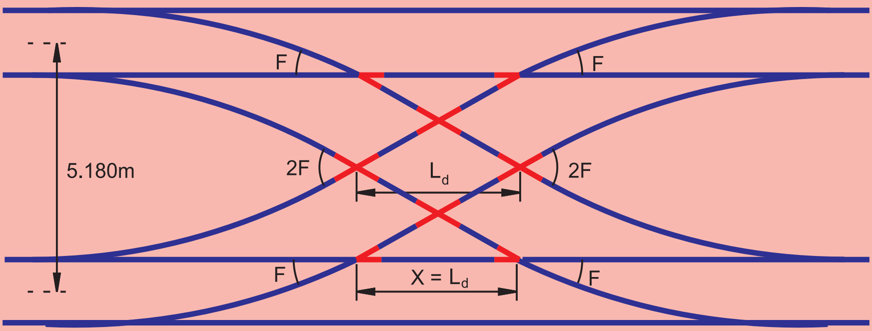
ज्ञान ज्योति से मार्गदर्शन

To Beam As A Beacon of Knowledge

Layout Calculations



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Foreword to Third Edition

Layout Calculations, as the name indicates, are the set of calculations for the various layouts so that the same can be correctly laid in the field. Deficiencies can be nipped in the bud if adequate care is taken by laying turnouts accurately after carrying out correct layout calculations. In this edition emphasis has been given on PSC layout as most of the layouts have already been converted to PSC layout and all future layouts will be only with PSC layout. One new chapter has been added for laying typical connections and special type of layout on PSC such as WYE connection, Diamond connection, Triangle connection for bypass, double junction, and gathering or ladder lines. Graphical method for laying turn out between any two undefined alignments has also been added which may be of good help to field Engineers.

The book has been revised and updated by Shri. R K Bajpai, Sr. Professor, Track-2 incorporating latest information and corrected formulas related to layout/turnout calculations.

I hope that the book on layout calculations will go a long way in fulfilling the need of railway Engineers for better designing of yards by correct laying of layouts.

The suggestions for improvement are welcome.

Pune — **Ajay Goyal**
November 2019. — **Director / IRICEN**

Foreword to Second Edition

The knowledge of turnout geometry and layout is an essential prerequisite for laying of new turnout, or improvement of existing layout geometry. A good layout results in improved riding quality as well as reduction in maintenance efforts. The calculations for Layout is not very complex provided necessary information/data, and methodology are available beforehand. This publication on layout calculation also includes layout calculation for improved turnout structure like PSC layout on 60kg/ 52kg PSC curved switches with elaborated and improved and legible diagrams. While laying out a turn out relevant provisions of IRPWM and Schedule of Dimensions to be always kept in mind which are incorporated in the book for ready reference.

The software Programme developed by Shri M.S. Ekbote, ex. AM (Civil) Railway Board could be of immense help for calculations for various yard layouts connections, cross over etc. available at IRICEN web site.

I hope this book will extremely useful for field engineer for understanding in layout calculation and apply it for improving reliability of assets, reduction in maintenance requirements as well as improved riding quality.

October - 2016

N. C. Sharda
Director
IRICEN

Preface to Second Edition

The maintainability and riding quality over a turnout depends largely on how accurately it is laid and maintained. It is a known fact that yard may require various combinations of turnouts (i.e. switches, leads & crossings), with curves and straights, to transfer trains from one track to another or enable trains to cross other tracks. For satisfying the various geometrical features of the layouts, one has to perform variety of trigonometric calculations .Understanding of Layout Calculations is necessary, all possible problems and proposed solutions are greatly covered in existing layout calculation book published by IRICEN.

This revised publication on layout calculation includes layout calculation for improved turnout structure like PSC layout on 60kg/ 52kg PSC curved switches with elaborated and improved and legible diagrams by removing old 90lbs layouts. Further for laying out a turn out relevant provisions of IRPWM and Schedule of Dimensions to be always kept in mind, are incorporated in the book for ready reference.

I am grateful to Shri N. C. Sharda, Director, IRICEN for giving me the opportunity for revising the contents and also for his encouragement and guidance from time to time for bringing out this publication. Thanks are also due to Shri Suresh Pakhare Professor (Track) IRICEN, now for checking the drafts and for giving his valuable suggestions. I am thankful to faculty and staff of IRICEN who have contributed immensely for this publication. Efforts taken by Shri Pravin Kotkar SI/ T in correcting the draft and scrutinizing the manuscript are also appreciated.

Suggestions from readers to improve the contents are welcome and can be sent to mail@iricen.gov.in which will be taken into account while bringing future editions.

October - 2016

N. K. Mishra
Associate Professor/Track
IRICEN

Foreword to First Edition

The maintainability and riding quality over a turnout depend largely on how accurately it is laid and maintained. Deficiencies can be nipped in the bud if adequate care is taken by laying turnouts accurately after carrying out layout calculations.

Layout calculations, as the name indicates, are the set of calculations for the various yard layouts so that the same can be correctly laid in the field. Layout calculations become more important in case of yard remodelling or designing a new yard. These calculations are intricate in nature and require considerable efforts on the part of field engineers which often get neglected due to other engagements in the field and therefore, this item of work does not get proper attention.

Railway Engineers had been expressing the need for bringing out a book on "Layout Calculations" which was out of print since long. Special efforts have been taken to make this book more effective by incorporating colored drawings of the layouts developed by using Auto Cad software. Worked out examples on practical situations commonly met with, have also been given for better understanding of this subject.

Another special feature of the book is the inclusion of a software on Layout Calculations, which had been developed by Shri M. S. Ekbote, Ex. AM(Civil Engineering), Railway Board, using Visual Basic with interactive and user friendly interface.

I hope that this book on Layout Calculations will go a long way in fulfilling the need of railway engineers for better designing and correct laying of layouts.

Shiv Kumar
Director
IRICEN

Acknowledgment to First Edition

Subject of "Layout Calculations" is being covered in various courses being held at IRICEN. In every course at IRICEN, trainee officers have expressed the need of a book on Layout Calculations as the earlier publication had become out of print. Besides, several developments had taken place in the field of turnout such as PSC layouts. Considering the requirement of the field engineers, the entire book has been rewritten. Apart from the theory and illustrations the book contains several new features such as coloured drawings, interpretations of trigonometric formulae and a software on Layout Calculations

We are very much grateful to Shri Abhay Kumar Gupta, Professor/ Track -1 for the proof checking of the entire book.

We are also very much grateful to Shri M.S. Ekbote, Ex. AM(Civil Engineering), Railway Board, for his active support for rewriting the chapter on Scissors Cross-over and developing a Software Program on Layout Calculations which is available on a CD attached with this book.

Above all, the authors are very much grateful to Shri Shiv Kumar, Director, IRICEN for his encouragement and guidance.

Abhai Kumar Rai
Professor/Works
IRICEN

Praveen Kumar
Professor/Computers
IRICEN

Common Abbreviations used in the Book

SJ/SRJ	Stock joint/stock rail joint
TTS	Theoretical toe of switch
ATS	Actual toe of switch
β	Switch angle
L	Lead
SL	Actual switch length
TSL	Theoretical switch length
t	Designed thickness of the switch at toe
d	Heel divergence
ANC	Actual nose of crossing
TNC	Theoretical nose of crossing
HOC	Heel of crossing
w	Length of straight leg of crossing ahead of TNC upto the tangent point of lead curve
F	Crossing angle
G	Gauge of the track
D	Distance between the track
R_m	Radius of the outer rail of curved main line
R_c	Radius of the outer rail of the turn in curve/ connecting curve
R	Radius of the outer rail of the lead curve

OL	Over all length of the layout
S	Length of straight portion outside the turnout
A	Distance from 'SJ' to the point of intersection in a turnout measured along the straight
B	Distance from the point of intersection to the heel of crossing measured along the straight
K	Distance from TNC of the crossing to the heel of crossing measured along the straight
c	Distance from SRJ to ATS
B(modified)	Distance from point of intersection of two center lines of turnout side & main line side to end of last common long sleeper beyond HOC
K(modified)	Distance from TNC to end of last common long sleeper beyond HOC

CONTENTS

Chapter 1

Turnouts

1.0 Introduction

1.0 (a) - Turnout is an assembly of track components which provide the means by which a train may be transferred from one track to another track. To be more specific, as per ORE report on Q. No. D.72, the term "Turnout" means a layout permitting the passage of rolling stock on two or more routes from one common route. In its simplest form, i.e. where only two routes are involved, it consists of a pair of switches (one right hand and the other left hand) and a common crossing assembly (composed of a common crossing, two wing rails and two check rails), together with lead rails connecting the two routes. As desired, the crossing ensures unobstructed flange way clearances for the wheels at the intersection between the left hand rail of one route and the right hand rail of the other.

Turnouts are, therefore, the most sophisticated component of railway track structure. To design and permit different types of turnouts to meet the varied requirements of operations has always been a challenging task for the permanent way engineer. Turnouts may take off from a straight track or a curved track.

A turnout has, therefore, three distinct portions (Fig 1.1);

- Switch Assembly
- Lead Assembly
- Crossing Assembly

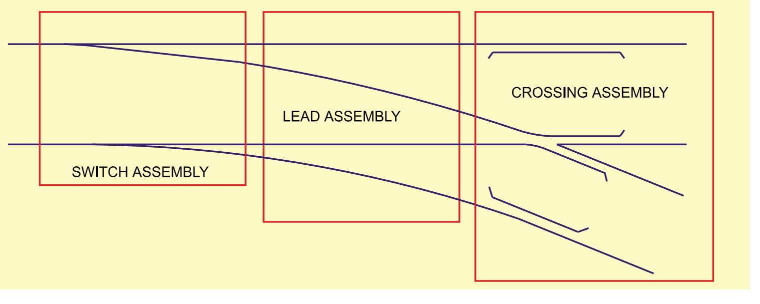


Figure 1.1: Turnout

Main features of a turnout are as shown in Fig 1.2.

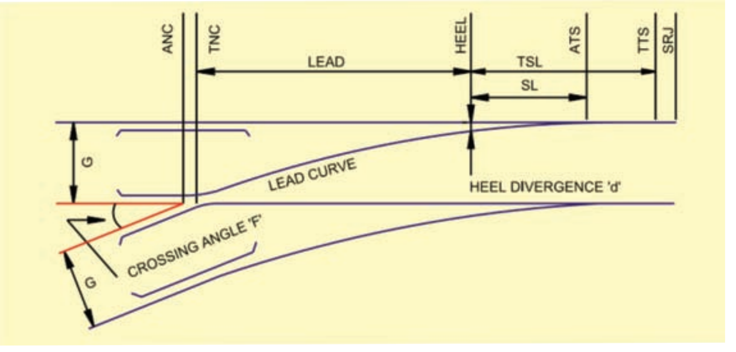


Figure 1.2: Main features of a turnout

The switch assemblies in use on Indian Railways are classified purely based on their geometry as shown below:

- **IRS- Straight Switches (Fig 1.3)**

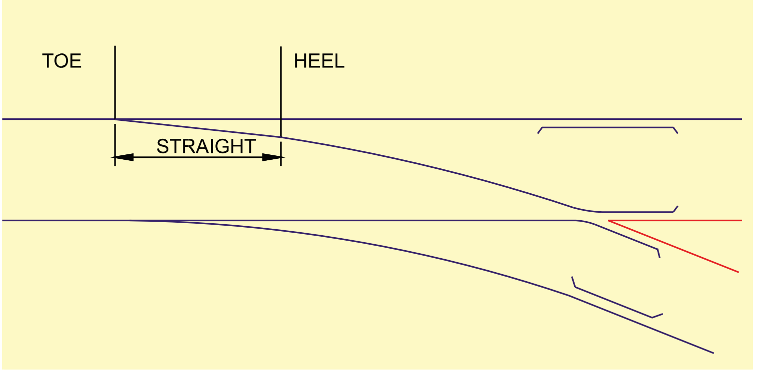


Figure 1.3: Straight switches

- **IRS- Partly Curved Switches (Fig 1.4)**

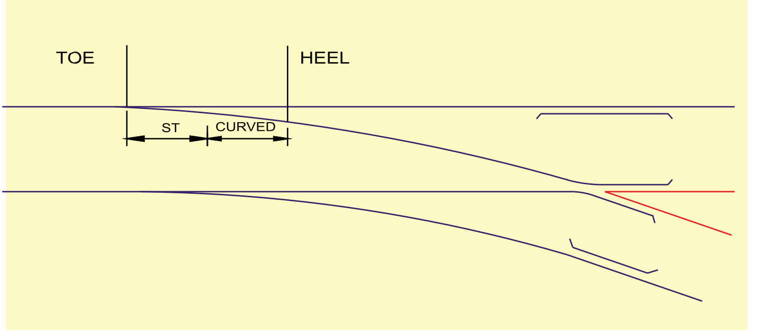


Figure 1.4: Partly curved switches

- **IRS-Curved Switches**

  The curved switches are further classified into the following types:

- **Non - Intersecting type (Fig 1.5a)**

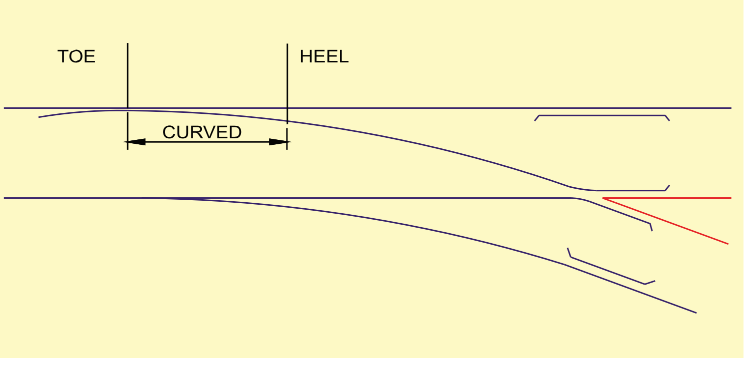


Figure 1.5a : Non-Intersecting type

- **Intersecting type (Fig 1.5b)**

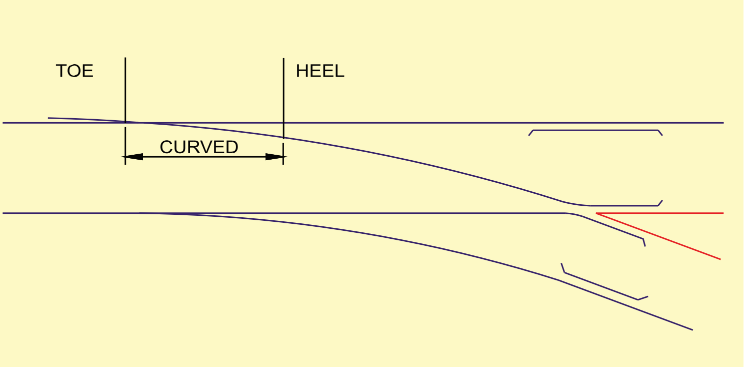


Figure 1.5b : Intersecting type

- **Tangential type (Fig 1.5c)**

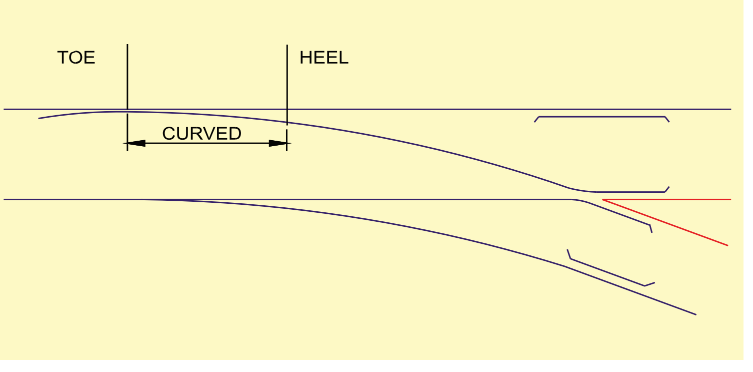
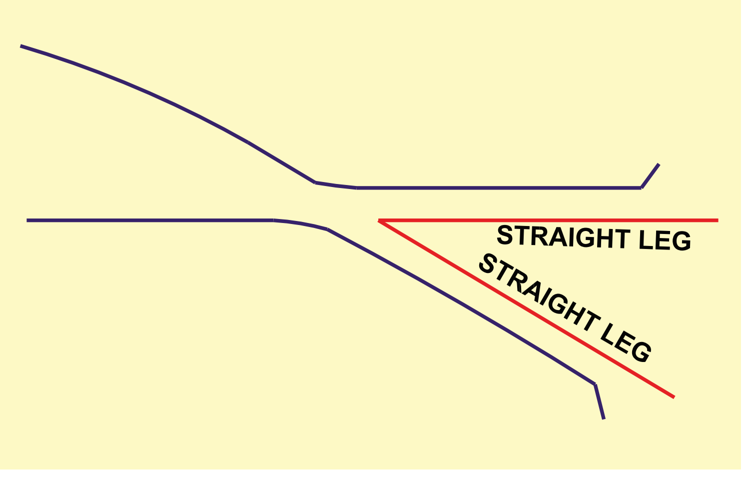
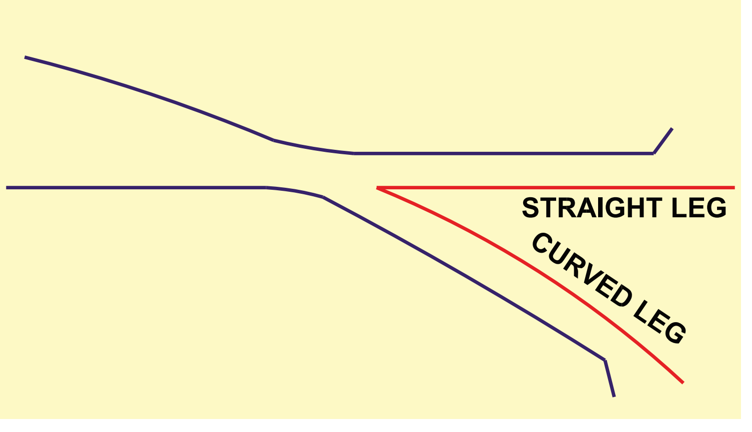


Figure 1.5c : Tangential type

Crossing may either be of the 'Straight' type or of the 'Curved' type as shown in Fig 1.6.



Straight crossing



Curved crossing

Figure 1.6: Type of crossing

In the latter case, one of the legs of the crossing is curved to the same radius as the lead curve, or in other words, the lead curve continues through the crossing. This naturally results in a flatter lead curve than in the case of a straight crossing for a given crossing angle. However, on Indian Railways only straight crossings are in use. Crossing can be of two types on the basis of material i.e. either Built Up (BU) or Cast Manganese Steel Crossing (CMS) crossing.

Lead curve has to be tangential to the switch at its heel and to the crossing at its toe so as to avoid kinks in the geometry. Subject to these two constraints, the lead curve may take one of the following forms;

- Simple Circular Curve
- Partly Curved, having a straight length near the crossing
- Transition Curve

By combining different types of switches and crossings with different forms of lead curves, a large variety of geometrical layouts can be obtained, each with its own characteristics of lead length and lead radius. The standard practice in India has so far been to use one particular switch with a particular crossing.

The standard Layouts of various Turnouts in use on Indian Railways are shown in Table 1.1

Table 1.1

S.No	**Crossing Angle**	**Types of Switches**			
		B.G.		**M.G.**	
1.	1 in 8.5	Straight	Curved	Straight	Curved
2.	1 in 12	Straight	Curved	-	Partly Curved
3.	1 in 16	-	Curved	-	Curved
4.	1 in 20	-	Curved	-	-
5.	1 in 24*	-	Curved	-	-

* Under Standardisation

1.0 (b) - Provisions of Indian Railway Permanent Way Manual (IRPWM)

Layout Calculations should be performed keeping in view the relevant provisions as contained in para 410 (2) & 410 (3) and 412 of IRPWM. The same has been reproduced for ready reference.

Para 410(2) of IRPWM

Turnouts on running line with passenger traffic :- Turouts in running lines over which passenger trains are received or despatched should be laid with crossing, not sharper than 1 in 12 for straight switch. However, 1 in 8.5 turnout with curved switches may be laid in exceptional circumstances, where due to limitation of room, it is not possible to provide 1 in 12 turnouts. Sharper crossings may also be used when the turnouts is taken off from outside of a curve, keeping the radius of lead curve within the following limits:

Gauge	Minimum Radius of Lead Curve
BG	350 m
MG	220 m
NG	165 m

Where it is not practicable to achieve the radius of curvature of turn in curves as specified above on account of existing track centres for turnout taking off from curves, the turn in curves may be allowed upto a minimum radius of 220m for BG and 120m for MG subject to the following:

a) Such turn in curves should be provided on PSC or steel trough sleepers only, with sleeper spacing same as that for the main line.

b) Full ballast profile should be provided as for track for main line.

Emergency crossovers between double or multiple lines whch are laid only in the trailing direction may be laid with 1 in 8.5 crossings.

In the case of 1 in 8.5 turnouts with straight switches laid on passenger running line, the speed shall be restricted to 10 Kmph. However, on 1 in 8.5 turnouts on non passenger running lines, speed of 15 Kmph may be permitted.

Para 410 (3) of IRPWM

Speed over interlocked turnouts : - Speed in excess of 15 kmph may be permitted for main line side of interlocked turnouts only under approved special instructions in terms of GR 4.10. In the case of 1 in 8.5, 1 in 12 and flatter turn-outs provided with curved switches, higher speeds as permitted under approved special instructions may be allowed on the turnout side, provided the turn-in curve is of a standard suitable for such higher speeds. While permitting speed beyond 15 kmph, provisions of Para 410 (4) may be kept in view. The permissible speed on turnouts taking off on the inside of the curve should be determined by taking into consideration the resultant radius of lead curve which will be sharper than the lead curve for turnouts taking off from the straight. 1 in 8.5 turnouts should not be laid on inside of curves.

Para 412 of IRPWM

No change of superelevation over turn-outs : -

There should be no change of cant between points 20 metres on B. G.15 meters on M.G., and 12 metres on N. G. outside the toe of the switch and the nose of the crossing respectively, except in cases where points and crossings have to be taken off from the transitioned portion of a curve.

Normally, turn-outs should not be taken off the transitioned portion of a main line curve. However, in exceptional cases, when such a course is Unavoidable a specific relaxation may be given by the Chief Engineer of the Railway. In such cases change of cant and/or curvature may be permitted at the rates specified in para 407 of IRPWM or such lesser rates as may be prescribed.

1.0 (c) - Provisions of schedule of dimension 2004 (Revised)
Points and crossings:
Maximum clearance of check rail
opposite nose of crossing **48mm**

Note :

(a) In case of turnouts laid with 1673mm gauge, the clearance shall be 45mm instead of 48mm

(b) In the obtuse crossing of diamond crossings, the clearances at the throat of the obtuse crossing shall be 41mm

Minimum clearance of check rail opposite nose of crossing **44mm**

Note :

(a) In case of turnouts laid with 1673mm gauge, the clearance shall be 41mm instead of 44mm

(b) In the obtuse crossing of diamond crossings the clearance at the throat of the obtuse crossing shall be 41mm

Maximum clearance of wing rail at nose of crossing **48mm**

Note :

In case of turnouts laid with 1673mm gauge, the clearance shall be 45mm instead of 48mm.

Minimum clearance of wing rail at nose of crossing **44mm**

Note :

In case of turn outs laid with 1673mm gauge, the clearance shall be 41mm instead of 44mm.

Minimum clearance between toe of open switch and stock rail

(i)	For existing works	**95mm**
(ii)	For new works or alteration to existing works	**115 ± 3mm**
(iii)	For thick web switches	**160mm**

Note :

The clearance can be increased upto 160mm in curved switches in order to obtain adequate clearance between gauge face of stock rail and back face of tongue rail.

Minimum radius of curvature for slip points, turnouts of crossover roads 218 metres (8 degree)

Note :

In special cases mentioned below this may be reduced to not less than the minimum of

(i) 213m radius in case of 1 in 8.5 BG turnouts with 6.4m over riding switch, and

(ii) 175m radius in case of 1 in 8.5 scissors crossing to allow for sufficient straight over the diamond crossing between crossovers.

Minimum angles of crossing (ordinary) 1 in 16

Note :

Crossings as flat as 1 in 20 will usually be sanctioned if recommended by the Commissioner of Railway Safety.

Diamond crossings not to be flatter than 1in 8.5

Note :

Diamond Crossings as flat as 1 in 10 will usually be sanctioned if recommended by the Commissioner of Railway Safety.

Minimum length of tongue rail 3660mm

Note :

There must be no change of superelevation (of outer over inner rail) between points 18m outside toe of switch rail and nose of crossing respectively, except in the case of special crossings leading to snag dead-ends or under circumstances as approved by Chief Engineer.

1.1 Layout Calculations

A yard may require various combinations of turnouts (i.e. switches, leads & crossings), with curves and straights, to transfer trains from one track to another or enable trains to cross other tracks. Depending upon the requirements, these combinations are known as layouts. For satisfying the various geometrical features of the layouts, one has to perform variety of trigonometric calculations and hence the name **'Layout Calculations'.**

Understanding of Layout Calculations is necessary for fixing the correct position of turnouts with respect to the existing tracks in case of remodelling of an yard or for designing an altogether new layouts. Turnouts can be fixed either by locating Stock Rail Joint(SRJ) or by locating Theoretical Nose of Crossing (TNC). SRJ/TNC can be located by **'Centre Line', 'Outer Rail'** or **'Graphical'** method .

In **'Centre Line'** method, the turnout is represented by center lines of straight and turnout side. This method is primarily used for locating SRJ for the cases when turnouts are taking off from Straight tracks.

In **'Outer Rail'** method, the turnout is represented fully by drawing the left rail and right rail of the turnout. This method is primarily used for locating TNC for the cases when turnouts are taking off from the curved tracks. However, this method is more versatile but cumbersome and can also be used for the cases when turnouts are taking off from straight tracks.

In **'Graphical'** method, the entire drawing will be made on computer by use of relevant drafting software like AutoCAD. After replicating the layout on the computer, all the calculations can be performed graphically. Now a days various advanced softwares are available. MX-Rail is one of the specialized software developed for the railway industry. Yard calculations are one of the powerful feature of this software.

Turn in Curve means the connecting curve starting after the heel of the crossing. This connecting curve may either be simple circular curve, compound curve or reverse curve.(Fig 1.7)

Lead Curve or Turnout Curve (Fig 1.7) means the curve starting from heel or toe of switches (Straight or curved) and extended upto toe of crossing. This value of Lead Curve Radius will become sharper if the turnout is taking off from inside of the main line and will become flatter if the turnout is taking off from outside of the main line.

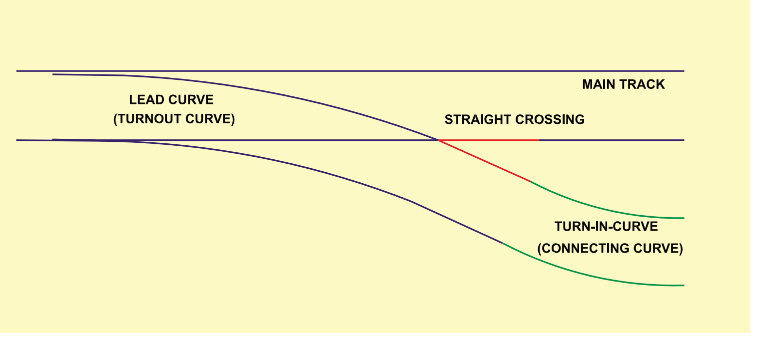


Figure 1.7

Turnouts Taking off from Curved Tracks

Turnouts can take off from the main line track either in the similar flexure or contrary flexure.

$\mathbf{D_M}$ is the degree of main line curve

$\mathbf{D_S}$ is the degree of turnout curve (Lead Curve) when taking off from straight (Fig 1.8a)

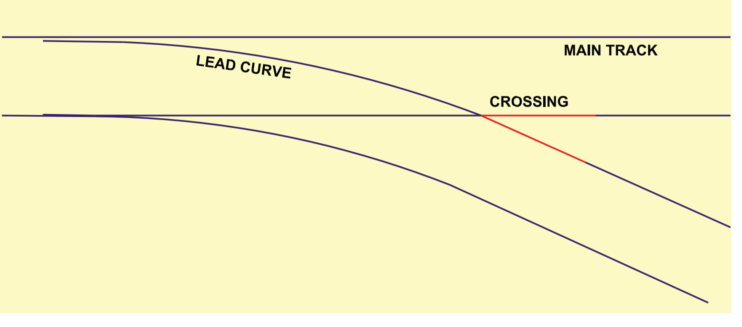


Figure 1.8a : Turnout taking off from a straight track

$\mathbf{D_R}$ is the resultant degree of turnout curve (Lead Curve) when taking off from a curved main line

Exact calculations for lead radius of lead curves for turnouts taking off from the curved main line are complicated in nature and time consuming. The difference in exact calculations and the formulae normally adopted for such layouts is very small and can be ignored for all the practical purposes. But resultant degree of curvatures of lead curves of turnouts taking off from curved main lines depends on whether turnout is taking off from inside or outside of a curved main line.

When $\mathbf{D_S}$ and $\mathbf{D_M}$ deflect in the same direction, it is known as a Similar **Flexure** layout. In this type of layout, crossing lie on the inner rail of the curved main line (Fig 1.8b). Resultant degree of curvature of such leads can be calculated by $\mathbf{D_R=D_S+D_M}$

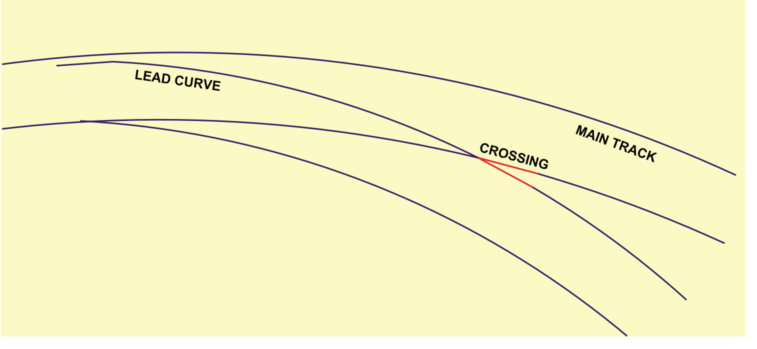


Figure 1.8b : Similar flexure

And if $\mathbf{D_M}$ deflects in a direction opposite to $\mathbf{D_S}$, then it is known as **Contrary Flexure.** In this type of layout, crossing lies on the outer rail of the curved main line. (Fig 1.8c). Resultant degree of curvature of such leads can be calculated by $\mathbf{D_R=D_S-D_M}$

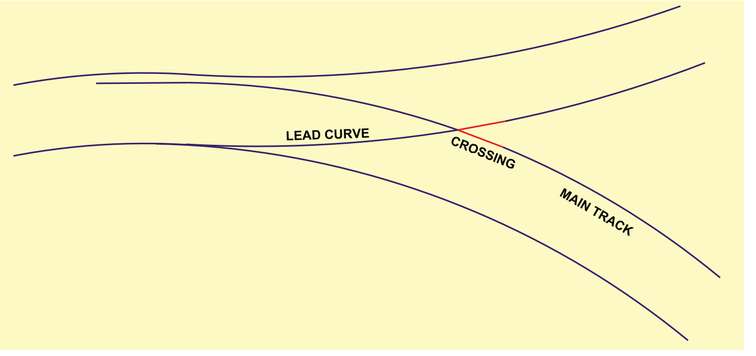


Figure 1.8c : Contrary flexure

When **D**s and **D**M are equal in a contrary flexure, then it is known as **Symmetrical Split.** (Fig 1.8d)

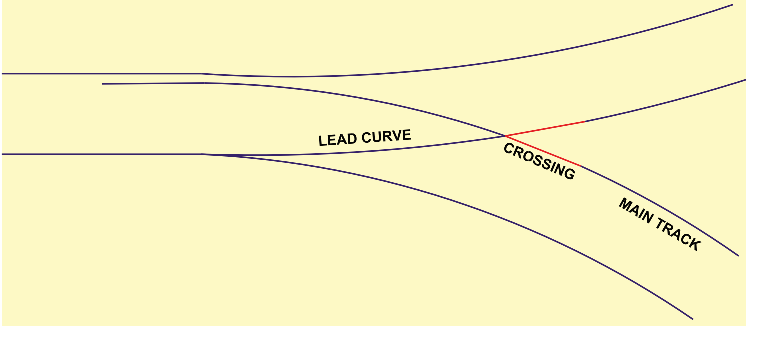


Figure 1.8d : Symmetrical Split

Sometimes it may so happen that crossing lie on the outer rail of the curved main line and even then deflecting in the same direction as that in the similar flexure.(Fig 1.8e) but actually this is a case of contrary flexure Resultant degree of curvature of such leads can be calculated by $\mathbf{D_R = D_M - D_S}$. This can be better explained if we take RH curve as plus and LH curve as minus degree of curvature & similarly RH turnout as plus and LH as with minus degree of curvature, than there will not be any confusion in calculating the resultant degree of curvature. As is figure 1.8e main line curve is a RH curve so degree of curvature for main line is + $\mathbf{D_M}$, turnout is LH so it becomes with - Ds. The resultant degree of curvature will be = Dm - Ds.

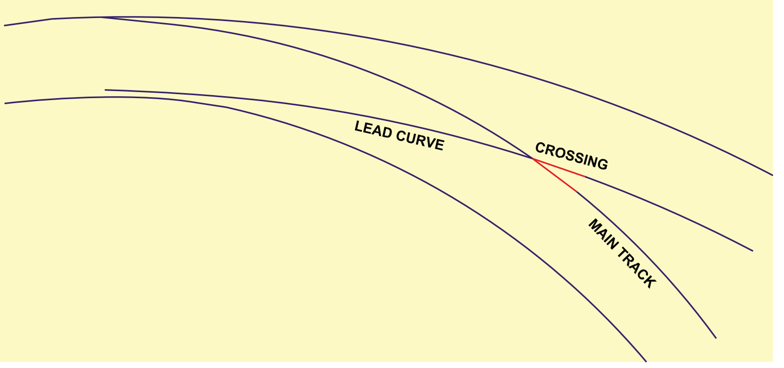


Figure 1.8e : Contrary flexure

From these formulae, resultant radii of lead curves can easily be calculated. Para 410(2) of IRPWM limits the value of the resultant radii of lead curves which can be calculated from the above formulae. It is from this limitation that 1 in 8.5 turnouts can not be laid on inside of the curved main line because in such layout, resultant radii of curvature of the lead curves will not satisfy the limits as given in the Para 410(2). Sharper crossings i.e. more than 1 in 12 can be laid when turnouts taking off from outside of the main line because of the fact that resultant radii of such leads will become flatter and may satisfy the limits as given in Para 410(2)

Radius of the connecting curve or **Turn in Curve** will be calculated from the various trignometrical formulae derived in the subsequent chapters of this book.

1.2 Representation of a Turnout on Centre Line (Ref. Fig. 1.9)

Draw the centre line of the straight main track and on it drop NN_1 perpendicular from N, the TNC of the Xing. Draw the centre line of the turnout track over the crossing length and extend it to meet the centre line of the straight track at P. Drop NN_2 perpendicular from N on this centre line. (Fig 1.9)

On the centre line the turnout is represented by two lines OPN_1W and PN_2Z. In this OW represents the overall length of turnout from SJ to the heel of crossing along the gauge line on which the crossing lies. To locate the turnouts on centre line method, it will be necessary to know the different components of centre line representation.

$$OP=A$$

$$PN_1=PN_2=M$$

$$N_1W=N_2Z=K$$

$$PW=PZ=B=M+K$$

Where **A, M & K** are known as turnout parameters.

Now, let us discuss the characteristics of these turnout parameters:

'M' is the distance from 'P' to the TNC and can be found out as explained below:

$$\Delta PN_1 N, \qquad \tan F/2 = \frac{NN_1}{PN_1} = \frac{G/2}{M}$$

$$\therefore \qquad M = G/2 \ \cot F/2$$

For a particular gauge of track 'G' & angle of crossing 'F', 'M' will become fixed.

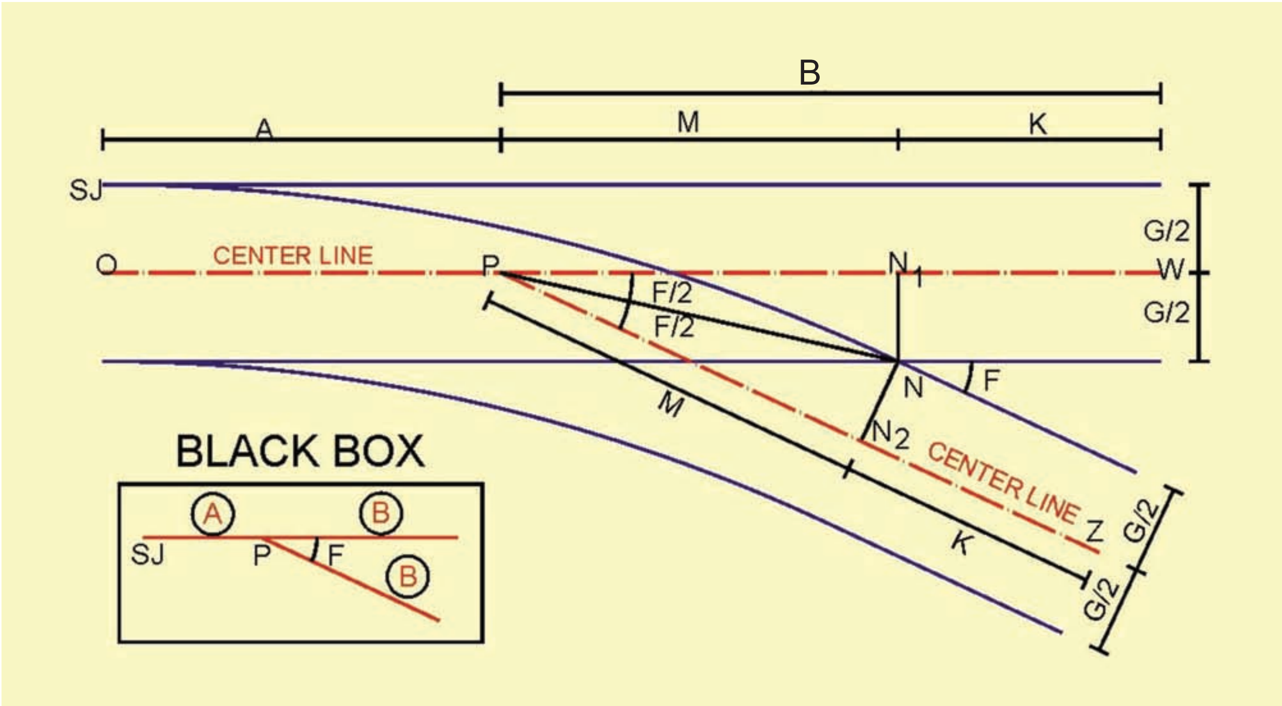


Figure 1.9 : Representation of a turnout on centre line

'K' is the length of the back leg of crossing from theoretical nose of crossing to heel of crossing (HOC) and will be dependent upon type of crossing i.e. Builtup (BU) or CMS crossing. Therefore for a particular type of crossing chosen for a yard, value of **'K'** will be fixed. Likewise, **B=M+K** will also become fixed.

'A' is the distance between 'SJ' to 'Point of intersection **'P'** of center line of mainline and turnout side which is basically dependent upon angle of crossing and not on type of switches or else whole yard will have to be redesigned in case of adopting new design of switches. As discussed earlier that value of **'M'** is fixed for a particular gauge of track & angle of crossing and hence distance between SJ to P i.e **'A'** will also be fixed.

In view of the above, it is therefore obvious that for a given gauge, crossing angle and crossing type (BU or CMS), value of these turnout parameters i.e. **'A', 'M'** & **'K'** are fixed. This can be conveniently understood as a **Black Box** (see Fig 1.9) containing a geometrical figure the dimensions of which are fixed. Then the rest is to fix this **Black Box** with respect to the existing yard geometry so as to satisfy all the geometrical conditions of the yard.

