

# 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**

The European Standard EN 13803-2:2006 has the status of a  
British Standard

ICS 93.100

## National foreword

This British Standard was published by BSI. It is the UK implementation of EN 13803-2:2006.

The UK participation in its preparation was entrusted by Technical Committee RAE/2, Railway track components, to Subcommittee RAE/2/-/3, Track design parameters, switches and crossings.

A list of organizations represented on RAE/2/-/3 can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

**Compliance with a British Standard cannot confer immunity from legal obligations.**

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 January 2007

© BSI 2007

ISBN 978-0-580-49961-6

### Amendments issued since publication

Amd. No.	Date	Comments

EUROPEAN STANDARD

EN 13803-2

NORME EUROPÉENNE

EUROPÄISCHE NORM

December 2006

ICS 93.100

English Version

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

Applications ferroviaires - Paramètres de conception du  
tracé de la voie - Ecartement 1435 mm et plus large -  
Partie 2: Appareils de voie et situations comparables de  
conception du tracé avec changements brusques de  
courbure

Bahnanwendungen - Oberbau - Linienführung in Gleisen -  
Spurweiten 1 435 mm und größer - Teil 2: Weichen und  
Kreuzungen sowie vergleichbare Trassierungselemente mit  
unvermitteltem Krümmungswechsel

This European Standard was approved by CEN on 4 November 2006.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, 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 United Kingdom.



EUROPEAN COMMITTEE FOR STANDARDIZATION  
COMITÉ EUROPÉEN DE NORMALISATION  
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: rue de Stassart, 36 B-1050 Brussels

## Contents

	Page
Foreword.....	4
1 Scope .....	5
2 Normative references .....	5
3 Terms and definitions .....	5
4 Symbols and abbreviations .....	6
5 General requirements.....	7
6 Principles for the assessment of abrupt changes of cant deficiency at abrupt changes in curvature.....	8
6.1 General.....	8
6.2 Principle based on limiting values of abrupt change of cant deficiency ( $\Delta I$ ) .....	8
7 Circular curves without transition curves.....	8
7.1 Limiting values based on the principle of abrupt change of cant deficiency $\Delta I_{lim}$ .....	8
7.1.1 General.....	8
7.1.2 Switch and crossing layouts .....	9
7.1.3 Plain line .....	10
7.2 Limiting values based on the principle of the virtual transition .....	10
7.3 Minimum radius of horizontal curves .....	10
8 Combinations of horizontal curves.....	10
8.1 General.....	10
8.2 Limiting length of intermediate element(s) between two abrupt changes of curvature ( $L_{slim}$ ).....	11
8.3 Abrupt change of cant deficiency ( $\Delta I$ ) at abrupt changes in curvature in combined curves .....	12
8.3.1 Length of intermediate element(s) equal to, or greater than the limiting minimum value ( $L_s \geq L_{slim}$ ) .....	12
8.3.2 Intermediate element(s) of sub-standard length ( $L_s < L_{slim}$ ) or no intermediate element ( $L_s = 0$ ) .....	12
8.4 Requirements for preventing buffer locking.....	13
9 Alignment rules and parameters for designing switch and crossing layouts .....	14
9.1 General rules .....	14
9.1.1 Horizontal alignment .....	14
9.1.2 Vertical alignment.....	14
9.2 Switch and crossing layouts in straight track without cant.....	15
9.2.1 Simple turnout.....	15
9.2.2 Turnouts with variable curvature .....	15
9.3 Switch and crossing layouts installed on horizontal curves .....	18
9.3.1 General rules .....	18
9.3.2 Horizontal radii.....	18
9.3.3 Cant $D$ .....	19
9.3.4 Cant deficiency $I$ .....	19
9.3.5 Cant excess $E$ .....	20
Annex A (informative) General design considerations .....	21
Annex B (informative) The installation of switch and crossing layouts.....	22
B.1 Standard switch and crossing units .....	22
B.2 Lateral track resistance at the switch panel .....	22
B.3 Stress transition zone between continuously welded track and jointed track .....	22
B.4 Switch and crossing layouts on, or near under-bridges .....	23

B.5	Limits for diamond crossings, diamond crossings with slips and tandem turnouts .....	23
B.6	Switch and crossing layouts with steel bearers .....	23
B.7	Abutting turnouts .....	23
B.8	Crossovers and follow-on turnouts with reverse curves .....	23
B.9	Scissors crossovers and single or double junctions .....	24
B.10	Tracks with cant gradients .....	24
B.11	Influence of cant on the deflection angle in the horizontal plane .....	24
<b>Annex C</b>	<b>(normative) Rules for converting parameter values for track gauges wider than 1435 mm .....</b>	<b>26</b>
C.1	Scope .....	26
C.2	Symbols and abbreviations .....	26
C.3	Basic hypothesis .....	26
C.4	Conversion rules .....	27
C.4.1	Application of $\Delta/l$ limiting values .....	27
C.4.2	Cant .....	27
C.4.3	Equilibrium cant .....	28
C.4.4	Other formulas and values of the standard .....	28
C.4.5	Annexes .....	29
<b>Annex D</b>	<b>(informative) Limits of lateral acceleration .....</b>	<b>30</b>
D.1	Introduction .....	30
D.2	Wheel-base effect .....	31
D.3	Limiting values of the non-compensated lateral acceleration .....	31
D.4	Conclusion .....	32
<b>Annex E</b>	<b>(informative) The principle of virtual transition .....</b>	<b>33</b>
E.1	Virtual transition at an abrupt change of curvature .....	33
E.2	Virtual transition at a short intermediate length between two abrupt changes of curvature .....	33
E.3	Limiting values based on the principle of the virtual transition .....	34
E.3.1	General .....	34
E.3.2	Characteristic vehicle with a distance of 20 m between bogie centres .....	34
E.3.3	Characteristic vehicle with a distance of 12,2 m and 10,06 m between bogie centres .....	35
<b>Annex F</b>	<b>(informative) A method for calculating the maximum permissible speed at the toe of a non-tangential switch .....</b>	<b>36</b>
<b>Annex G</b>	<b>(informative) Constraints and risks associated with the use of maximum (or minimum) limiting values .....</b>	<b>38</b>
<b>Annex H</b>	<b>(informative) The maximum permissible speed of tilting body trains over switch and crossing layouts .....</b>	<b>39</b>
H.1	General .....	39
H.2	The maximum permissible speeds over abrupt changes of curvature .....	39
H.3	The permissible speeds over switch and crossing layouts on curves .....	39
<b>Annex ZA</b>	<b>(informative) Relationship between this European Standard and the Essential Requirements of EU Directive 96/48/EC of 23 July 1996 on the interoperability of the trans-European high-speed rail system amended by the EU Directive 2004/50/EC of 29 April 2004 .....</b>	<b>40</b>
<b>Bibliography</b>	.....	<b>42</b>

## Foreword

This document (EN 13803-2:2006) 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 June 2007, and conflicting national standards shall be withdrawn at the latest by June 2007.

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 EU Directives:

- Council Directive 96/48/EC of 23 July 1996 on the interoperability of the European high-speed network<sup>1</sup>
- 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<sup>2</sup>
- Council Directive 91/440/EEC of 29 July 1991 on the development of the Community's railways<sup>3</sup>

For relationship with EU Directive 96/48/EC, see informative Annex ZA, which is an integral part of this document.

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 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, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Romania, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

---

<sup>1</sup> Official Journal of the European Communities N° L 235 of 1996-09-17

<sup>2</sup> Official Journal of the European Communities N° L 134 of 2004-04-30

<sup>3</sup> Official Journal of the European Communities N° L 237 of 1991-08-24

## 1 Scope

This European Standard specifies the rules and values for the track alignment design parameters used to determine the maximum operating speeds over tracks with abrupt changes in curvature and, consequently, abrupt changes of cant deficiency. Such conditions occur in the following situations:

- in the diverging tracks in switch and crossing layouts;
- when it is not practical to design an alignment with transition curves;
- if the length of a transition curve is less than the minimum required for plain line track.

Engineering requirements specific to the mechanical behaviour of switch and crossing components and subsystems are to be found in the relevant standards.

This European Standard presupposes that the homologation of the operating vehicles will be valid and specified for conditions corresponding to the limiting values specified in this European Standard.

This European Standard is applicable to abrupt changes in curvature in switch and crossing layouts and plain lines with track gauges of 1435 mm and wider. Annex C is applicable to track gauges wider than 1435 mm.

This European Standard specifies the requirements for preventing buffer locking.

The limiting values specified in this European Standard, when applied at the switch toe, are for switches with tangential geometry (as defined in EN 13232-1).

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

This European Standard is not applicable to track alignment requirements for tilting body vehicles. However, Annex H draws the designer's attention to the consequences and the restrictions imposed when tilting vehicles are operated over switch and crossing layouts and alignments without transition curves.

## 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 13232-1:2003, *Railway applications – Track – Switches and crossings – Part 1: Definitions*

EN 13232-9, *Railway applications – Track – Switches and crossings – Part 9: Layouts*

ENV 13803-1:2002, *Railway applications – Track alignment design parameters – Track gauges 1435 mm and wider – Part 1: Plain line*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 13232-1:2003 and ENV 13803-1:2002 and the following apply.

### 3.1

#### **abrupt change of cant deficiency $\Delta I$**

abrupt change of the cant deficiency and/or cant excess due to an abrupt change in curvature

**3.2**  
**rate of change of cant deficiency at an abrupt change in curvature as function of time  $\Delta I/\Delta t$**   
 value used in the theoretical model of the principle of the virtual transition calculation (see Annex E). The value of  $\Delta t$  is the time required to travel over the length of the virtual transition at the specified speed

**3.3**  
**distance between bogie centres  $L_b$**   
 distance between the bogie centres of the characteristic vehicle used to calculate  $\Delta I/\Delta t$  (see Annex E). The characteristic vehicle is usually the passenger vehicle with the shortest distance between bogie centres operating over a route

**3.4**  
**total length of the intermediate element(s) between two abrupt changes of curvature  $L_s$**   
 total length of the straight and/or curved element(s) between two abrupt changes of curvature (see Clause 8)

**3.5**  
**parameter of clothoid  $A$**   
 parameter describing the linear change of curvature as function of the length (see 9.2.2.2)

**3.6**  
**high speed lines**  
 (see Directive 96/48/EC)

**3.7**  
**conventional lines**  
 other than high speed lines

## 4 Symbols and abbreviations

The symbols and abbreviations specified in ENV 13803-1 are also applicable to this European Standard. Additional symbols and abbreviations are as follows :

**Table 1 — Symbols and abbreviations**

No.	Symbol	Designation	Unit
101	$A$	parameter of clothoid	m
102	$C$	factor for calculation of equilibrium cant	$\text{mm}\cdot\text{m}\cdot\text{h}^2/\text{km}^2$
103	$l_i$	cant deficiency of the alignment element $i$ ; $i = 1, 2$	mm
104	$l_{\max}$	maximum value of cant deficiency within the length of the diverging track	mm
105	$\Delta I$	abrupt change of the cant deficiency and/or cant excess due to an abrupt change in curvature	mm
106	$\Delta I/\Delta t$	rate of change of cant deficiency at an abrupt change in curvature as function of time	mm/s
107	$\Delta I_c$	abrupt change of cant deficiency on the crossing side of a turnout with curves of variable curvature in diverging track	mm
108	$\Delta I_i$	abrupt change of the cant deficiency and/or cant excess due to an abrupt change in curvature at tangent point $i$	mm
109	$\Delta I_s$	abrupt change of cant deficiency on the switch side of a turnout with curves of variable curvature in diverging track	mm
110	$L_b$	distance between bogie centres of the characteristic vehicle	m

No.	Symbol	Designation	Unit
111	$L_s$	total length of intermediate element(s) between two abrupt changes of curvature	m
112	$n$	inverse turnout angle	-
113	$q_A$	factor for calculation of rate of change of cant deficiency	$\text{mm}\cdot\text{m}^2\cdot\text{h}^3/(\text{s}\cdot\text{km}^3)$
114	$q_s$	factor for calculation of minimum length of intermediate element(s) between two abrupt changes of curvature	$\text{m}\cdot\text{h}/\text{km}$
115	$q_v$	factor for conversion of the units for vehicle speed	$\text{km}\cdot\text{s}/(\text{h}\cdot\text{m})$
116	$R_0$	radius of the diverging track of the switch and crossing unit in the version for straight track	m
117	$R_i$	radius of the alignment element $i$ within one track; $i = 1, 2$	m
118	$R_{id}$	equivalent radius for reverse curves (see 8.4)	m
119	$R_j$	radius of track $j$ within one switch and crossing unit; $j = I, II$	m
120	$R_s$	effective radius at a toe of a non-tangential switch	m
121	$t_i$	tangent length $i$	m
122	$v$	versine	m

## 5 General requirements

The track alignment designer is free to specify the most appropriate values for the various parameters at the specified operating speeds, when considering safety, geographical, engineering, historical, and economic constraints. These values and parameters shall be specified in the contract documents.

