EN standards 13803-1 and 13803-2 for track alignment

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Contents

- Introduction (2)
- Line categories vs traffic categories (4)
- Transition curves (1)
- Length between cant transitions (1)
- Tilting trains (2)
- Abrupt change of curvature (3)
- Buffer locking (5)
- Vertical bending (3)

Introduction - 1

- CEN TC256 - Railways
- CEN TC256/SC1 - Tracks
- CEN TC256/SC1/WG15 – Track alignment
- ENV 13803-1:2002 = Prestandard for “Plain Line”
- EN 13803-2 = CEN Standard for S&C
- EN 13803-1 = CEN standard for “Plain Line”
- prEN 13803 = merged and updated draft

Introduction - 2

IN CEN TC256/SC1/WG15

- Umbrella approach (avoid introducing criteria and limits that would require a change of existing track alignments that have proven to be workable and safe while being used in operation)
- The least conservative limit among European railways defines the "Exceptional limit"
- Not necessarily good practice, comfortable ride, low wheel/rail forces, or easy track maintenance
- "Normal limits" (in prEN 13803 just called "limits") are more conservative than "Exceptional limits"
- The standards are NOT design manuals - The limits are not intended to be used as normal design values

Line categories - 1

The prestandard ENV 13803-1:2002 contained many line categories such as:

- I Mixed traffic lines, $80 \leq V \leq 120$ (km/h)
- II Mixed traffic lines, $120 < V \leq 200$ (km/h)
- III Mixed traffic lines, $200 < V \leq 300$ (km/h)
- IV Mixed traffic lines, $V \leq 250$ (km/h), with vehicles incorporating special design characteristics
- V Dedicated passenger lines, $250 \leq V \leq 300$ (km/h)

Line categories - 2

Traffic categories have also been used in UIC Leaflet 703 from 1989:

- I Mixed traffic lines, $80 \le V \le 120$ (km/h)
- II Mixed traffic lines, $120 < V \le 200$ (km/h)
- III Mixed traffic lines, $200 < V \le 250$ (km/h), DB
- III Mixed traffic lines, $200 < V \le 250$ (km/h), FS
- IV Dedicated passenger lines, $250 \le V \le 300$ (km/h)

Line categories - 3

Problems with the “old” approach:

Lack of proper definitions

- What are “special design characteristics”
- Certain freight trains are “passenger trains”

Inconsistent rules

- V=115 required a longer cant transition than V=120
- V=200 required larger vertical radius than V=210
- Line cat IV (special design characteristics) required larger vertical radius than Line cat III
- Line cat IV (special design characteristics) required lower cant deficiency than Line cat III for certain speed intervals

Line categories - 4

"Old" approach had problems with Interoperability:

No rules for a "traditional" passenger train running on Line Category IV (Mixed traffic line where the passenger trains are supposed to have special design characteristics)

Step change to "Line categories"

- Old approach used terms such as "Passenger train", "Special design characteristics", "Freight trains", "dedicated freight wagons with special mechanical characteristics"
- New approach uses "Cant deficiency" and procedures for approval of vehicles acc. to EN 14363 (similar to UIC 518)
- The levels for cant deficiency coordinated with ERTMS
- ERTMS limits are not stable …

Transition curves

- Most European railway companies use clothoids and linear cant transitions
- Information about S-shaped ramps in an informative annex of EN 13803-1
- Normal limit for rate of change of cant is 50 mm/s for linear ramps and 55 mm/s for S-shaped ramps
- Realigning a linear ramp to an S-shaped ramp does not result in a higher permissible train speed (since the S-shaped ramp is steeper)

Length between cant transitions

Very conservative rules in ENV 13803-1 from 2002:

- Where $V \leq 200$ km/h: $L \geq V/5$ (m per km/h)
- Where $V > 200$ km/h: $L \geq V/2$ (m per km/h)

Requirements not applied in Sweden, UK and Germany, and therefore deleted from EN 13803-1 (… informative Annex).

Tilting trains - 1

Limits for tilting trains have been introduced in EN 13803-1 (cant deficiency, rate of change of cant, rate of change of cant deficiency)

Three European rail companies do not have any limit for rate of change of cant deficiency.

Due to the “umbrella approach”, there is no “Exceptional limit” for rate of change of c.d.

