SLOVENSKI STANDARD
SIST ENV 13803-1:2004

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

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

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

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

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Foreword

This document ENV 13803-1:2002 has been prepared by Technical Committee CEN/TC 256 “Railway applications”, the secretariat of which is held by DIN.

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 the following EC Directives:

- Council Directive 96/48/EC of 23 July 1996 on the interoperability of the European high-speed network[1]

- European Parliament and Council Directive 98/4/EC of 16 February 1998 in amendment of Council Directive 93/38/EC of 14 June 1993 co-ordinating the procurement procedures of entities operating in the water, energy, transport and telecommunications sectors[2]

- Council Directive 91/440/EEC of 29 July 1991 on the development of the Community's railways[3]

For the relationship with the EU Directives, see annex ZA.

This European Prestandard is one of a series of European Prestandards as listed below:

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

- *Railway applications - Track alignment design parameters - Track gauges 1435 mm and wider - Part 2: Switches and crossings*.

Annexes A, B, C, D, E, F, H and I are informative. Annex G is normative.

This document contains bibliographical references.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to announce this European Prestandard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope

This European Prestandard specifies the track alignment design parameters, the rules and the values that shall be used to determine the maximum operating speed for both new and existing lines. Alternatively, for a given specified speed, it defines the track alignment design parameters either for a new line or an upgraded line.

The track alignment designer is free to specify the values most appropriate for the various parameters, when considering safety, geographical, engineering, historical and economic constraints. These values are defined in the contract document. However, the choice should be such that the selected values are no worse than the maximum (or minimum) limiting values for the safety-related parameters.

Whenever necessary, the track alignment designer should take into account any specific requirements of the appropriate national standards.

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[1] Official Journal of the European Communities N° L 235 of 17.9.96 ; see annex ZA to this Prestandard

[2] Official Journal of the European Communities N° L 199 of 9.8.93 and N° L 101 of 1.4.98

[3] Official Journal of the European Communities N° L 237 of 24.8.91

The designer should endeavour to use the recommended limiting values specified in this European Prestandard and avoid unnecessary use of the maximum (or minimum) limiting values.

This European Prestandard applies to main lines with track gauges 1435 mm and wider with mixed or dedicated passenger traffic, running at operating speeds between 80 km/h and 300 km/h. Annex F (informative) describes the conversion rules which can be applied for tracks with gauges wider than 1435 mm. Annex G has a normative character and is applied for corresponding specific national conditions.

However, the values and conditions stated for this speed range can also be applied to lines where operating 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 Prestandard does not apply to urban and suburban lines.

This European Prestandard also considers the possibility of increasing the performance of line operation, without major alignment modifications, by means of particular rail vehicle types, such as:

- vehicles with a low axle mass;

- vehicles with a low suspension roll coefficient;

- vehicles equipped with tilting body systems to compensate for cant deficiency (active or passive systems).

The attention of the designer is drawn to the fact that this European Prestandard does not apply to track alignment design for tilting vehicles. However, annex E draws the attention of the designer to the consequences of track resistance, wear and fatigue due to the operation of such vehicles.

2 Terms and definitions

For the purposes of this European Prestandard, the following terms and definitions apply:

2.1
curves
this covers both horizontal and vertical curves and their related transitions.
Unless otherwise stated, the curve parameters are defined for the track centreline

2.1.1
circular curve
a curve of constant radius

2.1.2
transition curve
a curve of variable radius.
Transition curves may be found between two circular curves, each of a different radius, and between a circular curve and a straight. The clothoid (or cubic parabola) is normally used for transition curves, giving a uniform variation of curvature and cant. In some cases, the ends of the transition curves are even rounded by a larger radius.

Within these types of transitions, there is generally proportionality between curvature and cant.
It is possible to use other forms of transition curve which show a non-uniform variation of curvature and cant.
In principle, a transition curve is not used for the vertical alignment.

Annex A gives a detailed account of the alternative types of transitions that may be used in track alignment design

2.1.3
compound curve
a curve formed by two circular curves of different radii which curve in the same direction.
The two adjacent curves may be joined by a transition curve

2.1.4

reverse curve
a curve formed by two circular curves which curve in the opposite direction.
The two adjacent curves may be joined by a transition curve

2.2
cant
the amount by which one gauge rail is raised above the other gauge rail.

