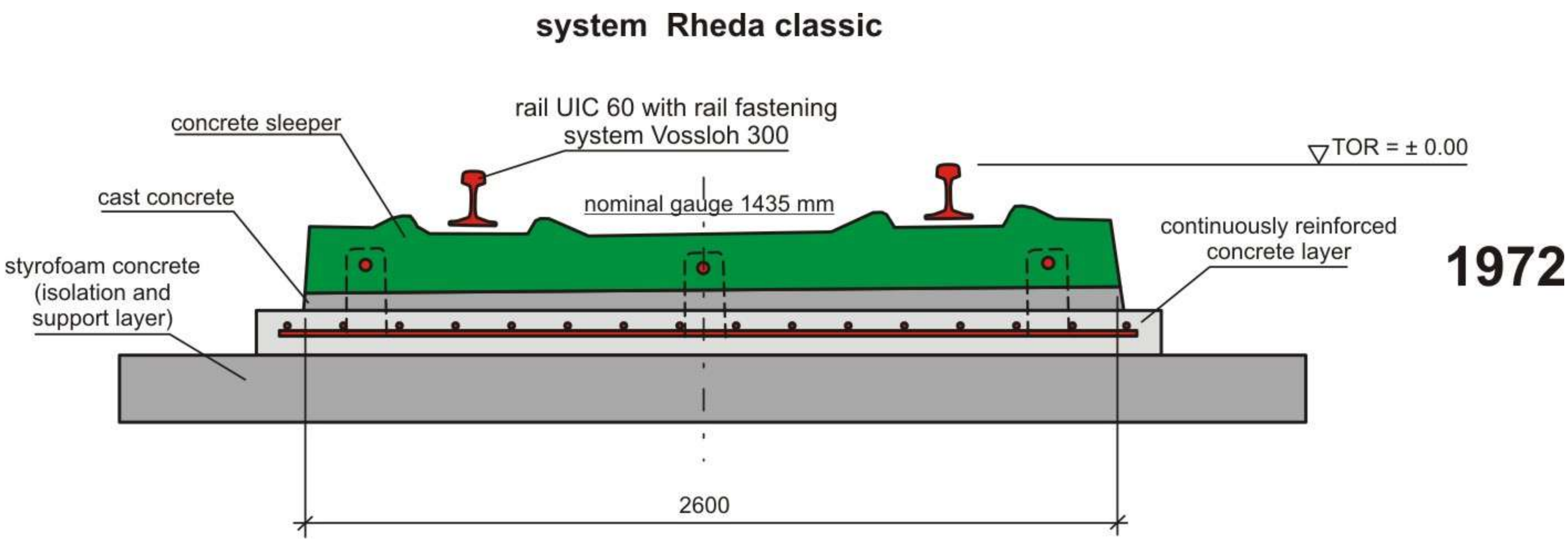
First ballastless track

installed at Rheda station

1972

First ballastless track installed at Rheda station 1972

Ballastless track systems



Continuous reinforced concrete pavements (CRCP)

Requirements for rail applications (DB standard)

-Design and construction of CRCP according to road standard

(e.g. minimum strength C30/37; minimum cement content 350kg/m³)

-Reinforcement 0.8% - 0.9% in neutral axis of slab (load transfer at crack)

- Maximum crack width 0.5mm

Free cracking allowed for systems using sleepers (fastening systems not integrated in CRCP);

Controlled cracking for CRCP with integrated fastening systems

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CEN/TC 256

Date: 2011-9

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CEN/TC 256

Secretariat: DIN

Railway applications - Ballastless track systems - Part 1: General requirements

Applications ferroviaires - Voie sans ballast système- Partie 1: Prescriptions générales

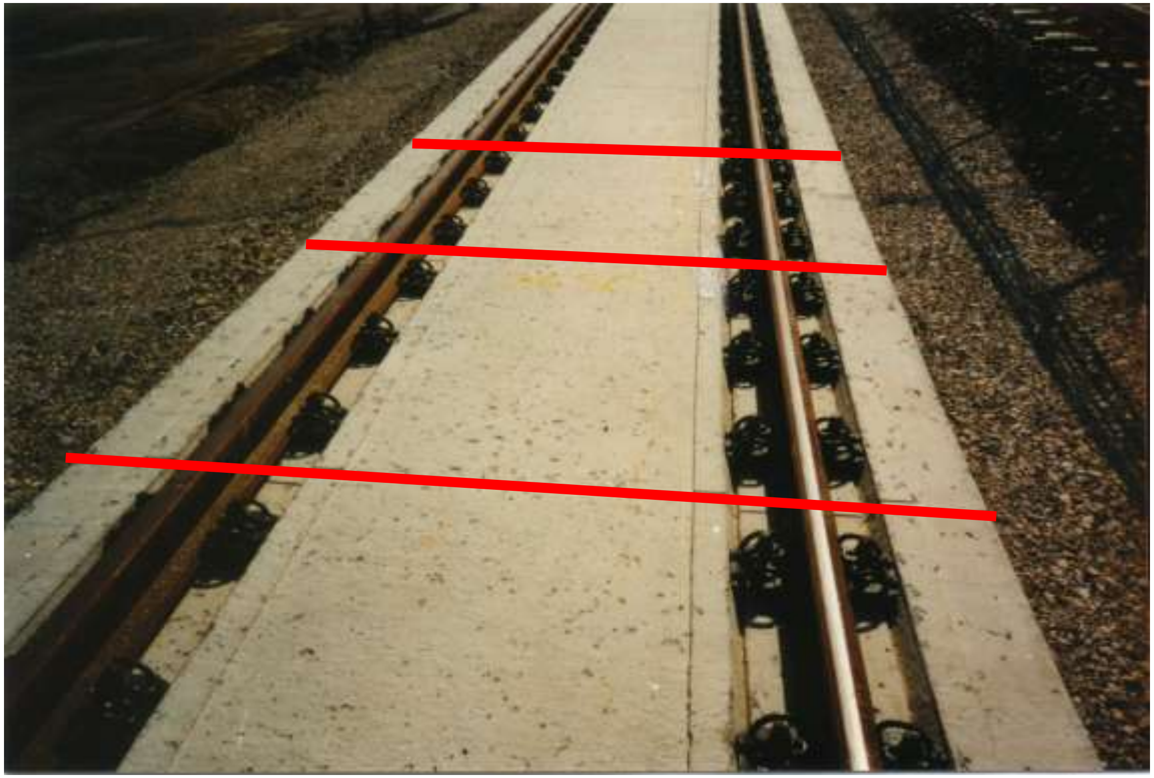
Bahnanwendungen – System Feste Fahrbahn - Teil 1: Allgemeine Anforderungen

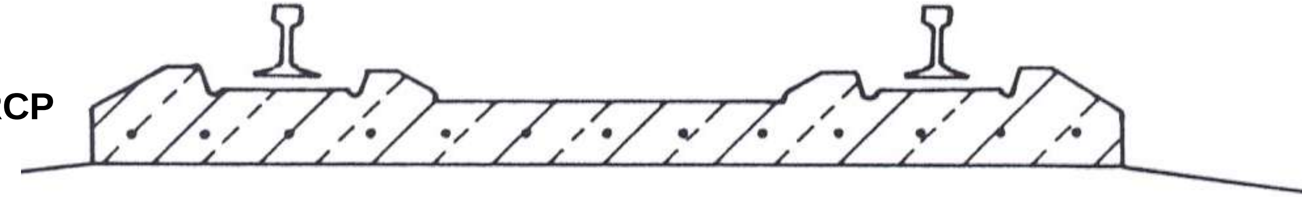
CRCP for ballastless tracks (Hannover-Berlin)

