

MATHEMATICS

■ The contents of this document are classified as guidance

User information

This Network Rail standard contains colour-coding according to the following Red–Amber–Green classification.

Red requirements – no variations permitted

- Red requirements are to be complied with and achieved at all times.
- Red requirements are presented in a red box.
- Red requirements are monitored for compliance.
- Non-compliances will be investigated and corrective actions enforced.

Amber requirements – variations permitted subject to approved risk analysis and mitigation

- Amber requirements are to be complied with unless an approved variation is in place.
- Amber requirements are presented with an amber sidebar.
- Amber requirements are monitored for compliance.
- Variations can only be approved through the national non-compliance process.
- Non-approved variations will be investigated and corrective actions enforced.

Green guidance – to be used unless alternative solutions are followed

- Guidance should be followed unless an alternative solution produces a better result.
- Guidance is presented with a dotted green sidebar.
- Guidance is not monitored for compliance.
- Alternative solutions should be documented to demonstrate effective control.

Amendment marks

- First document amendments are presented with a single black line to the right of the affected text.
- Second document amendments are presented with a double black line to the right of the affected text.

Contents

B.1.1: Curve Formulae	4
B.1.2: Compound Curves, Reverse Curves	10
B.1.3: Transition Lengths in Relation to Speed, Cant & Deficiency.....	11
B.1.4: Speeds Through Turnouts - Equivalent Radius Formulae	12
B.1.5: Speeds Through Turnouts with Track Reversing To Parallel Main - 1.....	13
B.1.6: Speeds Through Turnouts with Track Reversing to Parallel Main - 2	14
B.2.1: Vertical Curves	15
B.2.2: Compensating and Equivalent Gradients due to Curved Track	16
B.3.1: Permanent Way Mathematics - 1.....	17
B.3.2: Permanent Way Mathematics - 2.....	18
B.3.3: Permanent Way Mathematics - 3.....	19
B.3.4: Permanent Way Mathematics - 4.....	20
B.3.5: Permanent Way Mathematics - 5.....	21
B.3.6: Permanent Way Mathematics - 6.....	22
B.3.7: Permanent Way Mathematics - 7.....	23
B.3.8: Permanent Way Mathematics - 8 (Calculation of Diamonds)	24
B.4.1: Transition Curves - 1.....	25
B.4.2: Transition Curves - 2.....	26
B.4.3: Transition Curves - 3.....	27
B.4.4: Transition Curves - 4.....	28
B.4.5: Transition Curves - 5.....	29
B.4.6: Transition Curves - 6.....	30
B.4.7: Transition Curves - 7.....	31
B.5.1: End and Centre Throw - General.....	32
B.5.2: Additional Clearances required for Cant and Curvature	33
B.5.3: Centre Throw (Static) of Coaches Built to C1 Gauge.....	34
B.5.4: Centre Throw (Static) of Coaches with 16 m Bogie Centres (Type B) on Vertical Switches	35
B.5.5: End Throw (Static) of Type A and Type B Coaches on Vertical Switches	36
B.5.6: Relative Lateral Movement (Buffer Locking Considerations)	37
B.6.1: Calculation of Leads and Lags in Curved Jointed Track.....	38
B.6.2: Measurement of Crossing Angles.....	39
Table 1 – Speeds through turnouts with track reversing to parallel main.....	14
Table 2 – Speeds through turnouts with track reversing to parallel main.....	14
Table 3 – Compensation to grade due to curvature.....	16
Table 4 – Allowance for Overthrow of Rolling Stock on Curves.....	33
Table 5 – Allowances for Cant.....	33

B.1.1: Curve Formulae

Reference to Euronorms/TSI nomenclatures etc.....

Clarifying the origins of any constants identified, e.g 11.82

DERIVATION OF FORMULAE

Symbols

v = speed of train
s = distance between centres of rails
r = radius of curve
e_a = actual cant
e = equilibrium cant
d = deficiency of cant
g = acceleration due to gravity

In S.I Units

V = speed of train – kilometres per hour
V_e = equilibrium speed – kilometres per hour
V_m = maximum permissible speed – kilometres per hour
R = radius of curve - metres
E_a = actual cant - millimetres
E = equilibrium cant- millimetres
D = deficiency of cant- millimetres
L = length of transition - metres
S = shift - metres.

