DIRECTORATE GENERAL BORDER ROADS

TECHNICAL INSTRUCTION NO 1
(REVISION – 2022)

CLASSIFICATION AND GEOMETRIC STADARDS FOR ROADS

अजय भट्ट
AJAY BHATT

रक्षा एवं
पर्यटन राज्य मंत्री
भारत सरकार
Minister of State for
Defence and Tourism
Government of India

MESSAGE

The revised DGBR Technical Instructions are unique as they combine technical content and codes with practical advice on practice of specific subjects. These Technical Instructions have definite data/content which explicitly bring out tools, process and methodology to be followed for various road construction and infrastructure development associated activities.

The literature is a repository of technical and ground experience amassed by the BRO, working over six decades in inhospitable terrain with harsh climatic conditions as well as latest technical advancements in the field of road communication infrastructure development. I personally find these technical instructors informative, exhaustive and practical in approach. These will mitigate the need for ground executers to refer various books/codes where working on various aspects of road construction and will go a long way in assisting the coming generations of BRO executives.

Jai Hind !

Ajay Bhatt

(Ajay Bhatt)

Dated : 20 Dec, 2021

New Delhi

डा. अजय कुमार
रक्षा सचिव
Dr. Ajay Kumar
Defence Secretary

सत्यमेव जयते

आज़ादी का अमृत महोत्सव

भारत सरकार
रक्षा मंत्रालय
Government of India
Ministry of Defence

FOREWORD

1. I am pleased to note that the Border Roads Organisation (BRO) has revised its twenty seven Technical Instruction, after a gap of 10 years having updated technical content and IRC codes. These Technical Instructions will positively prove to be very useful and ready reckoner for the BRO ground executives while steering them towards the correct methodology and processes to be followed for diverse road construction and associated activities.

2. Since the past six decades, BRO has been developing road infrastructure in the remote regions of the nation. It has contributed immensely in nation building and ushered in prosperity and development in the border areas. A robust mechanism to channelize the road construction activities is an essential planning process and therefore, the revised Technical Instructions will facilitate in dissemination and application of engineering knowledge with updated codes and provisions, to enable the executives to construct roads with the latest specifications as laid down by IRC.

3. I congratulate Team BRO for their stupendous efforts put in for revision of the twenty seven Technical Instructions which will further strengthen their technical proficiency.

(Ajay Kumar)

New Delhi,

March 3, 2022.

श्रमेण सर्वम साध्यम्

ले. जनरल राजीव चौधरी, वी एस एम
महानिदेशक सीमा सड़क एवं कर्नल कमांडेंट
सीमा सड़क संगठन

Lt Gen Rajeev Chaudhry, VSM
Director General Border Roads &
Colonel Commandant
Border Roads Organisation

FOREWORD

1. DGBR Technical Instruction Number 1 (Revision 2022) lays down comprehensively Classification and Geometric Standards for Roads to be adopted in hills and plains by the BRO.

2. The Technical Instruction Number 1 has now been updated and revised incorporating the current standards and specifications laid down by Ministry of Road Transport & Highways (MoRT&H) and Indian Road Congress. The specific requirement of roads under BRO, have also been considered while formulating the Technical Instruction.

3. All technical Officers and Supervisors of the Organisation should make themselves fully conversant with the standards laid down and apply them correctly to achieve high quality good trafficability and safety standards for our roads.

4. This Technical Instruction will come into force with immediate effect.

Station: New Delhi

Dated: Mar 2022

(**Rajeev Chaudhry**)
Lt Gen
Director General Border Roads

INDEX

TECHNICAL INSTRUCTION NO 1

CLASSIFICATION AND GEOMETRIC STANDARDS OF ROADS INBORDER ROADS ORGANISATION

1. INTRODUCTION

1.1 India has a vast area in hilly regions consisting of the Himalayan region from North to North-East, the Central Highlands of Aravalli, Vindhya and Satpura ranges, the Sahyadri (Western Ghats) and the Eastern Ghats. The Himalayan region itself covers about a fifth of the country's total area and about 3000 kms of the country's sensitive international borders lie along this region. The Himalayas extend from Jammu and Kashmir in the north to Arunachal Pradesh in the east. These states along with Himachal Pradesh, Uttarakhand, and Sikkim lie mostly in the Himalayan region. Numerous Himalayan peaks rise over 7,000 m (23,000 ft) and the snow line ranges between 6,000 m (20,000 ft) in Sikkim to around 3,000 m (9,800 ft) in Kashmir. Kanchenjunga—on the Sikkim–Nepal border—is the highest point in the area administered by India. Most peaks in the Himalayas remain snowbound throughout the year. These hilly regions, generally, have extremes of climatic conditions, difficult and hazardous terrain, topography and vast high altitude areas. The region is sparsely populated and basic infrastructural facilities available in more developed plains of hinterland are mostly absent. The areas and, therefore, the roads are affected by floods consequent to torrential rainfall, land-slide, snow-fall, avalanche etc., compelling certain roads to be kept closed in part of the year, especially in winter months. However, these areas are rich in natural resources, flora and fauna, and are important to launch development projects, industries, tourism etc.

1.2 In view of the diverse problems met in the area, the necessity for preparation of a manual for "Design, Construction and Maintenance of Hill Roads" to bring in uniformity of standards and to serve as a guideline was projected by Border Roads Organisation and hence, Hill Roads Manual IRC SP-48 was formulated. This manual is being followed in India in addition to other guidelines for design and construction of Hill Roads. As the hill roads manual has not been updated since 1998, hence, there is a need to update the Technical Instruction No. 1 along with other instructions to have synchronization with latest IRC Codes.

1.3 The standard nomenclatures for classification of roads Class-5, Class-9, Class-9 (Snow Bound Area) and class-9 (enhanced) being adopted by BRO as specified in TI No. 1 are not aligned with standard classification of the roads being adopted by various central and state Govt. agencies as specified in IRC Codes.

1.4 This Technical Instruction supersedes DGBR Technical Instruction No.1 reprinted during 2012.

2. DEFINITIONS

2.1 ***Road Land Width*** is the land width acquired for construction of road. It is also known as Right-of-Way.

2.2 ***Formation Width*** is the finished top width of embankment in fill or hill cut for receiving the road structures including pavement. It includes carriageway width, shoulders, lined drain and parapet walls.

2.3 **Roadway Width** is the sum total of carriage way and shoulders on both sides of carriage way. It is the formation width excluding lined drain and parapet walls.

2.4 ***Carriageway Width*** is the width of pavement of the road used by vehicular traffic.

2.5 ***Shoulder*** is a portion of roadway between the outer edges of the pavement and inner edges of side drain or outer edge of the embankment in filling. Vehicular traffic may pass over shoulders occasionally. Shoulders provide support to the pavement and may be paved or unpaved.

2.6 ***Berm*** is a horizontal ledge or portion of a road land width left between the edge of the road in embankment and the inner edge of the drains. Whereas in cutting, berm is a portion of the road land left between the edge of the road including shoulders and lined drain on hill side and parapet wall on valley side. It may be a ledge between outer edge of the drain and bottom of hill face. It is also known as verge. Generally, it is grass area on side of the road.

2.7 ***Road Lane Width*** is the width of carriage way of the road. It is also known as traffic lane width. Road Lane Width for Single lane road is 3.75m, Intermediate lane is 5.50 m and for double lane road is 7.0 m. It is 7.50m with raised Kerbs. For multiple lane roads, the lane width is 3.50 m per additional lane.

2.8 ***Passing Lane*** is a lane in addition to the normal lanes for overtaking the normal vehicles.

2.9 ***Escape Lane*** is a lane provided for stopping the over-speeding vehicles in case of failure of brakes.

2.10 ***Passing Place*** is an area provided on the side of the road at convenient locations to facilitate crossing of vehicles approaching from the opposite direction. This place can also be used to toe aside a disabled/off road vehicle so that it does not obstruct traffic.

2.11 ***Building Line*** is a hypothetical line parallel to the road land boundary upto which building activity cannot be allowed.

2.12 ***Control Line*** is the distance beyond the building line upto which control on nature of building activities is ensured / exercised.

2.13 ***Camber*** is the convexity given to the cross section of the surface of the carriageway, in plains in straight stretches.

2.14 ***Cross Slope*** is the slope provided to the road surface on roads in hills other than straight stretches. It is at right angles to the road alignment of any part the roadway.

2.15 ***Crown*** is the highest point in cross section of a road surface at or near the centre. The level of the crown is called road surface level.

2.16 ***Super Elevation*** is an inward tilt or transverse inclination given to the cross section of the carriage way on a horizontal curve to reduce the effects of centrifugal force on a moving vehicle.

2.17 ***Plain Terrain*** is a terrain where cross slope of the country/hill face is generally less than 10 percent.

2.18 ***Rolling Terrain*** is a terrain with cross slope ranging between 10 to 25 percent.

2.19 ***Mountainous Terrain*** is a terrain with cross slope ranging from 25 to 60 percent.

2.20 ***Steep Terrain*** is a terrain where cross slope of the hill face is generally greater than 60 percent.

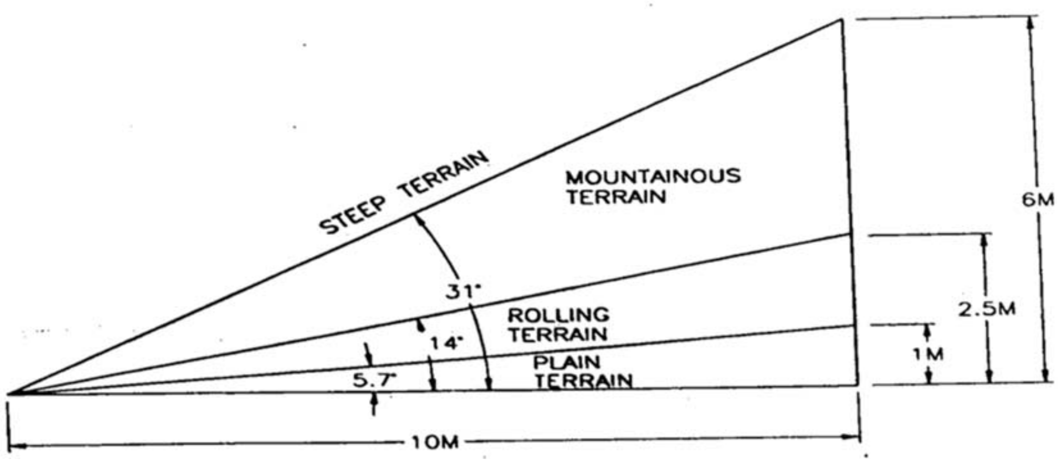


Fig. 1: Classification of Terrain

2.21 ***Gradient*** is the longitudinal slope provided to the road surface. It is the rate of rise or fall with respect to the horizontal line along the length of the road.

2.22 ***Ruling Gradient*** is a gradient which in normal course must never be exceeded in any part of a road beyond the specified limits.

2.23 ***Limiting Gradient*** is a gradient steeper than the ruling gradient which may be used in restricted road stretches where to maintain the ruling gradient is not feasible.

2.24 ***Exceptional Gradient*** is a gradient steeper than limiting gradient which may be used in short road stretches only in extraordinary situations.

2.25 ***Benching*** is the formation of a series of ledges on an inclined road surface.

2.26 ***Hair-pin Bend*** is a bend or curve for reversing the direction of the road alignment on the same hill face.

2.27 ***Vision Berm*** is a horizontal ledge on inner face of the hill at horizontal curves or hair pin bends to improve the visibility.

2.28 ***Slope*** is the inclination of a surface to the horizontal expressed as one vertical linear unit to the number of horizontal linear units.

3. SCOPE

3.1 The revised Technical Instruction is applicable for new roads and improvement of existing roads. However, it is not applicable for the existing roads.

3.2 The objective of revising this TI is to provide basic knowledge about classifications of roads being adopted by BRO in past and new classification in synchronization with IRC codes. In view of the sustainable development goals to be achieved by 2030, geometrics suitable for sustainable development of hill roads have been included based on inputs provided by various ground executives / experienced engineers of the Border Roads Organization and other stake holders of hill roads. The Technical Instruction may be referred as a reference book for maintaining the uniformity in the organisation.

4. CLASSIFICATION OF ROADS IN INDIA

4.1 Non-urban roads in India are classified into following five categories based on location and function according to Nagpur road plan:

- (a) National Highways (NH)
  - (i) National Highways Single Lane (NHSL)
  - (ii) National Highways Intermediate Lane (NHIL)
  - (iii) National Highways Double Lane (NHDL)
- (b) State Highways (SH)
- (c) Major District Roads (MDR)
- (d) Other District Roads (ODR)
- (e) Village Roads (VR)

4.2 Present system follows modified classification system as per third 20-year road development plan. The roads are now classified into following three classes, for the purpose of transport planning, functional identification, earmarking administrative jurisdictions and assigning priorities on a road network:

(a) **Primary system**

- Expressways
- National Highways(NH)

(b) **Secondary system**

- State Highways (SH)
- Major District Roads(MDR)

(c) **Tertiary system (Rural Roads)**

- Other District Roads (ODR)
- Village Roads(VR)

4.3 Present Classification of Roads in BRO

4.3.1 In addition to above classification, the roads constructed by BRO are classified as under:

(a) National Highways Double Lane (NHDL)

(b) National Highways Single Lane (NHSL)

(c) Class – 9 (E) Roads (Generally conforming to NHSL Roads)

(d) Class – 9 (N) Roads (Generally conforming to ODR)

(e) Class – 5 (N) Roads (Generally conforming to Village Roads)

(f) Class – 9 (SBA): Generally used for Snow Bound Area **(SBA)** with more carriage way width or with paved shoulders

4.3.2 Definition of Class - 9 & 5 Roads

(a) ***Class - 5 (N) Roads***: Roads having 5.2 m formation width and 3.2 m carriage way width. These roads can be equated with village roads (VR).

(b) ***Class - 9 (N) Roads***: Roads having 5.95 m formation width and 3.75 m carriage way width. These roads can be equated with other district roads (ODR).

(c) ***Class - 9 (Enhanced) Roads***: Roads having 12 m formation width and 3.75 m carriage way width. These roads can be equated with National Highways Single Lane (NHSL) roads.

4.4 **Classification of Roads Based on Terrain**

4.4.1 In BRO, the roads are constructed in plains as well as in hills. For this purpose of categorization, the roads are generally classified based on terrain as under:

(a) ***Plain Roads***: The roads falling in plain terrain and rolling

(b) ***Hill Roads***: The roads falling in mountainous terrain and steep terrain.

4.4.2 Terrain is classified for the purpose of deciding geometric standards. The general classification should be applied to the entire road stretch instead of changing it frequently for small stretches.

5. REVISED CLASSIFICATION OF ROADS IN BRO

5.1 A concept paper regarding standardization of road specifications for new road projects by BRO was forwarded to Military Operations Directorate vide HQ DGBR letter No. 21801/PC/DGBR/07/TP (Plg) dated 21 Mar 2016. The concept was further deliberated during the Technical Seminar held under the Chairmanship of Defence Secretary on 13 Aug 2016 and was agreed in principle. Accordingly, instructions were issued to all projects by DGBR with a copy to BRDB and DGMO (MO 4) vide HQ DGBR letter No. 21801/PC/DGBR/41/TP (Plg) dated 12 Jan 2017 for National Highway Single Lane (NHSL) in place of Class-9 & National Highway Single Lane (NHSL) with paved shoulders in place of class-9 (Enhanced) specifications.

5.2 Although the classification as explained in para4 above will continue but new roads shall be classified as following:

(a) National Highways Single Lane (NHSL):

- NHSL in place of Class -9
- NHSL with paved shoulders in place of Class – 9 (Enhanced)

(b) National Highways Double Lane (NHDL) : NHDL roads may be without paved shoulders or with paved shoulders depending upon the traffic intensity.

6. ROAD LAND WIDTH

6.1 Road land width is the land acquired for road construction purposes (Fig. 2). This is also termed as right-of way. Road land width for class 9 (N) and class 5 (N) Roads in various terrains is given in Table 1.