Details of A, B, M, K etc. turnout parameters for different types of turnout with CMS Xing and with Builtup Xing are given in table at annexure II, III & IV. In tables of annexures 'c' is distance from SRJ to ATS. In case of PSC layout, due to fixity of inserts of long common sleepers, a small straight length further extends beyond HOC hence it will not be possible to start the curve immediately after HOC. In PSC thurnouts thus it would be a good practice to add this small straight behind HOC in length of "K" and modify the block box accordingly. This additional straight length can be found out from actual RDSO drawing for 1 in 8.5, 1 in 12 or 1 in 16 layouts. This additional straight for different turnout is as under.

1 in 8.5	PSC Layout	3.3 m
1 in 12	PSC Layout	5.5 m
1 in 16	PSC Layout	9.0 m
1 in 20	PSC Layout	9.15 m

These values are reflected in values of **K** and **B** for PSC layout in annexure - III and given as B (modified) and K (modified).

■ ■ ■

Chapter 2

Lead and Radius of IRS Turnout

Lead and Radius of IRS Turnout

2.1 (a) IRS Turnout with Straight Switches
Calculation of length of lead curve and radius of lead curve

The lead curve in IRS turnout with straight switches are placed tangential to the tongue rail at the heel and to the front straight leg of the crossing. (Fig 2.1)

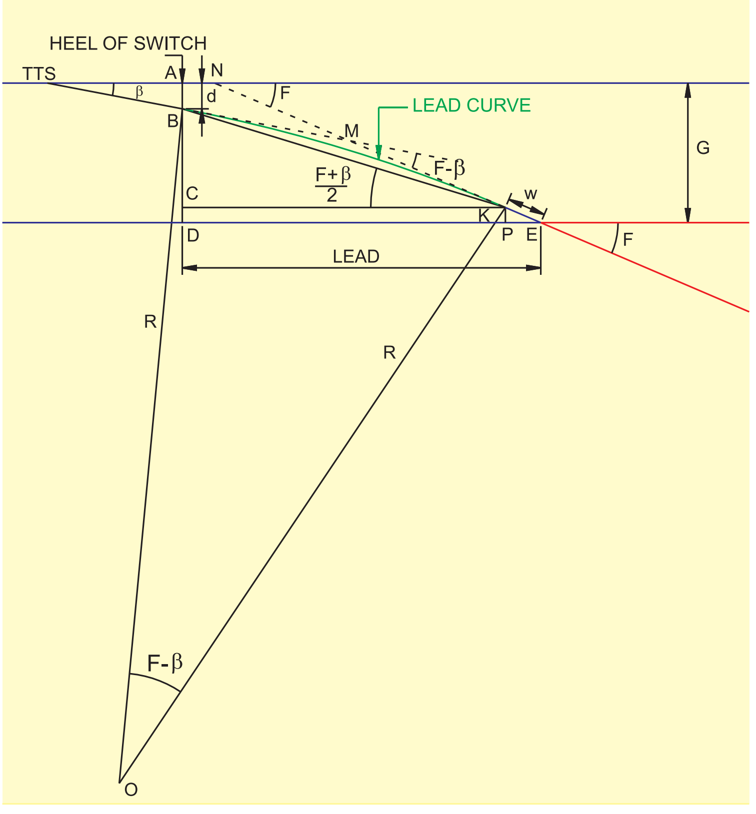


Figure 2.1: IRS Turnout with straight switches

In Δ BMK; BM = MK (Each being tangent length)

$$\angle MBK = \angle MKB = \frac{F-\beta}{2}$$

In Δ BKC; $\angle BKC = F-\left(\frac{F-\beta}{2}\right) = \frac{F+\beta}{2}$

BC = AD - AB - CD = AD - AB - KP = G - d - wSinF

$$KC = BC\ Cot\ \frac{F+\beta}{2} = (G - d - wSinF)\ Cot\ \frac{F+\beta}{2}$$

Lead = DE = DP + PE = KC + PE

$$\text{Lead} = (G\text{-}d\text{-}wSinF)\ Cot\ \frac{F+\beta}{2} + wCosF \qquad (2.1a)$$

In ΔOBK; $\angle BOK = F-\beta$, OB = OK = R

$$BK = RSin\ \frac{F-\beta}{2} + RSin\ \frac{F-\beta}{2}$$

$$\therefore \quad BK = 2RSin\ \frac{F-\beta}{2}$$

also in ΔBKC;

$$BK = \frac{BC}{Sin\frac{F+\beta}{2}} = \frac{G\text{-}d\text{-}wSinF}{Sin\frac{F+\beta}{2}} \qquad (2.1b)$$

equating Eq 2.1a & 2.1 b;

$$2RSin\ \frac{F-\beta}{2} = \frac{G\text{-}d\text{-}wSinF}{Sin\ \frac{F+\beta}{2}}$$

$$\therefore \ \text{Radius} = R = \frac{G\text{-}d\text{-}wSinF}{2Sin\ \frac{F+\beta}{2}\ Sin\ \frac{F-\beta}{2}} \qquad (2.2)$$

Where R = radius of lead curve, d = heel divergence
w = straight leg of crossing ahead of TNC, β= switch angle
G=Track gauge

2.1 (b) IRS Turnout with straight switch Calculation of offsets to lead curves

The lead curve is extended from heel at point 'B' to a point 'H' so that the tangent to the curve runs parallel to the gauge line at a distance 'Y' (offset) as shown in Fig 2.2.

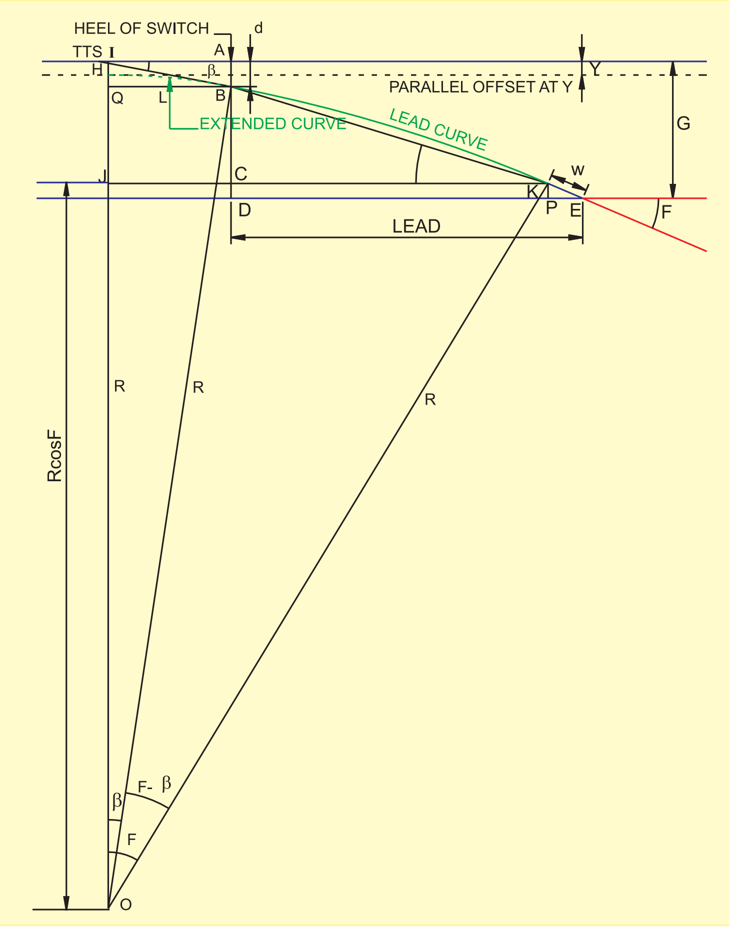


Figure 2.2: Offsets to lead curves for IRS turnout with straight switches

The point 'H' has been shown to lie inside the track, but in certain layouts, depending on the switch angle and the radius, the point 'H' may lie outside the track and therefore the value of 'Y' will work out as negative. The distance 'BQ' be denoted by 'L'.

In Δ KOJ,

$OK = R, \quad \angle KOJ = F, \quad \angle OJK = 90^0$

$JK = OKSinF = RSinF$

$$CK = (G\text{-}d\text{-}wSinF)Cot\,\frac{F+\beta}{2}$$

$CJ = BQ = L = JK - CK$

$$\therefore \; CJ = RSinF-(G\text{-}d\text{-}wSinF)Cot\,\frac{F+\beta}{2} \qquad (2.3)$$

$OI = OH + HI = R + Y$ (2.4)

also, $OI = OJ + JI = RCosF + G\text{-}wSinF$ (2.5)

equating (2.4) & (2.5),

$R + Y = RCosF + G\text{-}wSinF$

$\therefore \; Y = G\text{-}wSinF\text{-}R\,(1\text{-}CosF)$ (2.6)

Note It is also possible to work out values of 'L' & 'Y' directly from ΔOBQ,

$BQ = L = RSin\beta$ (2.7)

$Y = d\text{-}R\,(1\text{-}Cos\beta)$ (2.8)

But a word of caution is that as the value of 'β' is very small, it is difficult to get the correct values of Cosβ as variations in the region are not uniform. 'L' , however can be derived from $L = RSin\beta$

Example 2.1

Calculate the lead and the radius of a 1 in 8.5 IRS turnout with straight switches.

Given: G=1676mm, d=136mm, w=864mm

$$F = 6^0 42' 35'' \quad , \qquad \beta = 1^0 34' 27''$$

Solution :

$$\text{Lead} = (\text{G-d-wSinF}) \, \text{Cot} \frac{F+\beta}{2} + \text{wCosF}$$

$$= (1676\text{-}136\text{-}864 \times \text{Sin}6^0 42'\, 35'') \;\; \text{Cot} \; \frac{6^0 42'\, 35'' + 1^0 34'\, 27''}{2}$$

$$+864 \times \text{Cos}6^0\, 42'\, 35''$$

$$= 19871.79 + 858.08 = 20729.87\text{mm} \approx 2073\text{mm}$$

$$R = \frac{\text{G-d-wSinF}}{2\text{Sin}\frac{F+\beta}{2}\,\text{Sin}\frac{F-\beta}{2}}$$

$$= \frac{1676\text{-}136\text{-}864 \times \text{Sin}6^0\, 42'\, 35''}{2 \times \text{Sin}\,\frac{6^0\, 42'\, 35'' + 1^0\;\, 34'\, 27''}{2}\;\text{Sin}\;\frac{6^0\, 42'\, 35'' - 1^0\;\, 34'\, 27''}{2}}$$

$$= 222358.34\text{mm} \approx 222358\text{mm} \;\&\; \text{say } 222.36\text{m}$$

2.2 IRS Turnout with Curved Switches - Calculation of length of lead curve and radius of lead curve

The lead curves in these layouts at toe of switches are tangential to the switch angle and meets the straight leg of crossing tangentially at a distance 'w' from the TNC of the crossing. (Fig 2.2)

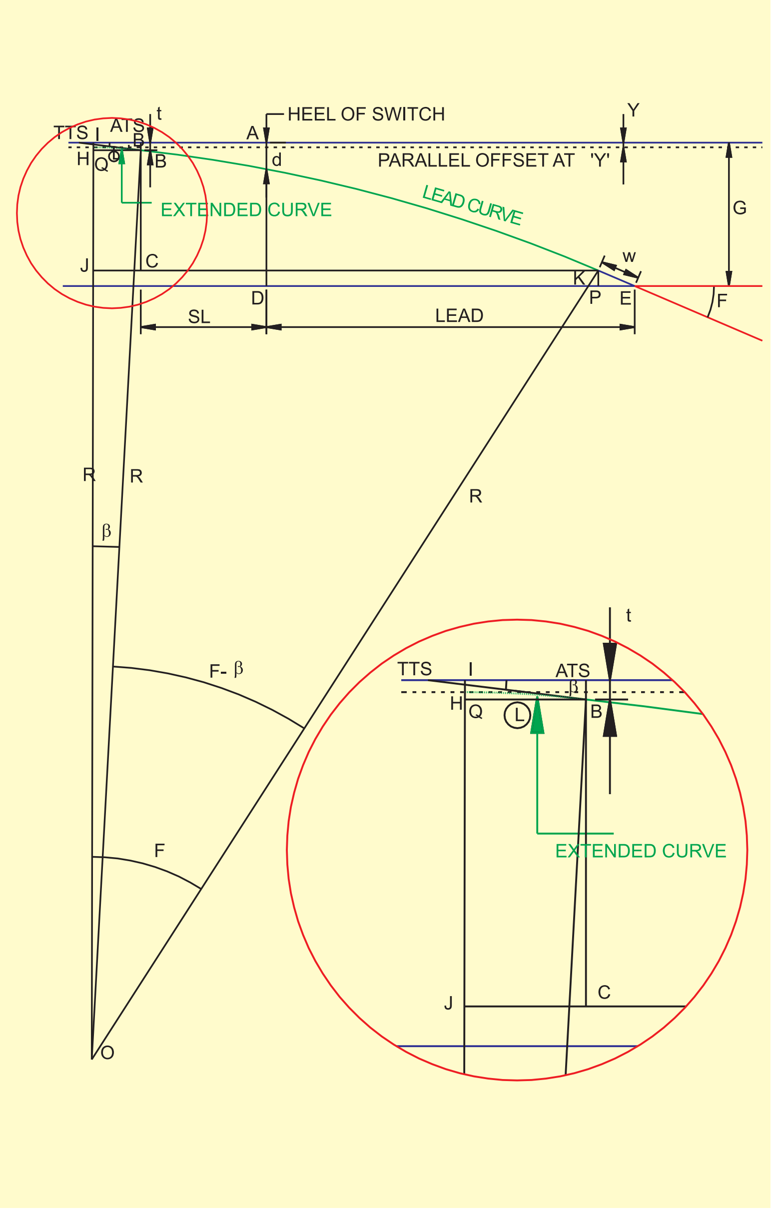


Figure 2.3: IRS Turnout with curved switches

At toe of switch, thickness of tongue rail is "t". Derivation for lead curve radius will be same as for IRS straight switches. The same can be derived by substituting "t" (toe thickness) for "d" (the heel divergence).

Formulae

$$CK = (G\text{-}t\text{-}w\ SinF)\ Cot\frac{F+\beta}{2} \qquad (2.9)$$

$$\text{Radius of Lead Curve, } R = \frac{G\text{-}t\text{-}wSinF}{2Sin\frac{F+\beta}{2}Sin\frac{F-\beta}{2}} \qquad (2.10)$$

For fixing positions of heel, it is necessary to find the point where offset to the lead curve from main line will be equal to heel divergence 'd'. For this, same principles are applied as for finding offsets to lead curve for straight IRS turnouts. It is, however, cautioned that the new tangent is drawn after extending the curve, so as to lie parallel to the main line, may be outside the track and distance 'Y' may come out as negative or positive. It has to be applied with its positive or negative sign arithmetically.

$$L = BQ = CJ = KJ - CK = RSinF\text{-}(G\text{-}t\text{-}wSinF)Cot\frac{F+\beta}{2} \qquad (2.11)$$

or, from Δ OQB,

$$L = BQ = RSin\beta \qquad (2.12)$$

$$Y = G\text{-}wSinF\text{-}R\ (1\text{-}CosF) \qquad (2.13)$$

$$\text{Switch Length, } SL = \sqrt{2R(d\text{-}Y)\text{-}(d\text{-}Y)^2}\text{-}L \qquad (2.14)$$

$$Lead = (G\text{-}d\text{-}wSinF)\ Cot\frac{F+\beta}{2} - SL + wCosF \qquad (2.15)$$

Example 2.2

Calculate the lead and the radius of a 1 in 12 IRS turnout with curved switches with CMS crossing on 52 Kg PSC sleepers as per RDSO/T4732.

Given: G=1673mm, d=175mm, w=1877mm

$$F = 4^0\,45'\,49'', \qquad \beta = 0^0\,20'\,0''$$

Solution :

$$R = \frac{G-t-wSinF}{2Sin\frac{F+\beta}{2}Sin\frac{F-\beta}{2}}$$

$$= \frac{1673-0-1877\times Sin4^0\,45'\,49''}{2\times Sin\frac{4^0\,45'\,49''+0^0\,20'\,0''}{2}\,Sin\frac{4^0\,45'\,49''-0^0\,20'\,0''}{2}}$$

= 441374mm *(As per RDSO / T* - 4732 *this value is* 441360*mm)*

Note : *In 1 in 12 IRS turnout with curved switches, Stock Rail is machined to house the tongue rail so that there is no projection of thickness of the tongue rail. Hence 't' is taken as zero.*

$$Lead = (G-t-wSinF)Cot\frac{F+\beta}{2} + wCosF\text{-}Switch\ Lenght$$

$$= (1673-0-1877\times Sin4^0\,45'\,49'')\ Cot\frac{4^0\,45'\,49''+0^0\,20'\,0''}{2}$$

$$+1877\ XCos4^0 45'\,49'' - 10125$$

= 25831.62 (*As per RDSO* / *T* - 4732 *Switch Length is* 25831mm)

Note : *From RDSO / T-* 4732 *Switch Length is* 10125mm

■ ■ ■

Chapter 3

Connections to Diverging Tracks

3.1 Connections to Diverging Tracks

Connection to non parallel sidings from an existing line can be of three types depending upon the comparative values of 'θ' and 'F'. Where 'θ' is the angle of intersection between the two lines and 'F' is the angle of crossing used for connection. There may be three situations viz;

$$\theta = F$$
$$\theta > F$$
and $$\theta < F$$

Now because of the local obstructions on the existing line, there can be further two sub categories namely; i.e Without obligatory points and With obligatory points on the main line. Therefore, connections to diverging tracks may have following situations;

For $\theta = F$

Case I	Without obligatory point on main line
Case II	With obligatory point on the main line

For **$>F$**

Case III	Without obligatory point on main line
Case IV	With obligatory point on the main line

For $<F$

Case V	Without obligatory point on main line
Case VI	With obligatory point on the main line

Case I

Produce the divergent track to meet the existing main line at point 'I'. For making the connection, point 'P' should coincide with point 'I'. Now for locating SJ (Stock Joint) an offset equal to 'A' can be taken from 'P'. After locating the 'SJ', the turnout can be laid with reference to 'SJ' (Fig 3.1)

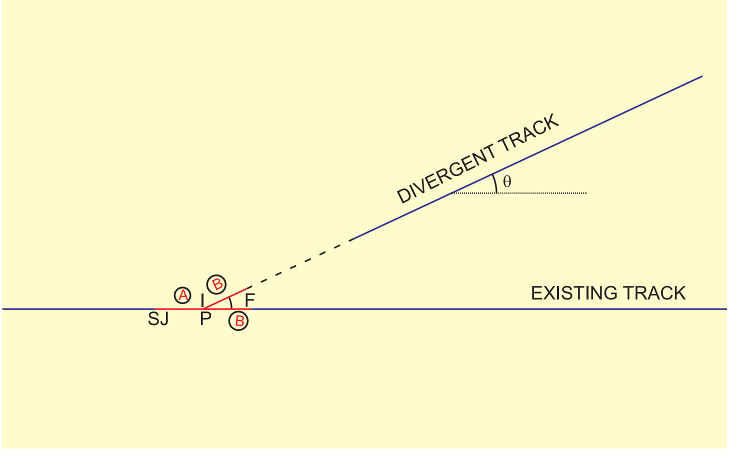


Figure 3.1: θ = F & Without obligatory point on main line

Case II

If because of some obstructions on the main line, the 'SJ' can not be fixed as given in Case I, and 'SJ' can be located either on left or right of 'SJ' as fixed vide Case I, then for making the connection, a reverse curve will have to be introduced starting after back leg of crossing and joining the divergent track. For this case, there can be numerous solutions and we have to choose the optimum alignment to meet the site conditions. (Fig 3.2)

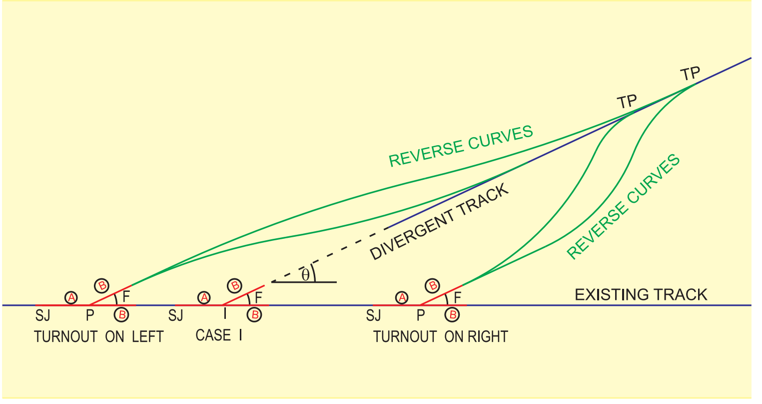


Figure 3.2: θ =F & With obligatory point on main line

Case III

In this case, if we are having the liberty in fixing the 'SJ', it should be on the left hand side of point of intersection 'I'. (Fig 3.3)

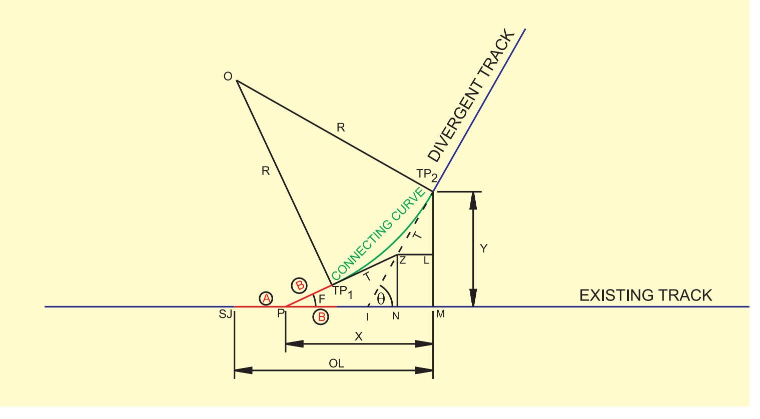


Figure 3.3: θ > F & Without obligatory point on main line

Formulae

$$T = R\tan\frac{\theta - F}{2} \qquad (3.1)$$

$$X = (B + T)\text{Cos}F + T\text{Cos}\theta \qquad (3.2)$$

$$OL = X + A \qquad (3.3)$$

$$Y = (B + T)\text{Sin}F + T\text{Sin}\theta \qquad (3.4)$$

Note : *For PSC layout, B (modified) parameter has to be taken in all calculations from annexure - III,*

Interpretation of Formulae & Field Practicalities

Intersection angle 'θ' has to be found out from the field surveying. The radius 'R' of the connecting curve has to be assumed. Normally the value of connecting curve radius is taken equal to that of radius of turnout curve. Now value of 'T' can be calculated from Eq:3.1. Once 'T' is known, the value of 'X' & 'Y' can be calculated from Eq:3.2 & 3.4 respectively. Having thus calculated the value of 'X'& 'Y', 'TP_2' is located first as the intersection point between the divergent track and a line drawn parallel to the existing track at a distance 'Y' and the location of 'SJ' is marked from point Z the perpendicular foot drawn from TP_2 on main line, and at a distance OL (Fig 3.3a)

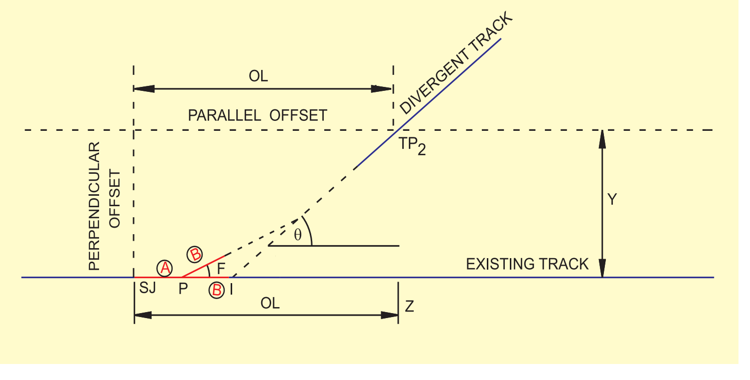


Figure 3.3a

Now after locating 'SJ', the turnout is linked and then the connecting curve is provided with radius equal to 'R'. This connecting curve will be starting from starting from last point on straight i.e. at distance B (modified) for PSC, and from HOC for other layout and ending at TP_2, thus establishing full connection.

Case IV

In Case III, radius 'R' of the connecting curve was assumed and the location of 'SJ' was so fixed. But, in certain circumstances, it may not be possible to locate 'SJ' because of some obstructions/obligatory points falling at that location. Position of 'SJ' will thus be fixed either to left or right side of 'SJ' as fixed in Case III.

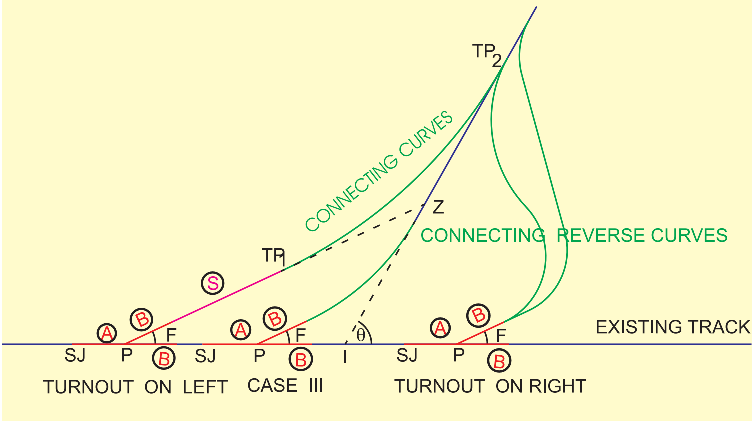


Figure 3.4: θ > F & With obligatory point on main line

When the 'SJ' is fixed to left of 'SJ' (Fig 3.4) as fixed vide Case III, radius of connecting curve will be quite large and can be calculated by the following formula;

$$R = \frac{T}{\tan\frac{\theta - F}{2}} \qquad (3.5)$$

by substituting the value of 'T', which will be calculated by field surveying, i.e. by extending crossing leg on the turnout side to intersect divergent track at 'Z'. Thus TP1Z will be the tangent length 'T'. Now the connecting curve of radius 'R' can be laid at the site. In this case, the radius 'R' of the connecting curve will be large, which can be reduced by providing a straight after the heel of crossing and connecting curve starting after this straight. For this case formulae can be modified as follows;

$$T = R\tan\frac{\theta - F}{2} \qquad (3.6)$$

$$X = (B + S + T)\mathrm{Cos}F + T\mathrm{Cos}\theta \qquad (3.7)$$

$$OL = X + A \qquad (3.8)$$

$$Y = (B + S + T)\mathrm{Sin}F + T\mathrm{Sin}\theta \qquad (3.9)$$

Now in another situation, when 'SJ' is located on right of 'SJ' (Fig 3.4) as fixed vide case III, there can be numerous solutions and an optimum alignment can be decided keeping in view the site conditions. In this case, connecting curve will have to be a reverse curve.

Case V

In this case, if we are having the liberty in fixing the 'SJ', it should be on the right hand side of point of intersection 'I'. (Fig 3.5)

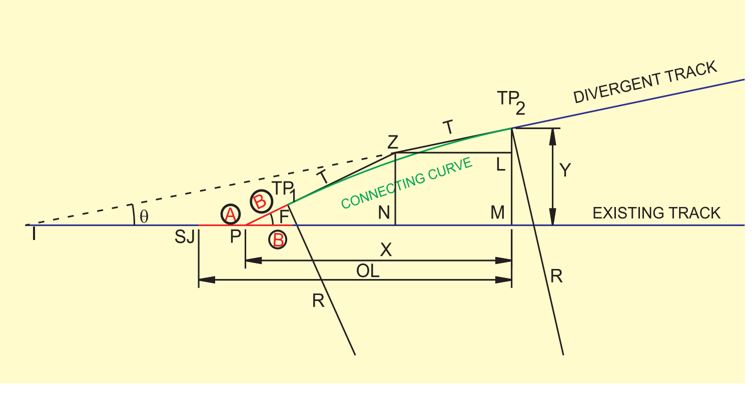


Figure 3.5: θ < F & Without obligatory point on main line

Formulae

$$T = R\tan\frac{F-\theta}{2} \qquad (3.10)$$

$$X = (B + T)\mathrm{Cos}F + T\mathrm{Cos}\theta \qquad (3.11)$$

$$OL = X + A \qquad (3.12)$$

$$Y = (B + T)\mathrm{Sin}F + T\mathrm{Sin}\theta \qquad (3.13)$$

Interpretation of Formulae & Field Practicalities

Intersection angle 'θ' has to be found out from the field surveying. The radius 'R' of the connecting curve has to be assumed. Normally the value of radius 'R' is taken equal to that of the radius of turnout radius. Now value of 'T' is calculated from Eq 3.9. Once 'T' is known, the value of 'X', 'OL' & 'Y' can be calculated from Eq 3.11, 3.12 & 3.13 respectively. 'TP_2' is located first as the intersection point between the divergent track and a line drawn parallel to the existing track at a distance 'Y' and the location of 'SJ' is marked with reference to 'TP_2' by drawing a perpendicular offset at a distance 'OL' from 'TP_2' (Fig 3.5a)

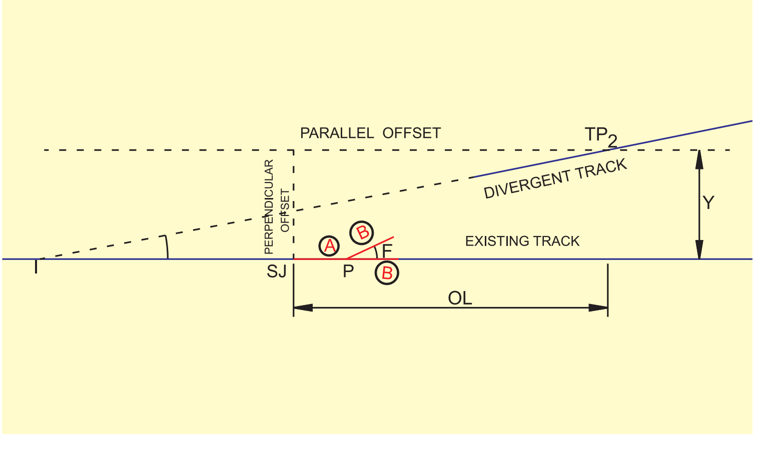


Figure 3.5a

Now after locating 'SJ', the turnout is linked and then the connecting curve is provided with a radius equal to 'R'. Thus connecting curve will be starting from back of crossing, TP_1 = (after distance ΔK as explained earlier in case of PSC layout) and ending at 'TP_2', thus establishing the full connection.

Case VI

In case V, radius of 'R' of the connecting curve was assumed and the location of 'SJ' was to be fixed. But in certain circumstances, it may not be possible to fix 'SJ' because of some obstructions/obligatory points falling at that location. Position of 'SJ' will thus be fixed either to the left or right side of 'SJ' as fixed in Case IV. (Fig 3.6)

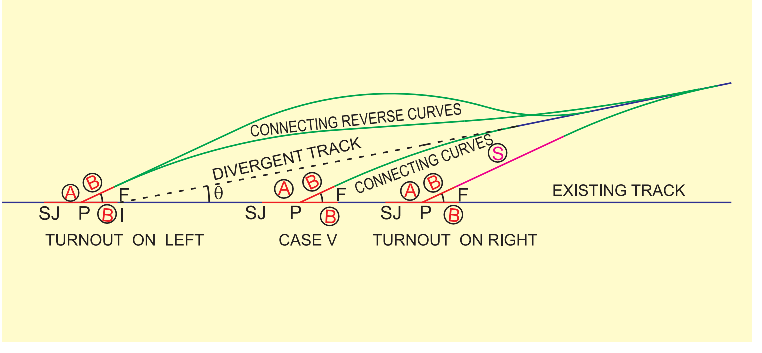


Figure 3.6: θ < F & With obligatory point on main line

When the 'SJ' is to be located on right of 'SJ' as fixed vide Case V, radius 'R' of connecting curve will be quite large and can be calculated by the following formulae;

$$R = \frac{T}{\tan\frac{F-\theta}{2}} \qquad (3.14)$$

by substituting the value of 'T', which will be calculated by field surveying, i.e by extending crossing leg of the turnout side to intersect divergent track at 'Z'. TP1 will be the tangent length 'T'. Now the connecting curve of radius 'R' can be laid at the site. In this case, radius 'R' of the connecting curve will be large, which can be reduced by providing a straight after the heel of crossing and connecting curve starting after this straight. For this case formulae can be modified as follows:

$$T = R\tan\frac{F-\theta}{2} \tag{3.15}$$

$$X = (B + S + T)\mathrm{Cos}F + T\mathrm{Cos}\theta \tag{3.16}$$

$$OL = X + A \tag{3.17}$$

$$Y = (B + S + T)\mathrm{Sin}F + T\mathrm{Sin}\theta \tag{3.18}$$

Now, in another situation, when 'SJ' is located on left of 'SJ' as fixed vide Case V, there can be numerous solutions and an optimum alignment can be decided keeping in view the site conditions. In this case, connecting curve has to be a reverse curve.

Example 3.1

A broad gauge siding is required to be connected to a main line track using a 52 Kg, 1 in 12 T/O. The angle of intersection between the two tracks being 10^0. Calculate the required distances for the layout assuming that the connecting curve starts from the heel of crossing.

Given: $F = 4^0 45' 49''$, $A = 16.953m$, $B = 23.981m$, $R = 441.282m$

Solution :

$$T = R\tan\frac{\theta - F}{2}$$

$$= 441.\ 282\tan\frac{10^0 - 4^0 45' 49''}{2}$$

$$= 20.179m$$

$$X = (B+T)\mathrm{Cos}F + T\mathrm{Cos}\theta$$

$$= (23.981 + 20.179)\ \mathrm{Cos}\ 4^0 45' 49'' + (20.179)\mathrm{Cos}10^0$$

$$= 44.007 + 19.872$$

$$= 63.879m$$

$$OL = X + A = 63.879 + 16.953 = 80.832m$$

$$Y = (B + T)\ \mathrm{Sin}\ F + T\mathrm{Sin}\theta$$

$$= (23.981 + 20.179)\mathrm{Sin}\ 4^0 45' 49'' + (20.179)\mathrm{Sin}10^0$$

$$= 3.667 + 3.504$$

$$= 7.171m$$

Example 3.2

A broad gauge siding is required to be connected to a main line track using 52 kg (PSC) (CMS) , 1 in 8.5 T/O. The angle of intersection between the two tracks is 3^0. Calculate the required distances for the layout.

Given: F = $6^0 42' 35''$, A=12.025m, B = 19.786m, R = 221.522m

Solution :

Since the connection is with PSC 1 in 8.5 layout with CMS Xing, B has been taken from annexure - III.

$$T = R\tan \frac{F-\theta}{2}$$

$$= 221.\ 522\tan \frac{6^0 42' 35'' - 3^0}{2}$$

$$= 7.174m$$

$$X = (B + T)CosF + TCos\theta$$

$$= (19.786 + 7.174)\ Cos\ 6^0 42' 35'' + (7.174)Cos3^0$$

$$= 26.805 + 7.164 = 30.659$$

$$X = 33.969$$

$$OL = X + A = 33.969 + 12.025 = 45.994$$

$$Y = (B + T)\ Sin\ F + TSin\theta$$

$$= (19.786 + 7.174)Sin\ 6^0 42' 35'' + (7.174)Sin3^0$$

$$= 3.153 + 3.504$$

$$= 3.528m$$

■ ■ ■

Chapter 4

Connections to Straight Parallel Tracks

4.0 Introduction

Type of Layout connections between the straight parallel tracks will depend upon the distance between the two tracks and the space availability in the yard. Accordingly distance between the two tracks may be treated as Normal or Large distance. Though there is no defining boundary for track centre to be large or normal, but for calculation purpose the track centre upto 8.0 m has been considered as normal distance and beyond 8.0 m as large distance.

4.1 With Normal Distance between the Straight Parallel Tracks

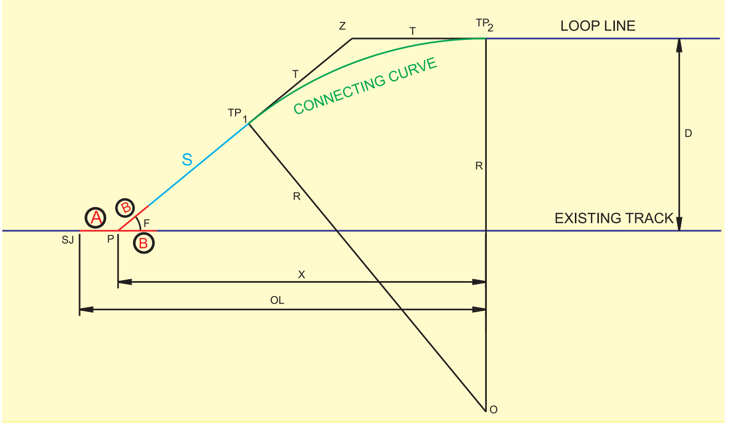


Figure 4.1: Normal distance between the straight parallel tracks

Formulae : See fig 4.1

$$T = R \tan\frac{F}{2} \qquad (4.1)$$

$$X = D \operatorname{Cot}F + T \qquad (4.2)$$

$$OL = X + A \tag{4.3}$$

$$(B + S + T)\mathrm{Sin}F = D \tag{3.18}$$

$$\therefore\ S = \frac{D}{\mathrm{Sin}F} - (B+T) \tag{4.4}$$

Interpretation of Formulae & Field Practicalities

First of all, radius of connecting curve 'R' has to be assumed keeping in view the content of Para 410 of IRPWM. Distance between the two straight parallel track will be found out from the field. Now after having the values of 'R' and 'D', calculate the values of 'T', 'X', 'OL' and 'S' from Eq 4.1, 4.2, 4.3 and 4.4 respectively.

Now, in the field, either of the two points i.e. TP2 and 'SJ' will be decided from the site conditions. With respect to one point, the other point will be fixed which will be at a distance 'OL' apart. After that, entire layout i.e. turnout, straight after heel of crossing and the connecting curve can be laid by field surveying.

Note:

In the above connection, it is evident that for a given value of 'D', if we increase/decrease the value of straight 'S' after heel of crossing, value of connecting curve 'R' decreases/increases respectively. Therefore, by controlling the value of 'S', value of 'R' can be controlled. For a given value of 'D', less the value of 'S', more will be the value of 'OL' i.e. overall length requirement. More the value of 'S', less will be the value of 'OL'. For S=0, 'OL' will be the maximum. 'S' can be increased to a maximum value till the value of 'R' reduces to $R=R_{recommended}$.

Correctness of Layout dependes basically on the correctness of the values of different variables as used in the above formulae. Any wrong value will disturb the geometry of layout at the field.

4.2 Layout Calculations with Fanshaped PSC Layout

Due to introduction of latest versions of 52 Kg and 60 Kg BG (1673 mm), 1 in 16, 1 in 12 and 1 in 8.5 turnouts on PSC sleepers to drawing Nos RDSO/T-5691, RDSO/T-4732, 4218 and RDSO/T-4865 respectively. Values of various turnout parameters have been given at the end of the book in **Table of Detailed Dimensions, at annexure - III**

Values of these turnout parameters can easily be calculated from the relevant RDSO drawings.

By default, the geometry of PSC layouts will be having a certain straight 'S' after the heel of crossing which should be accounted for by taking modified value of 'B' or 'K' as given in the **Table of Detailed Dimensions at annexure - III** given at the end of this book. The value of default straight can be determined from the relevant drawings. Hence in all formula mentioned earlier and in subsequent paras, whenever term B appear, the value of B(modified) same should be taken from table at annexure - III.

Example 4.1

A BG main line track is required to be connected to a loop line which is parallel at 4.725m distance by using a 52 Kg, 1 in 8.5 PSC (CMS)T/ O. Calculate the required distances for the layout, assuming the connecting curve radius as the same as turnout curve radius.

Given: $F = 6^{0}42^{'}35^{''}$, D = 4.725m, R = 221.522m, A = 12.02m,
B = 19.786m

Solution :

$$T = R\tan\frac{F}{2}$$

$$= 221.522\tan\frac{6^{0}42^{'}35^{''}}{2} = 12.991\text{m}$$

$$X = D\cot F + T = 4.725\cot 6^{0}42^{'}35^{''} + 12.991 = 53.137\text{m}$$

$$OL = X + A = 53.137 + 12.025 = 65.162\text{m}$$

$$S = \frac{D}{\sin F} - (B+T) = \frac{4.725}{\sin 6^{0}42^{'}35^{''}} - (19.786+12.991) = 7.663\text{m}$$

Since in above calculation B has been taken as B(modified) for PSC layout, the length so calculated above is after end of B for PSC i.e. after 3.3m behind HOC.