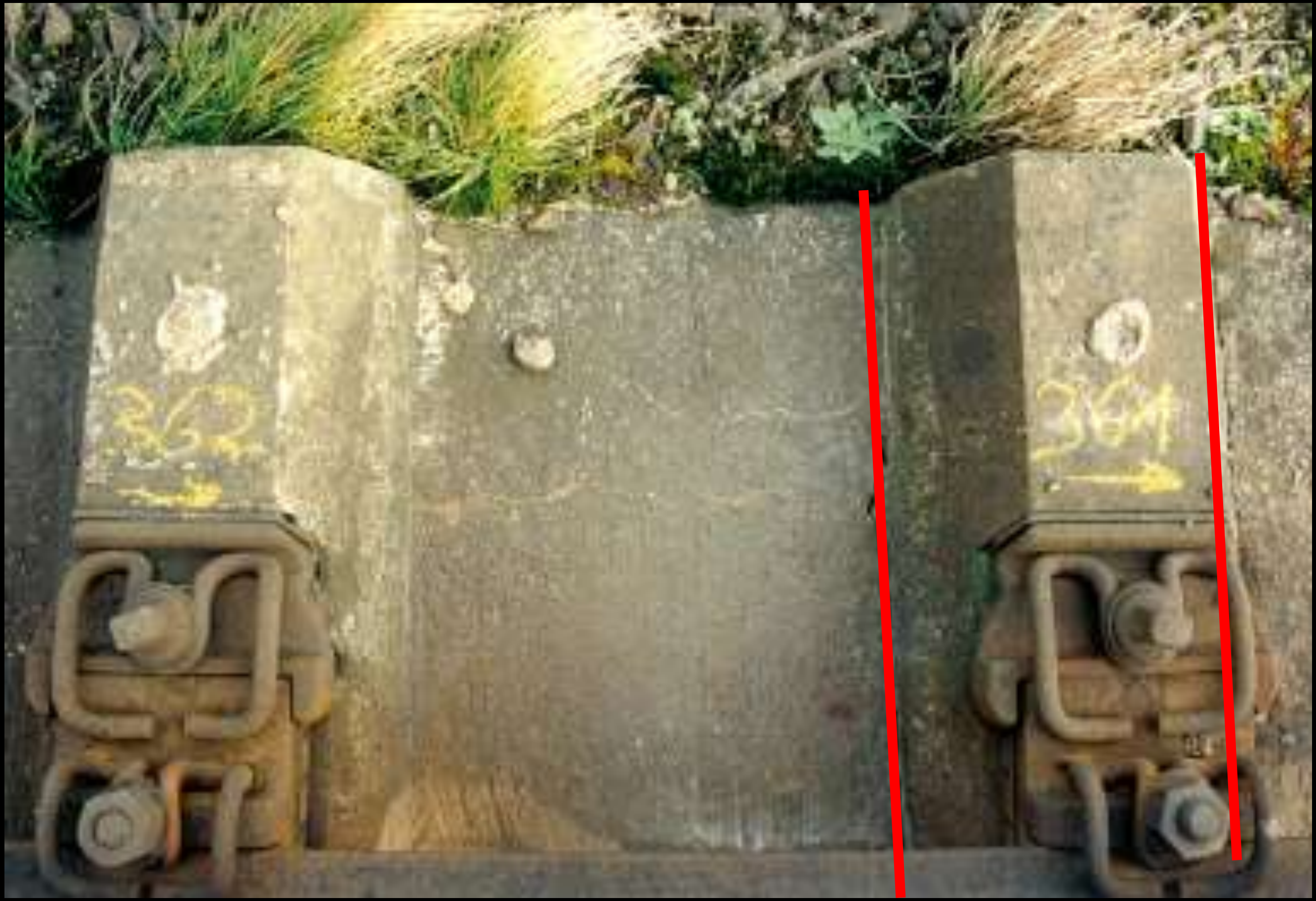
Free cracking of CRCP

Discrete rail seats on CRCP

(controlled cracking required)







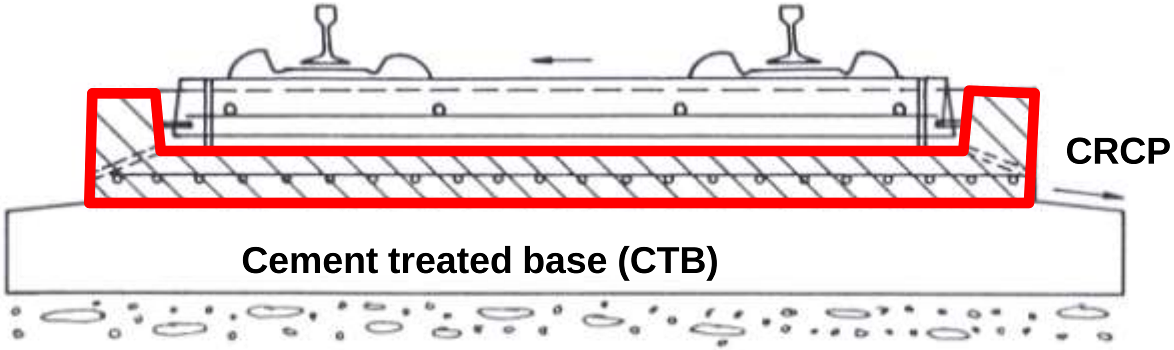
Cracking of CRCP „controlled“ by embedded prefabricted sleepers (Test section built 1978)

Sleeper panels on CRCP

Monolithic connection

Rheda with trough

(Hannover-Berlin 1988)



Sleeper panels on CRCP

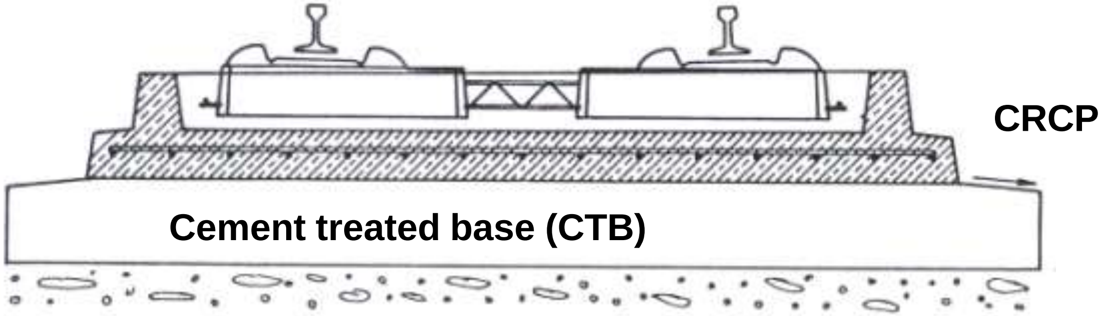
Monolithic connection

Rheda with trough

and two-block

or lattice girder sleepers

Cologne-Rhine/Main 2002



Sleeper panels on CRCP

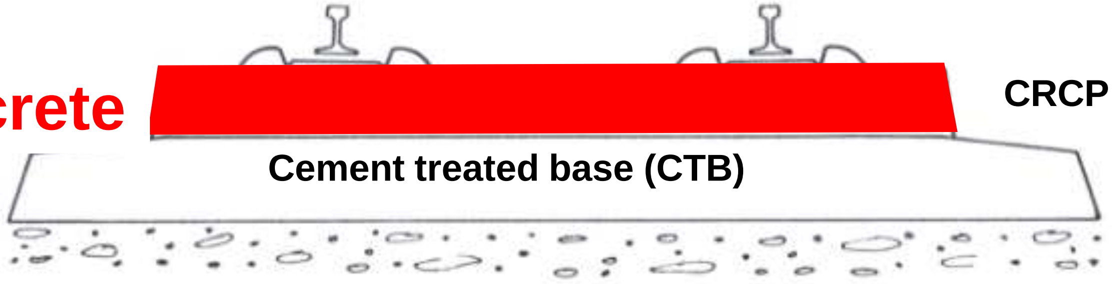
Monolithic connection

Rheda 2000

(without trough)

