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Železniške naprave - Zgornji ustroj - Parametri za projektiranje prog - Tirne širine 1435 mm in več - 1. del: Odprta proga

Railway applications - Track - Track alignment design parameters - Track gauges 1435 mm and wider - Part 1: Plain line

Bahnanwendungen - Oberbau - Linienführung in Gleisen - Spurweiten 1435 mm und grösser - Teil 1: Durchgehendes Hauptgleis

Applications ferroviaires - Voies - Paramètres de conception du tracé de la voie - Écartement 1435 mm et plus large - Partie 1: Voie courante

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45.080	Tračnice in železniški deli	Rails and railway components
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English Version

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Foreword

This document (EN 13803-1:2010) 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of an identical text or by endorsement, at the latest by December 2010, and conflicting national standards shall be withdrawn at the latest by December 2010.

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

This document supersedes ENV 13803-1:2002.

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(s).

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

- Council Directive 96/48/EC of 23 July 1996 on the interoperability of the European high-speed network[1]
- European Parliament and Council Directive 2004/17/EC of 31 March 2004 coordinating the procurement procedures of entities operating in the water, energy, transport and postal services sectors[2]
- Council Directive 91/440/EEC of 29 July 1991 on the development of the Community's railways[3]

EN 13803, *Railway applications – Track – Track alignment design parameters – Track gauges 1435 mm and wider* consists of the following parts:

- *Part 1: Plain line*
- *Part 2: Switches and crossings and comparable alignment design situations with abrupt changes of the curvature*

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, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

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[1] Official Journal of the European Communities N° L 235 of 1996-09-17

[2] Official Journal of the European Communities N° L 134 of 2004-04-30

[3] Official Journal of the European Communities N° L 237 of 1991-08-24

1 Scope

This European Standard specifies the rules and limits that determine permissible speed for a given track alignment. Alternatively, for a specified permissible speed, it defines limits for track alignment design parameters.

More restrictive requirements of the High Speed TSI Infrastructure and the Conventional Rail TSI Infrastructure, as well as other (national, company, etc.) rules will apply.

This European Standard applies to main lines with track gauges 1435 mm and wider with permissible speeds between 80 km/h and 300 km/h. Annex C (informative) describes the conversion rules which can be applied for tracks with gauges wider than 1435 mm. Normative Annex D is applied for track gauges wider than 1435 mm.

However, the values and conditions stated for this speed range can also be applied to lines where permissible speeds are less than 80 km/h, but in this case, more or less restrictive values may need to be used and should be defined in the contract.

This European Standard need not be applicable to certain urban and suburban lines.

This European Standard also takes account of vehicles that have been approved for high cant deficiencies.

For the operation of tilting trains, specific requirements are defined within this European Standard.

2 Normative references

The following referenced documents are indispensable for the application 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 13803-2, *Railway applications — Track — Track alignment design parameters — Track gauges 1435 mm and wider — Part 2: Switches and crossings and comparable alignment design situations with abrupt changes of curvature*

EN 14363, *Railway applications — Testing for the acceptance of running characteristics of railway vehicles — Testing of running behaviour and stationary tests*

EN 15686, *Railway applications — Testing for the acceptance of running characteristics of railway vehicles with cant deficiency compensation system and/or vehicles intended to operate with higher cant deficiency than stated in EN 14363:2005, Annex G*

EN 15687, *Railway applications — Testing for the acceptance of running characteristics of freight vehicles with static wheel axle higher than 225 kN and up to 250 kN*

ISO 80000-3, *Quantities and units — Part 3: Space and time*

3 Terms and definitions

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

3.1
alignment element
segment of the track with either vertical direction, horizontal direction or cant obeying a unique mathematical description as function of longitudinal distance

NOTE 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.

3.2
circular curve
alignment element of constant radius

3.3
transition curve
alignment element of variable radius

NOTE 1 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.

NOTE 2 It is possible to use other forms of transition curve, which show a non-linear variation of curvature. Informative Annex A gives a detailed account of certain alternative types of transitions that may be used in track alignment design.

NOTE 3 Normally, a transition curve is not used for the vertical alignment.