Exceptional limits are intended to be introduced in prEN 13803

Tilting trains - 2

Example (from the UIC project FACT):

- Radius = 2000 m, transition lengths = 20 m, and applied cant = 20 mm

With Enhanced speed = 230 km/h

- Cant deficiency = 292 mm
- Rate of change of cant = 65 mm/s
- Rate of change of cant deficiency = 933 mm/s !!!

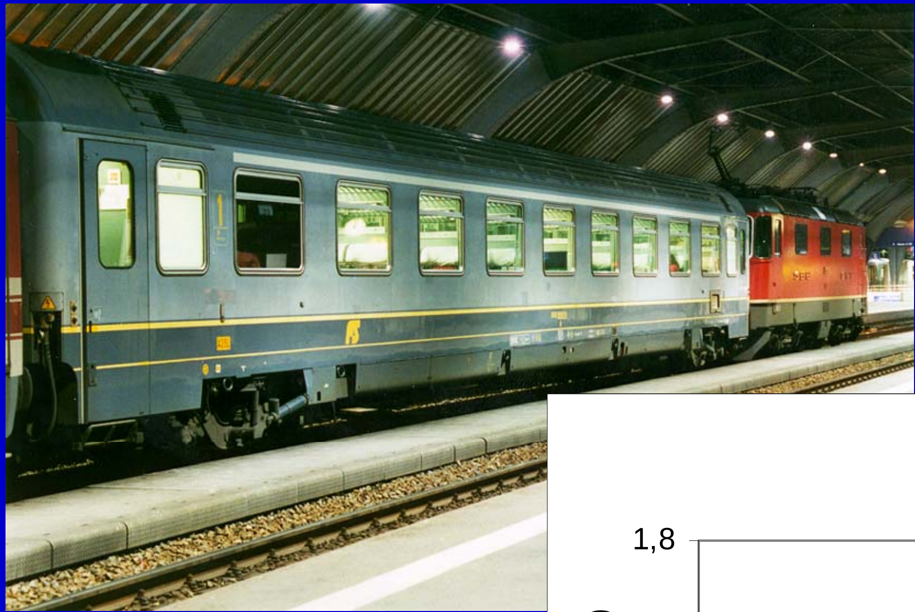
Abrupt change of curvature - 1

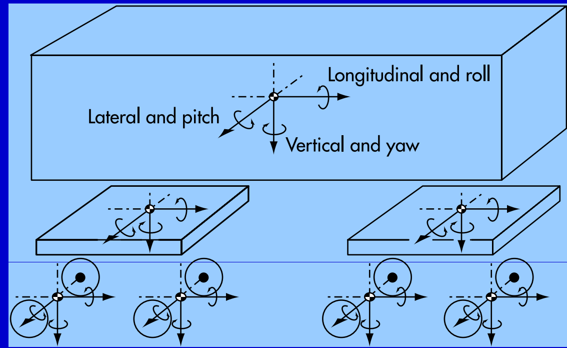
Lateral jerk (m/s^3) reduced by transition curves

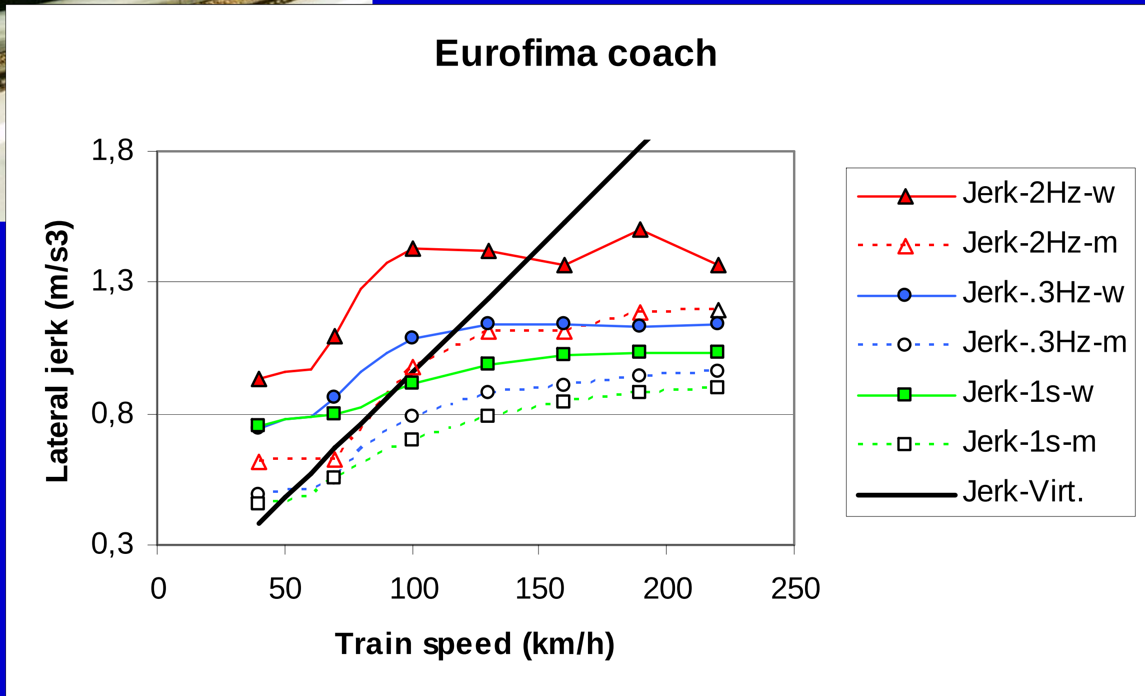
Where no transition curve, a need for a method to limit the lateral jerk:

- Constant limit for abrupt change of c.d.
- Virtual transition (bogie distance)
- Slightly reduced limit at higher speeds

Abrupt change of curvature - 2



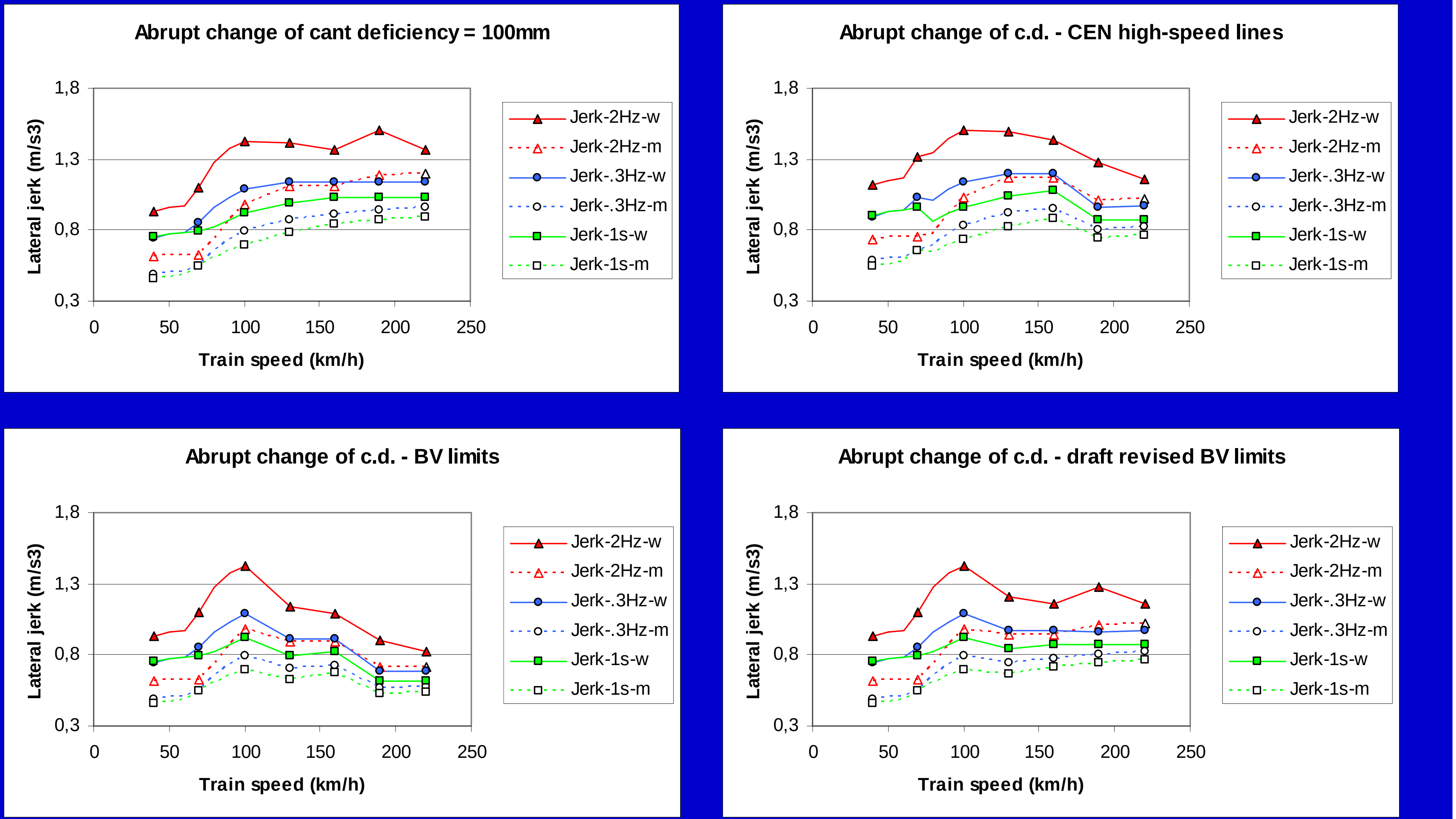




Simulations:

For all speeds, abrupt change of cant deficiency is 100mm

Abrupt change of curvature - 3



Buffer locking - 1

B = Buffer displacement = end throw

R=radius, L=vehicle length, W=bogie distance