In units commonly
used in practice

Equilibrium Cant

The factor of centrifugal force representing acceleration and which may be regarded as acting outwards = $\frac{v^2}{r}$ metres per sec. per sec.

The inward acceleration due to cant = $\frac{e_a g}{s}$ metres per sec. per sec.

**For equilibrium these two accelerations are equal i.e. $\frac{v^2}{r} = \frac{e_a g}{s}$ whence $e_a = e = \frac{s v^2}{g r}$ metres

In practical units: Equilibrium Cant, $E = 11.82 \frac{v_e^2}{r} \text{ mm}$

Equilibrium Speed $V_e = 0.29 \sqrt{R.E} \text{ km/h.}$

Cant deficiency

If a train runs at a speed in excess of equilibrium speed the outward radial acceleration due to centrifugal force will exceed the inward acceleration due to cant. There will then be an unbalanced outward radial acceleration the value of which is given by:-

$$\frac{v^2}{r} - \frac{e_a g}{s} = \frac{g}{s} \left(\frac{s v^2}{g r} - e_a \right) = \frac{g}{s} (e - e_a) = \frac{d g}{s} \text{ metres per sec. per sec.}$$

d being the deficiency of cant.

B.1.1: Curve Formulae (Continued)

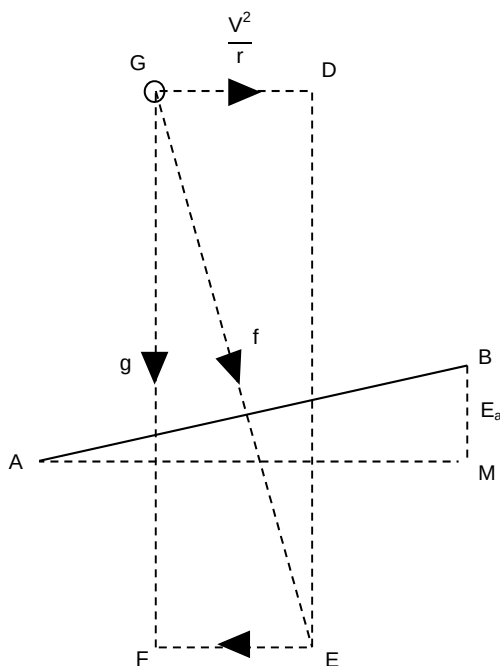


Figure 1

The above principles are illustrated diagrammatically in Figs. 1 and 2, where AB represents the canted track, G the centre of gravity of the vehicle, f the resultant of the acceleration due to gravity and the out-ward radial acceleration. The angle of inclination of the track being small, AB = s = AM approximately. For the case of Equilibrium Cant, Fig.1, the resultant force f passes through the mid-point C of the track AB, at right angles thereto.

Then from similar triangles ABM and EGD,

$$\frac{BM}{AM} = \frac{GD}{DE} \text{ or } \frac{e_a}{s} = \frac{v^2}{gr} \text{ whence } e_a = \frac{sv^2}{gr}$$

as shown in para. **

If speed is increased the resultant f deviates from C towards the outside of the curve. (See Fig.2). If the actual cant BM were increased to 1M, so as to become the equilibrium cant for the increased speed, the resultant f would cut AJ at right angles. From similar triangle AIM and IGH

$$\frac{JM}{AM} = \frac{GH}{HI} \text{ or } \frac{e_a + d}{s} = \frac{v^2}{gr} \text{ Whence } e_a + d = \frac{sv^2}{gr} \text{ shown in para**}$$

Switches - Effective Radius:

11.82 is defined for gauge but should be used as a constant for all standard gauge Network Rail lines regardless of gauge variations

To calculate the theoretical cant deficiency at the toes of switches, an Effective Radius ER(m) is used.

