Province Government

Bagmati Province

Ministry of Physical Infrastructure Development

Transport Infrastructure Directorate

Hetauda, Makawanpur

Bagmati Province Road Standard - 2076

January 2020

Hetauda, Nepal

Preamble

Bagmati Province is one of the seven provinces of Nepal, formed on 20 September 2015 in accordance with Schedule 4 of the Constitution of Nepal. It is situated at the central of the country that includes Capital city Kathmandu. The province is located between Tibet (China) in the north and province 2 in the south. The province covers an area of 20,300 sq. km and 13 districts of the 77 districts of Nepal. At the local level, there are 3 metropolitan cities, 1 sub metropolitan, 41 urban municipalities and 74 rural municipalities in this province. The population of the province is 5,529,452 as per the census of 2011.

Bagmati Province Government, Ministry of Physical Infrastructure Development, **Transport Infrastructure Directorate** is responsible for the planning, implementation and maintenance of activities related to provincial roads and bridges within the province. For qualitative and sustainable development of roads and uniformity and consistency in road design process and preparation of detailed project reports of road project, this Provincial Roads Standard, 2076 is prepared.

This Bagmati Province Roads Standard – 2076 aims to present technical advice and guideline to set the basic principle governing the design of all roads within the Bagmati Province. It provides broad guidance on classification of provincial road and selection of basic parameters used for road designing while preparing the detailed project report.

A very special gratitude goes to Mr **Dormani Paudel,** Chief Minister and Minister of Ministry of Physical Infrastructure Development of Bagmati Province and Mr **Tejraj Bhatta,** Secretary, Ministry of Physical Infrastructure Development who gave suggestion about the preparation of this standard. I would also like to acknowledge with much appreciation the crucial role of the Mr **Ranjan Suwal**, senior road engineer, who work actively to prepare this standard. I would like to thank SDE Mr **Navin Kumar Singh**, Er. **Punyaram Sulu**, Er. **Jyanendra Pun**, Er. **Kumar Pudasaini**, Er. **Prawin Karki**, Section Officer **Bhakta Bahadur Bhandari**, Account Officer **Rajesh Thapa** and other collegues for their comments that greatly improved the standard.

Dr. Sahadev Bahadur Bhandari

Acting Director

Table of Content

List of Figures

Abbreviation

ADT= Average Daily Traffic

BPRS= Bagmati Province Road Standard

CL= Centre Line

DoLI= Department of Local Infrastructure

DoLIDAR= Department of Local Infrastructure Development and Agricultural Road

km= kilometre

kmph= kilometre per hour

LOS= Levels of Services

LRN= Local Road Network

m= meters

min= minimum

mm= millimetre

MoPID = Ministry of Physical Infrastructure Development, Bagmati Province

NRRS= Nepal Rural Roads standards

NRS = Nepal Road Standard

PCU= Passenger Car Unit

PRN= Provincial Road Network

RoW= Right of Way

SRN= Strategic Road Network

TID = Transport Infrastructure Directorate, Bagmati Province

1. Introduction

Nepal has entered into a new federal system consisting of three levels of government: Federal government based in Kathmandu, the capital; 7 Province Governments, and 753 Local Governments. Province Government governs the seven provinces of Nepal, which form the second layer of government, between the Federal and Local Government.

Province Government, Bagmati Province, Ministry of Physical Infrastructure and Development (MoPID) is one of the ministries in Bagmati Province to make policy, implement plan, monitor and development of physical infrastructure in the provincial level. Transport Infrastructure Directorate (TID) is the line organisation in the province to implement roads, bridges and trail bridges related development activities within the MoPID.

Transport is simply the means or mode through which people or goods move from one place to another. In today's time, this has become one of the important parts of human life. Roads are major modes composing the land transport system, as it requires less capital investment as compared to other modes of transport.

The road network in Nepal consists of the Strategic Road Network (SRN), managed at the Federal Government, Provincial Road Networks (PRN) managed by the Province Government and Local Road Network (LRN) manage by Local Government.