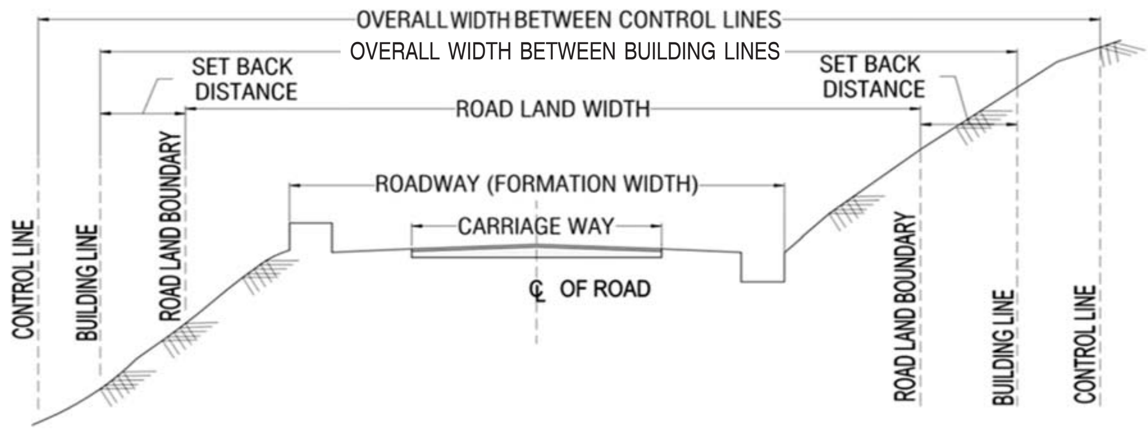


Fig. 2: Cross Section of a Hill Road

Table 1: Road land width/ROW (m) for different classes of roads

Sr No.	Road Classification	Plain and rolling terrain		Mountainous & steep terrain	
		Open area	Built-up-area	Open area	Built-up-area
1	Cl 9 (N)	15	15	15	12
2	Cl 5 (N)	12	10	9	9
3	NHSL*	45	30	24	18
4	NHDL*	45	30	24	18

Note: *ROW has been considered as per Annexure to HQ DGBR letter No. 21801/PC/DGBR/41/TP (Plg) dated 12 Jan 2017 & IRC.

6.2 In order to ensure proper sight distance, it may be necessary to acquire additional right-of-way over that indicated in Table 1. The right-of-way should be enough to ensure a minimum set-back of 5 m for building line from the centre line of the road.

6.3 Additional land with reference to the requirements may be acquired at locations involving deep cuts, high fills, unstable or landslide areas and road intersections.

6.4 If a road is expected to be upgraded to a higher-classification in the foreseeable future, the road land should correspond to the high class of road.

6.5 In order to prevent overgrowing and preserve sufficient space for future road improvement, it is advisable to lay down restrictions on building activity along the roads. Building activity should not be allowed within a prescribed distance from the road, which is defined by a hypothetical line set-back from the road boundary and called the "**Building Line**". In addition, it will be desirable to exercise control on the nature of building activity for a further distance beyond the building line upto what are known as the "**Control Lines**". Standard distances for Building and Control lines for roads in hilly areas are given in Table 2.

Table 2: Standards for Building Lines and Control Lines (m)

Sr No.	Road Classification	Plain and Rolling terrain			Mountainous and Steep Terrain	
		Open Areas		Built-up Area	Open Area	Built-up Area
		Overall width between Bldg, lines (Mtrs)	Overall Width between Control lines (Mtrs)	Distance between Bldg, line and Road Boundary (Set Back) (Mtrs)	Distance between Bldg line and Road Boundary (Set-Back) (Mtrs)	Distance between Bldg line and Road Boundary (Set-Back) (Mtrs)
1	2	3	4	5	6	7
1	Class 9 (N)	25	35	3-6	3-5	3–5
2	Class 5 (N)	25	30	3-6	3–5	3–5
3	NHSL	50	100	3-6	3–5	3–5
4	NHDL	80	150	3-6	3-5	3-5

7. ROADWAY WIDTH

7.1 The roadway width, unless specified otherwise, shall be as follows and it is excluding extra width on horizontal curves, side parapet and drains & medians:

(a) Plain/Rolling Terrain – 15.0 m

(b) Mountainous and Steep Terrain –

  (i) Open country with isolated built up area - 11.0 m

  (ii) Built up area – 10.50 m

7.2 The roadway width for plain and hill roads for NHSL and NHDL specification roads in Hard Rock stretches and snow bound areas shall be as given in Table 3.

7.3 In rocky strata, if excessive hard rock cutting is visualized and traffic volume is less than 8000 PCU/ day, the roadway width may be reduced to 7m as per MoRT&H letter No. No. NH-15017/ 28/ 2018 - P&M dated 23 Mar 2018. These modifications will reduce destabilization of hill slopes and progressive damaging effects on road alignments and structures in higher contours on hills due to excavation works, requirement for large-scale felling of precious trees, associated environmental damages. Further, additional acquisition of land for protective works will also reduce resulting into more sustainable roads.

7.4 Generally upgradation of single lane to intermediate lane or construction of new intermediate lane needs to be discouraged.

7.5 The roadway widths given in Table 3 (a) & 3(b) are exclusive of parapets (usual width 0.6 m) and side drains (usual width 0.6 m).

Table 3 (a) : Roadway Width for NHSL*

Sr No.	Road Classification	Roadway Width (m)	
		Plain & Rolling terrain	Mountainous & Steep terrain
1	NHSL	12.0	6.25

Table 3 (b) : Roadway width NHDL**

In Plain and Rolling Terrain of Hilly Area

Highway Classification	**Type of Section**	**Shoulder Width**				**Road-way Width**
		Paved (m)	**Earthen (m)**	**Total width of shoulders on one side (m)**	**Total width of shoulders on both sides (m)**	
National Highways and State Highways MDRs/ ODRs(a) Double Lane	Open country with isolated built-up area	2.5	1.5	4.0	8.0	15.0
	Built up area (2-lane section)	2.5	-	2.5	5.0	12.0
	Approaches to grade separated structures	2.5	-	2.5	5.0	12.0
	Approaches to Bridges and Culverts	2.5	1.5	4.0	8.0	15.0

In Mountainous and Steep Terrain

Highway Classification	**Type of Section**		**Paved (m)**	**Earthen (m)**	**Total width of shoulders on one side (m)**	**Total width of shoulders on both sides (m)**	**Road-way Width**
National Highways and State Highways MDRs/ ODRs(a) Double Lane	Open country with isolated built-up area.	Hill Side	1.5	-	1.5	4.0	11.0
		Valley Side	1.5	1.0	2.5		
	Built up area and Approaches to grade separated structures and bridges.	Hill Side	0.25 + 1.5 (Raised)		1.75	3.5	10.5
		Valley Side	0.25 + 1.5 (Raised)		1.75		

Notes: -

* Ref IRC:73-1980 (Table – 6)

** Ref IRC:52-2019 (Table – 6.2)

(i) Width of paved shoulders in approaches to grade separated structures shall extend on either side of the structures in entire length of retaining/RE wall. The retaining/RE wall on either side shall be abutting the paved shoulders and shall have crash barriers on top.

(ii) In Case retaining wall with parapet is provided on valley side, the earthen shoulder may not be provided.

(iii) On horizontal curve roadway width shall be increased to provide for extra widening of curve.

(iv) where embankment is more than 6 m high kerb with channel shall be provided at the end of paved shoulder to channelize the drainage as an erosion control device in accordance with section 6 of IRC: SP:73-2018 and earthen shoulder shall be raised upto the level of kerb.

(v) The roadway widths are exclusive of parapets (usual width 0.6m) and side drains (usual width 0.6m) and divider medians (usual width 2.00/1.20 meter). Formation width shall include width to accommodate carriage way divider/median (wherever required) + shoulder + parapet on valley side + drain on hill side + extra width on horizontal curves (wherever required).

(vi) On roads subject to heavy snow fall, where snow clearance is done over long periods, roadway width may be increased by 1.5m. However, the requirement of such widening may be examined with reference to ground conditions in each case considering terrain traffic and other influencing conditions and factors.

(vii) In hard rock stretchers or unstable locations where excessive cutting may lead to slope failures the width may be reduced by 0.8 m on two lanes. Where such stretches are to be provided continuously for long distances, passing places shall be provided.

(viii) Strategic and border roads for military/paramilitary/security forces operations/ movements shall be constructed for not less than two lane carriageway along with paved shoulder on hill side + paved and earthen shoulder on valley side on same lines of national highway.

(ix) Wherever, divider/median is required to be provided for the cases of divided highway of all category roads, the minimum 1.20 meter wide divider/median shall be provided.

7.6 On horizontal curves, the formation width should be increased corresponding to extra width of carriageway to be provided as per para 11.6.

7.7 Passing places are required on single lane hill roads to facilitate crossing of vehicles approaching from the opposite direction and to tow aside a disabled vehicle so that it does not obstruct traffic. They shall be provided at the rate of 2-3 per kilometer for roads having roadway width less than 7m only. Normal size of passing place is 3.75 m wide, 30 m long on inside edge and 20 m long on the farther side. The exact location of passing places shall be judiciously determined taking into consideration the available extra width and visibility. However, in general passing places should not be at intervals closer than 200 m. Even the passing lanes on alternate side of the roads may be provided depending upon the availability of space and stability of the hill face (Fig 3).

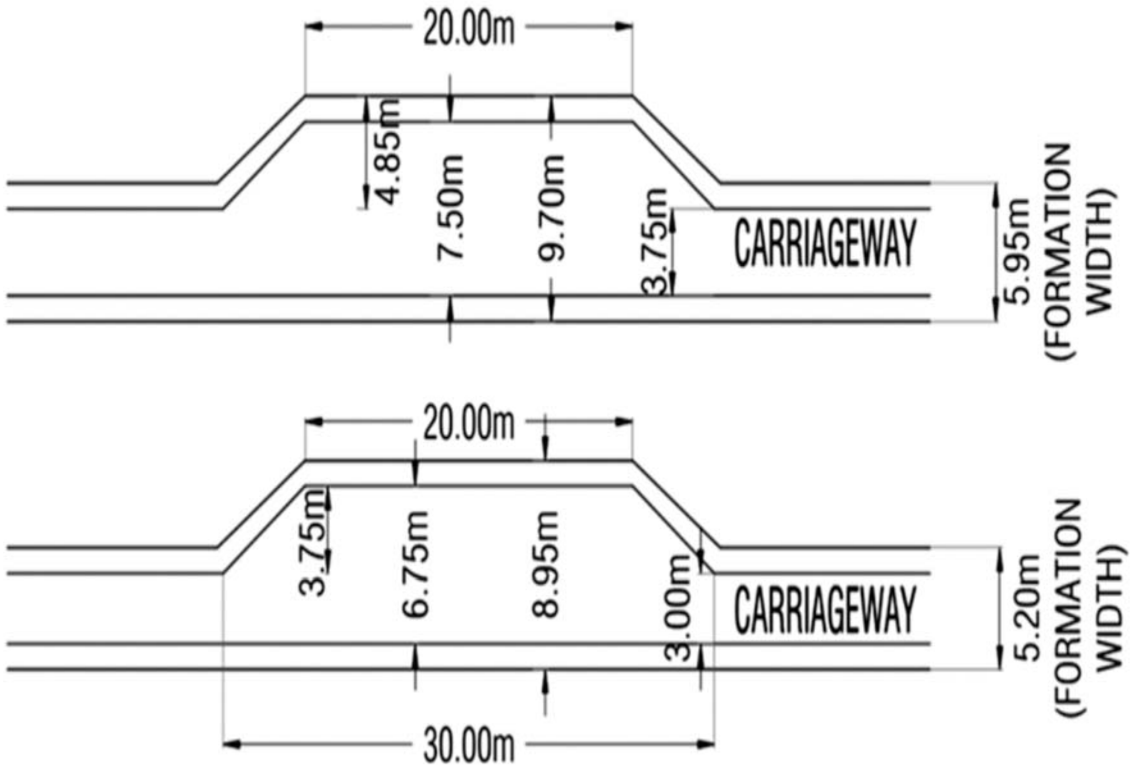


Fig. 3: Passing Places

7.8 For purpose of estimating, the width of jungle clearance may be taken as twice the formation width, which will cater for the required width before starting formation cutting/filling. However, jungle clearance for various classes of roads, should be done for a corridor of 1m extra width on either side of the edges of cutting the road. As far as possible, uprooting/grubbing of embankment should be done where vegetation and other deleterious materials have to be removed and surface has to be furrowed. Cutting of trees should be kept to barest minimum, confined only within the edges of cutting/embankment, except for those trees above and below edges of cutting which are required to be cut to improve the sight distance, to reduce the possibility of land slide under the self weight of tree and for exposing the road formation in perpetually damp areas to sunshine. The aim should be to protect the environment with barest minimum disturbance to the natural growth.

7.9 **Formation width at Cross Drainage Structures**

7.9.1 The width of cross drainage structures (culverts) upto 6 m span should be the same as the roadway width of the road including parapet walls. For culverts at horizontal curves, extra width shall be provided as mentioned in para 7.5.

7.9.2 At causeways, the minimum width of causeway should be same as the width of formation excluding side drains.

8. CARRIAGEWAY WIDTH

8.1 The width of carriageway for Class 9 (N) and NHSL roads should be 3.75 m and 3.00 m for Class 5 (N) roads. For NHDL specification Roads, the carriageway should be 7.00 m as shown in Table 4.

Table 4: Width of Carriageway

Sr No.	Road Classification	Carriageway Width (m)	
		Plain & Rolling Terrain	Mountainous & Steep Terrain
1	NHSL	3.75	3.75
2	NHDL	7.00	7.00

8.2 For roads in hilly and mountainous terrain which act as feeder roads to the Indo- China border or are of strategic importance for national security, the carriageway width should be 7.0 m with 1.50 m paved shoulder on either side.

8.3 For traffic volume of more than 10,000 PCUs/ day or the existing traffic volumes likely to witness a fast growth to reach this level within a period of 3 to 5 years, the carriageway width shall be of two lane NH configurations, i.e. of 7 m width. The carriageway widths shall be of two lane NH configurations with paved shoulders only in cases where the traffic is likely to increase at about more than 10 % per annum.

8.4 In snow bound areas and hard rock stretches, edge to edge carpeting will improve the life of pavement as well as of the retaining structures due to no scope for percolation of water.

8.5 At curves the carriageway will have to be widened as per para11.6 and on hair pin bends edge to edge carpeting should be done for smooth movement of vehicles.

8.6 Depending upon the traffic volume and type of design vehicles, even the NHSL roads may be surfaced with paved shoulders of 1m width on either side resulting into 5.75 m carriage width. NHSL in hard rock stretches (HR) and snow bound areas (SBA) should be constructed with paved shoulders on either side of the road only. There should not be any provision of earthen shoulders.

8.7 Road sign posts depicting roadway width should be erected if there is sudden change in the roadway width just ahead of the narrow road stretch.

9. DESIGN SPEED

9.1 Choice of design speed depends on the classification of terrain irrespective of the road classification as per IRC-52 and IRC-73. Table 5 gives the design speed for different terrains.

Table 5: Design Speed (Km/h)

Road Classification	Mountainous terrain		Steep terrain	
	Ruling	Min	Ruling	Min
National & State Highway	50	40	40	30
Class 9 (N) – (ODR)30	30	25	25	20
Class 5 (N) –Village road	25	20	25	20

9.2 Ruling design speed should normally be the guiding criterion for correlating the various geometric design features. Minimum design speed may however be adopted in selected sections where site conditions including cost do not permit the adoption of ruling design speed for design purposes.

9.3 For designing hair pin bends, design speed may be considered as 20 km/hr for cost effective and more sustainable curves depending upon the site conditions.

10. SIGHT DISTANCE

10.1 General

10.1.1 It is necessary that sight distance of adequate length should be available in different situations for the drivers of vehicles to have enough time and distance to control the vehicle sufficiently ahead of any potentially hazardous situation, for safety of travel on roads. For the design of summit vertical curves and the visibility at horizontal curves, three types of sight distance are to be considered, which are:-

(a) Stopping sight distance.
(b) Intermediate sight distance.
(c) Overtaking sight distance.

10.1.2 For valley curves, the design is governed by night visibility which is in terms of the distance ahead of a vehicle illuminated by the head light which is within the view of the driver during night.

10.2 Stopping Sight Distance

10.2.1 Stopping sight distance is the clear distance ahead needed by a driver to bring his vehicle moving at design speed to a stop before meeting a stationary object in his vehicle path, which is the sum of :-

(a) The distance travelled during perception of the stationary object and the reaction time taken to apply brakes and

(b) Distance the vehicle will travel after application of the brakes (the braking distance). Assuming a perception and brake-reaction time of 2.5 seconds and co-efficient of longitudinal friction varying from 0.40 at 20 Km/h to 0.35 at 100 km/h, stopping sight distances are given in Table 6.