The designer shall endeavour not to exceed the recommended limiting values specified in this European Standard and avoid unnecessary use of the maximum (or minimum) limiting values. Annex G describes the constraints and risks associated with the use of maximum (or minimum) limiting values.

Whenever necessary, the track alignment designer shall take into account national standards when these are more restrictive.

The most important requirements for the installation of switch and crossing layouts are specified in Annex B. These requirements have an influence on the design of the alignment elements for both tracks in switch and crossing layouts and, consequently, they influence the maximum operating speeds and life cycle costs. The designer should, as far as it is practicable, comply with these requirements.

Existing installations, which do not conform to this European Standard, should be modified as soon as possible if safety requirements (for example abrupt change of cant deficiency, length of element(s) between abrupt changes of curvature and the safety related parameters listed in ENV 13803-1) are compromised. Other non-conforming installations should, if possible, be modified during the next track renewal.

The railway authority or the manufacturer shall specify the limits (e.g. requirement for the switch entry angle) for non-tangential switches (see also EN 13232-9). Annex F describes a method for calculating the maximum permissible speed at the toe of a non-tangential switch.

## 6 Principles for the assessment of abrupt changes of cant deficiency at abrupt changes in curvature

### 6.1 General

The main principle described in 6.2 is based on in-service experiences in terms of safety and passenger comfort.

Some European railway authorities use the principle of the virtual transition described in Annex E (informative).

There are in current use various types of turnouts that have curves of variable curvature combined with circular curves or straights in the diverging track. The different geometrical layouts used in these types of turnout are described in 9.2.2. The curves of variable curvature used in these turnouts are normally of the Clothoid form.

Annex D describes a theoretical calculation method that can be used to compare the effects of a succession of different alignment elements with vehicles of different characteristics.

### 6.2 Principle based on limiting values of abrupt change of cant deficiency ( $\Delta I$ )

This principle is based on limiting the abrupt change in cant deficiency between an abutting curve and straight, or between the abutting arcs of a compound or reverse curve. The relationship between cant deficiency, speed, radius, and cant is expressed by the equation:

$$I_i = C \cdot \frac{V^2}{R_i} - D_i \quad [\text{mm}]$$

where

$$C = 11,8 \text{ mm} \cdot \text{m} \cdot \text{h}^2 / \text{km}^2 \text{ and } i = 1, 2$$

For curves with cant excess, the equation  $I = -E$  shall be used.

Between two abutting curves (i.e. two arcs without an intermediate element) the abrupt change in cant deficiency is  $\Delta I = |I_2 \pm I_1|$ . For a reverse curve it is  $\Delta I = |I_2 + I_1|$  and for a compound curve it is  $\Delta I = |I_2 - I_1|$ . The limiting values are specified in 7.1.

The limiting lengths of intermediate element(s) between two abrupt changes of curvature are specified in 8.2. The value of abrupt change in cant deficiency to be taken into account when there is no intermediate element between curves, or the intermediate element is of substandard length, is specified in 8.3.2.

## 7 Circular curves without transition curves

### 7.1 Limiting values based on the principle of abrupt change of cant deficiency $\Delta I_{\text{lim}}$

#### 7.1.1 General

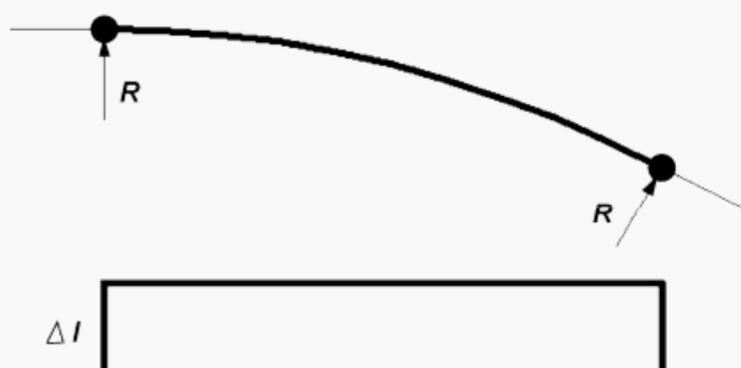
This principle of abrupt change of cant deficiency is described in 6.2.

The maximum permissible speed over an abrupt change in curvature between a curve without cant and a straight shall be based on the limiting values for abrupt change of cant deficiency ( $\Delta I_{\text{lim}}$ ) specified in 7.1.2 and 7.1.3.

$$\Delta I = C \cdot \frac{V^2}{R} \leq \Delta I_{\text{lim}} \quad [\text{mm}]$$

where

$$C = 11,8 \text{ mm} \cdot \text{m} \cdot \text{h}^2 / \text{km}^2$$



**Figure 1 — Combination of circular curve and straight without cant**

NOTE When designs are based on the principle of limiting values for abrupt change of cant deficiency ( $\Delta I_{\text{lim}}$ ), in accordance with 6.2, it is not necessary to conform to the limiting values for the rate of change of abrupt change of cant deficiency ( $\Delta I / \Delta t$ ), specified for the principle of the virtual transition as described in the informative Annex E.

### 7.1.2 Switch and crossing layouts

The limiting values for an abrupt change of cant deficiency in the tracks of a switch and crossing layout shall be as specified in Table 2.

**Table 2a — Limiting values of abrupt change of cant deficiency ( $\Delta I_{\text{lim}}$ ) – High-speed lines**

Speed $V$ (km/h)	$V \leq 70$	$70 < V \leq 170$	$170 < V \leq 230$
Recommended limiting values $\Delta I_{\text{lim}}$ (mm)	100	80	60
Maximum limiting values $\Delta I_{\text{lim}}$ (mm)	120	105	85

**Table 2b — Limiting values of abrupt change of cant deficiency ( $\Delta I_{\text{lim}}$ ) – Conventional lines**

Speed $V$ (km/h)	$V \leq 100$	$100 < V \leq 170$	$170 < V \leq 220$	$220 < V \leq 230$
Recommended limiting values $\Delta I_{\text{lim}}$ (mm)	100	133 – 0,33 $V$		60
Maximum limiting values $\Delta I_{\text{lim}}$ (mm)	120	141 – 0,21 $V$	161 – 0,33 $V$	

NOTE A tolerance of 10 mm on the maximum limiting values is permitted for existing turnouts laid on lines to be upgraded for high-speed.

### 7.1.3 Plain line

Plain line alignments with abrupt changes of cant deficiency shall only be used when the scope for designing the alignment is severely restricted. Such restrictions occur in stations, at small deviations in alignment within a limited length, or in compound curves when there is only a small variation in the radii of abutting curves.

The recommended limiting values for abrupt change of cant deficiency on plain line shall be as specified in Table 3.

**Table 3 — Recommended limiting values of abrupt change of cant deficiency ( $\Delta l_{lim}$ )**

Speed $V$ (km/h)	$V \leq 70$	$70 < V \leq 170$	$170 < V \leq 230$
Recommended limiting values $\Delta l_{lim}$ (mm)	50	40	30

The use of higher values of abrupt change of cant deficiency should, if possible, be avoided. If the use of higher values is unavoidable, for example in close conjunction to switch and crossing layouts, the limiting values shall not exceed those specified in 7.1.2.

## 7.2 Limiting values based on the principle of the virtual transition

Some European railway authorities use the principle of the virtual transition (see Annex E). The limits applicable for this principle are given in E.3.

## 7.3 Minimum radius of horizontal curves

On all tracks (including the diverging tracks in switch and crossing layouts) where different railway vehicles operate, the designed minimum radius for any curve shall not be less than 150 m. In the case of a reverse curve, or curves in opposite directions with short intermediate elements, the alignment design shall conform to 8.4.

# 8 Combinations of horizontal curves

## 8.1 General

Horizontal curves can be combined to form a reverse curve, curves in the opposite directions with an intermediate element, a compound curve, and curves in the same direction with an intermediate element. These types of situations are shown in Figure 2. The track elements may have constant curvature (as in Figure 2), but may also be transition curves (for a turnout placed on a transition curve and/or a turnout with variable curvature). In some cases the intermediate element may be a transition curve of sub-standard length, i.e. a transition curve that does not conform to the requirements of ENV 13803-1. In practice, such situations occur in:

- the diverging tracks in switch and crossing layouts;
- plain tracks abutting switch and crossing layouts;
- plain tracks where it is impractical to provide full transition curves (typically stations and sidings);
- plain track alignments with large radii curves;

- compound curves where there is only a small difference in the radii between abutting curves;
- plain tracks with a small deviation in direction or distance between track centre lines.

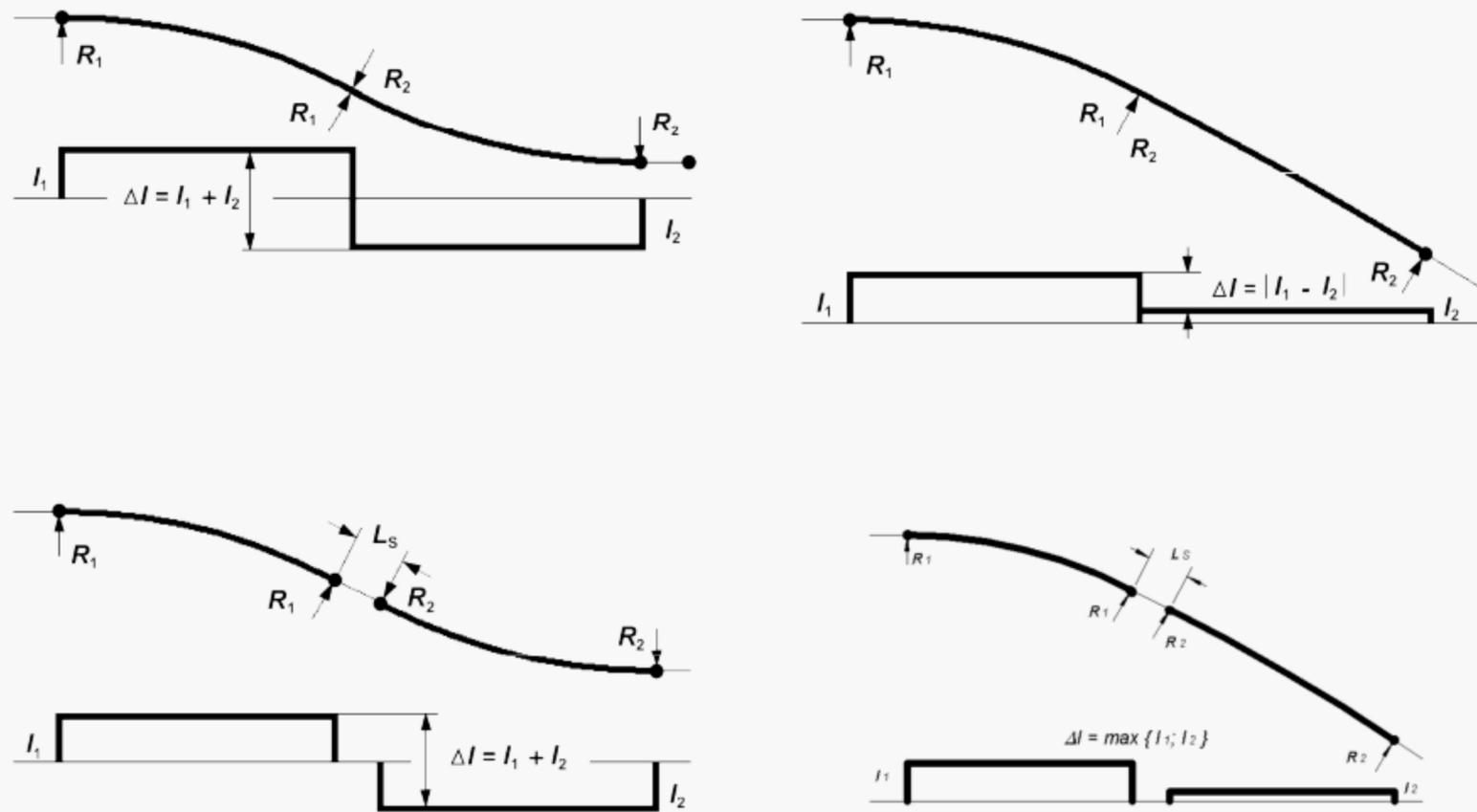


Figure 2 — Combinations of alignment elements

Clause 8 specifies:

- the limiting length of the intermediate element(s) between two abrupt changes of curvature ( $L_{slim}$ );
- the abrupt change of cant deficiency ( $\Delta l$ ) applicable for the each combination of alignment elements;
- the requirements for preventing buffer locking.