Design standards currently available related to the road in the country are

- Nepal Road Standard (NRS), 2nd Revision published by Department of Roads in 2070
- Nepal Rural Roads Standard (NRRS), 2nd Revision published by Department of Local Infrastructure Development and Agricultural Roads (DoLIDAR) in 2071
- Nepal Urban Road Standard, Draft published in 2068
- Provincial and Municipal Road Standards, Interim Edition published by Department of Local Infrastructure (DoLI) in January 2019
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This Bagmati Province Road Standard (BPRS) aims to provide guidance for the selection of geometric design parameters during the road design process. This design standard is prepared with the reference of the abovementioned design standard and the best practices of the other relevant road standards.

2. Scope of Use

This design standard covers the various aspects of design, construction and maintenance of provincial roads. The standard is used in new construction as well as in improvements of the Road. The carriageway width, shoulder and other physical parameters are largely based on the projected traffic volume at the end of 20 years of designed life whereas; geometric design parameters are based on the design speed and the topography of the area.

3. Road Classification

As per the Provincial Road Act of Province Government, Bagmati Province, Provincial roads are classified as follows:

3.1 Administrative Classification

- Province Expressway
- Province Highway
- Province Road
- Province Urban Road
- Province Other Transportation modes

3.1.1 Expressway

Expressway is the highway with control entries and exists within the province running two way traffic lane separated by median restricting lateral access to change the lane and no intersection at the grade (elimination of grade crossings). These are developed for high speed traffic flow.

OR

Expressway is a highway especially planned for high-speed traffic, usually having no intersection at a grade, limited points of access or exit, and a divider between lanes for traffic moving in opposite directions.

OR

Province Expressways are those highways that:

- have controlled access and exist;
- have two way traffic lane with median and no grade intersection at a grade; and
- Have restriction in lateral access to change the lane.

3.1.2 Province Highway

Province Highway is the road that connects to national highway with province headquarters or district headquarters, or, that Connects province headquarter with district headquarters, or, connects district headquarter with district headquarter within the same province, or, National highway with national highway.

OR

Province Highways are those roads that:

- Connects district headquarters to a road of equal or higher classification;
- Connects national highway to province headquarter (capital);
- Connects national highway to national highway.

3.1.3 Province Road

Province Road means the road that connects local centre with national highway or province highway or district headquarters, or, road connecting two or more local centres, or, national highway and province highway connected with important market places, religious places, historical, touristic and other important places.

OR

Province road are those road that:

- Connects local centres to a road of equal or higher classification;
- Connects national highway and province highway with important market places, religious places, historical, touristic and other important places.

3.1.4 Province Urban Road

An Urban Road is a road located within the boundaries of a built-up area in a province that does not include in any other types of roads above.

3.1.5 Province Other Transport

Rail Transport, Air Transport, Water Transport, cable car etc. fall under this class.

This standard covers on province expressway, province highway, and province road. The other classes are covered by separate standards.

3.2 Functional Classification

Based on the projected traffic in 20 yrs expressed in Average Daily Traffic (ADT), Provincial Roads are classified as from Class I to IV.

3.2.1 Class I

Class I roads are the roads with ADT of 10,000 PCU or more in 20 yrs perspective period.

3.2.2 Class II

Class II roads are the roads with ADT of 5,000 - 10,000 PCU in 20 yrs perspective period.

3.2.3 Class III

Class III roads are the roads with ADT of 1,000 - 5,000 PCU in 20 yrs perspective period.

3.2.4 Class IV

Class IV roads are the roads with ADT of less than 1,000 PCU in 20 yrs perspective period.

4. Traffic Characteristics

4.1 Vehicle Dimensions

The maximum dimensions of vehicles considered for design of roads in a Province are as follows:

Table 4-1: Vehicle Dimensions

Maximum Width, m	2.50
Maximum Height, m	4.75
Maximum Length, m	18.00
Maximum single axle load, kN	100

4.2 Equivalency Factors

It is not feasible to improve the standard of a road by very small increments and it is a standard practice to design and construct new roads and improvement works to withstand the estimated traffic at some future date.