Nuremberg-Ingolstadt 2006

CRCP + Filling Concrete




Temporary rail support required


Bahntechnik

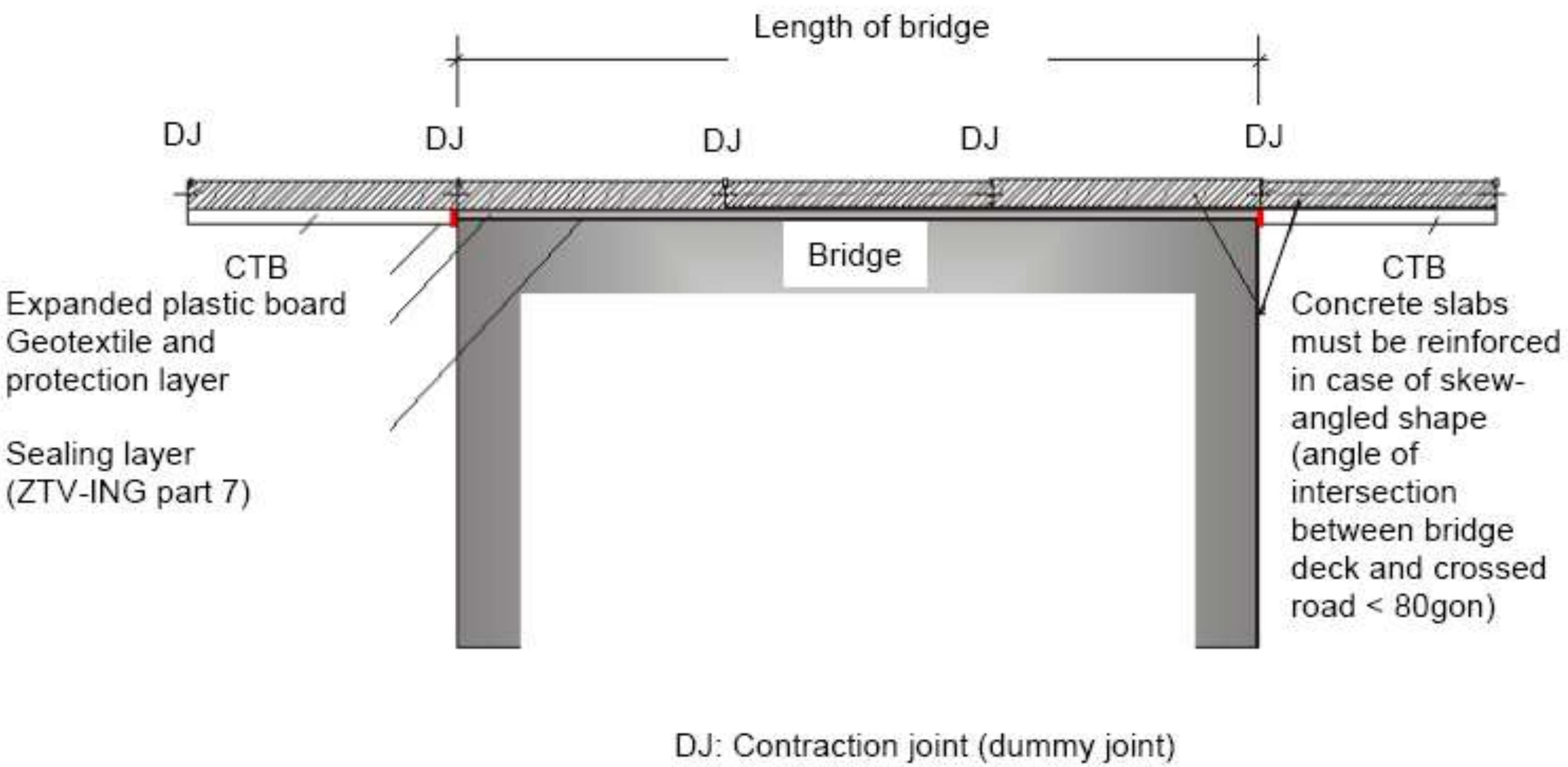
Temporary rail support removed

Curing according to road construction

Nürnberg – Ingolstadt

Cracks up to 0.5mm are according to CRCP design – no sealing required

Switches must be integrated

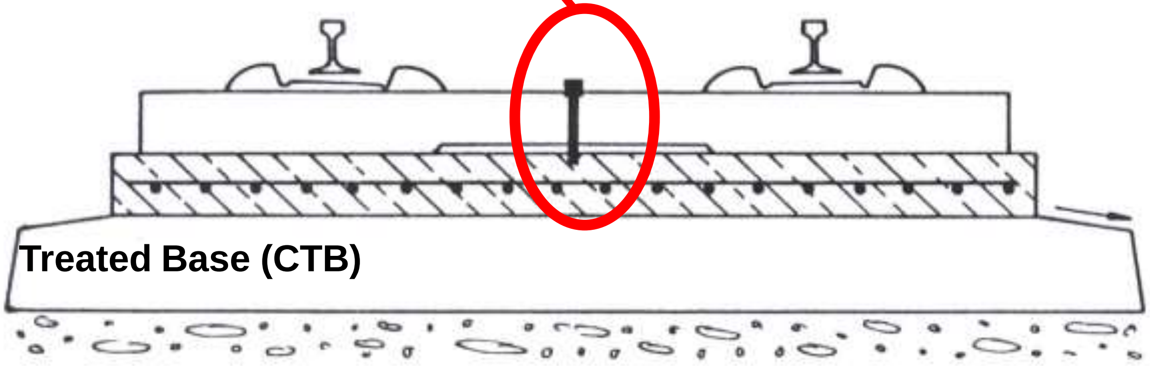

Length of bridge
DJ
DJ
DJ
DJ
DJ
Bridge
CTB
Expanded plastic board
Geotextile and
protection layer
Sealing layer
(ZTV-ING part 7)
CTB
Concrete slabs
must be reinforced
in case of skew-
angled shape
(angle of
intersection
between bridge
deck and crossed
road < 80gon)
DJ: Contraction joint (dummy joint)

CRCP for ballastless tracks (Hannover-Berlin)

Sleeper panels fixed on CRCP

BTD V2

(Hannover-Berlin 1988)



180mm CRCP

300mm Cement Treated Base (CTB)

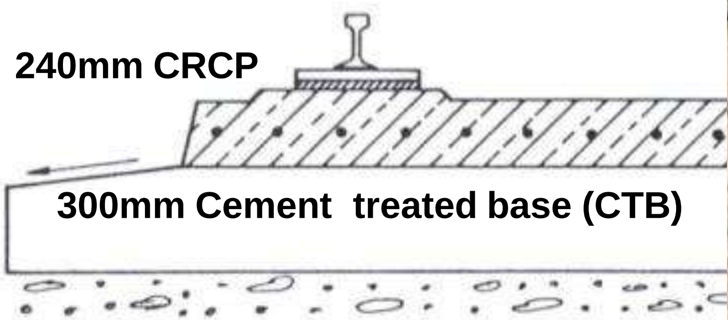
ATD-structure with sleepers on asphalt pavement (30cm)

