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Železniške naprave - Infrastruktura - Parametri za načrtovanje trase proge za mestno železnico

Railway applications - Infrastructure - Track alignment design parameters for urban rail

Bahnanwendungen - Oberbau - Streckentrassierungsparameter für den städtischen Schienenverkehr

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Bahnanwendungen - Oberbau - Streckentrassierungsparameter für den städtischen Schienenverkehr

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Contents

Page

European foreword 4
1 Scope 5
2 Normative references 5
3 Terms and definitions 5
4 Symbols and abbreviations 8
5 General 9
5.1 Background 9
5.2 Line categories 10
5.3 Alignment characteristics 10
6 Limits for 1 435 mm and 1 000 mm nominal track gauge 12
6.1 Horizontal radius R 12
6.2 Applied cant D 12
6.3 Cant deficiency I 13
6.4 Cant excess E 14
6.5 Length of cant transition L_D and transition curve in the horizontal plane L_K 14
6.5.1 General 14
6.5.2 Length of linear cant transition and clothoid 15
6.6 Cant gradient $\mathrm{d}D / \mathrm{d}s$ 15
6.7 Rate of change of cant $\mathrm{d}D / \mathrm{d}t$ 16
6.8 Rate of change of cant deficiency $\mathrm{d}I / \mathrm{d}t$ 16
6.9 Length of constant cant between two linear cant transitions L_i 16
6.10 Abrupt change of horizontal curvature 17
6.11 Abrupt change of cant deficiency ΔI 17
6.12 Length between two abrupt changes of horizontal curvature L_c 17
6.13 Length between two abrupt changes of cant deficiency L_s 18
6.14 Track gradient p 19
6.15 Length of constant gradient L_g 19
6.16 Vertical radius R_v 19
6.17 Length of vertical curve L_v 20
6.18 Abrupt change of track gradient Δp 21
Annex A (normative) Rules for converting parameter values for nominal track gauges other than 1 435 mm or 1 000 mm 22
A.1 Scope 22
A.2 Symbols and abbreviations 22
A.3 Basic assumptions and equivalence rules 23
A.3.1 General 23
A.3.2 Basic formulae 24
A.3.3 Basic data 24
A.4 Detailed conversion rules 25
A.4.1 General 25

A.4.2 Cant D_1 (6.2) ... 25
A.4.3 Cant deficiency I_1 (6.3) ... 27
A.4.4 Cant excess E_1 (6.4) ... 28
A.4.5 Length of cant transition L_D and transition curve in the horizontal plane L_K (6.5) ... 29
A.4.6 Cant gradient dD_1 / ds (6.6) ... 29
A.4.7 Rate of change of cant dD_1 / dt (6.7) ... 30
A.4.8 Rate of change of cant deficiency dI_1 / dt (6.8) ... 30
A.4.9 Abrupt change of curvature and abrupt change of cant deficiency ΔI_1 (6.10 and 6.11) ... 31
A.4.10 Other parameters (6.1, 6.9, 6.12, 6.13, 6.14, 6.15, 6.16, 6.17 and 6.18) ... 31

Annex B (normative) Three-dimensional track geometry with regards to resulting cant gradient and resulting vertical radius ... 32
B.1 General considerations regarding three-dimensional track geometry ... 32
B.2 Angular twist T_A and resulting cant gradient $(dD / ds)_r$ ... 32
B.2.1 Calculation of resulting cant gradient $(dD / ds)_r$ where cant is applied by lifting one rail $D / 2$ and lowering the other rail $D / 2$ ... 32
B.2.2 Calculation of resulting cant gradient $(dD / ds)_r$ when cant is applied by lifting one rail D ... 33
B.3 Resulting vertical radius $(R_v)_r$ ... 34

Annex C (normative) Sign rules for calculation of ΔD, ΔI and Δp ... 35
C.1 General regarding the sign rules ... 35
C.2 Sign rules for calculation of ΔD ... 35
C.3 Sign rules for calculation of ΔI ... 35
C.4 Sign rules for calculation of Δp ... 37

Annex D (normative) Lengths of intermediate elements L_c between small radius curves in opposite directions ... 38
D.1 General ... 38
D.2 Lengths of intermediate elements L_c for Line Category A1435 ... 38
D.3 Lengths of intermediate elements L_c for Line Category B1435 ... 39
D.4 Lengths of intermediate elements L_c for Line Category C1000 ... 41

Bibliography ... 42

European foreword

This document (prEN 17636:2021) has been prepared by Technical Committee CEN/TC 256 “Railway applications”, the secretariat of which is held by DIN.

