

NORTH EASTERN RAILWAY

CE'S P.WAY CIRCULAR NO. 47 OF 1965.

(SUPERSEADES CE'S P-WAY CIRCULAR NO. 28 OF 1964)

CURVE REGISTERS & REALIGNMENT OF CURVES

1. For smooth and satisfactory running on curves there should be no abrupt alteration of curvature or superelevation and the superelevation should be appropriate to the curvature at each point.
2. In order to ensure that running on curves is upto the mark, the instructions contained in Chapter VIII of the I.R.W.W. Manual, paras 820 to 822 should be strictly followed along with the following subsidiary instructions.
3. CHECKING OF CURVES (Reference Rly. Board's letter No. 64/W/8/RWT/2/8 dated 29.8.1964).

The versines and superelevation on each curve must be checked every six months, or earlier if the running is bad, the versines can be recorded either by the P.W.I. or the A.P.W.I. depending on the ability of the letter, but the decision to realign should be taken by the AEN.
4. Realignment of curves should be taken up in the dry season and not during the rains, except when this is unavoidable.

5. METHOD OF REALIGNMENT:

The realignment of curves should be done by 'stringlining' described hereunder. In certain cases, however, where the curves are over one kilometer long and calculations would be the AENs should submit in duplicate the versine readings of such curves to the Track Supply Officer, CKP. The final realignment and the slews in such cases will be determined on the 'Latise Curve Calculator' thus avoiding the lengthy process of the first and second summations and application of correcting couples.

6. STRINGLINING OPERATIONS:

The work of realigning the curve by means of stringlining operation consists of (i) survey of the existing curve by measurement of versines (ii) computation of slews and determination of revised alignment, including provision of correct superelevation, and (iii) slewing of the curve to the revised alignment.

7. VERGINE SURVEY OF THE CURVE:

7.1 The versine survey should not be done during rains or windy weather.

7.2 The versines should be taken on a chord length of 62 ft. in which case the versine in inches given the degree of curvature. A piano wire or suitable fish chord should be employed for this purpose.

7.3 Versine reading shall be taken along the gauge face of the outer rail.

7.4 In the case of reverse curves, the versine survey should be continuous, but transferred to the other rail at points where the curvature changes sign. It is probable that the exact point will not be definite, it is, therefore, desirable to keep to the original rail face until the change is certain.

7.5 To enable negative versines to be recorded from the same rail face, it is necessary to hold the fishing cord, or wire 1" clear of the rail edge at each end and subtract 1" from the reading at the centre. To facilitate this, "boulders" as shown in the sketch in Annexure 1 should be used for bolting the fishing cord or wire 1" clear at each end. The special design of the boulders also minimises the effect of the rail wear.

7.6 On double or multiple tracks, each curve should be stringlined independently instead of slewing the curves to uniform track centres as the existing track centres may not be uniform and the transsistions at the entry and exit may be of different lengths necessitating different track centres.

7.7 Curves should be thoroughly packed and roughly realigned by the eye before measuring the versines.

7.8 RECORDING OF VERSINE:

7.8.1 To ensure inclusion of the point of commencement of the curve, a mark is made on the gauge face of the outer rail at a distance of about three chord lengths behind the **apparent** tangent point and numbered zero. From this point stations 31 ft. apart are measured with a steel tone along the gauge face of the outer rail over the whole length of the curve and numbered serially 1,2,3,4 and so on and carried upto about three chord lengths beyond the apparent tangent point at the other end.

7.8.2 Those 'station' should be marked with a vertical line and numbered in the direction of increasing kilometrage with white point on the web on the gauge face of the outer rail. The station numbers shall also be painted on the foot of the rail near the vertical line. The markings shall be maintained permanently and periodically painted. This will avoid the cumbersome repetition of measure the chords during every survey and shall further facilitate easy measurement of versines at the same spot. This will also encourage frequent inspections by all concerned.

7.8.3 With the fishing or piano wire stretched over the full length of the chord, versines are measured to 1/16" occuracy serially at each 'station' from one end of the curve to the other with the rule held normal to the line and recorded against the appropriate stations.