Note :
In the above example, the turn-in-curve (connecting curve) radius has been assumed to be the same as that of the turnout curve radius i.e. 221.522m, which is quite sharp curvature from the point of view of maintainability. It is, therefore, desirable to flatten this curve and this can be achieved by reducing the straight after the heel of crossing. However, by doing so, overall length i.e. 'OL' will become more, which may not be available in the loop line.

Example 4.2

In the above example 4.1, calculate radius of the flattest turn-in-curve to maintain it satisfactorily. Also calculate the over all length of the layout.

Given: $F=6^0 42' 35''$, $D=4.725m$, $A=12.025m$, $B = 19.786m$

Solution :

For the flattest turn-in-curve, the straight 'S' after the end of B will be equal to zero.

$$S = \frac{D}{SinF} - (B + T)$$

substituting S = 0

$$\frac{D}{SinF} = (B + T)$$

$$T = \frac{D}{SinF} - B = \frac{4.725}{Sin\ 6^0 42' 35''} - 19.786 = 20.654m$$

now from equation, $T = R\tan\frac{F}{2}$

now from equation, $T = R\tan\frac{F}{2}$

$$R = \frac{T}{\tan\frac{F}{2}} = \frac{20.654}{\tan\frac{6^0 42' 35''}{2}} = 351.829$$

$$X = DCotF + T$$

$$= 4.725Cot\ 6^0 42' 35'' + 20.654 = 60.487$$

$$OL = X + A = 60.487 + 12.025 = 75.842m$$

which is more by 72.512 - 65.62 = 7.35m, in comparison with overall length requirement as in the previous example 4.1

Example 4.3

Calculate the minimum track centre for a connection between two straight parallel track with the turnout on PSC layout (52 Kg, 1 in 8.5, BG 1673mm gauge) and the recommended radius of turn-in-curve being 440m

Given: A=12.025m, B = 16.486, B (modified for PSC) =19.786m

a) Calculate as if turn-in-curve is starting just after the heel of crossing.
b) Calculate, when 'B' is modified because of a default straight after the heel of crossing due to prepositioned inserts for straight alignment behind the heel of crossing.

Solution :

a) For minimum track centre, 'S' has to be zero.

$$T = R\tan\frac{F}{2}$$

$$= 440 \times \tan\frac{6^0 42' 35''}{2} = 25.793\text{m}$$

$$S = \frac{D}{\text{SinF}} - (B + T)$$

substituting S = 0,

$$0 = \frac{\text{Dmin}}{\text{Sin } 6^0 42' 35''} - (16.486 + 25.793)$$

$$\therefore \text{ Dmin} = (16.486 + 25.793) \text{ Sin } 6^0 42' 35''$$

$$= 4.940\text{m}$$

Note:

Same calculation is applicable for 60kg 1 in 8.5 T/out as values A (12.025) & B (16.486) are same.

b) Taking B(modified) for PSC layout because of a default straight;

$$\frac{D}{\text{SinF}} = (\text{B(modified)} + \text{T})$$

$$D = (16.486 + 3.3 + 25.793)\text{Sin } 6^{0}42'35''$$

$$= 5.325$$

Therefore, minimum track centre should be say 5.3m to accommodate completely the 1 in 8.5 turnout on PSC sleepers, with radius of connecting curves equal to 440m. However if we reduce this radius of connecting curve to lower value the minimum track centre for simple connection reduces.

It is worth mentioning that either because of lesser track centre or wrong calculations, at several yards, last common sleepers are being removed so as to start connecting curve slightly earlier. It is therefore recommended that to accommodate PSC turnouts, the minimum track centre must be equal to 5.3m, otherwise either common sleepers will have to be removed or sharper turn-in-curve will be required to make the connection.

Example 4.4

Calculate the minimum track centre of 1 in 12 PSC turnout instead of 1 in 8.5 PSC layout as in case of example 4.3. Recommended radius 440 m.

Given A= 16.889, B=28.414, F= $4^0 45' 49''$

Solution :

From equation (4.4)

$$S = \frac{D}{\sin F} - (B+T)$$

For minimum track centre S should be zero.

$\therefore$ D=(B+T) Sin F

From equation 4.1 $\quad T = R \tan \frac{F}{2}$

Hence $T = 440 \tan \frac{(4^0 45' 49'')}{2}$

$= 18.301m$

Thus $D = (B+T) \sin F$

$= (28.414+18.301) \sin 4^0 45' 49''$

$= 3.879$ m

Hence it can be seen that track centre required for simple connection of 1 in 12 turnout with parallel straight is not a problem.

4.3 With Large Distance between Straight Parallel Tracks

When the distance between the two straight parallel tracks increases and if we go for the layout connections as per para 4.1, overall length 'OL' requirement will become too large, which may not be available at site. It is, therefore, desirable to introduce a connecting reverse curve starting from the heel of crossing so as to keep the overall length of the layout to the minimum. Now there can be two sub cases as explained below;

Case I With no straight in the reverse curves

Case II With a straight in the reverse curves

Case I With no straight between reverse curves. (Fig 4.2)

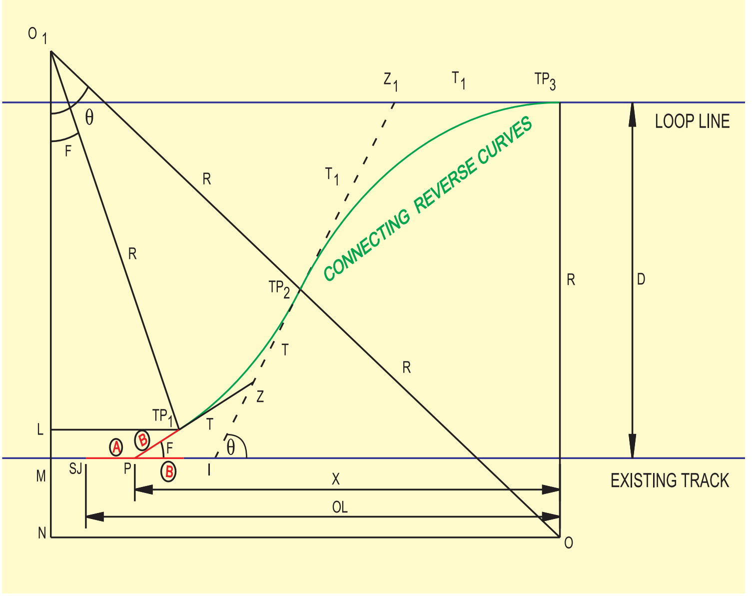


Figure 4.2: With large distance between straight parallel tracks having no straight in the reverse curves

Formulae

In ΔO_1NO

$$\text{Cos}\theta = \frac{O_1N}{O_1O} = \frac{O_1M + MN}{2R} = \frac{O_1L + LM + MN}{2R}$$

$O_1L = \text{RCosF}$, $LM = \text{BSinF}$, $MN = R - D$

$$\therefore \text{Cos}\theta = \frac{\text{RCosF} + \text{BSinF} + R - D}{2R}$$

$$\therefore \theta = \text{Cos}^{-1}\left\{\frac{\text{RCosF} + \text{BSinF} + R - D}{2R}\right\} \qquad (4.5)$$

$$T = \text{Rtan}\frac{\theta - F}{2} \qquad (4.6)$$

$$T_1 = \text{Rtan}\frac{\theta}{2} \qquad (4.7)$$

$$X = (B + T)\text{CosF} + (T + T_1)\text{Cos}\theta + T_1 \qquad (4.8)$$

$$OL = X + A \qquad (4.9)$$

Interpretation of Formulae and Field Practicalities

First of all, value of radius of connecting curve is to be assumed, which is generally the same as that the radius of lead curve. Distance 'D' will be known from the field. Value of various turnout parameters will be known once we have decided the type of turnout.

Now from Eq 4.5, value of 'θ' will be calculated. Then from Eq 4.6 & 4.7, tangent lengths 'T' & 'T_1 will be calculated. Value of 'X' and finally 'OL' will be calculated from Eq 4.8 & 4.9 respectively. Now with respect to 'TP_3', the location of 'SJ' can easily be fixed which will be at a distance equal to 'OL'. (Fig 4.2)

In the above case several variations can be made such as, different radii of curvature for two legs of the reverse curve or a straight between the heel of crossing & start of the reverse curve. Various formulae as derived in the previous case can be modified as follows;

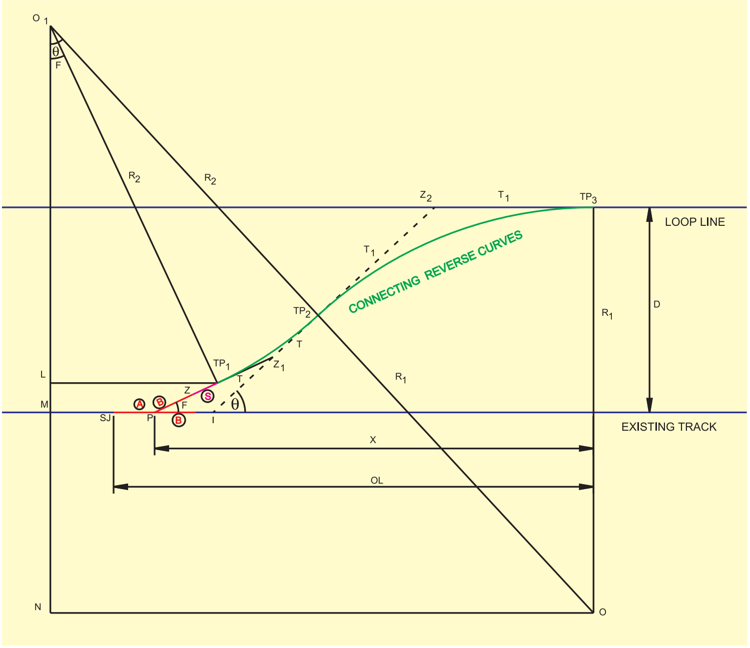


Figure 4.3

In $\Delta\, O_1NO$

$$Cos\theta = \frac{O_1N}{O_1O} = \frac{O_1M + MN}{R_1 + R_2} = \frac{O_1L + LM + MN}{R_1 + R_2}$$

$O_1L = R_2 CosF, \quad LM = (B + S) SinF, \quad MN = R_1 - D$

$$\therefore\ Cos\theta = \frac{R_2 CosF + (B + S) SinF + (R_1 - D)}{(R_1 + R_2)}$$

$$\therefore\ \theta = \mathrm{Cos}^{-1}\left\{\frac{R_2 \mathrm{Cos}F + (B+S)\mathrm{Sin}F + (R_1 - D)}{(R_1 + R_2)}\right\} \tag{4.10}$$

$$T = R_2 \tan\frac{\theta - F}{2} \tag{4.11}$$

$$T_1 = R_1 \tan\frac{\theta}{2} \tag{4.12}$$

$$X = (B + S + T)\,\mathrm{Cos}F + (T + T_1)\mathrm{Cos}\theta + T_1 \tag{4.13}$$

$$OL = X + A \tag{4.14}$$

Purpose of these variations in the above formulae is to show that, by altering one or other parameters, a layout connection can be designed to suit the diverse site conditions. Yard designer can design better layouts with this understanding. It is worth mentioning that, no trigonometrical formulae can solve a layout because of diverse site conditions and variety of obligatory points. Several trial & error calculations will be required for designing an optimum layout.

Note : *In case of PSC layout S will be measured after B (modified) as per annexure - III and not after HOC.*

Example 4.4

A BG track is required to be connected to a siding which is parallel at 15m distance. By using a 52kg PSC, 1 in 8.5 turnout and the radius of the connecting curve being the same as that of the lead curve of 1 in 8.5 turnout and without a straight between the reverse curve. Calculate the required distances for the layout connection.

Given: $F=6^0 42' 35''$, $D=15.000m$, $A=12.025m$, $B=19.786m$, $R=221.522$

Solution :

$$\text{Cos}\theta = \frac{\text{RCosF+B SinF+R-D}}{2R}$$

$$= \frac{221.522\text{Cos } 6^0 42' 35'' + (19.786)\text{Sin}6^0 42' 35'' + 221.522 - 15.0}{2 \times 221.522} =$$

$$\frac{428.842}{2 \times 221.522} = 0.9679$$

$$\therefore\ \theta = 14^0\ 33'\ 24''$$

$$T = \text{Rtan } \frac{\theta - F}{2}$$

$$= 221.522 \tan \frac{14^0 33' 24'' - 6^0 42' 35''}{2} = 15.193\text{ m}$$

$$T_1 = \text{Rtan} \frac{\theta}{2} = 221.522 \tan \frac{14^0 45' 37.2''}{2} = 28.692\text{ m}$$

$$X = (B+T)\ \text{CosF} + (T+T_1)\ \text{Cos}\theta + T_1$$

$$= (19.786+15.193)\text{Cos } 6^0 42' 35'' + (15.193+28.692)\text{Cos } 14^0 33' 24''$$

$$+ 28.692$$

$$= 34.854 + 42.476 + 28.692 = 105.937\text{m}$$

$$OL = X+A = 105.937+12.025 = 127.962\text{m}$$

Case II With a Straight between Reverse Curves

When as per Case I, it may be possible, that space available is less in comparison with what is required for making the connection then overall length 'OL' can be further reduced by introducing a straight between the reverse curve. In this Case, it is presumed that reverse curve is starting just after the heel of crossing. or after additional straight ΔB in case of PSC layout. In that case in all formula B (modified) is to be taken from annexure - III,

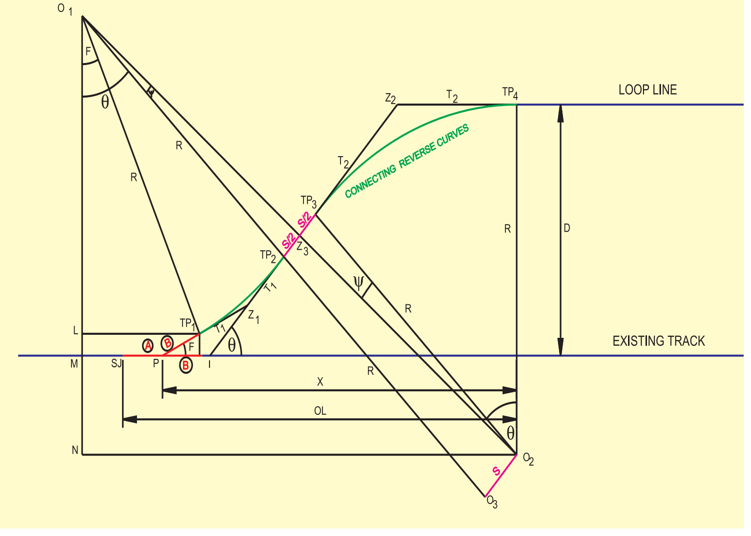


Figure 4.4: With large distance between straight parallel tracks having a straight in the reverse curve

Formulae

In $\Delta\, O_1TP_2Z_3$

$$\tan\psi = \frac{TP_2Z_3}{O_1TP_2} = \frac{S/2}{R} = \frac{S}{2R}$$

$$\psi = \tan^{-1}\left(\frac{S}{2R}\right) \tag{4.15}$$

In $\Delta\, O_1NO_2$

$$\mathrm{Cos}(\theta+\psi) = \frac{O_1N}{O_1O_2} = \frac{O_1M + MN}{O_1O_2} = \frac{O_1L + LM + MN}{O_1O_2}$$

$O_1L = \mathrm{RCosF}$, $LM = \mathrm{BSinF}$, $MN = R - D$

In $\Delta\, O_1O_3O_2$

$$\mathrm{Sin}\psi = \frac{O_2O_3}{O_1O_2} = \frac{S}{O_1O_2}$$

$$\therefore O_1O_2 = \frac{S}{\mathrm{Sin}\psi}$$

$$\mathrm{Cos}(\theta+\psi) = \frac{(\mathrm{RCosF} + \mathrm{BSinF} + R - D)\,\mathrm{Sin}\psi}{S}$$

$$\therefore \quad \theta = \mathrm{Cos}^{-1}\left\{\frac{(\mathrm{RCosF} + \mathrm{BSinF} + R - D)\,\mathrm{Sin}\psi}{S}\right\} - \psi$$

substituting the value of 'ψ' from Eq 4.15,

$$\theta = \mathrm{Cos}^{-1}\left\{\frac{(\mathrm{RCosF} + \mathrm{BSinF} + R - D)\,\mathrm{Sin}\psi}{S}\right\} - \tan^{-1}\left(\frac{S}{2R}\right) \qquad (4.16)$$

$$T_1 = R\tan\frac{\theta - F}{2} \qquad (4.17)$$

$$T_2 = R\tan\frac{\theta}{2} \qquad (4.18)$$

$$X = (B + T_1)\mathrm{CosF} + (T_1 + S + T_2)\mathrm{Cos}\theta + T_2 \qquad (4.19)$$

$$OL = X + A \qquad (4.20)$$

If we start the reverse curve after introducing another straight 'S_1' after the heel of crossing and different degree of curvature of the two legs of the reverse curve (R_1 & R_2).

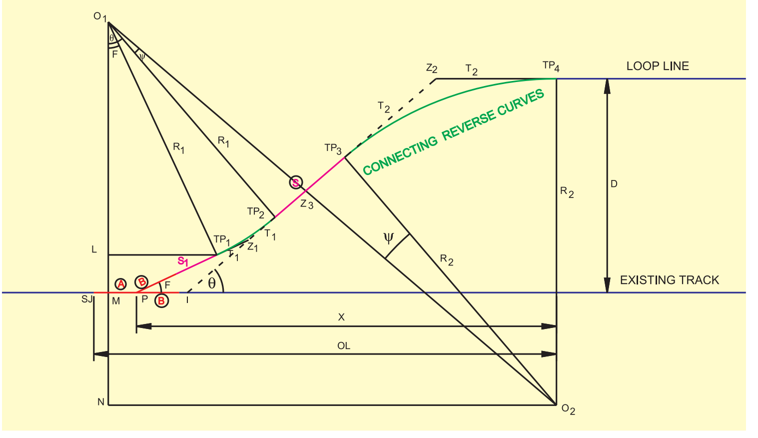


Figure 4.5

For the above variation (Fig 4.5) various formulae can be modified as explained under.

$$\psi = \tan^{-1}\left(\frac{S}{R}\right) \quad \text{where} \quad R = R_1 + R_2$$

$$\theta = \cos^{-1}\left\{\frac{\left[R_1 \cos F + (B + S_1)\sin F + R_2 - D\right]\sin\psi}{S}\right\} - \tan^{-1}\left(\frac{S}{R}\right) \qquad (4.21)$$

$$T_1 = R_1 \tan\frac{\theta - F}{2} \qquad (4.22)$$

$$T_2 = R_2 \tan\frac{\theta}{2} \qquad (4.23)$$

$$X = (B + S_1 + T_1)\cos F + (T_1 + S + T_2)\cos\theta + T_2 \qquad (4.24)$$

$$OL = X + A \qquad (4.25)$$

Note : *Here in above formula if B is taken for PSC layout then 'S' will be measured after B+ΔB, i.e. B (modified)*

Example 4.5

In the Example 4.4, if a straight of 10m has to be introduced between the reverse curves, calculate the required distances for the setting the layout.

$$\psi = \tan^{-1}\left(\frac{S}{2R}\right)$$

$$= \tan^{-1}\left(\frac{10}{2\times 221.522}\right) = 1^0 17' 35''$$

$$\text{Cos}(\theta+\psi) = \frac{(\text{RCosF+BSinF + R-D})\ \text{Sin}\ \psi}{S}$$

$$= \frac{\left(221.522\text{Cos}6^0 42' 35'' + 19.786 + \text{Sin}6^0 42' 35'' + 221.522 - 15\right)\ \text{Sin}1^0 17' 35''}{10}$$

$$= \frac{(220.004+2.315+206.522)\ \text{x}\ 0.0225661}{10} = 0.9677$$

$$\theta + \psi = \text{Cos}^{-1}(0.9677) = 14^0 36' 7.5''$$

$$\theta = 14^0 36'7.5'' - 1^0 17' 35'' = 13^0 18' 32.5''$$

$$T_1 = \text{Rtan}\frac{\theta\text{-F}}{2} = 221.522\tan\frac{13^0 18' 32.5'' - 6^0 42' 35'}{2} = 12.788\text{m}$$

$$T_2 = \text{Rtan}\frac{\theta}{2} = 221.522\tan\frac{13^0 18' 32.5''}{2} = 25.862\text{m}$$

$$X = (B+T_1)\ \text{CosF} + (T_1 + S + T_2)\ \text{Cos}\theta + T_2$$

$$= (19.786 + 12.788)\ \text{Cos}\theta + T_2$$

$$+ (12.788 + 10 + 25.862)\ \text{Cos}13^0 30' 42.6'' + 25.862$$

$$= 32.380 + 47.341 + 25.862 = 105.583$$

$$OL = X + A$$

$$= 105.583 + 12.025 = 117.608\ \text{mtr (Ans)}$$

■ ■ ■

Chapter 5

Crossover Connection between Straight Parallel Tracks

Type of Crossover connection between the straight parallel tracks will be dependent upon the distance between the two tracks and the space availability. Accordingly distance between the two tracks may be treated as Normal distance and Large distance. Concept of Normal distance and the Large distance is not decided by the spacing between the two tracks, it is the arrangement of layout and accordingly trigonometric formulae. For the calculation purpose, track centre upto 8.0 m is considered as normal distance.

5.1 With Normal Spacing between the Tracks and with Same Angle of Crossing

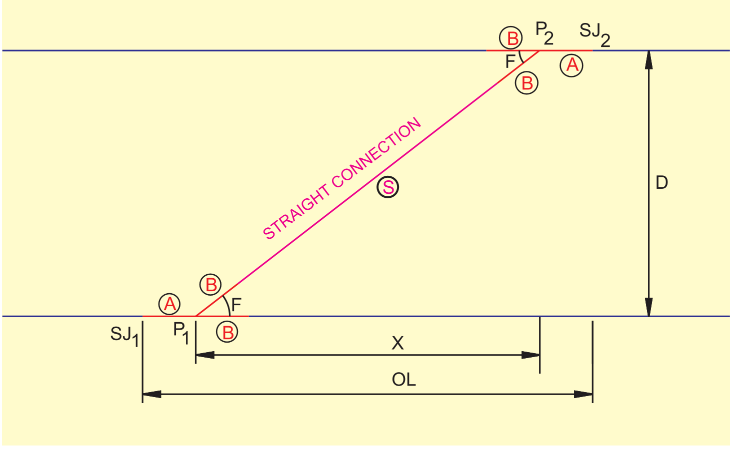


Figure 5.1: With normal spacing between the tracks and with same angle of crossing

Formulae

$(B+S+B)\ \text{Sin}F = D$

$$\therefore\ S = \frac{D}{\text{Sin}F} - 2B \qquad (5.1)$$

$$X = D\text{Cot}F = DN \qquad (5.2)$$

where N is the number of Xing. (CotF = N)

$$OL = X + 2A \qquad (5.3)$$

Interpretation of Formulae and Field Practicalities

First of all the value of 'D' will be known from the field surveying. Turnout prarmeters 'A', 'B' will be known once we have decided the type of turnout. Then from Eq 5.2 & 5.3, the values of 'X' & finally 'OL' will be calculated. Now with these values in the hand, location of one of 'SJ' can be fixed by keeping it at a distance 'OL' apart in refernce to another 'SJ'. After fixing the location of 'SJ', rest of the turnout can be set out by field surveying.

For the correctness of the crossover connection, it is very important that the distance 'D' must be same in the vicinity of turnouts and must be accurate. A small error in 'D' will get magnified by 'N'(number of crossing) times. It is therefore very important that the value of 'D' must be arrived at by field surveying and not from the yard drawings which might have been prepared long back and necessary corrections might not have been done.

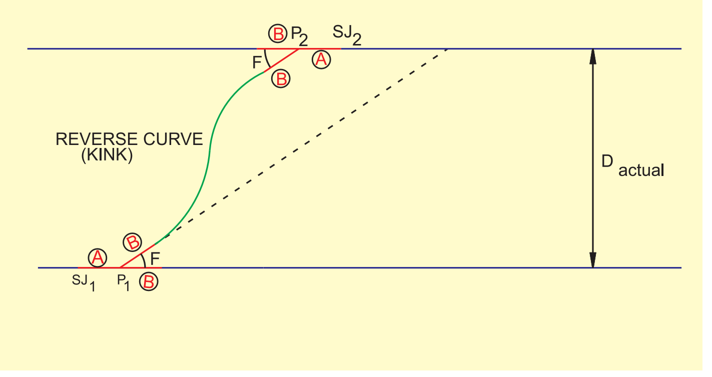
For example, if 'D' used for layout calculations is not equal to the actual distance available at the site, then two conditions may be thought of i.e;

$\mathbf{D_{cal} < D_{actual}}$

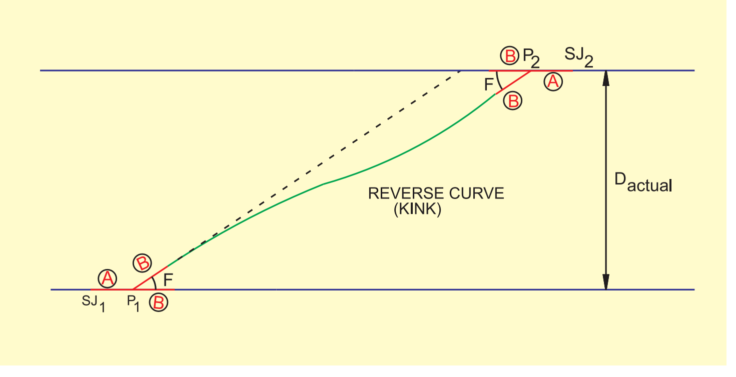
or

$\mathbf{D_{cal} > D_{actual}}$

Inboth the cases, 'SJ' will be fixed wrongly and the connection, instead of a straight,will become a reverse curve or a kink will be formed at the heel of crossing.



a) D_{cal}<D_{actual}



b) D_{cal}>D_{actual}

Figure 5.2

Now, when the train negotiate the crossover, it will try to straighten up the reverse curve, which will finally result into alignment kink in the main line and will result into bad running.

5.2 With Large Spacing between the Tracks with the Same Angle of Crossing

When the distance between the two straight parallel tracks increases and if we go for the layout connection as per para 5.1, overall length ‘OL’ requirement will become two large, for which space may not be available at the site. Space being the costly item in an yard, it is therefore desirable to introduce a connecting reverse curve starting from the heel or extended heal of crossing so as to keep the overall length of the layout to the minimum. In this type of layout, further there can be two sub cases i.e;

Case I With no Straight in the Reverse Curves

Case II With a given Straight in the Reverse Curves

Case I With no Straight in the Reverse Curves (Fig 5.3)

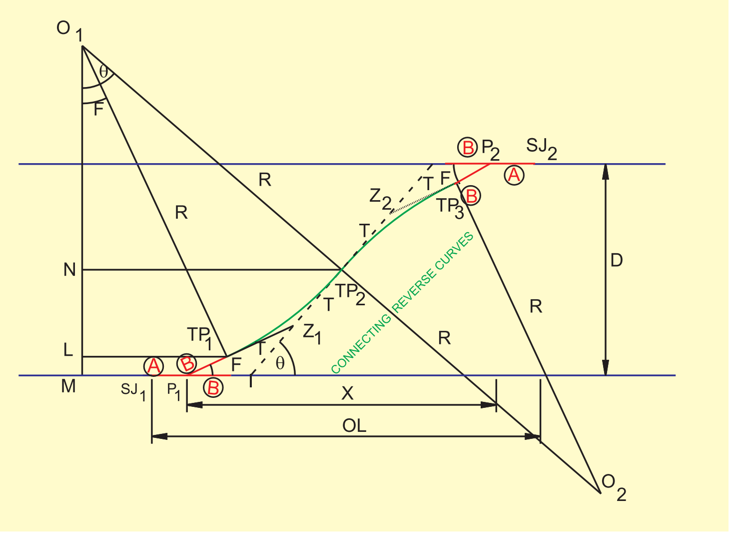


Figure 5.3: With no Straight between Reverse Curve

Formulae

$\Delta\, O_1 TP_2 N$

$$\text{Cos}\theta = \frac{O_1N}{O_1TP_2} = \frac{O_1M - NM}{O_1TP_2} = \frac{O_1L + LM - NM}{O_1TP_2}$$

$O_1L = \text{RCosF},\ \text{LM} = \text{BSinF},\ \text{NM} = D/2,\ O_1TP_2 = R$

$$\therefore\ \text{Cos}\theta = \frac{\text{RCosF} + \text{BSinF - D}/2}{R}$$

$$\therefore \theta = \text{Cos}^{-1}\left(\frac{\text{RCosF} + \text{BSinF} - D/2}{R}\right) \tag{5.4}$$

$$T = \text{Rtan}\,\frac{\theta\text{ - F}}{2} \tag{5.5}$$

$$X = 2\Big[(B + T)\text{CosF} + \text{TCos}\theta\Big] \tag{5.6}$$

$$OL = X + 2A \tag{5.7}$$

Interpretation of Formulae and Field Practicalities

First of all, value of radius of connecting reverse curve is to be assumed, which is generally the same as that of lead curve radius of the turnout. Distance 'D' between the two straight parallel track will be known from the field. Value of turnout parameters will be known once we have decided the type of turnout.

Now from Eq 5.4, value of θ can be calculated. Then from Eq 5.5, 5.6 & 5.7, value of 'T', 'X' ann hence 'OL' can easily be calculated respectively. Now the location of 'SJs' can easily be fixed which will be at a distance equal to 'OL'.

In the above case, several variations can be made such as , different radii of curvature of two legs of reverse curve or a straight between the heel of crossing or end of B (modified) for PSC layout and start of the reverse curve or different angle of crossing at the two ends. (Fig 5.4)

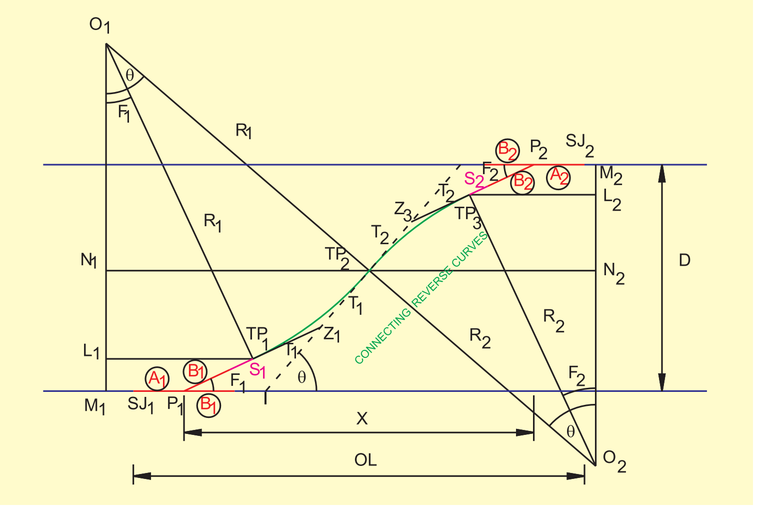


Figure 5.4

Formulae

In $\Delta\, O_1N_1TP_2$

$$\mathrm{Cos}\theta = \frac{O_1N_1}{O_1TP_2} = \frac{O_1M_1 - N_1M_1}{O_1TP_2} = \frac{O_1L_1 + L_1M_1 - N_1M_1}{O_1TP_2}$$

$$O_1L_1 = R_1\,\mathrm{Cos}F_1\,,\quad L_1M_1 = (B_1 + S_1)\,\mathrm{Sin}F_1\,,\quad O_1TP_1 = R_1$$

$$\therefore \mathrm{Cos}\theta = \frac{R_1\mathrm{Cos}F_1 + (B_1 + S_1)\,\mathrm{Sin}F_1 - N_1M_1}{R_1}$$

$$\therefore N_1M_1 = R_1\mathrm{Cos}F_1 + (B_1 + S_1)\,\mathrm{Sin}F_1 - R_1\mathrm{Cos}\,\theta$$

In $\Delta\, O_2 N_2 TP_2$

$$\mathrm{Cos}\theta = \frac{O_2 N_2}{O_2 TP_2} = \frac{O_2 M_2 - N_2 M_2}{O_2 TP_2} = \frac{O_2 L_2 + L_2 M_2 - N_2 M_2}{O_2 TP_2}$$

$$O_2 L_2 = R_2\,\mathrm{CosF}_2, \quad L_2 M_2 = (B_2 + S_2)\mathrm{SinF}_2, \quad O_2 TP_2 = R_2$$

$$\therefore \mathrm{Cos}\theta = \frac{R_2\,\mathrm{CosF}_2 + (B_2 + S_2)\mathrm{SinF}_2 - N_2 M_2}{R_2}$$

$$\therefore N_2 M_2 = R_2\,\mathrm{CosF}_2 + (B_2 + S_2)\mathrm{SinF}_2 - R_2\,\mathrm{Cos}\theta$$

$$N_1 M_1 + N_2 M_2 = R_1\,\mathrm{CosF}_1 + (B_1 + S_1)\mathrm{SinF}_1 - R_1\,\mathrm{Cos}\theta$$

$$+ R_2\,\mathrm{CosF}_2 + (B_2 + S_2)\mathrm{SinF}_2 - R_2\,\mathrm{Cos}\theta$$

$$N_1 M_1 + N_2 M_2 = D$$

$$\therefore \mathrm{Cos}\theta = \frac{R_1\,\mathrm{CosF}_1 + R_2\,\mathrm{CosF}_2 + (B_1 + S_1)\mathrm{SinF}_1 + (B_2 + S_2)\mathrm{SinF}_2 - D}{R_1 + R_2}$$

$$= \mathrm{Cos}^{-1}\left\{\frac{R_1\,\mathrm{CosF}_1 + R_2\,\mathrm{CosF}_2 + (B_1 + S_1)\mathrm{SinF}_1 + (B_2 + S_2)\mathrm{SinF}_2 - D}{R_1 + R_2}\right\} \quad (5.8)$$

$$T_1 = R_1 \tan\frac{\theta - F_1}{2} \qquad (5.9)$$

$$T_2 = R_2 \tan\frac{\theta - F_2}{2} \qquad (5.10)$$

$$X = (B_1 + S_1 + T_1)\mathrm{CosF}_1 + (T_1 + T_2)\mathrm{Cos}\theta$$

$$+ (B_2 + S_2 + T_2)\mathrm{CosF}_2 \qquad (5.11)$$

$$OL = X + A_1 + A_2 \qquad (5.12)$$

Now, these formulae have become more versatile and generalized by incorporating these variations. In case of PSC layouts the straight S1& S2 should be measured after B_1 (modified) and B_2 (modified).

Example 5.1

A crossover is required to be laid between the two parallel BG tracks at 15m distance by means of a 52 Kg, 1 in 12 turnout non PSC with no straight portion in the connection. Calculate the required parameters for the layout. Also calculate the saving in overall length in this layout over a layout with straight line connection between the crossing.

Given: $F = 4^0 45' 49''$, $A = 16.953m$, $B = 23.981m$, $R = 441.282m$

Solution :

$$\text{Cos}\theta = \frac{\text{RCosF} + \text{BSinF} - D/2}{R}$$

$$\text{Cos}\theta = \frac{441.282\text{Cos } 4^0 45' 49'' + 23.981\text{Sin } 4^0 45' 49'' - 15/2}{441.282}$$

$$= 0.9840628$$

$$\theta = 10^0 14' 34''$$

$$T = \text{Rtan}\frac{\theta - F}{2}$$

$$= 441.282 \times \tan\frac{10^0 14' 34'' - 4^0 45' 49''}{2}$$

$$= 21.116m$$

$$X = 2\left[(B + T)\text{CosF} + \text{TCos}\theta\right]$$

$$= 2\left[(23.981 + 21.116)\text{Cos } 4^0 45' 49'' + 21.116\text{Cos} 10^0 14' 34''\right]$$

$$= 2(44.941 + 20.779) = 131.441m$$

$$OL = X + 2A = 131.441 + 2 \times 16.953 = 165.347m$$

Overall length if straight line connection is provided between the crossing;

$$OL = \text{DCotF} + 2A = 15 \times 12 + 2 \times 16.953 = 213.906m$$

Therefore saving in the overall length $= 213.906 - 165.347 = 48.559m$

Case II With a given Straight in the reverse curves

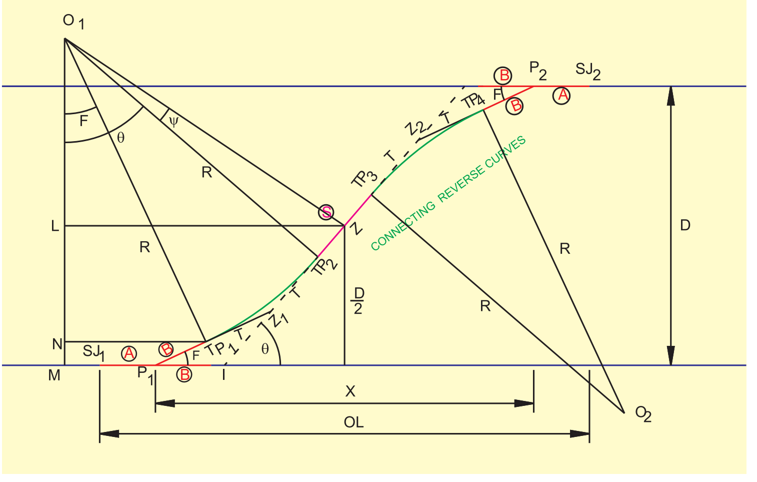


Figure 5.5 : With a given Straight in the reverse curve

Formulae

In $\Delta\, O_1TP_2Z$

$$\tan\psi = \frac{TP_2Z}{O_1TP_2} = \frac{S/2}{R} = \frac{S}{2R}$$

$$\psi = \tan^{-1}\left(\frac{S}{2R}\right) \tag{5.13}$$

In $\Delta\, O_1LZ$

$$\mathrm{Cos}(\theta + \psi) = \frac{O_1L}{O_1Z} = \frac{O_1M - LM}{O_1Z} = \frac{O_1N + NM - LM}{O_1Z}$$

$O_1N = R\mathrm{Cos}F, \quad NM = B\mathrm{Sin}F,$

In $\Delta\, O_1TP_2Z$

$$O_1Z = \frac{S}{2\mathrm{Sin}\psi}$$

$$\mathrm{Cos}(\theta + \psi) = \frac{2 \times \left(\mathrm{RCosF} + \mathrm{BSinF} - D/2\right)\mathrm{Sin}\psi}{S}$$

$$\therefore \quad \theta = \mathrm{Cos}^{-1}\left\{\frac{2 \times \left(\mathrm{RCosF} + \mathrm{BSinF} - D/2\right)\mathrm{Sin}\psi}{S}\right\} - \psi$$

$$\therefore \quad \theta = \mathrm{Cos}^{-1}\left\{\frac{2 \times \left(\mathrm{RCosF} + \mathrm{BSinF} - D/2\right)\mathrm{Sin}\psi}{S}\right\} - \tan^{-1}\left(\frac{S}{2R}\right) \tag{5.14}$$

$$T = \mathrm{Rtan}\,\frac{\theta - F}{2} \tag{5.15}$$

$$\begin{aligned} X &= (B + T)\mathrm{CosF} + (T + S + T)\mathrm{Cos}\theta + (T + B)\mathrm{CosF} \\ &= 2(B + T)\mathrm{CosF} + (2T + S)\mathrm{Cos}\theta \end{aligned} \tag{5.16}$$

$$OL = X + 2A \tag{5.17}$$

Now, In the above case, several variations can be made such as, different radii of curvature of the two legs of reverse curve or a straight length introduced between the heel of crossing and the start of the reverse curve on the two ends or different angle of crossing at the two ends.