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 or on the plain line immediately adjoining the turnout (see *Part 2: Track alignment design parameters - Track gauges 1435 mm and wider - Switches and crossings*).

When the speed of a vehicle negotiating a curve is such that the resultant of the weight of the vehicle and the effect of centrifugal force is perpendicular to the plane of the rails, the vehicle is not subjected to unbalanced centripetal force and is said to be in equilibrium. Obtaining this condition on curved track implies raising one gauge rail above the level of the other gauge rail by a designed amount. This amount is known as the **equilibrium cant**

2.3
cant excess
when the speed of a vehicle negotiating a curve is lower than the **equilibrium speed**, there will be an unbalanced centripetal force. The equilibrium cant is excessive for the lower speed and the resultant force will move towards the inner rail of the curve. Equilibrium conditions may be restored theoretically by taking into consideration the amount by which the equilibrium cant is in excess for the lower speed. This amount is known as **cant excess**

2.4
cant deficiency
when the speed of a vehicle negotiating a curve is higher than the **equilibrium speed**, there will be an unbalanced centrifugal force. The equilibrium cant is therefore insufficient for the higher speed and the resultant force will move towards the outer rail of the curve. Equilibrium conditions may be restored theoretically by taking into consideration the amount by which the equilibrium cant is deficient for the higher speed. This amount is known as deficiency of cant or **cant deficiency**

2.5
rate of change of cant as a function of length
the amount by which the cant is increased or decreased in a given transition length

2.6
rate of change of cant as a function of time
the rate at which cant is increased or decreased relative to the maximum speed of a vehicle negotiating a transition curve, for example 35 mm per second means that a vehicle travelling at the maximum speed permitted will experience a change in cant of 35 mm in each second

2.7
rate of change of cant deficiency as a function of time
the rate at which cant deficiency is increased or decreased relative to the maximum speed of a vehicle negotiating a transition curve, for example 35 mm per second means that a vehicle travelling at the maximum speed permitted will experience a change in cant deficiency of 35 mm in each second

2.8
maximum permissible speed
maximum speed permitted on a curve with associated transitions when radius, cant, cant deficiency, cant gradient and rates of change of cant and cant deficiency and other parameters have been taken into consideration

2.9
line speed
maximum speed at which vehicles are allowed to run on a line or branch or on sections of a line or branch.
The line speed limit is usually established after taking into consideration the incidence of permanent speed restrictions on the line or branch. On mixed traffic lines, several different line speed limits may exist at the same time due to the different types of traffic categories

2.10
recommended limiting values
values to be applied by the designer for the design of new railway lines or sections of such lines, or for the upgrading of existing lines. Such 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

2.11
maximum (or minimum) limiting values
extreme but permissible values used at maximum speed for most railway vehicles. As these values are extreme, it is essential that the use of maximum (or minimum) limiting values is as infrequent as possible on any given line

Annex H describes the constraints and risks associated with the use of maximum (or minimum) limiting values.