7.8.4 The process should be repeated starting from the other end and a second recording of the versines made against the different stations. The average of the two readings against each station should be taken as the final versine at that station and recorded in the "curve Registers" as per proforma in Annexure-IV, unless there is a wide variation in the readings in which case a fresh set of readings should be taken for such stations where the variation was appreciable.

7.8.5 The 'stations' should be so selected that a station falls on an 'obligatory' point such as a signal post, bridge abutment etc. which restricts the slew of the curve to a certain limit.

7.8.6 A record should also be made in the remarks column of the 'curve register' of such features which restrict the slewing of the track either inwards or outwards, mentioning the maximum extent inwards and outwards to which slewing may be done. If the maintenance of a curve is affected due to presence of such a restriction then the DEN/AEN/PWI should personally investigate the problem and submit proposals to the Chief Engineer in cases where considerable expenditure is involved.

7.8.7 In case of readings sent to TSO-GKP for calculations on 'Matisa Curve Calculator' area features along with the extent of slewing possible, must also be mentioned in the remarks column. For such curves, necessary computations will be made in the office of the TS and details of slews sent to the PWIs direct within a week. The PWIs will, thereafter, realign the curves in accordance with the procedure outlined in para 9 below.

7.8.8 On the top of each page of the curve Register, all the permanent details of the curve and track particulars shall be entered.

7.8.9 After the versine survey the curve alignment shall not be disturbed until the realignment is commenced; this interval should be the least possible.

8. DETERMINATION OF REVISED ALIGNMENT:

8.1 The determination of revised alignment, computation of slews and provision of correct superelevation should be done according to the procedure outlined in para 8211 of the I.R.W.W. Manual keeping the following sequence in view.

8.2 Estimate approximately the degree of the circular portion of the curve by deviding the total of the versines on the main body of the curve (excluding the transitions at the ends) by the number of stations on the main body.

8.3 Determine the actual superelevation 'E' to be provided for the degree of the circular curve determined in para 8.2 above. This may be read out directly from Annexure I & III (para 806) of the I.R.W.W. Manual (reproduced as Annexures II & III).

Also determine the requilibrium superelevation 'C' from the formula $C = \frac{GV^2}{1.25 R}$ as given in para 806(A)

(a) of the I.R.W.W. Manual. The cant deficiency 'D' will, therefore, be $D = C - E$.

8.4 Calculate, now the length of the transition from para 807(A) of the I.R.W.W. Manual for the actual superelevation and cant deficiency determined in para 8.3 above.

The actual length to be adopted should be fixed at the next higher full station i.e. the next higher multiple of 31 ft. A longer transition lengths may be adopted if site conditions permit.

8.5 Determine from the length of the transition the rate of change of actual cant at 31 ft (from one station to the next). This may be denoted by the letter 'M'.

8.6 With the value of M as determined above, the maximum rate of change of versine or the versine gradient can be easily determined from the following expression-

$$8.6.1 \quad K = \frac{(MV+31) 1.25 \times 5930}{GV^3}$$

Where K=maximum rate of change of versine in inches at every 31 ft.

M=rate of change of actual cant (inches) at every 31 ft.

V=Maximum permissible speed in miles per hour.

G=track gauge.

8.6.3 In order to facilitate calculations, the values of 'K' have been indicated in terms of 1/16" in the following table :-

TABLE I-Values of K, the max. versine increment in 31 ft. for different values of Cant increment and speed.

Max. permissible speed in M.P.H.	Values of K in terms of 1/16"									
	Meter Gauge					Broad Gauge				
	M=0	M=1/8" 1/4"	M=3/8" 1/2"	M=1/2"	M=3/4"	M=0	M=1/8" 1/4"	M=3/8" 1/2"	M=1/2"	M=3/4"
65	..	..	..	..	..	2	3	4	4	5
60	..	..	..	..	..	3	4	4	5	7
55	..	..	..	..	..	4	5	6	6	7
50	..	..	..	..	..	5	6	7	8	9
45	9	10	12	14	16	7	8	13	11	12
40	12	14	16	18	20	10	12	13	15	17
35	17	20	22	25	28	15	17	19	21	24
30	25	29	32	35	40	24	27	30	33	35
25	40	45	50	55	60	41	45	50	54	58
20	69	76	83	90	97	81	87	94	100	107
15	135	146	157	168	179					

8.7 SELECTION OF VERSINES FOR THE TRANSITIONS:

8.7.1 The versines at the various stations in the transition should be proposed as follows, keeping in view that the versine increment between two stations does not exceed the value 'K' given in the table I in para 8.6 above.