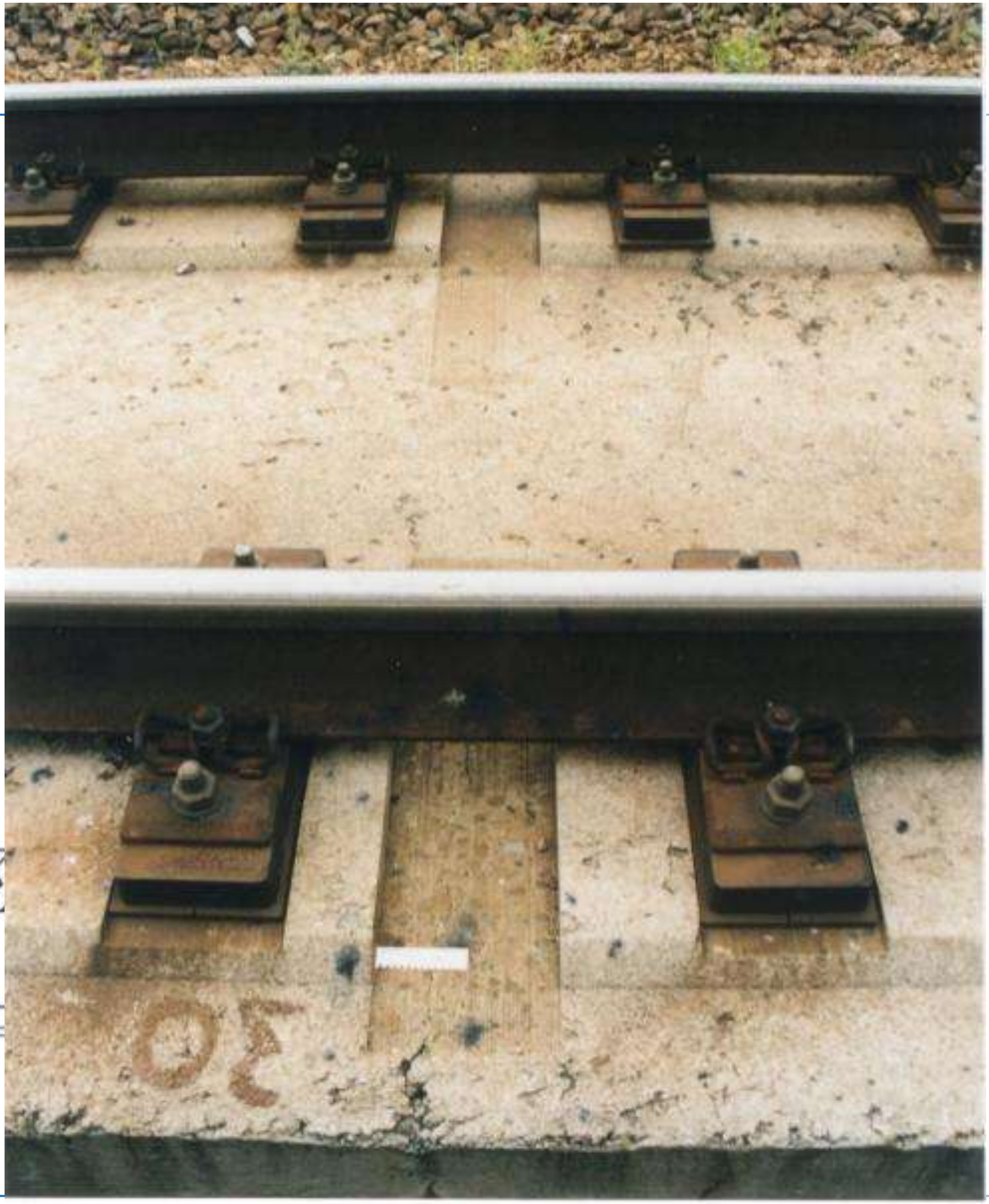
High-speed line Hannover–Berlin (1998)

Discrete rail seats on CRCP

Controlled Cracking required

BTE (ZÜBLIN)





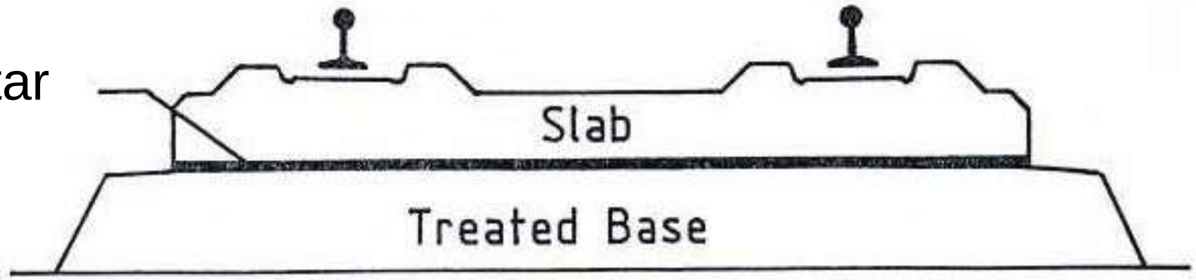
Pre-cast slabs or frames on a treated base

using grouting mortars

BÖGL

(Nuremberg-Ingolstadt 2006)

Grouting mortar




Nürnberg-
Ingolstadt

Ballastless tracks
Installation of noise absorption elements

- Introduction “Why ballastless tracks?”
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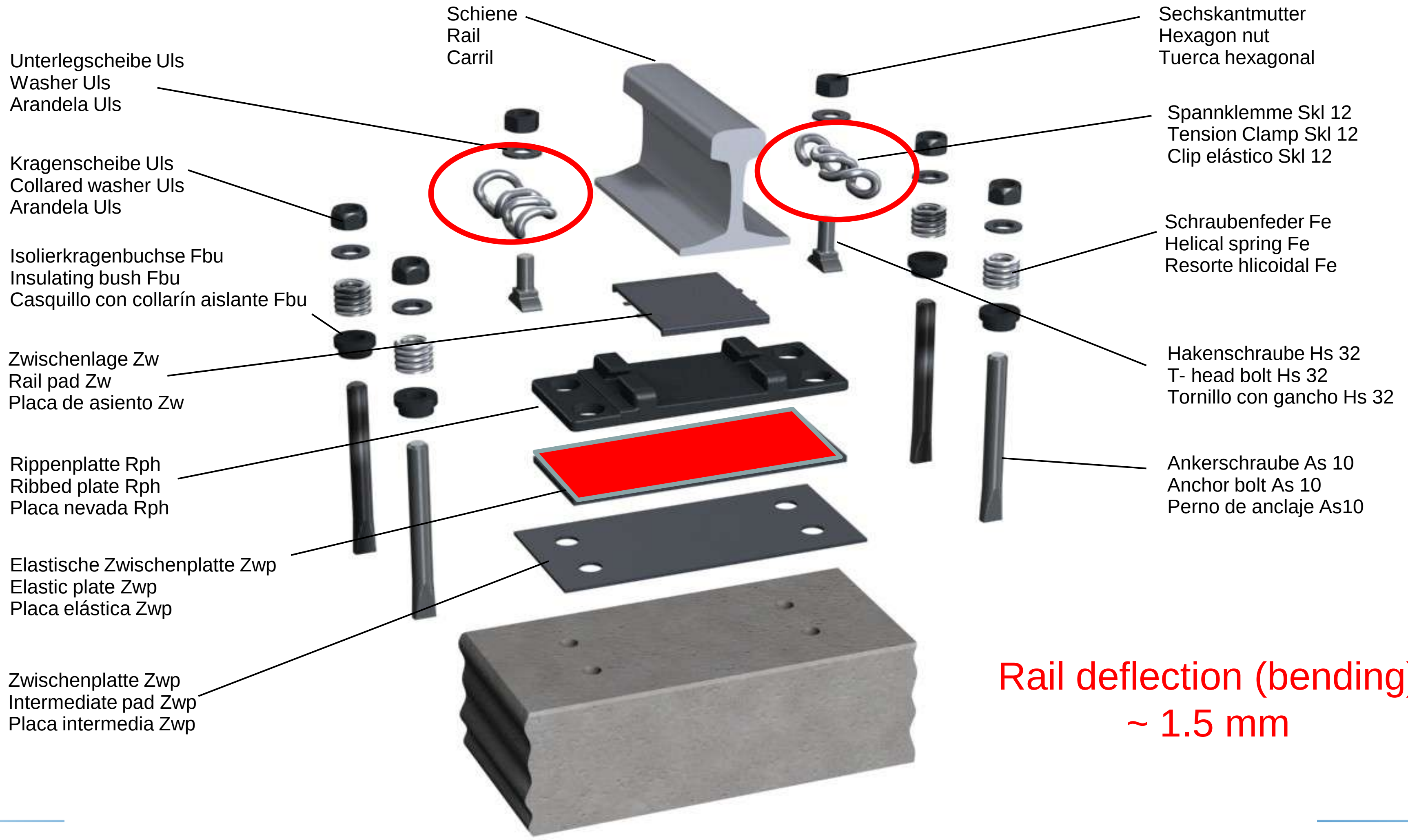
Vossloh Fastening System FF 336

