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Železniške naprave - Progovni sistemi z utrjenimi tirnicami - 2. del: Projektiranje sistema, podsistemi in sestavni deli

Railway applications - Ballastless track systems - Part 2: System design, subsystems and components

Bahnanwendungen - Feste Fahrbahn-Systeme - Teil 2: Teilsysteme und Komponenten

Applications ferroviaires - Systèmes de voies sans ballast - Partie 2 : Sous-systèmes et composants

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Bahnanwendungen - Feste Fahrbahn-Systeme - Teil 2: Systementwurf, Untersysteme und Komponenten

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
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CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

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European foreword

This document (EN 16432-2:2017) has been prepared by Technical Committee CEN/TC 256 “Railway applications”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by February 2018, and conflicting national standards shall be withdrawn at the latest by February 2018.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive 2008/57/EC.

For relationship with EU Directive(s), see informative Annex ZA, which is an integral part of this document.

This European Standard is one of the series EN 16432 “*Railway applications — Ballastless track systems*” as listed below:

— *Part 1: General requirements;*

— *Part 2: System design, subsystems and components;*

— *Part 3: Acceptance (in preparation).*

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

This part of the series EN 16432 covers the design of the ballastless track system, subsystems and components and is used in conjunction with the following parts:

— Part 1: General requirements;

— Part 3: Acceptance.

A ballastless track system may consist of, but is not limited to, subsystems and components shown in 5.1, Figure 1. Those items are designed in accordance with the requirements defined in this standard, or if applicable, other existing European standards.

NOTE Typical examples are rails defined in EN 13674–1, EN 13674–2 and EN 13674–3 or rail fastenings for ballastless track system defined in EN 13481–5.

1 Scope

This part of EN 16432 specifies system and subsystem design and component configuration for ballastless track system.

The system and subsystem design requirements are assigned from the general requirements of EN 16432-1. Where applicable, existing subsystem or component requirements from other standards are to be referenced.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

prEN 197-1:2014, *Cement — Part 1: Composition, specifications and conformity criteria for common cements*

EN 206:2013+A1:2016, *Concrete — Specification, performance, production and conformity*

EN 1097-6:2013, *Tests for mechanical and physical properties of aggregates — Part 6: Determination of particle density and water absorption*

EN 1992 series, *Eurocodes*

EN 1992-1-1:2004, *Eurocode 2: Design of concrete structures — Part 1-1: General rules and rules for buildings*

EN 1992-2:2005, *Eurocode 2 — Design of concrete structures — Concrete bridges — Design and detailing rules*

prEN 13043:2015, *Aggregates for bituminous mixtures and surface treatments for roads, airfields and other trafficked areas*

EN 13108-1:2016, *Bituminous mixtures — Material specifications — Part 1: Asphalt Concrete*

EN 13108-5:2016, *Bituminous mixtures — Material specifications — Part 5: Stone Mastic Asphalt*

EN 13230-1:2016, *Railway applications — Track — Concrete sleepers and bearers — Part 1: General requirements*

EN 13230-2:2016, *Railway applications — Track — Concrete sleepers and bearers — Part 2: Prestressed monoblock sleepers*

EN 13230-3:2016, *Railway applications — Track — Concrete sleepers and bearers — Part 3: Twin-block reinforced sleepers*

EN 13230-4:2016, *Railway applications — Track — Concrete sleepers and bearers — Part 4: Prestressed bearers for switches and crossings*

EN 13230-5:2016, *Railway applications — Track — Concrete sleepers and bearers — Part 5: Special elements*

prEN 13230-6:2015, *Railway applications — Track — Concrete sleepers and bearers — Part 6: Design*

EN 13242:2002+A1:2007, *Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction*

EN 13286-47:2012, *Unbound and hydraulically bound mixtures — Part 47: Test method for the determination of California bearing ratio, immediate bearing index and linear swelling*

EN 13481 (all parts), *Railway applications — Track — Performance requirements for fastening systems*

EN 13674-1:2011+A1:2017, *Railway applications — Track — Rail — Part 1: Vignole railway rails 46 kg/m and above*

EN 13674-2:2006+A1:2010, *Railway applications — Track — Rail — Part 2: Switch and crossing rails used in conjunction with Vignole railway rails 46 kg/m and above*

EN 13674-3:2006+A1:2010, *Railway applications — Track — Rail — Part 3: Check rails*

EN 13877-1:2013, *Concrete pavements — Part 1: Materials*

EN 13877-2:2013, *Concrete pavements — Part 2: Functional requirements for concrete pavements*

EN 13877-3:2004, *Concrete pavements — Part 3: Specifications for dowels to be used in concrete pavements*

EN 14227-1:2013, *Hydraulically bound mixtures — Specifications — Part 1: Cement bound granular mixtures*

EN 16432-1:2017, *Railway applications — Ballastless track systems — Part 1: General requirements*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply as well as terms and definitions according to EN 16432-1.