## 8.2 Limiting length of intermediate element(s) between two abrupt changes of curvature ( $L_{slim}$ )

A tangent point with an abrupt change of curvature generates disturbed vehicle dynamics. Therefore, there should be a minimum length to the next tangent point with an abrupt change of curvature.

The limiting length of intermediate element(s) between two abrupt changes of curvature is defined as:

$$L_{slim} = q_{slim} \cdot V \quad [m]$$

where

$q_{slim}$  is a factor (m·h/km) defined in Table 4

$V$  is the maximum train speed (km/h)

Table 4 — Limiting values of the factor defining the minimum length between two tangent points with abrupt changes of curvature ( $L_{slim}$ )

Speed $V$ (km/h)	$V \leq 70$		$70 < V \leq 100$		$100 < V \leq 230$	
Recommended limiting value for $q_{slim}$ (m·h/km)	0,20	(0,72·s) <sup>a</sup>	0,25 <sup>b</sup>	(0,90·s) <sup>a,b</sup>	0,30 <sup>b</sup>	(1,08·s) <sup>a,b</sup>
Minimum limiting value for $q_{slim}$ (m·h/km)	0,10	(0,36·s) <sup>a</sup>	0,15	(0,54·s) <sup>a</sup>	0,20	(0,72·s) <sup>a</sup>
<sup>a</sup> Is the interval (in seconds) corresponding to distance $L_{slim}$ and speed $V$ .						
<sup>b</sup> For new installations or if possible by renewal of existing installations.						

NOTE For switches and crossings placed on transition curves, the length between two abrupt changes of cant deficiency may involve more than one intermediate element.

If calculations are based on the principle of virtual transitions, the length of intermediate element(s) between two abrupt changes of curvature shall also be assessed according to Annex E.

### 8.3 Abrupt change of cant deficiency ( $\Delta I$ ) at abrupt changes in curvature in combined curves

#### 8.3.1 Length of intermediate element(s) equal to, or greater than the limiting minimum value ( $L_s \geq L_{slim}$ )

If the total length of intermediate element(s) is greater than the limiting length ( $L_s \geq L_{slim}$ ), the tangent points with abrupt changes of curvature shall be considered independently, and the abrupt change of cant deficiency ( $\Delta I$ ) for each tangent point shall be as specified in 7.1.

#### 8.3.2 Intermediate element(s) of sub-standard length ( $L_s < L_{slim}$ ) or no intermediate element ( $L_s = 0$ )

Where the total length of the intermediate element(s) does not conform to 8.2, the maximum permissible speed shall be based on the following abrupt changes of cant deficiency (see Figure 2):

- for a reverse curve:  $\Delta I = I_1 + I_2$ ;
- for two curves of the opposite directions and an intermediate straight:  $\Delta I = I_1 + I_2$ ;

Equivalent alignment cases are where two abrupt changes in curvature are separated by a length which is shorter than  $L_{slim}$ , and the second abrupt change of curvature interacts with the first abrupt change of curvature in a way that the total change of curvature over the two tangent points is increased. These cases shall be assessed using the equation  $\Delta I = \Delta I_1 + \Delta I_2$ .

- for a compound curve:  $\Delta I = |I_1 - I_2|$ ;
- for two curves of the same direction, with an un-canted intermediate straight:  $\Delta I = \max \{I_1 ; I_2\}$

Wherever possible, this combination should be avoided and a compound curve with  $L_s = 0$  shall be used.

Equivalent alignment cases are where two abrupt changes in curvature are separated by a length which is shorter than  $L_{slim}$ , and the second abrupt change of curvature interacts with the first abrupt change of curvature in a way that the total change of curvature over the two tangent points is decreased. As a general rule, all tangent points  $i$  shall be assessed with respect to  $\Delta I_i$ .

The values for abrupt change of cant deficiency shall be checked using the calculation principle in 6.2 and the limits as specified in 7.1.

#### 8.4 Requirements for preventing buffer locking

When the speed is less than 60 km/h, the designer shall consider the requirements for preventing buffer locking.

The requirements for estimating the minimum length of an intermediate straight in order to prevent buffer locking at curves in the opposite directions, with radii in the range from 150 m to 300 m, are based on the minimum distance required to centralise the buffer heads at low speeds and the composition of the rolling stock, when there are no longitudinal forces. Certain characteristics of the basic vehicle used in this analysis are as follows:

— distance between end axles, or bogie pivots	12 m;
— distance between buffer face and the end axle or bogie pivot	3 m;
— displacement within the vehicle	5 mm;
— movement of wheel set within a gauge 1470 mm	30 mm;
— minimum theoretical recovery of the buffer heads	25 mm.

The radii of the curves ( $R_1$  and  $R_2$ ) in the opposite directions are transformed to an equivalent radius ( $R_{id}$ ) by the equation:

$$R_{id} = \frac{R_1 \cdot R_2}{R_1 + R_2} \quad [\text{m}]$$

The limiting value for the length of intermediate straight between two circular curves in the opposite directions, based on the basic vehicle, is defined in Table 5 and Figure 3.

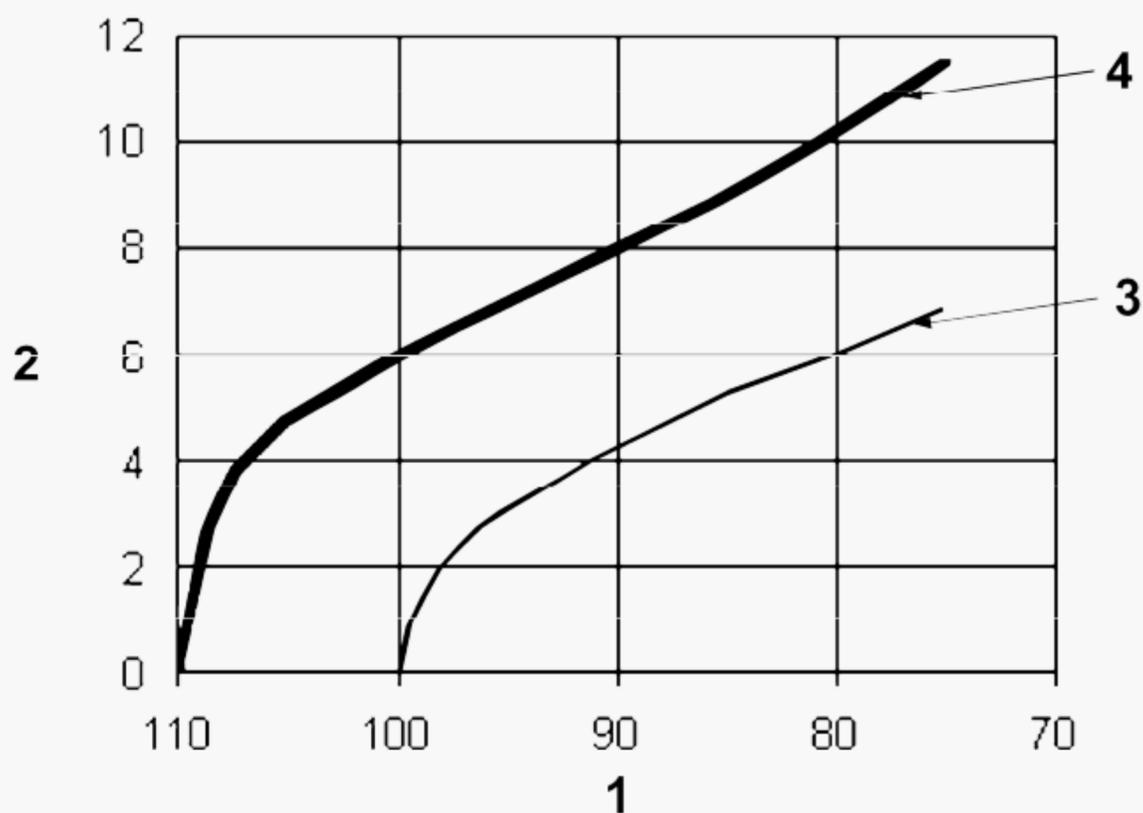
When free access is required for all types of vehicles, including long coaches with a theoretical recovery of 50 mm on the buffer heads, the recommended limiting values for  $L_s$  (based on in-service experiences) shall be used. When there are special conditions, such as multiple short alignment elements, or operating systems with higher longitudinal forces (e.g. push-pull systems), a more detailed theoretical analysis or field assessments shall be carried out.

NOTE In the defined cases of curves in the opposite directions only straights are considered as intermediate elements.

**Table 5 — Limiting values of the length of an intermediate straight ( $L_{slim}$ )**

$R_{id}$ (m)	110	105	100	95	90	85	80	75
<b>Recommended limiting value <math>L_{slim}</math> (m) <sup>a</sup></b>	0	4,8	6,0	7,0	8,0	9,0	10,2	11,5
<b>Minimum limiting value <math>L_{slim}</math> (m)</b>	-	-	0	3,2	4,3	5,1	6,0	6,8

<sup>a</sup> recommended value should be considered as the minimum limiting value for tracks for long coaches.



### Key

- 1  $R_{id}$  in m
- 2  $L_{slim}$  in m
- 3 minimum limiting value
- 4 recommended limiting value

**Figure 3 — Limiting values of the length of an intermediate straight ( $L_{slim}$ ) as a function of  $R_{id}$**

## 9 Alignment rules and parameters for designing switch and crossing layouts

### 9.1 General rules

#### 9.1.1 Horizontal alignment

Switch and crossing layouts should, if possible, be installed in straight tracks or in tracks with very large radii.

**NOTE** Switches and crossings placed on curves should be avoided due to higher maintenance cost and/or due to the lack of standardisation (special components). Such layouts may also require speed restrictions due to lower limits for cant and cant deficiency.

#### 9.1.2 Vertical alignment

Switch and crossing layouts should be installed where the tracks are level or on a constant gradient. If the installation of switch and crossing layouts on tracks with vertical curves is unavoidable, the radii of the vertical curves shall conform to the values specified in ENV 13803-1, and shall not be less than the limiting values specified in Table 6.

For a non-canted switch and crossing unit, the vertical alignment of the tracks shall follow each other up to the last common bearer.

For a canted switch and crossing unit, the vertical alignments shall be arranged to match the differences in track levels on the common bearers. The effects on vertical radius created by this arrangement may be neglected when applying the limits in Table 6.

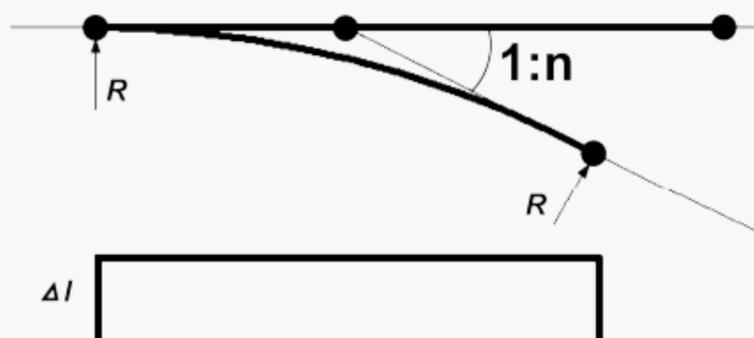
**Table 6 — Limiting values of radius of vertical curve ( $R_{vlim}$ )**

$R_{vlim}$	Crest	Hollow
<b>Recommended limiting value (m)</b>	5000	3000
<b>Minimum limiting value (m)</b>	3000	2000

NOTE Some national standards do not allow switch and crossing layouts to be installed on vertical curves.

## 9.2 Switch and crossing layouts in straight track without cant

### 9.2.1 Simple turnout



**Figure 4 — Standard turnout – Geometric layout and cant deficiency diagram**

The geometrical layout and the cant deficiency diagram for a simple turnout in a straight track without cant are shown in Figure 4. The diverging track in this type of turnout shall be designed to the requirements specified in Clause 6 and the design parameters specified in Clause 7. Circular curves, or curves that form a combination of curves in the diverging track shall be designed as specified in Clause 8. A cant gradient and cant on the diverging track shall only be applied after the last common bearer behind the crossing, unless the turnout has been designed to build up a cant on the diverging track using special components.

### 9.2.2 Turnouts with variable curvature

#### 9.2.2.1 General

The geometrical layout and the cant deficiency diagram for a typical turnout with curves of variable curvature are shown in Figure 5.