10.2.2 On hill roads, stopping sight distance is the absolute minimum from safety angle and must be ensured regardless of any other consideration. It will be good if this value can be exceeded and visibility corresponding to intermediate sight distance is provided wherever possible. Provision of overtaking sight distance may not be feasible, by and large on hill roads.

Table 6: Stopping Sight Distance for various Speeds

SpeedV Km/h)	Perception and brake reaction		Braking		Safe stopping sight Distance (m)	
	(Time t (Sec.)	Distance (m) $d_1=0.278V_t$	Co-eff of longitudinal friction (f)	$d_2 = V^2/254 f$	Calculated values $(d_1 + d_2)$	Rounded off values
20	2.5	14	0.40	4	18	20
25	2.5	18	0.40	6	24	25
30	2.5	21	0.40	9	30	30
40	2.5	28	0.38	17	45	45
50	2.5	35	0.37	27	62	60
60	2.5	42	0.36	39	81	80
65	2.5	45	0.36	46	91	90
80	2.5	56	0.35	72	128	130
100	2.5	70	0.35	112	182	180

10.3 **Intermediate Sight Distance**

10.3.1 Intermediate sight distance is defined as twice the safe stopping sight distance. It is the experience that intermediate sight distance affords reasonable opportunities to drivers to overtake with caution.

10.3.2 Design values of intermediate sight distance for different speeds are given in Table 7.

Table 7: Intermediate Sight Distance for various Speeds

Speed (Km/h)	Intermediate sight distance (m)
20	40
25	50
30	60
35	80
40	90
50	120
60	160
65	180
80	240
100	360

10.4 **Overtaking Sight Distance**

10.4.1 Overtaking sight distance is the minimum distance that is needed by a driver on a two way road to enable him to overtake another vehicle safety. Optimum condition for design is one in which the overtaking driver can following the vehicle ahead for a short time while he assesses his chances for overtaking, pulls out his vehicle, overtakes the other vehicle at design speed and returns to his own side of the road before meeting any oncoming vehicles coming in the opposite direction travelling at the same speed. However, on single lane roads in plains also, these criteria can be adopted.

10.4.2 Design values for overtaking sight distance are given in Table 8. These are based on a time component of 9 to 14 seconds for the actual overtaking maneuver depending on design speed, increased by about 2/3rd to take into account the distance travelled by a vehicle from the opposite direction during the same time. Overtaking sight distance for different speeds are given in Table 8.

Table 8: Overtaking Sight Distance for Various Speeds

Speed (Km/h)	Time component (seconds)		Total	Safe overtaking sight distance (m)
	For overtaking manoeuvre	For opposing vehicles		
40	9.0	6.0	15	165
50	10.0	7.0	17	235
60	10.8	7.2	18	300
65	11.5	7.5	19	340
80	12.5	8.5	21	470
100	14.0	9.0	23	640

10.5 Application of Sight Distance Standards

10.5.1 Normally in plain roads, the attempt should be to provide overtaking sight distance in as much length of the road as possible. Where this is not feasible, intermediate sight distance, which affords reasonable opportunities for overtaking, should be adopted as the next best alternative in no case, however, should the visibility correspond to less than the safe stopping distance which is the basic minimum for any road.

10.6 Headlight Sight at Valley Curves

10.6.1 During day time, visibility is not a problem on valley curves. However, for night travel the design must ensure that the roadway ahead is illuminated by vehicle headlights to a sufficient length enabling the driver to brake to a stop if necessary. This distance, called the headlight sight distance, should at least equal the safe stopping sight distance given in Table 6.

10.6.2 In designing valley curves, the following criteria of measurement should be followed as regards the headlight sight distance.

(a) Height of headlight above road surface is 0.75 m;

(b) The useful beam of headlight is upto one degree upwards from the grade of the road; and

(c) The height of object is nil.

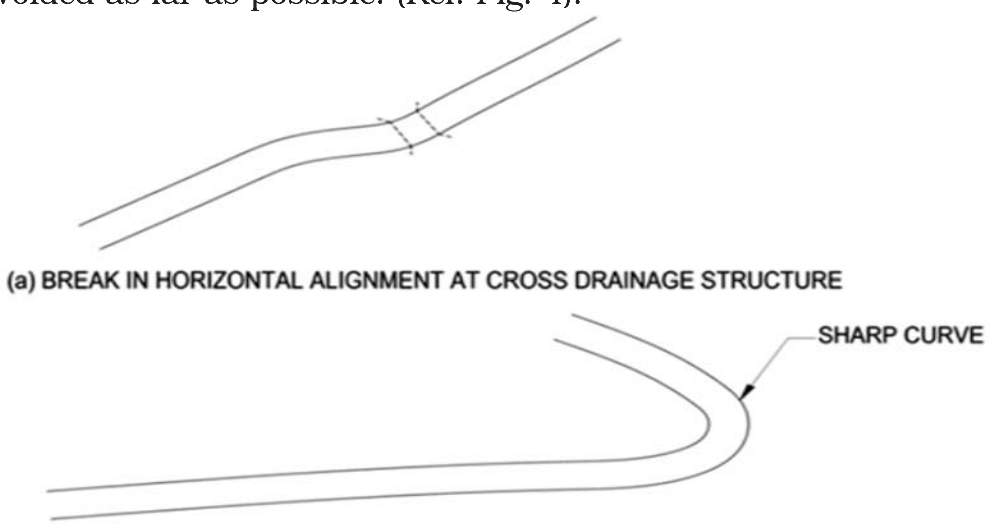
11. HORIZONTAL ALIGNMENT

11.1 The general principles governing horizontal alignments are given below:-

11.1.1 The horizontal alignment should be fluent and blend well with the surrounding topography. A flowing line which conforms to natural contours is aesthetically preferable to one with long tangents slashing through the terrain.

11.1.2 The horizontal alignment should be co-ordinated carefully with the longitudinal profile

11.1.3 Breaks in horizontal alignment at cross-drainage structures and sharp curves and the end of long tangents/straight sections should be avoided. Long tangent sections exceeding 3 Km in length should be avoided as far as possible. (Ref. Fig. 4).



(b) **Sharp Curve at the end of Long Tangent (Ref para 11.1.3)**

Fig. 4

11.1.4 Short curves give appearance of kinks, particularly for small deflection angles, and should be avoided. The curves should be sufficiently long and have suitable transitions to provide pleasing appearance. Curve length should be at least 150 m for a deflection angle of 5 degrees and should be increased by 30m for each one degree decrease in the deflection angle. For deflection angles less than one degree, no curve is required to be designed.

11.1.5 Reverse curves may be needed in difficult terrain. It should be ensured that there is sufficient length between the two curves for introduction of requisite transition curves. (Refer Fig. 5).

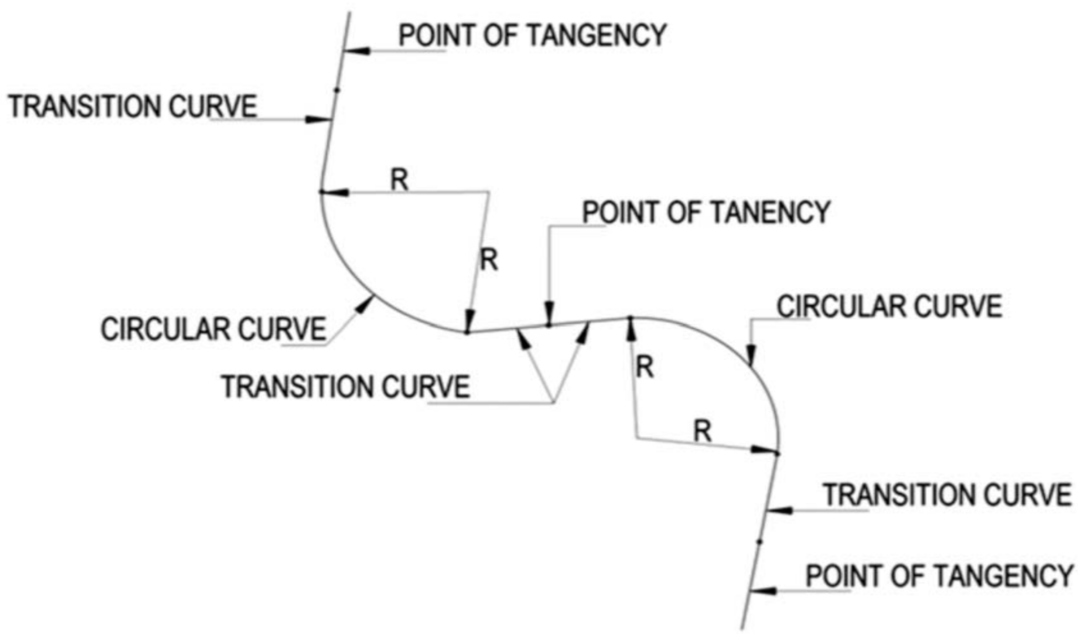


Fig.5: Reverse curve (Ref. Para.11.1.5)

11.1.6 Curves in the same direction separated by short tangents, known as broken-back curves, should be avoided as far as possible in the interest of aesthetics and safety and replaced by a single curve. If this is not feasible, a tangent length corresponding to 10 seconds travel time must at least be ensured between the two curves. (Ref. Fig 6).

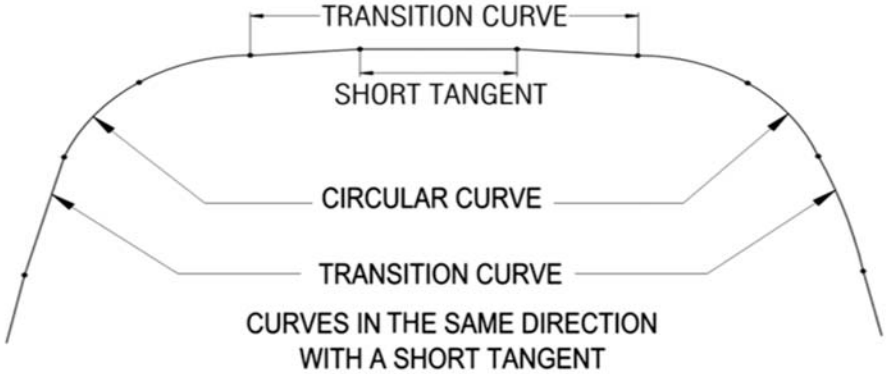
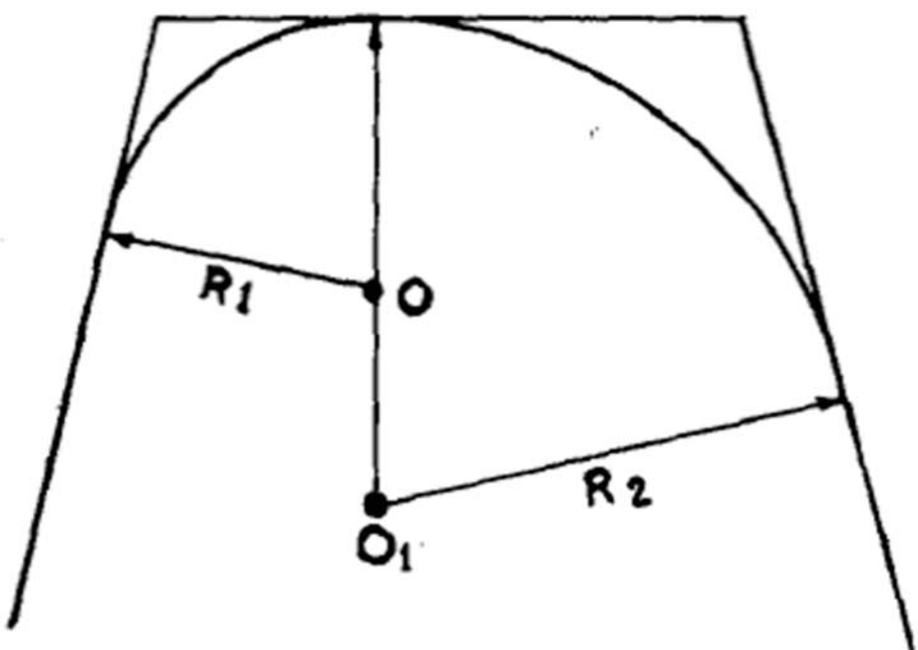


Fig. 6: Curves in the same direction with a short tangent (ref.para.11.1.6)

11.1.7 Compound curves may be used in difficult topography but only when it is impossible to fit in single circular curve. To ensure safe and smooth transition from one curve to the other, the radius of the flatter curve should not be disproportional to the radius of the sharper curve. A ratio of 1.5 : 1 should be considered the limiting value. (Refer Fig. 7).



R1 & R2 are different radii

Fig. 7: Compound Curve (Ref.Para.11.1.7)

11.2 **Horizontal Curves**

11.2.1 In general, horizontal curves should consist of circular portion of the curves followed by spiral transitions on both sides. Design speed, superelevation and coefficient of friction affect the design of curves. Length of transition curve is determined on the basis of rate of change of centrifugal acceleration or the rate of change of superelevation.

11.3 **Superelevation**

11.3.1 Super elevation is required to be provided at horizontal curves to counter the effects of centrifugal force and is calculated from the formula:-

$$e = \frac{V^2}{225} \mathbf{Rc}$$

Where

e = superelevation / width of roadway (m)

V = speed of vehicle in KMPH and

Rc = radius of curves (m)

11.3.2 The above formula assumes that the centrifugal force corresponding to three-fourth of design speed is balanced by superelevation and one- fourth counteracted by the side friction between the tyres of vehicles and the road surface.

11.3.3 Superelevation obtained from the above formula should however be kept limited to the following values:-

(a)	In plain and rolling terrain	-	7%
(b)	In snow bound areas	-	7%
(c)	In hilly areas not bound by snow	-	10%

11.3.4 Superelevation based on this limit for various design speeds may be seen from Table 9.

11.3.5 From the drainage point of view, the superelevation should not be less than the camber/crossfall appropriate to the type of wearing source (Please see para 11.9). Accordingly, when the value of superelevation obtained from the formula is less than the road camber/cross-fall, the later may be continued on the curved portion without providing any superelevation.

$$e = \frac{V^2}{225} \textbf{ Rc}$$

Table 9: Superelevation for different Speeds and Curve Radii

Terrain/Rolling terrain, and Mountainous/Steep terrain bound by snow										Mountainous Steep terrain not bound by snow				
Curve Rc (m)	Superelevation metre per metre width of roadway for design speed (km/h) of													
	20	25	30	35	40	50	65	80	100	20	25	30	40	50
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
15	0.070									0.100				
20	0.070									0.089	0.100			
25	0.070	0.070								0.071	0.100			
30	0.059	0.070								0.059	0.093	0.100		
40	0.044	0.069	0.070							0.044	0.069	0.100		
45	0.040	0.062	0.079							0.040	0.062	0.089		
50	0.036	0.056	0.070	0.070						0.036	0.056	0.080	0.100	
55	0.032	0.051	0.070	0.070						0.032	0.051	0.073	0.100	
60	0.030	0.046	0.067	0.070	0.070					0.030	0.046	0.067	0.100	
70	0.025	0.040	0.057	0.070	0.070					0.025	0.040	0.057	0.100	
80	0.022	0.035	0.050	0.068	0.070					0.022	0.035	0.050	0.089	0.100
90	0.020	0.031	0.044	0.060	0.070	0.070				0.020	0.031	0.044	0.079	0.100
100	0.018	0.028	0.040	0.054	0.070	0.070				0.018	0.028	0.040	0.071	0.100
125		0.022	0.032	0.044	0.057	0.070					0.022	0.032	0.057	0.089
150		0.019	0.027	0.036	0.047	0.070					0.019	0.027	0.047	0.074
170		0.016	0.024	0.032	0.042	0.065	0.070				0.016	0.024	0.042	0.065
200			0.020	0.027	0.036	0.056	0.070					0.020	0.036	0.056
250			0.016	0.022	0.028	0.044	0.070	0.070				0.016	0.028	0.044
300				0.018	0.024	0.037	0.063	0.070					0.025	0.037
350				0.016	0.020	0.032	0.054	0.070					0.020	0.032
400					0.018	0.028	0.047	0.070	0.070				0.018	0.028
500						0.022	0.038	0.057	0.070					0.022
600						0.019	0.031	0.047	0.070					0.019
700						0.016	0.027	0.041	0.063					0.016
800						0.014	0.023	0.036	0.056					0.014

Notes :

(i) Superelevation has been calculated by the formula $e=v^2/225$ Rc.