- 8.9 The slews and the final versines at each station should now be computed according to the details procedure indicated in para 807 (D)(a) to (c) of the I.R.W.W. Manual.
- 8.10 The correct superelevation to be provided on the circular portion of the curve should now be computed to the nearest $\frac{1}{4}$ " as in para 8.3 above and at each station on the transition to the nearest $\frac{1}{8}$ " (It will be seen that the variation from the values determined in para 8.3 above will be very minor). In order to ensure this, it would be necessary to supply cant boards to the gangs made in steps of $\frac{1}{8}$ ".

9. SLEWING OF THE CURVE TO THE REVISED ALIGNMENT:

9.1 The alignment of the realigned curve should be staked out with a steel tape by driving on the cress rail posts of about 4'-0" in length to a depth of about 3'-0" below the cress level.

9.2 These pegs should be fixed on the inner cress square to the track and in level with inner rail with the rail flange parallel to the track at exact one gauge distance from the outer edge of the inner rail.

9.3 The correctness of the rail pegs at this stage should be checked by reasuring the versines on these pegs and verifying that they correspond with the final versines of the realignment. In case of any minor difference, the pegs should be adjusted accordingly and the portion below the cress level concreted with either lime concrete or cement concrete and it should be seen that the pegs are well set in their final correct position.

9.4 The curve should then be correctly slewed to the alignment of the pegs.

9.5 The slewing should be done to $1/8$ " accuracy and actual versines again taken to ensure that they accord with the final versine of the realigned curve.

9.6 Along with slewing, of the curve the correct superelevation at each station as calculated in para 8.10 above should be given to accord with the curvature, particular attention being paid to the run-off on the transitions.

9.7 The alignment rail pegs (which are also known as 'recovery posts' as indicated in para 9.2 will be provided at every 31 ft. on the transition length, starting with the tangent point, and at every 62 ft. on the circular portion.

9.8 The superelevation of the outer rail or the rails will be indicated by a vertical notch cut on top of these pegs.

9.9 The rail pegs on the circular portion shall be painted white and these on the transition portion shall be painted red.

10. ^RPOST REALIGNMENT ATTENTION:

10.1 A curve after realignment should be given at least two or three through packings in order to bring the track to proper running condition, before removing the speed restriction, if any, imposed during the realigning operations.

10.2 The final versines of the curve must be measured again after realignment in order to ensure that the curve as realigned is satisfactory with uniform curvature.

11. CURVE BOARDS:

At each end of the curve, curve boards should be provided at the tangent points by means of name plates fixed to a rail post. The curve particulars shall be written with black letters on white back ground on these plates as indicated in the sketch in Annexure I.

12. RECORDING ENTRIES IN CURVE REGISTERS:

12.1 Assistant Engineers shall obtain the curve registers on requisition from Press Superintendent and supply to the PWIs.

12.2 Whenever the curve is measured in accordance with instructions laid down in para 3 above, the versine and cant along with the date of reading should be recorded in the Curve Register. Then immediately after stringlining, the corrected versines and cant along with the date of realigning should again be recorded in the adjacent column. This will form one set of readings. The details of computation of versines shall, however, be kept in the office file as usually. By such recording it will be easy to spot any persistent defect which may be due to reason other than more curvature or superelevation of the curve. The root cause in such cases should be investigated and defects rectified. Such a record will also give a history of the condition of the maintenance of the curve.

12.3 The entries in the curve register should be made by the PWIs expeditiously and the record kept upto-date. The curve registers must be kept to the PWIs with them always and put up to the Inspecting Officers whenever required.