$$B = \frac{(L/2)^2}{2 \cdot R} - \frac{(W/2)^2}{2 \cdot R} = \frac{L^2 - W^2}{8 \cdot R}$$

Buffer locking - 2

B = Buffer displacement = end throw

R_i=radius (+/-), L=vehicle length, W=bogie distance, L_S=Length of intermediate straight

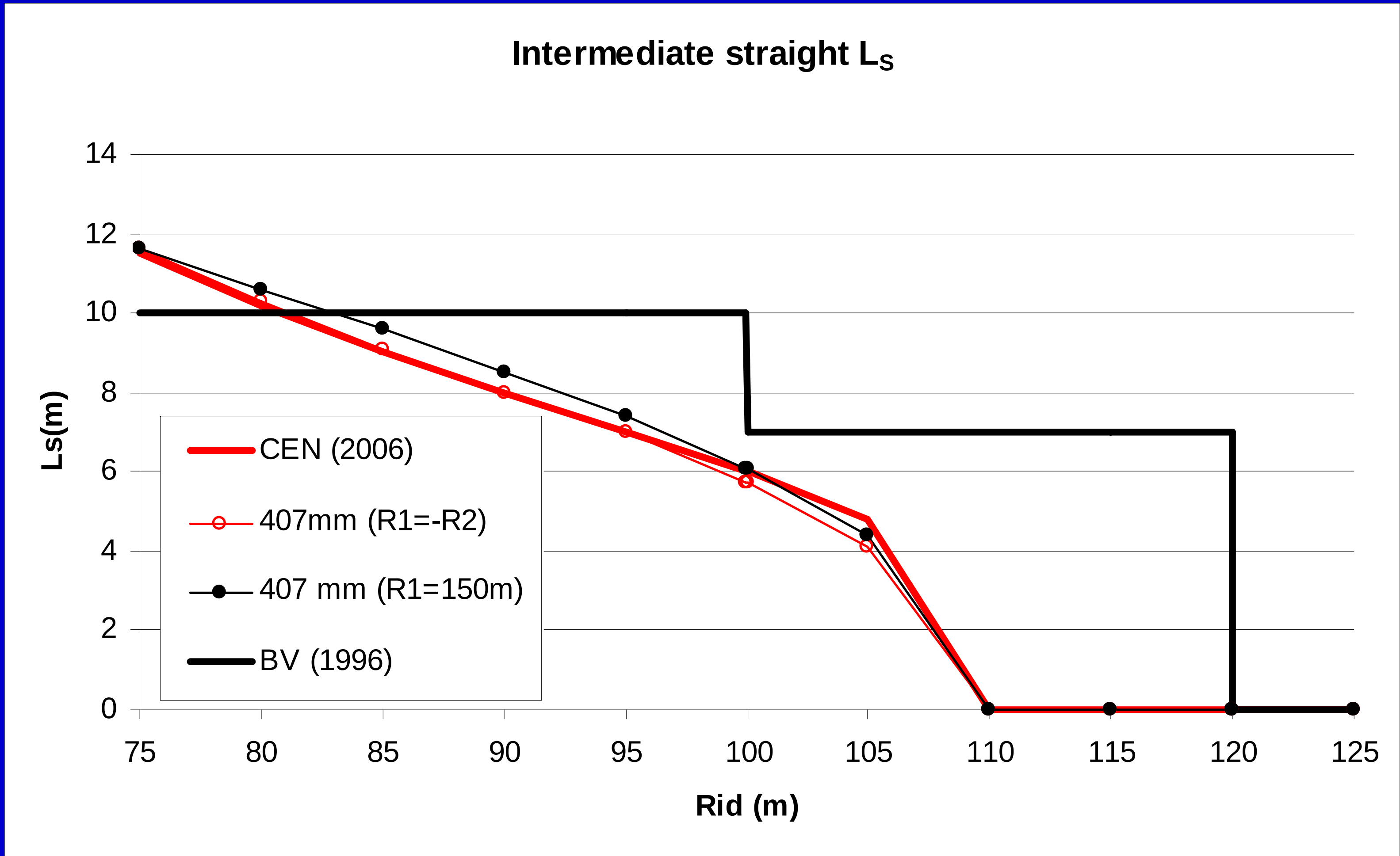
$$B = \frac{L^2 - W^2}{8} \cdot \left(\frac{1}{R_1} - \frac{1}{R_2} \right) - \frac{L_S^2}{2} \cdot \frac{1}{R_1 - R_2}$$