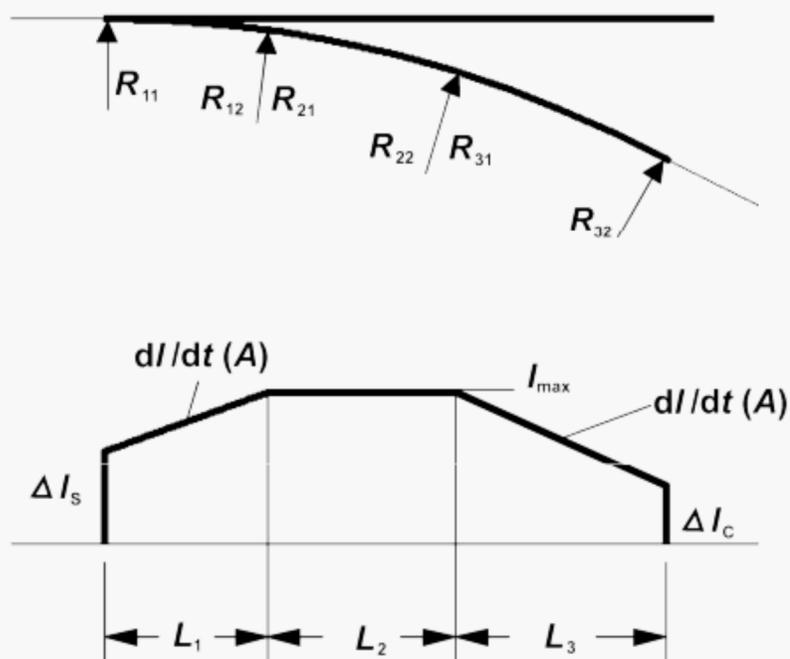


Figure 5 — Standard turnout with curves of variable curvature

Possible variations to the geometrical layout and cant deficiency diagram shown in Figure 5 are as follows:

- the abrupt change of cant deficiency at the crossing side of the turnout ( $\Delta I_c$ ) could be zero;
- one or two of the element lengths  $L_1$ ,  $L_2$ , or  $L_3$  could be zero.

Figure 6 shows cant deficiency diagrams for a variety of transitioned turnouts with either one, or two, curves of variable curvature in the diverging track.

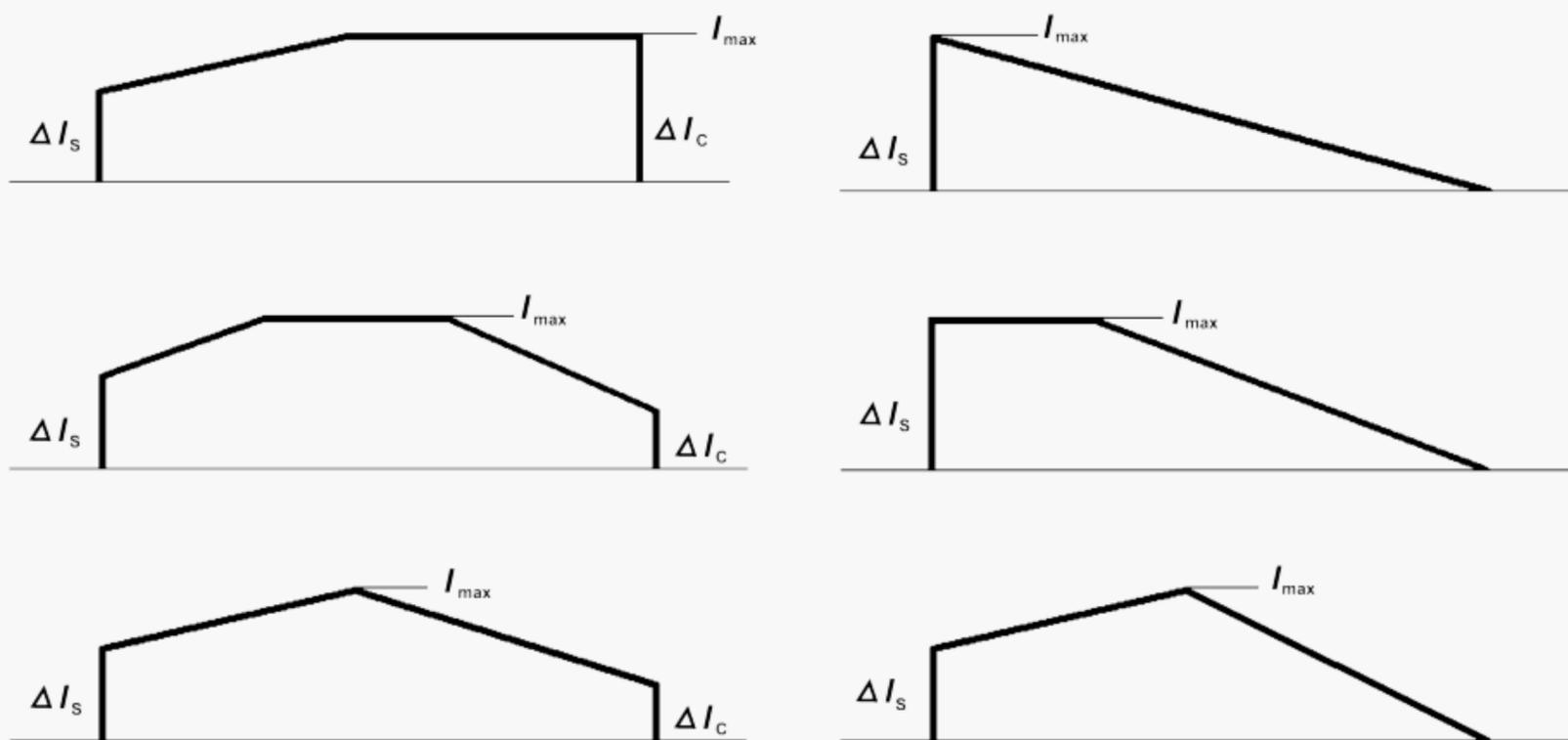


Figure 6 — Cant deficiency diagrams for various turnouts with curves of variable curvature

NOTE Curves of variable curvature usually have a linear rate of change of curvature e.g. a Clothoid curve.

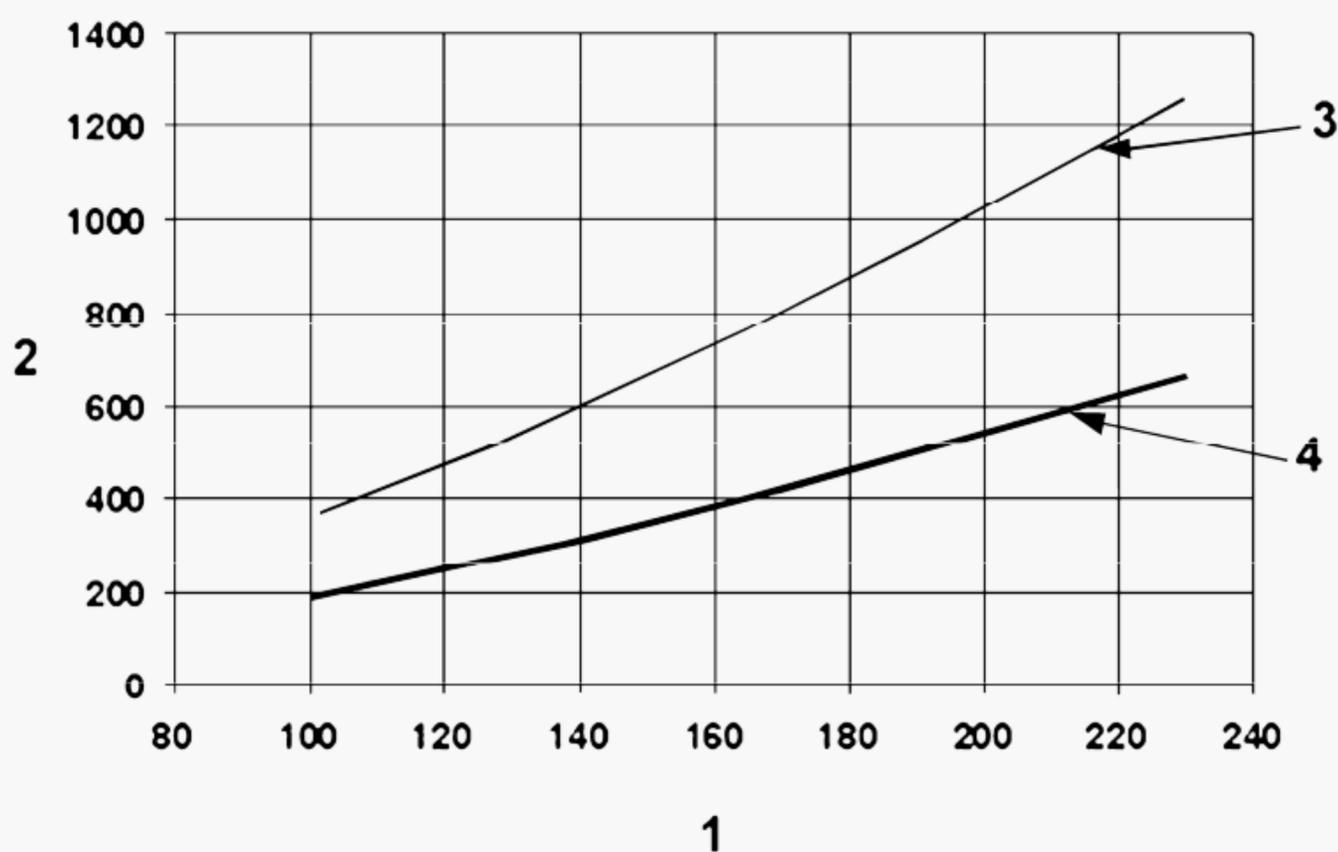
The general requirements for the geometrical layout of the diverging track in a turnout with curves of variable curvature are as follows:

- The length of an alignment element, measured along the track centre line, shall be sufficient to allow the wheelsets to take up the free play between wheel and rail and follow the alignment of the track.
- The design of the alignment elements shall be such that vehicles are able to run in a stabilised condition.
- Turnouts for crossovers shall have a low abrupt change of cant deficiency on the crossing side of the turnout ( $\Delta/c$ ).

#### 9.2.2.2 Range of parameter of clothoid ( $A$ )

The range of the parameter of clothoid ( $A$ ), for existing turnouts with curves of variable curvature (Clothoid curves), is shown in Figure 7. This range corresponds to a rate of change of cant deficiency ( $d//dt$ ) of between 25 mm/s and 90 mm/s.

Curves of variable curvature in the diverging tracks of turnouts should be designed with a parameter of clothoid ( $A$ ) conforming to the ranges specified in Figure 7.



#### Key

- 1 line speed in km/h
- 2 parameter of clothoid in m
- 3  $A$  max ( $d//dt = 25$  mm/s)
- 4  $A$  min ( $d//dt = 90$  mm/s)

Figure 7 — Range of parameter of clothoid ( $A$ ) in relation to speed

NOTE When the cant is constant the relationship between the parameter of clothoid ( $A$ ) and the rate of change of cant deficiency as function of time ( $dI/dt$ ) is expressed by the equation:

$$\frac{dI}{dt} = q_A \cdot \frac{V^3}{A^2} \quad [\text{mm/s}]$$

where

$$q_A = 3,28 \text{ mm} \cdot \text{m}^2 \cdot \text{h}^3 / (\text{s} \cdot \text{km}^3)$$

### 9.2.2.3 Limiting values for abrupt change of cant deficiency at switch side ( $\Delta I_s$ ) and crossing side ( $\Delta I_c$ )

In turnouts with curves of variable curvature the limiting values for abrupt change of cant deficiency at the switch side ( $\Delta I_s$ ) and at the crossing side ( $\Delta I_c$ ) shall be as specified in Table 2.

### 9.2.2.4 Limiting values for cant deficiency ( $I_{\max}$ ) in the diverging track

The limiting cant deficiency on the diverging tracks of turnouts with curves of variable curvature shall be as specified in 9.3.4.

## 9.3 Switch and crossing layouts installed on horizontal curves

### 9.3.1 General rules

Switch and crossing layouts, comprising of standard switches and crossings can be installed in curved tracks, which may be either canted or un-canted. The construction of a switch and crossing layout to suit a curved track is achieved by curving standard units to match the curvature of the first designed track. This curving alters the curvature of both tracks within practical limits, but the crossing angle at the end of the crossing remains the same. However, there are limits to which standard units can be curved and, consequently, a switch and crossing layout may have to be constructed from specially designed switches and crossings components.

The tracks of switch and crossing layouts on horizontal curves shall be designed to the principles and parameters specified in Clauses 6, 7, and 8.