13. Sample calculations for a curve realigned as per above method are enclosed as Annexure V.

ANNEXURE-II
(Para 806)

BROAD GAUGE (Transitioned curves)
Cant Deficiency allowed = 3"

Degree of curve	1°	2°	3°	4°	5°							
Radius(in ft.)	5730	2865	1910	1432	116							
Speed limit from formula in 6R of Recommended dimensions	111.34 MPH	77.14 MPH	61.66 MPH	52.21 MPH	45.64 MPH							
1.5/R-220 =												
Maximum :3/4th permis- :of sp- ible :eed in speed of :Col.1 section :subject in MPH :to :minimum :of 30MPH:	Ca-:Sp- nt :eed in :in (1/ 8")	Ca-:Sp- nt :eed in :in (1/ 8")	Ca-:Sp- nt :eed in :in (1/ 8")	Ca-:Sp- nt :eed in :in (1/ 8")	Ca-:Sp- nt :eed in :in (1/ 8")							
	1	2	3	4	5	6	7	8	9	10	11	12
65	50	15	79.7	31	66.9	44	60.7	44	52.21	44	45.64	
60	45	12	76.6	25	68.2	37	57.5	44	52.21	44	45.64	
50	40	10	74.4	20	59.8	30	54.1	39	50.6	44	45.64	
45	35	8	72.2	15	56.3	23	50.3	30	46.9	28	44.9	
40	30	6	69.9	11	53.4	17	47.2	22	43.3	28	41.1	
35	30	6	69.9	11	53.4	17	47.2	22	43.3	28	41.1	
30	30	6	69.9	11	53.4	17	47.2	22	43.3	28	41.1	

Cols. 3,5,7,9 & 11 indicate the cant to be provided in units of 1/8th inch for speed in col. 2 or limiting speed whichever is less.

Cols. 4,6,8,10 & 12 indicate the speed in M.P.H. at which trains could run without exceeding cant deficiency for this cant or limiting speed whichever is less.

- Note:**
1. Superelevation assessed for 3/4th of maximum permissible speed of the section or the safe speed, whichever is less & subject to maximum permissible cant values.
 2. Superelevation figures rounded off to 1/8".
 3. The maximum limit of superelevation which is normally 3 1/2 " for B.G., where provided may be reduced suitably on considerations of traffic and railwear.
 4. For sharper curves, similar calculations may be continued.
 5. Similar calculations may be made for curves of various radius for varying speeds.

ANNEXURE III (Para 806)
METRE GAUGE (Transitioned Curves)
 Cant Deficiency allowed = 2".

Degree of Curve	1°	2°	3°	4°	5°	6°							
Radius (in ft.):	5730	2865	1910	1432	1146	955							
Speed limit													
in miles													
per hour													
from formula	111.34	77.14	61.66	52.21	45.64	40.67							
1.5/D-220													
(110R or													
recommended													
dimensions													
Maxi- : 3/4th	:Ca	Sp-:Ca	Sp-:Ca	Sp-:Ca	Sp-:Ca	Sp-:Ca							
imum : of	:nt	eed:nt	eed:nt	eed:nt	eed:nt	eed:nt							
permi-speed	:in	:in	:in	:in	:in	:in							
scible:in	:(1"	:(1"	:(1"	:(1"	:(1"	:(1"							
speed : Col.1	: 8)	: 8)	: 8)	: 8)	: 8)	: 8)							
of Sec-subj-													
ion in ect to													
MPH : Minimum:													
: of 30													
: MPH													
1	2	3	4	5	6	7	8	9	10	11	12	12	14
50	40	6	77.5	12	61.8	18	55.6	23	51.6	28	45.6	28	40.67
45	35	4	73.3	9	58.5	13	51.4	18	48.2	22	45.6	27	40.67
40	30	3	72.1	7.56	10	48.7	13	44.5	16	41.8	20	40.5	
35	30	3	72.1	7	56.1	10	48.7	13	44.5	16	41.8	20	40.5
30	30	3	72.1	7	56.1	10	48.7	13	44.5	16	41.8	20	40.5

Cols. 3, 5, 7, 9, 11 & 13 indicate in the cant to be provided in units of 1/8th inch for speed in col. 2 or limiting speed whichever is less.