(ii) No superelevation need to provided if the superelevation value is less than the normal pavement camber.

(iii) For a given design speed, adopt the largest possible radius below the firm stepped line.

11.3.6 **Superelevation at Culverts in Curves**

The top surface of the wearing course of culverts should have the same cross profile as the approaches. The superelevation may be given on the abutments keeping the deck slab thickness uniform as per design. The level of the top of the slab of the culvert should be the same as the top level of pavement of the approaches so that any undue Jerk while driving on the finished road is avoided.

11.3.7 Table 10 shows the radii of horizontal curves for different camber rates beyond which superelevation will not be required.

Table10: Radii beyond which Superelevation is not required

Design speed (Km/h)	Radius (m)for camber of				
	4 %	**3 %**	**2.5 %**	**2 %**	**1.7 %**
20	50	60	70	90	100
25	70	90	110	140	150
30	100	130	160	200	240
35	140	180	220	270	320
40	180	240	280	350	420
50	280	370	450	550	650
65	470	620	750	950	1100
80	700	950	1100	1400	1700
100	1100	1500	1800	2200	2600

11.3.8 **Methods of Attaining Superelevation**

11.3.8.1 The normal cambered section of the road is changed into super elevated section in two stages. First stage is the removal of adverse camber in outer-half of the pavement. In the second stage, superelevation is gradually built up over the full width of the carriageway so that required superelevation is available at the beginning of the circular curve.

11.3.8.2 There are three different methods for attaining superelevation:-

(a) **Revolving Pavement about the Centre Line**. This can be adopted in normal course.

(b) **Revolving Pavement about the Inner Edge**. This can be adopted where lower edge profile is major control for drainage.

(c) **Revolving Pavement about the Outer Edge**. Where overall appearance is the criterion, this method is preferable since the outer edge profile which is most noticeable to drivers is not distorted. Fig. 7 illustrates these methods diagrammatically. The small cross sections at the bottom of each diagram indicate the pavement cross slope condition at different points.

11.3.8.3 The superelevation should be attained gradually over the full length of the transition curve so that the design superelevation is available at the starting point of the circular portion. Sketches in Fig. 8 have been drawn on this basis. In cases where transition curve cannot, for some reason, be provided two-third superelevation may be attained on the straight section before start of the circular curve and the balance one-third on the curve.

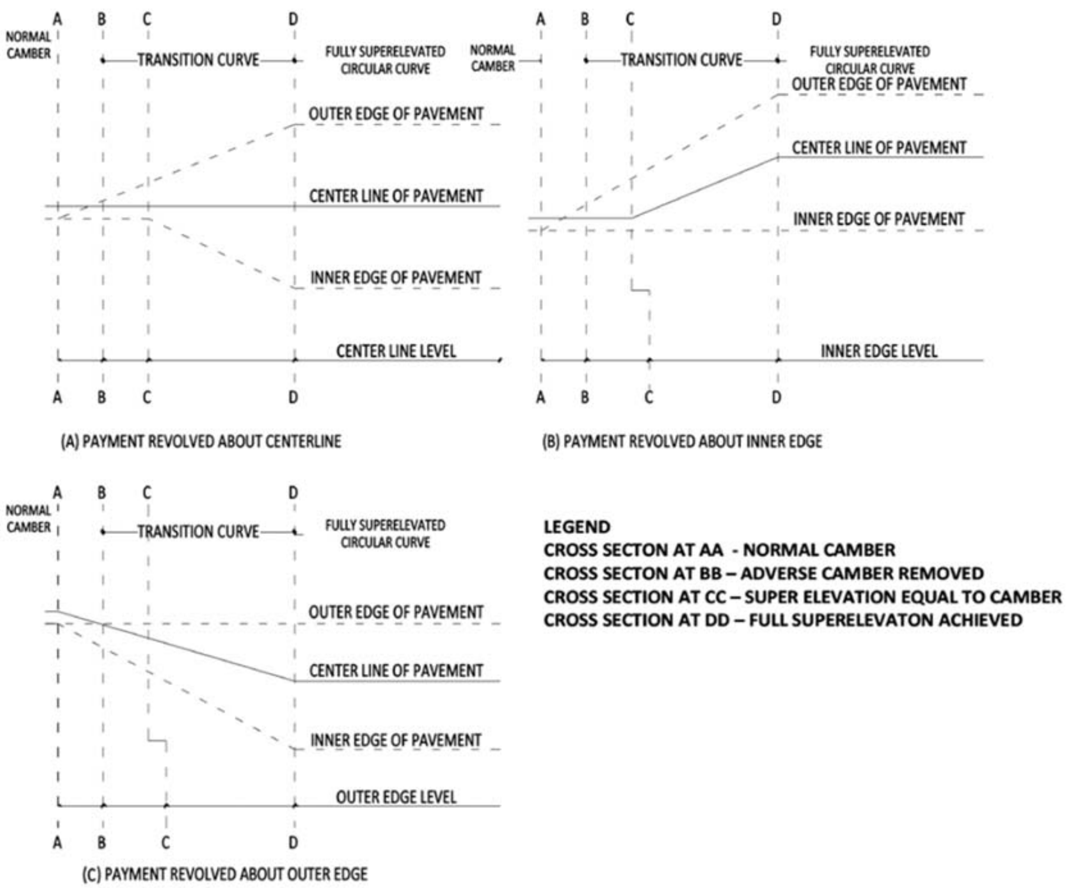


Fig. 8: Schematic diagrams showing different method of attaining superelevation

11.3.8.4 In developing the required superelevation, it should be ensured that the longitudinal slope of the pavement edge compared to the centre line (i.e. the rate of change of superelevation) is not steeper than 1 in 150 for roads in plain and rolling terrain, and 1 in 60 in mountainous and steep terrain. When cross-drainage structures fall in a horizontal curve, their deck should be superelevated in the same manner as described above.

11.4 **Radii of Horizontal Curve**

11.4.1 On a horizontal curve, the centrifugal force is balanced by the combined effects of superelevation and side friction. The basic equation for this condition of equilibrium is:

$$Rc = \frac{V^2}{127(e+f)}$$

Where

Rc = radius of curves in (m).

V = vehicle speed in km/h.

e = superelevation ratio in m per m width of roadway.

f = co-efficient of side friction between vehicle tyres and pavement (taken as 0.15).

11.4.2 Based on this equation and the maximum permissible values of superelevation given in para 11.3.3, radii for horizontal curves corresponding to ruling minimum and absolute minimum design speeds are shown in Table 11.

Table 11. Minimum Radii of Horizontal Curves (m) for different Terrain Conditions

Classification of road	Plain terrain		Rolling terrain		Mountainous terrain				Steep terrain			
					Areas not affected by snow		Snow bound areas		Areas not affected by snow		Snow bound areas	
	Ruling (min)	Absolute (Min)	Ruling (min)	Absolute (Min)	Ruling (min)	Absolute (Min)	Ruling (min)	Absolute (Min)	Ruling (Min)	Absolute (Min)	Ruling (Min)	Absolute (Min)
Class 9 (N) Roads (ODR)	155	90	90	60	30	20	33	23	20	14	23	15
Class 5 (N) Roads (VR)	90	60	60	45	20	14	23	15	20	14	23	15
NHSL/ NHDL	360	230	230	155	80	50	90	60	50	30	60	33

Notes:

(i) Absolute minimum and ruling minimum radii correspond to the minimum design speed and ruling design speed respectively vides Table 5.

(ii) For guidance in application, see para 11.4.3.

11.4.3 On new roads, horizontal curves should be designed to have the largest practicable radius, generally more than the values corresponding to the ruling design speed (see Table 11). However, absolute minimum values based on minimum design speed (Table 5) might be resorted to if economics of construction or the site conditions so dictate. While improving existing roads, curves having radii corresponding to absolute minimum standards may not be flattered unless it is necessary to realign the road for some other reason. It must, however be noted that a sub-standard curve, reduces the trafficability of road permanently.

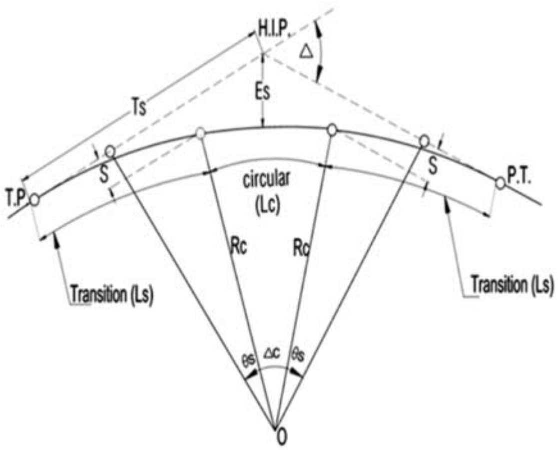
11.5 **Transition Curves**

11.5.1 When a vehicle travels from a straight stretch of road to a curve or from a curve to another curve of a different radius it is subjected to an outward centrifugal force causing a shock and sway to the passengers. In order to minimise this discomfort & accompanying hazards, transition curves are to be introduced which enables the driver to turn the steering wheel gradually because the centrifugal force is developed gradually and permitting the gradual application of superelevation necessary for safe driving.

11.5.2 Essential requirements of a transition curve are:-

(a) Radius of curvature should decrease gradually from infinity to the minimum to enable the steering wheel to be turned gradually and to eliminate the shock due to application of centrifugal force

(b) The rate of change of centrifugal acceleration should be such as not to cause discomfort or undesirable oscillation. (Since the radial acceleration is inversely proportional to the radius of curvature for any fixed speed, the transition should be such that the radius of curvature should be inversely proportional to the length of the curve from the starting point). A sketch showing a combination of circular and transition curve is given in Fig 9.



TANGENT POINT .......................T.P. P.T.
HORIZONTAL INTERSECTION POINT ....H. I. P.
TOTAL DEVIATION ANGLE....................Ä
DEVIATION AND CENTRAL ANGLE OF CIRCULAR ARC ....Äc
DEVIATION ANGLE OF TRANSITION CURVE...ès
RADIUS OF CIRCULAR CURVE.............Rc
SHIFT ....s
TANGENT DISTANCE ....Ts
APEX DISTANCE ....Es
LENGTH OF TRANSITION ....Ls
LENGTH OF CIRCULAR CURVE Lc

Fig. 9: Visibility at Horizontal Curves (Ref.Para 11.8.2)

11.5.3 The recommended minimum transition lengths for different speeds and curve radii, are shown in Table 12. The table also indicates the radii beyond which no transition is required.

Table 12: Minimum Transition Lengths for different Speeds and Curve Radii

Curve radius R (m)	**Plain & rolling terrain Design speed (km/h)**						**Curve radius (m)**	**Mountainous & steep terrain Design speed (km/h)**				
	100	**80**	**65**	**50**	**40**	**35**		**50**	**40**	**30**	**25**	**20**
	Transition length (m)							**Transition length (m)**				
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
45	-			-	NA	70	14	-	-	-	NA	30
60	-			NA	75	55	20	-	-	-	35	20
90	-			75	50	40	25	-	-	NA	25	20
100	-		NA	70	45	35	30	-	-	30	25	15
150	-		80	45	30	25	40	-	NA	25	20	15
170	-		70	40	25	20	50	-	40	20	15	15
200	-	NA	60	35	25	20	55	-	80	20	15	15
240	-	90	50	30	20	NR	70	NA	30	15	15	15
300	NA	75	40	25	NR	-	80	55	25	15	15	NR
360	130	60	35	20	-	-	90	45	25	15	15	-
400	115	55	30	20	-	-	100	45	20	15	15	-
500	95	45	25	NR	-	-	125	35	15	15	NR	-

Note : NA – Not applicable, NR – Transition not required

11.5.4 **Curves Transitional Throughout (Self Transitioning Curves)**

When a fully transitional curve is desired without a central circular curve, the total angle consumed by the transition which is the tangent deviation angle of the transition is equal to half the total deviation angle of the curve. For any one deviation angle, there are innumerable combinations of radii and the length of the transition which give a fully transitional curve. Table 13 gives the tangent and apex distance for fully transitional curves for deviation angles from 6° to 1389. The Ts and Es values figured are for a length of transition of 100 m. For lengths other than 100 m, the values will have to be proportionately increased or decreased or decreased. Fig. 9 shows the use of Table 13 for design of fully transitional curves.

Table 13: Tangent and Apex Distances of Curves Transitional throughout

▲	Ts	Es	▲	Es	▲	Ts	Es	
6	100.064	1.747	53	105.452	16.966	100	125.475	42.852
7	100.087	2.040	54	105.680	17.352	101	125.216	43.687
8	100.114	2.332	55	105.913	17.742	102	126.980	44.544
9	100.144	2.625	56	106.153	18.317	103	127.765	45.422
10	100.178	2.918	57	106.399	18.536	104	128.573	46.321
11	100.216	3.212	58	106.651	18.940	105	129.405	17.243
12	100.257	3.507	59	106.909	19.348	106	13.261	48.149
13	100.302	3.802	60	107.124	19.762	107	131.142	49.148
14	100.350	4.098	61	107.446	20.181	108	132.049	50.152
15	100.402	4.396	62	107.724	20.604	109	132.983	51.172
16	100.458	4.693	63	108.010	21.034	110	133.947	52.220
17	100.518	4.992	64	108.302	21.468	111	134.941	53.298
18	100.581	5.292	65	108.602	21.908	112	135.965	54.406
19	100.648	100.648	66	108.909	22.355	113	137.022	55.544
20	100.719	100.719	67	109.223	22.807	114	138.113	56.715
21	100.794	100.794	68	109.546	23.266	115	139.239	57.921
22	100.873	100.873	69	109.876	23.731	116	140.405	59.163
23	100.955	100.955	70	110.214	24.203	117	141.602	60.443
24	101.042	101.042	71	110.561	24.681	118	142.846	61.763
25	101.132	101.132	72	110.917	25.167	119	144.123	63.126
26	101.226	101.226	73	111.281	25.660	120	145.643	64.532
27	101.324	101.324	74	111.654	26.161	121	146.840	65.983
28	101.427	101.427	75	112.036	26.669	122	148.267	67.484
29	101.533	101.533	76	112.427	27.186	123	149.747	69.036
30	101.644	101.644	77	112.828	27.710	124	151.281	70.641
31	101.758	101.758	78	113.240	28.244	125	152.871	72.302
32	101.877	101.877	79	113.661	28.786	126	154.523	74.023
33	102.000	102.000	80	114.092	29.337	127	156.239	75.808
34	102.128	102.128	81	114.535	29.898	128	158.024	77.661
35	102.260	102.260	82	114.988	30.464	129	159.882	79.585
36	102.396	102.396	83	115.453	31.048	130	161.816	83.661
37	102.537	102.537	84	115.930	31.639	131	163.828	81.503
39	102.832	102.832	86	116.919	32.854	133	168.116	88.079
40	102.987	102.987	87	117.433	33.478	134	170.405	90.428
41	103.146	103.146	88	117.960	34.115	135	172.797	92.880
42	103.310	103.310	89	118.500	34.763	136	175.300	95.445
43	103.479	103.479	90	119.054	35.425	137	177.668	98.120
44	103.653	103.653	91	119.623	36.099	138	180.668	100.434
45	103.831	103.831	92	120.207	36.788	Rc = Curve Radius		
46	104.015	104.015	93	120.806	37.490	TS = Tangent Distance		
47	104.204	104.204	94	121.421	38.207	Es = Apex Distance		
48	104.399	104.399	95	122.052	38.940	▲ = Total Deviation Angle		
49	104.598	104.598	96	122.700	39.688	S = Shift		
50	104.804	104.804	97	123.366	40.453	K= The distance along straight from TP to PC		
51	105.014	105.014	98	124.050	41.234			
52	105.230	105.230	99	124.753	42.430			

11.6 **Extra Width of Pavement at Horizontal Curves**

11.6.1 For horizontal curves of different radii extra width of pavement should be provided as per Table 14 given below:-

Table 14: Extra Width of Pavement at Horizontal Curves

Radius of curve (m)	Upto 20	20 to 40	41 to 60	61 to 300
Extra width (m) for single-lane road Cl 9 (N) and Cl 5 (N)	0.9	0.6	0.6	Nil

11.6.2 The widening should be effected by increasing the width at an approximately uniform rate along the transition curve. The extra width should be continued over the full length of the circular curve. On curves having no transition, widening should be achieved in the same way as the superelevation i.e. two-third being attained on the straight section before start of the curve and one-third on the curve.