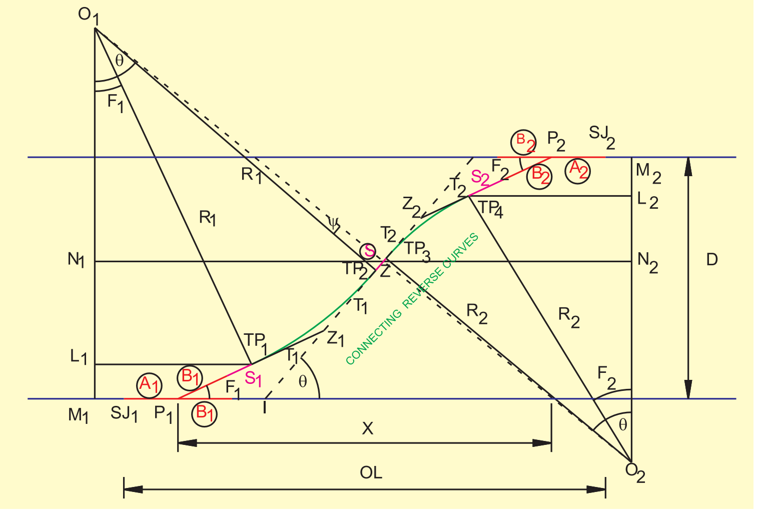


Figure 5.6

For this case , various formulae can be revised as follows:

Formulae

In $\Delta\, O_1TP_2Z$

$$\tan\psi = \frac{TP_2Z}{O_1TP_2} = \frac{TP_2Z}{R_1}$$

In $\Delta\, O_2TP_3Z$

$$\tan\psi = \frac{TP_3Z}{O_2TP_3} = \frac{TP_3Z}{R_2}$$

$$TP_2Z + TP_3Z = (R_1 + R_2)\tan\psi$$

$S = (R_1 + R_2)\tan\psi \quad (\text{where } TP_2Z + TP_3Z = S)$

$$\therefore \tan\psi = \frac{S}{(R_1 + R_2)}$$

$$\therefore \psi = \tan^{-1}\left(\frac{S}{R_1 + R_2}\right) \tag{5.18}$$

In ΔO_1ZN_1

$$\mathrm{Cos}(\theta + \psi) = \frac{O_1N_1}{O_1Z} = \frac{O_1M_1 - N_1M_1}{O_1Z} = \frac{O_1L_1 + L_1M_1 - N_1M_1}{O_1Z}$$

$$\mathrm{Cos}(\theta + \psi) = \frac{\left(R_1\mathrm{Cos}F_1 + (B_1 + S_1)\mathrm{Sin}F_1 - N_1M_1\right)}{O_1Z} \tag{5.19}$$

In ΔO_2ZN_2

$$\mathrm{Cos}(\theta + \psi) = \frac{\left(R_2\mathrm{Cos}F_2 + (B_2 + S_2)\mathrm{Sin}F_2 - N_2M_2\right)}{O_2Z} \tag{5.20}$$

From Eq 5.19 & 5.20,

$$N_1M_1 = R_1\mathrm{Cos}F_1 + (B_1 + S_1)\mathrm{Sin}F_1 - O_1Z\mathrm{Cos}(\theta + \psi)$$

$$N_1M_2 = R_2\mathrm{Cos}F_2 + (B_2 + S_2)\mathrm{Sin}F_2 - O_2Z\mathrm{Cos}(\theta + \psi)$$

$$D = N_1M_1 + N_1M_2$$

$$D = R_1\mathrm{Cos}F_1 + R_2\mathrm{Cos}F_2 + (B_1 + S_1)\mathrm{Sin}F_1 + (B_2 + S_2)\mathrm{Sin}F_2$$
$$- (O_1Z + O_2Z)\mathrm{Cos}(\theta + \psi) \tag{5.20a}$$

where $O_1Z + O_2Z = O_1O_2$

In ΔO_1TP_2Z

$$\mathrm{Sin}\psi = \frac{TP_2Z}{O_1Z}$$

In ΔO_2TP_3Z

$$\operatorname{Sin}\psi = \frac{TP_3Z}{O_2Z}$$

$$TP_2Z + TP_3Z = (O_1Z + O_2Z)\operatorname{Sin}\psi$$

$$\therefore S = O_1O_2\operatorname{Sin}\psi$$

considering Eq (5.20 a), $\operatorname{Cos}(\theta + \psi)$ is equal to :

$$= \left\{\frac{\left[R_1\operatorname{Cos}F_1 + R_2\operatorname{Cos}F_2 + (B_1 + S_1)\operatorname{Sin}F_1 + (B_2 + S_2)\operatorname{Sin}F_2 - D\right]\operatorname{Sin}\psi}{S}\right\}$$

$$\theta = \operatorname{Cos}^{-1}\left\{\frac{\left[R_1\operatorname{Cos}F + R_2\operatorname{Cos}F + (B_1 + S_1)\operatorname{Sin}F_1 + (B_2 + S_2)\operatorname{Sin}F_2 - D\right]\operatorname{Sin}\psi}{S}\right\}$$

$$- \tan^{-1}\left(\frac{S}{R_1 + R_2}\right) \qquad (5.21)$$

$$T_1 = R_1 \tan\frac{\theta - F_1}{2} \qquad (5.22)$$

$$T_2 = R_2 \tan\frac{\theta - F_2}{2} \qquad (5.23)$$

$$X = (B_1 + S_1 + T_1)\operatorname{Cos}F_1 + (T_1 + S + T_2)\operatorname{Cos}\theta + (T_2 + S_2 + B_2)\operatorname{Cos}F_2 \qquad (5.24)$$

$$OL = X + 2A \qquad (5.25)$$

Now these formulae have become more generalized by incorporating these variations. In case of PSC layouts the straight S1& S2 should be measured after B_1 (modified) and B_2 (modified).

Example 5.2

What is the minimum distance required to lay a cross over between two parallel straight with

(a) 60 kg 1in 12 PSC turnouts on both ends.

(b) 60 kg 1 in 8.5 PSC turnouts on both ends

Find out overall x-over length also.

Given $F_1 = 4^0 45' 49''$, $A_1 = 16.989$m, $B = 28.412$m

$F_2 = 6^0 42' 35''$, $A_2 = 12.025$m, $B_2 = 19.786$m.

Solution:

(a) As per Equation (5.1)

$$S = \frac{D}{(\text{Sin F})} - 2B$$

For minimum track distance S will be zero

$$\therefore \frac{D}{(\text{Sin F})} = 2B$$

Or D = 2(B) Sin F

$= 2(28.412) \text{ Sin } 4^0 45' 49''$

$= 4.718 = 4.72$m

Overall length from equation (5.2) and (5.3)

OL $= x + 2A$

$= \text{DCot F} + 2A$

$= 4.72 \text{ Cot } 4^0 45' 49'' + 2x16.989$

$= 90.605$ m

(b) For 1in8.5

D $= 2 \text{ BSin F2}$

$= 2 (19.786) \text{ Sin } 6^0 42' 35''$

$= 4.63$ m

OL $= x + 2A$

$= \text{D Cot F} + 2\text{ A2}$

$= 4.63 \text{ Cot } 6^0 42' 35'' + 2x12.025$

$= 63.405$m

Example 5.3

A crossover is required to be laid between two parallel BG tracks at 15m distance by means of 60Kg PSC, 1 in 12 turnout and with a straight of 40m in connection. Calculate the required parameters for the layout. Also calculate the saving in overall length in this layout over a layout with straight line connection between the crossing.

Given: F = $4^0 45' 49''$, A = 16.989m, B = 28.412m, R = 400m,
S = 40m

Solution : From equation 5.13 & 5.14

$$\psi = \tan^{-1}\left(\frac{S}{2R}\right) = \tan^{-1}\left(\frac{40}{2\times 400}\right) = 2^0 51' 45''$$

$$\theta = \mathrm{Cos}^{-1}\left\{\frac{2\times(\mathrm{RCosF}+\mathrm{BSinF}-D/2)\mathrm{Sin}\,\psi}{S}\right\} - \psi$$

$$= \mathrm{Cos}^{-1}\left\{\frac{2\times\left(400\mathrm{Cos}4^0 45' 49''+28.412\ \mathrm{Sin}4^0 45' 49''-15/2\right)\mathrm{Sin}2^0 51' 45''}{40}\right\}$$

$$-\ 2^0 51' 45'' = \mathrm{Cos}^{-1}\left\{\frac{2\,(\,398.618+2.359-15/2)\mathrm{Sin}2^0 51' 45''}{40}\right\} - 2^0 51' 45''$$

$$= \mathrm{Cos}^{-1}\left\{\frac{39.299}{40}\right\} - 2^0 51' 45''$$

$$= 10^0 44' 7.8'' - 2^0 51' 45'' = 7^0 52' 20.5''$$

$$T = \mathrm{Rtan}\,\frac{\theta - F}{2} = 400\tan\frac{7^0 52' 20.5'' - 4^0 45' 49''}{2} = 10.854\mathrm{m}$$

$$X = 2(B+T)\,\mathrm{CosF} + (2T+S)\mathrm{Cos}\ \theta$$

$$= 2\ (28.412 + 10.854)\ \mathrm{Cos}4^0 45' 49'' + (2\mathrm{x}10.854+40)\ \mathrm{Cos}\ 7^0 52' 20.5''$$

$$= 78.26 + 61.126 = 139.386\mathrm{m}$$

OL = X + 2A = 139.386 + 2 x 16.989 = 173.386 (When limited straight 40 m considered)

Overall length, if straight line connection is given between the crossing,

OL = DCotF + 2A = 15 × 12 + 2 × 16.989 = 213.979m (When only straight)

Therefore saving in overall length = 213.979-173.364 = 40.614m

5.3 With Different Angles of Crossing and Normal Distance between the two Straight Parallel Tracks

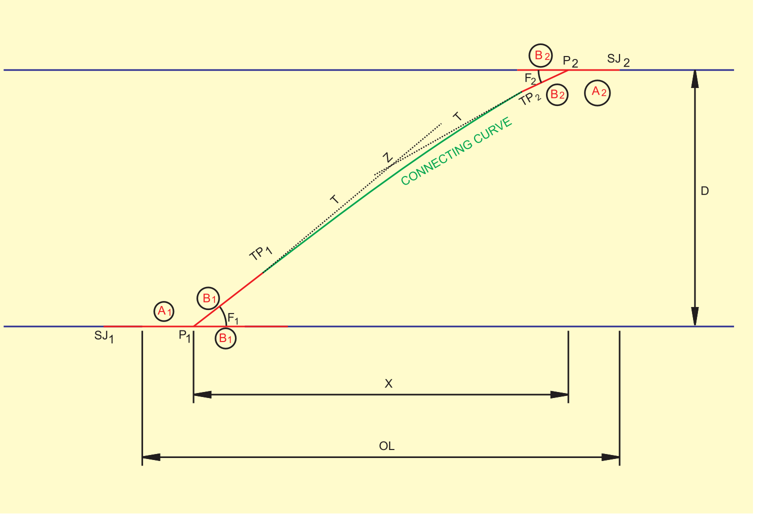


Figure 5.7 : With different Angles of crossing and normal distance between the two straight parallel tracks

Formulae

$$(B_1 + T)\mathrm{Sin}F_1 + (T + B_2)\mathrm{Sin}F_2 = D \tag{5.26}$$

$$\therefore T = \frac{D - (B_1\mathrm{Sin}F_1 + B_2\mathrm{Sin}F_2)}{\mathrm{Sin}F_1 + \mathrm{Sin}F_2} \tag{5.27}$$

$$T = R\tan\frac{F_1 - F_2}{2} \tag{5.28}$$

$$X = (B_1 + T)\mathrm{Cos}F_1 + (T + B_2)\mathrm{Cos}F_2 \tag{5.29}$$

$$OL = X + A_1 + A_2 \tag{5.30}$$

In the derivation of the various formulae for the above case, it is assumed that connecting curve is starting just after the heel of crossing. It may also happen, to suit the varied site conditions, that a straight after the heel of crossing is required. Such as in case of PSC layouts where straight equal to ΔB has to be provided because of prepositioned inserts or as the case may be Those formulae can be modified as follows; (Fig 5.8)

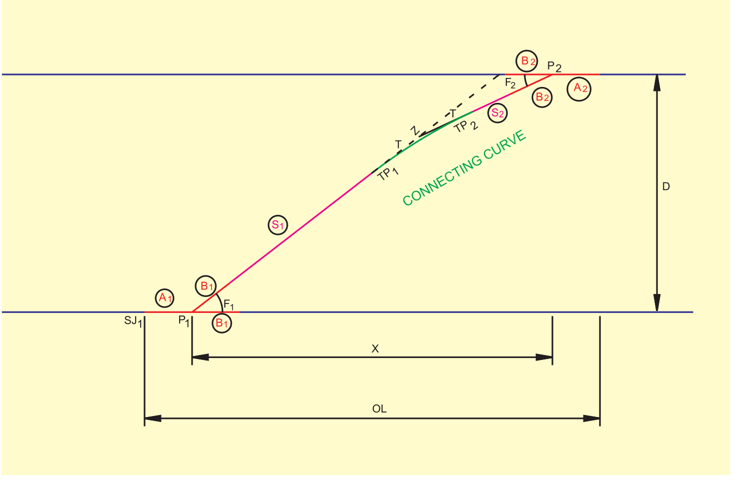


Figure 5.8

$$(B_1 + S_1 + T)\text{Sin}F_1 + (T + S_2 + B_2)\text{Sin}F_2 = D \qquad (5.31)$$

$$\therefore T = \frac{D - \left[(B_1 + S_1)\text{Sin}F_1 + (B_2 + S_2)\text{Sin}F_2)\right]}{\text{Sin}F_1 + \text{Sin}F_2} \qquad (5.32)$$

$$T = R\tan\frac{F_1 - F_2}{2} \qquad (5.33)$$

$$X = (B_1 + S_1 + T)\text{Cos}F_1 + (T + S_2 + B_2)\text{Cos}F_2 \qquad (5.34)$$

$$OL = X + A_1 + A_2 \qquad (5.35)$$

In case of PSC layouts the straight S1& S2 should take in to account the straight length behind HOC i.e. they should always be more than 3.3m in case of 1 in 8.5 and 5.5m in case of 1 in 12 PSC layout.

Example 5.4

A crossover is required to be laid between the two straight parallel tracks at 4.725m centres by using a 52 Kg, 1 in 8.5 & 1 in 12 turnouts. Calculate the required parameters for the layout.

Given:

Turnout	A	B	F
1 in 8.5	12.000m	17.418m	$6^0 42' 35''$
1 in 12	16.953m	23.981m	$4^0 45' 49''$

Solution :
First of all, value of 'T' tangent length will be calculated from,

$$T = \frac{D - (B_1 \text{Sin}F_1 + B_2 \text{Sin}F_2)}{\text{Sin}F_1 + \text{Sin}F_2}$$

$$= \frac{4.725 - (17.418 \text{Sin } 6^0 42' 35'' + 23.981 \text{Sin } 4^0 45' 49'')}{\text{Sin } 6^0 42' 35'' + \text{Sin } 4^0 45' 49''}$$

$$= \frac{4.725 - (2.035 + 1.992)}{0.19988} = 3.492\text{m}$$

$$R = \frac{T}{\tan \frac{F_1 - F_2}{2}} = \frac{3.492}{\tan \frac{6^0 42' 35'' - 4^0 45' 49''}{2}} = 205.597\text{m}$$

Note:

Radius of connecting curve, thus, coming is prohibitive for negotiating the passenger trains. It is recommended that radius of connecting curve should be at least equal to the radius of lead curve of 1 in 8.5 turnout, which can be taken as 220m.

$$X = (B_1 + T)\text{Cos}F_1 + (B_2 + T)\text{Cos}F_2$$

$$= (17.418 + 3.492)\text{Cos }6^0 42' 35'' + (23.981 + 3.492)\text{Cos }4^0 45' 49''$$

$$= 20.767 + 27.378 = 48.145\text{m}$$

$$OL = X + A_1 + A_2$$

$$= 48.145 + 12.000 + 16.953 = 77.098\text{m}$$

Example 5.5

In example 5.4, if the radius of connecting curve radius is required to be the same as that of the radius of lead curve of 1 in 12 turnout, calculate the minimum distance 'D' between the two tracks and the various parameters for the layout. Radius of connecting curve can be taken as equal to 441.282m.

$$T = R\tan\frac{F_1 - F_2}{2} = 441.282 \times \tan\frac{6^0 42' 35'' - 4^0 45' 49''}{2} = 7.495\text{m}$$

$$D = (B_1 + T)\text{Sin}F_1 + (T + B_2)\text{Sin}F_2$$

$$= (17.418 + 7.495)\text{Sin }6^0 42' 35'' + (23.981 + 7.495)\text{Sin }4^0 45' 49''$$

$$= 2.911 + 2.614 = 5.525\text{m}$$

$$X = (B_1 + T)\text{Cos}F_1 + (T + B_2)\text{Cos}F_2$$

$$= (17.418 + 7.495)\text{Cos }6^0 42' 35'' + (23.981 + 7.495)\text{Cos }4^0 45' 49''$$

$$= 24.742 + 31.367 = 56.110\text{m}$$

$$OL = X + A_1 + A_2$$

$$= 56.110 + 12.000 + 16.953 = 85.062\text{m}$$

Ans : Hence D = 5.525m when minimum connecting curve radius is taken on 441.282 mtr.

Example 5.6

In the foregoing example 5.5, if the layout is on PSC sleepers, then calculate the minimum distance 'D' between the two tracks and other parameters for correctly laying the layout in the field. Minimum radius of connecting curve to be taken as that of the lead curve radius of 1 in 12 turnout.

Given :

Turnout	A	B (modified)	F
1 in 8.5	12.025m	19.786m	$6^0 42' 35''$
1 in 12	16.989m	28.412m	$4^0 45' 49''$

(These turnout parameters are for PSC layouts, 1673mm Gauge)

$$T = R\tan\frac{F_1 - F_2}{2} = 441.282 \times \tan\frac{6^0 42' 35'' - 4^0 45' 49''}{2} = 7.495\text{m}$$

$$D = (B_1\,(\text{modified}) + T)\text{Sin}F_1 + (B_2\,(\text{modified} + T)\text{Sin}F_2$$

$$= (19.786 + 7.495)\ \text{Sin}\ 6^0 42' 35''$$

$$+ (28.412 + 7.495)\text{Sin}\ 4^0 45' 49'' = 3.187 + 2.992 = 6.168\text{m}$$

$$X = (19.786 + 7.495)\text{Cos}\ 6^0 42' 35'' + (28.412 + 7.495)\text{Cos}\ 4^0 45' 49''$$

$$= 27.094 + 35.782 = 62.876\text{m}$$

$$OL = X + A_1 + A_2 = 62.876 + 12.025 + 16.989 = 91.890\text{m}$$

Note:

It is therefore, very important that when yard layout is on PSC Fan Shaped layout and track centre is less, then section engineer should remove long common sleepers from the Fan Shaped layout so that the connecting curve can be started earlier. It may also happen that, while performing the layout calculations, if one takes value of B instead of B (modified) and therefore during laying the turnout, geometry of the layout will be disturbed because of mismatch of calculations and the actual site parameters. Because of this mismatch, alignment will become kinky in the connecting curve, which in turn will be reflected as the kink in main line.

5.4 Crossover between a Loop Line and the Main Line with the Symmetrical Split on the Loop Line

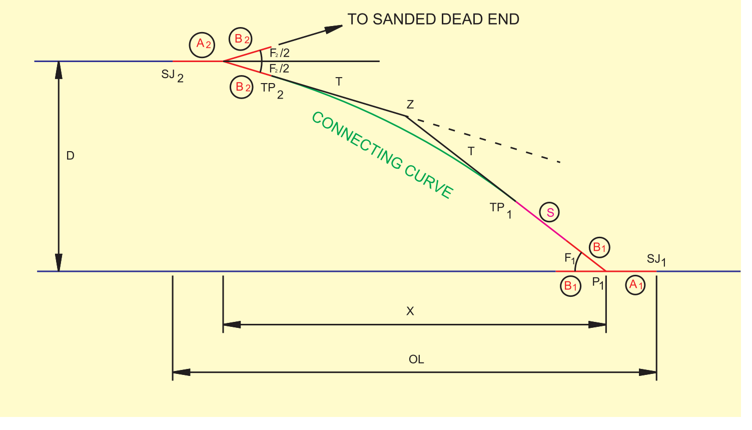


Figure 5.9 : Crossover between a loop line and the main line with the symmetrical split on the loop line

Formulae

$$(B_1 + S + T)\text{Sin}F_1 + (T + B_2)\text{Sin}\frac{F_2}{2} = D$$

$$\therefore S = \frac{D - (B_2 + T)\text{Sin}\frac{F_2}{2}}{\text{Sin}F_1} - (B_1 + T) \qquad (5.36)$$

$$T = R\tan\frac{\left(F_1 - \frac{F_2}{2}\right)}{2} \qquad (5.37)$$

$$X = (B_1 + S + T)\text{Cos}F_1 + (T + B_2)\text{Cos}\frac{F_2}{2} \qquad (5.38)$$

$$OL = X + A_1 + A_2 \qquad (5.39)$$

Interpretation of Formulae and Field Practicalities

From the field, value of 'D' will be known. Radius of connecting curve will be assumed as per the guidelines. From Eq 5.37 value of 'T' can be calculated and the from Eq 5.36, 5.38 & 5.39, valus of 'S', 'X' & 'OL' can be calculated respectively. Now the work left is locating one Stock Joint with respect to another by keeping it at a distance 'OL' apart.

The same formulae can be used differently, when 'S' is given. Then from Eq 5.36 value of 'T' can be calculated and then from Eq 5.37, value of 'R' can be calculated. Value of 'R' thus arrived may or may not satisfy the recommended radius of connecting curve.

Several variations can also be thought of like a straight after both the Turnouts or a reverse curve between the heel of crossing or two ends of turnouts. Purpose of incorporating these variations is basically for designing an optimum layout keeping in view the space constraints, infringements or obligatory points.

Example 5.7

What is the minimum track centre required to lay a cross over with one end 60 kg 1 in 12 PSC layout and other end with 60kg 1 in 8.5 symmetrical split. Also calculate the overall length of x-over with this minimum track centre. Assume radius of connecting curve as 440m.

Given A1= 16.989m , B1= 28.412 m, F1= $4^0 45' 49''$

A2= 12.025m , B2= 19.786 m, F2= $6^0 42' 35''$

Solution:

As per equation (5.37)

$$T = R \tan \frac{(F_1 - F_2/2)}{2}$$

$$= 440 \tan \left(\frac{4^0 45' 49'' - 3^0 21' 17.5''}{2} \right)$$

$$= 5.409\text{m}$$

From equation (5.36) for "S" to be zero for minimum track centre; Hence

$$D - (B_2 + T) \sin \frac{F_2}{2} = (B_1 + T) \sin F_1$$

$$\text{OR } D = (B1 + T) \sin F1 + (B2 + T) \sin \frac{F_2}{2}$$

$$= (28.412 + 5.409) \sin 4^0 45' 49'' + (19.786 + 5.409)$$

$$\sin 6^0 42' 35''/2$$

$$= 2.808 + 1.4736$$

$$= 4.282 \text{ m}$$

Overall length from equation (5.38) and (5.39)

$$OL = (B_1 + T) \cos F_1 + (B_2 + T) \text{COS} \frac{F_2}{2} + (A_1 + A_2)$$

$$= (28.412 + 5.409) \cos F_1 + (19.786 + 5.409) \cos \frac{F_2}{2} + (16.989 + 12.025)$$

$$= 33.704 + 12.511 ++ 29.014$$

$$= 75.229\text{m.}$$

Example 5.8

A crossover is required to be laid between a Loop Line and a parallel main line at 4.725m track centres by using a 52 Kg PSC, 1 in 8.5 symmetrical split turnout on the Loop Line and 52Kg PSC, 1 in 12 turnout on the main Line. Radius of the connecting curve being equal to the lead radius of the 1 in 8.5 symmetrical split. Calculate the required parameters for the layout.

Given:

Turnout	A	B	F
1 in 8.5	12.025m	19.786m	$6^0 42^' 35^{''}$
1 in 12	16.989m	28.414m	$4^0 45^' 49^{''}$

Solutions : Radius of connecting curve given is same as the lead radius of symmetrical split, which is equal to 464.070 m for 1 in 8.5 PSC symmetrical split turnout as per RDSO drg. No. RDSO/T-5353.

$$T = R\tan\frac{\left(F_1 - \frac{F_2}{2}\right)}{2} = 464.070 \times \tan\frac{\left(4^0 45^' 49^{''} - \frac{6^0 42^' 35^{''}}{2}\right)}{2} = 5.705$$

$$S = \frac{D - (B_2^' + T)\ \mathrm{Sin}\frac{F_2}{2}}{\mathrm{Sin}F_1} - (B_1^' + T)$$

$$= \frac{4.725 - (19.786 + 5.457)\mathrm{Sin}\frac{6^0 42^' 35^{''}}{2}}{\mathrm{Sin}4^0 45^' 49^{''}} - (28.414 + 5.705) = 4.989$$

$$X = (B^' 1 + S + T)\mathrm{Cos}F_1 + (T + B^' 2)\ \mathrm{Cos}\ \frac{F_2}{2}$$

$$= (28.414 + 4.989 + 5.705)\ \mathrm{Cos}4^0 45^' 49^{''} + (5.705 + 19.786)\ \ \mathrm{Cos}\frac{6^0 42^' 35^{''}}{2}$$

$$= 38.972 + 25.447 = 64.419$$

$$OL = X + A_1 + A_2 = 64.149 + 16.989 + 12.025 = 93.433\mathrm{m}$$

5.5 Crossover in Multi Track Area

Crossover in Multi Track area known as 'Double Junctions' involve provision of a diamond crossing in between two Turnouts. Such layouts permit diversion of UP/DN directional train from fast corridor to the slow corridors and vice versa. The turnouts are normally of 1 in 12 spread, while the diamond crossing is of 1 in 8.5 spread. Hence the connection will involve a connecting Curve.

It will be seen that for such a connection, the minimum track centre distance required for introducing a connecting curve of 1 in 12 turnout lead curve radius is 5.5m on BG which is not always available. The following alternatives are recommended in such layouts;

- At locations where such layouts are already laid with the existing distance between track centres , it is preferable to replace the existing 1 in 12 turnout with 1 in 8.5 turnout with curved switches to have a straight line connection i.e. without a curve between the heel of crossings. This will not only improve the layout alignment but also result in saving in the overall distance which may be of a great advantage in the restricted suburban area. If the replacement as suggested above can not be effected for some reason or other, then existing layout can be improved by correctly calculating the resultant radius of connecting curve after properly assessing the track centres distance and providing the same with accuracy and care.

- Whenever such crossovers are newly introduced, intermediate diamond crossings should be of the same spread as that of the turnout. Therefore, for 1 in 12 turnout, the diamond crossing in between shall be of movable switch type so that the connection will be by means of straight line connection between the heel of crossings.

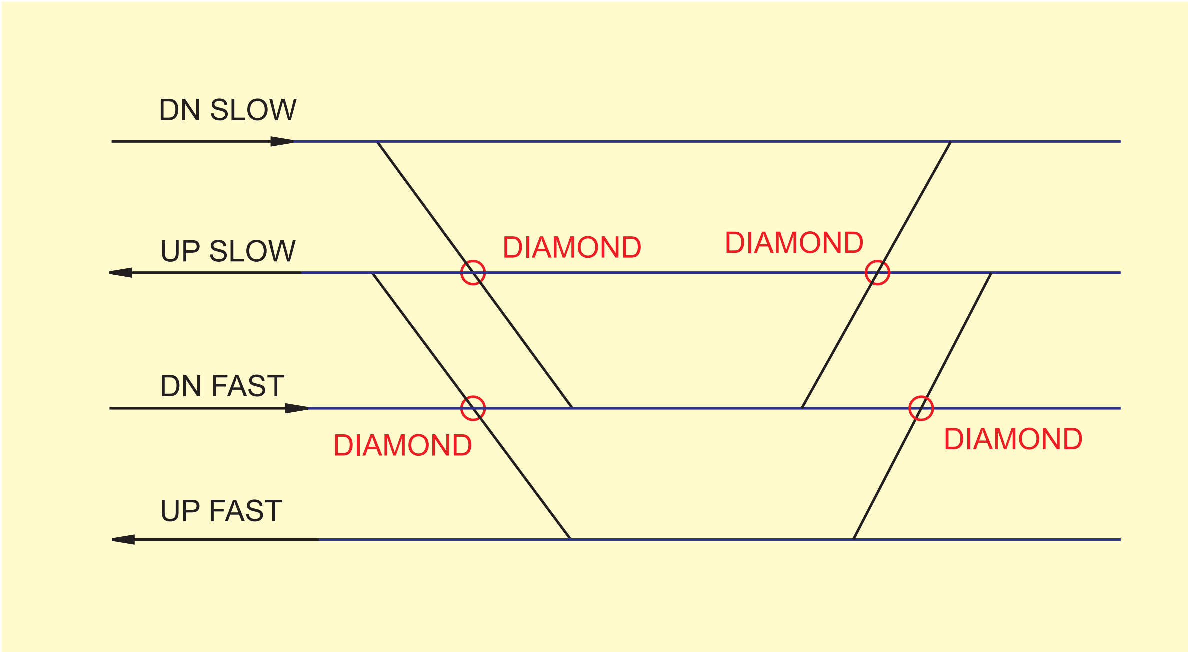


Figure : 5.10 cross over in multi track area

Chapter 6

Scissors Cross-Over between Straight Parallel Tracks

6.1 Scissors Cross-Overs

When two cross-overs overlap each other, preferably exactly opposite to each other, a scissors cross-over is said to have been formed. A diamond is formed where the cross-over cross each other in addition to the four turnouts. The same function can be achieved by two cross-overs facing each other.(Fig 6.1)

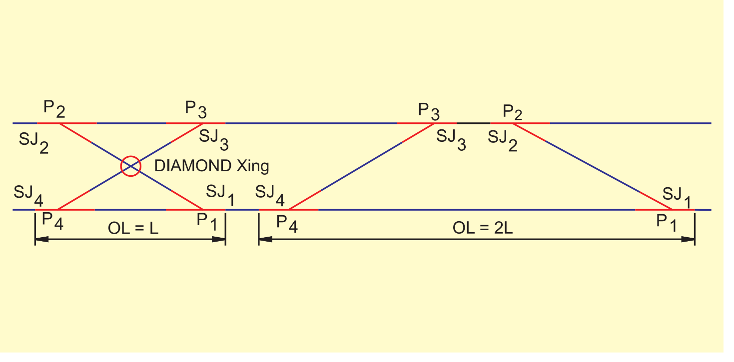


Figure : 6.1 : Scissors cross-overs

The advantage of providing a scissors cross over is the saving of space in an important congested yard, but this involves having an additional diamond crossing in the yard. A scissors cross-over is equated to three cross-overs for the purpose of assessing the maintenance cost.

The angle of diamond crossings are twice the crossing angle of turnout. They are also commonly called by half the number of the turnout crossing e.g. for 1 in 8.5 turnouts the diamond crossing is listed as

1 in 4.25, though it is strictly incorrect because cot (2F) will not be half that of cot (F). On Broad Gauge, scissors cross-over layouts have been finalized only for two track centers (on wooden layouts) viz: 4.725 m (15'6") and 5.180 m (17'0"). They can not be laid at track centers in between these distances due to difficulty in providing effective check rail guidance over the unguided gap in front of the ANCs of acute crossings for a wheel movement over the cross-overs.

6.2 Broad Gauge Scissors Cross-Over at 4.725m Track Centers

At 4.725 m track centers, the distance between the TNCs of the acute crossings of the diamond (L_d) formed in between the tracks is greater than the distance between the TNCs of the main line acute crossings (X). Hence the acute crossings of diamond lie outside the acute crossing of the main line turnouts as can be seen from the Fig 6.2.

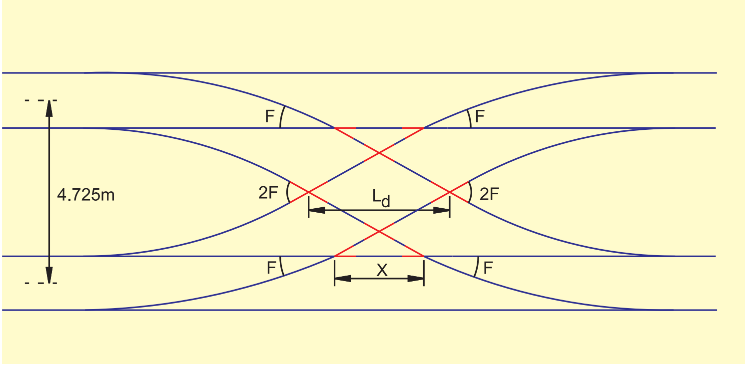


Figure : 6.2 : Broad gauge scissors cross-over at 4.725m track centers

The distances involved for negotiating 1 in 8½ crossovers at 4.725 m track centers are as under-

Distance between TNCs of crossings on main line (X),

$$X = DCotF - GCot\frac{F}{2} = 11572mm$$

The long diagonal of the diamond (L_d),

$$L_d = \frac{G}{SinF} = 14345mm$$

Hence distance between the TNCs of the acute crossings on

main line and diamond (X_1) is $= \dfrac{L_d - X}{2} = 1386mm$

Distance between ANCs along the straight (X_2),

$$X_2 = 1386 + 118 \text{ (for 1 in 8.5)} + 59 \text{ (for 1 in 4.25)} = 1563mm$$

The distance between ANCs along the cross - over as would be

traversed by a vehicle moving over the cross - over (X_3),

$$X_3 = \frac{1563}{CosF - GtanF} = 1377mm$$

The distance 1377 mm includes two gaps of 496 mm and 248 mm in front of 1 in 8.5 and 1 in 4.25 acute crossings respectively, which are required to be protected by provision of check rails opposite them. Since the distance between ANCs (X_3) i.e. 1377 mm is greater than total unguided gap (744 mm) at 4.725 m track centers, it is possible to provide special check rails for guiding the movement of wheels along the cross-over.

As the track center distance increases the distance between TNCs of main line turnouts (X) also increases while the dimensions of the diamond (L_d) remains constant with the result that the distance between ANCs of the acute crossings of main line and diamond (X_2 and X_3) get progressively reduced making it difficult to provide check rails opposite unguided gap. If the distance (X_3) comes closer to 744 mm, the total unguided gap, or lower than 744 mm then provision of check rail is not possible. This aspect would be clear from the following table 6.1 for 1 in 8.5 scissors cross-overs.

Table : 6.1

D	4725	4800	4900	5000	5015	5100	5200	5300
X	11572	11210	13060	13910	14037	14760	15610	16460
L_d	14344	14344	14344	14344	14344	14344	14344	14344
X_1	1386	1067	642	217	153	-208	-633	-4158
X_2	1563	1244	819	394	330	-31	-456	-881
X_3	1377	1056	628	200	136	-228	-656	-1084

As the track center increases the position becomes safe when ANCs of the diamond and ANCs of the main line crossings fall opposite each other i.e. when distance X_2 becomes zero (Fig 6.3). This occurs when the track centers become 5.015 m beyond which the wing rails of the crossing on main line and that of acute crossing of than diamond can be so extended that they perform the function of check rail opposite the crossings and give the effective guidance. This is possible till such increased track center is obtained when independent check rails can be placed opposite the respective gaps. The position is identical with 1 in 12 and 1 in 16 turnouts.

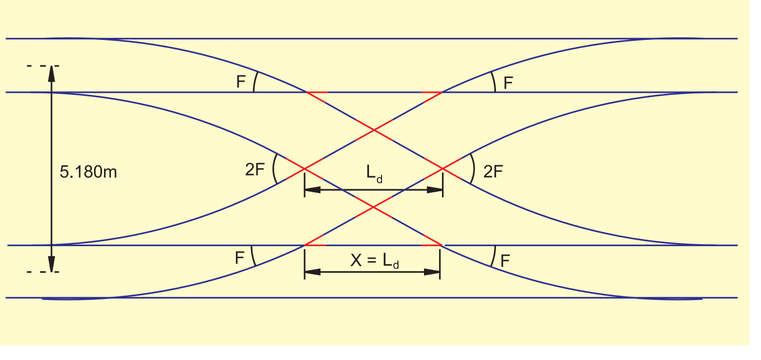


Figure : 6.3

For this purpose, Indian railways have finalized standard designs for 4.725 m (15'6") and 5.18 m (17') track centers on wooden layouts with extended wing rails for use on all new constructions. The design for 4.725 m track center is to cover existing situation since majority of the yards are laid at 4.725 (15'6") track centers.

A design for scissors cross-over on concrete sleeper layout at 4.725m track centre has been finalized for use in the field. However no design has been finalized for 5.18m track centres on concrete sleepers.

No designs have been finalized for 5.3 m track center which is now the recommended track center for new constructions because as per the recommended guidelines, use of scissors cross-over is to be avoided and on new constructions, layouts should be designed with the use of normal cross-overs.

For the Meter Gauge, effective independent check railing arrangements are possible even when they are laid at 4.265 m track centers as the distances between the TNCs are 5317 mm and 7548 mm in the case of 1 in 8.5 and 1 in 12 scissors cross overs respectively. This is large enough to place indepent checkrails opposite the nose of crossings.

■ ■ ■

Chapter 7

Crossovers between Non Parallel Straight Tracks

7.1 Crossovers between Non Parallel Straight Tracks

In the field, several situatios may arise where crossovers are to be laid between two non parallel straight tracks. Depending upon the site conditions, variety of connections can be made like with same or different angle of crossing, connecting curve being simple or reverse curve starting just after the heel of crossing or after a straight behind the heel of crossing. If the connecting curve being the reverse curve then it may be with or without a straight in between. It means that, there can be several permutations & combinations and variety of formulae can be generated.

Let us derive the set of formulae for a crossover connection between two non parallel straight tracks with the following conditions;

7.1.1 Connecting curve being simple circular curve between the ends of two turnouts and angle of crossings being different on the two ends.

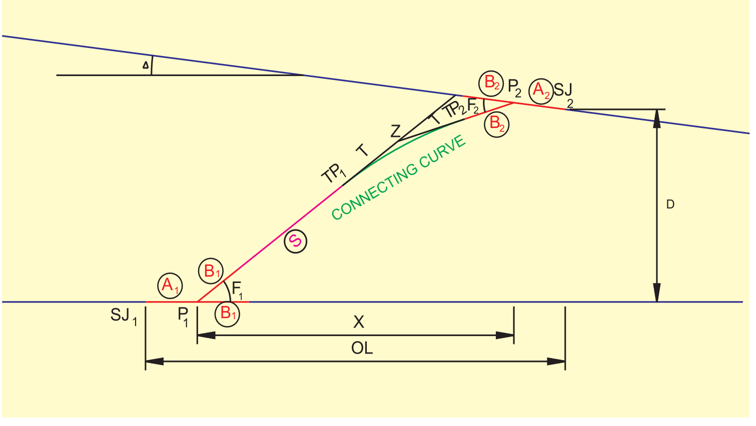


Figure 7.1 : Crossover between non parallel straight tracks

$$T = R\tan\frac{\Delta + F_1 - F_2}{2} \quad \text{Where } \Delta \text{ is angle between two non parallel straight} \tag{7.1}$$

$$(B_1 + T)\text{Sin}F_1 + (T + B_2)\text{Sin}(F_2 - \Delta) - A_2\text{Sin}\Delta = D \tag{7.2}$$

$$X = (B_1 + T)\text{Cos}F_1 + (B_2 + T)\text{Cos}(F_2 - \Delta) \tag{7.3}$$

$$OL = X + A_1 + A_2\text{Cos}\Delta \tag{7.4}$$

Interpretation of Formulae and Field Practicalities

Given 'R', Angle between two non parallel straight tracks 'Δ' and turnout parameters;

Eq 7.1 will be used for calculating the value of 'T'. Once 'T' is known, Min 'D' (Where 'SJ_2' will be fixed) will be calculated from Eq 7.2 and finally 'X' & 'OL' will be calculated from Eq 7.3 & 7.4 respectively. Now 'SJ_1' can be fixed at a distance 'OL' from 'SJ_2'.

Given 'D'(where'SJ_2' is fixed), Angle between two non parallel straight tracks 'Δ' and turnout parameters;

Eq 7.2 will be used for calculating the value of 'T'. Once 'T' is known, value of 'R' can be calculated from Eq 7.1 which may or may not satisfy the recommended radius of turn-in-curve. After that the value of 'X' & 'OL' can be calculated from Eq 7.3 & 7.4 respectively.

Note : *For PSC layout B_1 & B_2 Shall be choosen from annexure-III and curve will accordingly start from end of B (modified).*

Example 7.1

A crossover consisting of 52 Kg, 1 in 12 and 1 in 8.5 turnouts is required to be laid between non parallel straight tracks at a minimum distance between the two track centres. The angle between the two non parallel straight tracks is $3^0 50' 0''$. Calculate the various parameters required to lay the crossover connection assuming the connecting curve radius equal to 400m.