### 9.3.2 Horizontal radii

When standard switch and crossing units are bent to match the curvature of the firstly designed track ( $1/R_I$ ), the curvature of the second track ( $1/R_{II}$ ) is affected. The exact value the curvature of the second track ( $1/R_{II}$ ) depends on the principles for lengthening and shortening the rails on the closure panel. An approximate estimation of the curvature of the second track ( $1/R_{II}$ ) is based on the superposition of curvatures (the small angle approximation):

— for an inside curved switch and crossing:

$$\frac{1}{R_{II}} \approx \frac{1}{R_I} + \frac{1}{R_0} \quad [\text{m}^{-1}]$$

— for an outside curved switch and crossing:

$$\frac{1}{R_{II}} \approx \left| \frac{1}{R_I} - \frac{1}{R_0} \right| \quad [\text{m}^{-1}]$$

where

$1/R_0$  is the curvature ( $m^{-1}$ ) of the diverging track of the switch and crossing unit in the version for straight track

NOTE 1 For transition curves,  $1/R_0$ ,  $1/R_1$  and  $1/R_{II}$  are the magnitudes of the local curvatures.

NOTE 2 An inside curved switch and crossing unit is similar flexure. An outside curved switch and crossing unit may be similar flexure ( $1/R_1 > 1/R_0$ ), straight ( $1/R_1 = 1/R_0$ ) and/or contra flexure ( $1/R_1 < 1/R_0$ ) (See also EN 13232-1 for definitions).

The approximate estimation of the magnitude of the curvature  $1/R_{II}$  is useful for calculation of equilibrium cant, cant deficiency, cant excess, for checking the minimum radius criterion and for buffer locking considerations. It should not be used in the alignment calculation.

### 9.3.3 Cant $D$

The cant on curved tracks with switch and crossing layouts shall be restricted to the limiting values specified in Table 7.

**Table 7 — Limiting values of cant  $D_{lim}$**

Recommended limiting value <sup>a</sup>	Maximum limiting value <sup>a</sup>
100 mm	160 mm

<sup>a</sup> To avoid the risk of derailment of torsionally-stiff freight wagons on small radii curves, it is recommended that cant should be restricted to the following limit (see as reference ENV 13803-1):  $D_{lim} = (R - 50)/1,5$  (mm). This recommendation applies to all tracks in a switch and crossing unit.

On one of the tracks of canted contrary flexure turnouts, and on certain curves in close conjunction to canted switch and crossing layouts, the cant will be negative, i.e. the outer rail will be lower than the inner rail. With negative cant, the cant deficiency equals:

$$I = C \cdot \frac{V^2}{R} + |D| \quad [\text{mm}]$$

where

$$C = 11,8 \text{ mm} \cdot \text{m} \cdot \text{h}^2 / \text{km}^2$$

The cant deficiency shall comply with 9.3.4.

### 9.3.4 Cant deficiency $I$

The maximum limiting values for cant deficiency on tracks with switch and crossing layouts shall be as specified in ENV 13803-1.

The recommended limiting values for cant deficiency on tracks with a non-continuous outer rail are specified in Table 8.

Table 8 — Recommended limiting values for cant deficiency  $l_{lim}$ 

$l_{lim}$ (mm)	$V \leq 160$ (km/h)	$160 < V \leq 230$ (km/h)	$230 < V \leq 300$ (km/h)
<b>Fixed common crossings</b>	110	90	Excluded
<b>Obtuse crossings</b>	100	75	Excluded
<b>Crossings with movable parts</b>	130 <sup>a</sup>	120 <sup>a</sup>	80
<b>Expansion devices</b>	100	80	60

<sup>a</sup> Recommended limiting value  $l_{lim}$  for freight trains (see ENV 13803-1).

### 9.3.5 Cant excess $E$

As guidance, the same values as specified in ENV 13803-1 are permissible i.e.:

- recommended limiting value 110 mm ;
- maximum limiting value 130 mm (110 mm for passenger trains).

The recommended limiting values for cant excess on tracks with a non-continuous low rail are specified in Table 9.

Table 9 — Recommended limiting values for cant excess  $E_{lim}$ 

$E_{lim}$ (mm)	$V \leq 160$ (km/h)	$160 < V \leq 230$ (km/h)	$230 < V \leq 300$ (km/h)
<b>Fixed common crossings</b>	110	90	Excluded
<b>Obtuse crossings</b>	100	75	Excluded
<b>Crossings with movable parts</b>	110	110	80
<b>Expansion devices</b>	100	80	60

## Annex A (informative)

### General design considerations

Railway vehicles in motion are passively guided to follow the track alignment. The reactions from rail-wheel interactions provide lateral guiding forces that steer the wheel sets through the alignment. The actual path followed by a railway vehicle is dependent upon a variety of different factors:

- a) The theoretical path for railway vehicles is fixed by the designed alignment of the track layout, by means of the rails' theoretical position in space. Usually this theoretical position is defined by the mean track alignment, or by the mean projection of the rails in both the horizontal plane and longitudinal profile (the horizontal and vertical alignment), and, in addition, the designed variation in track cross level, or cant.
- b) Compared to the designed alignment, the track in practice will have deviations, or track irregularities, relative to the permitted track geometry deviations, which are not the subject of this European Standard.
- c) The dynamic influences of variable or different track elasticity due to the track substructure and/or track components.
- d) The wheel-rail contact i.e. the guiding forces that control vehicle behaviour along the track, cannot be assumed to vary in a consistent manner i.e. the same wheels of the same vehicle may not have the same wheel-rail contact points during repeated runs over the same section of track. Consequently, this may introduce random variations in the guiding forces.
- e) The variations in the guiding forces result in movements of the wheel sets within the free play between the wheel and the rail, movements of bogie, and movements of the vehicle body. These movements are influenced also by elements in the switch and crossing panels and change the wheel-rail contact point on the running surface of the rail. Consequently, the lateral position of the wheel sets within the track gauge influence the path followed by the vehicle in relation to the track alignment.
- f) The dynamic influences at designed discontinuities along the running edge of the rail, or at guiding elements such as switch parts, crossings, wing rails and check rails could in some cases be very important and are to be taken into account, along with the influence of cant deficiency.

Track alignment designs normally only take into account the first of the preceding factors. This is quite valid when the alignment designs are for plain line track, where straight and curved alignment elements are joined by transition curves with gradually increasing or decreasing radii. In such cases, the relative influence of the rail-wheel interactions and vehicle suspension behaviour are satisfied by the track alignment design parameters specified in ENV 13803-1. However, when there are abrupt changes, rather than gradual changes in the curvature, vehicles respond differently and this part of the European Standard specifies the track alignment design parameters for such situations.

Generally it must be accepted, that in alignments with such abrupt changes the continuous behaviour of the vehicles is disturbed and the level of the passenger comfort, in comparison to the alignments based on ENV 13803-1, is always clearly reduced.

Railway practice and experience has shown that for abrupt changes in curvature, it is possible to derive general rules for the design of track alignments. These rules, which can be applied as a common reference for different types of vehicle, do not require a study of the behaviour of each vehicle, based on a detailed calculation of the wheel-rail contact points and the forces generated. Consequently, on-site measurements are only recommended for special combinations of alignment elements.

This assumption, based on experience, allows separating track alignment design from the other sources of vehicle movements, as stated above. The detailed wheel-rail contact is determined by the wheel and rail profiles, which are specified in the relevant standards for wheels and rails. The rails may be either rails used in plain track, or rails specially machined for the manufacture of switches and crossings. The contact points created depends upon the specific alignment parameters, the position of the wheels within the track gauge, and the suspension characteristics of the vehicle.

## Annex B (informative)

### The installation of switch and crossing layouts

#### B.1 Standard switch and crossing units

In a turnout with a curved diverging track through the crossing panel, as shown in Figure B.1 a), the crossing, check rail, and other components are subjected to higher forces due to the cant deficiency on the diverging track. The alignment of the diverging track through the crossing panel of a standard turnout should, wherever possible without introducing additional abrupt changes of curvature, be straight, as shown in Figure B.1 b).

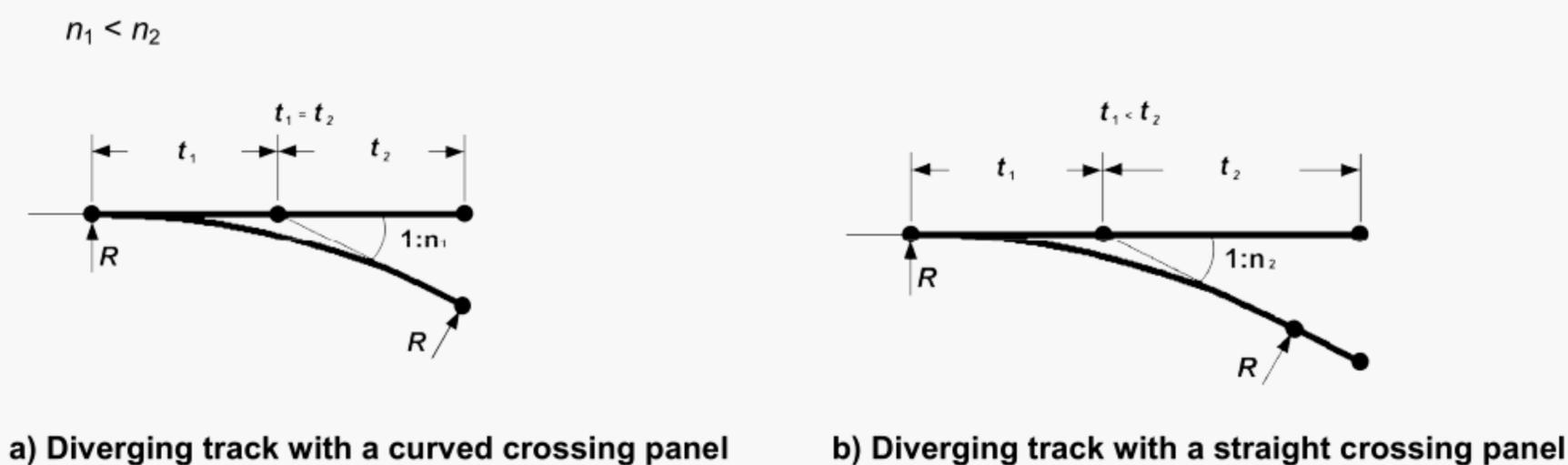


Figure B.1 — Different alignments through the crossing panel

The angles of fixed obtuse crossings in diamond crossings, single slips or double slips should not be flatter than 1:9 (see EN 13232-9). Switch diamonds should be used when the angle of the obtuse crossing would be flatter than 1:9.

Turnouts laid on high-speed lines yet to be built for speeds greater than or equal to 280 km/h (on the main), should have crossings with movable parts (swing nose crossings). On conventional lines, consideration should be given to providing crossings with movable parts for lower speeds.

#### B.2 Lateral track resistance at the switch panel

The designer should take into consideration that over the length of the switch panel, depending upon the type of bearers and the radius of the diverging track, there could be a reduction in the lateral resistance and stability of the track. This possible reduction in lateral track resistance occurs over the same length as where the thermal forces in the rails are greater than the thermal forces in continuously welded plain line track. In sections of track with small radii curves, or special combinations of turnouts, it may be necessary to increase the lateral resistance of the switch panels and the abutting track panels.

#### B.3 Stress transition zone between continuously welded track and jointed track

Track stability, when switch and crossing layouts are installed in the stress transition zones at the end of continuously welded rails, should be assured, by using appropriate design and construction standards, and conforming to national standards. If necessary, rail expansion joints should be installed to separate switch and crossing layouts from abutting continuously welded rails.

#### **B.4 Switch and crossing layouts on, or near under-bridges**

When the expandable length of a bridge deck is greater than 30 m to 40 m, a switch and crossing layout should, wherever possible, not be installed in lengths of track affected by movements at the expansion joint in the bridge deck. If this is unavoidable, a detailed analysis of the interaction between the bridge structure and the switch and crossing layout should be carried out. The installation of switch and crossing layouts across expansion joints in bridge decks is normally not possible. Over massive viaducts, without moveable bearings, no such restrictions have to be taken into consideration.

#### **B.5 Limits for diamond crossings, diamond crossings with slips and tandem turnouts**

The installation of diamond crossings, diamond crossings with slips, and tandem turnouts in tracks with high speeds, or very high loads should, whenever possible, be avoided. The accumulations of discontinuities in the running plane increase the rolling dynamic effects and, consequently, higher maintenance costs are incurred. Such switch and crossing layouts should, if possible, be redesigned to form layouts with only simple turnouts. When speeds are greater than 100 km/h to 140 km/h, rail-wheel interaction at fixed obtuse crossings should be considered, taking into account the constructional characteristics of the obtuse crossing and the requirements of national standards.