In Nepal this forward period (perspective period) shall be 20 years, i.e. roads shall be designed with a capacity sufficient to cater for the estimated traffic volume 20 years after the date of completion of the works.

Different types of vehicles take up differing amounts of road space and have different speeds (For geometric design) and impose differing loads on the road structure (For structural design).

It is, therefore, necessary to adopt a standard traffic unit to which other types of vehicles may be related.

For geometric design of roads this standard is the 'Passenger Car Unit (PCU)' which is that of a normal car (passenger car), light van or pick-up. Other types of vehicles are taken into account by multiplying by the following equivalency factors.

Table 4-2: Vehicle Types, Equivalency Factors

SN	Vehicle Type	Equivalency Factor
1	Car, Auto Rickshaw, SUV, Light Van and Pick Up	1.0
2	Light (Mini) Truck, Tractor, Rickshaw	1.5
3	Truck, Bus, Minibus, Tractor with trailer	3.0
4	Bicycle, Motorcycle	0.5
5	Non-motorized carts	6

5. Level of Service

Level of Service can be categorised as follows:

- Level of Service A: Free-flow traffic with individual users virtually unaffected by the presence of others in the traffic stream.
- Level of Service B: Stable traffic flow with a high degree of freedom to select speed and operating conditions but with some influence from other users.
- Level of Service C: Restricted flow that remains stable but with significant interactions with others in the traffic stream. The general level of comfort and convenience declines noticeably at this level.
- Level of Service D: High-density flow in which speed and freedom to maneuver are severely restricted and comfort and convenience have declined even though flow remains stable.

- Level of Service E: Unstable flow at or near capacity levels with poor levels of comfort and convenience.
- Level of Service F: Forced traffic flow in which the amount of traffic approaching a point exceeds the amount that can be served. LOS F is characterized by stop-and-go waves, poor travel times, low comfort and convenience, and increased accident exposure.

Among six Levels of Services (LOS) viz. 'A' to 'F' it is recommended to adopt a LOS 'B' for the design capacity of roads.

Under this condition, traffic will experience congestion and inconvenience during some of the peak hours, which may be acceptable.

Design capacity governs the number of lanes required for the design volume of traffic.

At the level of service B, volume of traffic will be around 45 percent of maximum capacity under mixed traffic condition. Design traffic volume should be taken as the volume at the end of the design life considering the equivalency factors.

6. Terrain Classification

Road design needs to ensure the economic justification and the preservation of nature by adaption road alignment to the natural terrain.

Terrain is classified based on the percent cross slope along the road alignment in percentage slope and short stretches of varying terrain is ignored during the terrain classification.

Table 6-1: Terrain Classification

Terrain Type	Plain	Rolling	Mountainous	Steep
Percent Cross Slope	0-10	> 10-25	>25-60	>60
Degree	0o – 5.7o	> 5.7o – 14o	> 14 o – 31o	> 31o

7. Design Speed

Design speed is a selected speed used to determine the various geometric features of the roadway. The assumed design speed should be a logical one with respect to the topography, anticipated operating speed, the adjacent land use, and the functional classification of the highway. The design speed to be adopted for various classes of roads is given in Table 7-1. But in very difficult terrains and unavoidable circumstances design speed can be reduced to 75% of the values given on the Table 7-1.

Table 7-1: Design Speeds, kmph

Road Class	Plain		Rolling		Mountainous		Steep		Functional Classification
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	
I	120	100	100	80	80	60	60	50	Expressway
II	100	80	80	60	60	40	40	30	Expressway Highway
III	80	60	60	40	40	30	30	25	Highway Road
IV	60	40	40	30	30	20	20	20	Road

8. Sight Distance

The visibility of the road ahead of the driver (sight distance) is necessary as it helps in the safe and efficient operation of the vehicles. Sight distances are usually governed by the distance required for stopping (stopping distance) and overtaking (overtaking distance).