3 Symbols and abbreviations

1	2	3	4
No.	Symbol	Designation	Unit
1	a_q	non-compensated lateral acceleration in the track plane	m/s²
2	da_q / dt	rate of change of non-compensated lateral acceleration as a function of time	m/s^3
3	a_i	quasi-static lateral acceleration parallel to the vehicle floor	m/s²
4	da_i / dt	rate of change of quasi-static lateral acceleration parallel to the vehicle floor as a function of time	m/s^3
5	a_v	quasi-static vertical acceleration on vertical curve	m/s²
6	D	Cant	mm
7	D_l	cant limit	mm
8	dD/dt	rate of change of cant as function of time	mm/s
9	$dD/d\ell$	rate of change of cant as function of length	mm/m
10	E	cant excess	mm
11	e	distance between wheel treads of an axle (about 1500 mm)	mm
12	h_g	height of the centre of gravity	mm
13	I	cant deficiency	mm
14	dI/dt	rate of change of cant deficiency as function of time	mm/s
15	L	length of transition curve or cant gradient	m
16	L_i	length of alignment elements (circular curves and straights)	m
17	R	radius of horizontal curve	m
18	R_v	radius of vertical curve	m
19	s	roll flexibility coefficient according to UIC 505-5 OI	—
20	t	Time	s
21	V	line speed	km/h
22	V_{max}	maximum curving speed of fast trains	km/h
23	V_{min}	minimum curving speed of slow trains	km/h
24	g	acceleration due to gravity - 9,81 m/s²	m/s²
25	lim	limiting value (index)	—
26	Δa_q	overall variation of non-compensated lateral acceleration along the whole transition curve	m/s²
27	ΔI	overall cant deficiency variation along a transition curve, between straight track and plain curve or between two adjacent curves of different radii	mm
28	ΔD	overall cant variation along a transition curve, between straight track and plain curve or between two adjacent curves of different radii	mm
29	Q	dynamic wheel load	N
30	Q_N	nominal wheel load	N
31	ΔQ	overall wheel load variation	N
32	Y	guiding force at the wheel rail contact	N

4 Requirements

4.1 Background

The following technical normative rules assume that standards for acceptance of vehicle, track construction and maintenance cover the conditions defined in the cited informative annexes.

A good compromise has to be found between train dynamic performance, maintenance of the vehicle and track and construction costs. The choice of alignment elements depends upon the operation requirements, the parameters specified (and their values) and on local conditions. The specified parameters and values within this European Prestandard may have to be adjusted in consultation with the train operator.

4.1.1 Track alignment design parameters

The following parameters are specified in 4.2:

- radius of horizontal curve R (m) **(*S)**
- cant D (mm) **(*S)**
- cant deficiency I (mm) **(*S)**
- uncompensated (quasi-static) lateral acceleration at track level a_q (m/s²) **(*S)**
- cant excess E (mm)
- rate of change of cant as a function of time dD/dt (mm/s)
- rate of change of cant as a function of length dD/dl (mm/m) **(*S)**
- rate of change of cant deficiency as a function of time dI/dt (mm/s)
- length of alignment elements (circular curves and straights) L_i (m)
- length of transition curves in the horizontal plane L (m)
- radius of vertical curve R_V (m)
- vertical acceleration a_V (m/s²)
- speed V (km/h) **(*S)**

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

Annex B describes an alternative means of classification for the above mentioned parameters, as a function of their relative influence on safety, comfort and cost efficiency of the track/vehicle system.

4.1.2 Parameter quantification

For each of the parameters, two different types of limiting values are specified:

- a recommended limiting value,

- a maximum limiting value which may have two different meanings:

a) **For safety-related parameters**, it shall be considered as the absolute maximum limit of this parameter; this maximum limit may depend upon the actual track mechanical and geometrical state. See annex B for further information.

It should also be noted that the maximum limiting value is safety-related and may (for some parameters) induce a reduced comfort level : most operators will reduce these values by at least 10%, and refer to the proposed limits as "exceptional" values to be used only under special circumstances or after a specific safety case analysis.

The attention of the operators is drawn to the fact that limiting values are defined with respect to a commercial train operating pattern. If and when running trials are conducted, for example to ascertain the vehicle dynamic behaviour (by continually monitoring of the vehicle responses), exceeding the limiting values (particularly in terms of cant deficiency) shall be permitted and it shall be 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 values shall be considered as the limit above which passenger comfort may be affected and track maintenance significantly increased; however, to cope with special situations, operators may choose values in excess of these specified values, but they should not exceed the safety limits.

NOTE The following parameters for interoperable high speed lines, are specified by the Technical Specification for Interoperability:

- cant;
- cant deficiency.

4.1.3 Traffic categories

A distinction is made between the following traffic categories:

I - mixed traffic lines, with passenger train speeds from 80 km/h to 120 km/h maximum;
IIa - mixed traffic lines, with passenger train speeds greater than 120 km/h and up to 160 km/h maximum;
IIb - mixed traffic lines, with passenger train speeds greater than 160 km/h and up to 200 km/h maximum;
III - mixed traffic lines, designed for passenger train speed higher than 200 km/h to 300 km/h;
IV - mixed traffic lines, with passenger train speeds up to 230 km/h (or 250 km/h on upgraded lines) with vehicle incorporating special technical design characteristics (low axle mass, low roll flexibility coefficient, etc…);
V - dedicated passenger lines with speeds between 250 km/h and 300 km/h.