$$\frac{1}{R_{id}} = \frac{1}{R_1} - \frac{1}{R_2}$$

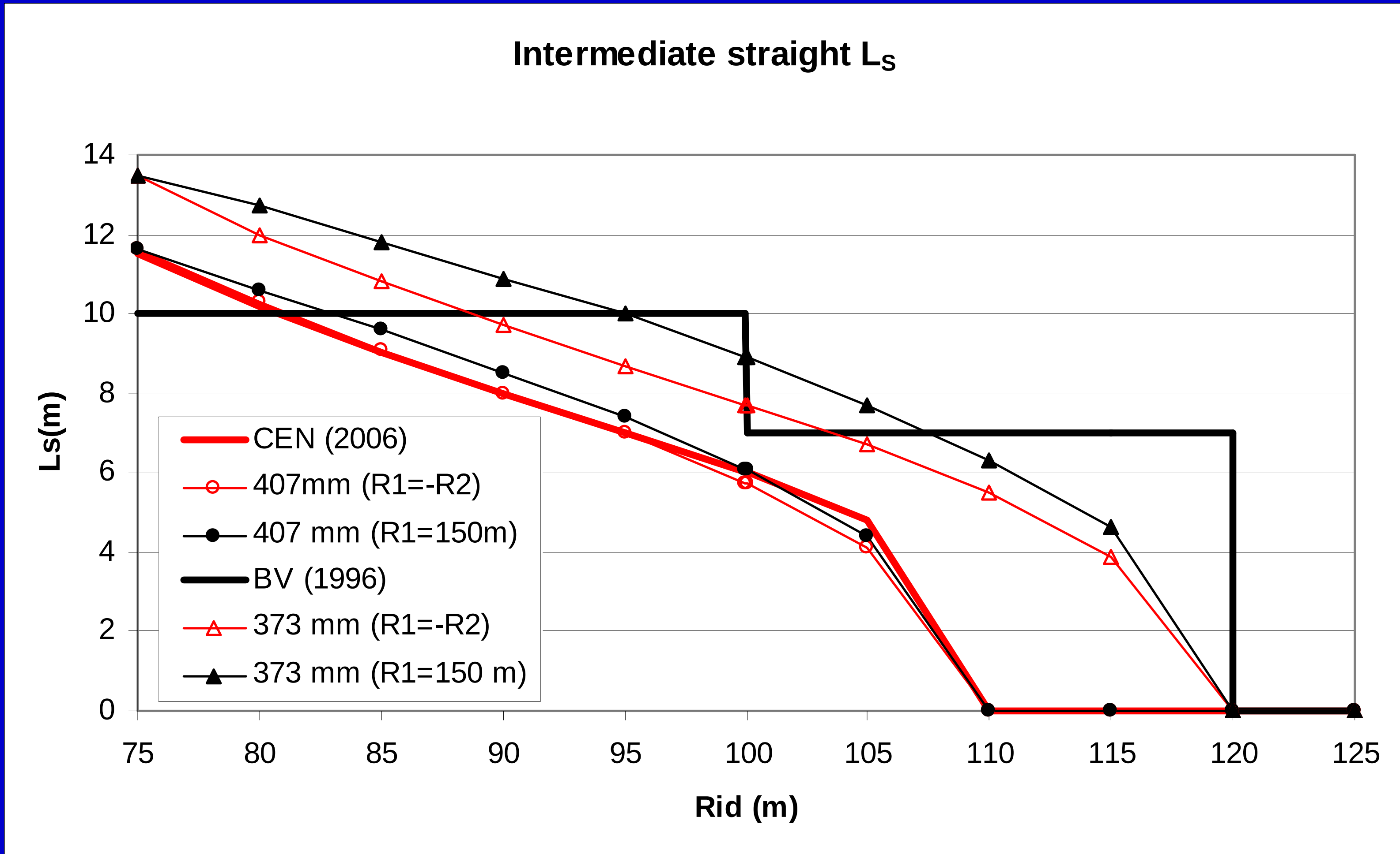
$$B = \frac{L^2 - W^2 - L_S^2}{8 \cdot R_{id}}$$