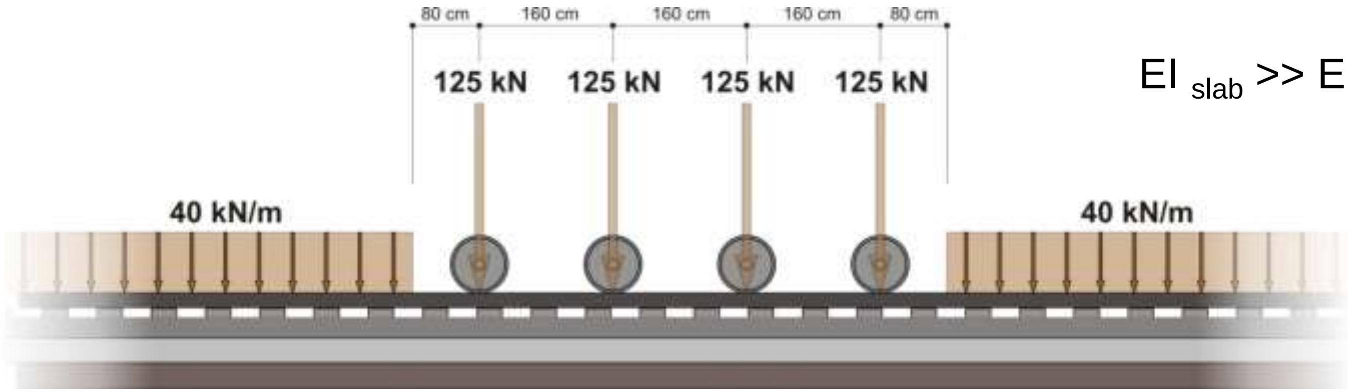


Rail deflection (bending)
~ 1.5 mm

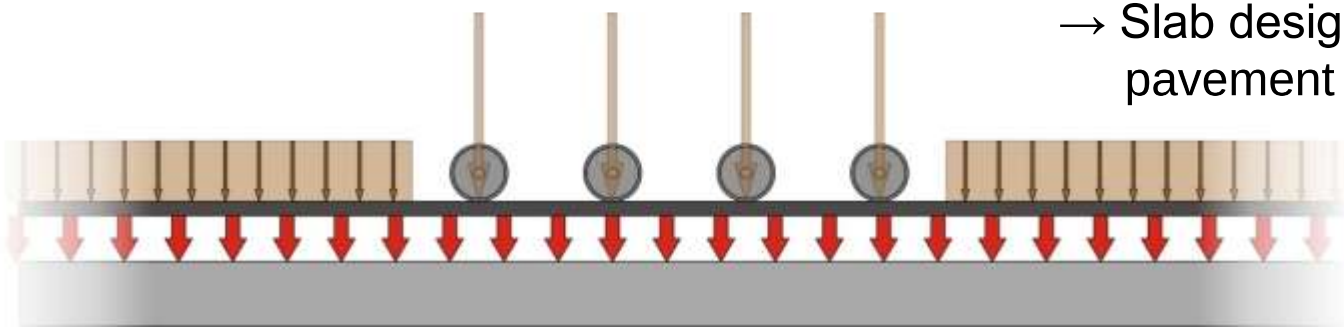
Load scheme UIC 71

Rails with elastic fastening system

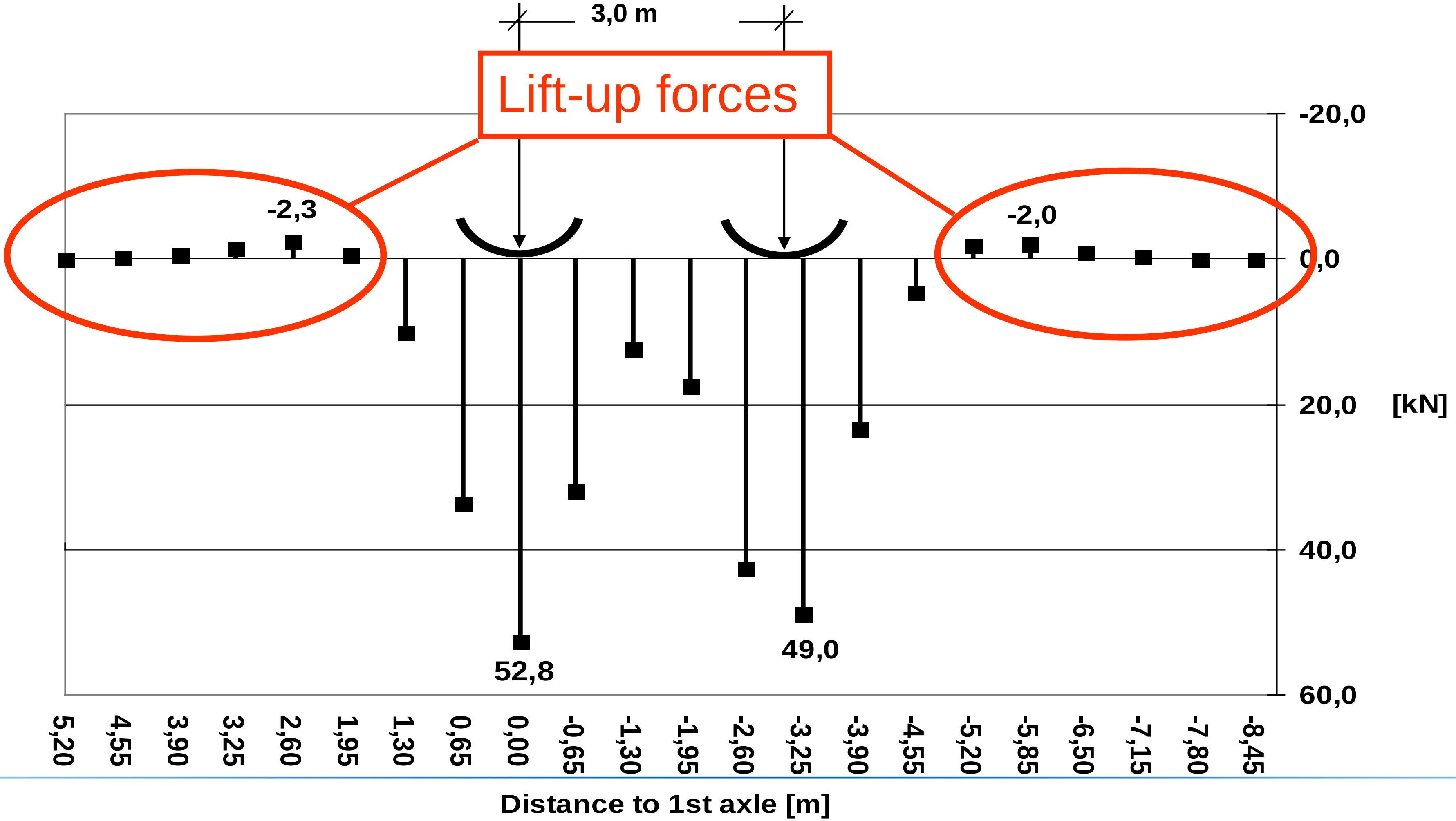
$EI_{slab} >> EI_{rail}$



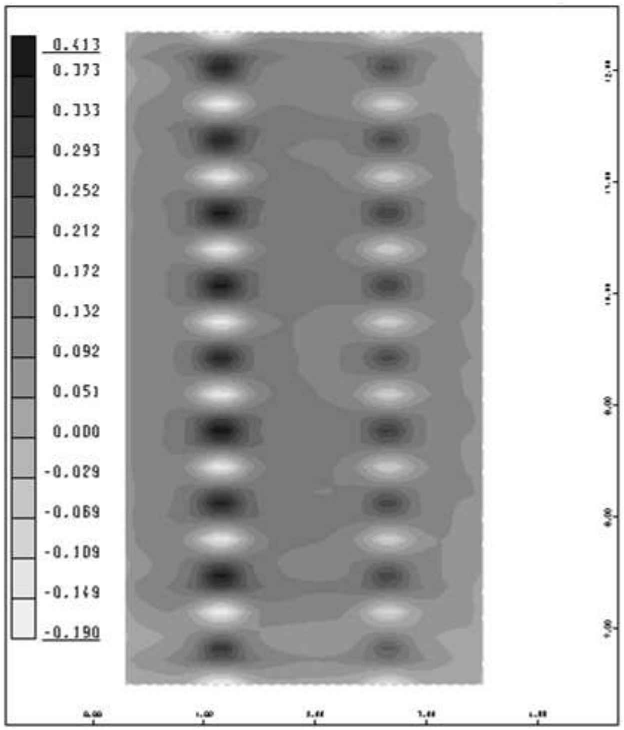
→ Load distribution by rail
→ Slab loaded by rail seat loads
→ Slab design according to road pavement design