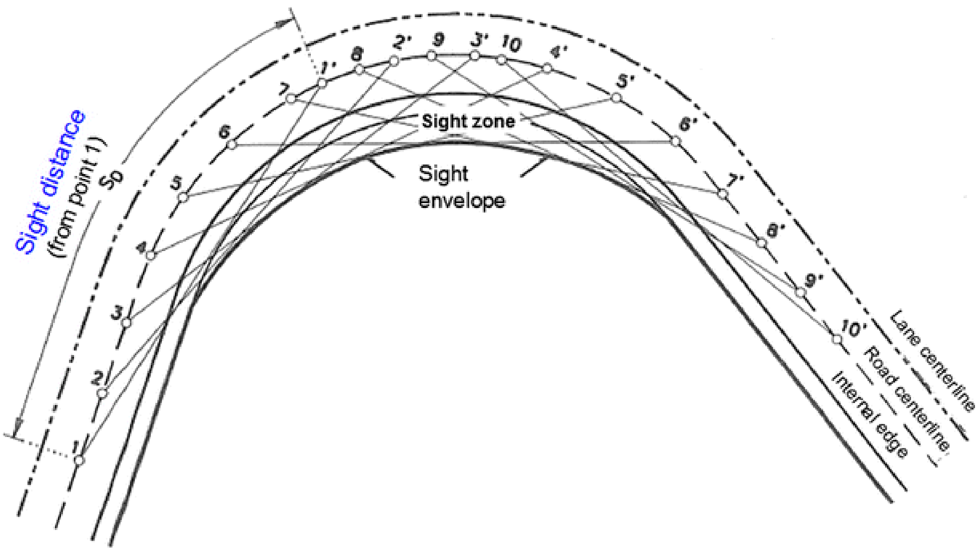


Figure 8-1: Sight Envelope along the Horizontal Curve

8.1 Stopping Distance

Stopping distance is the distance that the driver must be able to see ahead along the roadway while travelling at or near the design speed and to safely stop before reaching an object whether stationary or not.

Stopping distance for various speed are given in Table 8-1.

Table 8-1: Stopping Distance

Speed, kmph	20	30	40	60	80	100	120
Stopping Distance, m	20	30	50	80	130	190	260

8.2 Overtaking Distance

Overtaking sight distance is the minimum distance available for the driver to safely overtake the slow vehicle in front of him by considering the traffic in the opposite direction. This distance will make driver to see whether the road is clear to undergo an overtaking movement. Overtaking distances for various design speeds are given in Table 8-2.

Table 8-2: Overtaking Distance

Speed, kmph	30	40	60	80	100	120
Minimum Overtaking Distance, m	100	165	300	470	640	880

8.3 Application of Sight Distance Standards

Normally attempts should be made to provide a sight distance equal to the overtaking distance in as much length of the road as possible. Where this is not feasible, a sight distance equal to twice the stopping distance should be made available.

In no case should the visibility of the road ahead be less than stopping distance for multi lane roads (>=2 lanes) and twice the stopping distance for single lane roads.

It is always recommended to provide visibility of road ahead to as much distance as possible.

For calculating the visibility of the road, the driver's eye is assumed to be located at 1.2 m above the road surface and any object lying on the roads surface to be 0.15 m high.

8.4 Overtaking Zones

In stretches of roads where sufficient overtaking sight distance cannot be provided or on single lane roads where overtaking or crossing opportunity is not available, overtaking or passing zones shall be provided.

The width of the overtaking zone shall be the same as that of a minimum two lane road.

Length of the overtaking zone shall be at least 3 times the overtaking distance on two and more lane roads.

On single lane roads length of passing zones shall be at least 2 times the overtaking sight distance.