$$R_2 = -R_1$$

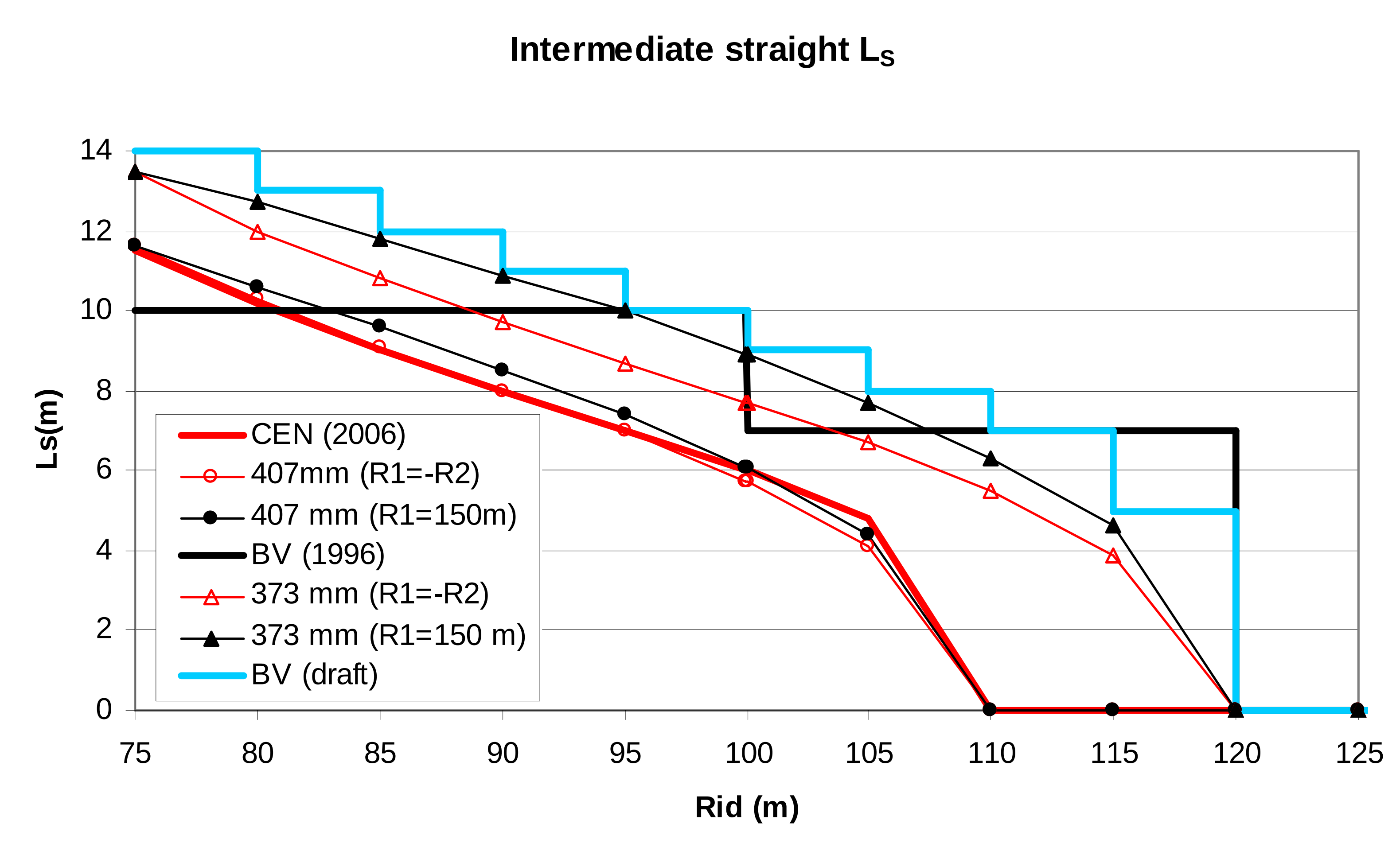
Buffer locking - 3



Buffer locking - 4



Buffer locking - 5



Vertical bending - 1

$$z_{II}(s) = z_I(s) - \frac{D(s)}{1.5\text{m}} \cdot y(s)$$

- $z_{II}(s)$ is level of track *II,*
- $z_I(s)$ is level of track *I*,
- $y(s)$ is lateral distance between the two tracks,
- $D(s)$ is cant [metres] and
- s is chainage

Vertical bending - 2

$$\frac{dz_{II}}{ds}(s) = \frac{dz_I}{ds}(s) - \frac{1}{1.5\mathrm{m}} \cdot \left(D(s) \cdot \frac{dy}{ds}(s) + \frac{dD}{ds}(s) \cdot y(s) \right)$$

$$\frac{d^2 z_{II}}{ds^2}(s) = \frac{d^2 z_I}{ds^2}(s) - \frac{1}{1.5\mathrm{m}} \cdot \left(D(s) \cdot \frac{d^2 y}{ds^2}(s) + 2 \cdot \frac{dD}{ds}(s) \cdot \frac{dy}{ds}(s) + \frac{d^2 D}{ds^2}(s) \cdot y(s) \right)$$

$$\frac{d^2 z_{rp}}{ds^2}(s) = \frac{d^2 z}{ds}(s) \cdot \cos\left(\arcsin\left(\frac{D(s)}{1.5\mathrm{m}} \right) \right) + \frac{1}{R_h(s)} \cdot \frac{D(s)}{1.5\mathrm{m}}$$

Vertical bending - 3

Example	Ex 1	Ex 2	Ex 3	Ex 4	Ex 5
Horizontal radius, track *I* [m]	300	300	300	300	400
Cant [m]	0.100	0.100	0.100	0.100	0.100
Cant gradient [m/m]	0	0	0.0	1/400	0