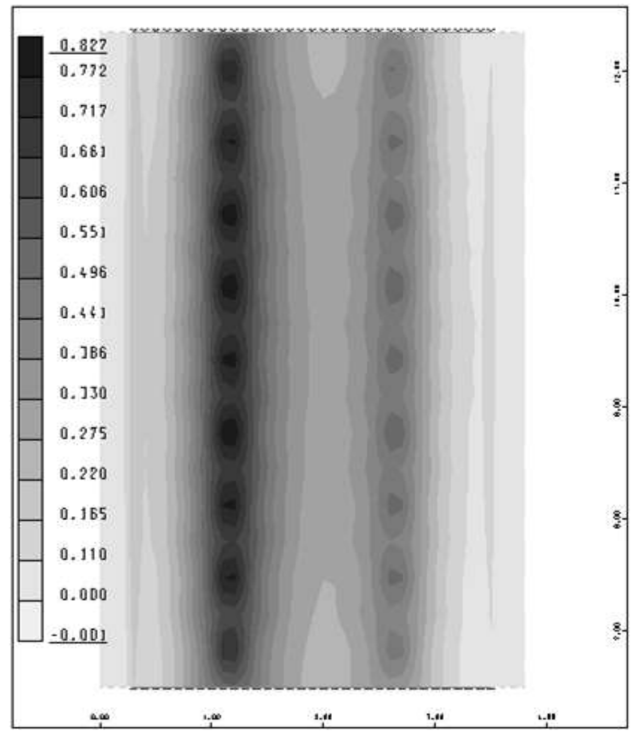
Boogie of ICE 1



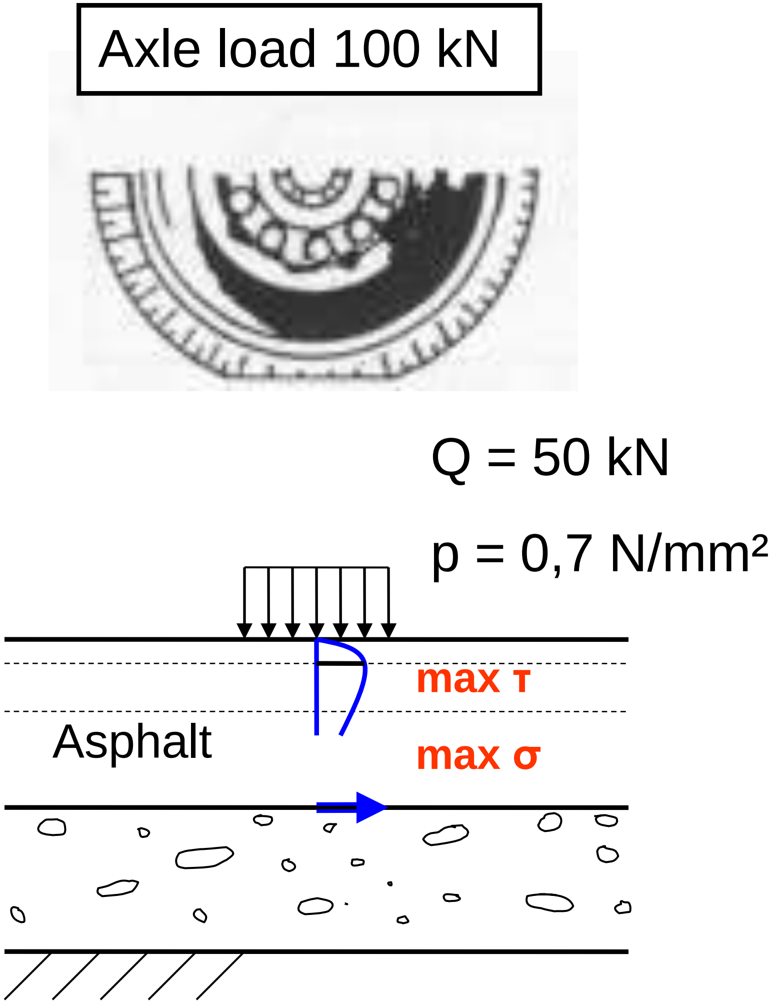
Thickness design using slab theory models (Westergaard) or FEM