It is calculated by placing a 12.2m chord centred on the switch toe, and using the versine v(mm) measured at the toe:

$$ER = \frac{12.2^2}{8v} = \frac{18.605}{v}, \text{ Then: } D = \frac{11.82v^2}{ER}$$

If the actual cant e_a on the track were increased by the amount d to a total of $(e_a + d)$, then the outward and inward radial acceleration would balance and the train would be running under equilibrium conditions and then:-

$$\frac{v^2}{r} = \frac{(e_a + d)}{s} g, \text{ whence } e_a + d = \frac{sv^2}{gr} \text{ metres}$$

In practical units,

$$E_a + D = 11.82 \frac{v_m^2}{R} \text{ millimetres for 1432.}$$

$$E_a + D = 11.84 \frac{v_m^2}{R} \text{ millimetres for 1435.}$$

Where D is the maximum allowable deficiency of cant, then:- Max.

$$\text{permissible speed } V_m = 0.29 \sqrt{R(E_a + D)}, \text{ km/h}$$

In practice it is not necessary to use distinctive symbols for actual and equilibrium cant, and the above formula is usually written:-

$$V_m = 0.29 \sqrt{R(E + D)}, \text{ km/h.}$$

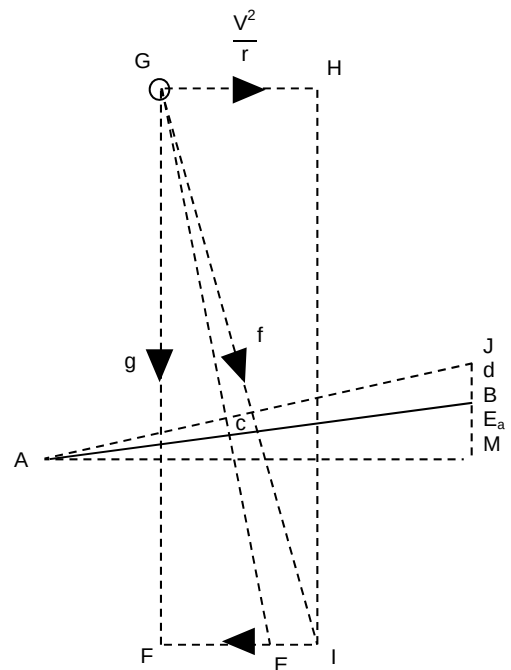


Figure 2

B.1.1: Curve Formulae (Continued)

For formulae relating radius to tangent length, chord length, offset, versine etc., see Sheet C.1.2.

Form of Transition Curve:

The equation of a cubic parabola is $y = kx^3$, where k is a constant. The slope of the curve is $\frac{dy}{dx} = 3kx^2$.

The curvature is approximately $\frac{d^2y}{dx^2} = 6kx$. When $x =$ the length of the transition (L) and R is the radius of the circular curve,

$$\frac{d^2y}{dx^2} = \frac{1}{R} = 6kL \text{ whence } k = \frac{1}{6LR} \text{ and the equation of the}$$

$$\text{curve is } y = \frac{x^3}{6LR}$$

Substituting

$$\frac{1}{6LR} \text{ for } k, \text{ the curvature at any point is } \frac{d^2y}{dx^2} = \frac{x}{RL} \text{ from}$$

which it is evident that the curvature of any point along the transition is proportional to the distance x .

The ordinate at the shift point of the curve is $S/2$ and since at this point:

$$x = \frac{L}{2}, y = \frac{S}{2} = \frac{L^3}{48LR} = \frac{L^2}{48R} \text{ and shifts } S = \frac{L^2}{24R}$$

The ordinate at the end of the curve, when $x = L$, is given by $y = \frac{L^3}{6LR}$ or $\frac{L^2}{6R} = 4S$.

The slope at the end of the curve, when $x = L$, is given by $\frac{dy}{dx} = \frac{3L^2}{6LR} = \frac{L}{2R}$

Length of transition in relation to speed, cant and cant deficiency

The curvature of the cubic parabola increases directly with the distance from the start of the transition and it follows that the uniform increase of cant (and in the case of speed above equilibrium speed, the cant deficiency also) from the start of the transition to its juncture with the circular curve will be directly related to curvature. The rate of change of cant or cant deficiency should not exceed 35 mm/sec. except where precluded by restricted site conditions. In such circumstances a maximum rate of change of 55 mm/sec. may be permitted. Generally speaking S. & C. provides such conditions and a rate of change of 55 mm/sec. is acceptable, with a relaxation to 80 mm/sec. for the improved design of vertical S.&C. In practical units the desirable length of transition $L = 0.0075 EV$ or $0.0015 DV$. The greater of the two lengths is to be used.