Given:

Turnout	A	B	F
1 in 8.5	12.000m	17.418m	$6^0 42' 35''$
1 in 12	16.953m	23.981m	$4^0 45' 49''$

Solution : This is a non PSC layout

$$T = R\tan \frac{\Delta + F_1 - F_2}{2}$$

$$= 400 \times \tan \frac{3^0 50' 0'' + 6^0 42' 35'' - 4^0 45' 49''}{2} = 20.191\text{m}$$

$$\text{Dmin} = (B_1 + T)\text{Sin } 6^0 42' 35'' + (T + B_2)\text{Sin}(F_2 - \Delta) - A_2 \text{Sin}\Delta$$

$$= (17.418 + 20.191)\text{Sin } 6^0 42' 35''$$

$$+ (20.191 + 23.981)\text{Sin } (4^0 45' 49'' - 3^0 50' 0'') - 16.953\text{Sin } 3^0 50' 0''$$

$= 4.394 + 0.717 - 1.133 = 3.978$m so SJ_2 will be located where the distance between two parallel track between 3.978m.

$$X = (B_1 + T)\text{Cos}F_1 + (T + B_2)\text{Cos}(F_2 - \Delta)$$

$$= (17.418 + 20.191)\text{Cos } 6^0 42' 35''$$

$$+ (20.191 + 23.981)\text{Cos } (4^0 45' 49'' - 3^0 50' 0'')$$

$$= 37.351 + 44.166 = 81.517\text{m}$$

$$\text{OL} = X + A_1 + A_2 \text{Cos}\Delta$$

$$= 81.517 + 12.000 + 16.953\text{Cos } 3^0 50' 0'' = 110.432\text{m}$$

7.1.2 Crossover between non parallel straight track and connecting curve after a straight "S" from main line turnout :

If there is a straight behind crossing of main line turnout as shown in fig 7.1 then the formula be modified as under.

$$(B_1 + S + T) \text{ Sin } F_1 + (B_2 + T) \text{ Sin } (F_2 - \Delta) - A_2 \text{ Sin } \Delta = D \quad (7.5)$$

$$X = (B_1 + S + T) \text{ Cos} F_1 + (T + B_2) \text{ Cos } (F_2 - \Delta)$$

Then OL from equation 7.4, (7.6)

$$OL = X + A_1 + A_2 \text{ Cos } \Delta$$

Hence, while choosing the value of straight "S" one has to take care that for PSC layout an additional straight length behind HOC of 5.5 m for 1.12 and 3.3 m for 1 in 8.5 has already been taken in to account at the time of taking values of B (modified) in above formula. The rest of interpretation and application on ground is similar as discussed in para 7.1.1.

Example 7.2

In previous example 7.1, calculate various parameter required to lay a cross over connection if the turnouts are on PSC layout and a suitable straight is to be laid behind end of PSC layout or from heel of crossing.

Given: $\Delta = 3°50'0"$

Turnout	A	B (modified)	F
1 in 8.5	12.025m	19.786 m	$6^0 42' 35''$
1 in 12	16.989.m	28.414 m	$4^0 45' 49''$

Solution :

The above turnout parameters are for PSC layout where B is upto end of last common sleeper. Let "S" the straight length after this extended length of PSC turnout be 9.7. Then from equation 7.1

$$T = 400 \text{ Tan } \frac{3^0 50' 0'' + 6^0 42' 35'' - 4^0 45' 49''}{2}$$

$= 20.191$ m.

Then from equation 7.5

$D_{min} = (B_1 + S + T) \sin F_1 + (B_2 + T) \sin (F_2 - \Delta) – A_2 \sin \Delta$

$= (19.786+9.7+20.191) \sin 6^0 42' 35'' + (28.414 + 20.191)$

$\sin (4^0 45' 49'' - 3^0 50' 0'') - 16.989 \sin 3^0 50' 0''$

$= 5.80 + 0.789 – 1.135$

$= 5.458$ m

Hence SJ2 will be located at a point where the difference between track centre distances becomes 5.458m

From equation 7.6

$X = (B_1 + S + T) \cos F_1 + (T + B_2) \cos(F_2 - \Delta)$

$= (19.786 + 9.7 + 20.191) \cos 6^0 42' 35'' + (20.191 + 28.414)$

$\cos (4^0 45' 49'' - 3^0 50' 0'')$

$= 49.336 + 48.598$

$= 97.934$

$OL = X + A_1 + A_2$

$= 97.934 + 12.025 + 16.989$

$= 126.948$ m

Note :

Here value of S has been taken as 9.7m so as to make a straight length behind HOC of 1 in 8.5 turnout (Turnout on mainline) equal to 9.7 +3.3 = 13.0 m

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Chapter 8

Connection between Curved Track to Parallel Curved Track or Divergent Straight Track

Connections have at times to be laid from Curved Track to either parallel track or divergent straight track. Understanding about such connections is very important for a field engineer so that the same can be applied for proper design of such layouts. Several situations can be thought of such that;

- Connection between two curved parallel tracks. Connection being on outside of main Line curve without a straight between the heel of crossing and the connecting curve.

- Connection between two curved parallel tracks. Connection being on outside of main Line curve with a straight between the heel of crossing and the connecting curve.

- Connection between two curved parallel tracks. Connection being on inside of main Line curve

- Connection between a curved track to straight track, the intersection being on the inside of the main line curve.

- Connection between a curved track to straight track, the intersection being on the outside of the main line curve.

8.1 Connection between two Curved Parallel Tracks. Connection being on Outside of Main Line Curve without a Straight between the Heel of Crossing and the Connecting Curve.

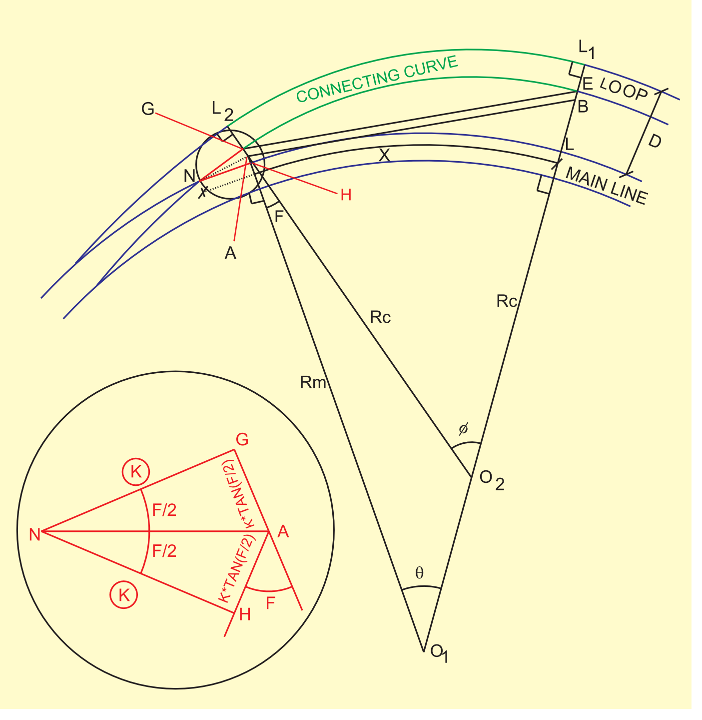


Figure 8.1 : Connection between two curved parallel tracks. connection being on Outside of main line curve without a straight between the heel of crossing and the connecting curve

Formulae

Join G with E and Draw a Line AB Parallel to GE

R_m = radius of curved main line (outer rail)

R_c = radius of connecting curve (outer rail)

From the Geometry of the Fig 8.1,

$\angle O_1 AO_2 = F$

In $\Delta\, O_2 G\, E$ (Isoceles Triangle)

$\angle O_2 G\, E = \angle O_2 E\, G$

$\therefore \angle O_2 A\, B = \angle O_2 BA$ (AB is Parallel to GE)

In $\Delta\, O_1 A\, B$, Applying tan Formula,

$$\tan \frac{\angle O_1 A\, B - \angle O_1 B\, A}{2} = \frac{O_1 B - O_1 A}{O_1 B + O_1 A} \mathrm{Cot} \frac{\angle A\, O_1 B}{2}$$

$$\angle O_1 A\, B - \angle O_1 B\, A = \angle O_1 AO_2 + \angle O_2 A\, B - \angle O_1 BA$$

$$= \angle O_1 AO_2 + \angle O_2 A\, B - \angle O_2 A\, B \quad (\because \angle O_1 BA = \angle O_2 BA = \angle O_2\, AB)$$

$$= \angle O_1 AO_2 = F$$

$$O_1 B = O_1 L - L_1 E - EB = R_m + D - G - K\tan \frac{F}{2}$$

where $EB = GA = K\tan \frac{F}{2}$

$$O_1 A = O_1 H + HA = R_m + K\tan \frac{F}{2}$$

$$\therefore\ O_1 B - O_1 A = R_m + D - G - K\tan \frac{F}{2} - R_m - K\tan \frac{F}{2}$$

$$= D - G - 2K\tan \frac{F}{2}$$

$$O_1B + O_1A = R_m + D - G - K\tan\frac{F}{2} + R_m + K\tan\frac{F}{2}$$

$$= 2R_m + D - G$$

$$\therefore \tan\frac{F}{2} = \left(\frac{D - G - 2K\tan\frac{F}{2}}{2R_m + D - G}\right)\mathrm{Cot}\frac{\theta}{2}$$

$$\therefore \tan\frac{\theta}{2} = \left(\frac{D - G - 2K\tan\frac{F}{2}}{2R_m + D - G}\right)\mathrm{Cot}\frac{F}{2}$$

$$\therefore \theta = 2\tan^{-1}\left\{\left(\frac{D - G - 2K\tan\frac{F}{2}}{2R_m + D - G}\right)\mathrm{Cot}\frac{F}{2}\right\} \quad \text{.................................(8.1)}$$

$\Delta O_1 A O_2$ Apply Sine Formula,

$$\frac{\mathrm{Sin}\angle O_1 O_2 A}{O_1 A} = \frac{\mathrm{Sin}\angle A O_1 O_2}{O_2 A}$$

$$O_1A = R_m + K\tan\frac{F}{2}$$

$$O_2A = O_2L_2 - L_2G - GA = R_c - G - K\tan\frac{F}{2}$$

$$\therefore \frac{\mathrm{Sin}(180 - \varphi)}{R_m + K\tan\frac{F}{2}} = \frac{\mathrm{Sin}\theta}{R_c - G - K\tan\frac{F}{2}}$$

$$\frac{\sin(\theta + F)}{R_m + K\tan\frac{F}{2}} = \frac{\sin\theta}{R_c - G - K\tan\frac{F}{2}} \qquad \text{where } \varphi = \theta + F$$

$$\therefore R_c = \frac{\sin\theta\left(R_m + K\tan\frac{F}{2}\right)}{\sin(\theta + F)} + G + K\tan\frac{F}{2} \qquad \text{........................(8.2)}$$

$$X = NH + HL = K + R_m\,\theta \qquad \text{where '}\theta\text{' is in radians}$$

$$= K + \frac{\pi R_m \theta}{180} \qquad \text{where '}\theta\text{' is in degrees} \quad \text{........................... (8.3)}$$

Note :
For PSC layout connecting curve will start from end of extended or modified length of K.

Interpretation of Formulae and Field Practicalities

When the connections pertaining to curved lines are required to be laid in the field, it will be prudent to fix the crossing first and then the entire turnout and connecting curves are laid.

Distance 'D' between the two curved parallel tracks and radius of main line 'R_m' will be known from field surveying. Value of turnout parameters will be known once we have decided the turnout.

Now from Eq 8.1, value of θ will be calculated. Eq 8.2 will be used for calculating the value of radius of connecting curve 'R_c'. And Finally 'X' will be calculated from Eq 8.3. Point 'L_1' will be decided from field constraints to locate a point on loop. Then point 'L' will be marked redially from point 'L_1' on main line. Now with refernce to 'L', distance 'X' will be measured along the outer rail of curved main line to fix the TNC. It may also happen that TNC is already fixed, then Point 'L' can be fixed by measuring a distance 'X' along the outer rail of the curved main line. After 'L' being fixed, 'L_1' can easily be fixed by field surveying.

It is evident from the formulae, that value of connecting curve radius 'R_c' will be fixed for a given set of boundary conditions like 'R_m', 'D' & turnout parameters. It may so happen that 'R_c' may or may not satisfy the recommended radius of connecting curve.

Example 8.1

Calculate the radius of connecting curve 'R' and layout distance 'X' for a connection between a curved main line and a curved parallel track at 4.725m distance. Connection being on the outside of the main line without a straight after the heel of crossing by using 1 in 8.5 crossing.

Given; K=3.123m, F=$6^0 42' 35''$, Rm = 450m

$$\theta = 2\tan^{-1}\left\{\left(\frac{D - G - 2K\tan\frac{F}{2}}{2R_m + D - G}\right)\mathrm{Cot}\frac{F}{2}\right\}$$

$$= 2\tan^{-1}\left\{\left(\frac{4.725 - 1.676 - 2\times 3.123\tan\frac{6^0 42' 35''}{2}}{2\times 450 - 4.725 - 1.676}\right)\mathrm{Cot}\frac{6^0 42' 35''}{2}\right\}$$

$$= 2\tan^{-1}\left(\frac{2.682857\times 17.0589}{903.049}\right) = 5^0 49' 33''$$

$$R_c = \frac{\mathrm{Sin}\theta\left(R_m + K\tan\frac{F}{2}\right)}{\mathrm{Sin}(\theta + F)} + G + K\tan\frac{F}{2}$$

$$= \frac{\mathrm{Sin}\ 5^0 49' 33'' \times \left(450 + 3.123\times\tan\frac{6^0 42' 35''}{2}\right)}{\mathrm{Sin}(5^0 49' 33'' + 6^0 42' 35'')}$$

$$+ 1.676 + 3.123\times\tan\frac{6^0 42' 35''}{2} = 212.395\mathrm{m}$$

$$X = K + \frac{\pi R_m \theta}{180} = 3.123 + \frac{\pi\times 450\times 5^0 49' 33''}{180} = 48.877\mathrm{m}$$

Note :

Calculations as performed above are the direct calculations. But in case of designing a layout connection, limiting the radius of the connecting curve 'R_c', it will be required to calculate the required radius of curved main line so as to satify the predecided radius of connecting curve. For such calculations, problem can best be solved by 'Trial & Error' process with a number of values of 'R_m'. A ready made graph can also be prepared between 'R_m' & 'R_c' for different track centres for a given turnout, connection being on outside of main line without a straight after the heel of crossing. If radius of main line is predecided then track centres will have to be varied so as to ensure that R_c the radius of connecting curve is not sharper than 220m.

8.2 Connection between two curved parallel tracks. Connection being on outside of main Line curve with a straight between the heel of crossing and the connecting curve

The author is against this type of layout unless ‘D’ is very large as otherwise the ‘Rc’ is reduced considerably because of a straight between the heel of crossing and the connecting curve. For normal distances of the loop line, the ‘R_c’ will have prohibitive values unless ‘D’ is very very large. This layout as well as the layout discussed in previous clause, three curves i.e. lead curve, connecting curve & parallel curved line are laid and for good maintenance, it is very much desirable to have the curves as large as possible.

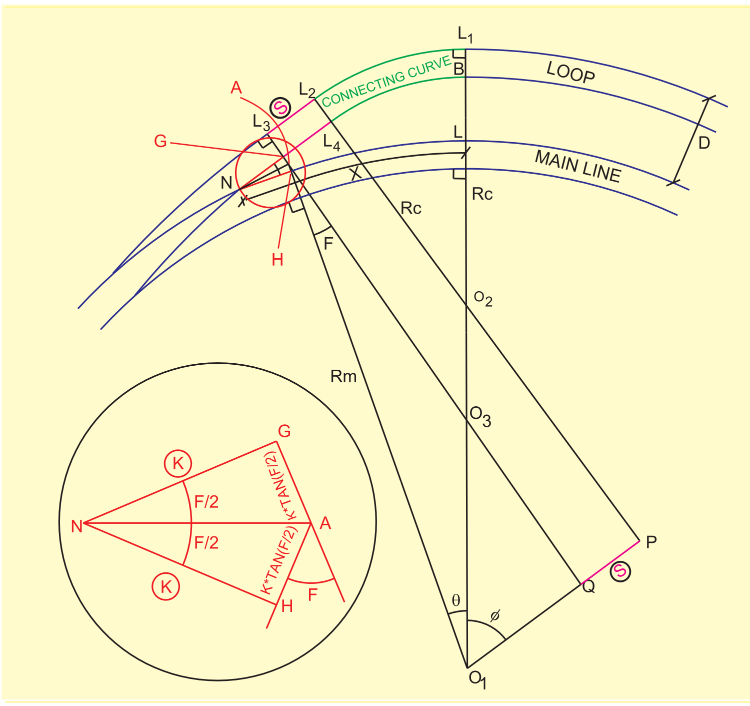


Figure 8.2: Connection between two curved parallel tracks. Connection being on outside of main line curve with a straight between the heel of crossing and the connecting curve.

Formulae

$L_2 O_2$ is extended upto P as same radial line. AQ is drawn parallel to L_2 P. O_1QP is drawn normal from O_1 to AQ and L_2P

R_m = Radius of curved main line (outer rail) = O_1 H

R_c = Radius of connecting curve (outer rail) = $O_2L_1 = O_2L_2$

S = Straight after the heel of crossing = L_3L_2=GL_4

From the Geometry of the Fig 8.2,

GA =HA = K tan F/2

$O_1A = O_1H+HA = Rm+K \tan F/2$

Let $\angle O_2O_1P = \varphi$

In $\Delta\ O_1 P O_2$

$$O_1O_2 = O_1L_1 - L_1O_2 = O_1L + LL_1 - L_1O_2$$

$$= R_m + D - R_c$$

$$O_1P = O_1Q + QP = O_1A\mathrm{Sin}F + S \quad \textit{where } QP = GL_4 = S$$

$$= (R_m + K\tan\frac{F}{2})\mathrm{Sin}F + S \qquad \textit{where } O_1A = R_m + K\tan\frac{F}{2}$$

$$O_2P = L_4P - O_2L_4 = GQ - O_2L_4 = GA + AQ - (O_2L_2 - L_2L_4)$$

$$= K\tan\frac{F}{2} + (R_m + K\tan\frac{F}{2})\mathrm{Cos}F - (R_c - G)$$

$$\therefore O_2P = (R_m + K\tan\frac{F}{2})\mathrm{Cos}F + K\tan\frac{F}{2} - (R_c - G)$$

$$O_1O_2^2 = O_1P^2 + O_2P^2$$

Substituting the values of O_1O_2 ,O_1P & O_2P in the above Equation;

$$(R_m + D - R_c)^2 = \left\{(R_m + K\tan\frac{F}{2})\mathrm{Sin}F + S\right\}^2$$
$$+ \left\{(R_m + K\tan\frac{F}{2})\mathrm{Cos}F + K\tan\frac{F}{2} + G - R_c\right\}^2$$

$$(R_m + D)^2 + R_c{}^2 - 2(R_m + D)R_c = \left\{(R_m + K\tan\frac{F}{2})\mathrm{Sin}F + S\right\}^2$$

$$+ \left\{(R_m + K\tan\frac{F}{2})\mathrm{Cos}F + K\tan\frac{F}{2} + G\right\}^2 + R_c{}^2$$

$$- 2R_c\left\{(R_m + K\tan\frac{F}{2})\mathrm{Cos}F + K\tan\frac{F}{2} + G\right\} \text{ now solving for } R_c$$

$$R_c = \frac{(R_m + D)^2 - \left\{(R_m + K\tan\frac{F}{2})\mathrm{Sin}F + S\right\}^2}{2\left\{R_m + D - (R_m + K\tan\frac{F}{2})\mathrm{Cos}F - G - K\tan\frac{F}{2}\right\}}$$

$$- \frac{\left\{(R_m + K\tan\frac{F}{2})\mathrm{Cos}F + K\tan\frac{F}{2} + G\right\}^2}{2\left\{R_m + D - (R_m + K\tan\frac{F}{2})\mathrm{Cos}F - G - K\tan\frac{F}{2}\right\}} \quad \text{...........(8.4)}$$

$$\mathrm{Cos}\varphi = \frac{O_1P}{O_1O_2} = \frac{(R_m + K\tan\frac{F}{2})\mathrm{Sin}F + S}{R_m + D - R_c} \quad \text{.............................. (8.5)}$$

$$\text{In } \Delta\, AQO_1,\ F + \theta + \varphi + 90 = 180 \ \&\text{ hence } \ \theta = 90 - (F + \varphi) \text{ ......(8.6)}$$

$$X = NH + HL = K + \frac{\pi R_m \theta}{180} = K + \frac{\pi R_m \{90 - (F + \varphi)\}}{180} \text{..........(8.7)}$$

Note :

For PSC layout, the straight so assumed should take into account the extended straight length behind HOC due to prefixed inserts.

Interpretation of Formulae and Field Practicalities

Distance 'D' between the two curved parallel tracks and radius 'R' of main line will be known from field surveying. Value of turnout parameters will be known once we have decided the type of turnout. Now value of 'S' will have to be assumed. Then from Eq 8.4 value of 'R_c' will be calculated. Value of 'φ'and finally 'X' can be calculated from Eq 8.5, 8.6 & 8.7 respectively. Now TNC can be fixed easily as discussed in the previous clause.

Example 8.2

A curved main line track of 600m radius is required to be connected to a parallel siding at 4.725m distance on the outside by using a 60 Kg PSC, 1 in 12 turnout and with a straight portion of 10m behind the heel of crossing. Calculate the various parameters for the layout.

Given: $F = 4^0 45' 49''$, $K = 2.803m$, K (modified) $= 8.301m$

Solution :
Since straight behind HOC is 10m, it is taking care of straight length needed for fixity of inserts, hence K value as given above for CMS crossing without modifying for PSC will be used in calculation.

$$R_c = \frac{(R_m + D)^2 - \left\{(R_m + K\tan\frac{F}{2})\text{Sin}F + S\right\}^2}{2\left\{R_m + D - (R_m + K\tan\frac{F}{2})\text{Cos}F - G - K\tan\frac{F}{2}\right\}}$$

$$- \frac{\left\{(R_m + K\tan\frac{F}{2})\text{Cos}F + K\tan\frac{F}{2} + G\right\}^2}{2\left\{R_m + D - (R_m + K\tan\frac{F}{2})\text{Cos}F - G - K\tan\frac{F}{2}\right\}}$$

$$= \frac{(600+4.725)^2 - \left\{(600+2.803\times\tan\frac{4^0 45' 49''}{2})\text{Sin}4^0 45' 49'' + 10\right\}^2}{2\left\{600 + 4.725 - (600 + 2.803\times\tan\frac{4^0 45' 49''}{2})\text{Cos}4^0 45' 49'' - 1.676 - 2.803\tan\times\frac{4^0 45' 49''}{2}\right\}}$$

$$- \frac{\left\{(600+2.803\times\tan\frac{4^0 45' 49''}{2})\text{Cos}4^0 45' 49'' + 2.803\times\tan\frac{4^0 45' 49''}{2} + 1.676\right\}^2}{2\left\{600+4.725-(600+2.803\times\tan\frac{4^0 45' 49''}{2})\text{Cos}4^0 45' 49'' - 1.676 - 2.803\tan\frac{4^0 45' 49''}{2}\right\}}$$

$= 236.310$ m

$$\text{Cos}\varphi = \frac{(R_m + K\tan\frac{F}{2})\text{Sin}F + S}{R_m + D\text{-}R_c}$$

$$= \frac{(600+2.803\times\tan\frac{4^0 45' 49''}{2})\text{Sin } 4^0 45' 49'' + 10}{600+4.725 - 236.310} = 0.15952055$$

$\therefore \varphi = 80^0 49' 15''$, therefore $\theta = 90\text{- }(4^0 45' 49'' + 80^0 49' 15'' = 4^0 33' 34''$

$$X = K + \frac{\pi R_m \theta}{180}$$

$$= 2.803 + \frac{\pi\times 600 \times 4.559}{180}$$

$$= 50.525\text{m.}$$

From the above examples, it is evident that introduction of straight behind the heel of crossing is not desirable, since it reduces the radius of connecting curve.

8.3 Connection between two curved parallel tracks. Connection being on inside of main Line curve

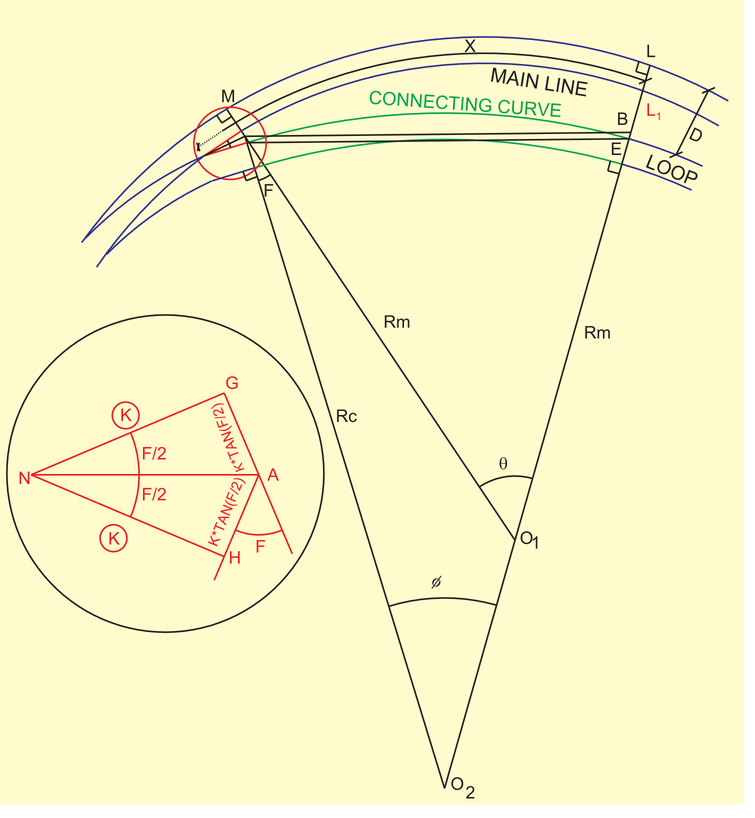


Figure 8.3 : Connection between two curved parallel tracks.
Connection being on inside of main Line curve

Formulae

Join H with E and Draw a Line AB Parallel to HE

R_m = radius of curved main line (outer rail)

R_c = radius of connecting curve (outer rail)

GA = AH = K tan F/2

From the Geometry of the Fig 8.3,

In ΔO_2HE (Isoceles Triangle) $\angle O_2HE = \angle O_2EH$

In ΔO_2AB,

$\therefore \angle O_2AB = \angle O_2BA$ (AB is Parallel to HE)

In ΔO_1AB, Applying tan Formula,

$$\tan \frac{\angle O_2BA - \angle O_1AB}{2} = \frac{O_1A - O_1B}{O_1A + O_1B} \operatorname{Cot} \frac{\theta}{2}$$

$$\angle O_1BA - \angle O_1AB = \angle O_1BA - \left(\angle O_2AB - \angle O_2AO_1\right)$$

$$= \angle O_1BA - \angle O_2AB + \angle O_2AO_1 = F$$

$\angle O_2HE$ & $\angle O_2AB$ are similar triangles hence $\angle O_2HE = \angle O_2EH$

OR $\angle O_2AB = \angle O_2BA = \angle O_1BA$ ($\angle O_2BA$ and $\angle O_1BA$ being same angle).

$$O_1A = O_1M - MG - GA = R_m - G - K\tan\frac{F}{2}$$

$$O_1B = O_1L - LE + EB = R_m - D + K\tan\frac{F}{2}$$

$$O_1A - O_1B = R_m - G - K\tan\frac{F}{2} - R_m + D - K\tan\frac{F}{2}$$

$$= D - G - 2K\tan\frac{F}{2}$$

$$O_1A + O_1B = R_m - G - K\tan\frac{F}{2} + R_m - D + K\tan\frac{F}{2} = 2R_m - D - G$$

$$\therefore\ \tan\frac{F}{2} = \frac{D - G - 2K\tan\frac{F}{2}}{2R_m - D - G}\,\text{Cot}\,\frac{\theta}{2}$$

$$\therefore\ \theta = 2\tan^{-1}\left\{\frac{\left(D - G - 2K\tan\frac{F}{2}\right)}{\left(2R_m - D - G\right)}\,\text{Cot}\,\frac{F}{2}\right\} \qquad (8.7)$$

In $\Delta\, O_1O_2A$, $\theta = F + \varphi \qquad \therefore \varphi = \theta - F$

applying Sin Formula,

$$\frac{\text{Sin}(\theta - F)}{O_1A} = \frac{\text{Sin}(180 - \theta)}{O_2A}$$

$$O_1A = R_m - G - K\tan\frac{F}{2}$$

$$O_2A = R_c + K\tan\frac{F}{2}$$

$$\therefore\ \frac{\text{Sin}(\theta - F)}{R_m - G - K\tan\frac{F}{2}} = \frac{\text{Sin}\theta}{R_c + K\tan\frac{F}{2}}$$

$$\therefore\ R_c = \frac{\text{Sin}\theta(R_m - G - K\tan\frac{F}{2})}{\text{Sin}(\theta - F)} - K\tan\frac{F}{2} \qquad (8.8)$$

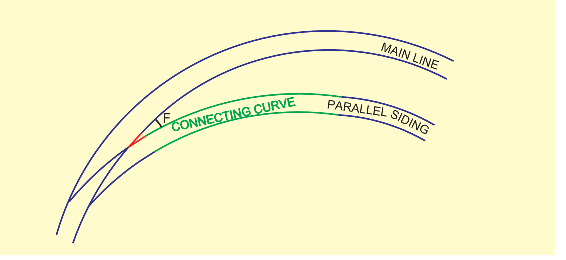
$X = NH + HL_1$, measured along inner rail of main line curve

$$= K + \frac{\pi(R_m - G)\theta}{180} \quad \text{where } \theta \text{ is in degrees} \qquad (8.9)$$

The value of K or K (modified) has to be selected based on whether it is PSC layout or otherwise

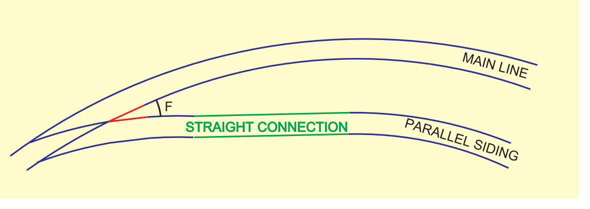
Note:
It may be observed that value of R_c can have a positive, infinate or a negative value depending on 'R_m', 'Sin (θ - F)' & 'D', other variables like 'K', 'F' & 'G' being constant. Three type of connections are possible in such layouts namely;

Type I $\theta - F > 0$,'R_c' will be positive and then 'R_c' & 'R_m' are in similar flexure.



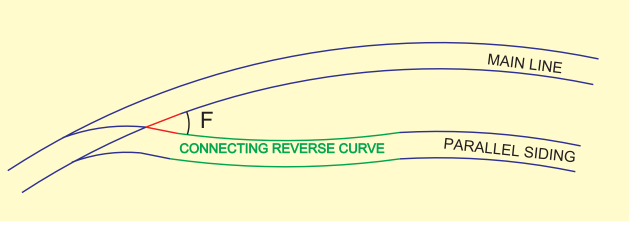
Type I

Type II $\theta - F = 0$, 'R_c' will be infinite, i.e. there will be no curve between the heel of Xing and the siding and the connections will be by means of a straight track.



Type II

Type III $\theta - F < 0$, 'R_c' will be negative, and therefore it will be in reverse direction to the main line curve.



Type III

Example 8.3

A curved main line track of 500m radius is required to be connected to a curved parallel siding at 4.725m distance, the connection being on the inside of the curve by means of a 52 Kg, 1in 12 PSC turnout. Calculate the various parameters for the layout.

Given: $F = 4^0 45' 49''$, K (modified) = 8.303m

Solution : This is case of 1 in 12 PSC layout, hence K(modified) as given in annexure-III shall be used.

$$\theta = 2\tan^{-1}\left\{\left(\frac{D - G - 2K\tan\frac{F}{2}}{\left(2R_m - D - G\right)}\right)\text{Cot}\,\frac{F}{2}\right\}$$

$$= 2\tan^{-1}\left\{\frac{\left(4.725 - 1.676 - 2\times 8.303\times\tan\frac{4^0 45' 49''}{2}\right)}{\left(2\times 500 - 4.725 - 1.676\right)}\text{Cot}\,\frac{4^0 45' 49''}{2}\right\}$$

$$= 6^0 31' 54'' > F \text{ (Type I)}$$

$$R_c = \frac{\text{Sin}\theta(R_m - G - K\tan\frac{F}{2})}{\text{Sin}(\theta - F)} - K\tan\frac{F}{2}$$

$$R_c = \frac{\text{Sin } 6^0 31' 54'' \ (500 - 1.676 - 8.303\times\tan\frac{4^0 45' 49''}{2})}{\text{Sin }(6^0 31' 54'' - 4^0 45' 49'')}$$

$$- 8.303\times\tan\frac{4^0 45' 49''}{2} = 1835.628\text{m}$$

$$X = K + \frac{\pi(R_m - G)\theta}{180} = 8.303 + \frac{\pi(500 - 1.676)\times 6^0 31' 54''}{180} = 65.082\text{m}$$

Example 8.4

In the previous example 8.3, if the connection is to be made with a straight between the heel of crossing and the curved parallel track, calculate the radius of curved main line and other parameters for the layout.

Solution :

If it is to be with a straight line connection, then θ =F. Substituting this value in the equation 8.7. Since it is a PSC layout k(modified) will be used in all calculations.

$$\theta = 2\tan^{-1}\left\{\frac{\left(D - G - 2K\tan\frac{F}{2}\right)}{\left(2R_m - D - G\right)}\operatorname{Cot}\frac{F}{2}\right\}$$

$$\therefore\ 2R_m - D - G = \left(D - G - 2K\tan\frac{F}{2}\right)\frac{\operatorname{Cot}\frac{F}{2}}{\tan\frac{\theta}{2}}$$

$$\therefore\ R_m = \frac{\left(D - G - 2K\tan\frac{F}{2}\right)\left(\operatorname{Cot}\frac{F}{2}\right)^2}{2} + \frac{D + G}{2}$$

$$= \frac{\left(4.725 - 1.676 + 2 \times 8.303 \times \tan\frac{4^0 45' 49''}{2}\right)\left(\operatorname{Cot}\frac{4^0 45' 49''}{2}\right)^2}{2}$$

$$+ \frac{4.725 + 1.676}{2} = 1080.788\text{m}$$

$$X = K + \frac{\pi(R_m - G)\theta}{180} = 8.303 + \frac{\pi(1080.788 - 1.676) \times 4^0 45' 49''}{180}$$

$$= 98.021\text{m}$$

Example 8.5

A curved main line track of 2000m radius is required to be connected to a curved parallel siding at a distance 4.725m apart. The connection being on the inside of the main track by means of a 52 Kg, 1 in 12 PSC turnout. Calculate the various parameters for the layout.

Given: $F = 4^0 45' 49''$, K(modified) = 8.303m

Solution :

$$\theta = 2\tan^{-1}\left\{\frac{\left(D - G - 2K\tan\frac{F}{2}\right)}{(2R_m - D - G)}\text{Cot}\frac{F}{2}\right\}$$

$$= 2\tan^{-1}\left\{\frac{\left(4.725 - 1.676 - 2 \times 8.303 \times \tan\frac{4^0 45' 49''}{2}\right)}{(2 \times 2000 - 4.725 - 1.676)}\text{Cot}\frac{4^0 45' 49''}{2}\right\}$$

$$= 1^0 53' 30'' < F \quad \text{(Type III)}$$

$$R_c = \frac{\text{Sin}\theta\,(R_m - G - K\tan\frac{F}{2})}{\text{Sin}(\theta - F)} - K\tan\frac{F}{2}$$

$$R_c = \frac{\text{Sin}1^0 53' 30''\,(2000 - 1.676 - 3.834 \times \tan\frac{4^0 45' 49''}{2})}{\text{Sin}\,(1^0 53' 30'' - 4^0 45' 49'')} - 8.303 \times \tan\frac{4^0 45' 49''}{2}$$

$= -1320.36$ m (- indicates the reverse curve)

$$X = K + \frac{\pi(R_m - G)\theta}{180} = 8.303 + \frac{\pi(2000 - 1.676) \times 1^0 53' 30''}{180} = 74.279\text{m}$$

8.4 Connection between a curved track to straight track, the intersection being on the inside of the main line curve

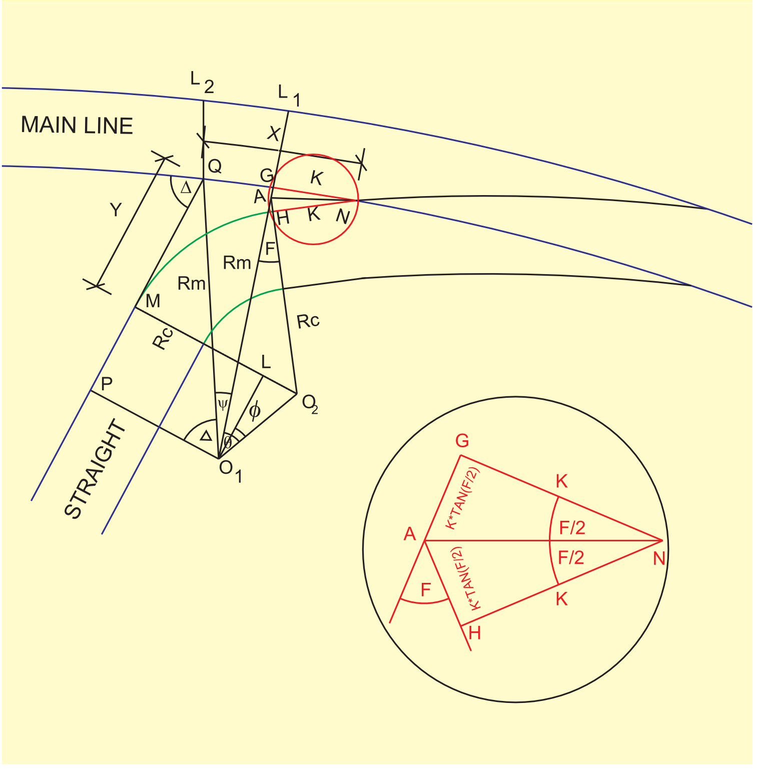


Figure 8.4 : Connection between a curved track to straight track, the intersection being on the inside of the main line curve

Formulae

R_m = radius of curved main line (outer rail)

R_c = radius of connecting curve (outer rail)

Δ = Angle made by straight track with the tangent at a point where it interacts with inner rail of curved track.

$$O_2A = O_2H + HA = R_c + K\tan\frac{F}{2} = R_1 \text{ (say)}$$

$$O_1A = O_1L_1 - L_1G - GA = R_m - G - K\tan\frac{F}{2} = R_2 \text{ (say)}$$

In $\Delta\, O_1O_2A$, apply Cos formula

$$O_1O_2^2 = O_1A^2 + O_2A^2 - 2 \times O_1A \times O_2A \times \mathrm{Cos}F$$

$$\therefore O_1O_2 = \sqrt{R_1^{\,2} + R_2^{\,2} - 2R_1R_2\mathrm{Cos}F} \quad \text{..............................} (8.10)$$

now applying Sine formula,

$$\frac{\mathrm{Sin}\theta}{O_2A} = \frac{\mathrm{Sin}F}{O_1O_2}$$

$$\therefore \mathrm{Sin}\theta = \frac{R_1\mathrm{Sin}F}{\sqrt{R_1^2 + R_2^2 - 2R_1R_2\mathrm{Cos}F}} \quad \text{..............................} (8.11)$$

In $\Delta\, O_1LO_2$,

$$O_2L = O_2M - LM = R_c - PO_1 = R_c - O_1Q\mathrm{Cos}\Delta$$

$$= R_c - (O_1L_2 - L_2Q)\mathrm{Cos}\Delta$$

$$= R_c - (R_m - G)\mathrm{Cos}\Delta$$

$$\mathrm{Sin}\varphi = \frac{O_2L}{O_1O_2} = \frac{R_c - (R_m - G)\mathrm{Cos}\Delta}{\sqrt{R_1^2 + R_2^2 - 2R_1R_2\mathrm{Cos}F}} \quad \text{..........................} (8.12)$$

From the geometry of the figure,

$\angle P\,O_1 L = 90^0$ therefore, $\Delta + \psi + \theta - \varphi = 90^0$

$\therefore\ \psi = (90^0 + \varphi) - (\theta + \Delta)$

$X = NG + GQ$

$$= K + \frac{\pi(R_m - G)\psi}{180} \quad \text{where} \quad \psi = (90^0 + \varphi) - (\theta + \Delta) \text{ ....(8.13)}$$

$Y = PQ - PM$

$= (R_m - G)\mathrm{Sin}\Delta - O_1 L$

$= (R_m - G)\mathrm{Sin}\Delta - O_1 O_2 \mathrm{Cos}\varphi$

$$= (R_m - G)\mathrm{Sin}\Delta - \left(\sqrt{R_1^2 + R_2^2 - 2R_1 R_2 \,\mathrm{CosF}}\right)\mathrm{Cos}\varphi\text{..(8.14)}$$

Interpretation of Formulae and Field Practicalities

From the field survey, value of , Rm will be known. Once we have decided the type of turnout, turnout parameters will also be known. Assume suitable value of radius of connecting curve 'Rc'. From Eq 8.13 & 8.14 , value of 'X' & 'Y' can easily be calculated. From the field survey, point Q on the inner rail of curved main line can be established. Then by measuring along the inner rail of curved main line, a distance equal to 'X', TNC can be fixed. After TNC getting fixed, rest of the layout can be laid in the field.