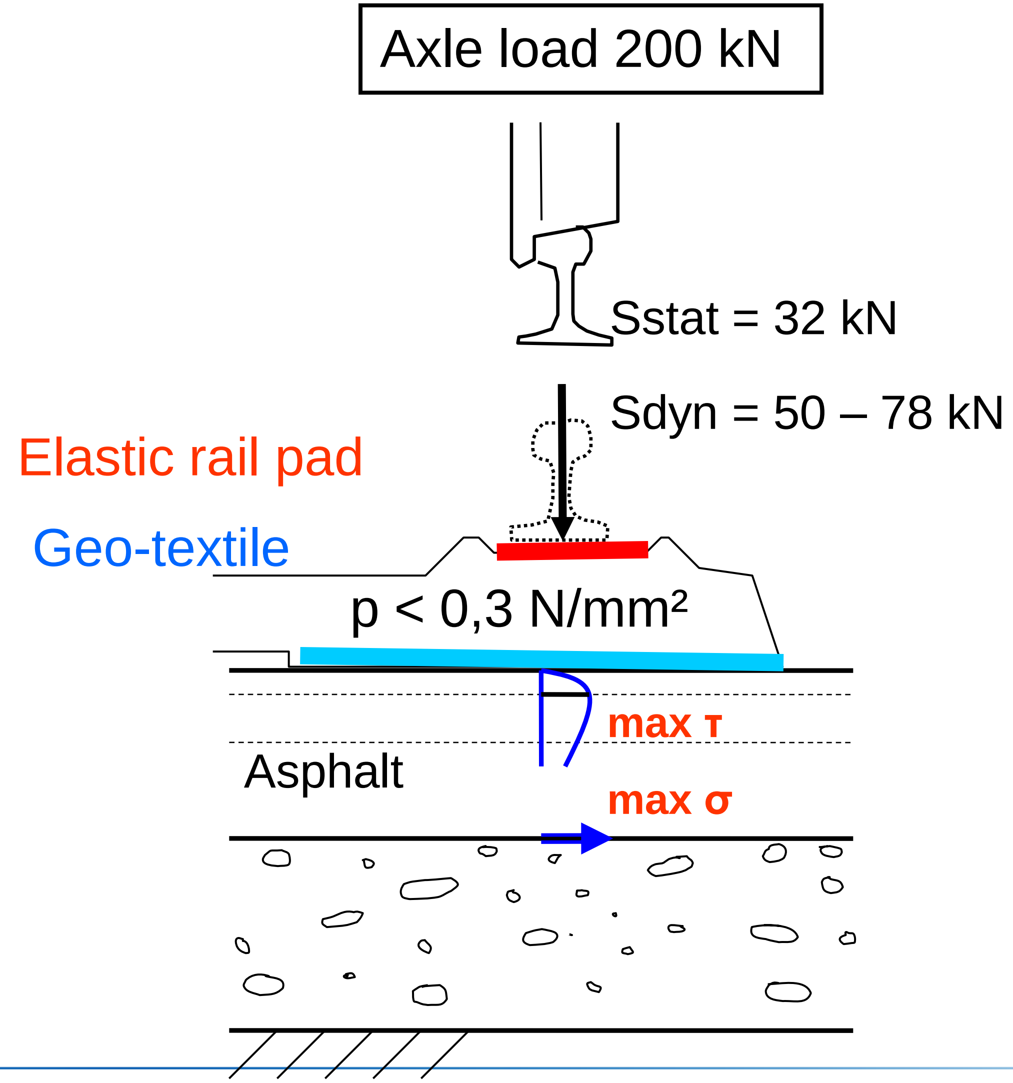


Static bending stresses in concrete layer in longitudinal direction

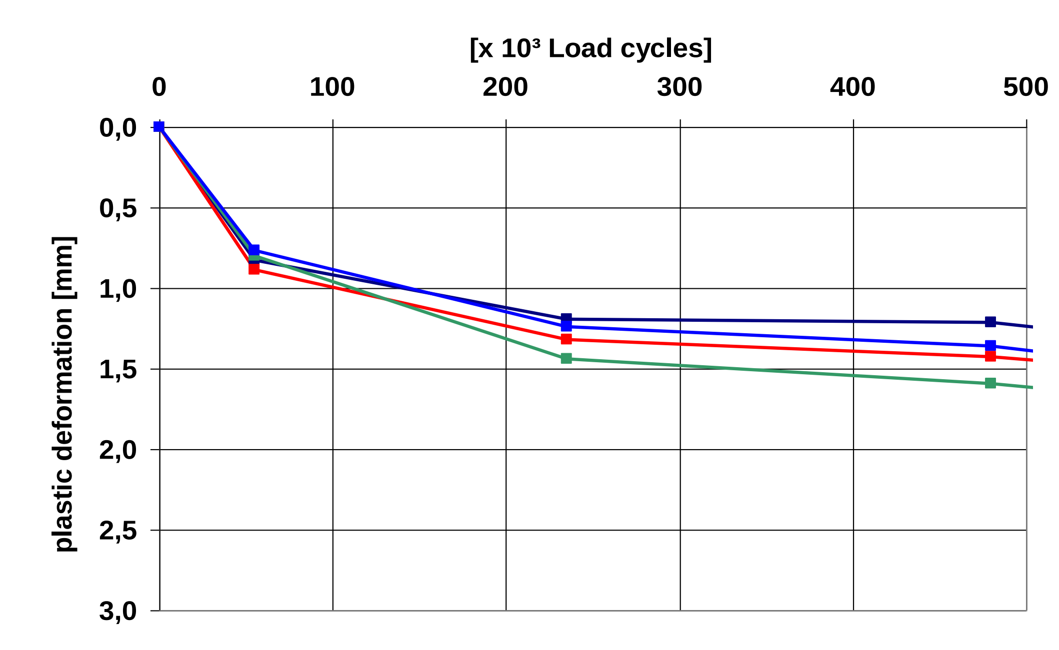


Static bending stresses in concrete layer in transversal direction

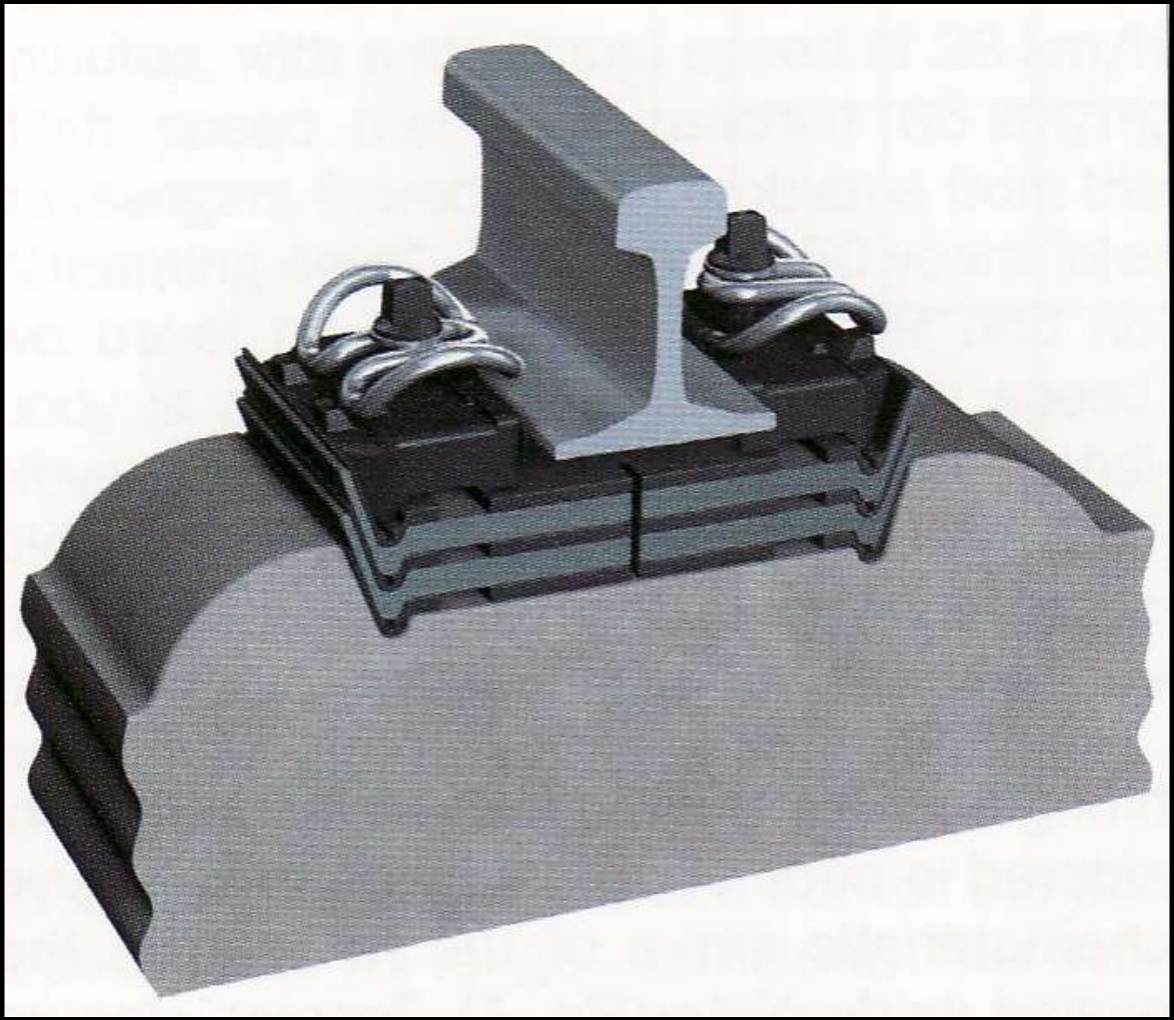

Axle load 100 kN
Q = 50 kN
p = 0,7 N/mm²
max τ
max σ
Asphalt


Axle load 200 kN
Sstat = 32 kN
Sdyn = 50 – 78 kN
Elastic rail pad
Geo-textile
p < 0,3 N/mm²
max τ
Asphalt
max σ