11.6.3 Preferably the entire widening should be done only on the inside of the curve. The extra widening may be attained by means of off-sets radial to the centre line. It should be ensured that the pavement edge lines are smooth and there is no apparent kink.

11.7 **Methods of Curve Ranging**

11.7.1 Methods of lay-out, ranging and setting out of horizontal curves with examples are given in Appx 'A'.

11.8 **Vision Berms (Batter Benching / Lateral Clearance)**

11.8.1 Requisite sight distance is calculated from the following equation (see Fig. 10 for definitions).

$$M = R - (R - N) \cos \theta$$

$$\text{Where } \theta = \frac{S}{2(R-n)} \text{ radians}$$

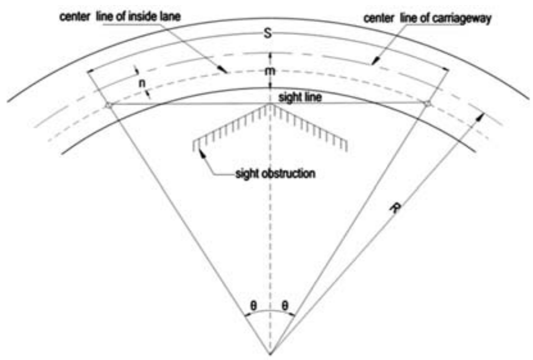
M = the minimum lateral clearance from the centre line of the road to sight obstruction (m) at the middle of the curve,

R = radius of centre line of the road (m).

N = distance between the centre line of the road and the insidelane (m)

S = sight distance (m)

In the above equation, sight distance is measured along the middle of inner lane. On single lane roads, sight distance is measured along the centre line of the road and 'n' is taken as Zero.



R – RADIUS OF CURVE

S – SIGHT DISTANCE

m – MINIMUM SET-BACK DISTANCE

n – DISTANCE BETWEEN CENTRE LINE OF CARRIAGEWAY AND CENTRE LINE OF INSIDE LANE

Fig. 10: visibility at horizontal curves (ref para 11.8.1)

11.8.2 Utilising the above equation, the design values for lateral clearance corresponding to safe stopping distance for single lane carriageway are given in Table 15. These design values relate basically to circular curves longer than the design sight distance. For shorter curves, the values of set-back distance given in Table-15 will be somewhat on the higher side, but these can any way be used as a guide.

Table 15: Lateral Clearance for Single Lane Carriageway

Radius of circular curves (m)	Lateral Clearance (m)				
	S=20m (V=20 Km/h)	S=25m (V=25 Km/h)	S=30m (V=30 Km/h)	S=45m (V=40 Km/h)	S=60m (V=50 Km/h)
14	3.4	-	-	-	-
15	3.2	-	-	-	-
20	2.4	3.8	-	-	-
23	2.1	3.3	-	-	-
30	1.7	2.6	3.7	-	-
33	1.5	2.3	3.4	-	-
50	1.0	1.6	2.2	5.0	-
60	-	1.3	1.9	4.2	-
80	-	1.0	1.4	3.1	5.6
100	-	0.8	1.1	2.5	4.5
120	-	0.7	0.9	2.1	3.7
150	-	0.5	0.8	1.7	2.3

11.8.3 Lateral clearances for intermediate sight distance can be computed similarly but the set-back required is usually too large to be economically feasible on hill roads.

11.8.4 Where there is a cut slope on the inside of the horizontal curve, the average height of sight line can be used as an approximation for deciding the extent of clearance. For stopping sight distance, this may be taken as 0.7 m. Cut slopes should be kept lower than this height at the line demarcating the set-back distance envelope, either by cutting back the slope or benching suitably, (see Fig. 11).

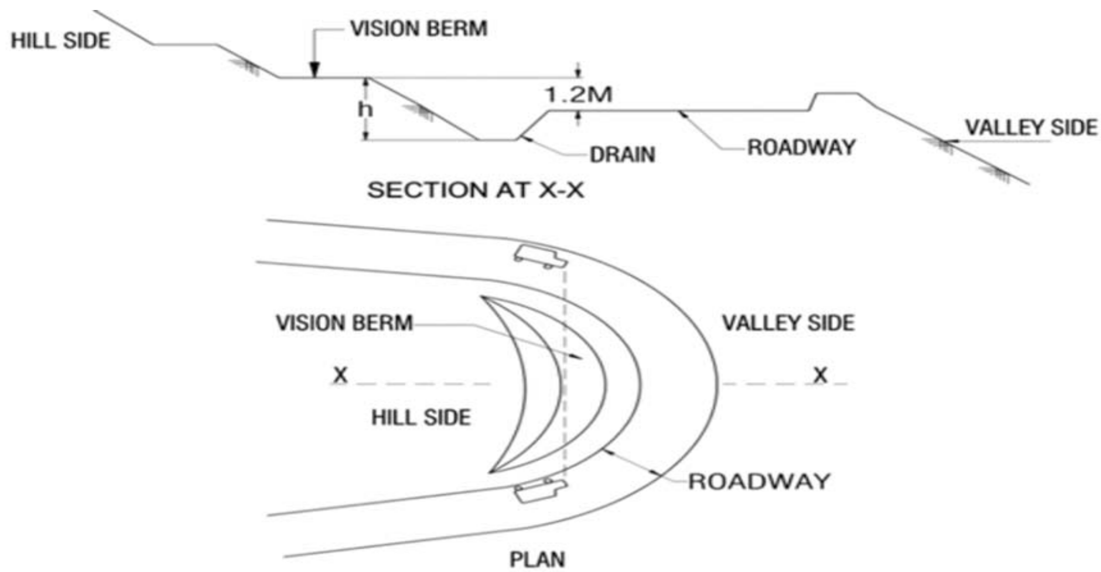


Fig. 11: Batter Benching

11.8.5 Where a horizontal and summit vertical curve overlap, the line of sight will not be over the top of the crest but to one side, and in part may be off the roadway. Design in such cases should provide for the required sight distance both in the vertical direction along the pavement and in the horizontal direction on the inside of the curve.

11.9 **Camber & Cross Fall**

11.9.1 The pavement on straight stretches should be provided with a crown in the middle with surface on either side sloping towards the edge. In stretches of winding alignment where straight stretches are few and far between, it may not be possible in all situation to provide it. In such cases, instead of normal camber, surface may be given a unidirectional cross fall towards the hill side with due regard to factors such as direction of superelevation at the flanking horizontal curves, ease of drainage, problem of erosion and so on (Refer Fig. 12). The camber or cross fall on straight of the roads is given in Table 16.

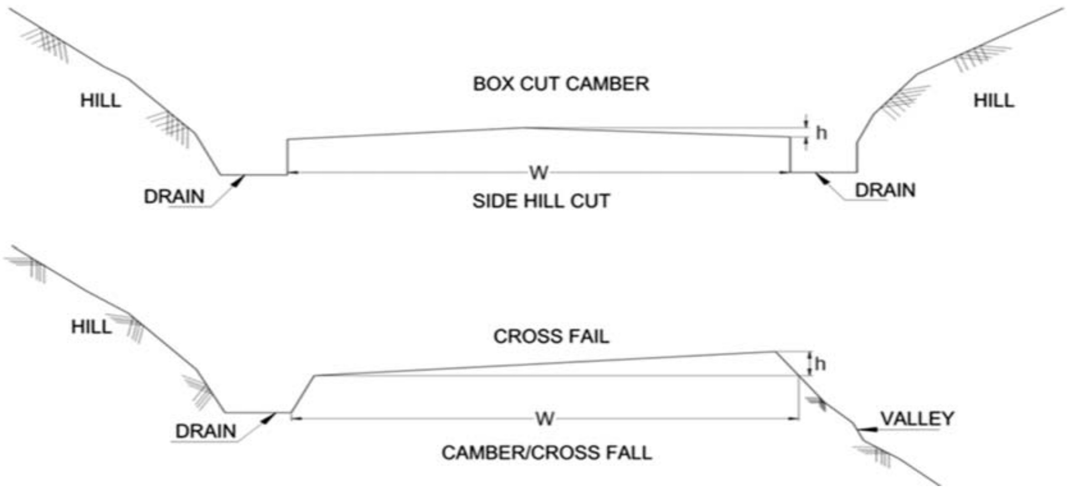


Fig. 12: Camber & Cross Fall

Table 16: Camber/ Cross Fall

Type of road	**Camber of cross fall**	
Earth Roads	1 in 33 to 1 in 25	3.0 to 4.0%
Gravel of WBM surface	1 in 40 to 1 in 33	2.5 to 3.0%
Thin Bituminous surface	1 in 50 to 1 in 40	2.0 to 2.5%
Dense / Semi Dense type bituminous Surface or cement concrete surface	1 in 60 to 1 in 50	1.7 to 2.0%

11.9.2 In area of heavy rainfall, the steeper value of camber given above should be adopted. In areas where intensity of rainfall is low, lower camber values may be adopted.

11.9.3 The cross fall for earth shoulders should be at least 0.5% more than the pavement camber subject to a minimum of 1 in 33 (3%).

11.9.4 If the shoulders are paved, cross fall as appropriate as per Table may be adopted.

11.9.5 On superelevated sections, the shoulder should normally have the same cross fall as the pavement.

12. VERTICAL ALIGNMENT

12.1 Gradients

12.1.1 The vertical alignment should provide for a smooth longitudinal profile consistent with the category of the road and lay of the terrain. Changes in grades should not be too frequent as to cause kinds and visual discontinuities in the profile. Grades should be carefully selected keeping in view the design speed, terrain condition and nature of traffic expected on the road.

12.1.2 The gradients for different classes of terrain are given below in Table 17.

Table 17: Gradients for Different Terrains

Terrain	Ruling	Limiting	Exceptional
Plain or rolling terrain	3.3% (1 in 30)	5% (1 in 20)	6.7% (1 in 15)
Mountainous and steep terrain upto 3000 m above MSL	6% (1 in 16.7)	7% (1 in 14.3)	8% (1 in 12.5)
Steep terrain more than 3000m above MSL	5% (1 in 20)	6% (1 in 16.7)	7% (1 in 14.3)

Note: (i) Gradients have been taken as per IRC 52-2019.

(ii) In case road alignment traverses through steep terrain above 3000m and also passes through a terrain upto 3000 m altitude for a continuous stretch of 5 kms or more, the ruling gradient may be considered as 6% for the entire road stretch.

12.1.3 Gradients upto the 'Ruling Gradient' may be used as a matter of course in design. However, in special situations such as isolated over-bridges in flat country or roads carrying a large volume of slow moving traffic, it will be desirable to adopt a flatter gradient of 2 percent from the point of aesthetics, traffic operations, and safety.

12.1.4 The 'Limiting Gradients' may be used where the topography of a place compels this course or where the adoption of gentle gradients would add enormously to the cost. In such cases, the length of continuous gradient steeper than the ruling gradient should be as short as possible.

12.1.5 Exceptional gradients are meant to be adopted only in very difficult situations and for short length not exceeding 100 m at stretch. In mountainous and steep terrain, successive stretches of exceptional gradient must be separated by a minimum length of 100 m having gentler gradient (i.e. limiting gradient or flatter).

12.1.6 The rise in elevation over a length of 2 km shall not exceed 100m in mountainous terrain and 120m steep terrain.

12.1.7 **Gradients for drainage**

On un-kerbed pavements in embankment, near level grades may be provided when the pavement has sufficient camber to drain the storm water laterally, But in cut sections or in kerbed embankments, it is necessary for the road to have some gradients for efficient drainage or the road side drain should have the ensure flow of water. Desirable minimum gradient for the road surface in kerbed embankment or cut sections is 0.5% in which are the side drain should be lined or 1% if the drain is unlined.

12.1.8 **Grade Compensation at curves**

At horizontal curves, the gradients should be eased by an amount known as “Grade compensation’ which is intended to offset the extra tractive effort involved at curves, using the formula.

Grade compensation (%) - (30 + R)/R

Subject to a maximum of 75/R, where R is the radius of curve in meters.

12.1.9 Grade compensation is not necessary for gradients flatter than 4% (1 in 25).

12.2 **Vertical Curves**

12.2.1 For smooth transition at grade changes, vertical curves are to be provided. At summits & valleys these curves have to be convex and concave respectively and should be designed as square parabolas. (For design please refer to IRC:52-2019).

12.2.2 The length of vertical curves is controlled by sight distance requirements, but curves with greater length are aesthetically better

12.2.3 Curves should be provided at all grade changes exceeding those indicated in Table 18. For satisfactory appearance, the minimum length should be as shown in the Table.

Table 18: Minimum Length of Vertical Curves

Design speed km/h	**Minimum grade change(%) not requiring vertical curve**	**Min length of vertical curve(m)**
upto 35	1.5	15
40	1.2	20
50	1.0	30
65	0.8	40
80	0.6	50
100	0.5	60

12.3 **Summit Curves** (Refer Fig. 13)

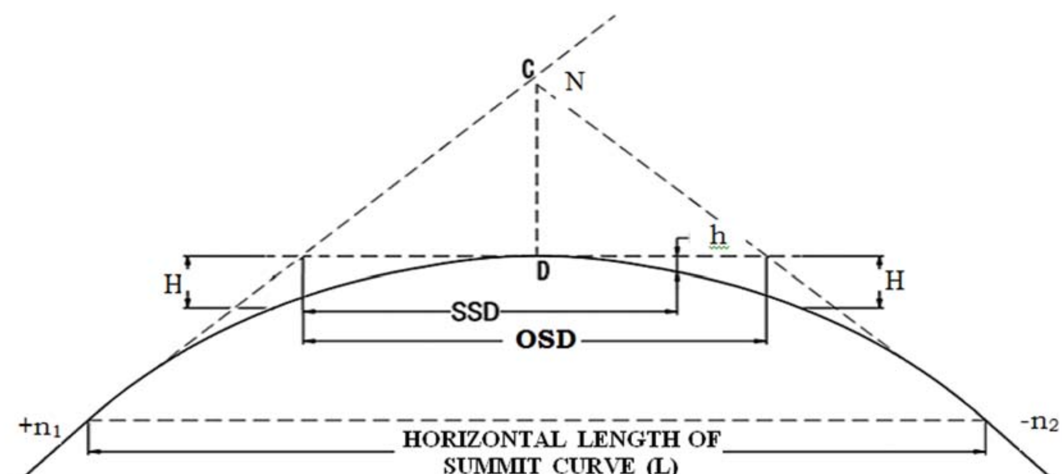


Fig. 13: Summit Curve

SSD = STOPPING SIGHT DISTANCE

OSD = OVERTAKING SIGHT DISTANCE

h = HEIGHT OF OBJECT ABOVE PAVEMENT SURFACE

H = HEIGHT OF EYE LEVEL OF DRIVER OVER PAVEMENT SURFACE

N = DEVIATION ANGLE

n1 = ASCENDING GRADIENT

n2 = DESCENDING GRADIENT

12.3.1 The length of summit curves is governed by the choice of sight distance, whether stopping sight distance or the intermediate sight distance. The length is calculated from the formula:-

(a) For safe stopping sight distance

Case (i) when the length of curve exceeds the required sight distance i.e. L is greater than S

$$L=\frac{NS^2}{4.4}$$

Where

N= Deviation angle i.e. the algebraic difference between the two grades.

L = Length of parabolic vertical curve in meters.

S = Required sight distance in meters.

Case (ii) where the length of curve is less than the required sight distance i.e. L is less than S

$$L=2S - \frac{4.4}{N}$$

(b) For intermediate or over taking sight distance

Case(i) where L is greater than S

$$L=\frac{NS^2}{9.6}$$

Case (ii) where L is Less than S = $2S - \frac{9.6}{N}$

Example: Calculate the length of summit curve for the following parameters : (Refer Fig.12)

(i) Design speed = 25 kmph

(ii) Ascending gradient, n1 = 1:25

(iii) Descending gradient,n2 = 1:20

Solution:

Deviation angle N=n1-(-n2)

$= \frac{1}{25} - \frac{(-1)}{20}$

$= \frac{1}{25} + \frac{1}{20}$

$= \frac{4+5}{100} = \frac{9}{100}$

Stopping sight distance S for a design speed of 25 kmph from table 6, S = 25m

If L>S

$L = \frac{NS^2}{4.4}$

$= \frac{9}{100} x \frac{625}{4.5}$

=12.78m

i.e.L < S

Hence equation for the condition L<S.