The minimum length of transition $L_1 = 2/3L$, is based upon the maximum permitted rate of change of cant deficiency of 55 mm/sec. The expression based on deficiency of cant $L_1 = \frac{V_m D}{198}$, provides the minimum length of transition for all speeds.

The expression based on cant $L_1 = \frac{V_m D}{198}$ applies only to speeds above 80km/h. Below this speed it will be found that the expression gives a cant gradient steeper than 1 in 400, the limiting gradient which certain four-wheel wagons will negotiate with a reasonable margin of safety. Below this speed, therefore, the minimum length of transition is given by $L(m) = \frac{400E(mm)}{1000}$ or $0.4E(mm)$ which represents a cant gradient of 1 in 400.

When $E = D$ the longest length of transition is obtained within the permitted limits. When the transition length is restricted the speed on the curve should be reduced, but this reduction is optimised when $E = D$; this condition is based upon the expression:-

$$L_1(\text{restricted}) = \frac{\text{Speed (m/sec)} \times 1/2 (E+D)}{55} = \frac{V_m \times (E+D)}{198} \text{ metres}$$

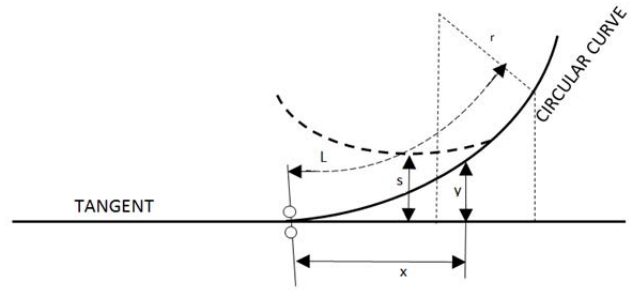


Figure 3

B.1.1: Curve Formulae (Continued)

CURVES WITHOUT TRANSITIONS

Principle of Virtual Transition

The determination of maximum permissible speeds on curves without transitions involves the concept of a virtual transition. Consider a coaching vehicle, having bogie centres C_1 and C_2 , B metres apart, travelling at a uniform speed from the straight on to a circular curve of radius ' r ', tangential to the straight at TP (Fig.4,5&6). The vehicle moves with uniform velocity in a straight line until the bogie centre C_1 reaches TP. Here the motion of the vehicle begins to change as it passes on to the curve, and the vehicle gradually acquires angular velocity. The change continues until the bogie centre C_2 reaches TP, after which the vehicle moves round the curve with uniform angular velocity. The change of motion of the vehicle from straight to curve conditions takes place in a distance B metres. The length B may therefore be considered as a virtual transition. The value of B to be used is the shortest distance between the bogie centres of the standard British Railway coaches, viz. 12.2m.

Deficiency of cant is considered as being gained in the length of the virtual transition, commencing on the straight 6.1m before TP, and terminating on the curve 6.1m beyond TP. Cant will normally be gained in the same length in a similar manner, but the cant gradient should not be steeper than 1 in 400. The run up should be extended, as necessary, or alternatively the cant can be suitably reduced so as not to exceed this gradient.

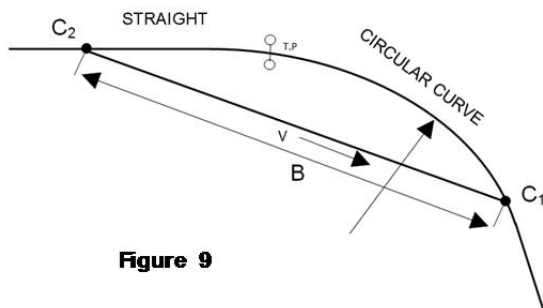


Figure 9

EXAMPLES OF VIRTUAL TRANSITIONS

Curve tangential to straight

Zero cant. Radius 800m.