Note :
For PSC layout K should be choosen from annexure-III as K (modified) value.

Example 8.6

A curved track of 450m radius is required to be connected to a straight track intersecting on the inside rail of the curved track at an angle of 50^0. The connection is to laid by means of 52 Kg, 1 in 12 PSC turnout with a connecting curve radius of 300m. calculate the various parameters for the turnout.

Given: $F = 4^0 45' 49''$, K (modified) = 8.303m

Solution :

$$R_1 = R_c + K\tan\frac{F}{2}$$

$$= 300 + 8.303 \times \tan\frac{4^0 45' 49''}{2} = 300.345\text{m}$$

$$R_2 = R_m - G - K\tan\frac{F}{2}$$

$$= 450 - 1.676 - 8.303 \times \tan\frac{4^0 45' 49''}{2} = 447.978\text{m}$$

$$\text{Sin}\theta = \frac{R_1 \text{SinF}}{\sqrt{R_1^2 + R_2^2 - 2R_1 R_2 \text{CosF}}}$$

$$= \frac{300.345 \times \text{Sin}\,4^0 45' 49''}{\sqrt{300.345^2 + 447.978^2 - 2 \times 300.345 \times 447.978 \times \text{Cos}\,4^0 45' 49''}}$$

$$= \frac{24.927}{\sqrt{22725.013}}$$

$$\therefore\ \theta = 9^0 31' 25''$$

$$\text{Sin}\varphi = \frac{R_c - (R_m - G)\text{Cos}\Delta}{\sqrt{R_1^2 + R_2^2 - 2R_1 R_2 \text{CosF}}}$$

$$\text{Sin}\varphi = \frac{300 - (450 - 1.676)\text{Cos}50^0}{\sqrt{227250.013}}$$

$$\therefore\ \varphi = 4^0 21^{'} 53.6^{''}$$

$$\psi = 90 + 4^0 21^{'} 53.6^{''} - (9^0 31^{'} 25^{''} + 50^0) = 34^0 58^{'} 28.6^{''}$$

$$X = K + \frac{\pi(R_m - G)\psi}{180} = 8.303 + \frac{\pi(450 - 1.676) \times 34^0 58^{'} 28.6^{''}}{180}$$

$$= 8.303 + 273.667 = 281.97\text{m}$$

$$Y = (R_m - G)\text{Sin}\Delta - \left(\sqrt{R_1^2 + R_2^2 - 2R_1 R_2 \text{CosF}}\right)\text{Cos}\varphi$$

$$= (450 - 1.676)\text{Sin}50^0 - \left(\sqrt{22725.013}\right) \text{Cos } 4^0 21^{'} 53.6^{''}$$

$$= 193.152\text{m}$$

8.5 Connection between a curved track to straight track, the intersection being on the outside of the main line curve

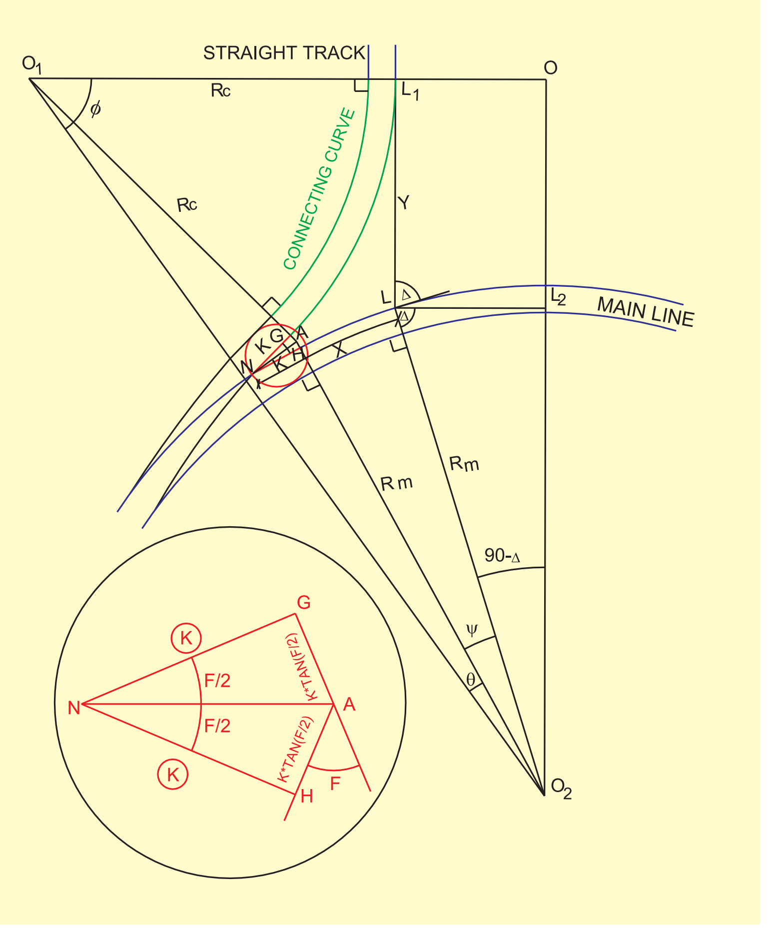


Figure 8.5 : Connection between a curved track to straight track, the intersection being on the outside of the main line curve

Formulae

R_m = radius of curved main line (outer rail)

R_c = radius of connecting curve (outer rail)

Δ =Angle made by straight track with the tangent at point where it intersects with outer rail of main line curve track.

$$O_1A = O_1G + GA = R_c + K\tan\frac{F}{2} = R_1 \qquad \text{(say)}$$

$$O_2A = O_2H + HA = R_m + K\tan\frac{F}{2} = R_2 \quad \text{(say)}$$

In $\Delta\, O_1O_2A$, apply Cos formula

$$O_1O_2^2 = O_1A^2 + O_2A^2 - 2\times O_1A\times O_2A\times \mathrm{Cos}O_1AO_2$$

$$= R_1^2 + R_2^2 - 2R_1R_2\mathrm{Cos}(180 - F)$$

$$\therefore O_1O_2 = \sqrt{R_1^2 + R_2^2 + 2R_1R_2\mathrm{Cos}F} \qquad \text{.................................(8.15)}$$

In $\Delta\, O_1OO_2$,

$$\mathrm{Cos}\varphi = \frac{O_1O}{O_1O_2} = \frac{O_1L_1 + L_1O}{O_1O_2} = \frac{R_c + LL_2}{O_1O_2}$$

where $LL_2 = R_m\,\mathrm{Cos}\Delta$

$$\therefore\ \mathrm{Cos}\varphi = \frac{R_c + R_m\,\mathrm{Cos}\Delta}{\sqrt{R_1^2 + R_2^2 + 2R_1R_2\mathrm{Cos}F}} \qquad \text{...............................(8.16)}$$

In $\Delta\, O_1AO_2$,

$$\frac{\mathrm{Sin}\theta}{O_1A} = \frac{\mathrm{Sin}(180 - F)}{O_1O_2}$$

$$\therefore \ \mathrm{Sin}\theta = \frac{\left(R_c + K\tan\frac{F}{2}\right)\mathrm{SinF}}{\sqrt{R_1^2 + R_2^2 + 2R_1R_2\,\mathrm{CosF}}} \tag{8.17}$$

$$\text{In } \Delta\, O_1 O O_2, \qquad \mathrm{Sin}\varphi = \frac{OO_2}{O_1O_2}$$

$$\therefore \ OO_2 = \left(\sqrt{R_1^2 + R_2^2 + 2R_1R_2\,\mathrm{CosF}}\right)\mathrm{Sin}\varphi$$

$$Y = OL_2 = OO_2 - L_2O_2$$

$$= O_1O_2\,\mathrm{Sin}\varphi - R_m\,\mathrm{Sin}\Delta$$

$$= \left(\sqrt{R_1^2 + R_2^2 + 2R_1R_2\,\mathrm{CosF}}\right)\mathrm{Sin}\varphi - R_m\,\mathrm{Sin}\Delta \tag{8.18}$$

$$\text{In } \Delta\, O_1 O O_2, \quad 90 + \theta + \psi + 90 - \Delta + \varphi = 180$$

$$\therefore \ \psi = \Delta - (\varphi + \theta)$$

$$X = NH + HL = K + \frac{\pi R_m \psi}{180} \tag{8.19}$$

where $\psi = \Delta - (\varphi + \theta)$

Interpretation of Formulae and Field Practicalities

From the field survey, value of 'R_m' and will be known. Once we have decided the type of turnout, turnout parameters will also be known. Assume suitable value of radius of connecting curve i.e. 'R_c'. Now calculate O_1O_2 from Eq 8.15. Once O_1O_2 is known, calculate φ from Eq 8.16. Calculate the value of θ, From Eq 8.17. Value of 'Y' & 'X' can be calculated from Eq 8.18 & 8.19 respectively. From the field survey, point 'L' on the outer rail of main line can be established. Then measuring along the outer rail of main line a distance of 'X', TNC can be easily fixed. After TNC getting fixed, rest of the layout can be laid in the field. In above formula K needs to be replaced with K (modified) as given in annexure - III for PSC layout.

Example 8.7

A curved track of 450m radius is required to be connected to a straight track intersecting the outer rail of the curve at an angle of 30^0. The connection is to be laid by means of 60Kg (PSC), 1 in 8.5 turnout and a connecting curve of 300m radius.

Given: $F = 6^0 42' 35''$, K (modified) $= 5.516\text{m}$, $R = 300\text{ m}$

$$R_1 = R_c + K\tan\frac{F}{2} = 300 + 5.516 \times \tan\frac{6^0 42' 35''}{2} = 300.323\text{m}$$

$$R_2 = R_m + K\tan\frac{F}{2} = 450 + 5.516 \times \tan\frac{6^0 42' 35''}{2} = 450.323\text{m}$$

$$\text{Cos}\varphi = \frac{R_c + R_m \text{ Cos}\Delta}{\sqrt{R_1^2 + R_2^2 + 2R_1R_2\text{CosF}}}$$

$$= \frac{300 + 450 \times \text{Cos}30^0}{\sqrt{300.323^2 + 450.323^2 + 2 \times 300.323 \times 450.325 \times \text{Cos}6^0 42' 35''}}$$

$$= \frac{689.711}{\sqrt{561622.8083}}$$

$$\frac{689.711}{749.411} = 0.9203 \quad \text{hence} \quad \varphi = 23^0 1' 28.3''$$

$$\text{Sin}\theta = \frac{\left(R_c + K\tan\frac{F}{2}\right)\text{SinF}}{\sqrt{R_1^2 + R_2^2 + 2\,{}_1R_2R\text{CosF}}}$$

$$= \frac{300.323 \times \text{Sin } 6^0 42' 35''}{\sqrt{561622.8083}} = 0.0468228$$

$$\therefore \theta = 2^0 41' 1.43''$$

$$\psi = \Delta - (\varphi + \theta) = 30^0 - \left(23^0 1' 28.3'' + 2^0 41' 1.43''\right)$$

$$= 4^0 17' 30.27''$$

$$X = K^1 + \frac{\pi R_m \psi}{180} = 5.516 + \frac{\pi \times 450 \times 4^0 17' 30.27''}{180} = 39.223\text{m}$$

$$Y = \left(\sqrt{R_1^2 + R_2^2 + 2R_1 R_2 \text{ Cos F}}\right) \text{Sin } \varphi - \text{Rm Sin } \Delta$$

$$= 749.41 \text{ Sin } 23^0\ 1'\ 28.3'' - 450 \text{ Sin } 30^0$$

$$= 68.113 \text{ m}$$

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Chapter 9

Crossover Connection between two Curved Parallel Tracks

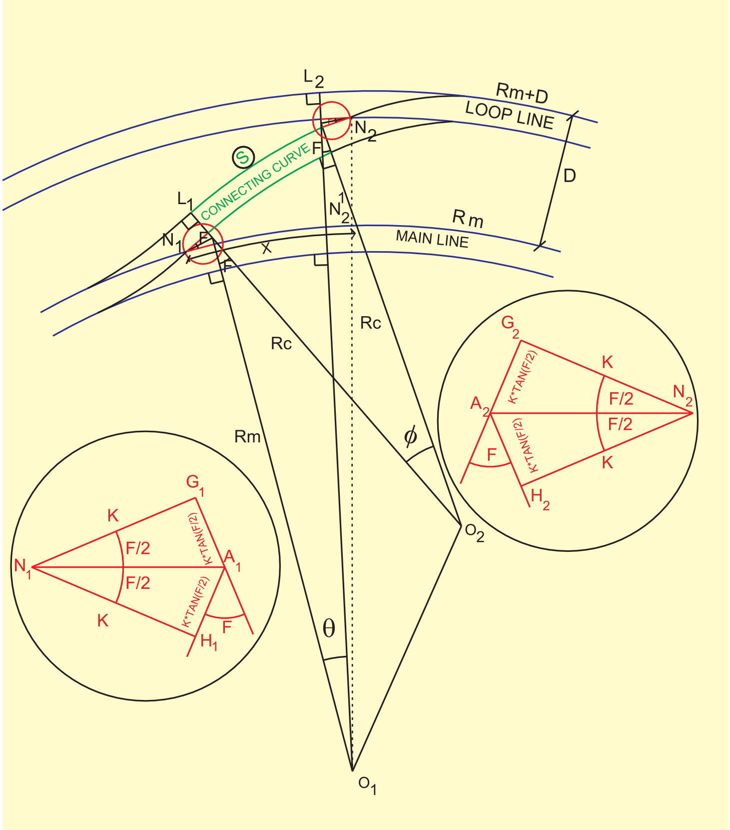

Figure 9.1 : Crossover connection between two curved parallel tracks

Tan F/2 = 0.0586

Formulae

R_m = radius of curved main line (outer rail)

R_c = radius of connecting curve (outer rail)

In $\Delta\ O_1A_1O_2$, $\angle O_1A_1O_2 = F$

$$O_1A_1 = O_1H_1 + H_1A_1 = R_m + K\tan\frac{F}{2}$$

$$O_2A_1 = O_2L_1 - L_1G_1 - G_1A_1 = R_c - G - K\tan\frac{F}{2}$$

$$O_1O_2^2 = O_1A_1^2 + O_2A_1^2 - 2\times O_1A_1\times O_2A_1\operatorname{Cos}F$$

$$= \left(R_m + K\tan\frac{F}{2}\right)^2 + \left(R_c - G - K\tan\frac{F}{2}\right)^2$$

$$- 2\times\left(R_m + K\tan\frac{F}{2}\right)\times\left(R_c - G - K\tan\frac{F}{2}\right)\times\operatorname{Cos}F$$

$$= \left(R_m + K\tan\frac{F}{2}\right)^2 + R_c^{\ 2} + \left(G + K\tan\frac{F}{2}\right)^2 - 2R_c\left(G + K\tan\frac{F}{2}\right)$$

$$- 2R_c\left(R_m + K\tan\frac{F}{2}\right)\operatorname{Cos}F + 2\operatorname{Cos}F\left(G + K\tan\frac{F}{2}\right)\left(R_m + K\tan\frac{F}{2}\right)$$

$$= R_c^{\ 2} - 2R_c\left[\left(G + K\tan\frac{F}{2}\right) + \left(R_m + K\tan\frac{F}{2}\right)\operatorname{Cos}F\right] + \left(R_m + K\tan\frac{F}{2}\right)^2$$

$$+ \left(G + K\tan\frac{F}{2}\right)^2 + 2\operatorname{Cos}F\left(G + K\tan\frac{F}{2}\right)\left(R_m + K\tan\frac{F}{2}\right) \qquad (8.20)$$

In $\Delta\ O_1A_2O_2$, $\angle O_1A_2O_2 = F$

$$O_1A_2 = O_1L_2 - L_2G_2 - G_2A_2 = R_m + D - G - K\tan\frac{F}{2}$$

$$O_2A_2 = R_c + K\tan\frac{F}{2}$$

$$O_1O_2^2 = O_1A_2^2 + O_2A_2^2 + 2\times O_1A_2\times O_2A_2\times \mathrm{Cos}F$$

$$= \left(R_m + D - G - K\tan\frac{F}{2}\right)^2 + \left(R_c + K\tan\frac{F}{2}\right)^2$$

$$-2\left(R_m + D - G - K\tan\frac{F}{2}\right)\left(R_c + K\tan\frac{F}{2}\right)\mathrm{Cos}F$$

$$= R_c^2 + 2R_c K\tan\frac{F}{2} + \left(K\tan\frac{F}{2}\right)^2 + \left(R_m + D - G - K\tan\frac{F}{2}\right)^2$$

$$-2R_c\left(R_m + D - G - K\tan\frac{F}{2}\right)\mathrm{Cos}F - 2\mathrm{Cos}F\left(R_m + D - G - K\tan\frac{F}{2}\right)K\tan\frac{F}{2}$$

$$= R_c^2 - 2R_c\left[\left(R_m + D - G - K\tan\frac{F}{2}\right)\mathrm{Cos}F - K\tan\frac{F}{2}\right]$$

$$+\left(R_m + D - G - K\tan\frac{F}{2}\right)^2 + \left(K\tan\frac{F}{2}\right)^2$$

$$-2\mathrm{Cos}F\left(R_m + D - G - K\tan\frac{F}{2}\right)K\tan\frac{F}{2} \qquad (8.21)$$

Equating the Eq 8.20 & 8.21 for solving R_c

$$2R_c\left[\left(R_m + D - G - K\tan\frac{F}{2}\right)\text{Cos}F - K\tan\frac{F}{2} - \left(G + K\tan\frac{F}{2}\right) - \left(R_m + K\tan\frac{F}{2}\right)\text{Cos}F\right] = \left(R_m + D - G - K\tan\frac{F}{2}\right)^2 - \left(R_m + K\tan\frac{F}{2}\right)^2$$

$$+\left(K\tan\frac{F}{2}\right)^2 - \left(G + K\tan\frac{F}{2}\right)^2$$

$$-2\text{Cos}F\left(K\tan\frac{F}{2}\right)\left(R_m + D - G - K\tan\frac{F}{2}\right)$$

$$+\left(G + K\tan\frac{F}{2}\right)\left(R_m + K\tan\frac{F}{2}\right)$$

$$R_c = \frac{\left(2R_m + D - G\right)\left(D - G - 2K\tan\frac{F}{2}\right) - G\left(G + 2K\tan\frac{F}{2}\right)}{2\left[D\text{Cos}F - \left(G + 2K\tan\frac{F}{2}\right)\left(1 + \text{Cos}F\right)\right]}$$

$$- \frac{2\text{Cos}F\left[\left(2R_m + D\right)\left(K\tan\frac{F}{2}\right) + R_m G\right]}{2\left[D\text{Cos}F - \left(G + 2K\tan\frac{F}{2}\right)\left(1 + \text{Cos}F\right)\right]} \qquad (8.22)$$

In $\Delta\ O_1A_1O_2$, applying Cos formula

$$\text{Cos}\frac{\angle A_1O_1O_2}{2} = \sqrt{\frac{S_1(S_1 - a)}{bc}} \qquad (8.23)$$

$$\angle A_1O_2O_1 = 180 - (\angle A_1O_1O_2 + F) \qquad (8.24)$$

where $S_1 = \dfrac{A_1O_2 + O_1A_1 + O_1O_2}{2}$

In $\Delta\ O_1A_2O_2$, applying Cos formula,

$$\text{Cos}\frac{\angle A_2O_1O_2}{2} = \sqrt{\frac{S_2(S_2 - a)}{bc}} \quad \text{.......................................(8.25)}$$

$$\angle A_2O_2O_1 = 180 - (\angle A_2O_1O_2 + F) \quad \text{....................................(8.26)}$$

$$\text{where } S_2 = \frac{A_2O_2 + O_1A_2 + O_1O_2}{2}$$

$$\therefore \quad \theta = \angle A_1O_1O_2 - \angle A_2O_1O_2$$

$$\therefore \quad \varphi = \angle A_2O_2O_1 - \angle A_1O_2O_1$$

$$X = \frac{\pi R_m \theta}{180} + 2K - \frac{KD}{R_m} \quad \text{...(8.27)}$$

where 'θ' is in Degrees. X is measured along outer rail of main line curve from Nose N_1 to radially projected point N_2

$\left(\frac{KD}{R_m}\right)$ is the projection of values of 'K' from the outer curve to inner curve

$$S = \frac{\pi \times R_c \times \varphi}{180} \quad \text{where '}\varphi\text{' is in Degrees}$$

Note:

When we introduce straight crossing on curves, we introduce kinks on the junction of the crossings on either end. The curve is allowed to maintain same curve outside. Similar kinks will appear on the ends of crossings on the connecting track. In some countries the main line curves are realigned after introducing crossings. This type of layouts are only suitable when the main line curve is fairly easy. It is found that if these calculations are being done by assuming them as that for crossover connection between two straight parallel tracks, the difference between them is negligible. If we calculate for 'X' assuming them as two straight parallel track at a track centre of 'D', then,

$$X = D\text{Cot}F - G\text{Cot}\frac{F}{2}$$

Example 9.1

A 60 Kg PSC, 1 in 12 cross-over is required to be laid between two curved parallel tracks. Assuming the radius of the outer rail of the inner track as 1000m and the track centre as 5m. Calculate the various parameters for the layout.

Given: $F=4^0 45' 49''$, $K= 8.303m$

Solution :

$$R_c = \frac{\left[(2R_m + D - G)\left(D - G - 2K\tan\frac{F}{2}\right) - G\left(G + 2K\tan\frac{F}{2}\right)\right]}{2\left[DCosF - \left(G + 2K\tan\frac{F}{2}\right)(1+CosF)\right]}$$

$$- \frac{2CosF\left[(2R_m + D)\left(K\tan\frac{F}{2}\right) + R_m G\right]}{2\left[DCosF - \left(G + 2K\tan\frac{F}{2}\right)(1+CosF)\right]}$$

Numerator of first component

$$\left[(2R_m + D - G)\left(D - G - 2K\tan\frac{F}{2}\right) - G\left(G + 2K\tan\frac{F}{2}\right)\right]$$

$$= (2\times1000 + 5 - 1.676)\left(5 - 1.676 - 2\times 8.303\times\tan\frac{4^0 45' 49''}{2}\right)$$

$$-1.676\left(1.676 + 2\times 8.303\times\tan\frac{4^0 45' 49''}{2}\right)$$

$= 5275.322 - 3.967 = 5271.355$

Numerator of second component

$$2CosF\left[(2R_m + D)\left(K\tan\frac{F}{2}\right) + R_m G\right]$$

$$2\times \text{Cos } 4^0 45' 49'' \left[(2\times1000+5)\left(8.303\times\tan\frac{4^0 45' 49''}{2} \quad +1000\times1.676\right)\right]$$

$= 4720.5217$

Denominator (same for both numerator)

$$= 2\left[\text{DCosF} - \left(\text{G} + 2\text{Ktan}\frac{\text{F}}{2}\right)(1+\text{CosF})\right]$$

$$= 2\left[5\times\text{Cos } 4^0 45' 49'' - \left(1.676 + 2\times 8.303\times\tan\frac{4^0 45' 49''}{2}\right)\left(1+\text{Cos } 4^0 45' 49''\right)\right]$$

$= 0.51494$

$$\text{Rc} = \frac{5271.355 - 4720.5217}{0.51494} = 1069.703\text{m}$$

for solving θ' '

$$\text{O}_1\text{A}_1 = \text{R}_m + \text{Ktan}\frac{\text{F}}{2} = 1000 + 8.303\times\tan\frac{4^0 45' 49''}{2} = 1000.345\text{m}$$

$$\text{O}_2\text{A}_1 = \text{R}_c - \text{G} - \text{Ktan}\frac{\text{F}}{2} = 1069.703 - 1.676 - 8.303\times\tan\frac{4^0 45' 49''}{2}$$

$= 1067.682$

$$\text{O}_1\text{O}_2 = \sqrt{1000.345^2 + 1067.682^2 - 2 \text{ x } 1000.345 \text{ x } 1067.682 \text{ x Cos} 4^0 45' 49''}$$

$= 109.145$

$$\text{S}_1 = \frac{1000.345 + 1067.682 + 109.145}{2} = 1050.80\text{m}$$

$$\text{Cos}\frac{\angle \text{A}_1\text{O}_1\text{O}_2}{2} = \sqrt{\frac{1088.586\ (1000.345) - 1067.682}{1000.345\times\ 109.\text{k}5}}$$

$\therefore \angle \text{A}_1\text{O}_1\text{O}_2 = 125^0 40' 23.3''$

$$\text{O}_1\text{A}_2 = \text{R}_m + \text{D} - \text{G} - \text{Ktan}\frac{\text{F}}{2}$$

$$= 1000 + 5 - 1.676 - 8.303\times\tan\frac{4^0 45' 49''}{2} = 1002.978$$

$$\text{O}_2\text{A}_2 = \text{R}_c + \text{Ktan}\frac{\text{F}}{2} = 1069.703 + 8.303\times\tan\frac{4^0 45' 49''}{2} = 1070.048$$

$$\text{S}_2 = \frac{1002.978 + 1070.048 + 109.145}{2} = 1091.085$$

$$\mathrm{Cos}\,\frac{\angle A_2O_1O_2}{2} = \sqrt{\frac{1002.978 + 1070.048 + 109.145}{1002.978\ \mathrm{x}109.0145}}$$

$$\therefore\quad \angle A_2O_1O_2 = 125^0 29' 46.4''$$

$$\theta = \angle A_1O_1O_2 - \angle A_2O_1O_2 = 125^0 40' 23.3'' - 125^0 29' 46.4''$$

$$= 0^0 10' 36.84''$$

$$X = \frac{\pi R_m \theta}{180} + 2K - \frac{KD}{R_m}$$

$$= \frac{\pi \times 1000 \times\ 0^0 10'\ 36.84''}{180} + 2\times 8.303 - \frac{8.303\times 5}{1000} = 19.652$$

If we solve the above problem as that for crossover connection between straight parallel tracks, then

$$X = \mathrm{DCotF} - \mathrm{GCot}\frac{F}{2} = 5\times 12 - 1.676\times \mathrm{Cot}\frac{4^0 45' 49''}{2} = 19.71\mathrm{m}$$

The difference between the two values is (19.71 - 19.652) = 5.8cm

Note :

It can be seen that the difference over length of cross-over when calculated treating the two two curved lines as parallel is of very small magnitude. Hence for ease of calculation if done manually it would be a acceptable practice to calculate layout parameters for cross-over treating the two curved lines as parallel straight, for the benefit of readers the difference in overall length for various degree of curvature and track centre of 5.3m are given as under.

Radius of Curve	X-over type	O.L.treating as curve	O.L.treating as straight	Difference in mm
2	1 in 12	97.513	97.578	65
3	1 in 12	97.481	97.578	97
4	1 in 12	97.449	97.578	129
5	1 in 12	97.416	97.578	162

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Chapter No. 10

Special Layout Cases with PSC Sleepers

10.1 General :

In a typical yard many times we may encounter a situation where special lay out such as diamond, ladder, double junction or a WYE connection etc. need to be provided for facilitating traffic flow. Each such special layout will have to be designed as per the site features and constraints. However in this chapter efforts have been made to take normally prevailing site conditions and then the solution is given in more generalized way so as to be useful in most of the situation.

The special cases considered are

(1) WYE connection
(2) Gathering lines
(3) Double junction
(4) Diamond connection
(5) Cross over between two tracks of varying track geometry

All the cases will be considered only for PSC layouts.

10.2 WYE (Y) connection :

These are used for turning engines or for directly taking a train from main line to other branch line without undergoing engine reversal at main yard. These turnouts are laid with 1 in 8.5 turnouts if the WYE connection is used only for engine reversal. However if the coaching trains are to negotiate WYE connection for movement from main line to branch line or vice-versa, it may require connection with1 in 12 turnout on main line and with 1 in 8.5 symmetrical split on branch line for further raising speed potential. Flatter turnouts may also be used .

A. Triangle connection from a straight main line:-

Refer fig 10.1. On straight main line two turnout with Xing angle F1 are taking off and they are joining the two legs of a symmetrical split turnout having Xing angle F2 at M and L. To lay a triangle the distance between P_1 and P_2 on straight track and the height 'P_3E' from Centre line of straight track is needed. Radius of connecting curve Rc will have to be assumed.

In triangle $O_1N\ O_2$,

$O_1N = O_2N = R_C + B_2 \text{ Tan } \frac{F_2}{2}$, $\angle$ N =180 - F_2

$O_1O_2 = 2\ O_1\ N \text{ Cos } \frac{F_2}{2} = O_1Q + QO_2$

Hence,

$$O_1O_2 = 2\ (R_C + B_2 \tan \frac{F_2}{2}) \text{ Cos } \frac{F_2}{2}$$

$$= 2\ (R_C \text{Cos} \frac{F_2}{2} + B_2 \text{Sin} \frac{F_2}{2})$$

$$O_1Q = O_2Q = R_C \text{Cos} \frac{F_2}{2} + B_2 \text{ Sin } \frac{F_2}{2}$$

In $\triangle$ O_2 HW,

$O_2H = R_C + B_1 \tan F_1$ and $\angle$ $O_2 = F_1$ and $\angle$ O_2 WH = 90^0

$\therefore$ WH = $(R_C + B_1 \tan F_1) \text{ Sin } F_1$

$O_2W = (R_C + B_1 \tan F_1) \text{ Cos } F_1$

$= (R_C \text{ Cos } F_1 + B_1 \text{Sin } F_1)$

Triangle O_2 HW and O_1 J S are congruent, therefore

$O_1J = O_2H$, JS = WH , and Also $P_2\ H = P_1J = B_1 \text{ Sec } F_1$

$\therefore$ $P_1P_2 = 2(WE + P_2W) = 2\ (O_2\ Q + P_2H - HW)$

$$= 2\ [\ R_C \text{ Cos } \frac{F_2}{2} + B_2 \text{ Sin } \frac{F_2}{2} + B_1 \text{ Sec } F_1 - (R_C + B_1 \tan F_1) \text{ Sin } F_1]$$

$$X \quad = 2[R_C\ (\text{Cos} \frac{F_2}{2} - \text{Sin } F_1) + B_2 \text{ Sin} \frac{F_2}{2} + B_1\ (\text{Sec } F_1 - \text{Sin } F_1 \tan F_1]$$

$$= 2[R_C\ (\text{Cos } \frac{F_2}{2} - \text{Sin } F_1) + B_2 \text{ Sin } \frac{F_2}{2} + B_1 \text{ Cos } F_1] \text{.......} \ (10.1)$$

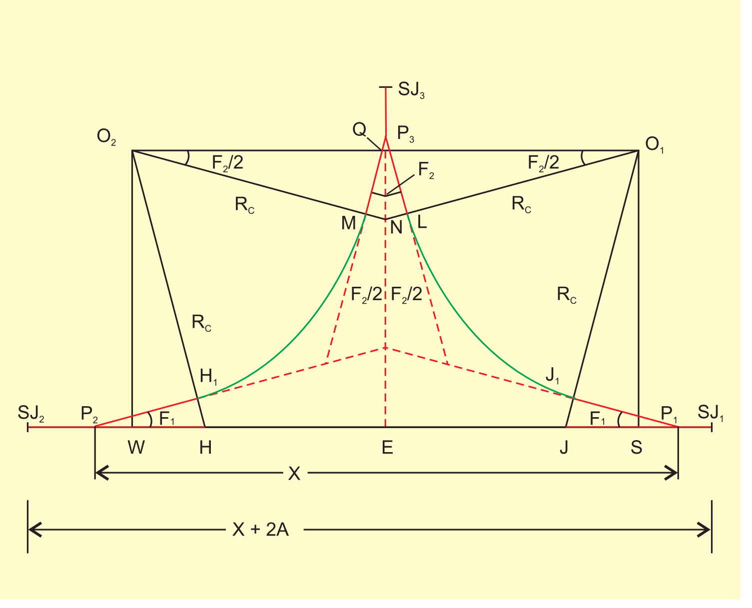


Figure 10.1

Now, to locate P_3:

The distance E P_3 (i.e. Z) is neaded

$EP_3 = O_2W + P_3Q$

$= O_2W + P_3N - QN$

$= (R_C \, CosF_1 + B_1 \, Sin \, F_1) + B_2 \, Sec \, \frac{F_2}{2} - O_2Q \, Tan \, \frac{F_2}{2}$

$= R_C \, Cos \, F_1 + B_1 \, Sin \, F_1 + B_2 \, Sec \, \frac{F_2}{2} - \; (R_C \, Cos \, \frac{F_2}{2} + B_2 \, Sin \, \frac{F_2}{2}) \, tan \, \frac{F_2}{2}$

$= R_C \, Cos \, F_1 + B_1 \, Sin \, F_1 + B_2 \, Sec \, \frac{F_2}{2} - \; (R_C \, Sin \, \frac{F_2}{2} + B_2 \, Sin \, \frac{F_2}{2} \, tan \, \frac{F_2}{2} \,)$

$Z \quad = R_C \, (CosF_1 - Sin \, \frac{F_2}{2} \,) + B_1 \, Sin \, F_1 + B_2 \, Cos \, \frac{F_2}{2}$ .... (10.2)

Interpretation of Formulae and field Application:

First of all Radius of connecting curve is assumed. Then calculate distance Z as per formulae 10.2 then draw a line parallel to straight main line track by drawing two perpendicular lines of length Z from base main line and then join them. This parallel line will cut the third line of triangle at P_3. From P_3 draw a perpendicular on main line track to meet at 'E'. From E measure X/2 on either side to locate P_1 and P_2. Thus all the intersection points of Triangle are located. After Knowing P_1, P_2 and P_3 their SRJs SJ_1, SJ_2 and SJ_3 can be located and hence all three turnout can be laid. After locating P1 P2 and P3 location of M, L H_1 and J_1 is established. Now locate the connecting curve between H_1M and J_1L.

B. Triangle connection from a curved main line i.e. all three sides of triangle curved:

In this case the main line is curve of radius Rm1 which is to be provided with a triangle. In such a connection it is more economical in space if we provide all the crossings with 1 in 8.5. The problem gets further simplified if radius of connecting curve is also made same as that of radius of main line. In that case triangle $O_1O_2O_3$ becomes an equilateral triangle with all angles as 60°. Please refer Figure 10.2. Here we have considered triangle on curved lines with all crossings as 1 in 8.5 and radius of connecting curve same as radius of main line.

Without going in to details of derivation we will directly use the formulae. Here we have to calculate angle "θ" so as to calculate "X" and then calculate apex distance N_2C to locate all Nose of crossings of all the three sides. From Fig 10.2 ;

$O_1A_1 = O_1A_3 = R_m + K \text{ Tan } F/2$

$O_3 A_2 = O_2 A_2 = R_c + K \tan F/2$

$O_1 O_2 = O_1 O_3 = \sqrt{\{(Rm + K \text{ Tan } F/2)^2 + (R_c + K\text{Tan}F/2)^2 -}$

$2 \times (R_m + K\text{Tan}F/2) \times (R_c + K \text{ Tan}F/2) \times \text{Cos}F\}$

In triangle $O_2 A_2 O_3$

$O_2 O_3 = 2 (Rc + K\text{Tan}F/2)\text{Cos } F/2$

From triangle $O_1 O_2 L$

$$\theta + 2\emptyset = 2 \text{ Cos}^{-1} \frac{\sqrt{\{(O_1 O_2)^2 - (O_2 O_3)^2/4\}}}{O_1 O_2} \quad ...... \quad (10.3)$$

From triangle $O_1O_3A_1$

$$\emptyset = 2\ \text{Cos}^{-1}\ \frac{1}{2}\ \frac{\sqrt{(O_1\,O_2 \;+ O_1A)^2 - (O_3\,A)^2}}{O_1\,A \times O_1\,O_2} \qquad \ldots\ldots\ldots(10.4)$$

Form this first find $\emptyset$ and then angle θ from above equations.

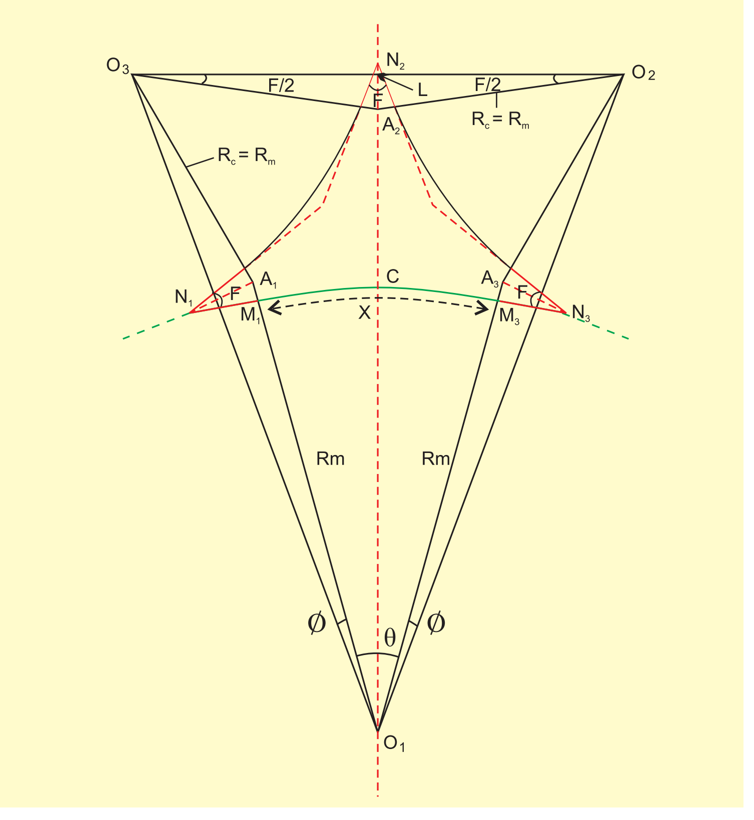


Figure 10.2

After calculating value of θ, then distance $M_1\,M_3$, i.e. 'X' is given by

$$X = \frac{(2\pi Rm\theta)}{360} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (10.5)$$

Distance from Nose N_1 to N_3 is 'X' +2K

The height of the crossing at apex is given by 'Z'

$$Z = CN_2 = O_1L + N_2L - O_1C$$
$$= O_1L + N_2A_2 - A_2L - O_1C$$

$$Z = CN_2 = \sqrt{\{R_m + K\,Tan\frac{F}{2})^2 + (R_c + K\,Tan\frac{F}{2})^2 - 2 \times (R_m + K\,Tan\frac{F}{2}) \times (R_c + K\,Tan\frac{F}{2})\,CosF\} \times Cos\,(\theta/2 + \emptyset)}$$

$$+ K\,Sec\frac{F}{2} - (R_c + K\,Tan\frac{F}{2}) \times Sin\frac{F}{2} - R_m \quad ..\,(10.6)$$

Field Practicalities and implementation :

First mark central point on the main line C. then measure X/2 on either side to locate M_1 and M_3. SJ_1 and SJ_3 can be located as per RDSO drawing. Then from C measure vertical height Z' to locate N_2. After locating N_2, SJ_2 can easily be located.