$L = 2S - \frac{4.4}{N}$

$= 2x25 — \frac{4.4}{9} x100$

L= 1.11 m

From Table 18, minimum length of vertical curve upto a design speed of 35 kmph is 15m which is greater than the value of length of curve calculated above. So length of summit curve=15m.

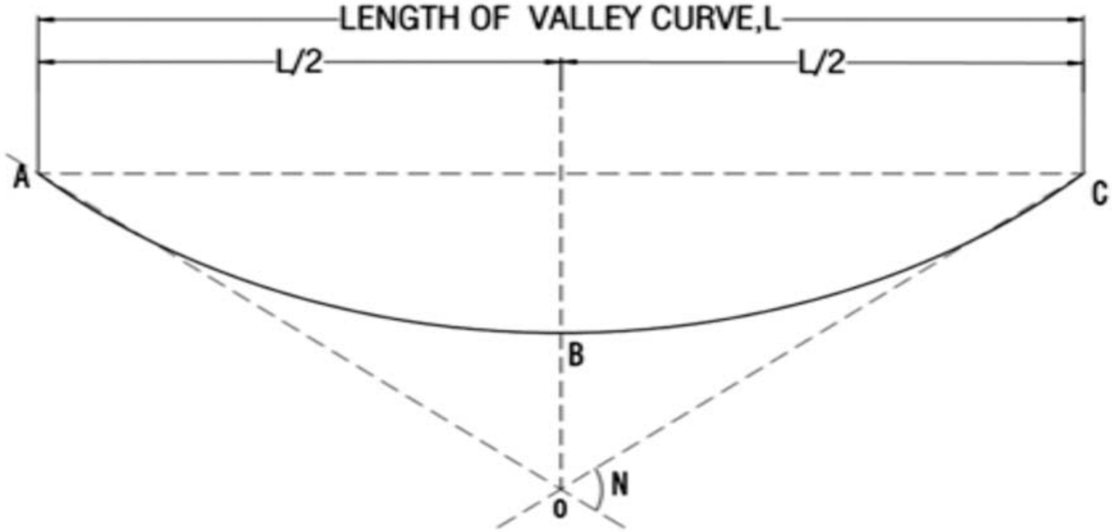


Fig. 14: Valley Curve

12.3.2 The length of valley/sag curves should be such that for night travel, the head-light beam distance is equal to the stopping sight distance. Based on this criterion the length of curve may be calculated as per formula given below:-

Case (i) where L is greater than S

$$L = \frac{NS^2}{1.50+0.035S}$$

Case(ii) where L is less than S

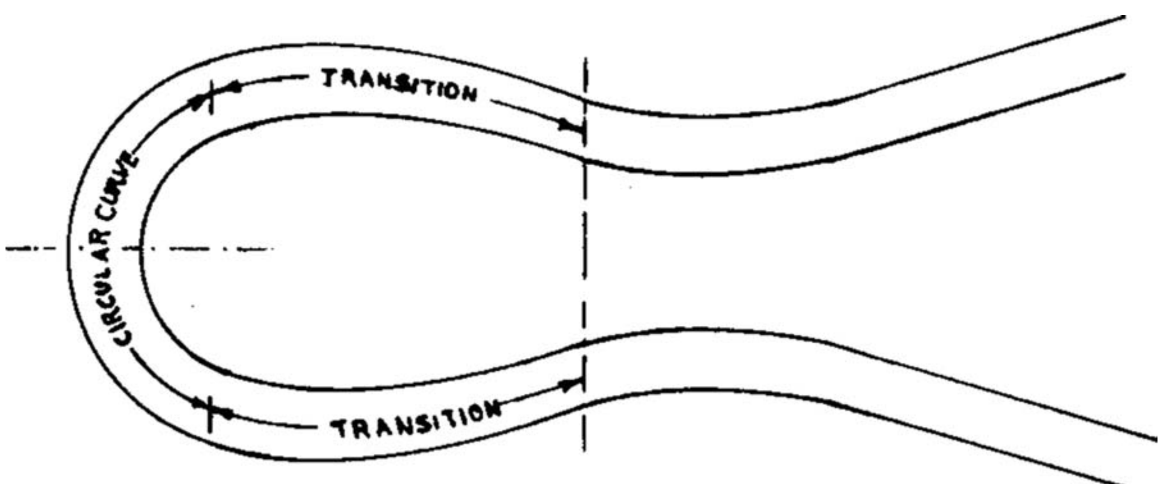


Fig-15: Hair pin Bend

12.3.3 Hairpin bends, where unavoidable, may be designed either as a circular curve with transition at each end or as a compound circular curve. The following criteria should be followed normally for their design:-

(a) Minimum design speed = 20km/h

(b) Minimum roadway width at apex

  (i) Class 9(N) Road = 7.5m

  (ii) Class 5(N) Road = 6.5m

(c) Minimum radius for the inner curve 14.0m

(d) Minimum length of transition curve15.0m

(e) Gradient

  (i) Maximum - 1 in 40 (2.5 percent)

  (ii) Minimum - 1 in 200 (0.5 percent)

  (f) Superelevation - 1 in 10 (10 percent)

12.3.4 Inner and outer edges of the roadway should be concentric with respect to centre line of the pavement. Where a number of hairpin bends have to be introduced, a minimum inner venting horizontal distance of 60 m should be provided between the successive bends to enable the driver to negotiate the alignment smoothly.

12.3.5 Widening of hairpin bends subsequently is a difficult and costly process. Moreover, gradients end to become sharper as generally widening can be achieved only by cutting the hill side. These points should be kept in view at the planning stage, especially if a series of hairpin bends is involved.

12.3.6 At hair-pin bends, preferably the full roadway width should be surfaced.

13. CO-ORDINATION OF HORIZONTAL AND VERTICAL ALIGNMENTS

13.1 The overall appearance of a highway can be enhanced considerably by judicious combination of the horizontal land vertical alignments. Plan and profile of the road should not be designed independently but in unison so as to produce an appropriate three-dimensional effect. Proper co-ordination in this respect will ensure safety, improve utility of the highway and contribute to overall aesthetics.

13.2 The degree of curvature should be in proper balance with the gradients. Straight alignments or flat horizontal curves at the expense of steep or long grades, or excessive curvature in a road with flat grades, do not constitute balanced design and should be avoided.

13.3 Vertical curvature superimposed upon horizontal curvature gives a pleasing effect. As such the vertical and horizontal curve should coincide as far as possible and their length should be more or less equal. If this is difficult for any reason, the horizontal curve should be somewhat longer than the vertical curve.

13.4 Sharp horizontal curves should be avoided at or near the apex of pronounced summit/sag vertical curves from safety considerations.

13.5 Fig16 illustrates some typical cases of good and bad alignment co-ordination.

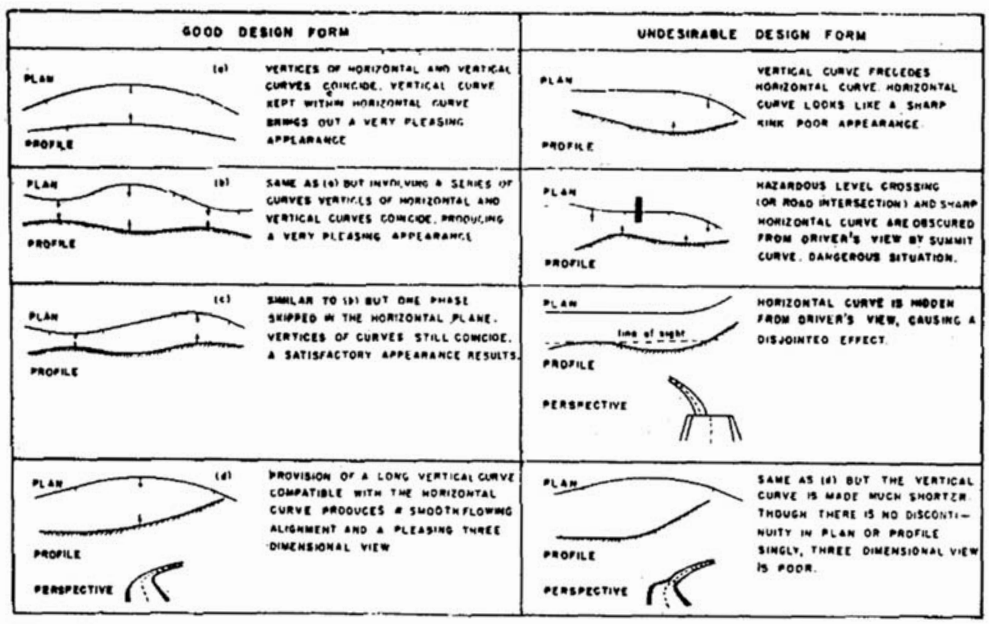


Fig.16: Sketch showing good and bad alignment coordination

14. LATERAL AND VERTICAL CLEARANCES AT UNDERPASSES

14.1 **Lateral Clearance**

14.1.1 Desirably the full roadway width at the approaches should be carried through the underpass. This implies that the minimum lateral clearance (i.e. the distance between the extreme edge of the carriageway and the face of nearest support whether a solid abutment, pier or column) should equal the normal shoulder width.

14.1.2 On roads in hill areas having comparatively narrow shoulders, it will be desirable to increase the roadway width at under passes to a certain extent keeping in view the principles set forth in IRC; 54-1974 "Lateral and Vertical Clearances at Underpasses for Vehicular Traffic".

14.2 **Vertical Clearance**

Minimum vertical clearance of 5.50 m should be ensured over the full width of the roadway at all underpasses, and similarly at over hanging cliffs and any semi tunnel sections etc. The vertical clearance should be measured with regard to the highest point of the carriageway, i.e. the crown or the super elevated edge of the carriageway as the case may be. Due allowance for any future raising/strengthening of the pavement should also be made. Also see fig.17 for reference.

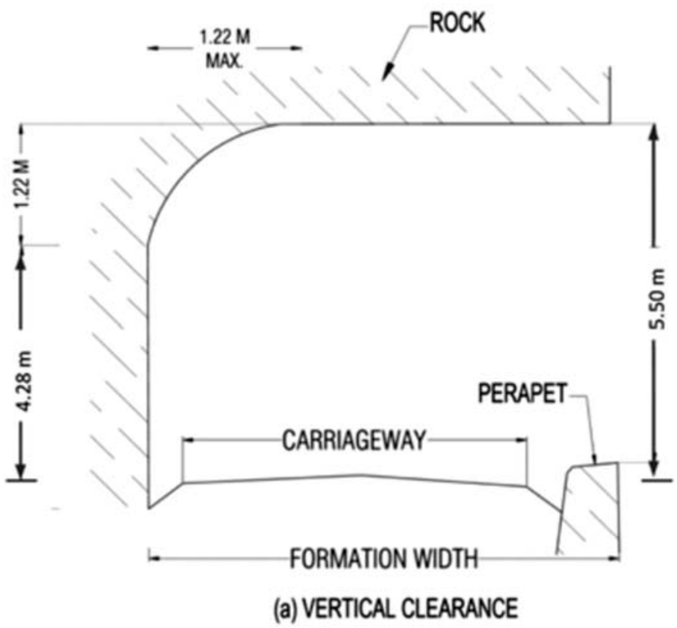


Fig. 17: Vertical Clearance

15. CONCLUSION

15.1 This Technical Instruction has been compiled based on various standards, guidelines and specifications of Indian Roads Congress, Instructions of MoRT&H (Roads Wing), specifications for Road and Bridge works of MoRT&H published by IRC, Policy Instructions of MoRT&H and DGBR, and previously published DGBR Technical Instructions. A list of IRC publications for more exhaustive understanding of the subject is given in Appendix 'B'.

Appendix 'A'

METHODS OF CURVE RANGING

1. **There are two methods for setting out curves. These are:-**

   (a) Linear or chain and tape method
   (b) Angular or instrumental method

2. Linear methods are those in which the curve is set out with a chain and tape only. Instrumental methods are those in which a theodolite with or without a chain is employed to set out the curve.

3. **Location of Tangent Points (See Fig A l)**

The procedure to locate the tangent points T1 and T2 is as under:-

Having fixed the centre line of the road on the straight portion on either end of the curve, extend them to meet at point 'B'. Set up a theodolite at the intersection point B and measure the angle of intersection I <T1BT2. Find the deflection angle S from the relation.

$\phi = 180° - I$

Calculate the tangent length from the formula

$BT_1 = BT_2 = R \tan \frac{\phi}{2}$

Locate T_1 and T_2 by measuring the tangent length from inter section point B.

4. If an angle measuring instrument is not available, the angle of intersection may be found by chain measurement as follows:-

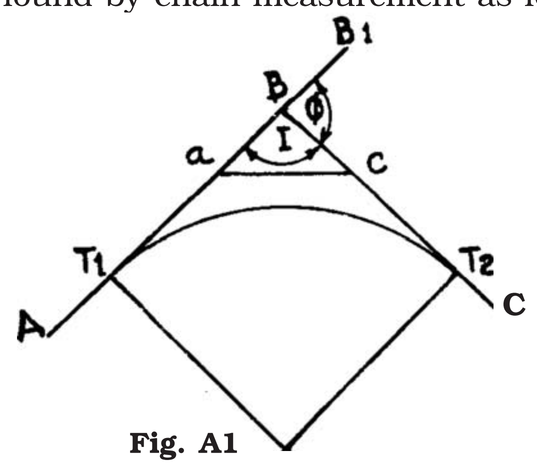


Fig. A1

Set off from B equal distance Ba and Bc along BA and BC. Measure accurately.

From triangle B a c,

$$\text{Sin}\ \frac{aBC}{2} = \text{Sin}\ \frac{I}{2} = \frac{ac}{2Ba}$$

$$\text{Or } I = 2\ \text{Sin}^{-1}\ \frac{(ac)}{2Ba}$$

$$f = 180° - I = 180° - 2\ \text{Sin}^{-1}\ \frac{(ac)}{2Ba}$$

5. Chain and Tape Method Of Setting Out a Simple Circular Curve. (See fig.A2)

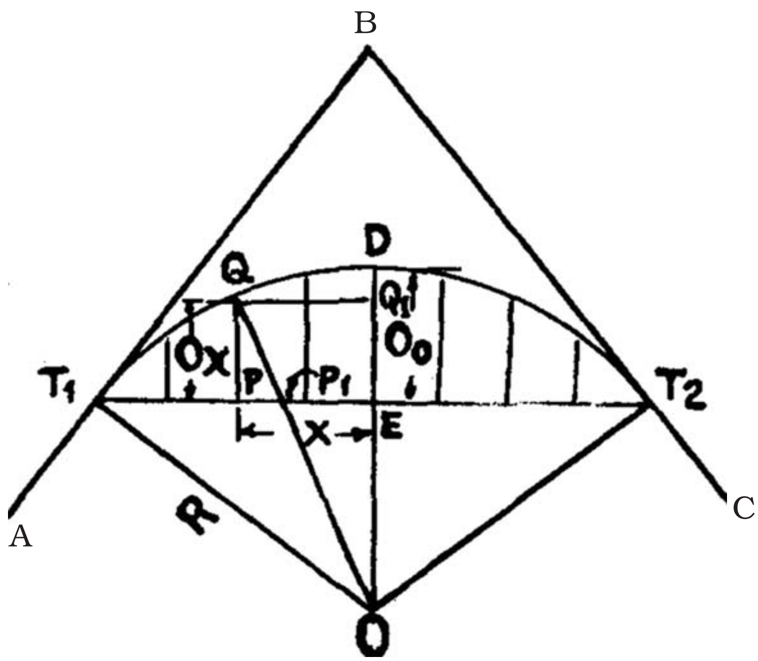


Fig. A2

Let AB and BC	=	The tangents to the curve $T_1\ DT_2$
T_1 and T_2	=	The tangent points
$T_1\ T_2$	=	The long chord of length L.
$ED=O_0$	=	The offset at the midpoint of T_1T_2

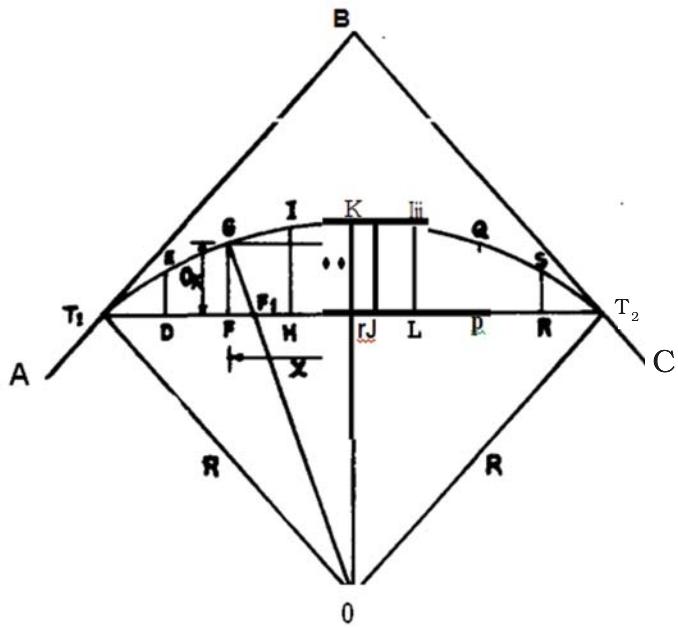


Fig. A3

In Fig. A3

$T_1J = JT_2 = 8m$

$OT_1 = OT_2 = \mathbf{R} = 20m$

Select points D, F, H and L, P, R on either side of J in such away so that

$T_1D = DF = FH = HJ = 2$ m

The x offset at J= O_o = OK - OJ = R - OJ

$OJ = \sqrt{R^2 - T_1J^2} = \sqrt{20^2 - 8^2} = \sqrt{336} = 18.33m$

ie, R-Oo = 18.33 m

JK = R - OJ = 20 - 18.33 = 1.67 m

offset HI $= \sqrt{R^2 - x^2} - (R - Oo)$

$= \sqrt{20^2 - 2^2} - 18.33$

$= \sqrt{396} - 18.33$

= 19.9 = 18.33 = 1.57 m

Offset FG = $\sqrt{20^2 - 4^2}$ - 18.33

= $\sqrt{384}$ - 18.33

= 19.6 - 18.33

= 1.27 m

Offset DE = $\sqrt{20^2 - 6^2}$ - 18.33

= $\sqrt{364}$ - 18.33

= 19.08 - 18.33 = 0.75m

Since the curve is symmetrical, the offsets on the right side will be the same as those on the left side.