To find V_m and D .

The virtual transition is 12.2m.

The minimum length of transition is with $E = D$. In this case of no cant, it is appropriate to use a transition length of 6.1m. With this length and radius at 800m the V_m is 54.5km/h. D at 54.5km/h on 800m radius is 42mm.

Limited Cant and Deficiency. Radius. 1000m.

Max. speed will be obtained when $E = D$

With a virtual transition length of 12.2m and radius 1000m gives a V_m of 74.3km/h.

$E + D$ at 74.3km/h on 1000m radius curve is 66 i.e. $E = D = 33$ mm. The cant gradient of $\frac{33}{12200}$ i.e. $\frac{1}{370}$ is, however, excessive and the length of cant run up should be increased to $0.4E$ or 13m, or the speed and cant reduced.

As will be seen from Fig.5 the virtual transition is 12.2 m in length, as in the case of curves tangential to the straight.

Zero cant. To find V_m D_1 and D_2 .

$R_1 = 1600$ m and $R_2 = 1200$ m. radius

Then $R_E = \frac{1600 \times 1200}{400} = 4800$ m.

$$(R_E = \frac{R_1 \times R_2}{R_1 - R_2})$$

Where R_E = Equivalent Radius.

A radius of 4800m and L of 6.1m gives a maximum speed of 99km/h.

A V_m of 99km/h on a radius of 1600m gives D_1 as 73mm and on a radius of 1200m gives D_2 as 97mm. D_2 is too high for jointed track and V_m would require reduction to restrict D to 90mm.

Uniform cant on both curves.

Since V_m is based upon the maximum permissible rate of change of cant deficiency on the virtual transition it is unaltered by the application of cant, and may be obtained, as in above. D_1 and D_2 , must, of course, both be reduced by the uniform applied cant E .

Equilibrium Cant on each curve

$R_1 = 1600$ m and R_2 1200m radius

Then $R_E = \frac{1600 \times 1200}{400} = 4800$ m.

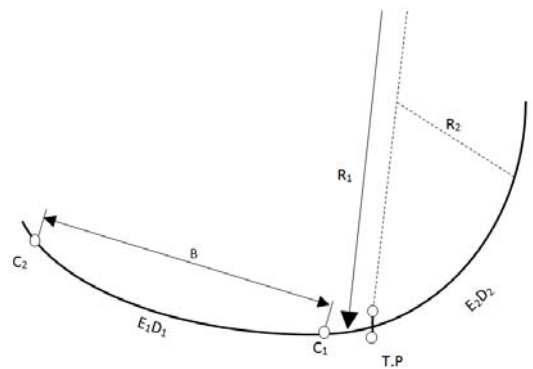


Figure 5

B.1.1: Curve Formulae (Continued)

This case is treated as above, with the same results, but substituting E_1 and E_2 for D_1 and D_2 . Cant difference should be applied over 6.1m each side of the common tangent point.

Limited Cant and Deficiency.

Max. speed will be obtained when $E_1 = D_1$ and $E_2 = D_2$.

$R_1 = 1600\text{m}$ and $R_2 = 1200\text{m}$ radius.

Then $R_E = 4800\text{m}$.

The virtual transition length is taken as 12.2m and cant difference should be applied over this length, 6.1m each side of the common tangent point.

A radius of 4800 m and L of 12.2 m, V_m is 125km/h.

A V_m of 125km/h on a radius of 1600m gives $E_1 + D_1$ as 116mm ($E_1 = D_1 = 58\text{mm}$) and on a radius of 1200m gives $E_2 + D_2$ as 154mm ($E_2 = D_2 = 77\text{mm}$).

Reverse Curves with Intermediate Straight (Fig.6)

If the length of straight track between the two curves is equal to or greater than 12.2m, the case will be treated as two un-transitioned curves off the straight.

If the length of straight is less than 12.2m, change of motion of a vehicle will commence when C_1 reaches T.P.1. and terminate when C_2 reaches T.P.2.; that is, it will take place in a length $A + B$ i.e. $A + 12.2\text{m}$, and this length is considered as the virtual transition.