On single lane roads overtaking/passing lanes should be provided at no more than 1km interval.

The start and end of overtaking zone shall be well informed by placing appropriate signs at least stopping distance before the start and end of the zone.

9. Horizontal Alignment

9.1 Radius of Horizontal Curves

Minimum recommended values of radius of horizontal curves for various design speeds are given below. However, as far as site conditions permit largest possible values of radius should be used.

Table 9-1: Minimum Radius of Horizontal Curves

<table>
<tr><th colspan="4" rowspan="2">Road Class</th><th rowspan="2">Design Speed, kmph</th><th colspan="3">Minimum Recommended Radius, m</th></tr>
<tr><th>When no superelevation provided (2.5% camber i.e. negative superelevation)</th><th>When Maximum Superelevation of 10% provided</th><th>From the comfort criteria of passengers(Max lateral force 15% of vertical force)</th></tr>
<tr><td rowspan="4">I</td><td></td><td rowspan="2"></td><td rowspan="3"></td><td>120</td><td>1730</td><td>600</td><td>760</td></tr>
<tr><td rowspan="4">II</td><td>100</td><td>870</td><td>370</td><td>530</td></tr>
<tr><td rowspan="4">III</td><td>80</td><td>440</td><td>210</td><td>340</td></tr>
<tr><td rowspan="4">IV</td><td>60</td><td>200</td><td>110</td><td>190</td></tr>
<tr><td rowspan="3"></td><td>40</td><td>70</td><td>40</td><td>90</td></tr>
<tr><td rowspan="2"></td><td>30</td><td>30</td><td>20</td><td>50</td></tr>
<tr><td></td><td>20</td><td>20</td><td>10</td><td>30</td></tr>
</table>

Some theoretical background for the selection of radius of horizontal curve is given in annex III.

9.2 Transition Curves or Spirals

Transition curves are necessary to allow a vehicle smoothly enter the circular curve from straight section and vice versa.

All horizontal curves with radius less than 1000m should be provided with transition curves.

When circular curves of very large radius (>1000m) are provided the effect of transition from straight section to circular section becomes negligible and no transition curves are provided.

Clothoid curves (Euler's spiral) with curvature changing linearly with the length are used for transition curves.

Minimum length of transition curves should be as shown in Table 9-2.

Table 9-2: Length of Transition Curves

Radius, m	20	30	50	60	80	100	150	200	250	300	400	500	1000
Length of transition curve, m	20	30	35	40	45	50	60	70	80	90	100	110	120

When the shift value of the transition curve is less than 0.25 m no transition curve need to be provided.

Details of combined circular and transition curves are given in Annex III

9.3 Hair Pin Bends

In hilly areas, it may become difficult to avoid bends where the direction of the road reverses. Design criteria for such bends, commonly known as hair pin bends, are given below in Table 9-3.

Table 9-3: Hair Pin Bends Design Parametres

Minimum design speed	20 kmph
Minimum Radius of curvature	15m
Minimum length of transition curve	15m
Maximum longitudinal gradient	4%
Maximum superelevation	10%

A minimum distance of 60m should be provided between successive bends of consecutive hair pin bends.

At hair pin bends it is preferable to pave the road to the full width of the roadway.

9.4 Extrawidening

When a vehicle negotiates a horizontal curve the rear wheels do not exactly follow the path of the front wheels. Their path is shifted towards the centre of the curve in relation to the front wheels path.

In curves, the drivers of the vehicles have a tendency to keep a greater clearance between them as compared to the straight sections of the road.

For the reasons mentioned above the width of carriageway of roads at the curves is made wider than on the straight sections.

Value of extrawidening is adopted as shown below in Table 9-4.

Table 9-4: Extrawidening on Curves

Radius of curve, m		20	20-40	40-60	60-100	100-300	>300
Extra width, m	Single lane road	0.9	0.6	0.6	Nil	Nil	Nil
	Double lane road	1.5	1.5	1.2	0.9	0.6	Nil
	Multi lane (n- lane) road	0.75n	0.75n	0.6n	0.45n	0.3n	Nil

Extrawidening should be introduced gradually at an approximately uniform rate along the transition curve. On curves having no transition two third of it should be attained before the start of the circular curve and one third on the curve.