3.4
compound curve
sequence of curved alignment elements, including two or more circular curves in the same direction

NOTE The compound curve may include transition curves between the circular curves and / or the circular curves and the straight tracks

3.5
reverse curve
sequence of curved alignment elements, containing alignment elements which curve in the opposite directions

NOTE A sequence of curved alignment elements, may be both a compound curve and a reverse curve.

3.6
cant
amount by which one running rail is raised above the other running rail

NOTE Cant is positive when the outer rail on curved track is raised above the inner rail and is negative when the inner rail on curved track is raised above the outer rail. Negative cant is unavoidable at switches and crossings on a canted main line where the turnout is curving in the opposite direction to the main line and, in certain cases, on the plain line immediately adjoining a turnout (see EN 13803-2).

3.7
equilibrium cant
cant at a particular speed at which the vehicle will have a resultant force perpendicular to the running plane

3.8
cant excess
difference between applied cant and a lower equilibrium cant

NOTE 1 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 Cant on a straight track results in cant excess, generating a lateral force towards the low rail.

3.9
cant deficiency
difference between applied cant and a higher equilibrium cant

NOTE 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.

3.10
cant transition
alignment element where cant changes with respect to longitudinal distance

NOTE 1 Normally, a cant transition should coincide with a transition curve.

NOTE 2 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 It is possible to use other forms of cant transition, which show a non-linear variation of cant. Informative Annex A gives a detailed account of certain alternative types of transitions that may be used in track alignment design.

3.11
cant gradient
absolute value of the derivative (with respect to longitudinal distance) of cant

3.12
rate of change of cant
absolute value of the time derivative of cant

3.13
rate of change of cant deficiency
absolute value of the time derivative of cant deficiency (and/or cant excess)

3.14
maximum permissible speed
maximum speed resulting from the application of track alignment limits given in this standard

3.15
normal limit
limit not normally exceeded

NOTE The actual design values for new lines should normally have a margin to the normal limits. These values ensure maintenance costs of the track are kept at a reasonable level, except where particular conditions of poor track stability may occur, without compromising passenger comfort. To optimize the performance of existing lines it may be useful to go beyond the normal limits.

3.16
exceptional limit
extreme limit not to be exceeded

NOTE As exceptional limits are extreme, it is essential that their use is as infrequent as possible and subject to further consideration. Informative Annex H describes the constraints and risks associated with the use of exceptional limits.

4 Symbols and abbreviations

No.	Symbol	Designation	Unit
1	a_i	quasi-static lateral acceleration, at track level, but parallel to the vehicle floor	$\mathrm{m/s^2}$
2	a_q	non-compensated lateral acceleration in the running plane	$\mathrm{m/s^2}$
3	C	factor for calculation of equilibrium cant	$\mathrm{mm \cdot m \cdot h^2/km^2}$
4	$\mathrm{d}a_\mathrm{i}/\mathrm{d}t$	rate of change of quasi-static lateral acceleration, at track level, but parallel to the vehicle floor	$\mathrm{m/s^3}$
5	$\mathrm{d}a_\mathrm{q}/\mathrm{d}t$	rate of change of non-compensated lateral acceleration	$\mathrm{m/s^3}$
6	$\mathrm{d}D/\mathrm{d}s$	cant gradient	mm/m
7	$\mathrm{d}D/\mathrm{d}t$	rate of change of cant	mm/s
8	$\mathrm{d}I/\mathrm{d}t$	rate of change of cant deficiency (and/or cant excess)	mm/s
9	D	Cant	mm
10	D_{EQ}	equilibrium cant	mm
11	e	distance between the nominal centre points of the two contact patches of a wheelset (e.g. about 1500 mm for track gauge 1435 mm)	mm
12	E	cant excess	mm
13	g	acceleration due to gravity: 9,81 $\mathrm{m/s^2}$	$\mathrm{m/s^2}$
14	h_g	height of the centre of gravity	mm
15	I	cant deficiency	mm
16	L_D	length of cant transition	m
17	L_K	length of transition curve	m
18	L_i	length of alignment elements (circular curves and straights) between two transition curves	m
19	lim	limit (index)	-
20	max	maximum value (index)	-
21	min	minimum value (index)	-
22	q_D	factor for calculation of length of cant transition	$\mathrm{m \cdot h/(km \cdot mm)}$
23	q_I	factor for calculation of length of transition curve	$\mathrm{m \cdot h/(km \cdot mm)}$
24	q_N	factor for calculation of length of cant transition or transition curve with non-constant gradient of cant and curvature, respectively	-
25	q_R	factor for calculation of vertical radius	$\mathrm{m \cdot h^2/km^2}$
26	q_V	factor for conversion of the units for vehicle speed: 3,6 km·s/(h·m)	km·s/(h·m)
27	R	radius of horizontal curve	m
28	R_v	radius of vertical curve	m
29	s	longitudinal distance	m
30	s_r	roll flexibility coefficient, equivalent to flexibility coefficient s in EN 15273-1	-
31	s_t	tilt compensation factor of a tilt system	-
32	t	time	s
33	V	speed	km/h
34	V_max	maximum speed of fast trains	km/h
35	V_min	minimum speed of slow trains	km/h
36	Δa_q	overall variation of non-compensated lateral acceleration	$\mathrm{m/s^2}$
37	ΔD	overall variation of cant along a cant transition	mm
38	ΔI	overall variation of cant deficiency (and/or cant excess)	mm