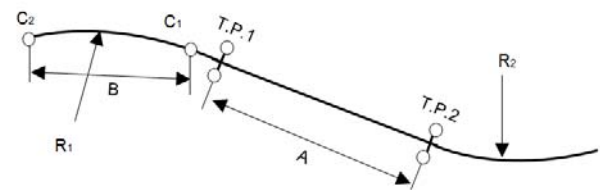


Figure 6

Zero cant.

$R_1 = 600\text{m}$, $R_2 = 400\text{m}$ and $A = 5\text{m}$.

Then $R_E = \frac{600 \times 400}{1000} = 240\text{m}$.

Then virtual transition is $12.2 + 5\text{m} = 17.2\text{m}$.

Since deficiency only is involved, a length of 8.6m should be used to determine V_m on a radius of 240m. V_m is read as 40km/h.

A V_m of 40km/h on 600m gives D_1 as 32mm and on 400m D_2 as 47mm.

(D for R_E of 240m at 40km/h is 79mm).

Equal cants, positive on both curves. Let $E = 20\text{mm}$.

Using the same premises as above V_m is, for $(E + D) = (79 + 20) = 99$ on 240m curve, 44.5km/h. A V_m of 44.5km/h on 600m gives $(E + D_1)$ as 39mm ($D_1 = 19\text{mm}$) and on 400m curve $(E + D_2)$ as 58mm ($D_2 = 38\text{mm}$).

The cant would be applied over 8.6m from the centre of the straight in either direction.

The cant gradient would be $\frac{20}{8600}$ or 1 in 430.

Equal cants, negative on one curve. $E_1 = 20$, $E_2 = -20$.

Using the same premises as in paragraphs above V_m is, for $(D - E) = (79 - 20) = 59$ on 240m curve, 34.5km/h (9.6 m/sec.).

A V_m of 34.5km/h on 600m gives $(E_1 + D_1)$ as 23.5mm ($D_1 = 3.5\text{mm}$) and on 400m curve $(-E_2 + D_2)$ as 35mm ($D_2 = 55\text{mm}$).

The cant gradients would each be $\frac{20}{8600}$ or 1 in 430.

The rate of change of cant deficiency ($\frac{55 \times 9.6}{8.6} = 61.5\text{mm/sec.}$) is, however, excessive, and speed should be reduced.

B.1.1: Curve Formulae (Continued)

Limited Cant and Deficiency on both curves.

Max. Speed will be obtained when $E_1 = D_1$ and $E_2 = D_2$.

Using the same premises as previously, in this case the full virtual transition of 17.2m is used with the R_E of 240m to give V_m as 52km/h.

A V_m of 52km/h on 600m gives $E_1 = D_1 = 27\text{mm}$ and on 400m curve $E_2 = D_2 = 40\text{mm}$.

Note: The cant gradients would be $\frac{27}{8600}$ and $\frac{40}{8600}$ i.e., 1 in 318 and 1 in 215 respectively and would have to be extended so as not to exceed 1 in 400. The respective lengths of run up of cant would be 27×0.4 and 40×0.4 i.e. 11m and 16m. Cant and therefore V_m could also be reduced to obtain 1 in 400.

Reverse Curves without Intermediate Straight

Max. Speed will be obtained when $E_1 = D_1$ and $E_2 = D_2$.

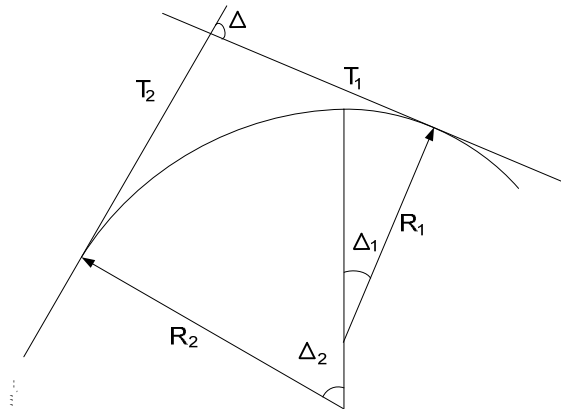
Using the same premises as previously, the virtual transition of 12.2m is used with the R_E of 240m to give V_m of 46km/h.