10.4 Two converging or diverging lines are to be connected by triangle :

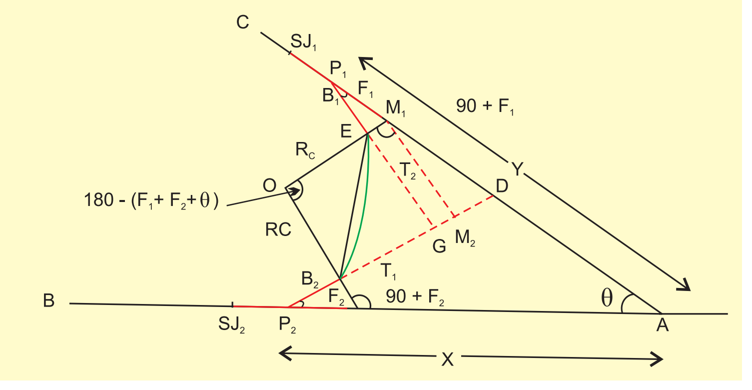


Figure 10.3

Formulae : See Figure 10.3

$$T_1 = R_c \tan\left[90 - \frac{(F_1+F_2+\theta)}{2}\right] = T_2$$

$$EM_1 = GM_2 = B_1 \tan F_1$$

$$M_1M_2 = T_2 = R_C \tan\left[90 - \frac{(F_1+F_2+\theta)}{2}\right]$$

$$M_2D = T_2\,Tan\,F_1$$

$$P_2D = B_2+T_1+GM_2+M_2D$$

$$= B_2 + R_C \tan\left[90 - \frac{(F_1+F_2+\theta)}{2}\right] + B_1 \tan F_1 +$$

$$R_C \tan\left[90 - \frac{(F_1+F_2+\theta)}{2}\right] \tan F_1$$

$$= (B_2 + B_1 \tan F_1) + R_C \tan (90 - \frac{(F_1+F_2+\theta)}{2} (1+ \tan F_1)$$

In triangle P_2 D A, P_2 D is calculated as above, angle θ & F_2 are known hence other sides can be calculated by applying sign rule

$$\frac{P_2A}{(\text{Sin } D)} = \frac{P_2D}{(\text{Sin } \theta)}$$

$$\therefore P_2A = \frac{P_2D\text{Sin}D}{(\text{Sin } \theta)} = X$$

$$\text{'X'} = \frac{(B_2+B_1 \tan F_1)}{(\text{Sin } \theta)} (RC \tan (90 - \frac{(F_1+F_2+\theta)}{2}) \times \text{Sin } (90+F_1)$$

………………… (10.7)

Similarly

$$\frac{DA}{(\text{Sin } F_2)} = \frac{P_2D}{(\text{Sin } \theta)} \quad \text{OR } DA = \frac{(P_2D \text{ Sin } F_2)}{(\text{Sin } \theta)}$$

$$DA = \frac{(\text{Sin } F_2 (B_2+B_1 \tan F_1) + \{RC \tan (90 - \frac{(F_1+F_2+\theta)}{2} \} (1+ \tan F_1)}{(\text{Sin } \theta)}$$

…………….. …(10.8)

$\therefore P_1 A = P_1M_1 + M_1D + DA = Y$

$\therefore Y = B_1 \text{ Sec } F_1 + M_1 M_2 \text{ Sec } F_1 + DA$

Hence

$$Y = B_1 \text{ Sec } F_1 + R_C \tan (90 - \frac{(F_1+F_2+\theta)}{2}) \text{ Sec } F_1 +$$

$$\frac{(\text{Sin } F_2)}{(\text{Sin } \theta)} (B_2+B_1 \tan F_1) + (RC \tan (90 - \frac{(F_1+F_2+\theta)}{2}) (1+ \tan F_1)$$

-------------(10.9)

Field Implementation:

First find or locate the intersection of two converging lines 'A' then locate point P_1 and P_2 at distance 'X' and 'Y' as calculated above. The radius of connecting curves R_C has to be assumed suitably and angle 'θ^'needs to be measured from field survey.

10.5 Gathering Lines:

Gathering lines or ladder track is laid to cater for shunting or receiving trains in multiple lines in a big yard. Ladder track is one in which a number of parallel tracks merge. Two types of gathering lines are discussed below.

A) Gathering lines laid at an angle of crossing :

Refer figure 10.4

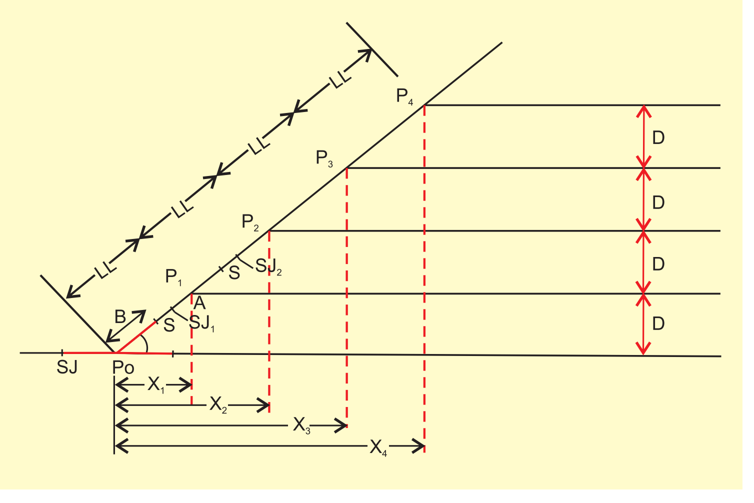


Figure 10.4

This is the simplest and most commonly adopted layout for gathering lines especially in a passenger yard. In this layout, distance P_0 P_1, P_1 P_2, P_2 P_3 etc. are equal and this distance 'LL' is greater than the overall length of turnout. The best method to lay a gathering line is by coordinate of other deflection points, P_1, P_2 etc with reference to the first deflection point Po (point of intersection of first point taking off from base line).

The distance between two parallel line can be decided based on space available or the minimum track Centre as per SOD.

$$\text{Length, LL} = \frac{D}{(\text{Sin } F)}$$

$X = X_1 = D \text{ Cot } F$

$X_2 = 2\ X1$

$X_3 = 3\ X\ 1$ etc.

$Y = Y_1 = D$

$Y_2 = 2D$

$Y_3 = 3D$

In this case length LL is more than the overall length of turnout i.e. A + B. Hence a cut rail of required length equal to LL – (A + B) has to be inserted between HOC of previous point and SRJ of next point. The ladder is a straight line up to last point.

Field practicalities & implementation :-

Depending upon choice of crossings angle F, the intersection point Po is first decided as per site condition. Track center D is decided and all coordinates are worked out. Then center line of ladder $P_o – P_4$ is marked, then marking of various P_1, P_2, P_3 etc. is done from known coordinates X_1, Y_1 etc. SRJ and HOC, can be marked from known values of A and B parameters of turnouts. The length of cut rail to be provided between HOC of previous point and SRJ of next point is to be decided based on LL – (A+B). Since this is a straight line arrangement B need not to be replaced by B (modified).

B) Ladder at Limiting Angle :

Limiting angle for a ladder is the desired angle at which the same can be inclined to the parallel tracks. This angle is directly proportional to the distance between two tracks and inversely proportional to the overall length of the turnout.

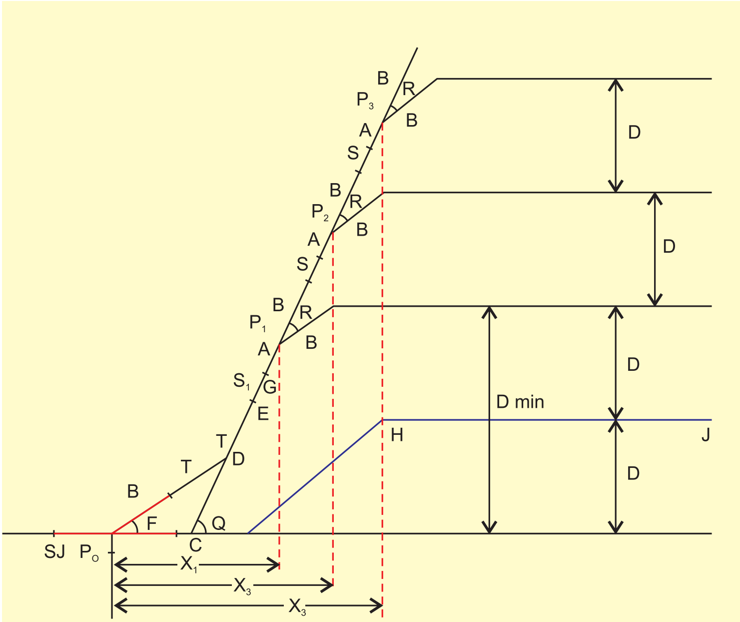


Figure 10.5

Ladder at limiting angle is required only when space available is limited. Here the turnout are laid butting against each other except between the first two turnouts where a curve is introduced to deflect the gathering line to the limiting angle 'Q'. However in case of PSC layout we need to introduce a straight length minimum 3.3m for 1 in 8.5 and 5.5m for 1 in 12 for prefixed inserts of common long sleepers. Since in such a ladder, 1 in 8.5 turnout is used most of the time a '4m' or 6.5m cut rail (or a glued joint if required for signaling purpose) can be provided from first point of ladder onward(i.e. P1 onward) . This is denoted as 'S' in Fig 10.5.

$$Q\,min = Sin^{-1} \frac{D}{(A+B+S)}$$

Where 'S' is inclusive of joint gaps, if gaps or welding is provided

$$\text{Tangent 'T'} = R \tan \frac{(Q-F)}{2}$$

First turnout is provided with SRJ located at SJ and intersection point at Po. Next point on ladder can be provided either immediately after the curved portion i.e. locating next SRJ at "E" or after providing a straight S or S_1 after curve and locating SJ_1 at G.

It would be better to create a space between base line and first point on ladder 'P_1' so that another line QHJ can be provided. Accordingly the length of straight 'S_1' between turnout base line and first point on ladder is provided. Let $Dmin_1$ is be the gap between base line and first line of ladder with no additional line in between and $Dmin_2$ be the gap between base line and first line of ladder with additional line as shown in blue color in between the two.

Case -1 ; $S_1 = 0$, SJ_1 lies immediately after curve

$D\,min_1 = (B+T)\ \{Sin\,F + Sin\,(Q-F)\}\ + (T+A)\,Sin\,Q$

Case -2 ; SJ_1 after S_1

$D\,min_2 = (B+T)\ \{Sin\,F + Sin\,(Q-F)\}\ + (T+A+S_1)\,Sin\,Q$

To insert another line HJ, Dmin2 should be equal to 2D. Hence equating this equation to 2D, value of S_1, to be provided can be calculated.

Coordinates of P_1, P_2, and P_3 etc. for both the cases shall be give as under,

Case - 1

Coordinates of P_1;

$X_1 = (B+T)\,Cos\,F + (T+A)\,Cos\,Q$

$Y_1 = (B+T)\,Sin\,F + (T+A)\,Sin\,Q$

Coordinates of P_2

$X_2 = X_1 + D\,Cot\,Q$, also $= X_1 + (B+'S'+A)\,Cos\,Q$

$Y_2 = Y_1 + D$

Coordinates of P_3

$X_3 = X_2 + D\,Cot\,Q$, also $= X_2 + (B+'S'+A)\,Cos\,Q$

$Y_3 = Y_2 + D$

Case - 2 ; With additional line in between base line and first ladder point.

Coordinates of P_1

$X_1 = (B+T)\,Cos\,F + (T+S_1+A)\,Cos\,Q$

$Y_1 = (B+T)\,Sin\,F + (T+S_1+A)\,Sin\,Q$

Coordinates of P_2

$X_2 = X_1 + D \text{ Cot } Q$

$Y_2 = Y_1 + D$

Coordinates of P_3

$X_3 = X_2 + D \text{ Cot } Q$

$Y_3 = Y_2 + D$

Note :-

For PSC layout B (modified) is taken for taking care of fixity of inserts of long common sleepers. For values of 'S' if a cut rail of l, m is chosen to be provided between HOC of previous point starting from P1 and SRJ of next point, then value of 'S' shall be l - 3.3m for 1 in 8.5 and l - 5.5m for 1 in 12 turn out. The value of S is not affected this way.

Field practicalities & implementation:-

Choose appropriate track center distance following SOD. Choose length of cut rail S_1 and S to be provided or calculated. Calculate T, Calculate Dmin, depending on whether you want additional line between base line and first point of the ladder.

$$P_0C = \frac{(B+T)}{(\text{Sin } Q)} \text{ x Sin } (Q-F), \text{ from } P_0.$$

Calculate angle Qmin, locate SJ at base line, mark P_0 and locate point C, i.e. the foot of the ladder line at distance P_0C. Draw center line of ladder from 'C' at an angle Q, Mark various points P_1, P_2, P_3 etc on ladder at limiting angle 'Q' , then locate various SRJs and HOCs. Connect them with pre decided value of S & S1 as above.

10.6 Cross overs in double junction layouts in multiple track

Cross over in double junction layouts are laid generally in multiple tracks usually in suburban sections. These are used for directing trains from slow lines to fast lines e.g. from DN slow to DN fast or vice-versa. Such crossings involves one diamond of 1 in 8.5 between two track with 1 in 8.5 or 1 in 12 turnouts on either side tracks, as can be seen from following figure. In Figure 10.6 A& B indicate diamonds and C & D indicate normal turnouts either 1 in 12 or 1 in 8.5. The diamond at line 2 or 4 are to be assembled as per standard RDSO drawing for which desired minimum straight length along long diagonal is required. Accordingly minimum track centre is needed to cater for this minimum diagonal length and also turnouts on either side. Two arrangements of 1 in 8.5 diamond with 1 in 8.5 turnouts on either side & 1 in 12 turnouts on either side have been discussed.

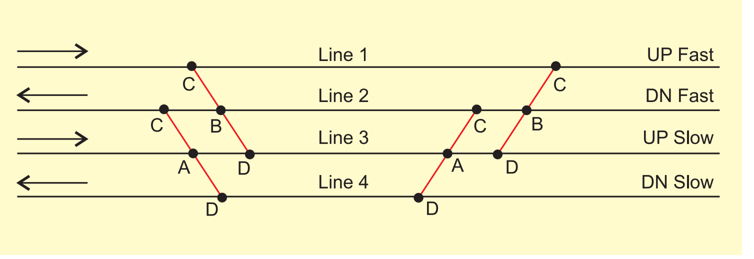


Figure 10.6

A) With 1 in 8.5 diamond and 1 in 8.5 turnouts on either side.

This is a simple arrangement and can be easily understood and laid in field. Ref Fig 10.7.
Let "D" be the track centre, F is the crossing angle.
Then the total length
$P_1 P_2 = 2$ D cosec F
The straight length RE for providing diamond is "LL".
LL = RE = 2 D cosec F – 2B .... (10.6)

For PSC layout turnout and diamond, care for accommodating common long sleepers has to be taken while deciding the track centre or for providing the double junction with 1 in 8.5 turnouts on either side. However provision of 1 in 8.5 turnouts will impede the speed of passenger trains, which may not be desirable. Hence in most of the cases the double junction is provided with 1 in 12 turnouts on either side as discussed below.

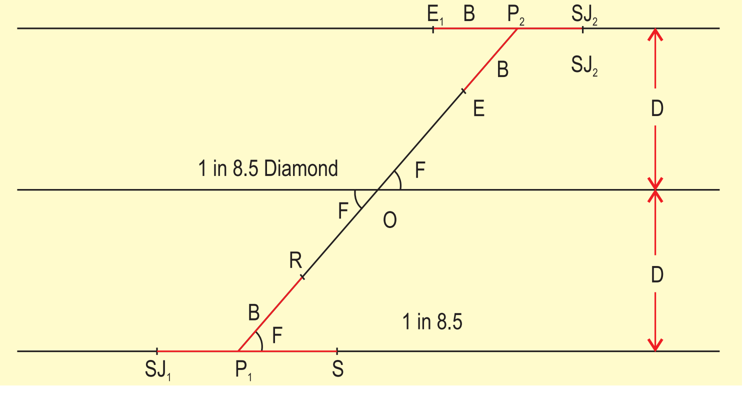


Figure 10.7

B) Double junction with 1 in 8.5 diamond and 1 in 12 turnouts on either side ; Refer Fig 10.8

P_1& P_2 are intersection points and SJ_1 SJ_2 are stock rail joints for 1 in 12 turnouts, on the two outer tracks.

F_1 is crossing angle of 1 in 12 turnout, F_2 is angle corresponding to 1 in 8.5 diamond crossing. S_1 & S_4 points are at end of K (modified) after HOC and are joining with diamond at S_2& S_3 with curve having tangent length "T".

Let us assume radius of connecting curve as "R" , then;

$T = R \tan\left(\frac{F_2\text{-}F_1}{2}\right)$

Let track centre be D_1& D_2 as shown in Fig 10.8, then from triangle $O_1 P_1 O_1^1$

$O_1O_1^1 = (B+T) \operatorname{Sin} F_1$

$L O_1 = D_2 - O_1O_1^1$

$\quad = D_2 - (B+T) \operatorname{Sin} F_1$

Then from triangle $L O_1 O$

$O_1 O = LO_1 \operatorname{Cosec} F_2$

$\quad = \{D2\text{-}(B+T)\operatorname{Sin} F_1\} \operatorname{Cosec} F_2$

Similarly from triangle $O_2 P_2 O_2'$

$O_2O_2' = (B+T) \operatorname{Sin} F_1$; and,

$O_2L_1 = D_1 - O_2O_2'$

$\quad = D_1 - (B+T) \operatorname{Sin} F_1$

Then ; $O O_2 = O_2 L_1 \operatorname{cosec} F_2$

$\quad = \{D_1\text{-}(B+T)\operatorname{Sin} F_1\} \operatorname{Cosec} F_2$

The length available for laying diamond is S_2 S_3 represented as "LL" , then

$LL = O_1O_2 - 2T = O_1 O + OO_2 \text{-}2T$

$\quad = \{D_2\text{-}(B+T)\operatorname{Sin} F_1\} \operatorname{Cosec} F_2 + \{D_1\text{-}(B+T) \operatorname{Sin} F_1\} \operatorname{Cosec} F_2 - 2T$

$\quad = (D_2+D_1) \operatorname{Cosec} F_2 - 2 (B+T) \operatorname{Sin} F_1 \operatorname{Cosec} F_2 - 2T$

OR $= \{(D_2+D_1)\text{-}2(B+T)\operatorname{Sin} F_1\} \operatorname{Cosec} F_2 - 2T$

Since this is the entire length for laying diamond, it has to satisfy the minimum required length for laying diamond as per RDSO standard drawing, say (L_1)

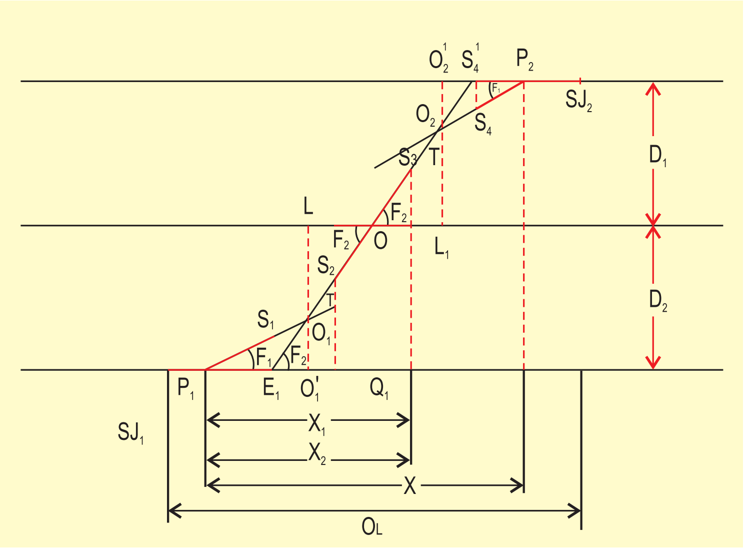


Figure 10.8

Further to lay the curve of connecting radius 'R', as assumed, minimum track center D_1 & D_2 shall be calculated as under:

In Triangle $P_1 O_1 E$

$P_1 O_1 = B+T$

$$E_1O_1 = \frac{P_1O_1}{(\text{Sin } F_2)} \text{ x Sin } F_1$$

$$\therefore D_2 \text{ Cosec } F_2 \text{ (i.e. } E_1O) - E_1O_1 - O_1 S_2 \geq \frac{LL}{2}$$

OR $$D_2 \text{ Cosec } F_2 - \frac{(B+T)}{(\text{Sin F2})} \text{Sin } F_1 - T \geq \frac{LL}{2}$$

OR $$D_2 \text{ Cosec } F_2 - \{(B+T)\text{Sin } F_1\} \text{ Cosec } F_2 - T \geq \frac{LL}{2}$$

OR $$\{D_2-(B+T)\text{Sin } F_1\} \text{ Cosec } F_2 \geq \frac{LL}{2}$$

Similarly on other side

$$\{D_1-(B+T)\text{Sin } F_1\} \text{ Cosec} F_2 \geq \frac{LL}{2}$$

To find co-ordinates of S_2 and S_3 and distance "X" between P_1 & P_2 and overall length of crossover from SJ_1 to SJ_2 on X axis.

Coordinates of S_2:

$X_1 = (B+T) \text{Cos } F_1 + T \text{Cos } F_2$

$Y_1 = (B+T) \text{Sin } F_1 + T \text{Sin } F_2$

Coordinates of S_3:

$X_2 = X_1 + S_2S_3 \text{Cos } F_2$

$= X_1 + [\{(D_2+D_1)\text{-}2(B+T)\text{Sin } F_1\} \text{ Cosec } F_2 - 2T] \text{ Cos } F_2$

$Y_2 = Y_1 + S_2S_3 \text{ Sin } F_2$

$= Y_1 + [\{(D_2+D_1)\text{-}2(B+T)\text{Sin } F_1\} \text{ Cosec } F_2 - 2T] \text{ Sin } F_2$

Distance "X"

$X = 2(B+T) \text{Cos } F_1 + (2T+S_2S_3) \text{ Cos } F_2$

$= 2(B+T) \text{Cos } F_1 + [2T + \{(D_2+D_1)\text{-}2(B+T)\text{Sin } F_1\} \text{ Cosec} F_2 - 2T] \text{Cos } F_2$

$= 2(B+T) \text{Cos } F_1 + \{(D_2+D_1)\text{-}2(B+T)\text{Sin } F1\} \text{ Cot } F_2$

Overall length from SJ_1 to SJ_2

$OL = X + 2A$

Here it may be noted that on either side same crossing angle F1 has been taken because there is no advantage taking different crossing angle, as the speed of trains will be governed by the speed of shortest crossing angle. As a general practice, the radius of connecting curve may be selected based on the type of crossing of turnouts. For PSC layout B (modified) has to used for B.

Field Practicalities & Implementation :

First the type of turnouts to be provided shall be decided. It is better to provide 1 in12 or 1 in 16 turnouts for increased speed potential. Then location of one of the SRJ to be fixed. Thereafter with the assumed radius "R" for connecting curve, track centre D_1, D_2 and turnout parameters. Coordinates of S_2 & S_3 will be calculated including tangent length T. Then location of P2 shall be marked at distance "X" from P_1. Diamond shall be laid between S_2 & S_3.

Note : *In software developed by Shri. M S Ekbote it has been assumed that 1 in 12 turnout is to be connected with 1 in 8.5 diamond.*

Example 1:

Lay one double junction layout in multiple line connecting DN slow to DN fast having track centres D_1 = 5.3 & D_2 = 5.5 m with PSC 1 in 12 turnouts on either side & 1in 8.5 diamond in between. Length of diamond as per RDSO drawing (On PSC layout upto long sleepers from one end to the other) is 34.672m.

Given:

For 1 in 12 PSC layout

A = 16.929, B (modified) = 28.592m

F1= $4^0 45' 49''$, xing angle for diamond, $F_2 = 6^0 42' 35''$

Solution:

Let radius of connecting curve = 440 m.

$$T = R \tan \frac{(F_2 - F_1)}{2}$$

$= 440 \tan ((6^0 42' 35'' - 4^0 45' 49'')/2)$

$= 7.473$m.

Length available for diamond Xing L_1 from formulae

$LL = \{(D_2+D_1)-2(B + T)\text{Sin } F_1\} \text{ Cosec } F_2 - 2T$

$\therefore LL = \{(5.3+5.5)-2(28.592+7.473)\text{Sin } 4°45'49''\} \text{ x Cosec } 6^0 42' 35''$

$- 2 \text{ x } 7.473 = 26.221$m

Which is less than the minimum required for laying 1 in 12 T/O and 1 in 8.5 diamond on PSC (34.672 m)

Hence double junction with 1 in 12 Turnout on either side with radius of connecting curve of 440 m and PSC diamond of 1 in 8.5 cannot be laid with the given track centre.

There are following alternatives to provide a double junction in this case.

1. Increase the track centre.
2. Reduce the connecting curve radius
3. Provide 1 in 8.5 Turnouts on either side.

Option no. 2 & 3 will result in reductionof speed potential. Option no.1 is better one provided space for increasing the track centre is available.

Example2 :

What is the minimum track centre required to accommodate double junction with above detail as given in previous example. Assume $D_1 = D_2$,
L (Length of diamond) =34.672m.

Solution:

Assuming connecting curve radius to be 440 m. So that T = 7.473m.

$LL = 34.672 = \{2D - 2(B + T)\text{Sin}F_1\}\ \text{Cosec}\ F_2 - 2T$

$= \{2D - 2(28.592+7.473)\text{Sin}\ 4°45'\ 49''\}\ \text{x Cosec}\ 6°42'35''$

$- 2 \text{ x } 7.473$

OR $2D = (49.618 \text{ x Sin } 6°42'35'' + 5.99)$

OR D = 5.894 m. Say 5.9.

Example : 3

What is the minimum track centre distance required to provide double junction arrangement with 1 in 8.5 T/Outs on either and 1 in 8.5 diamond crossing on PSC layout.

Given A = 12.025m, B = 19.786

LL = 34.672m

Solution:

From equation 10.6

Length LL = 2D Cosec F - 2 B

$34.672 = 2\ D\ \text{Cosec}\ 6°42'35'' - 2\ (19.786)$

$$\text{Or } D = \frac{(34.672 + 2\ (19.786)}{(2\ \text{Coxc}\ 6^0 42' 35'')} = 4.341 \text{ m} \quad \text{Say } 4.35\text{m}$$

Hence if track centres are limited or less than 5.9m, then we can go for double junction with 1 in 8.5 turnouts on either side.

10.7 Cross over between two lines of undefined and mixed alignment

Sometimes there can be a situation where a cross over is to be laid between two loops or one siding and a loop which have highly irregular and mixed alignment of track. It means whatever cases we have covered in this book for provision of cross over between two lines, does not fit in any case discussed earlier.

Consider following figure, where a cross over needs to be provided between line $O_1 O_2$ and $O_3 O_4$.

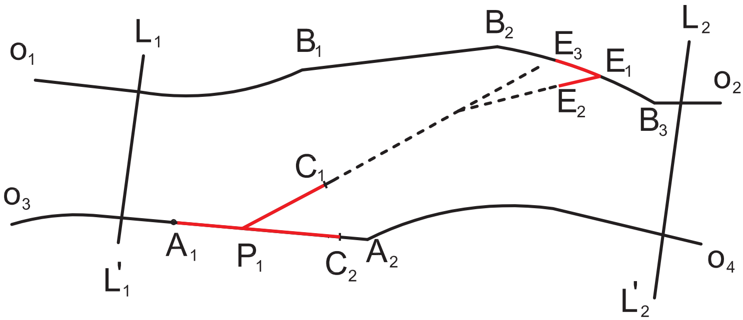


Figure 10.9

We can see that both the lines are quite distributed and does not have a defined alignment instead it follows a mixed alignment. The track centre is non uniform, the line consists of curve and straight lines. The requirement is to provide a crossover between $L_1L'_1$ & $L_2L'_2$ which are say 200m apart.

Two methods of solving such problems are discussed as under:

A) Manual Trial & Error method :-

In this method the crossover has to be provided without any calculation, but by placing individual black boxes (turnout) key diagram on either line of required crossing angle depending upon the track centre distance and space availability. Then these two turnouts are to be joined with combination of straight and curve as explained below;

1. First survey the area and plot both the lines on a drawing with all features on a predefined sale. The horizontal and vertical scale should be same.

2. Between L_1L_1' & L_2L_2' we can locate a suitable patch say A_1 A_2 on O_3 O_4 line and another patch B_2 B_3 on line O_1O_2, let it be a curve patch of some degree of curvature. Let us decide to provide a turnout of crossing angle F_1 (Either 1 in 12 or 1 in 8.5) on line O_1O_2. Then suitably place a black box of this crossing angle on straight patch which may require a straight length of approximately 33 m for 1 in 8.5 and about 46m for 1 in 12, as shown A_1P_1 C_1C_2 where P_1 is intersection point.

3. Next Place another black box on second line O_3 O_4. This can be either a "curved black box" or straight line black box depending upon whether it falls on curved portion of track or straight patch of the track. Let us assume that here it falls on curved part B_2 B_3, hence place a curve black box i.e. only crossing portion, as shown by $E_1E_2E_3$.

4. After placing the two black boxes, the next step is to join C_1 & E_2 by a curve or a combination of straight line and suitable curve. This completes the laying of cross over. Here it is to be ensured that while placing these two black boxes all provisions of P-Way Manual i.e. lead radius and turn-in-curve radius etc are followed.

B) Graphical Method :-

This is more scientific and simple method, applicable for all kinds of layouts.

Alignment of turnout :

By examining the key diagram of standard turnout, the alignment of the turnout can be described as under: (say for 1 in 12: 60 Kg fan shaped Turnout):

a) Straight from SRJ to Actual Toe of Switch (ATS). At ATS it changes direction at an angle called switch entry angle.

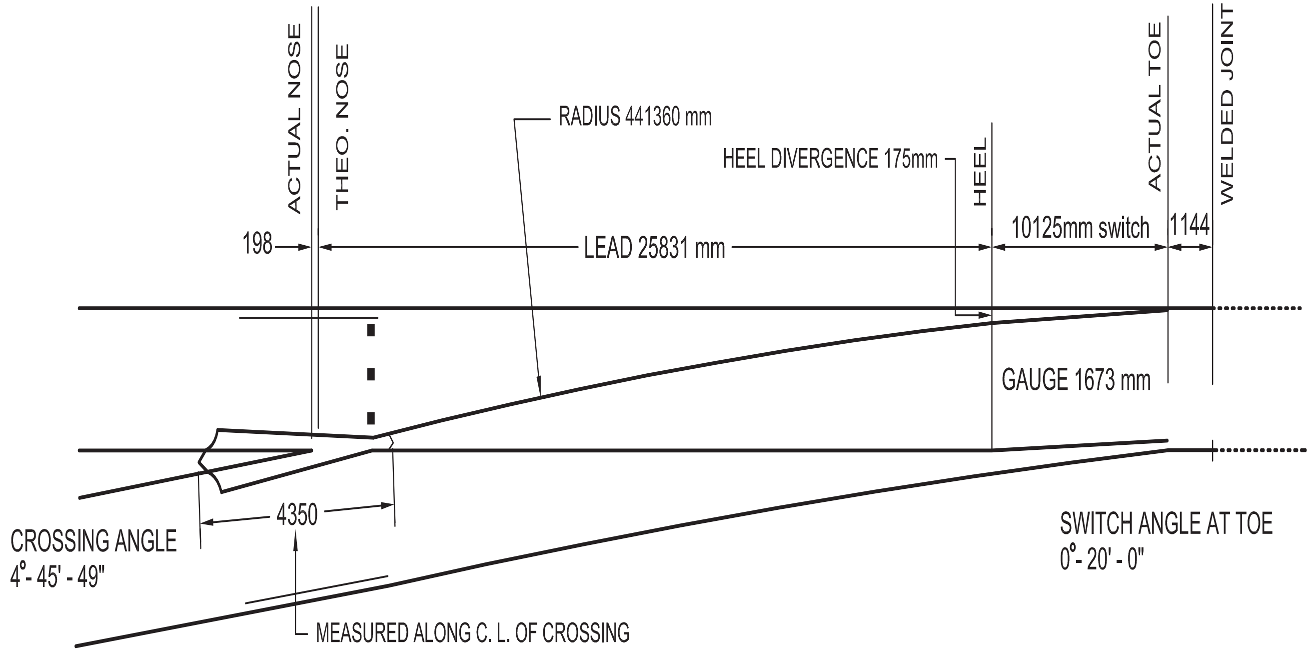
b) Beyond ATS, up to Toe of Crossing (TOC), it changes direction and follows a circular curve passing through heel of switch (HOS).

c) At TOC the alignment again changes direction and is straight up to Heel of Crossing (HOC) for a length equal to length of crossing.

d) From HOC up to last long sleeper (LLS), due to pre-positioned inserts, the alignment follows the same straight or curve as that of main line i.e. if main line is straight, the alignment in this portion will be straight. In case the main line is curved the alignment in this portion will be a curve tangential to straight of crossing, having the same curvature as that of main line.

The table 1 on next page gives above dimensions with good approximation for 1in 8-1/2, 1 in 12, 1 in 16 and 1 in 20 IRS curved fan shaped turnouts with CMS crossings.

The turnout alignment from SRJ to LLS (last long sleeper) is fixed as per the designs and the curvature only varies as per the main line geometry. The alignment beyond LLS can be designed based on the field requirement. In case of connection to other line, the alignment can be designed beyond the LLS up to the point of connection (PC). In case of crossovers, the alignment can be designed between LLS to LLS of connecting turnouts. The connection can be straight, single circular curve or a reverse curve depending upon the field conditions which vary depending upon type of turnouts, geometry of main lines, track centres and available space between SRJ to SRJ.



KEY DIAGRAM OF 1 IN 12 LAYOUT WITH CMS CROSSING

Figure 10.10

Table-1: Important dimensions of turnout geometry
(Curved switch on fan shaped PSC sleeper layout with CMS crossing)

Crossing	Crossing Angle F	Heel Divergence (mm)	Turnout Radius from Straight Track (mm)	SRJ to TTS (mm)	TTS to HOS measured along main line curve (mm)	HOS To TNC measured on turnout curve (mm)	Total Length of crossing TOC to HOC (mm)	TNC to HOC measured along crossing leg (mm)	TNC to TOC measure d along crossing leg (mm)	Long sleepers beyond HOC Up to LLS (mm)	ANC to TOC along main line (mm)	Offset at TOC from main line (mm)	HOS to TOC (mm)
1 in 8.5	$6^0 42'35''$	182	232260	1500	6400	18395	3300	2216	1225	3300	1084	1559	17311
1 in 12	$4^0 45'49''$	175	441360	1144	10125	25831	4350	2803	1547	5500	1745	1517	24284
1 in 16	$3^0 34'35''$	145	784993	844	11200	35720	5400	3764	1636	8400	1900	1515	34084
1 in 20	$2^0 51'45''$	133	1283100	844	12460	46027	6200	4550	1650	9150	1980	1579	44377

Basic Geometric Principles used : The method proposed here is simple and is applicable for all kinds of layouts. The idea is to draw the layout in AutoCAD, exactly as it would be in the field using the key layout given in the standard RDSO drawings. The geometry indicated in para above is drawn in AutoCAD.
The method uses simple principles of geometry and can be used for all layouts with any complex geometry without involving complex trigonometrical equations, as under:

I. A circular curve can be drawn passing through any three non-linear co-planner points. It works by joining two pairs of points to create two chords. The perpendicular bisectors of a chord always passes through the centre of the circle. By this method we find the centre and can then draw the circle or circular arc.

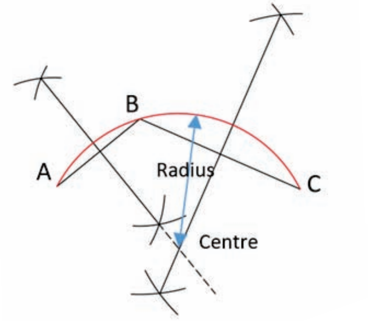


Fig. 10.11 Perpendicular bisectors of chords always meet at centre

II. A circle or a circular arc can be drawn between two lines intersecting at a point (called apex). If we mark an equal length T from apex on both lines (TP1 and TP2) then we can locate the centre of curve by drawing perpendicular lines from TP1 and TP2. The point of intersection of these perpendicular lines will be the centre of curve. We can draw a curve of radius $R = T/\tan \Delta/2$ from the centre. Here "T" is the tangent length which is equal to the distance from Apex to TP1 or TP2 and Δ is the deflection angle i.e. the external angle between the two intersecting lines. The curve or circular arc will start at TP1 called first tangent point and end at TP2 called second tangent point. The balance portion of the line before TP1 and after TP2 will remain as straight portion in the alignment. This way we can introduce straights whenever required, before the start of curve (TP1) and/or after the end of curve (TP2) in alignment .

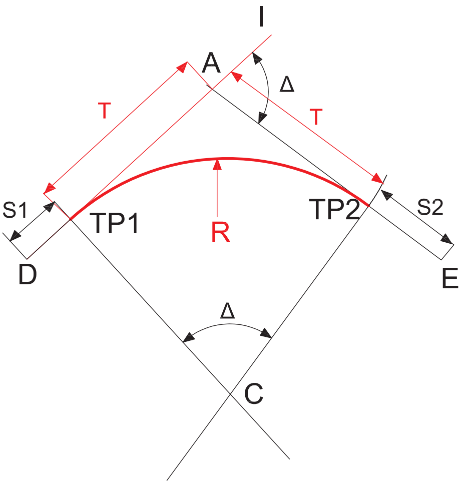


Figure 10.12

It can be understood that the maximum radius possible will be when full length of the shorter line is taken tangent length and the equal length cut from the longer line will form another tangent of the same length. The balance portion of the longer line shall remain as straight portion in the alignment and no straight will be on shorter line.

III. A tangent to a circular curve at a point on the curve can be drawn by drawing a line perpendicular to its radius at the point of contact.

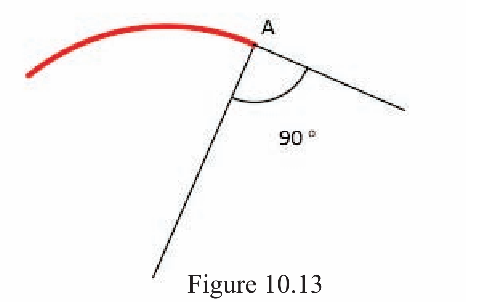


Figure 10.13

Turnout dimensions:

The turnout dimensions indicating distances and offsets of various geometrical points where curvature of the turnout alignment changes have been given in table -1.

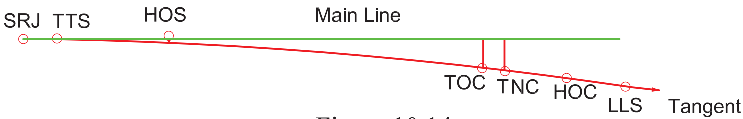


Figure 10.14

Method :
With the knowledge of above horizontal and vertical distances, the layouts of connections or crossovers can be drawn easily in AutoCAD (More easily using Civil 3D or Bentley Rail Track). The steps involved are described below. The steps described use dimensions for 1 in 12 turnouts. The other turnouts can be drawn using their respective dimensions.

Step-1

SRJ is first marked on the main line. Then, TTS, HOS, TOC and TNC are marked on the main line curve at their respective distances.

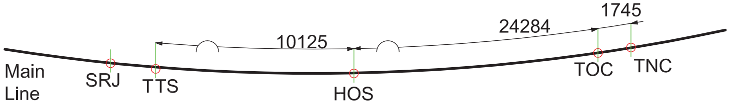


Figure 10.15

Step-2

Actual locations of HOS, TOC and TNC are located by drawing perpendicular offsets from the main line at their respective marks on main line as shown below.

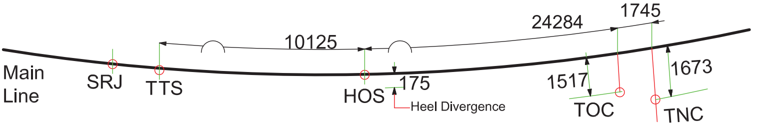


Figure 10.16

Step-3

Now a curve can be drawn by joining three points TTS, HOS and TOC. This is turnout curve. Its radius R can be measured easily in AutoCAD and annotated.