Extrawidening shall be applied on both sides of the carriageway, except that on hill roads it will be preferable if the entire widening is done only on the inside. Similarly, the widening should be provided only on the inside when the curve is plain circular and has no transition curve.

9.5 Set-Back Distance at Horizontal Curves

Adequate sight distance should be available across the inside of horizontal curves. Distance from the road centre line within which the obstructions should be cleared to ensure the needed visibility i.e. the "set-back distance", can be calculated from geometrical considerations as shown in Figure 9-1.

The set-back distance is calculated as follows:

$$\boldsymbol{m = R - (R - n)\cos\theta} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \textbf{9-1}$$

Where,

$\theta = \frac{S}{2(R-n)}$ Radians

m - Minimum set-back distance to sight obstruction in metres (measured from the centre line of the road)

R - Radius at the centre line of the road in metres

n - Distance between the centre line of the road and the centre line of the inside lane in metres S-sight distance in metres (measured along the centre line of the road)

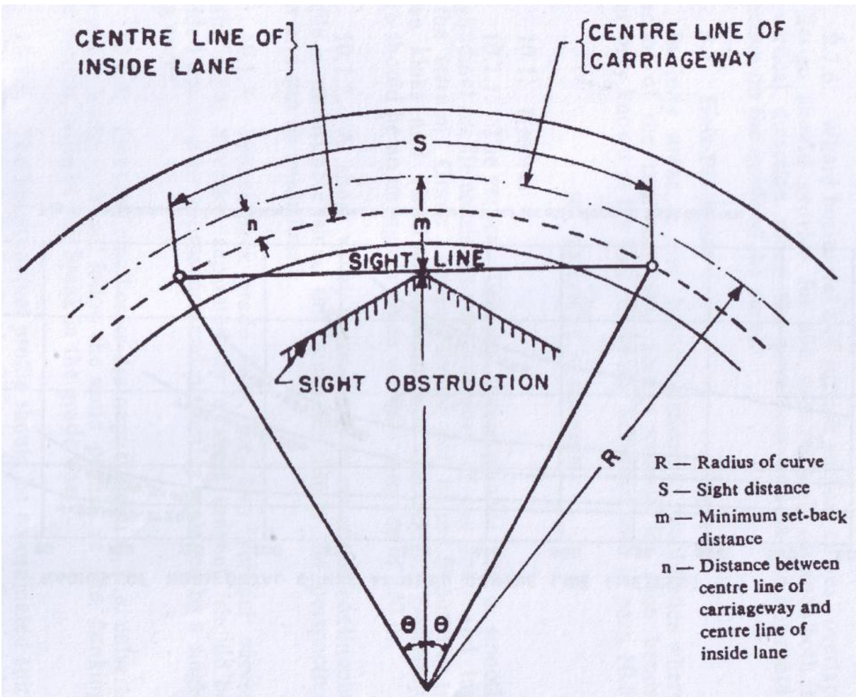


Figure 9-1: Set Back Distance

10. Vertical Alignment

The vertical alignment of the road should provide for a smooth longitudinal profile without any kinks and visual discontinuities in the profile. Grade changes in vertical alignments should be as less frequent as possible.

10.1 Gradients

10.1.1 Maximum gradients

Vehicle operation cost is directly related with the longitudinal gradients, and so it is recommended to adopt their values as small as possible.

Right from the early stage of alignment fixing, it should be born in mind that it becomes very difficult to flatten the gradient at later stage.

Maximum gradient depends on the dynamic characteristics of commercial trucks, design speed and maximum allowable reduction in speed during climbing up the gradient.