A V_m of 46km/h on 600m gives $E_1 = D_1 = 21\text{mm}$ and on 400m curve $E_2 = D_2 = 31\text{mm}$.

Note: So as not to exceed 1 in 400, the cant gradients would have to be extended to 8 and 12m respectively or reduce cant and V_m .

Where no cant is applied, a virtual transition of 6.1m is used with the R_E of 240m to give a V_m of 35 km/h.

B.1.2: Compound Curves, Reverse Curves



R_1 is the smaller radius
 R_2 is the larger radius
 Δ_1 is the central angle of the arc radius R_1
 Δ_2 is the central angle of the arc radius R_2
 Δ is the deflection angle of the complete curve
 T_1 is the tangent touching the arc radius R_1
 T_2 is the tangent touching the arc radius R_2

$$\Delta = \Delta_1 + \Delta_2$$

$$T_1 = \frac{R_2 - R_1 \cos \Delta - [(R_2 - R_1) \cos \Delta_2]}{\sin \Delta}$$

$$R_1 = \frac{R_2 (\cos \Delta - \cos \Delta_1) + T_2 \sin \Delta}{1 - \cos \Delta_1}$$

$$T_2 = \frac{R_1 - R_2 \cos \Delta + [(R_2 - R_1) \cos \Delta_1]}{\sin \Delta}$$

$$R_2 = \frac{R_1 (\cos \Delta - \cos \Delta_2) + T_1 \sin \Delta}{1 - \cos \Delta_2}$$

Compound curves with transitions

The length of the transition (L) is obtained from the GREATER length of:

$$L = \frac{(E_1 - E_2)V_{\max}}{3.6(\text{rate of change of } E)}$$

OR

$$L = \frac{(D_1 - D_2)V_{\max}}{3.6(\text{rate of change of } D)}$$

- a) E_1 and E_2 represent the cant applied to curves 1 and 2 respectively in mm.
- b) D_1 and D_2 represent the deficiency of cant on curves 1 and 2 respectively in mm.
- c) $V_{\max}$ is the maximum permissible speed in km/h.

Using the desirable rate of change of 35mm/sec, these equations become:

$$L = 0.0079365(E_1 - E_2) V_{\max}$$

OR

$$L = 0.0079365(D_1 - D_2) V_{\max}$$

Using the maximum rate of change of 55mm/sec, the MINIMUM length of transition ($L_{\min}$) becomes:

$$L_{\min} = 0.0050505(E_1 - E_2)V_{\max}$$

OR

$$L_{\min} = 0.0050505(D_1 - D_2)V_{\max}$$

Reverse curves

The rates of change of cant and cant deficiency on the transition should be the same on each side of the reverse point.

Using the same abbreviations as shown above, the length of the transition, L , is obtained from the GREATER length of:

$$L = \frac{(E_1 + E_2)V_{\max}}{3.6(\text{rate of change of } E)}$$

OR

$$L = \frac{(D_1 + D_2)V_{\max}}{3.6(\text{rate of change of } D)}$$

Using the desirable rate of change of 35mm/sec, these equations become:

$$L = 0.0079365(E_1 + E_2) V_{\max}$$

OR

$$L = 0.0079365(D_1 + D_2) V_{\max}$$

Using the maximum rate of change of 55mm/sec, the MINIMUM length of transition ($L_{\min}$) becomes:

$$L_{\min} = 0.0050505(E_1 + E_2)V_{\max}$$

OR

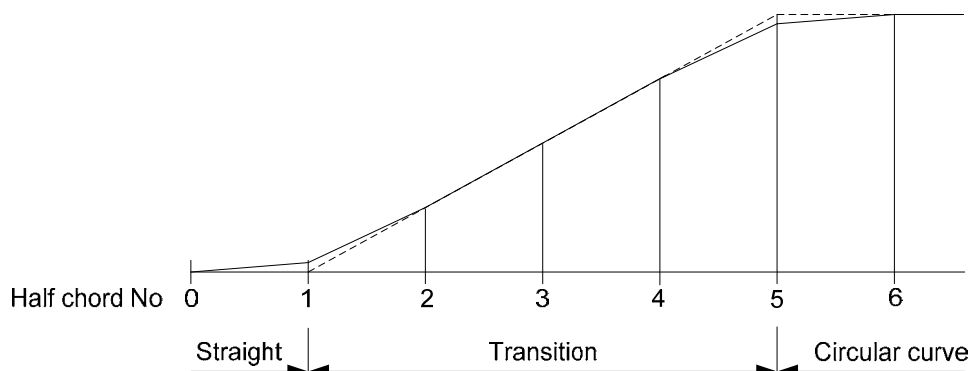
$$L_{\min} = 0.0050505(D_1 + D_2)V_{\max}$$

B.1.3: Transition Lengths in Relation to Speed, Cant & Deficiency

For the form of transition curves, see Sheets B.4.1 to B.4.7 inclusive.

Versines should be taken on overlapping chords and curves adjusted by the Hallade or other similar method.

If the half-chords are measured out along the track and not the baseline, the resultant realignment will be a clothoid spiral.



The diagram of versines in graphical form shows a transition from straight to circular curve. The versine at HC 1 should be one-sixth of the versine at HC 2, and similarly at the other end of the transition - in the example shown above, the versine at HC 5 will be reduced by one-sixth of the difference between versines at HC 6 and HC 4.

The length of the transition (L) is obtained from the GREATER length of:

$$\frac{E \times V_{\max}}{3.6(\text{rate of change of } E)} \quad \text{OR} \quad \frac{D \times V_{\max}}{3.6(\text{rate of change of } D)}$$

where E = applied cant in mm, D = deficiency of cant in mm, $V_{\max}$ = maximum permissible speed in km/h, and rate of change is measured in mm/sec..

Using the desirable rate of change of 35mm/sec, these equations become:

$$L = 0.0079365 E \cdot V_{\max} \quad \text{OR} \quad L = 0.0079365 D \cdot V_{\max}$$

Using the maximum rate of change of 55mm/sec, the MINIMUM length of transition ($L_{\min}$) becomes:

$$L = 0.0050505 E \cdot V_{\max} \quad \text{OR} \quad L = 0.0050505 D \cdot V_{\max}$$

It should be noted that the equation ($L_{\min} = 0.0050505 E \cdot V_{\max}$) only applies to speeds equal to or greater than 50mph (80km/h). Below this figure, the minimum cant gradient of 1 in 400 is the critical factor, and L is obtained from:

$$L_{\min} = 0.4 E$$

Where the calculated minimum length of transition is unobtainable due to site conditions, the cant (E) or cant deficiency (D) should be reduced on the circular curve. This will also reduce the maximum permissible speed ($V_{\max}$) and may involve the imposition of a lower speed restriction on the curve.

The minimum Normal Design transition length is 30 metres; the Minimum Design value is 25 metres. Minimum transition lengths are necessary to support the manual control of tampers.

B.1.4: Speeds Through Turnouts - Equivalent Radius Formulae

Where the main line is curved, the turnout radius should be adjusted in accordance with the following formulae to obtain its “equivalent radius”.

For turnouts diverging with contraflexure,

$$Re = \frac{R_m \times R}{R_m - R}$$

For turnouts diverging with similar flexure,

$$Re = \frac{R_m \times R}{R_m + R}$$

Where Re = equivalent radius, R_m = radius of the main line, R = radius of turnout from a straight main line as shown on Sheets C.1.2 and C.2.2.

The cant on the main line should be taken into account when assessing the cant deficiency and maximum permissible speed under these conditions. Where negative cant involved, the maximum permissible speed on the contraflexure turnout is governed by:

for CEN56E1 Vertical and earlier designs	$D = (90 - E)\text{mm}$
for NR60 designs up to and including 105 mph	$D = (110 - E)\text{mm}$
for NR60 designs above 105 mph:	$D = (85 - E)\text{mm}$

where E is the numerical value of the negative cant.

In crossovers, the lowest speed calculated from both the turnouts and from the reverse curve should form the speed restriction.