5 Requirements

5.1 Background

5.1.1 General

The following technical normative rules assume that standards for acceptance of vehicle, track construction and maintenance are fulfilled.

A good compromise has to be found between train dynamic performance, maintenance of the vehicle and track, and construction costs. More restrictive limits than those in this European Standard may be specified in the contract.

Unnecessary use of the exceptional limits specified in this European Standard should be avoided. A substantial margin to them should be provided, either by complying with the normal limits or by applying a margin with respect to permissible speed.

For further details, see informative Annex G.

5.1.2 Track alignment design parameters

The following parameters are specified in 5.2:

- radius of horizontal curve R (m) **(*S)**;
- cant D (mm) **(*S)**;
- cant deficiency I (mm) **(*S)**;
- cant excess E (mm);
- cant gradient $\mathrm{d}D/\mathrm{d}s$ (mm/m) **(*S)**;
- rate of change of cant $\mathrm{d}D/\mathrm{d}t$ (mm/s);
- rate of change of cant deficiency (and/or cant excess) $\mathrm{d}I/\mathrm{d}t$ (mm/s);
- length of cant transitions L_D (m) **(*S)**;
- length of transition curves in the horizontal plane L_K (m);
- length of alignment elements (circular curves and straights) between two transition curves L_i (m);
- radius of vertical curve R_v (m);
- speed V (km/h) **(*S)**.

Parameters followed by the **(*S)** note indicate **safety-related parameters**.

5.1.3 Parameter quantification

For most of the parameters, two different types of limits are specified:

- a normal limit;
- an exceptional limit which may have two different meanings:

  a) For **safety-related parameters**, it shall be the absolute maximum limit of this parameter; this maximum limit may depend upon the actual track mechanical and geometrical state.

NOTE 1 The exceptional limits are safety-related and may (for most parameters) induce a reduced comfort level. These limits are extreme and should be used only under special circumstances or after specific safety-case analysis.

NOTE 2 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.

  b) For non-safety related parameters, the limits shall be considered as the limit above which passenger comfort may be affected and the need for track maintenance increased; however, to cope with special situations, values in excess of the limits may be used, but they shall not exceed any safety limit.

The use of exceptional limits should be avoided, especially use of exceptional limits for several parameters at the same location along the track.

For cant deficiency, not all vehicles are approved for the normal or exceptional limits. For such vehicles, the operational limit shall be consistent with the approved maximum cant deficiency.

5.2 Normal limits and exceptional limits for track alignment design parameters

5.2.1 Radius of horizontal curve *R*

The largest curve radii and transition permitted by track design constraints should be used where possible. Normal limit for radius is 190 m and exceptional limit is 150 m. Note that these small radii will result in a permissible speed less than 80 km/h. Hence, normal and exceptional limits for the radius shall also be derived from the requirements below.

The parameters that shall be considered in the determination of the minimum curve radius are:

- the maximum and minimum speeds;
- the applied cant;
- the limits for cant deficiency and cant excess.