6. Angular or Instrumental Method : (Ref Fig A4)

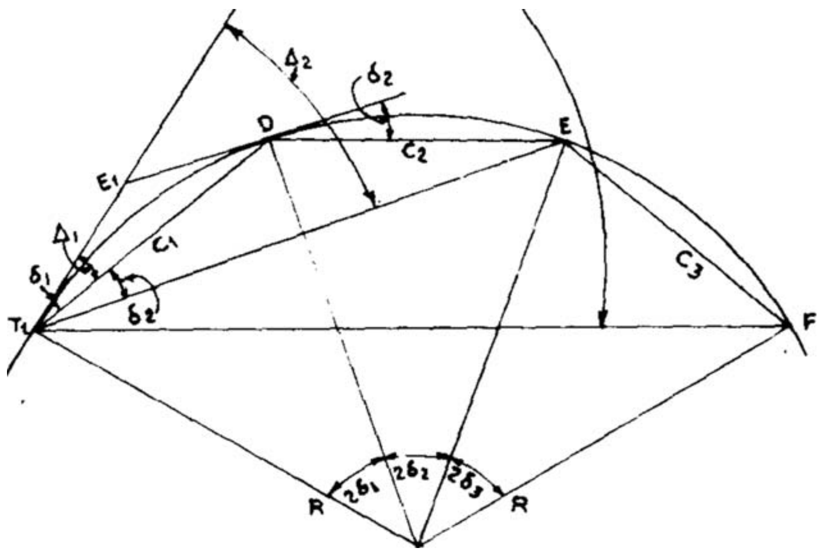


Fig. A4

AB = The rear tangent to the curve

T_1 = The tangent point

D,E,F etc = Successive points on the curve

δ1, δ2, δ3 etc. = Tangential angles, which each of the successive chords T_1 D, DE, EF, etc. makes with the respective tangents at T_1, D, E, etc.

$\Delta 1$, $\Delta 2$, $\Delta 3$ etc.	=	The total tangential or deflection angles (between the rear tangent AB and each of the lines T_1D, T_1E, T_1F etc) for the chords T_1D, DE, EF, etc.
C_1, C_2, C_3 etc.	=	The length of chord T_1 D, DE, EF, etc.
R	=	Radius of the curve

From the formula,

$\delta n = 1718.9 \frac{Cn}{R}$ minutes. we have

$\delta 1 = 1718.9 \frac{C_1}{R}$ minutes

$\delta 2 = 1718.9 \frac{C_2}{R}$ minutes. we have

Also,

$\Delta_1 = \delta 1$

$\Delta_2 = \delta 1 + \delta 2 = \Delta 1 + \delta 2$

$\Delta_3 = \delta 1 + \delta 2 + \delta 3 = \Delta 2 + \delta 3$

$\Delta_n = \delta 1 + \delta 2 + \delta 3 + \text{-----} + \delta n = \Delta_{n-1} + \delta n$

Procedure : To set out the curve,

Step-1. Set up the theodolite over the tangent point (T_1) and level it.

Step 2. Clamp both the plates of theodolite at Zero and direct the telescope to the ranging rod at point of intersection B and bisect it.

Step-3. Release the vernier plate and set the vernier to the first deflection angle Δ_1, the telescope being thus directed along T_1D.

Step - 4. Fix the Zero end of the tape at T_1 and holding the arrow at a distance on tape equal to the length of first chord and swing it around T1 until the arrow is bisected by the line of sight which is point D. Thus the point D is located on curve.

Step -5. Unclamp the upper plate and set the vernier to the second deflection angle Δ_2. The line of sight is now directed along T_1E.

Step -6. Fix the Zero end of the tape at D. Holding the arrow at a distance on tape equal to the length of chord, DE, swing the other end around D until the arrow held at the other end is bisected by the line of sight which is point E. Thus second point E, on the curve is located.

Step-7. Repeat the process unit the end of curve is reached.

Example (Ref. Fig. A5)

Let the radius of curve, R	=	20 meters
Deflection angle,	=	75^0
Peg interval	=	5 meters

Solution

Lenght of the curve $= \dfrac{\pi R \Delta}{180^0}$

$$= \frac{\pi \times 20 \times 75^0}{180^0}$$

$$= 26.18\text{m}$$

Since the peg interval is 5 mtrs, the curve will consist of 5 unit chords of 5 mtrs & one (last) sub-chord of (26.18 - 5 x 5) = 1.18 mtrs length.

From the formula,

$$\delta n = 1718.9 \frac{Cn}{R} \text{ minutes}$$

(Ref para 7)

for first chord

$$= 1718.9 \frac{C_1}{R} \text{ minutes}$$

$$= \frac{1718.9 \times 5}{20} \text{ minutes}$$

$$= 429.7 \text{ minutes}$$

$$= 7^0\ 9'\ 43''$$

Since, $C_1 = C_2 = C_3 = C_4 = C_5$

$\delta 1 = \delta 2 = \delta 3 = \delta 4 = \delta 5 = 7^0\ 9'\ 43''$

Last sub chord C6 = 1.18 metres

$\delta 6$ for last sub-chord $= 1718.9 \times C6/R$

$= 1718.9 \times 1.18/20$

$= 101.42$ minutes

$= 1^0\ 41\ 25^n$

The total tangential (deflection) angles for the chords are

$\Delta_1 = \delta 1 \qquad = 7^0\ \ 9'\ \ 43''$

$\Delta_2 = \delta 1 + \delta 2 = \Delta 1 + \delta 2 \qquad = 14^0\ \ 19'\ \ 26''$

$\Delta_3 = \delta 1 + \delta 2 + \delta 3 = \Delta 2 + \delta 3 \qquad = 21^0\ \ 29'\ \ 09''$

$\Delta_4 = \delta 1 + \delta 2 + \delta 3 + \delta 4 = \Delta 3 + \delta 4 \qquad = 28^0\ \ 38'\ \ 52''$

$\Delta_5 = \delta 1 + \delta 2 + \delta 3 + \delta 4 + \delta 5 = \Delta 4 + \delta 5 \qquad = 35^0\ \ 48'\ \ 35''$

$\Delta_6 = \delta 1 + \delta 2 + \delta 3 + \delta 4 + \delta 5 + \delta 6 = \Delta 5 + \delta 6 \qquad = 37^0\ \ 30'\ \ 00''$

Once the .angles are calculated set the theodolite at point T_1. Measure the angles Δ_1, Δ_2, Δ_3, Δ_4, Δ_5, Δ_6 from the rear tangent and fix the points D, E, F, G & H and complete the curve.

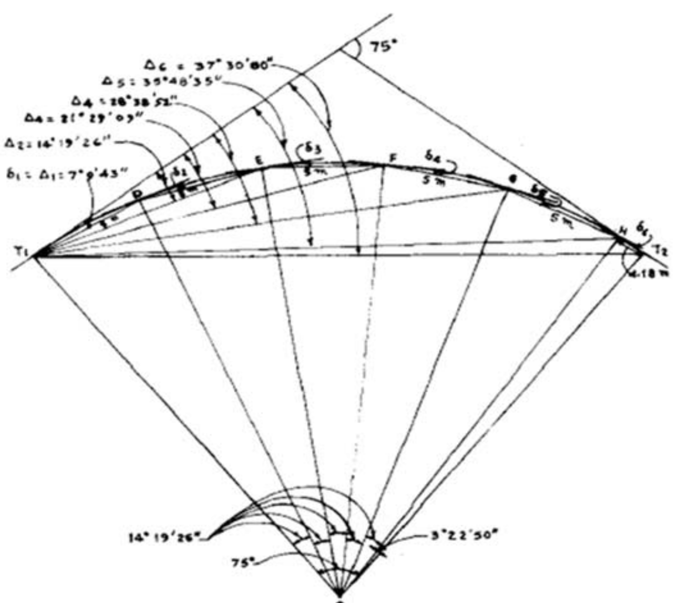


Fig. A5..SETTING OUT A SIMPLE CIRCULAR CURVE WITH THEODOLITE.
(Ref. para 8)

8. **Point or Intersection Inaccessible (See fig A6)**

When the point of intersection B is inaccessible, as it happens in most of the curves on hill roads, the procedure for determining the value of deflection angle Φ and the location of the tangent points T_1 and T_2 is explained below:-

Fix points M and N suitably on the tangents AB and BC respectively so that M and N are inter visible and the line MN runs on moderately level ground. If the ground beyond the curve is not suitable, the points may be fixed inside the curve as at M and N. Measure MN accurately. Set up the instrument at M and measure the angle AMN (Φ 1).Transfer the instrument to N and measure the angle CNM (Φ 2).

In the triangle **BMN,**

$\alpha = 180° - \theta_1$

$\beta = 180° - \theta_2$

The deflection angle $\Phi = \alpha + \beta$

Find out the distances B M and B N from the formula

$$\mathbf{BM} = \frac{MN \sin \beta}{\sin \{180° - (\alpha + B)\}}$$

$$\mathbf{BN} = \frac{MN \sin \alpha}{\sin \{180° - (\alpha + B)\}}$$

Calculate the tangent lengths BT_1 and BT_2 from the formula

$$T = R \tan \frac{\Phi}{2}.$$

To obtain the distances MT_1 and NT_2

$MT_1 = BT_1 - B\,M$ and

$NT_2 = BT_2 - BN$

Measure the distances MT_1 and NT_2 from M and N respectively along the tangents BA and BC and fix the points T_1 and T_2.

If the points are fixed inside the curve, the procedure is the same as above, except for the distances to be measured from the points M and N to locate the tangent points T_1 and T_2, MT_1 and NT_2 being respectively equal to $(BM-BT_1)$ and $(BN-BT_2)$

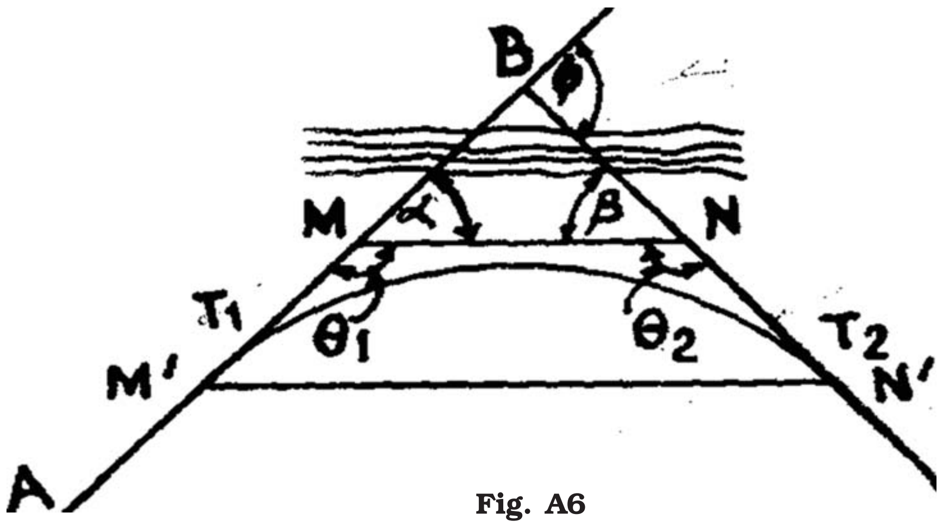


Fig. A6

10. Example (Ref Fig A7)

$MN = 12$ M

$\theta_1 = 135^0$

$\theta_2 = 120^0$ C

$R = 20$ M

In Δ BMN. $\angle BMN = 180^O - \theta_1 = 180^O - 135^O = 45^O = \alpha$

$\angle BNM = 180 - \theta_2 = 180^O - 120^O = 60^O = \beta$

Deflection angle $\phi = (\alpha + \beta) = 45^0 + 60^O = 105^O$

From the

$$BM = \frac{MN \sin \beta}{\sin \{ 180^0 - (\alpha + \beta) \}}$$

$$BM = \frac{12 \text{ Sin } 60^0}{\text{Sin } (180^0 - 105^0)} = \frac{12 \text{ Sin } 60^0}{\text{Sin } 75^0} = 10.76 \text{ m}$$

$$\text{Similarly } \frac{MN \text{ Sin } \alpha}{\text{Sin } \{ 180^0 - (\alpha + \beta) \}}$$

$$BN = \frac{12 \text{ Sin } 45^0}{\text{Sin } 75^0} = 8.78\text{m}$$

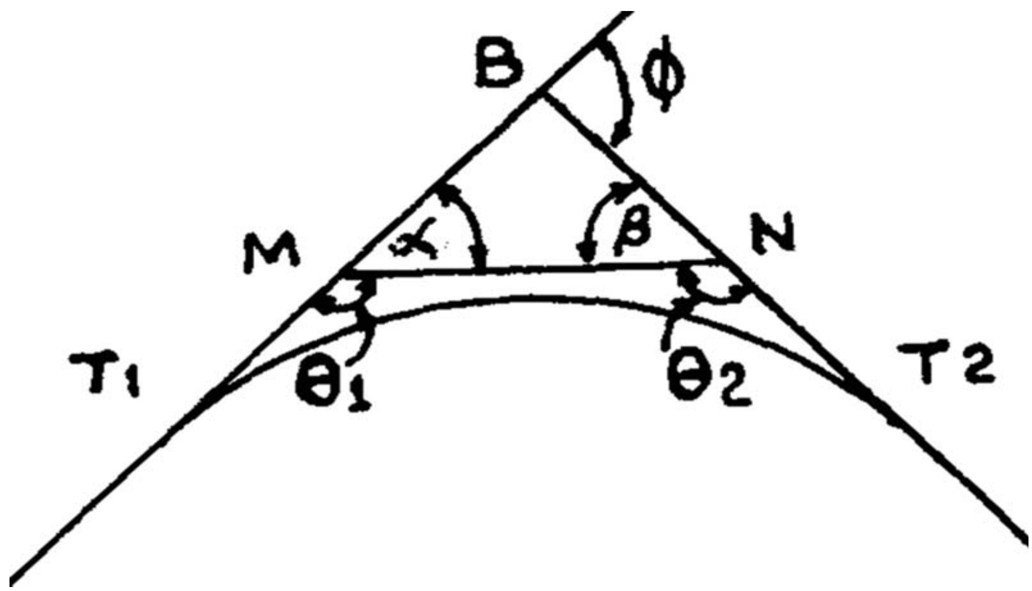
MN Sin α

Tangent length $BT_1 = R \tan \Phi/2$

$= 20 \tan \frac{105°}{2} = 26.06\text{m}$

$MT_1=BT_1-BM=26.06-10.76=15.30\text{m}$

$NT_2=BT_2-BN=26.06-8.78=17.28\text{m}$



A **Fig. A7** **C**

11. Setting out Combined Circular and Transition Curve (Refer fig. A8)

The procedure for setting out a combined circular and transition curve is explained below:-

Notations

(a)	Deflection angle between the straights	=	Δ
(b)	The radius of the circular curve	=	R
(c)	The length of the transition curve	=	L
(d)	Spiral angle	=	$\Phi 1$
(e)	Shift of the circular curve	=	S
(f)	Distance to any point measured. along the curve from tangent point	=	l

Step-1. The length of transition curve (L) be taken from table 12 depending upon the design speed and radius of circular curve.