This document is currently submitted to the CEN Enquiry.

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1 Scope

This document specifies rules and limits for track alignment design parameters, including alignments within switches and crossings. Several of these limits are functions of speed. Alternatively, for a given track alignment, it specifies rules and limits that determine permissible speed with regards to track alignment.

This document applies to urban or suburban rail networks for passenger services not integrated with the national network.

Sections of urban or suburban rail networks integrated in the national rail networks are not covered by this document. They are covered by EN 13803 (or for nominal track gauges smaller than 1 435 mm by national alignment rules).

For the purpose of this document, urban or suburban rail networks include:

— Networks designed for own right of way and segregated from general road and pedestrian traffic,

and

— Networks (partly) not segregated from general road and pedestrian traffic, with shared lanes.

This document applies to rail systems with steel wheels running on steel vignole or grooved rails. Rail systems with specific construction issues (e.g. rack railways, funicular railways and other types of cable drawn rail systems) are not covered by this document.

This document defines the parameters, rules and limits for nominal track gauges of 1 435 mm and 1 000 mm with permissible speeds up to 120 km/h. For other nominal track gauges, this document defines conversion rules which shall be used to define the limits.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 15273-1, *Railway applications — Gauges — Part 1: General — Common rules for infrastructure and rolling stock*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
track gauge
distance between the corresponding running edges of the two rails

3.2
nominal track gauge
single value which identifies the track gauge but may differ from the design track gauge, e.g. the most widely used track gauge in Europe that has a nominal value of 1 435 mm although this is not the design track gauge normally specified

3.3
limit
design value not to be exceeded

Note 1 to entry: These values ensure maintenance costs of the track are kept at a reasonable level, except where particular conditions of poor track stability can occur, without compromising passenger comfort. However, the actual design values for new lines should normally have substantial margins to the limits.

Note 2 to entry: For certain parameters, this document specifies both a normal limit and an exceptional limit. Exceptional limits are intended for use only under special circumstances and can require an associated maintenance regime as well as requiring to be verified against the local rolling stock.

3.4
alignment element
segment of the track with either vertical direction, horizontal direction or cant obeying a unique mathematical description as a function of chainage

Note 1 to entry: Unless otherwise stated, the appertaining track alignment design parameters are defined for the track centre line and the longitudinal distance for the track centre line is defined in a projection in a horizontal plane.

3.5
chainage
longitudinal distance along the horizontal projection of the track centre line

3.6
curvature
derivative of the horizontal direction of the track centre line with respect to chainage

Note 1 to entry: In the direction of the chainage, curvature is positive in a right-hand curve and negative on a left-hand curve. The magnitude of the curvature corresponds to the inverse of the horizontal radius.

3.7
circular curve
curved alignment element of constant curvature

3.8
transition curve
alignment element where curvature changes with respect to chainage

Note 1 to entry: The clothoid (sometimes approximated as a 3rd degree polynomial, “cubic parabola”) is normally used for transition curves, giving a linear variation of curvature. In some cases, curvature is smoothed at the ends of the transition. A transition can also be created by a sequence of short circular curves with radii which changes stepwise.

Note 2 to entry: It is possible to use other forms of transition curve, which show a nonlinear variation of curvature. EN 13803 gives a detailed account of certain alternative types of transitions that may be used in track alignment design.

Note 3 to entry: Normally, a transition curve is not used for the vertical alignment.

3.9
compound curve
sequence of curved alignment elements, including two or more circular curves in the same direction

Note 1 to entry: The compound curve can include transition curves between the circular curves and/or the circular curves and the straight tracks.

3.10
reverse curve
sequence of curved alignment elements, containing alignment elements which curve in the opposite directions

Note 1 to entry: A sequence of curved alignment elements can be both a compound curve and a reverse curve.

3.11
applied cant
amount by which one running rail is raised above the other running rail, at base measurement for applied cant

3.12
equilibrium cant
cant at a particular speed at which the vehicle will have a resultant force perpendicular to the running plane

3.13
cant deficiency
difference between applied cant and a higher equilibrium cant

Note 1 to entry: When there is cant deficiency, there will be an unbalanced lateral force in the running plane. The resultant force will move towards the outer rail of the curve.

3.14
cant excess
difference between applied cant and a lower equilibrium cant

Note 1 to entry: When there is cant excess, there will be an unbalanced lateral force in the running plane. The resultant force will move towards the inner rail of the curve.