Cols. 4, 6, 8, 10, 12 & 14 indicate the speed in MPH at which trains could run without exceeding cant deficiency for this cant or limiting speed whichever is less.

Note: 1. Superelevation assessed for 3/4th of maximum permissible speed of the section or the safe speed, whichever is less and subject to maximum permissible cant-values.

2. Superelevation figures rounded off to 1/8".

3. The maximum limit of superelevation which is normally 3/2" for M.G. where provided, may be reduced suitably on considerations of traffic and railwear.

4. For sharper curves, similar calculations may be continued.

5. Similar calculations may be made for curves of various radius for varying speed.

ANNEX IV

1. Curve No.

2. From Km...To...

3. Between stations ... & ...

4. Direction of curve with reference to increasing mileage Lef hand/Right hand

5. Transitioned..Yes/No

6. Degree

7. Radius

8. Max.Cant provided

9. Length of curve

(a)Transition

(b)Circular

10. Gradient

(a)1 in KM..to KM..

(b)1 in KM..to KM..

12.Track particulars:-

(a)Rail...lbs.

(b)Sleepers..

(c)Sleeper density

(d)Staggered joints

(e)Ballast cushion

(f)A chors(if wooden sleepers)

Note:i)Versines are to be measured in 1/16' units on 62' chord.

ii)Realignment (i.e.,by string lining)or spot adjustment should be written below the date of survey of versines.

Date							
Versines	Read	Corrected	Read	Corrected	Read	Corrected	Read
and cant	Ver- Ca-	Ver- Ca-	Ver- Ca-	Ver- Ca-	Ver- Ca-	Ver- Ca-	Ver- Ca-
Read &	sine nt	sine nt	sine nt	sine nt	sine nt	sine nt	sine nt
Corrected							

Corrected	Read	Corrected
Ver- Cant	Ver- Cant	Ver- Cant
sine	sine	sine

Annexure - V

Radius 3056 ft.
Max. per. speed 72 Km. P.H.

The computations made in order to determine the revised alignment are 11 outlined below and the results entered in columns 3 to 13.

DETERMINATION OF REVISED ALIGNMENT:

1. APPROXIMATE DEGREE OF CIRCULAR CURVE:

A look at the existing versines will show that versines from stations 5th to 17th are more or less of uniform value and, therefore the main body of the circular curve lies from Stns. 5th. to 17th.

Sum of versines on the main body i.e., stations 5th to 17th = 387.

∴ approximate versine of the circular curve = $\frac{387}{13} = 30$

∴ degree of the circular curve = $= \frac{30}{16} = 1.875^\circ$

∴ radius of the circular curve = $= \frac{5730}{1.875} = 3060'$

2. SUPERELEVATION FOR CIRCULAR CURVE:

(a) Actual superelevation 'E' required for curve of $1.875^\circ = 1 \frac{1}{8}"$ (approx.) from Annexure III)

Rounding off to the nearest $\frac{1}{4}"$, $E = 1 \frac{1}{4}"$

(b) Equilibrium superelevation of the curve for V_m of 45 mph is given by $C = \frac{GV}{1.25R} = \frac{3.28 \times 45^2}{1.25 \times 3060} = 1.74"$

(c) Cant Deficiency $D = 1.74 - 1.25 = 0.490"$.

3. LENGTH OF THE TRANSITION AS PER PARA 807(A) OF THE I.R.W.W. MANUAL IS THE HIGHEST OF (A) $L = E \times V_m$, (b) $L = D \times V_m$ and (c) $L = 60 \times E$

For V_m of 45 mph the highest value in this case is given by $L = 60 \times E$.

∴ Length of transition = $60 \times 1 \frac{1}{4} = 74.0'$

Rounding off to next higher multiple of 31' length of transition = 93 ft.

It is, however, better to adopt a still longer transition length, if possible.