For the purposes of this European Prestandard, the reference speed is that for passenger trains.

The above classification uses speed as the most relevant criteria to be considered when defining operational conditions for the different traffic categories.

Other criteria may be considered for the production of such a traffic classification, namely, aspects related to safety, comfort and cost efficiency. Further information on such systems of classifications can be found in annex D.

4.2 Recommended limiting values and maximum (or minimum) limiting values for track alignment design parameters

4.2.1 Radius of horizontal curve R

The track alignment designer shall endeavour to use the largest curve radii permitted by track design constraints. This will cater for any future increase of speed. In any event, the track alignment designer shall not use curve radii less than 180 m for new alignments.

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

- the maximum and minimum operating speeds,
- the applied cant,
- the limiting values for cant deficiency and cant excess.

The minimum allowable curve radius for the maximum operating speed, usually with cant deficiency **I**, shall be calculated using the following equation:

$$R = \frac{11{,}8}{D + I} V_{max}^2 \qquad [m]$$

The minimum allowable curve radius for the minimum operating speed, usually with cant excess **E,** shall be calculated using the following equation:

$$R = \frac{11{,}8}{D - E} V_{min}^2 \qquad [m]$$

The minimum curve radius shall be determined such that the values of **D, I** and **E** comply with the limits specified in this European Prestandard and satisfy the following condition:

$$\frac{11{,}8 \cdot V_{min}^2}{D - E} \geq R \geq \frac{11{,}8 \cdot V_{max}^2}{D + I} \qquad [m]$$

NOTE 1 Compliance with the above formulae generates a minimum radius of around 200 m. It should be noted that on existing main lines sharper radii curves (minimum radius around 150 m) and operating speeds under 80 km/h can occur.

NOTE 2 Sharp radius curves generally necessitate a widening of the track gauge in order to improve vehicle curving. This widening of the track gauge can be used in conjunction with the installation of a check rail. The installed check rail serves a dual purpose:

- it increases stiffness of the track panel;
- it provides better guidance of the inner face of the wheel and absorption of part of the curving force.

NOTE 3 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.

4.2.2 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 causes additional reductions (see as reference [ORE B55/Rp 8]);

cant exceeding 160 mm may cause freight load displacement and the deterioration of passenger comfort when a train makes an unscheduled stop at a location where high cant has been applied. Furthermore, with such high cant, 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.

Table 1 - Cant D_{lim}

Traffic categories (speed in km/h)	**I** Mixed traffic lines 80 ≤ V ≤ 120	**Iia** Mixed traffic lines 120 < V ≤ 160	**IIb** Mixed traffic lines 160 < V ≤ 200	**III** Mixed traffic lines designed for passenger train speed 200 < V ≤ 300	**IV** Mixed traffic lines with passenger train speeds V ≤ 230 (or 250) (with vehicles incorporating special technical design characteristics)	**V** High-speed lines with dedicated passenger traffic 250 ≤ V ≤ 300
Recommended Limiting value [a] [mm]	160	160	160	160	160	160
Maximum limiting value [a] [mm]	180	180	180	180	180	200

[a] To avoid the risk of derailment of torsionally-stiff freight wagons on sharp radii curve, cant should be restricted to the following limit (see as reference [ORE B 55/Rp 5 and 8]).

$$D_l = \frac{R-50}{1{,}5} \qquad \text{[mm]}$$

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.

4.2.3 Cant deficiency I

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

$$I = 11{,}8\,\frac{V_{max}^2}{R} - D \le I_{lim} \qquad \text{[mm]}$$

I_{lim} can be replaced with the value $(a_q)_{lim}$:

$$a_q = \frac{V_{max}^2}{12{,}96 \cdot R} - \frac{g \cdot D}{1500} = \frac{I}{153} \le (a_q)_{lim} = \frac{I_{lim}}{153} \qquad \text{[m/s}^2\text{]}$$