Note 2 to entry: Cant on a straight track results in cant excess, generating a lateral force towards the low rail.

3.15
cant transition
alignment element where cant changes with respect to chainage

Note 1 to entry: Normally, a cant transition coincides with a transition curve.

Note 2 to entry: Cant transitions giving a linear variation of cant are usually used. In some cases, cant is smoothed at the ends of the transition.

Note 3 to entry: It is possible to use other forms of cant transition, which show a nonlinear variation of cant. EN 13803 gives a detailed account of certain alternative types of transitions that may be used in track alignment design.

3.16
cant gradient
absolute value of the derivative (with respect to chainage) of cant

3.17
resulting cant gradient
derived gradient of cant on a track gradient which results in the same angular twist as a cant gradient on a level track

3.18
angular twist
the derivative of roll angle (rotation around the longitudinal axis) with respect to longitudinal distance measured in coordinate system which has the same direction as the sloping track on a track gradient

3.19
rate of change of cant
absolute value of the time derivative of cant

3.20
rate of change of cant deficiency
absolute value of the time derivative of cant deficiency (and/or cant excess)

4 Symbols and abbreviations

No.	Symbol	Designation	Unit
1	$\mathrm{d}D/\mathrm{d}s$	cant gradient	mm/m
2	$(\mathrm{d}D/\mathrm{d}s)_{\mathrm{r}}$	resulting cant gradient	mm/m
3	$\mathrm{d}D/\mathrm{d}t$	rate of change of cant	mm/s
4	$\mathrm{d}I/\mathrm{d}t$	rate of change of cant deficiency (and/or cant excess)	mm/s
5	D	applied cant	mm
6	D_{EQ}	equilibrium cant	mm
7	E	base measurement for applied cant, 1500mm for 1435mm gauge, 1060mm for 1000mm gauge	mm
8	E	cant excess	mm
9	G	acceleration due to gravity according to EN ISO 80000-3	m/s^2
10	I	cant deficiency	mm
11	L_{c}	length between two abrupt changes of curvature	m
12	L_D	length of cant transition	m
13	L_g	length of constant gradient	m
14	L_K	length of transition curve	m
15	L_i	length of alignment elements between two linear cant transitions	m
16	L_s	length between two abrupt changes of cant deficiency	m
17	L_v	length of vertical radius	m
18	P	track gradient	-

No.	Symbol	Designation	Unit
19	q_E	factor for calculation of equilibrium cant: 11,8 for 1435mm gauge, 8,3 for 1000mm gauge	mm·m·(h/km)²
20	q_N	factor for calculation of length of cant transition or transition curve with non-constant gradient of cant and curvature, respectively	-
21	q_R	factor for calculation of vertical radius	m·h²/km²
22	q_s	factor for calculation of lengths between abrupt changes of cant deficiency	-
23	q_V	factor for conversion of the units for vehicle speed: 3,6	km·s/(h·m)
24	R	radius of horizontal curve	m
25	R_v	radius of vertical curve	m
26	$(R_v)_r$	resulting vertical radius	m
27	s	longitudinal distance	m
28	t	Time	s
29	T_A	angular twist	Rad/m
30	V	Speed	km/h
31	lim	limit (index)	-
32	r	index for resulting parameters in three-dimensional calculations	-
33	R, lim	additional limit applicable at small radius curves (index)	-

5 General

5.1 Background

This document specifies rules and limits for track alignment design. These limits assume that standards for acceptance of vehicle, track construction and maintenance are fulfilled (construction and in-service tolerances are not specified in this document). Engineering requirements specific to the mechanical behaviour of switch and crossing components and subsystems are to be found in the relevant standards.

This document is not a design manual. The limits are not intended to be imposed as usual design values. However, design values shall be within the limits stated in this document.

Limits in this document are based on practical experiences of European Urban Rail networks. Limits are applied where it is necessary to compromise between train performance, comfort levels, maintenance of the vehicle and track, and construction costs.

Unnecessary use of design values close to limits should be avoided, substantial margins to them should be provided. There are often conflicts between the desire for margins to one parameter and another, these should be distributed over all design parameters, possibly by applying a margin with respect to speed.

For certain parameters, this document also specifies exceptional limits less restrictive than normal limits. Such limits are intended for use only under special circumstances and can require an associated maintenance regime as well as requiring to be verified against the local rolling stock. In particular, use of exceptional limits (instead of normal limits) for several parameters at the same location shall be avoided.

Operational limits for speed and cant deficiency shall be applied to specific vehicles according to their approval parameters. Speed may also be restricted for other reasons than track alignment, for example reduced visibility and operational rules.