Considering these factors (weight to power ratio of trucks-120kg/kW, with a maximum reduction of speed by 25 kilometre per hour (kmph) below the design speed) maximum gradients for various design speeds shall be as follows:

Table 10-1: Maximum Gradients

Design Speed, kmph	20	30	40	60	80	100	120
Maximum Gradient,%	12	10	9	7	6	5	4

Minimum longitudinal gradients for longitudinal drainage purpose is 0.5%

10.1.2 Grade Compensations

Maximum value of longitudinal gradient shall be eased by 0.5% for each rise of 500m above mean sea level.

Due to loss of tactive efforts of the vehicle on curves it is recommended to ease the gradients by an amount calculated as follows:

$$\boldsymbol{Grade\ Compensation}\ (\%) = \frac{\mathbf{30 + R}}{\boldsymbol{R}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad \textbf{10-1}$$

Subject to a maximum of 75/R,

Where,

R - Radius in meters (m).

It is not necessary to compensate grades below 4%.

10.1.3 Maximum (Critical) Length of Grade

Maximum length of road with a gradient should be limited to the following values:

Table 10-2: Maximum (Critical) Length of Gradient

Gradient,%	4	5	6	7	9	10	12
Maximum(critical) Length, m	600	450	400	300	200	150	150

11. Road Cross Section Elements

11.1 Carriageway

The standard width of carriageway shall be as shown on the following table. Total width of pavement shall be determined based on the volume of the traffic and capacity of each lane.

Table 11-1: Width of Carriageways, m

Single lane road	Intermediate lane	Multilane pavements width per lane
3.75 (upto 3.0 m in difficult terrain)	5.5	3.5

In case of single lane roads it is recommended to have two treated shoulders on either side to make a total width of 5.5m of treated surface.

11.2 Shoulder

The width of shoulders on either side of the carriageway shall be at least 0.75m. Recommended width of shoulder for various classes of roads is given below in Table 11-2.

For protection of pavement from water percolating under it from shoulder it is recommended to treat at least a 0.50-0.75m wide strip of shoulder near the edge of the pavement with impervious to water surfacing.

If a small gap(<1m) of untreated shoulder is formed between the edge of the pavement and edge of the side drain in hill roads it is recommended to treat this gap with appropriate surface treatment.

Table 11-2: Width of Shoulders, m

Road Class	Class I	Class II	Class III	Class IV
Minimum shoulder width, m	2.5 to 3.75	2.0 to 2.5	1.0 to 2.0	0.5 to 1.5

For mountainous and steep terrains, the above values can be reduced to a minimum value for a lower class of the road but not less than 0.50 m.

It is desirable that the colour and texture of shoulders be different from those of the carriageway.

This contrast serves to clearly define the carriage way at all times, particularly at night and during inclement weather, while discouraging the use of shoulders as additional through lanes.

Very wide shoulders (more than 3.75m wide) are also not desirable due to tendency of vehicles misusing it as a carriageway.

11.3 Medians

For roads with 4 or more lanes, it is recommended to provide medians or traffic separators. Medians should be as wide as possible.

A minimum median width of 5m is recommended. But a width of 3m can be adopted in areas where land is restricted.

In mountainous and steep terrains maximum possible width of median dictated by the topography should be provided. In such situations simple barriers may be provided to function as a median or individual carriageways could be designed at different levels.

On long bridges and viaducts the width of the median may be reduced to 1.5m, but in no case this should be less than 1.2m.

The median should be of uniform width in a particular section of the highway. However, where changes are unavoidable, a transition of 1 in 20 must be provided.

11.4 Formation or Roadway Width

Formation width shall be a total of widths of carriageways, medians and shoulders as discussed in previous paragraphs.

11.5 Camber

All straight sections of roads shall have a camber or cross fall as given on the Table 11-3.

On roads with undivided carriageways, the camber shall be on both directions from the centre line of the road. On roads with divided carriageways, unidirectional camber can be provided.