#### **B.6 Switch and crossing layouts with steel bearers**

Switch and crossing layouts with steel bearers can cause higher vibrations in the ballast bed and, consequently, a reduction in the lateral resistance of the track at the check rails, which tends to the lower geometrical quality of the track. Switch and crossing layouts with steel bearers should not be used when the speed is greater than 50 km/h.

NOTE This restriction does not apply to the steel bearers used as part of an integrated switch locking system.

#### **B.7 Abutting turnouts**

When turnouts are to follow each other, the distance between the heel of crossing and the toe of the following turnout should be such that :

- the crossing and the following switch are standard units, or a practical length of plain closure rail can be installed between the heel of the crossing and the stock front joint;
- the long bearers at the heel of the crossing do not interfere with bearers at the front of the following switch.

When two turnouts face each other, the distance between the switch toes should be such that the switches are standard units with stock rail fronts abutting, or a practical length of plain closure rail can be installed between the stock front joints. Additionally, the distance between the switch toes should conform to the requirements of 8.2.

#### **B.8 Crossovers and follow-on turnouts with reverse curves**

The assessment of the maximum operating speeds over crossovers and follow-on turnouts forming reverse curves, in straight tracks without cant, should be in accordance with Clauses 6, 7 and 8. The designer should endeavour, for the given speed and track separation distance, to use standard turnouts with straight common crossings. Such turnouts, when used in crossovers, increase the length of the intermediate straight and reduce the dynamic effects on the check rails. Within the central area of a crossover, the vertical alignments of all tracks should enable the rails to be in the same running plane.

## **B.9 Scissors crossovers and single or double junctions**

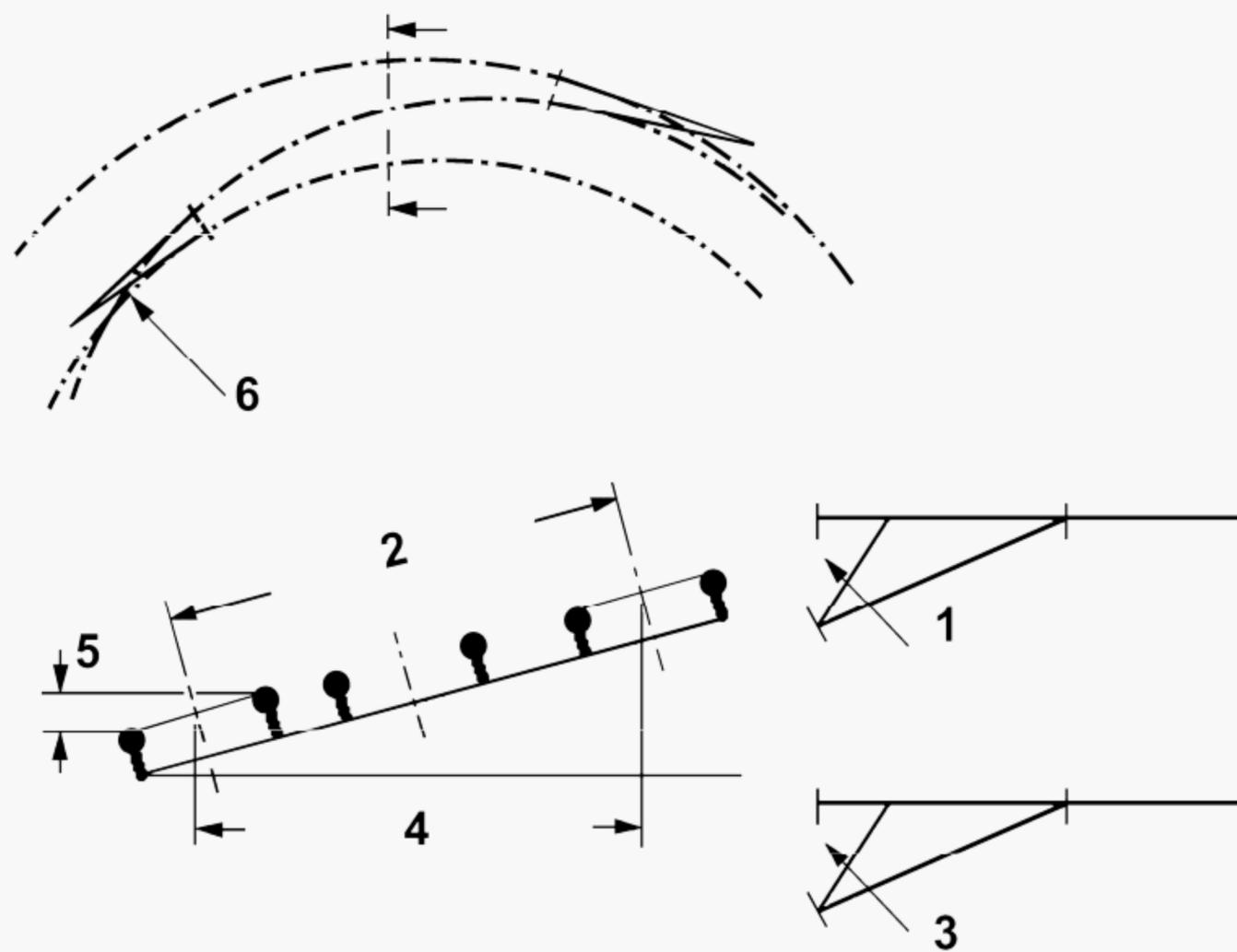
Normally such switch and crossing layouts should only be installed where the tracks are un-canted and all rails are at the same level (at least in the area of the long bearers). When crossovers are in curved tracks, all rails in the area of the long or common bearers should be in the same running plane and the longitudinal profiles along connected diverging tracks should match each other.

## **B.10 Tracks with cant gradients**

The installation of switch and crossing layouts in tracks with cant gradients should be avoided. The torsional stiffness of a turnout depends upon characteristics such as rail profile and type of crossing. Furthermore, there is a considerable variation between the torsional stiffness of a switch panel and a crossing panel. The situation is more complex if the start and/or end of a cant gradient is within the length of the switch and crossing layout. A detailed analysis should be carried out to establish the feasibility of installing a switch and crossing layout on a cant gradient.

## **B.11 Influence of cant on the deflection angle in the horizontal plane**

When a layout of the standard turnout is installed in curved tracks (e.g. crossover) with 50 mm or more of cant, the influence of the cant on the deflection angle at the heel of the crossing should be taken into consideration. The method for calculating the deflection angle in the horizontal plane is shown in Figure B.2.



### Key

- 1 turnout angle of the standard turnout (in the running plane):  $1:n$
- 2 track distance in the running plane
- 3 deflection angle in the horizontal plane:  $1: \frac{n}{\cos \left[ \arcsin \left( \frac{D}{e} \right) \right]}$ , where  $e = 1500$  mm
- 4 track distance in the horizontal plane
- 5 cant  $D$
- 6 crossing triangle

**Figure B.2 — Influence of cant on the deflection angle in horizontal plane**

## Annex C (normative)

### Rules for converting parameter values for track gauges wider than 1435 mm

#### C.1 Scope

The rules that can be applied to transpose the values of the part 2 of this standard for track gauges wider than 1435 mm are described in this annex.

The validity of the rules has been stated for track gauges up to 1668 mm.

#### C.2 Symbols and abbreviations

See Clause 4.

The following complementary parameters, corresponding to track gauges wider than 1435 mm, are specific of this annex. The parameters with (') are the values corresponding to track gauges wider than 1435 mm.

**Table C.1 — Symbols and abbreviations**

No.	Symbol	Designation	Unit
123	$C'$	equilibrium cant coefficient $C' = e'/127$	$10^{-9} \text{ h}^2$ (squared hours)
124	$D'$	cant	mm
125	$D_e, D'_e$	equilibrium cant ( $D_e = D + I, D'_e = D' + I'$ )	mm
126	$e'$	distance between wheel treads of an axle	mm
127	$I'$	cant deficiency	mm
128	$I'_i$	cant deficiency of the alignment element with radius $R_i$	mm
129	$\Delta I'$	abrupt change of cant deficiency and/or cant excess	mm
130	$\Delta I'/\Delta t$	rate of change of cant deficiency at an abrupt change in curvature as function of time	mm/s
131	$\Delta I'_c$	abrupt change of cant deficiency on the crossing side of the turnout with curves of variable curvature in diverging track	mm
132	$\Delta I'_s$	abrupt change of cant deficiency on the switch side of the turnout with curves of variable curvature in diverging track	mm

#### C.3 Basic hypothesis

The transformation rules for the parametric values for track gauges wider than 1435 mm, are established on the same basic hypothesis and the principles related to the track and rolling stock, indicated in ENV 13803-1.

The track-vehicle system is a mechanic system where rail vehicles are guided along the track, being, consequently, the rail-wheel interaction forces which govern the system behaviour.

Cant deficiency is a proportional parameter to the non-compensated lateral acceleration in the track plane. The relation between  $l$ ,  $l'$  and  $a_q$  (ENV 13803-1) is:

$$\frac{a_q}{g} = \frac{l}{e} = \frac{l'}{e'}$$

The track-vehicle system behaviour face to the lateral forces (which origin is the trajectory followed by the vehicles) and its variation will be similar if, being respected the conditions of the Annex F of ENV 13803-1:2002, the actions (interaction forces) are similar. Bearing in mind the existent proportionality between forces and accelerations (through the mass) the control of this behaviour can be done by the control of the accelerations.

## C.4 Conversion rules

### C.4.1 Application of $\Delta l$ limiting values

For each track gauge over 1435 mm, the  $l'$  cant deficiency will be equivalent to the  $l$  associated to the track gauge 1435 mm, through the formula (see Annex F of ENV 13803-1:2002):

$$l = \frac{l'}{r}$$

The  $r$  value shall be rounded to the 2<sup>nd</sup> decimal figure.

As derivation results:

$$dl/dt = \frac{dl'/dt}{r}$$

In the same way, for cant deficiency sudden variations (discontinuities):

$$\Delta l = \frac{\Delta l'}{r}$$

The same limit values, associated to  $l$ ,  $\Delta l$ ,  $\Delta l/\Delta t$ ,  $l_i$ ,  $\Delta l_s$ ,  $\Delta l_c$  or  $dl/dt$  (corresponding to track gauge 1435 mm), will be applied with these equivalence formulas.

The equivalence results shall be rounded to mm (or mm/s).

The 10 mm tolerance mentioned in the note of 7.1.2, becomes  $10 \cdot r$  mm (rounded the result to mm).

### C.4.2 Cant

For the formulas in which  $D$  takes part must be considered the equivalence defined by:

$$D = \frac{D'}{r}$$

The application of this formulas result shall be rounded to mm.

The cant limit for vehicles of high torsional rigidity on curves with reduced radius (Table 7) becomes:

$$D' = r^2 \cdot \frac{R - 50}{1,5}$$

$r^2$  shall be rounded to the 2nd decimal figure and  $D'$  to mm.

### C.4.3 Equilibrium cant

For the equilibrium cant must be considered that:

$$D_e = \frac{D'_e}{r}, \text{ being } D'_e = C' \cdot \frac{V^2}{R}$$

$C'$  shall be rounded to the 1<sup>st</sup> decimal figure and  $D'_e$  to mm.

### C.4.4 Other formulas and values of the standard

#### C.4.4.1 Requirements for preventing buffer locking

The 1470 mm track gauge mentioned in 8.4, becomes the value that results by adding 35 mm to the nominal track gauge.

#### C.4.4.2 Limiting values for parameter of clothoid (A)

The formula, indicated in the note of 9.2.2.2, that defines (when cant is constant) the relationship between the parameter of clothoid (transition curve)  $A$  (m) and the cant deficiency variation in function of the time for track gauge over 1435 mm, is converted into:

$$\frac{dl'}{dt} = r \cdot q_A \cdot \frac{V^3}{A^2}$$

As the equivalence is verified:

$$\frac{dl'}{dt} = \frac{dl'}{r}$$

the same clothoid parameters limits will be of application whatever track gauge be.

#### C.4.4.3 Cant excess $E$

As guidance, the values specified in 9.3.5, will become:

- recommended limiting value:  $110 \cdot r$  mm;
- maximum limiting value:  $130 \cdot r$  mm ( $110 \cdot r$  mm for passenger trains);
- the resultant values shall be rounded to 5 mm multiples.

**C.4.4.4 Negative cant**

The formula that allows to calculate the cant deficiency value corresponding to a negative cant (see 9.3.3), for track gauges over 1435 mm is:

$$I' = C' \cdot \frac{V^2}{R} + |D'| \quad [\text{mm}]$$

$I'$  shall be rounded to mm.