3.1
filling layer
monolithic structure connecting prefabricated elements or subsystems of a ballastless track system and establishing load transfer to the pavement or any supporting structure

3.2
pavement
continuous, layered structure that forms a hard and durable surface and it is designed to provide bearing capacity

3.3
system design
process of applying a systematic approach to ensure that all elements specified will work together to fulfil the performance requirements

Note 1 to entry: This process involves dealing with the general requirements for ballastless track systems as defined in EN 16432–1 and combining these into a set of scenarios to analyse and resolve in order to provide final dimensioning and a satisfactory specification.

3.4
track stiffness
resistance of the entire track structure to deformation in relation to the applied force

4 Symbols and abbreviations

Symbol	Definition	Unit
AC	Asphalt Concrete	
CRCP	Continuously Reinforced Concrete Pavement	
CTB	Cement Treated Base layer	
FEM	Finite Element Method	
FST	Floating Slab Track	
JPCP	Jointed Plain Concrete Pavement	
PmB	Polymer modified Bitumen	
RAMS	Reliability, Availability, Maintainability, Safety	
SLS	Serviceability Limit State	
SMA	Stone Mastic Asphalt	
ULS	Ultimate Limit State	
A	Axle load	N
A_i	Layer cross-section area calculated based on 1 mm width of the first layer	mm^2
A_{LS}	Contact area or area of the loading surface	mm^2
a	Rail seat spacing or reference length of embedded rail section	mm
a_s	Total cross-section area of steel reinforcement calculated based on 1 mm slab width	mm^2
α_t	Coefficient of thermal expansion	1/K
B	Width of the slab or pavement	mm
B_{crit}	Critical width of slab or pavement	mm
B_1 and B_2	Width of the layers 1 and 2, respectively	mm
b	Reference radius of contact area	mm
b_B	Half of slab width or width of beam	mm
b_h	Width of beam	mm
b_1	Width of upper layer (1st layer)	mm
b_2	Width of 2nd layer	mm
c	Material correction factor for concrete layers or hydraulically bonded layers, e.g. c = 0,83	
c_{tot}	Total system stiffness	N/mm
c_1	Stiffness of the fastening system specified for dynamic loading and low temperature	N/mm
c_2	Stiffness of an additional elastic element (e.g. booted block)	N/mm

Symbol	Definition	Unit
	supporting rail seat (if applicable)	
Dpr	Proctor Density	g/mm^3
d	Diameter of the steel bars Joint/crack width	mm
E	Young's Modulus	N/mm^2
E_{conc}	Young's modulus of concrete	N/mm^2
E_{dyn}	Dynamic Young's modulus	N/mm^2
E_R	Young's modulus [N/mm^2] of the rail, (typically E_R = 210 000 N/mm^2)	N/mm^2
E_S	Young's modulus of steel	N/mm^2
E_{V2}	Modulus of deformation obtained on 2nd loading in the plate bearing test	N/mm^2
E_1	Young's modulus of the 1st layer of a beam or a slab/pavement	N/mm^2
E_2	Young's modulus of the unbound granular material or substructure	N/mm^2
E_1, E_2, E_3	Young's modulus of the concrete, unbound base layer and the substructure, respectively	N/mm^2
e_a	Distance between pavement surface and neutral axis	mm
e_b	Distance between bottom of pavement and neutral axis	mm
f_{ck}	Characteristic concrete compressive strength (cylinder or cube) after 28 days	N/mm^2
f_{ctk}	Characteristic concrete tensile strength	N/mm^2
h	Equivalent thickness	mm
h	h_I or h_{II} or h_{III} thickness of Winkler slab/pavement thickness of system h_I or h_{II} or h_{III} the thickness of the slab/pavement [mm] or h_I or h_{II} or h_{III}	mm
h^*	Reference thickness of the layer based on the normalized Young's modulus	mm
h_i	Layer thickness	mm
h_1	Thickness of the 1st layer of a beam or a slab/pavement	mm
$h_1{}^*$	Equivalent height of the beam or slab/pavement having same Young's modulus as the half-space beneath	mm
$h_2{}^*$	Equivalent height of the unbound base layer having same Young's as the half-space beneath	mm