For every combination of maximum speed $V_{\max}$ and maximum cant deficiency $I_{\lim}$, the minimum permissible curve radius shall be calculated using the following equation:

$$R_{\min} = \frac{C}{D + I_{\lim}} \cdot V_{\max}^2 \qquad \text{[m]}$$

where C = 11,8 mm·m·h^2/km^2

Where $D > E_{\lim}$, the maximum permissible curve radius for the minimum speed $V_{\min}$ shall be calculated using the following equation:

$$R_{\max} = \frac{C}{D - E_{\lim}} \cdot V_{\min}^2 \qquad \text{[m]}$$

where C = 11,8 mm·m·h^2/km^2, and $D > E_{\lim}$

NOTE 1 It is recommended that the radius of tracks alongside platforms should not be less than 500 m. This is to restrict the gap between platform and vehicles to facilitate safe vehicle access and egress by passengers.

NOTE 2 Small radius curves may require gauge widening in order to improve vehicle curving.

5.2.2 Cant *D*

Cant shall be determined in relation to the following considerations:

- high cant on small-radius curves increases the risk of low-speed freight wagons derailing. Under these conditions, vertical wheel loading applied to the outer rail is much reduced, especially when track twist (defined in EN 13848-1) causes additional reductions;
- cant exceeding 160 mm may cause freight load displacement and the deterioration of passenger comfort when a train makes a stop or runs with low speed (high value of cant excess). Works vehicles and special loads with a high centre of gravity may become unstable;
- high cant increases cant excess values on curves where there are large differences between the speeds of fast trains and slow trains.

Normal limit for cant is 160 mm.

NOTE It is recommended that cant should be restricted to 110 mm for tracks adjacent to passenger platforms. Some other track features, such as level crossings, bridges and tunnels may also, in certain local circumstances, impose cant restrictions.

Exceptional limit for cant is 180 mm.

To avoid the risk of derailment of torsionally-stiff freight wagons on small radius curve (R < 320 m), cant should be restricted to the following limit:

$$D_{\lim} = \frac{R - 50\text{m}}{1{,}5\text{m/mm}} \qquad \text{[mm]}$$

The application of this limit assumes a high maintenance standard of the track, especially regarding twist. For further information, see informative Annex H.

5.2.3 Cant deficiency *I*

For given values of local radius R and cant D, the cant deficiency I shall determine the maximum permissible speed through a full curve such that:

$$I = C \cdot \frac{V^2}{R} - D = D_{EQ} - D \le I_{\lim} \qquad \text{[mm]}$$

where C = 11,8 mm·m·h^2/km^2

NOTE 1 $I_{\lim}$ can be replaced with the value $(a_q)_{\lim}$: $a_q = \left(\frac{V}{q_V}\right)^2 \frac{1}{R} - \frac{g \cdot D}{e} = \frac{g \cdot I}{e} \le \left(a_q\right)_{\lim} = \frac{g \cdot I_{\lim}}{e}$ [m/s^2]

Normal and exceptional limits for cant deficiency are given in Table 1. These limits apply to all trains operating on a line. It is assumed that every vehicle has been tested and approved according to the procedures in EN 14363, EN 15686 and/or EN 15687 in conditions covering its own range of operating cant deficiency.

Table 1 — Cant deficiency I_{lim}

	Normal limits	Exceptional limits
Non-tilting trains		
80 km/h < $V \leq$ 200 km/h	130 mm	183 mm
200 km/h < $V \leq$ 230 km/h	130 mm	168 mm[ab]
230 km/h < $V \leq$ 250 km/h	130 mm	153 mm[ab]
250 km/h < $V \leq$ 300 km/h	100 mm	130 mm[abc]
Tilting trains		
80 km/h $\leq V \leq$ 260 km/h[d]	275 mm[b]	306 mm[b]

[a] Trains complying with EN 14363, equipped with a cant deficiency compensation system other than tilt, may be permitted by the Infrastructure Manager to run with higher cant deficiency values.

[b] The Infrastructure Manager may require qualification of a part of a line for the introduction of trains running at these or higher cant deficiencies, taking into account the required track quality and other conditions.

[c] The limit may be raised to 153 mm for non ballasted track.

[d] Currently, there are no lines used or planned where maximum speed for tilting trains exceeds 260 km/h.