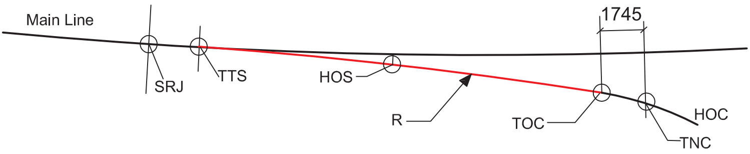


Figure 10.17

Step-4

Draw line from TOC to TNC and extend it by specified distance (2473 mm for 1 in 12) to get the location of HOC. The total length of crossing from TOC to HOC shall be 4350 mm for 1 in 12. From HOC we draw a curve of same curvature and direction as that of main line curve having specified length (5500 mm for 1 in 12 curve). This will give location of LLS. Now draw a line from LLS tangential to the curve from HOC to LLS.

(Note: It is important to note that due to pre-positioned inserts on PSC sleepers, the alignment from HOC to LLS will follow the same alignment as that of main line which will be straight for straight main line and curved for curved main line having same degree of curvature).

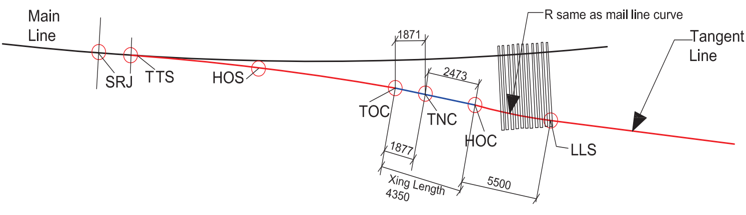


Figure 10.18

(A) Connection to a divergent line (single curve)

Once we draw the tangent line beyond LLS then we can connect the turnout with another line by drawing tangent of the other. If both these tangents intersect, then using the two tangents, we use the second principle of geometry mentioned in earlier para and draw a connecting curve. Thus, the connection is a single circular curve. The radius of the curve will be R= T/tan $\Delta/2$, where T is the length of the tangent. The portion of the longer tangent over and above length T will remain as straight portion in the alignment. The maximum radius can be achieved if full length of the shorter intersecting tangent line is taken as T. The balance portion of longer tangent line over and above T will automatically remain as straight portion in the alignment once we draw the curve between two tangents.

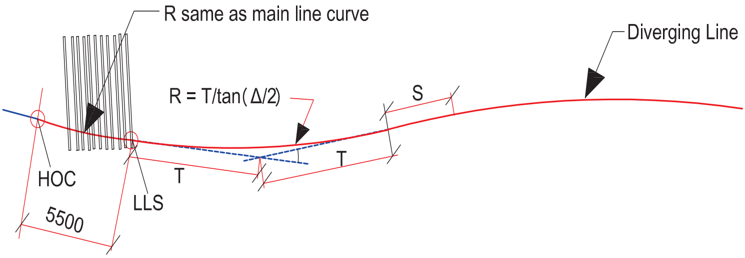


Figure 10.19

(B) Connection to a divergent line (Connecting reverse curve):

In case the two tangents (Tangents from LLS and tangent on diverging line) do not intersect within the available space, we can connect by a reverse curve. We take a length say T1 on the tangent beyond LLS and T2 on tangent on TP of connecting line to locate apex A1 and A2. We join A1 and A2 and draw curves between tangents using the second principle of geometry mentioned in earlier para. The radius of first curve will be R1= T1/tan Δ1/2 and second curve will be R2= T2/tan Δ2/2. The middle portion of A1A2 left will automatically be a straight portion between two curves. For obtaining optimum radii of reverse curves, we try to eliminate straight portions and attempt to adjust length of tangents T1 and T2. We start the curve immediately after LLS. For this we measure the distance from LLS to TP (meeting point on diverging line) and divide it by four to have approximate equal length of tangents i.e. T1=T2=T (~ distance between LLS to TP divided by 4). If we need, we can introduce straight portions before, and/or after and/or in the middle portion of reverse curve if required. In that case the radius of reverse curve will reduce. It is to be ensured that the radius of any of the curves obtained should not be less than 218 m (IRSOD para 17 chapter II). In case one of the radii say R1 is more than 218 m and one say R2 is less than 218 m, we can reduce T1 slightly and increase T2 so that R1 is decreased and R2 is increased. The most optimum radii will be when R1=R2=R. In case even without straights the optimum radius achieved is less than 218 m, then it should be considered that the connection is not feasible, and we may have to shift SRJ to different location.

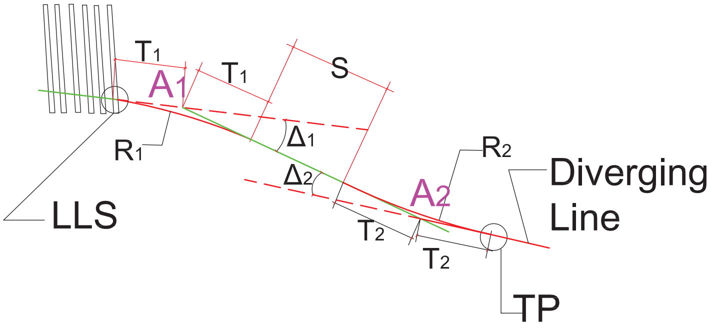


Figure 10.20

(C) Connection to a divergent line (Connecting straight) :

When there is no constraint of placing SRJ and TP of diverging line, it may be possible to provide a simple connecting straight when both tangents meet in a straight line. With few trials can achieve the locations of SRJ and Point of connection to achieve straight connection.

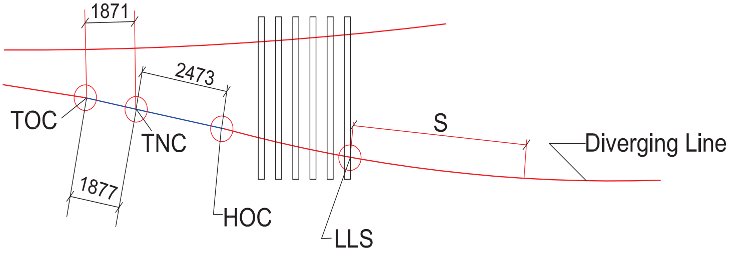


Figure 10.21

(D) Crossover connections :
In case of crossover connections, we use the same principles described above. The turnout curves are drawn on both tracks and the connection is drawn between LLS to LLS by extending their tangents. The connection can be connecting reverse curve if the two tangents do not intersect within the available space. For obtaining maximum radius of reverse curves we attempt to eliminate straights and attempt to

maximise length of tangents (without straights) and we start the curve immediately after LLS. For this we adopt same method as that described in the former para for connection to diverging track. In case even without straights and with equal radius of both curves (optimum radius R1=R2=R) achieved is less than 218 m, then it should be considered that the connection is not feasible, and we may have to shift one or both SRJs to different location. (Fig. 10.22 A overleaf).

The connecting curve can be single circular curve if the two tangents intersect within the available space. (Fig. 10.22 B overleaf).

The connection can be straight if there is no constraint of placing SRJs and we can fix it anywhere on the main lines, then we can design the two tangents meeting in a straight line. With few trials can achieve the locations of SRJs. (Fig. 10.22 A overleaf).

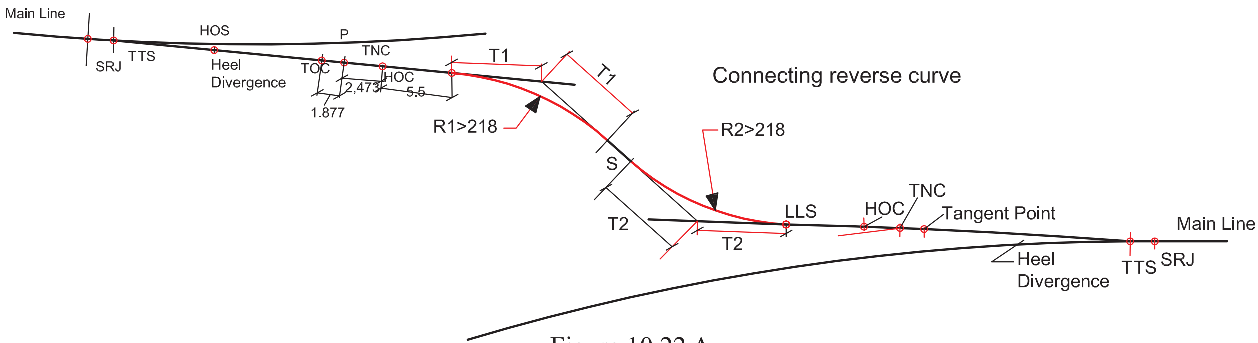


Figure 10.22 A

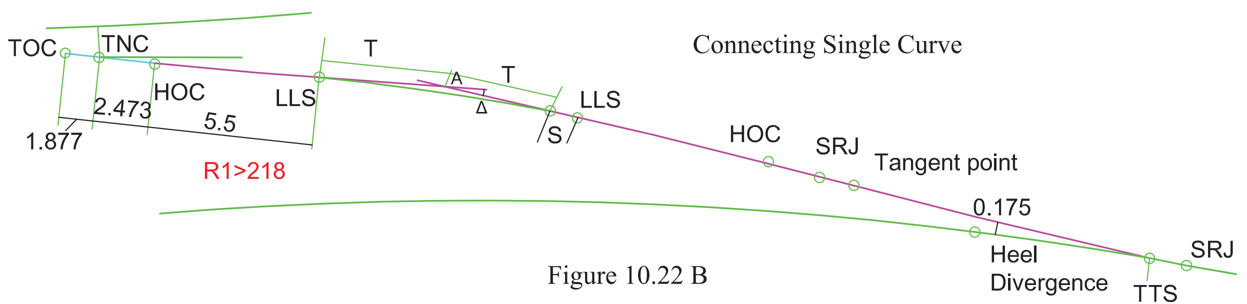


Figure 10.22 B

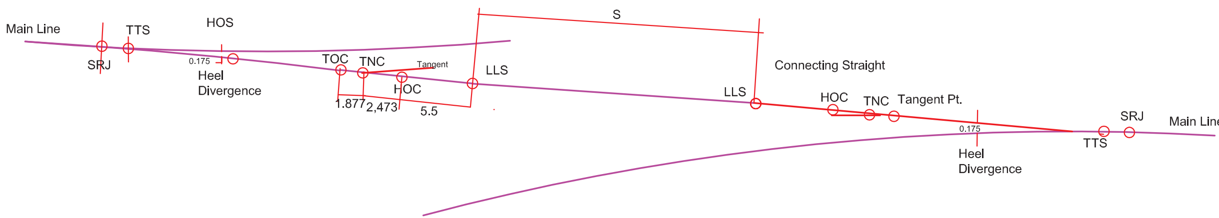


Figure 10.22 C

■ ■ ■

Chapter 11

Software on Layout Calculations

11.1 Introduction

In their day to day work P. way officials have to deal with complicated yard layouts. The maintainability and riding quality over a turnout depends largely on how accurately it is laid and maintained. Kinks in points and crossings can be avoided if adequate care is taken at the time of laying itself.

For ensuring correct laying it is essential that necessary calculations are correctly done before layouts are laid in the field. These calculations are intricate in nature and require considerable efforts on the part of P. Way officials. Due to their remaining busy in routine works on many occasions this item of work does not get the attention it deserves.

11.2 Layouts

While the insertion of crossover, diamonds in existing layouts, yard remodelling etc. are being taken up, errors in calculations may result in:

- Incorrect laying (i.e. incorrect TNC distances) – Results in bad running and in extreme cases unsafe conditions may occur on defective/bad layouts.
- Long crossovers at angle 'F' being laid even though space could be saved by having curves in between two turnouts.
- During doubling/gauge conversion projects new layouts are being inserted forcibly resulting into undesirable curvatures which give bad running and are potential locations needing frequent attention.
- It is suggested that even while replacing an old layout an opportunity be taken to correct all known defective layouts.

The book on "Layout Calculations" gives all the formulae and sample calculations and is of great help in ensuring correct laying of crossovers and other connections. For assisting the field engineers, a software has been developed in Visual Basic for all the cases presented in the book on "Layout Calculation". The salient features of the Software are:

- Highly interactive
- No need to refer to any book
- All data on standard dimensions stored in subroutines
- Crossings can be fixed straight away based on these calculations

11.3 Scope

The Software covers the following:

Connections between

- Diverging Tracks
- Straight Parallel Tracks
- Curved Parallel tracks
- Curved and straight Tracks

Cross-overs between

- Straight Parallel Tracks
- Non Parallel Straight Tracks
- Curved Parallel tracks
- Sanded Dead End and Main Line
- Double Junction

The Software generally follows the pattern as given in the book on "Layout Calculations".

While running the Software for a particular case, the user has to give the data on section, Details of crossing from a drop down menu, track centers, Radius of connecting curve etc and the results are obtained instantaneously.

11.4 Instructions for Using the Software

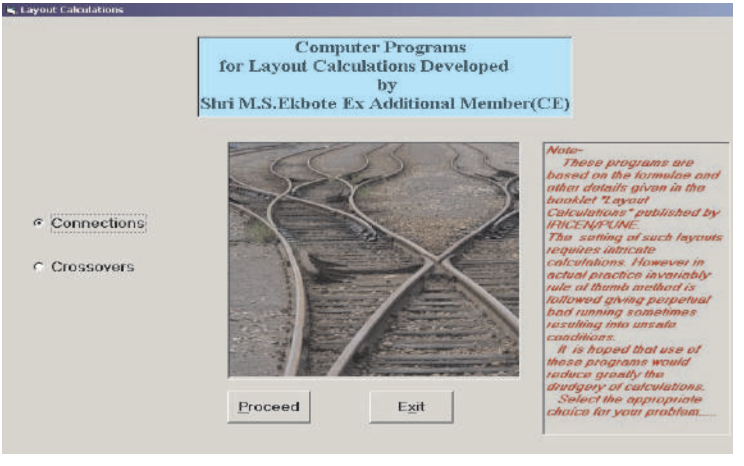
Installation

For installing the Software insert the CD in your CD drive. Go to "My computer" select the drive containing the CD; locate the "set up" file from the "Layout" folder or subfolder and double click the setup icon. The Software will be installed instantaneously on your computer and will be available in your "start" menu.

Alternately if you do not wish to install the Software go to start menu select the "Run" command and on browsing locate the file "Layout_Calculations.exe" in your CD and Click "OK" and the Software will get loaded.

11.5 Illustration

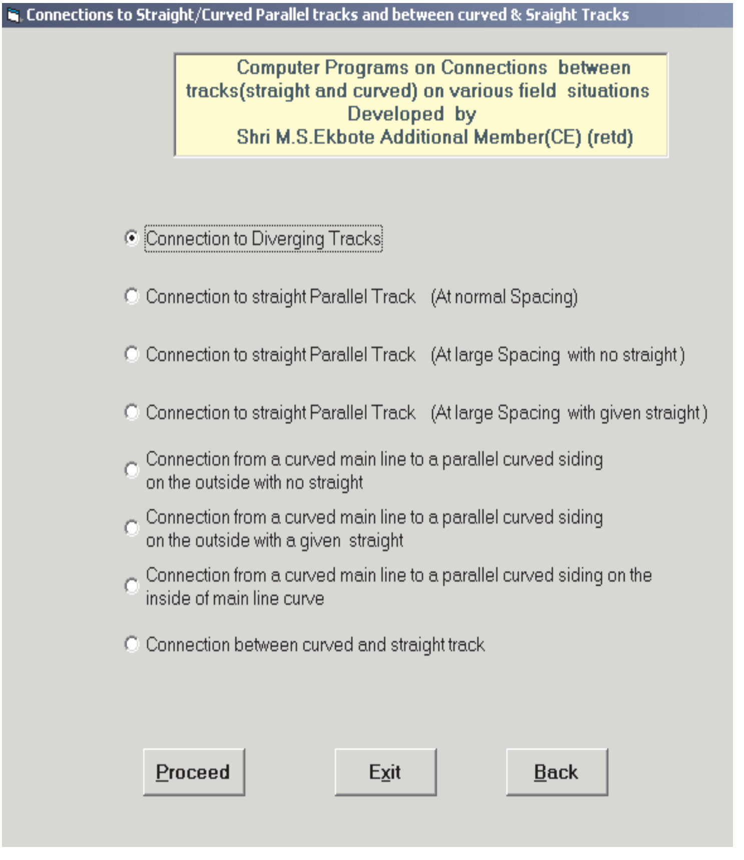
As soon as the Software is loaded, the following screen is visible:



Screen 11.1

Disclaimer : Due care has been taken in developing these programs and the results have been verified by manual calculations in a few sample cases. The users are however advised to check the results independently before using them in the field. The author of the programme cannot be held accountable for any loss or damage occurring in this account.

Let us first take “Connections”. After choosing the “Connections” option button and clicking “Proceed” Button next screen opens as given below giving list of options under “Connections”.



Screen 11.2

Let us select “Connections to straight parallel track” and click “Proceed” Button. It opens the next Screen which gives a sketch and text boxes for data entry, Screen 11.3 on page 165.

Certain features of the Software are common to all the cases and are listed below:

- Selecting the appropriate Gauge option opens a drop menu for standard turnout dimensions on BG or MG as the case may be. The labels of the items needing data entry have been shaded white. Other text boxes are locked and will not accept any data. They will only display results.

- Units of dimensions have to be in mm except where specifically mentioned.

- Please ensure that data in all text boxes requiring data entry are correctly entered and the type of turnout is selected from the drop down menu before clicking "Compute" Button else you will get run time errors.

- For non Standard turnouts the red label is required to be clicked as indicated on the screen and it opens text boxes for giving data on turnouts viz. description, turnout number (e.g. 12 in case of 1 in 12 turnouts) and centre line dimensions A,M,K etc.

- The most ideal type of suggested output is to take a print of the form displaying the results by clicking "Print" Button. Alternately textural output on a file is also possible. For this purpose the Button "Copy results in a file" is to be clicked which will open an input box to give the file name for output. Please be sure to enter the complete file name with drive name and folder where you want the output. The output file so created can be easily opened in any text editor such as Word pad.

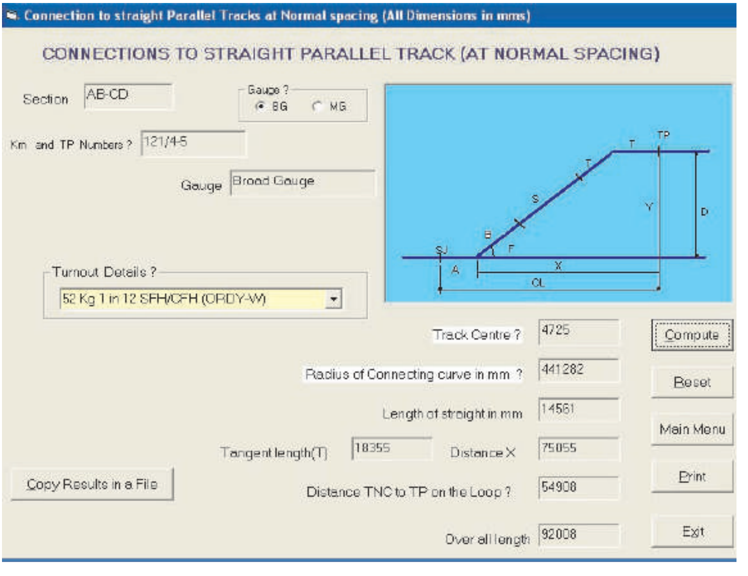
- The Software also gives warnings by way of displaying message boxes – when results are unacceptable such as resulting curvatures being sharp and beyond permissible limits specified in Schedule of dimensions.

- If you solve a problem for PSC layout then a dialogue box appears asking "consider enhanced straight value behind the crossing due to prepositioned inserts".

  In case of PSC turnouts it has been explained that we need to select B (modified) or K(modified) from annexure-III. While doing manual calculations for taking care of additional straight length due to fixity of inserts, which is 5.5m for 1 in 12 and 3.3m for 1in 8.5 turnouts. If due to constraints, somebody wants to remove one, two or more number of common long sleepers so as to reduce this additional straight, he can do so by clicking on red ink marked option of " for turnouts not listed in drop down menu" and feeding the details of turnout and parameters. If one sleeper is removed then K (modified), which is denoted as K (mm) on screen, shall be reduced by 600mm, for two sleepers - 1200mm and so on.

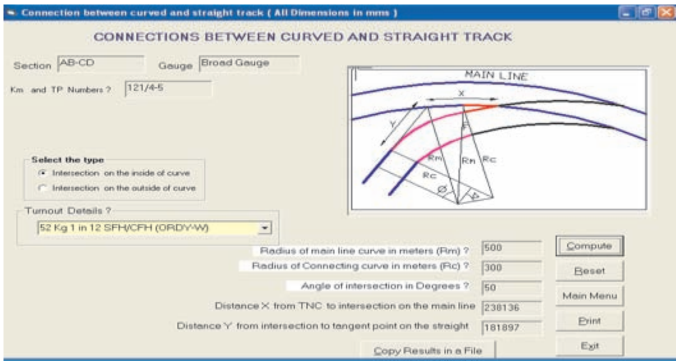
For example for 1 in 12, 60 kg PSC layout if 3 common long sleepers are to be removed then values of K (mm) will be fed as 8303-1800 = 6503mm which is from annexure-III K (modified) - 3x600mm.

On getting the Screen as mentioned above, the values have to be entered. We have to select the appropriate turnout from drop down menu and on clicking compute button results in the screen to appear as under:



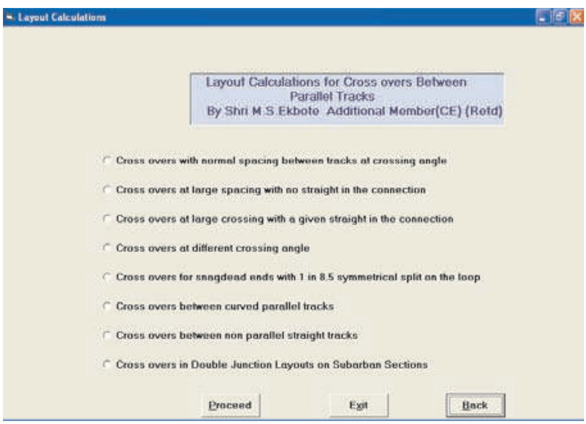
Screen 11.3

The second case for demonstration in "Connections" is taken as "Connections between Curved and straight track". On Clicking the "Proceed" Button it opens the appropriate screen which has separate frames for Gauge selection and whether the intersection on the inside or outside of the curve. After you select appropriate Gauge and then type of intersection would display appropriate sketch and after complete data entry and clicking "Compute" Button would give the results as shown below:



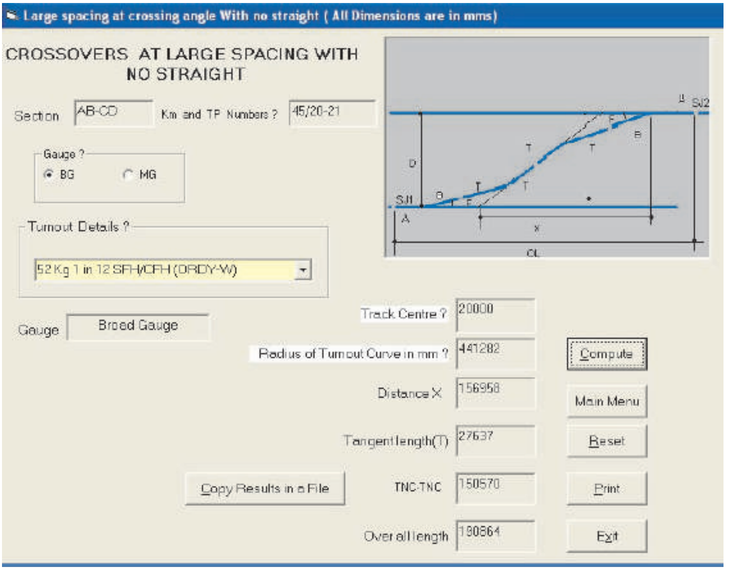
Screen 11.4

Next we take the Cases of "Cross-overs". On selecting Crossovers from the first screen as described in Para 5.3 and clicking " Proceed Button takes us to the screen showing the choices under " Crossovers" as under.



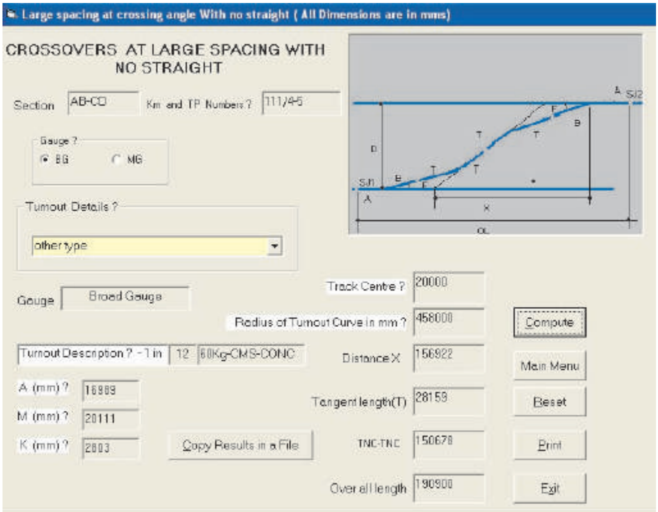
Screen 11.5

Let us first take the case of cross over between straight parallel tracks and click proceed button. Thereafter select BG or MG and select the option(2) from the menu for connection type i.e. “Cross-overs at large spacing with no straight in between” On selecting Gauge, appropriate Turnout from the drop down menu and entering all the data we get following screen after clicking Compute Button.



Screen 11.6

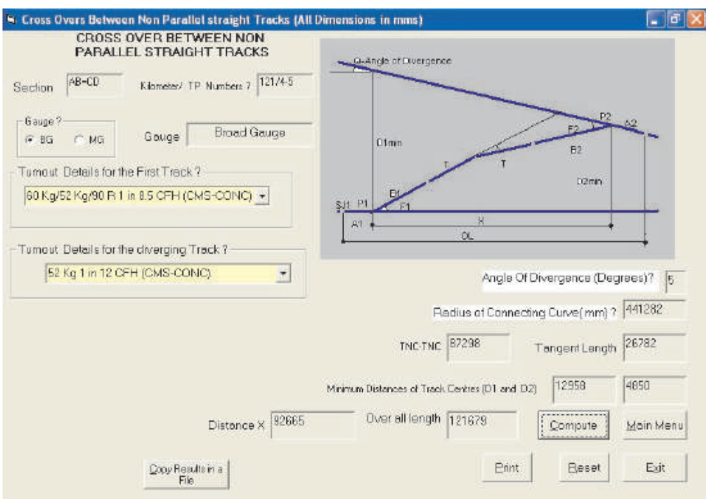
If the same case is solved treating it as a case for non standard turnout then the text of the drop down menu is to be changed as “other type” in lower case and it opens the new text boxes for entering the data for the turnouts. On entering a sample data and clicking the “ compute” button gives the results as shown in screen 11.7.



Screen 11.7

The above feature is available in all the cases.

We take the next case of Crossovers between inclined tracks. The final results after entering data etc is as below:



Screen 11.8

11.6 Conclusions

It is considered that the Software explained above would be of considerable help to the field Engineers in improving the running quality over turnouts and ensuring safety by way of correct laying.

■ ■ ■

Annexure - I

TABLE OF DETAILED DIMENSIONS

Crossing No	Section	Type			Dimensions (mm)					
			L	TSL	SL	d	w	F	β	R
Broad Gauge (other than PSC sleeper)										
1 in 8 ½	60 kg	C, FH.	18424	7872	7135	182.5	880	6^{0}-42’-35”	4^{0}-35’-0”	231440
1 in 8 ½	52 kg	S, LH	20730	4950	4725	136	864	6^{0}-42’ 35”	1^{0}-34’-27”	222360
1 in 8 ½	52 kg	C, FH	18395	6835	6400	182.5	864	6^{0}-42’ 35”	0^{0}-47’-27”	232320
1 in 8 ½	90R	S, LH	20730	4950	4725	136	864	6^{0}-42’ 35”	1^{0}-34’-27”	222360
1 in 8 ½	90R	C, FH	18395	6835	6400	182.5	864	6^{0}-42’-35”	0^{0}-47’-27”	232320
1 in 12	60 kg	C, FH	25831	11156	10125	175	1877	4^{0}-45’-49”	0^{0}-20’-0”	441360
1 in 12	52 kg	C, FH	29200	6724	6400	133	1232	4^{0}-45’-49”	1^{0}-0’44”	442120
1 in 12	52 kg	S, FH	27870	8478	10125	133	1232	4^{0}-45’-49”	0^{0}-27’-35”	458120
1 in 12	90 R	C, FH	29200	6724	6400	133	1232	4^{0}-45’-49”	1^{0}-8’-0”	442120
1 in 12	90 R	S, FH	27870	8487	7730	133	1232	4^{0}-45’-49”	0^{0}-17’-11”	458120
1 in 16	52 kg	C, FH	37170	10594	6500	153	1377	3^{0}-34’-35”	0^{0}-24’-27”	824225
1 in 16(HS)	52 kg	C, FH	37565	12320	7730	133	1377	3^{0}-34’-35”	0^{0}-24’-27”	816480
1 in 16)	90R	C, FH	37170	10594	9750	133	1377	3^{0}-34’-35”	0^{0}-46’-59”	824225
1 in 20	90R	C, FH	46210	11194	11150	133	1377	2^{0}-51’-45”	0^{0}-46’-59”	1303810
Broad Gauge (1673 mm) on PSC Sleepers										
1 in 8 ½	60 kg	C, FH	18395	6839	6400	182.5	1225	6^{0}-42’-35”	0^{0}-46’-59”	232260
1 in 8 ½	52 kg	C, FH	18395	6839	6400	182.5	1225	6^{0}-42’-35”	0^{0}-46’-59	232260
1 in 12	60 kg	C, FH	25831	10125	10125	175	1877	4^{0}-45’-49”	0^{0}-20’-0”	441360
1 in 12	60 kg	C, FH	25831	10125	10125	175	1877	4^{0}-45’-49”	0^{0}-20’-0”	441360
1 in 16	60 kg	C, FH	35720	11200	11200	145	2526	3^{0}-34’-35”	0^{0}-20’-0”	784993
1 in 20	60 kg	C, FH	46027	12460	12460	133	1877	2^{0}-51’-45”	0^{0}-20’-0”	1283100
Metre Gauge										
1 in 8 ½	90R	C, FH	9515	6206	5500	169	915	6^{0}-42’-35”	0^{0}-29’-13”	130210
1 in 8 ½	75R	S, LH	11560	4320	4115	120	915	6^{0}-42’-35”	1^{0}-35’-30”	119610
1 in 8 ½	75R	C, FH	9515	6206	5500	169	915	6^{0}-42’-35”	0^{0}-29’-14”	130210
1 in 8 ½	60R	S, LH	11560	4320	4115	120	915	6^{0}-42’-35”	0^{0}-24’-27”	119610
1 in 8 ½	60R	C, FH	9515	6206	5500	169	915	6^{0}-42’-35”	1^{0}-9’-38”	130210
1 in 12	90R	Partly C, FH	14678	7974	7130	130	1220	4^{0}-45’-49”	0^{0}-24’-27”	258300
1 in 12	75R	S, FH	16323	5777	5485	117	1220	4^{0}-45’-49”	1^{0}-9’-38”	240600
1 in 12	75R	Partly C, FH	15108	7544	6700	117	1220	4^{0}-45’-49”	0^{0}-24’-27”	258300
1 in 12	60R	S, FH	16323	5777	5485	117	1220	4^{0}-45’-49”	1^{0}-9’-38”	240600
1 in 12	60R	Partly C, FH	15108	7544	6700	117	1220	4^{0}-45’-49”	0^{0}-24’-27”	258300
1 in 16	60R	C, FH	20060	8264	7420	117	1378	3^{0}-34’-35”	0^{0}-24’-27”	46240
Metre Gauge on PSC Sleepers										
1 in 8 1/2 HTC	52 Kg	C, FH	9515	6206	5500	169	1047	6^{0}-42'-35"	0^{0}-29'14"	130205
1 in 12 CMS	52 Kg	Partly C, FH	14678	7974	7130	130	1405	4^{0}-45'-49"	0^{0}-24'-27"	258310
Narrow Gauge										
1 in 8 ½	60R	S, LH	8280	4320	4115	120	915	6^{0}-42’-35”	1^{0}-35’-30”	82800
1 in 12	60R	S, LH	11723	5777	5485	117	1220	4^{0}-45’-49”	1^{0}-9’-389”	167340

Note:

C	**Curved**
S	**Straight**
FH	**Fixed Heel**
LH	**Loose Heel**
CMS	**Cast Manganese Steel Crossing**
HTC	**Heat Treated Crossing**
HS	**High Speed**

Annexure - II

TABLE OF DETAILED DIMENSIONS

CENTRE LINE LAYING (FOR BG WITH ORDINARY CROSSING)

Section	Gauge	crossing No	Type	Dimensions (mm)					Assembly Drg No
				A	B	C	M	K	
52 KG	BG	1 IN 8 1/2	S, LH	12000	16274	840	14295	1979	RDSO T/285
52 KG	BG	1 IN 8 1/2	C, FH	12000	16274	1500	14295	1979	RDSO/T-286
90 R	BG	1 IN 8 1/2	S, LH	12000	16260	840	14295	1965	RDSO/T-360
90 R	BG	1 IN 8 1/2	C, FH	12000	16260	1500	14295	1965	RDSO/T-307
52 KG	BG	1 IN 12	S, FH	16953	22706	1500	20147	2559	RDSO/T-32
52 KG	BG	1 IN 12	C, FH	16953	22706	1500	20147	2559	RDSO/T-184
90 R	BG	1 IN 12	S, FH	16953	22687	1500	20147	2540	RDSO/T-184
90 R	BG	1 IN 12	C, FH	16953	22687	1500	20147	2540	RDSO/T-31
52 KG	BG	1 IN 16	C,FH	20922	30750	844	26842	3908	RDSO/T-135
52 KG	BG	1 IN 16 (HS)	C,FH	22693	30750	850	26842	3908	RDSO/T-231
90 R	BG	1 IN 16	C,FH	20922	30750	844	26842	3882	RDSO/T-67
90 R	BG	1 IN 20	C,FH	24664	38118	844	33540	4578	RDSO/T-98

CENTRE LINE LAYING (FOR BG WITH CMS CROSSING Non - PSC)

Section	Gauge	Crossing No	Type	Dimensions (mm)					Assembly Drg No
				A	B	C	M	K	
52 KG	BG	1 IN 8 1/2	S, LH	12000	17418	840	14295	3123	TA-20122, TA-20804
52 KG	BG	1 IN 8 1/2	C, FH	12000	17418	1500	14295	3123	TA-20196, TA-20835
90R	BG	1 IN 8 1/2	S, LH	12000	17404	840	14295	3109	TA20110, TA-20198,etc
90R	BG	1 IN 8 1/2	C, FH	12000	17404	1500	14295	3109	TA-20148, TA-20822
52 KG	BG	1 IN 12	S, FH	16953	23981	1500	14295	3834	TA-5268(M), TA-20222, TA-20801
52 KG	BG	1 IN 12	C, FH	16953	23981	1500	20147	3834	TA-20171, TA-20831
90R	BG	1 IN 12	S, FH	16953	23962	1500	20147	3815	TA-5044(M), TA-20184, etc
90 R	BG	1 IN 12	C, FH	16953	23962	1500	20147	3815	TA-20125, TA-20839
52 KG	BG	1 IN 16	C, FH	20922	31447	844	20147	4605	TA-20141, TA-20828
52 KG	BG	1 IN 16 (HS)	C, FH	22693	31447	850	26842	4605	RDST/T-403
90 R	BG	1 IN 16	C, FH	20922	31421	844	26842	4579	TA-20138, TA-20813
90 R	BG	1 IN 20	C, FH	24664	39470	844	26842	5930	TA-20122, TA-20804

Annexure - III

TABLE OF DETAILED DIMENSIONS

CENTRE LINE LAYING (FOR BG WITH CMS CROSSING ON PSC SLEEPER)

Section	Gauge	Crossing No	Type	Dimensions (mm)							Assembly Drg No
				A	B	B (Modified)*	C	M	K	K (Modified)*	
60 KG	BG (PSC)	1 IN 8 1/2	C, FH	12025	16486	19786	1500	14270	2216	5516	RT-4865
52 KG	BG (PSC)	1 IN 8 1/2	C, FH	12025	16486	19786	1500	14270	2216	5516	RT-4865
60 KG	BG (PSC)	1 IN 12	C, FH	16989	22914	28412	1144	20111	2803	8301	RT-4218
52 KG	BG (PSC)	1 IN 12	C, FH	16989	22912	28414	1144	20111	2801	8303	RT-4218
60 KG	BG(PSC)	1 IN 16	C,FH	20970	30558	39558	844	26794	3764	12764	RDSO/T-5691
60 KG	BG(PSC)	I IN 20	C, FH	25850	38031	47181	844	33480	4550	13700	RDSO/T-5858

* considering enhanced length of straight behind HOC due to fixity of inserts of common long sleepers.

Note : *The values given in above table for "B" are from point of intersection "P" to heel of xing (HOC). In case of PSC layout due to fixity of inserts of common long sleepers the curve cannot be started immediately after HOC. Hence for PSC sleeper layout, the additional straight length behind HOC due to fixity of inserts is 5.5m for 1in12 T/O and 3.3m for 1in8.5 T/O.*

Annexure - IV

TABLE OF DETAILED DIMENSIONS

CENTRE LINE LAYING (FOR METRE GAUGE & NARROW GAUGE)

Crossing No	Section	Type	Dimensions (mm)					Assembly Drg No
			A	B	C	M	K	RDSO/T
Metre Gauge (with CMS crossing)								
1 in 8.5	75R	S, LH	7986	10376	840	8529	1847	393
1 in 8.5	75R	C,FH	7986	10376	1500	8529	1847	386
1 in 8.5	60R	S, LH	7986	10360	840	8529	1831	379
1 in 8.5	60R	C, FH	7986	10360	1500	8529	1831	372
1 IN 12	75R	S, FH	11287	14321	1500	12021	2300	394
1 IN 12	75R	PARTLY C, FH	11287	14321	1500	12021	2300	401
1 IN 12	60R	S, FH	11287	14296	1500	12021	2275	367
1 IN 12	60R	PARTLY C, FH	11287	14296	1500	12021	2275	423
1 IN 16	75R	C, FH	12309	19054	844	16015	3039	189
1 IN 12 (PSC)	52KG	Partly C, FH	11287	14489	1500	12021	2468	T-6450
Meter Gauge (with Heat Treated crossing)								
1 IN 8.5 (PSC)	52 KG	C, FH	7986	11932	1500	8529	3403	T-6327
Metre Gauge (with Ordinary crossing)								
1 IN 8.5	90R	C, FH	7981	11638	1500	8530	3108	TA-20497
1 IN 8.5	75R	S, LH	7986	11632	840	8529	3103	TA-20404, TA-21004
1 IN 8.5	75R	C, FH	7986	11632	1500	8529	3103	TA-20451, TA-21019
1 IN 8.5	60R	S, LH	7986	11615	840	8529	2086	TA-204007, TA-20460
1 IN 8.5	60R	C, FH	7986	11615	1500	8529	2086	TA-20463, TA-21007
1 IN 12	90R	Partly C, FH	1286	15176	1500	12021	3155	TA-20416
1 IN 12	75R	S, FH	11287	15166	1500	12021	3145	TA-20466
1 IN 12	75R	Partly C, FH	11287	15166	1500	12021	3145	TA-20401, TA-21001
1 IN 12	60R	S, FH	11287	15143	1500	12021	3122	TA-20464, TA-21016
1 IN 12	60R	Partly C, FH	11287	15143	1500	12021	3122	TA-21410, TA21410, TA-21010
1 IN 16	60R	C, FH	12309	19635	844	16015	3680	TA-20466
								TA-20413, TA-21013
Narrow Gauge (with Ordinary crossing)								
1 in 8.5	60R	S, L H	6736	9585	840	6499	3086	TA-20604
1 in 12	60R	S, FH	9548	12282	1500	9160	3122	TA-20601

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