The limits are defined for normal service operations. If and when running trials are conducted, for example to ascertain the vehicle dynamic behaviour (by continually monitoring of the vehicle responses), exceeding the limits (particularly in terms of cant deficiency) should be permitted and it is up to the infrastructure manager to decide any appropriate arrangement. In this context, safety margins are generally reinforced by taking additional steps such as ballast consolidation, monitoring of track geometric quality, etc.

5.2 Line categories

Urban and suburban rail systems are local systems of different character. The requirements on the infrastructure are related to the vehicle types to be used on the network. Three line categories are defined, including systems for nominal track gauge 1 435 mm and 1 000 mm:

— Category A1435, lines for medium size rail vehicles with nominal track gauge 1 435 mm

— Category B1435, lines for small rail vehicles with nominal track gauge 1 435 mm

— Category C1000, lines for small rail vehicles with nominal track gauge 1 000 mm

For other nominal track gauges, limits can be defined using conversion rules specified in normative Annex A.

It is assumed that all vehicles have been tested and approved according to the relevant standards in conditions for the line category.

5.3 Alignment characteristics

The alignment defines the geometrical position of the track. It is divided into horizontal alignment and vertical alignment.

The horizontal alignment is the projection of the track centre line on a horizontal plane. The horizontal alignment consists of a sequence of alignment elements, each obeying a unique mathematical description as a function of longitudinal distance along the horizontal projection (chainage). The elements for horizontal alignment are connected at tangent points, where two connected elements have the same coordinates and the same directions. Elements for horizontal alignment are specified in Table 1.

Table 1 — Elements for horizontal alignment

Alignment element	Characteristics
Straight line	No horizontal curvature
Circular curve	Constant horizontal curvature
Transition curve, Clothoid type [a]	Horizontal curvature varies linearly with chainage
Compound transition	A sequence of short circular curves where curvature increases or decreases stepwise
[a] EN 13803 gives a detailed account of certain alternative types of transition curves that may be used in track alignment design	

Most modern switches have a tangential geometry, where the diverging track starts with an alignment that is tangential with the through track. However, switch designs may start with an abrupt change of horizontal direction at the beginning of the switch. When a turnout is placed on a track gradient other than zero, a vertical curve and/or cant, the horizontal geometry of the diverging track will deviate slightly from the element types in Table 1.

The vertical alignment defines the level of the track as a function of chainage (the longitudinal position along the horizontal projection of the track centre line). The elements for vertical alignment are connected at tangent points, where two connected elements have the same level and the same track gradient p (with certain exceptions). Elements for vertical alignment are specified in Table 2.

Table 2 — Elements for vertical alignment

Alignment element	Characteristics
Constant gradient	No vertical curvature
Vertical curve, parabola	Derivative of gradient with respect to chainage is constant
Vertical curve, circular	Derivative of vertical angle with respect to sloping length along the track is constant

NOTE A vertical curve in track that starts or ends in canted switches and crossings can be of a higher order polynomial than a parabola.

The applied cant D in the track is the difference in level of two running rails. Cant can be applied by raising one rail above the level of the vertical profile and keeping the other rail on the same level as the vertical profile, or by a pre-defined relation raising one rail and lowering the other rail (a common relation is 50 %/50 %). The cant can be considered as a sequence of elements connected at tangent points where two elements have the same magnitude of applied cant. (At a tangent point with cant, the same rail is the high rail before and after the tangent point.) Elements for applied cant are specified in Table 3.

Table 3 — Elements for cant

Alignment element	Characteristics
Constant cant	Cant is constant along the entire element
Cant transition, linear [a]	Cant varies linearly with chainage
[a] EN 13803 gives a detailed account of certain alternative types of cant transitions that may be used in track alignment design.	

Cant transitions should normally coincide with transition curves, but exceptions are possible.

Lateral and vertical directions in track alignment design refers to the directions of an earth-bound coordinate system. When the alignment has a track gradient and/or applied cant, lateral and/or vertical directions (as perceived by vehicles as well as track components) will change. The effects can be significant for vertical radius and track twist (cant gradient). Normative Annex B specifies formulae to quantify the effects.

All normal limits and exceptional limits in Clause 6 apply, hence the permissible range for one parameter, for example horizontal radius R, can be further restricted due to the chosen values of other parameters. For example, at a certain location in an alignment sequence, the permissible range for horizontal radius R can be limited due to applied cant D, limit for cant deficiency I and/or characteristics of adjacent elements.