NOTE 1 The European signalling system ERTMS includes vehicle limits of cant deficiency I_{lim} of 92 mm, 100 mm, 115 mm, 122 mm, 130 mm, 153 mm, 168 mm, 183 mm, 245 mm, 275 mm and 306 mm. These values reflect the current practice of operating different train categories in Europe.

NOTE 2 Freight vehicles are normally approved for a cant deficiency in the range 92 mm to 130 mm.

NOTE 3 Non-tilting passenger vehicles are normally approved for a cant deficiency of 130 mm to 168 mm.

NOTE 4 Depending on the characteristics of certain special features in track, such as certain switches and crossings in curves, bridges carrying direct-laid ballastless track, tracks with jointed rails, certain sections of line exposed to very strong cross winds, etc., it may be necessary to restrict the permissible cant deficiency. Rules in respect of these restrictions cannot be formulated beforehand since they will be dictated by the design of the special features; definition of such a frame of reference can only be left to the initiative of the Infrastructure Manager.

NOTE 5 For further considerations of rolling stock required to operate at high cant deficiencies, passenger comfort with respect to lateral acceleration may be analysed as follows:

- The quasi-static lateral acceleration a_i (at track level, but parallel to the vehicle floor) is a measure of the acceleration felt by passengers inside the vehicle;
- For a non-tilting train a_i is greater than the lateral non-compensated acceleration in the track plane a_q: $a_i = (1+s_r)\cdot\frac{I}{e}\cdot g = (1+s_r)\cdot a_q$ [m/s^2];
- For a tilting train this can be expressed approximately by $a_i = (1+s_r)\cdot(1-s_t)\cdot\frac{I}{e}\cdot g$ [m/s^2];
- The roll flexibility coefficient s_r is positive for non-tilting vehicles, as the longitudinal rotation axis of the coach body is low (around the top of the suspension plane), hence the lateral acceleration felt by passengers due to cant deficiency is greater than that applied to the running plane. This coefficient can be reduced by choosing a dedicated suspension

system. With tilt techniques s_t > 0, the lateral acceleration felt by passengers for uncompensated acceleration in the running plane will be reduced;

— The influence of lateral acceleration on passenger comfort is described in EN 12299.

NOTE 6 For further details regarding operations with tilting trains, see informative Annex F

5.2.4 Cant excess E

There is cant excess when the following has a positive value:

$$E = D - C \cdot \frac{V^2}{R} = D - D_{EQ} \qquad \text{[mm]}$$

where C = 11,8 mm·m·h^2/km^2

Normal limit for cant excess E_{lim} is 110 mm.

The value of E affects inner-rail stresses induced by slow trains, since the quasi-static vertical wheel/rail force of an inner wheel is increased.

5.2.5 Cant gradient dD/ds

The following limits apply everywhere along the track where cant is varying:

$$\left(\frac{\mathrm{d}D}{\mathrm{d}s}\right)_{\max} \le \left(\frac{\mathrm{d}D}{\mathrm{d}s}\right)_{\lim} \qquad \text{[mm/m]}$$

Normal limit: $\left(\frac{\mathrm{d}D}{\mathrm{d}s}\right)_{\lim} = 2{,}25\ \mathrm{mm/m}$

Exceptional limit: $\left(\frac{\mathrm{d}D}{\mathrm{d}s}\right)_{\lim} = 2{,}50\ \mathrm{mm/m}$

NOTE For permissible speed lower than 80 km/h, a higher cant gradient may be used after a safety-case analysis, see Annex H.

For cant transitions with constant cant gradient, $\left(\frac{\mathrm{d}D}{\mathrm{d}s}\right)_{\max}$ can be calculated from the overall cant variation ΔD and the length L_{D}:

$$\frac{\mathrm{d}D}{\mathrm{d}s} = \frac{\Delta D}{L_D} \le \left(\frac{\mathrm{d}D}{\mathrm{d}s}\right)_{\lim} \qquad \text{[mm/m]}$$

There are no further special limits for the tilting trains.

5.2.6 Rate of change of cant dD/dt

5.2.6.1 Rate of change of cant dD/dt for non-tilting trains

Cant transitions are normally found in transition curves. However, it may be necessary to provide cant transitions in circular curves and straights.