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Railway applications - Infrastructure - Track alignment design parameters - Urban rail

Bahnanwendungen - Oberbau - Streckentrassierungsparameter für den städtischen Schienenverkehr

Applications ferroviaires - Infrastructure - Paramètres de conception du tracé de la voie pour le rail urbain

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Bahnanwendungen - Oberbau - Streckentrassierungsparameter für den städtischen Schienenverkehr

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European foreword

This document (EN 17636:2023) 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of an identical text or by endorsement, at the latest by April 2024, and conflicting national standards shall be withdrawn at the latest by April 2024.

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 Standardization Request given to CEN by the European Commission and the European Free Trade Association.

Any feedback and questions on this document should be directed to the users' national standards body. A complete listing of these bodies can be found on the CEN website.

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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 is applicable 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 is applicable to rail systems with steel wheels running on steel vignole rails or steel 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, and specifies 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 are used to specify the limits.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org

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

3.3
limit
restriction for design values not to be exceeded

Note 1 to entry: These values ensure that track maintenance costs and ride comfort are within a reasonable range.

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 in 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 change stepwise.

Note 2 to entry: It is possible to use other forms of transition curve, which show a nonlinear variation of curvature.

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

3.9
reverse curve
sequence of curved alignment elements, containing alignment elements which curve in opposite directions

3.10
running plane
flat plane tangential to the running surface of both rail heads at the considered cross section

3.11
track gradient
absolute value of the derivative (with respect to chainage) of track level

3.12
cant
amount by which one running rail is raised above the other running rail, in a track cross section

Note 1 to entry: Measured over e the base measurement for cant.

3.13
applied cant
design value for cant

3.14
equilibrium cant
cant at a particular speed at which the vehicle will have a resultant force perpendicular to the running plane

3.15
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.

3.16
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.

3.17
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.

3.18
cant gradient
absolute value of the derivative (with respect to chainage) of cant

3.19
helical track
track with a track gradient combined with horizontal curvature

Note 1 to entry: This combination leads to a twisted track, even though applied cant is not changing along the track.

3.20
resulting cant gradient
equivalent gradient of cant for a helical track situation (plus coexisting cant gradient, if present), which results in the same angular twist as a cant gradient on a level track

3.21
angular twist
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

3.22
rate of change of cant
absolute value of the time derivative of cant (resulting from vehicle speed)

3.23
rate of change of cant deficiency
absolute value of the time derivative of cant deficiency and/or cant excess (resulting from vehicle speed)

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 cant	mm
8	E	cant excess	mm
9	g	acceleration due to gravity	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 track 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 curve	m
18	p	track gradient	-
19	q_E	factor for calculation of equilibrium cant	mm·m/(km/h)^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_{Rv}	factor for calculation of vertical radius	m/(km/h)^2
22	q_s	factor for calculation of lengths between abrupt changes of cant deficiency	m/(km/h)
23	q_V	factor for conversion of the units for vehicle speed	(km/h)/(m/s)
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	$_{\mathrm{lim}}$	limit (index)	-
32	$_{\mathrm{r}}$	index for resulting parameters in three-dimensional calculations	-
33	$_{\mathrm{R,\ lim}}$	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 normal limits are not intended to be used as usual design values. However, design values shall be within the limits stated in this document.

This document takes into account the usually tighter and more manifold alignment situations in urban environments, by differentiating into line categories A, B and C (see 5.2). Due to the strong interrelation of alignment limits and kinematic vehicle restrictions, local vehicles have often been tailored to the respective network and vice versa. The main reason for this may be the absence of European Standards within the urban rail sector, a situation the present document may contribute to leave in the long run.

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 (including safety) and comfort levels, maintenance of the vehicle and track, and construction costs.

The use of design values close to normal 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. The use of design values outside the normal limits should be documented.

Operational limits for speed and cant deficiency shall be applied to specific vehicles according to their approval parameters. Limits for train speed shall be calculated from the speed dependent alignment limits by solving for vehicle speed V, using 6.3, 6.4, 6.7, 6.8, 6.11, 6.13 and 6.16. As different vehicle sections may be located on alignment sections with different speed limits, it is always the most restrictive speed limit over the train length that applies. Speed may also be restricted for other reasons than track alignment, for example reduced visibility and operational rules.

The limits are specified for normal service operations. If and when running trials are conducted, for example to ascertain the vehicle dynamic behaviour (by continual monitoring of the vehicle responses), exceeding the limits (particularly in terms of cant deficiency) should be permitted and it is up to the responsible body to decide any appropriate arrangement.

NOTE In common with other track alignment standards and specifications, this document uses vehicle speed V expressed in km/h.

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 metro types of rail vehicles with nominal track gauge 1 435 mm

— Category B1435, lines for tram types of rail vehicles with nominal track gauge 1 435 mm

— Category C1000, lines for tram types of rail vehicles with nominal track gauge 1 000 mm

Table 1 specifies fixed parameters for Line Categories A1435, B1435 and C1000.

Table 1 — Fixed parameters for Line Categories A1435, B1435 and C1000

Parameter	Line Category		
	A1435	**B1435**	**C1000**
nominal track gauge [mm]	1 435	1 435	1 000
e, base measurement for cant [mm]	1 500	1 500	1 060
q_E, factor for calculation of equilibrium cant [mm·m/(km/h)²]	11,8	11,8	8,3

For other nominal track gauges, limits that depend on track gauge (6.2, 6.3, 6.4, 6.6, 6.7, 6.8 and 6.9) shall be specified based on the limit values of A1435 and B1435 applying conversion factors (see normative Annex A).

The conversion is done by multiplying the respective limit with the ratio $W = e_1 / e$, where e_1 is the base measurement for cant for the considered track gauge. However, for the cant gradient (6.6), the limit is obtained by multiplying with $W^2 \cdot (e + 500\text{mm})^2 / (e_1 + 500\text{mm})^2$.

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

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 the 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 2.

Table 2 — 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 2.

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 3.

Table 3 — Elements for vertical alignment

Alignment element	Characteristics
Constant track gradient	No vertical curvature
Vertical curve, parabola	Derivative of track 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. 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 4.

Table 4 — 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 resulting vertical radius (combination of small radius curves with high value of applied cant) and angular twist/resulting cant gradient (helical tracks with steep track gradient and small-radius curves). Normative Annex B specifies formulae to quantify the effects.

All 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, track gradient p, vertical radius R_v and/or characteristics of adjacent elements.