Step-2. Find the shift of the circular curve(S) from the formula,

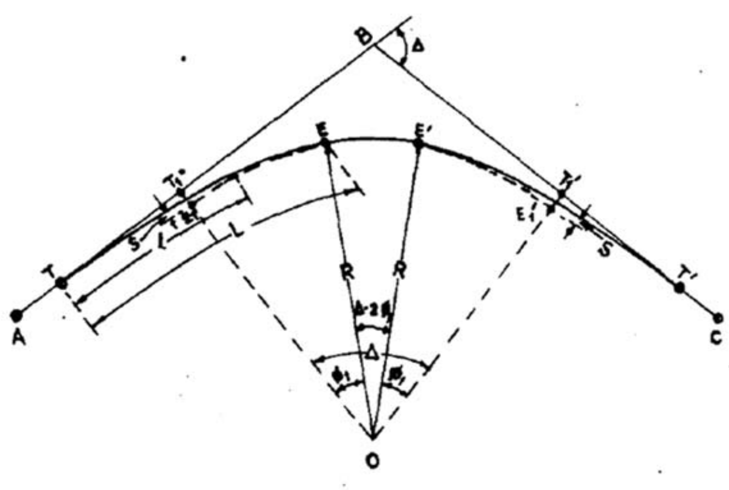


Fig. A8.- COMBINED CURVE

$$S = \frac{L^2}{24\,R}$$

Step-3. Compute the total tangent length from formula,

$$TB = T'B = (R + S)\tan\frac{\Delta}{2} + \frac{L}{2}\left(1 - \frac{S}{5R}\right)$$

Step-4. Calculate the spiral angle S1 from the formula,

$$\Phi_1 = \frac{L}{2R} \quad \text{radians}$$

and central angle EOE from the formula,

<EOE'= $(\Delta - 2\,\Phi_1)$

Step-5. Calculate the length of circular curve (EE) from the formula

$$EE = \frac{\pi R\,(\Delta - 2\,\Phi_1)}{180^\circ}$$

Step-6. The length of combined curve

$$TT' = \frac{\pi R\,(\Delta - 2\,\Phi_1)}{180^0} + 2L$$

Step-7. Find the location of the beginning and end points of the combined curve **(T)** & **(T)** by measuring the total tangent length form the point of intersection **'B'.**

FIXING OF CHAINAGE OF T,T',E & E' (Ref. Fig. A9)

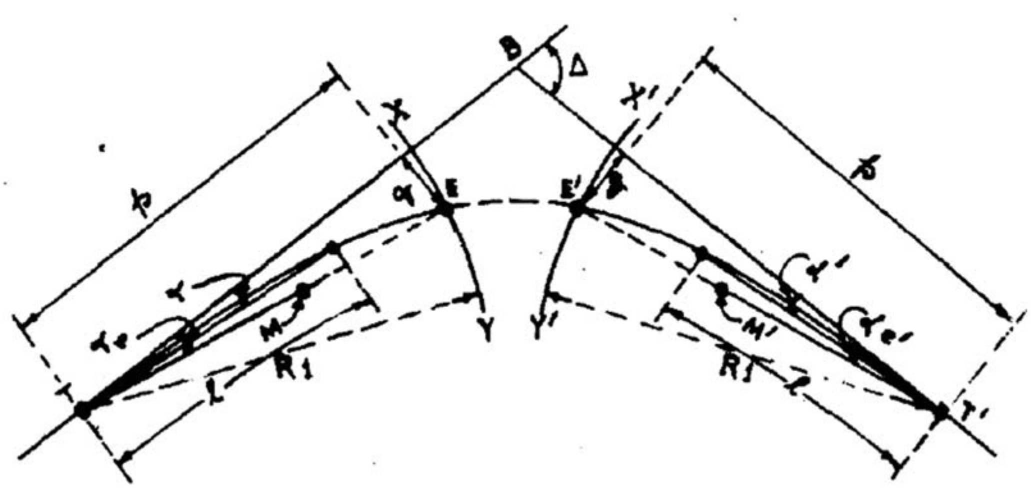


Fig. A9: Transition and Circular Curve

Step - 8. Assuming the chainage of beginning point T (located as per step 7 above) as zero, the chainage of junction point E of the transition curve with the circular curve can be obtained by adding the length of transition curve to the chainage of T i.e, zero +length of transition curve = chainage of E. The co-ordinates of the point E with T as origin are given by the formula.

and

$$p=L\left(1-\frac{3S}{5R}\right) \text{ and}$$

$$q = \frac{L^2}{6R}\left(1-\frac{L^2}{56R^2}\right)$$

Thus the point E will lie on the arc of a circle have the radius R_1 which is equal to $\sqrt{p^2 + q^2}$.

Step - 9. Determine the chainage of the other junction point E with other transition curve by adding the length of circular curve to the chainage of E.

Step-10. Similarly the chainage of end point, T of the combined, curve can be determined by adding the length of transition curve to chainage of E. The point E will be on the arc of a circle having the radius R1 which is equal to $\sqrt{p^2+q^2}$. The values of p & q are obtained as per formulae given in step 8 above.

LOCATION OF POINTS E & E'

Step 11. Calculate the deflection angle for the transition curve from the formulae.

$$\alpha = \frac{573I^2}{RxL} \text{ in minutes}$$

Where I is the length measured along curve from T.F or the condition I=L, <BTM = αe = 573L/R. Once the value of < αe is known, the point E can be located by setting the angle BTM, and extending it to meet the arc with radius $\sqrt{p^2+q^2}$

LOCATION OF INTERMEDIATE POINTS ON TRANSITION CURVES.

Step - 12 Calculate the deflection angles for intermediate points on the curve from formula given in step11 for different lengths at suitable intervals. (Ref Fig. A9).

Step-13 Thus both transition curves (one from T & other from T') can be set out by fixing a theodolite at point T & T' respectively for deflection angles as calculated above.

Step-14 The circular curve EE can be set out as mentioned in para 5/7.

12. Example - Set out a combined circular and transition curve for the following Parameters.

(a)	Deflection Angle Δ	=	75^0
(b)	Design speed	=	25 Km/hr
(c)	Radius of circular curve	=	25m

Procedure (Ref Fig. A10)

Step–1 Length of transition curve from Table–12 for Design speed 25 kmph and radius R.

R = 25m

ie, L = 25m

Step-2. Shift $S = \frac{L^2}{24 \times R}$

L = 25 meters, R=25 meters

$$S = \frac{25^2}{24x25} = 1.042 \text{ m}$$

Step-3 Total tangent lengths TB= T'B

$$= (R + S) \text{ Tan } \frac{\Delta}{2} + \frac{L}{2}\left(1 - \frac{S}{5 R}\right)$$

R = 25 m

S = 1.042 m

= 75^0

TB = TB = $(25 + 1.042)\ \tan \frac{75^0}{2} + \frac{25}{2}\left(1 - \frac{1.042}{5 \times 25}\right)$

= 19.982 + 12.396
= 32.378 m

Step-4 Spiral Angle ϕ 1 = $\frac{L \times 180^0}{2 \pi R}$

= $\frac{25 \times 180^0}{2 \times \pi \times 25}$ = 28.6470 = 280 38'52"
$75^0 - 28.647 \times 2 = 17.706^0$
17^0 42'16

Central Angle EOE' = $\Delta - 2\ \phi_1$

Step-5. Length of circular curve

EE' = $\pi R \frac{(\Delta - 2\ \phi_1)}{180^0}$

= $\frac{\pi \times 25 \times 17.706^\circ}{180^\circ}$

= 7.726 m

Step-6. Length of combined curve IT

= $\pi R \frac{(\Delta - 2\ \phi_1)}{180^0} + 2L$

= 7.726+2 x 25 = 57.726m

Step-7. With the known length of TB & T'B, the point T&T' can be located by measuring the distance along BT & BT' (i.e, 32.378m from B)

FIXING OF CHAINAGE T, E, E' & T' (Ref Fig A9)

Step-8. Measure the tangent length 32.378 m from point 'B' along the centre line and fix the tangent point T and T'.

Assume the chainage of T + length of transition curve

Chainage of E = chainage of T + length of transition curve

= 0.00+25

= 25m

The co-ordinates of the junction point E are given by the formulae

$$P = L\left(1 - \frac{3S}{5R}\right)$$

$$= 25\left(1 - \frac{3 \times 1.042}{5 \times 25}\right) = 24.375\text{m}$$

$$q = \frac{L^2}{6R}\left(1 - \frac{L^2}{56 R^2}\right) = \frac{25^2}{6x25}\left(1 - \frac{25^2}{56x25^2}\right)$$

= 4.09 m

Radius of circular arc, R1

$= \sqrt{p^2 + q^2}$

$= \sqrt{24.375^2 + 4.09^2}$

= 24.72 m

Thus draw an arc of radius R1 with T as centre.

Step - 9. Chainage of E' = Chainage of E + length of circular curve

= 25 + 7.726 m

= 32.726 m

Step - 10. Chainage of end point T' =

chainage of E' + length of Transition curve

= 32.726 + 25

= 57.726 m

With T'as centre draw an arc (x' y') of radius

R1 = 24.72 m (as worked out in step 8)

LOCATION OF POINTS E & E'

Step - 11. The Deflection angle a = $\frac{5731^2}{RxL.}$ minutes

for E & E', l = L

we have α = $\frac{573\ L}{R}$ minutes

L = 25 m & R = 25 m

$\alpha_e = 573 \times \frac{25}{25}$

$\alpha_e = \alpha_{e'}$ - 573 minutes

= 9^0 33' 0"

Set the angles ∠BTM = ∠BT' M' = 9^0 33' 0"

and extend the line TM & T'M' to meet arc xy & x' y' at points E & E' respectively

LOCATION OF INTERMEDIATE POINTS ON TRANSITION CURVES

Step - 12. The deflection angle α = $\frac{573l^2}{RxL.}$ minutes

= $\frac{5731^2}{25 \times 25}$ = $0.9168l^2$

Chainage of T = 0.00

Chainage of first point = 8 m, l_1 = 8 m, $\alpha_1 = 0.9168 \times 8^2$

= 58.67 minutes

= 0^0 48' 41"

Chainage of second point = 16 m, l_2= 16m, $\alpha_e = 0.9168 \times 16^2$

= 234.7008 minutes

= 3^0 53' 42"

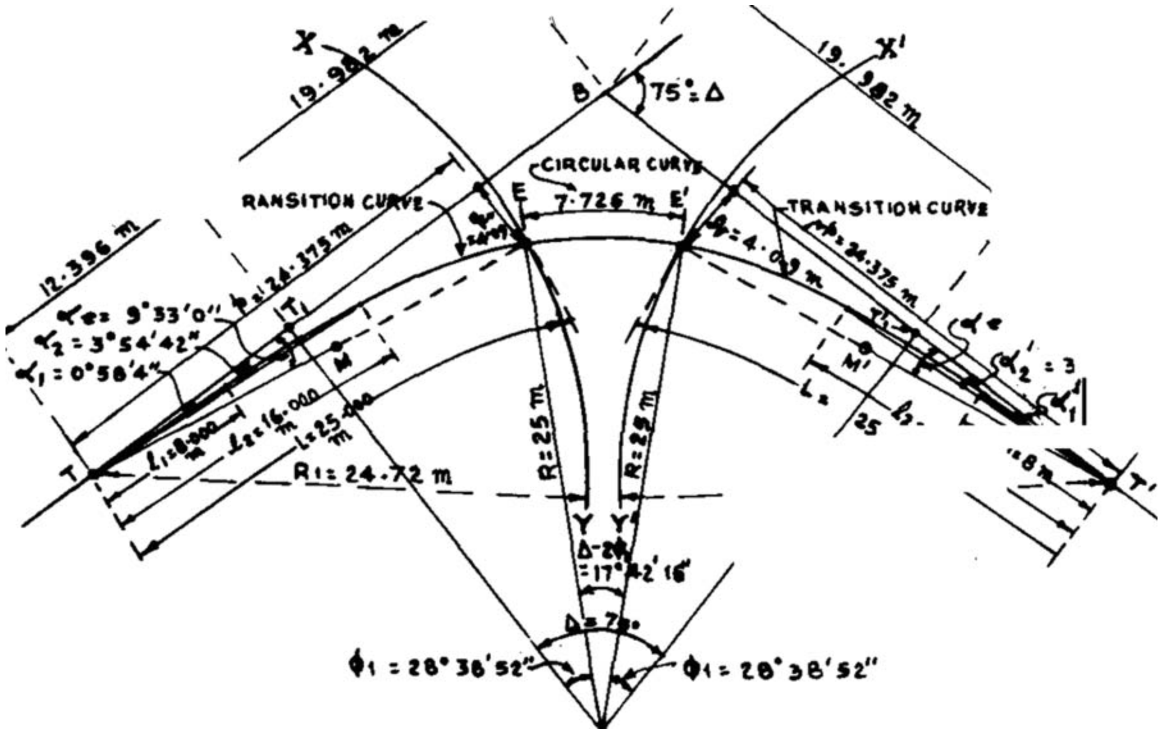


Fig-A10: Combined Curve

Chainage of third point = 25 m, l_3 = 25 m, $\alpha_3 = 0.9168 \times 25^2$

= 573 minutes

= 9^0 33' 0"

Step-13 Fix the intermediate points on both the transition curves by setting out these angles by a theodolite and measure and distances l_1, l_2 etc.

Step-14 Set up the circular curve as explained in para 5/7

IRC PUBLICATIONS PERTAINING TO GEOMETRIC STANDARDS OF ROADS FOR REFERENCE

1.	IRC:3-1983	Dimensions and Weights of Road Design Vehicles (First Revision)
2.	IRC:11-2015	Recommended Practice for the Design and Layout of Cycle Tracks Type (First Revision)
3.	IRC:12-2016	Unified Guidelines for Access Permission to Fuel Stations, Private Properties, Rest Area Complexes and Such Other Facilities Along National Highways (Fourth Revision)
4.	IRC:32-1969	Standard for Vertical and Horizontal Clearances of Overhead Electric Power and Tele communication Lines as Related to Roads
5.	IRC:38-1988	Guidelines for Design of Horizontal Curves for Highways and Design Tables (First Revision)
6.	IRC:39-1986	Standards for Road-Rail Level Crossings (First Revision)
7.	IRC:41-1972	Guidelines for the Designs for Check Barriers (First Revision)
8.	IRC:52-2019	Guidelines for the alignment Survey and Geometric Design of Hill Roads (Third Revision)
9.	IRC:54-1974	Lateral and Vertical Clearance at Underpasses for Vehicular Traffic
10.	IRC:62-1976	Guidelines for Control of Access on Highways
11.	IRC:64-1990	Guidelines for Planning and Design of Road in Rural Areas (First Revision)
12.	IRC:65-2017	Guidelines for Planning and Design of Road about (First Revision)
13.	IRC:66- 1976	Recommended Practice for Sight Distance on Rural Highways (First Revision)

14.	IRC: 69-1977	Space Standards for roads in Urban Areas.
15.	IRC:70-2017	Guidelines on Regulation and Control of Mixed Traffic in Urban Areas (First Revision)
16.	IRC:73-1980	Geometric Design Standards for Rural (Non-urban) Highways
17.	IRC:80-1981	The Designs for Pick-up Bus Stops on Rural (i.e. Non-Urban) Highways
18.	IRC:86-2018	Geometric Design Standards for Urban Roads and Streets (First Revision)
19.	IRC: 92-2017	Guidelines for the Design of Interchanges in Urban Areas (First Revision)
20.	IRC: 98-2011	Guidelines on Accommodation of Utility Services on Roads in Urban Areas (Second Revision)
21.	IRC: 103-2012	Guidelines for Pedestrian Facilities (First Revision)
22.	IRC: SP:12-2015	Guidelines for Parking Facilities in Urban Roads (First Revision)
23.	IRC:SP:23-1983	Vertical Curves for Highways