**C.4.5 Annexes****C.4.5.1 Annex B**

The formula (Figure B.2, key no. 3):

$$1: \frac{n}{\cos \left[ \arcsin \left( \frac{D}{e} \right) \right]}$$

becomes:

$$1: \frac{n}{\cos \left[ \arcsin \left( \frac{D'}{e'} \right) \right]}$$

**C.4.5.2 Annex H**

The range of maximum permissible values of cant deficiency from 275 mm to 300 mm, when tilting trains are involved (clause H.3), becomes  $275 \cdot r$  mm to  $300 \cdot r$  mm. The resultant values shall be rounded to 5 mm multiples.

## Annex D (informative)

### Limits of lateral acceleration

#### D.1 Introduction

The non-compensated lateral acceleration ( $a_{\theta}$ ) perceived by the body of the vehicle (suspended mass) at each point along the alignment, is the resultant of the acceleration due to gravity ( $g$ ) and the centrifugal acceleration ( $V^2/R$ ), acting parallel to the vehicle floor.

The acceleration, which arises from the dynamic interaction of the vehicle with the track irregularities, is added to the one above.

As the vehicle rides over the singular points in the alignment, i.e. those where a discontinuity  $\Delta(D - s/l)$ ,  $\Delta(\dot{D} - s \cdot \dot{l})$  or  $\Delta\Psi$  ( $\Psi$  is the angle between the tangent to the alignment, at each point, and a set direction in its plane) is present, generates a transient acceleration (damped) which is added to the  $a_i$  acceleration, leading to:

$$a_{\theta} = a_i + a_{tr}$$

The  $a_{tr}$  value, after a vehicle has gone over the singular point is:

$$a_{tr} = g \cdot e^{-\xi\omega_0 t} (C \cdot \sin\omega_0 t + S \cdot \cos\omega_0 t)$$

The  $C$  and  $S$  values are found from Table D.1, where  $\xi$  is the relative suspension damping,  $\omega_0 = 2\pi f$  ( $f$  is the own, not damped, rolling frequency) and  $t$  is the time elapsed since the vehicle went over the singular point.

Thes,  $\xi$  and  $\omega_0$  values, which are dependent on the type of vehicle, are shown in ENV 13803-1.

**Table D.1 — Values for C and S**

Discontinuity	$\Delta(D - s \cdot l)$	$\Delta(\dot{D} - s \cdot \dot{l})$	$\Delta\Psi$
<b>C</b>	0	$\Delta(\dot{D} - s \cdot \dot{l}) / (b \cdot \omega_0)$	$s \cdot V \cdot \omega_0 \cdot \Delta\Psi / g$
<b>S</b>	$\Delta(D - s \cdot l) / b$	0	0

If the vehicle has previously run over other singular points, the respective transient accelerations which have been generated (the time in question is that elapsed since the vehicle went over the respective singular point) have to be added; the  $a_{tr}$  absolute values are decreasing due to the  $\xi$  damping.

Simply, through a derivative, we get :

$$\dot{a}_{tr} = da_{tr} / dt = g \cdot \omega_0 \cdot e^{-\xi\omega_0 t} (C \cdot \cos\omega_0 t - S \cdot \sin\omega_0 t)$$

And, therefore,

$$a_{\vartheta} = (1 + s) \cdot a_q + a_{tr}$$

$$\dot{a}_{\vartheta} = (1 + s) \cdot \dot{a}_q + \dot{a}_{tr}$$

## D.2 Wheel-base effect

The wheel-base of the vehicle has been estimated so far to be negligible. This assumption is quite close for  $\Delta(\dot{D} - s \cdot i)$  discontinuities and fairly large alignments (as specified in ENV 13803-1), but, situations arise when the wheel-base has to be taken into account, i.e., for two axles (bogies) separated by  $L_b$  in this event, the body is assumed to be a rigid solid.

The mean section (between axles or bogies) of the body, for  $\lambda = X/L_b$  where  $X$  is the distance from any cross section to the mean one ( $X$  is positive in the vehicle's forward direction), will be the section of reference.

The  $a_{\vartheta;0}$  acceleration of the body mean section is the arithmetic mean value of the  $a_{\vartheta}$  accelerations for the vehicle's two axles (bogies). This is due to the linear change of centrifugal accelerations all over the length of the vehicle and to the lateral tilt angle of the body, in equilibrium, induced in the two axles (bogies) by the different cant of the track, is representative of the mean cant.

The  $a_{\vartheta;\lambda}$  acceleration represents a section that is  $\lambda \cdot L_b$  away from the track mean section:

$$a_{\vartheta;\lambda} = \lambda \cdot g(D_{e;0,5} - D_{e;-0,5})/b + a_{\vartheta;0}$$

Here,  $D_e = D + l$  is the cant for an equilibrium condition. Therefore,  $D_{e;0,5}$  is the equilibrium cant for the first axle (bogie),  $D_{e;-0,5}$  is that for the second axle, and  $a_{\vartheta;0} = (a_{\vartheta;0,5} + a_{\vartheta;-0,5})/2$ ;  $a_{\vartheta;0,5}$  and  $a_{\vartheta;-0,5}$  are the  $a_{\vartheta}$  accelerations computed as shown in D.1.

Through a simple derivative, it is determined:

$$\dot{a}_{\vartheta;\lambda} = \lambda \cdot g(\dot{D}_{e;0,5} - \dot{D}_{e;-0,5})/b + \dot{a}_{\vartheta;0}$$

Therefore, the lateral non-compensated acceleration values and the time based change for any section in a vehicle going over an alignment can be determined.

## D.3 Limiting values of the non-compensated lateral acceleration

The lateral accelerations generated in a vehicle by the alignment can be inferred from the maximum values (in absolute value) of  $a_{\vartheta;\lambda}$  and  $\dot{a}_{\vartheta;\lambda}$ .

The limiting values will be the ones defined in Tables D.2 and D.3. Those values agree with ENV 13803-1 and the respective types of vehicles in A.2 of ENV 13803-1:2002.

Table D.2 — Limiting values  $a_{\theta}$  (m/s<sup>2</sup>);  $V$  (km/h)

Type of Traffic	I	II	III	IV 200 < V ≤ 230	IV 230 < V ≤ 250	V V = 250	V 250 < V ≤ 300
LR <sup>a</sup>	1,40	1,40	0,65	0,95	0,80	0,80	0,65
LM <sup>b</sup>	1,60	1,60	1,00	1,30	1,20	1,20	1,00
<sup>a</sup> LR: Recommended limiting value							
<sup>b</sup> LM: Maximum limiting value							

Table D.3 — Limiting values of  $\dot{a}_{\theta}$  (m/s<sup>3</sup>)

Type of Traffic	I	II	III	IV	V
LR <sup>a</sup>	0,70	0,70	0,65	0,65	0,65
LM <sup>b</sup>	0,95	1,00	0,90	0,90	0,90
<sup>a</sup> LR: Recommended limiting value					
<sup>b</sup> LM: Maximum limiting value					

## D.4 Conclusion

The riding quality of a vehicle travelling over an alignment, which does not meet the requirements described in ENV 13803-1, is determined as follows.

The maximum values (absolute values) of the non-compensated lateral acceleration,  $a_{\theta}$ , and its time based change,  $\dot{a}_{\theta}$ , at the mean section of the vehicle and at the respective sections for two axles (bogies), are determined and checked against the limit values shown in Tables D.2 and D.3.

Therefore, the following has to compute:  $a_{\theta;0}$ ,  $a_{\theta;0,5}$ ,  $a_{\theta;-0,5}$ ,  $\dot{a}_{\theta;0}$ ,  $\dot{a}_{\theta;0,5}$  and  $\dot{a}_{\theta;-0,5}$ .

If the computed values surpass limits, the track layout should be modified, or the maximum speed should be decreased along the singular point of the alignment where limits are exceeded.

The above-mentioned checks should be performed for all the alignment elements that do not meet the requirements described in ENV 13803-1, and this includes the surrounding elements such as, for instance, short length elements.

NOTE 1 The vehicle motions are degraded by any alignment discontinuity. The designer should wherever possible achieve an alignment that meets the requirements of ENV 13803-1. At the same time he should minimize any discontinuities in the designed alignment.

NOTE 2 The limiting values and formulae specified above are also valid for track gauges of 1435 mm and wider.

## Annex E (informative)

### The principle of virtual transition

#### E.1 Virtual transition at an abrupt change of curvature

This principle is based upon the assumption that a characteristic vehicle travelling over an abrupt change in curvature gains, or loses, cant deficiency (and/or cant excess) over a length equal to the distance between the bogie centres of the characteristic vehicle ( $L_b$ ). This distance is also denoted virtual transition and is assumed to extend a distance  $L_b/2$  each side of the abrupt change in curvature.

The rate of change of abrupt cant deficiency ( $\Delta I/\Delta t$ ) is expressed by the equation:

$$\frac{\Delta I}{\Delta t} = \frac{\Delta I}{L_b} \cdot \frac{V}{q_v} \quad [\text{mm/s}]$$

where

$$q_v = 3,6 \text{ km}\cdot\text{s}/(\text{h}\cdot\text{m}) \text{ and } V \text{ is vehicle speed in km/h}$$

The calculated rates of change of abrupt cant deficiency are dependant upon the distance between the bogie centres of the vehicle. Consequently, the values of  $\Delta I/\Delta t$  are not comparable with the rates of change of cant deficiency ( $dI/dt$ ) on transition curves specified in ENV 13803-1.

Limits for the rate of change of abrupt cant deficiency ( $\Delta I/\Delta t$ ) are given in E.3.

The corresponding value for  $\Delta I$  (see 6.2) for a given speed  $V$ , a given length  $L_b$  and a given value of  $\Delta I/\Delta t$  is expressed by following equation:

$$\Delta I = \frac{q_v}{V} \cdot \frac{\Delta I}{\Delta t} \cdot L_b \quad [\text{mm}]$$

where

$$q_v = 3,6 \text{ km}\cdot\text{s}/(\text{h}\cdot\text{m}) \text{ and } V \text{ is vehicle speed in km/h}$$

The values for the abrupt change of cant deficiency, when based on the principle of the virtual transition, should also conform to the limiting values specified in 7.1.

#### E.2 Virtual transition at a short intermediate length between two abrupt changes of curvature

Where two abrupt changes in curvature are separated by a length which is shorter than the distance between the bogie centres of the characteristic vehicle ( $L_b$ ), and the second abrupt change of curvature interacts with the first abrupt change of curvature in a way that the total change of curvature over the two tangent points is increased, the length ( $L_s$ ) of the intermediate element(s) is assessed by calculating a rate of abrupt cant deficiency ( $\Delta I/\Delta t$ ) using the following equation:

$$\frac{\Delta I}{\Delta t} = \frac{\Delta I_1 + \Delta I_2}{L_b + L_s} \cdot \frac{V}{q_v} \quad [\text{mm/s}]$$

where

$$q_v = 3,6 \text{ km}\cdot\text{s}/(\text{h}\cdot\text{m}) \text{ and } V \text{ is vehicle speed in km/h}$$

NOTE 1 Each of the two changes of curvature should also be assessed according to E.1.

The calculated rates of change of abrupt cant deficiency are dependant upon the distance between the bogie centres of the vehicle. Consequently, the values of  $\Delta I/\Delta t$  are not comparable with the rates of change of cant deficiency ( $dI/dt$ ) on transition curves specified in ENV 13803-1.

Limits for the rate of change of abrupt cant deficiency  $\Delta I/\Delta t$  are given in E.3.

The limiting value for  $L_s$  for a given speed  $V$ , a given combination of  $\Delta I_1$  and  $\Delta I_2$ , and a given value of  $(\Delta I/\Delta t)_{\text{lim}}$  is expressed by following equation:

$$L_{\text{slim}} = \frac{\Delta I_1 + \Delta I_2}{\left(\frac{\Delta I}{\Delta t}\right)_{\text{lim}}} \cdot \frac{V}{q_v} - L_b \quad [\text{m}]$$

where

$$q_v = 3,6 \text{ km}\cdot\text{s}/(\text{h}\cdot\text{m}) \text{ and } V \text{ is vehicle speed in km/h}$$

NOTE 2 Negative values for  $L_{\text{slim}}$  mean that an intermediate element is not required and consequently may have any length according to the principle of virtual transition.

The value for the intermediate length  $L_s$ , when based on the principle of the virtual transition, should also conform to the limiting values specified in 8.2 and 8.3. This compliance with this requirement must always be checked, i.e. also for cases where  $L_s > L_b$ .

## E.3 Limiting values based on the principle of the virtual transition

### E.3.1 General

The principle of the virtual transition is described in E.1 and E.2.

European railway companies that use the principle of the virtual transition usually have different characteristic vehicles and, consequently, there is a variation in the distance between the bogie centres. Also, the limiting values for the rate of change of abrupt cant deficiency ( $\Delta I/\Delta t$ ) are different for these railway companies. Some of these railways companies limit their use of the principle of virtual transition to speeds below 160 km/h.