Vertical curvature, track *I*, perpendicular to horizontal plane [m^{-1}]	0	-1/4500 (convex)	1/3000 (concave)	1/3000 (concave)	-1/6000 (convex)
Cone effect, track *I* [m^{-1}]	1/4500	1/4500	1/4500	1/4500	1/6000
Vertical curvature, track *I*, perpendicular to the canted running plane [m^{-1}]	1/4500 (concave)	0	1/1800 (concave)	1/1800 (concave)	0
Branch diverging …	outwards	outwards	outwards	outwards	inwards
Horizontal radius, track *II* [m]	400	400	400	400	300
Vertical curvature, track *II*, perpendicular to horizontal plane [m^{-1}]	1/18000 (concave)	-1/4500 +1/18000 =-1/6000 (convex)	1/3000 +1/18000 =1/2571 (concave)	1/3000 +1/18000 +1/13200 =1/2152 (concave)	-1/6000 -1/18000 =-1/4500 (convex)
Cone effect, track *II* [m^{-1}]	1/6000	1/6000	1/6000	1/6000	1/4500
Vertical curvature, track *II*, perpendicular to the canted running plane [m^{-1}]	1/4500 (concave)	0	1/1800 (concave)	1/1584 (concave)	0

Discussion & Conclusions

- The formulation of criteria and limits in a standard is a balancing act between relevance and accuracy against user friendliness.
- The CEN standard EN 13803-2 is affected by the umbrella approach. The “worst” limits have been dictating.
- Company standards and local specifications may be more conservative.