Symbol	Definition	Unit
h_2	Thickness of the unbound base layer	mm
h_I	Thickness Variant I (single layer)	mm
h_{II}	Half-space equivalent thickness Variant II (unbonded multiple layer)	mm
h_{III}	Half-space equivalent thickness Variant III (bonded multiple layer)	mm
I	Vertical Moment of inertia of a T-beam	mm^4
I_B	Vertical Moment of inertia of the beam	mm^4
I_R	Vertical moment of inertia of the rail	mm^4
I_1	Moment of inertia of upper layer (1st layer)	mm^4
k	Bedding modulus	N/mm^3
k	Permeability	m/s
k_d	Dynamic load factor	
k_q	Factor to increase the static wheel loads by additional vertical load (additional quasi static wheel load acting on outside rail along curves)	
L	Slab length / crack or joint spacing	mm
L_{el}	Elastic length	mm
l	Joint or crack spacing	mm
l_b	Length of full bond between steel bar and concrete	mm
l_e	Strain length of steel bar	mm
$M_{lat,neigh}$	Lateral bending moment activated by neighbouring loads	Nmm
$M_{lat\ I,II,III}$	Lateral bending moment	Nmm
$M_{lat\ I}$	Lateral bending moment activated in system I	Nmm
$M_{lat\ II}$	Lateral bending moment activated in system II (unbonded multiple layers)	Nmm
$M_{lat,1}$	Lateral bending moment activated by neighbouring load P_1	Nmm
$M_{long,neigh}$	Additional longitudinal bending moment activated by neighbouring loads	Nmm
$M_{long,I}$	Longitudinal bending moment activated in system I (single layer on substructure)	Nmm
$M_{long,II}$	Longitudinal bending moment activated in system II (unbonded multiple layers)	Nmm
$M_{long,1}$	Longitudinal bending moment activated by neighbouring load P_1	Nmm

Symbol	Definition	Unit
$M_{\text{long II}}$ and $M_{\text{lat II}}$	Longitudinal and lateral bending moments activated in system II (unbonded multiple layers)	Nmm
$M_{\text{long III}}$ and $M_{\text{lat III}}$	Longitudinal and lateral bending moments activated in system III (bonded multiple layers)	Nmm
$M_{\text{long I,II,III}}$	Longitudinal bending moment	Nmm
$M_{j\_\text{r,t}}$	Radial and tangential bending moment	Nmm
$M_{\text{r,t}}$	Radial and tangential bending moment	Nmm
M_0	Rail bending moment	Nmm
$M_{0\ \text{I, II, II}}$	Bending moment	Nmm
n	Number of trains Number of load cycles, usually the number of axles	
P_j	Rail seat load due to wheel loads Q_i	N
p	Load contact pressure	N/mm^2
Q_i	Wheel load	N
r	Radius for circular contact area A_{LS}; $r = \sqrt{\frac{A_{\text{LS}}}{\pi}}$;	mm
s	Distance between rail axis (1,5 m for normal gauge)	mm
W_F	Rail section modulus at underside of rail foot	mm^3
x_i	Distance between rail seat and position of wheel	mm
x_j	Distance between the rail seat 0 and the rail seat j	mm
$X_{\text{s,i}}$	Distance between centre of layer cross-section area A_i and neutral axis of the T-beam model	mm
y	Vertical deflection of slab or pavement in	mm
y_i	Vertical displacement due to Q_i	mm
y_0	Rail deflection	mm
α_s	Total cross-section area of steel reinforcement calculated based on 1mm slab width	$\text{mm}^2/\text{ mm}$
β_fs	Bending tensile strength of concrete	N/mm^2
β_j, β_1	Angle between longitudinal track direction and line between P_0 and neighbouring rail seat load	°
Δd	Change of crack or joint width	mm
ΔT	Difference between top and bottom temperature	K
Δt	Temperature gradient according to the thickness h_1 of the	K/mm