In this curve, it is easily possible to provide a transition length of 5 stations.

∴ rate of change of actual cant from one stn. to the next $\phi = 1 \frac{1}{8} \times \frac{1}{5} = \frac{9}{40}''$ or $\frac{1}{4}''$ (rounding off to the nearest $\frac{1}{8}''$)

From table I of para 8.6.3, value of K., the max. permissible versine increment in 31 ft. for a value of $M = \frac{1}{4}''$ (M.S.) = 16

Proposed Versines:

Sum of the total versines = 474

Adopt a versine of 30 on the circular curve (which is the average versine as existing on stns. 5 to 17).

∴ Value of m (see para 8.7.1) the versine on the circular curve = 30

As the transition now fixed will consist of 5 stns. the value of n, the number of stn. where the transition joins the circular curve = 5

∴ According to para 8.7.1, the proposed versine on the transition are as follows:-

1st stn. (Tangent point) $= \frac{m}{6(n-1)} = \frac{30}{6(5-1)} = 1.25$ or 1.
2nd stn., versine $= \frac{m}{6(n-1)} = \frac{30}{6(5-1)} = 7.5$ or 7. (*)

(*) lower value taken to see that versine on T.P. is as nearly as possible 1/5th of the versine at the next station).

$$\begin{aligned} \text{3rd stn., versine} &= 2 \times 7.5 = 15 \\ \text{4th ,, ,,} &= 3 \times 7.5 = 22.5 \text{ or } 23. \\ \text{5th ,, ,,} &= \frac{30-30}{645-1} = 30-1.25 = 28.75 \text{ or } 29. \end{aligned}$$

Max. versine increments in the proposed versines determined above is (15-7) or (23-15) i.e., 8, and is less than the value of K= 16, determined above. Therefore, the versines as proposed above for the transition will be suitable.

$$\begin{aligned} \text{Now, sum of versines on the transition} &= 1 + 7 + 15 + 23 + 29 = 75 \\ \text{. . . , on the transitions } 2 \times 75 &= 150 \\ \text{. . . , circular portion} &= 474 - 150 = 324 \\ \text{. . No. of stns. on circular portion} &= \frac{324}{30} = 10.8 \text{ (rounding off to next whole number)} \end{aligned}$$

In order to have an exact no. of 11 stns. with a versine of 30 each on the circular portion, we have to adopt, 11x30 or 330 as sum of versines on the circular portion and carry out minor adjustments on the transition versines to obtain a total of 474 on the entire curve. (The sum of existing and proposed versines must be same).

We may, therefore adopt the versines as 1,6, 14,22 and 29 on the transition giving a total of 72.

- the total of proposed versines on the entire curve, now = $11 \times 30 + 72 \times 2 = 474$, which is the same as the sum of existing ones .

The computation by finding out 1st summation and 2nd. summation, applying correcting couples to ensure that the latter is Zero, have been indicated in column 5 to 9. The slews which are double the second summation(col.10) at each station are given in col.(11).

Full versines are indicated in col.12.

COMPUTATION OF SUPERELEVATION:

For a max.versine of 30 on the circular curve, degree of curve = 1.875°

- .. superelevation to be provided as per Annexure III for a speed of 45 MPH
= $1\frac{1}{8}''$ or $1\frac{1}{4}''$ rounding off to the nearest $1\frac{1}{4}''$)
- No. of stations on transition = 5
- .. Superelevation increment at each stn.
= $1\frac{1}{4}'' \times 1\frac{1}{5}$ or $1\frac{1}{4}''$ (rounding off to the nearest $1\frac{1}{8}''$).

Superelevation at stn. 1 (T.P.)		= 0
" " 2		= $1/4"$
" " 3		= $1/4" + 1/4" = 1/2"$
" " 4		= $1/2" + 1/4" = 3/4"$
" " 5		= $3/4" + 1/4" = 1"$
" " 6		= (on the circular curve)
		= $1" 1/4" = 1 1/4"$

In a similar manner S.E. at stns. 17 to 21 is also determined. The values of S.E. so determined are indicated in col. 13 against each stations.

...o...