Examples of limits are given in E.3.2 and E.3.3.

### E.3.2 Characteristic vehicle with a distance of 20 m between bogie centres

The limiting values for the rate of change of cant deficiency at an abrupt change in curvature as function of time ( $\Delta I/\Delta t$ ) for a characteristic vehicle with a distance of 20 m between bogie centres are specified in Table E.1.

**Table E.1 — Limiting values for the rate of change of cant deficiency at an abrupt change in curvature ( $\Delta/\Delta t$ )**

	<b>S &amp; C layout</b>	<b>Plain line</b>
<b>Recommended limiting value (mm/s)</b>	125	-
<b>Maximum limiting value (mm/s)</b>	150	55

### **E.3.3 Characteristic vehicle with a distance of 12,2 m and 10,06 m between bogie centres**

The limiting values for the rate of change of cant deficiency at an abrupt change in curvature as function of time ( $\Delta/\Delta t$ ) for characteristic vehicles with distances of 12,2 m and 10,06 m between bogie centres are specified in Table E.2.

**Table E.2 — Limiting values for the rate of change of cant deficiency at an abrupt change in curvature ( $\Delta/\Delta t$ )**

	<b>S &amp; C layout</b>	<b>Plain line</b>
<b>Recommended limiting value (mm/s)</b>	35	35
<b>Maximum limiting value (mm/s)</b>	80	55

## Annex F (informative)

### A method for calculating the maximum permissible speed at the toe of a non-tangential switch

The cant deficiency for the effective radius at the switch toe ( $R_s$ ) is a parameter that governs the maximum permissible speed over the diverging track in switch and crossing layout. The effective radius at a switch toe, when the switch is placed on a straight track, is obtained by considering the offset between the toe and chord equal to the distance between bogie centres ( $L_b$ ) as a versine ( $v$ ), see Figure F.1. The effective radius at the switch toe is:

$$R_s = \frac{L_b^2}{8 \cdot v} \quad [\text{m}]$$

where

$L_b$  and  $v$  are in metres

The length of chord  $L_b$  is usually equal to the shortest distance between the bogie centres of passenger coaches operating over a route or railway (see Annex E).

If the switch is placed in a curved track of radius  $R_l$ , then the effective radius at the switch toe ( $R'_s$ ) is:

— when the switch toe is of type inside curved switch:

$$R'_s = \frac{R_s \cdot R_l}{R_s + R_l} \quad [\text{m}]$$

— when the switch toe is of the type outside curved switch:

$$R'_s = \left| \frac{R_s \cdot R_l}{R_s - R_l} \right| \quad [\text{m}]$$

NOTE An inside curved switch is always similar flexure, while an outside curved switch may be considered similar flexure ( $R_s > R_l$ ), contra flexure ( $R_s < R_l$ ) or straight ( $R_s = R_l$ ).

The cant deficiency can be calculated as follows:

— for a switch placed on a straight:

$$I_s = C \cdot \frac{V^2}{R_s} - D \quad [\text{mm}]$$

— for a switch placed on a curve:

$$I_s = C \cdot \frac{V^2}{R'_s} - D \quad [\text{mm}]$$

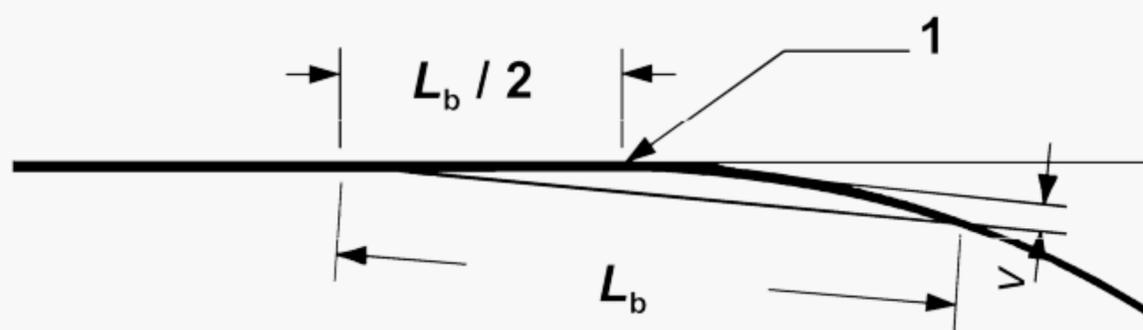
where

$C = 11,8 \text{ mm} \cdot \text{m} \cdot \text{h}^2 / \text{km}^2$  and  $D$  is the cant (mm), which can be either positive or negative

NOTE Negative values for  $I_s$  may occur, indicating cant excess.

In these cases, a maximum limiting value of 125 mm is used for the absolute value of  $I_s$ .

The rate of change of cant deficiency for the effective radius at the switch toe is not taken into consideration when determining the maximum permissible speed over the diverging track in switch and crossing layouts.



#### Key

1 Switch toe

Figure F.1 — Parameters for calculating the effective radius at a switch toe

## Annex G (informative)

### Constraints and risks associated with the use of maximum (or minimum) limiting values

The main consequences of using limiting values are described in ENV 13803-1. Similarly, these consequences are also applicable to this European Standard. Therefore, the designer should avoid unnecessary use of the maximum (or minimum) limiting values for the permissible speed, either by complying with the recommended limiting values specified in this European Standard or by using a margin with respect to design speed.

Switches and crossings are more susceptible to the dynamic influences at higher speeds especially within curved layouts and, therefore, the consequences of using maximum, or minimum, values are greater than in comparable conditions of the plain track.

Due to the constructional complexity of switch and crossing units the economic consequences of using high dynamic values or not optimising the design becomes very important.

Increased wear on track components causes more rapid deterioration of track quality, increases track maintenance, and could result in poor reliability and availability of track installations.

The constraints and risks associated with the use of maximum (minimum) limiting values are dependent upon the types of vehicles using the track, the magnitude of the wheel-rail forces, and the traffic density.

The interaction between the vehicles and switch and crossing layouts, or other alignment configurations with abrupt change of cant deficiency is complex. Currently there are no international specifications for the homologation of vehicles for such conditions and for radii lower than 250 m. Relevant documents only recommend travelling over the diverging track at the maximum speed; they do not specify either the limiting guiding forces between wheel and rail, or describe assessment procedures. Furthermore, there is no possibility of using similar assessments based on statistical methods.

In curves of less than 200 m radius, the following factors could also have an increased influence on the derailment risk for different vehicles:

- lubrication conditions at the wheel-rail interface;
- rotational resistance of the bogies;
- stiffness of shock absorbers between the bogies and vehicle bodies;
- longitudinal forces within the train composition;
- entry angle at the switch toe.

When combinations of alignment elements are unproven, or the maximum limiting values are applied, then verification of the wheel-rail interactions by on site measurements may be necessary.

## Annex H (informative)

### The maximum permissible speed of tilting body trains over switch and crossing layouts

#### H.1 General

The most important characteristics of tilting body trains are described in Annex E of ENV 13803-1:2002. A characteristic of the tilting system for the vehicle body inclination relatively to the level of the track, is that the system must have a certain reaction and working time to change the original body inclination at the beginning of the transition curve to its final inclination at the entry into the circular curve. If there is no transition curve between two alignment elements i.e. there is an abrupt change of cant deficiency, the tilting system cannot react and work in the proper manner.

#### H.2 The maximum permissible speeds over abrupt changes of curvature

Generally, the consequence of the functional properties of tilting trains is that higher speeds are not possible over the diverging tracks of switch and crossing layouts with abrupt changes of the curvature. Therefore, for most tilting systems, the permissible speed over the diverging tracks of switch and crossing layouts is the same as for conventional rolling stock. This is particularly the case with reverse curves or crossovers, where the reaction and working time of the tilting system is much longer than the time required to travel over each track alignment element.

#### H.3 The permissible speeds over switch and crossing layouts on curves

Because of the constructional discontinuities in the running edge at the switches and the influences of the check rails or wing rails at the crossing nose, the dynamic behaviour and the peak values of the lateral wheel-rail forces are higher than in the plain track. These situations can be critical when the switch and crossing layouts are installed in tracks with high cant deficiencies.

Despite the reduced axle loads of tilting trains, the level of such peak forces can be increased by speeds higher than conventional trains. In order to avoid damage to either track or wheel, the permissible cant deficiency for tilting trains in curved main lines with switch and crossing layouts or other similar features, such as expansion devices, should be reduced.

The maximum permissible cant deficiency for tilting trains in plain track is currently specified as 275 mm to 300 mm. However, to reach a comparable level of lateral forces and stresses imposed by conventional trains, the maximum permissible cant deficiency for tilting trains over curved main lines with switch and crossing layouts may have to be reduced.

For the verification of the maximum permissible speed and by respecting the diversity of the running properties of different tilting trains, the reactions should be measured directly on the elements of track and wheel. It should also be taken into account, that the conventional measurements on wheel, according to the EN 14363, are influenced by the filtering frequencies of about 20 Hz to 40 Hz.

It may be necessary, therefore, to complement the measuring system on the wheels by taking direct measurements on track components such as stock rail, check rail and/or wing rail. The need to strengthen track components can be avoided, if the forces exerted by tilting trains running at higher speeds are not greater than the forces imposed by conventional trains operating at maximum speed. It may also be necessary to evaluate the situation at the check rails when there is maximum lateral wheel flange wear, since the peak lateral forces may be greater than when the wheel flanges are unworn.

## Annex ZA (informative)

### Relationship between this European Standard and the Essential Requirements of EU Directive 96/48/EC of 23 July 1996 on the interoperability of the trans-European high-speed rail system amended by the EU Directive 2004/50/EC of 29 April 2004

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association to provide a means of conforming to Essential Requirements of the New Approach Directive 96/48/EC of 23 July 1996 on the interoperability of the trans-European high-speed rail system<sup>4</sup> amended by the EU Directive 2004/50/EC of 29 April 2004<sup>5</sup>.

Once this standard is cited in the Official Journal of the European Communities under that Directive and has been implemented as a national standard in at least one Member State, compliance with 8.4 and Annex A of this standard confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding Essential Requirements of that Directive and associated EFTA regulations.

**WARNING** — Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

---

<sup>4</sup> Official Journal of the European Communities No L 235 of 1996-09-17.

<sup>5</sup> Official Journal of the European Communities No L 164 of 2004-04-30.

Table ZA.1 — Comparison between this European Standard and EC Directive 96/48/EC

Chapter, article, paragraph and annex of Directive 96/48/EC	Chapter, paragraph and annex of Infrastructure TSI	Corresponding clauses, sub-clauses and annexes of this Standard	Comments
Chapter II; Article 5 Annex II and Annex III	Chapter 4: Functional and technical specifications of the domain  Sub-clause 4.2.7: Track cant          Sub-clause 4.2.8 (first part): Cant deficiency on plain track and on the through route of switches and crossings          Sub-clause 4.2.8 (second part): Abrupt change of cant deficiency	Sub-clause 9.3.3: Cant $D_{lim}$          Sub-clause 9.3.4: Cant deficiency $l_{lim}$          Sub-clause 7.1.2: Abrupt change of the cant deficiency $\Delta l_{lim}$	More restrictive limits when there are switches and crossings on a horizontal curve.          The recommended limits are more restrictive when there is a non-continuous outer rail (crossings and expansion devices). The same limits apply for all tracks in a switch and crossing unit.

## Bibliography

- [1] EN 13232-2, *Railway applications – Track – Switches and crossings – Part 2: Requirements for geometric design*
- [2] EN 14363, *Railway applications – Testing for the acceptance of running characteristics of railway vehicles – Testing of running behaviour and stationary tests*
- [3] *Technical Specification for the interoperability relating to the infrastructure subsystem for the trans-European high-speed rail system*
- [4] UIC 510-2, *Trailing stock: wheels and wheelsets – Conditions concerning the use of wheels of various diameters*
- [5] UIC 518, *Testing and approval of railway vehicles from the point of view of their dynamic behaviour – Safety – Track fatigue – Ride quality*
- [6] UIC 527-1, *Coaches, vans and wagons – Dimensions of buffer heads – Track layout on S-curves*
- [7] ERRI D 202, *Improved knowledge of forces in CWR Track (including switches)*
  - RP 12 (April 1999), *Final report*
- [8] ORE B 55, *Prevention of derailment of goods wagons on distorted tracks:*
  - RP 5 (October 1973), *Enquiry on the distribution of track twists for base lengths of 1,80 to 19,80 m*
  - RP 8 (April 1983), *Conditions for negotiating track twists – Recommended values for the track twist and cant – Calculation and measurement of the relevant vehicle parameters*