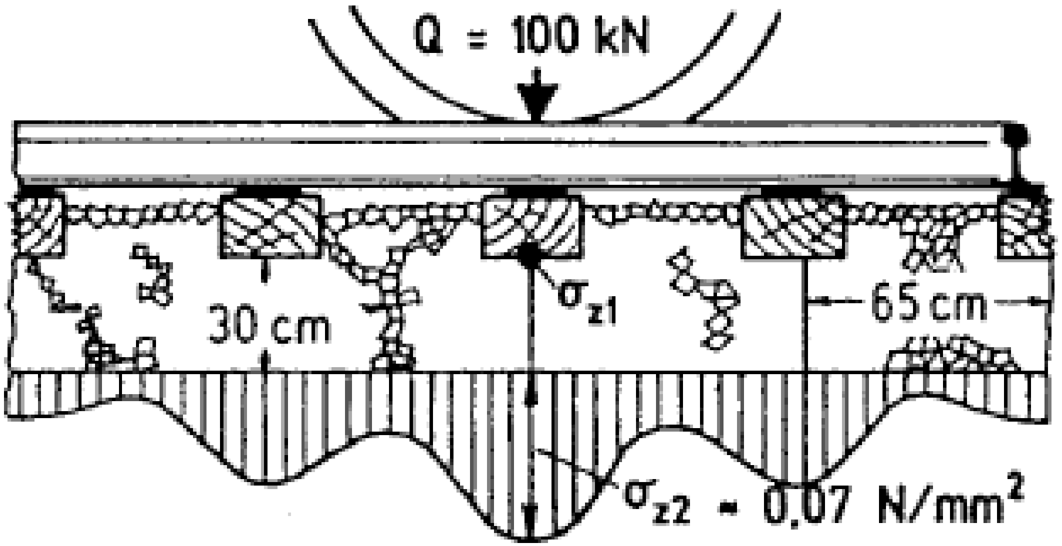
Sleeper panel on asphalt pavement



- Deformation
- Erosion
- Frost

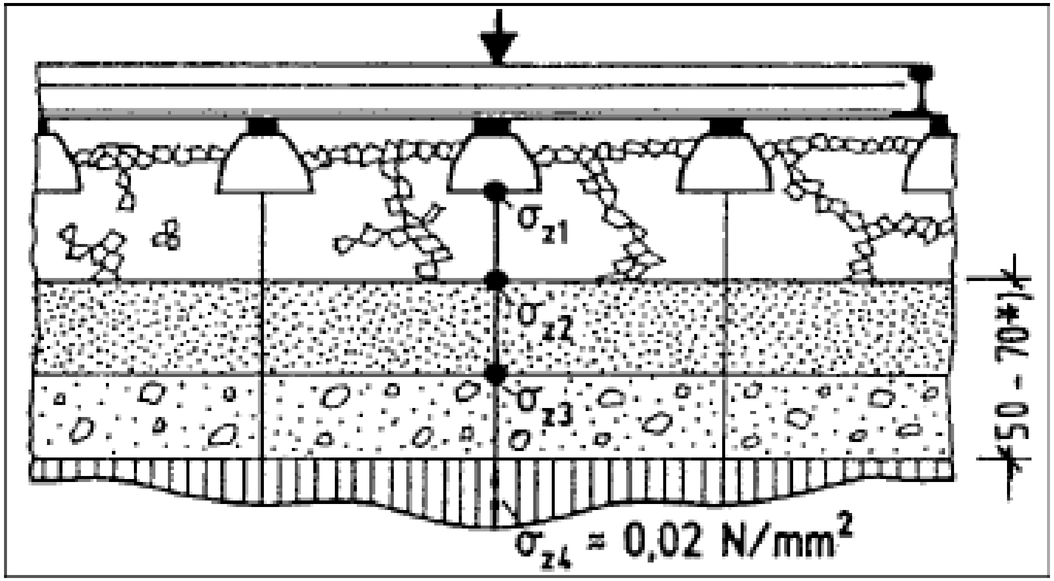


Height adjustment within fastening system + 76mm / -24mm to compensate slab settlement or heaving



Old, conventional tracks

Vertical stresses σ_z acting on subgrade



Protection layer

Frost blanket layer

Actual, conventional tracks for hightspeed v ≥ 250km/h

Vertical stresses σ_z acting on subgrade

Transition Design

- Ballasted / Ballastless

Approval of new track designs or track components

Industry

Develops new track

Application for approval
- Design / dimensioning
- Certificates
  - Testing
  - Expert reports

Federal Rail Agency (EBA)

Approval for in-situ testing

Approval

Safety

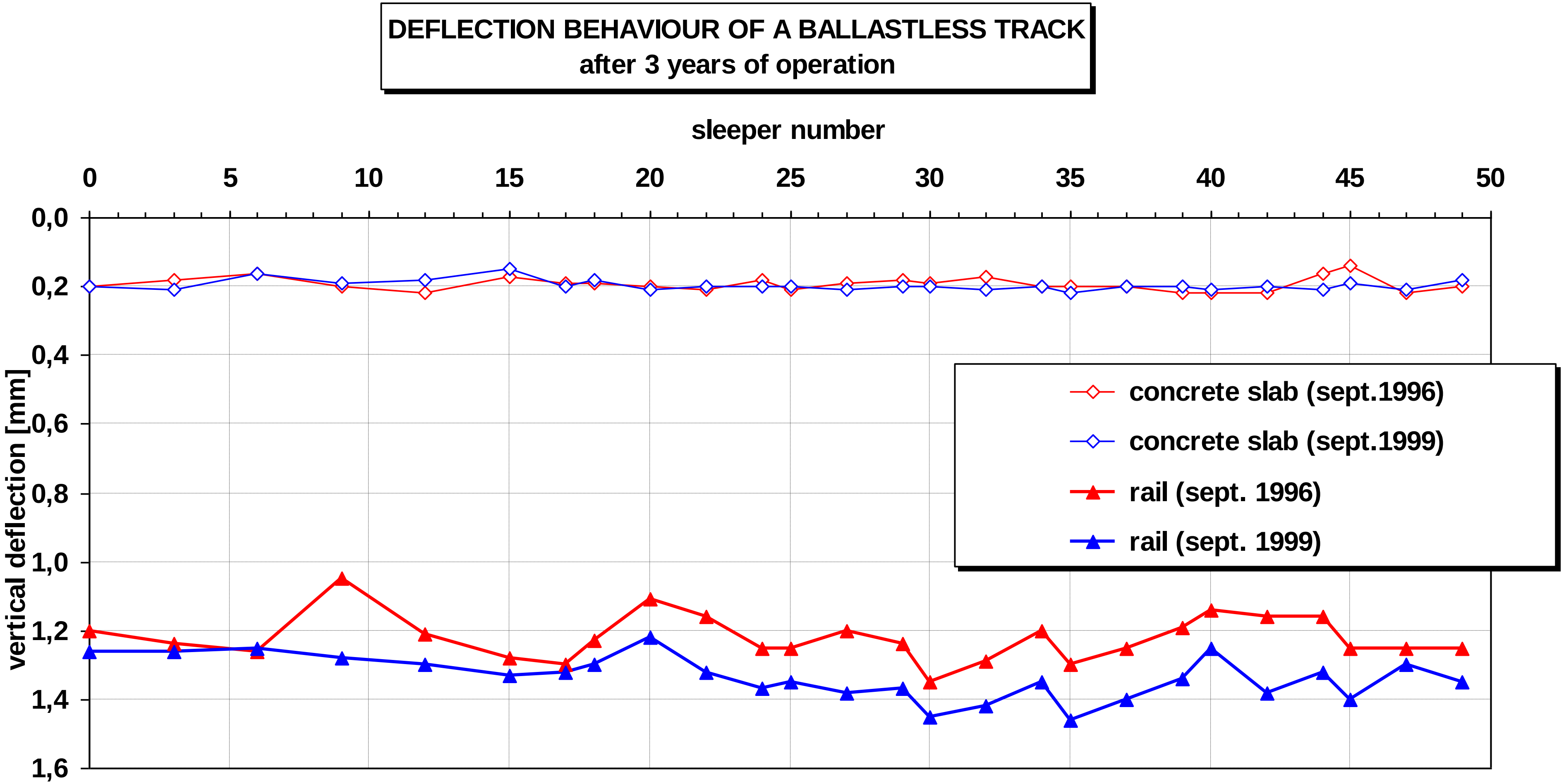
Client /operator (DB – AG)

Declaration of usage

LCC

Order

Track movable Benkelman beam to check track quality



DEFLECTION BEHAVIOUR OF A BALLASTLESS TRACK
after 3 years of operation
sleeper number
0
5
10
15
20
25
30
35
40
45
50
vertical deflection [mm]
0,0
0,2
0,4
0,6
0,8
1,0
1,2
1,4
1,6
concrete slab (sept.1996)
concrete slab (sept.1999)
rail (sept. 1996)
rail (sept. 1999)

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Further developments of ballastless tracks with concrete pavements

New track designs using long term experiences of the road sector

- Concrete pavement on unbound base layer

- Jointed plain concrete pavement (JPCP)

-…

Conclusions

Concrete pavement technology for road application is platform for high level rail application (but not only)

Rail requirements are specific and tight

Interface between pre-fabricated and built in place components is critical

Obrigado pela sua atenção !

Thanks for your attention !

Dr.-Ing. Bernhard Lechner

Technische Universität München
Chair and Institute of Road, Railway and Airfield Construction
Baumbachstraße 7
81245 München
Germany

Tel +49.89.289.27033
Fax +49.89.289.27042

E-Mail: bernhard.lechner@vwb.bv.tum.de
Internet: www.vwb.bv.tum.de

Discrete rail seats on CRCP

(controlled cracking required)

BES (WALTER-HEILIT)