Railway Concrete Pavements

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Continuously Reinforced Concrete Pavement for ballastless tracks (Nuremberg-Ingolstadt)
High speed line Cologne – Rhine/Main opened 2002

\[ V_{\text{max}} = 300 \text{ km/h} \]
\[ R_{\text{reg}} = 3350 \text{ m} \]
\[ \text{Cant}_{\text{max}} = 170 \text{ mm} \]
\[ \text{Grade}_{\text{max}} = 40 \% \]
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

Unsprung mass of axle up to 2t

Rail deflection under 20t single axle load
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
Conventional sleeper B 70
Sleeper B 75 increased contact area
High resilient fastening system
Conventional Fastening System
Resistance against track buckling

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

Dr.-Ing. Bernhard Lechner
Cologne – Rhine/Main 2002

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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: 550-700 T€  Annual maintenance costs 0.25 T€
Total cost for the new construction of a railway line (without rolling stock)

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 \(\rightarrow 100\%\)
- 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
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GENERAL SYSTEMS OF BALLASTLESS TRACKS

- DISCRETE RAIL SEATS OR CONTINUOUSLY EMBEDDED RAIL ON CONCRETE SLAB (CRCP)
- PRE-CAST SLABS ON TREATED BASE
- SLEEPER PANEL ON CONCRETE PAVEMENT (fixed or monolithic) OR ASPHALT PAVEMENT (fixed)

Ref: Max Bögl GmbH
Ref: Pfleiderer track systems
First ballastless track installed at Rheda station 1972
First ballastless track installed at Rheda station 1972
Ballastless track systems

system Rheda classic

- concrete sleeper
- cast concrete
- styrofoam concrete (isolation and support layer)
- rail UIC 60 with rail fastening system Vossloh 300
- nominal gauge 1435 mm
- continuously reinforced concrete layer

\[ \triangle \text{TOR} = \pm 0.00 \]

Dimensions:
- 2600
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
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 prefabricated 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

Cement treated base (CTB)
Temporary rail support required
Temporary rail support removed
Curing according to road construction
Cracks up to 0.5mm are according to CRCP design – no sealing required.
Switches must be integrated
DJ: Contraction joint (dummy joint)

CTB: Concrete slabs must be reinforced in case of skew-angled shape (angle of intersection between bridge deck and crossed road < 80gon)

Expanded plastic board
Geotextile and protection layer
Sealing layer (ZTV-ING part 7)
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)

240mm CRCP

300mm Cement treated base (CTB)
Pre-cast slabs or frames on a treated base using grouting mortars

BÖGL

(Nuremberg-Ingolstadt 2006)
Nürnberg-Ingolstadt
Ballastless tracks
Installation of noise absorption elements
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Vossloh Fastening System FF 336

- Schiene (Rail)
- Sechskantmutter (Hexagon nut)
- Spannklemme Skl 12 (Tension Clamp Skl 12)
- Hakenschraube Hs 32 (T-head bolt Hs 32)
- Schraubenfeder Fe (Helical spring Fe)
- Elastische Zwischenplatte Zwp (Elastic plate Zwp)
- Zwischenplatte Zwp (Intermediate pad Zwp)
- 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

Distance to 1st axle [m]

Lift-up forces

Distance to 1st axle [m]
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

Axle load 200 kN

Elastic rail pad
Geotextile

$Q = 50 \text{ kN}$

$\rho = 0.7 \text{ N/mm}^2$

$S_{\text{stat}} = 32 \text{ kN}$

$S_{\text{dyn}} = 50 - 78 \text{ kN}$

$\rho < 0.3 \text{ N/mm}^2$

Asphalt

max $\tau$
max $\sigma$

Asphalt

max $\tau$
max $\sigma$
- Deformation
- Erosion
- Frost

Sleeper panel on asphalt pavement
Height adjustment within fastening system + 76mm / -24mm to compensate slab settlement or heaving
Old, conventional tracks

Vertical stresses $\sigma_z$ acting on subgrade
Actual, conventional tracks for highspeed $v \geq 250\text{km/h}$

Vertical stresses $\sigma_z$ 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

vertical deflection [mm]

- 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!

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Discrete rail seats on CRCP

(controlled cracking required)

BES (WALTER-HEILIT)