However, on some sections of hill roads with undivided carriageway a unidirectional camber can be adopted. In this case the adverse effect of negative camber on movement of vehicles on curves should be properly checked.

Table 11-3: Camber, %

Pavement type	Cement Concrete	Bituminous	Gravel	Earthen
Camber, %	1.5 to 2.0	2.5	4.0	5.0

On straight sections of roads, shoulders should have a higher crossfall than that of the carriageway by 0.5%.

11.6 Superelevation

Superelevation is provided on horizontal curves. Value of super elevation is calculated using following formula:

Where,

$$e = \frac{V^2}{127R} - f \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \textbf{11-1}$$

e - Value of superelevation, m/m

R - Radius of horizontal curve

V - Design Speed, kmph

f - co-efficient of lateral friction, depends on the vehicle speed and taken as in Table A-4:.

Maximum superelevation to be provided is limited to:

In plain and rolling terrain	7%
In snow bound areas	7%
In hilly areas not bound by snows	10%

Minimum value of superelevation should be equal to the rate of camber of the pavement.

The rate of introduction of superelevation (i.e. longitudinal grade developed at the pavement edge compared to through grade along the centre line) should be such as not to cause discomfort to travelers or to make the road unsightly.

Rate of change of the outer edge of the pavement should not be steeper than 1 in 150 in plain and rolling terrain and 1 in 60 in mountainous and steep terrain in comparison with the grade of the centre line.

11.7 Side Slopes

Side slopes of embankment and cuttings depend on the type of fill/cut materials and height/depth of filling/cutting.

Recommended side slopes for embankments are given below. But wherever possible flatter slopes are recommended for aesthetic reason and traffic safety.

Table 11-4: Embankment Side Slopes

Height, m	Side Slope(vertical: horizontal)
<1.5	1:4
1.5-3.0	1:3
3.0-4.5	1:2.5
4.5-12.0	1:2

Height, m	Side Slope(vertical: horizontal)
>12.0	Design specially

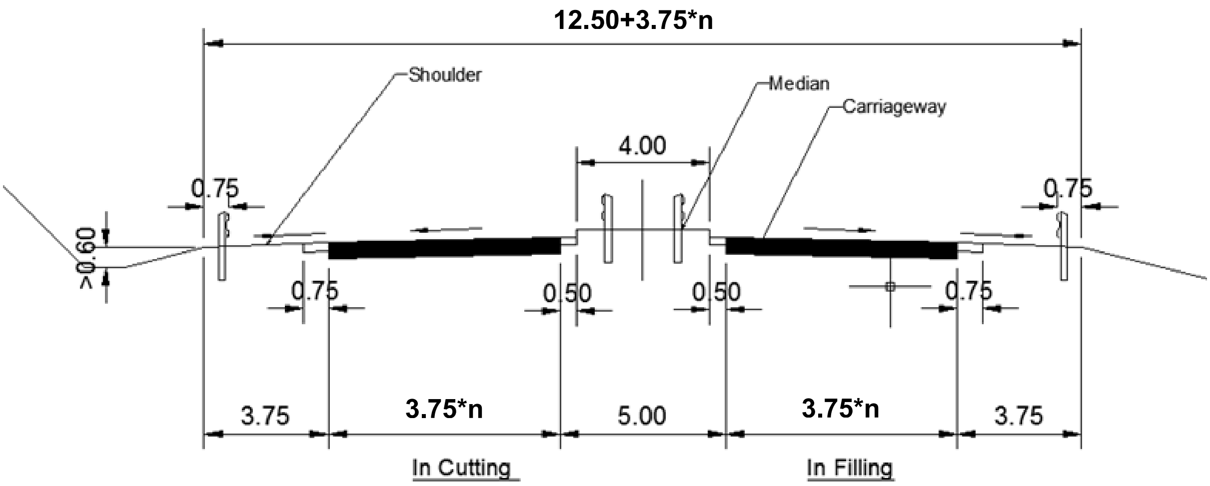
If natural cross slope of the ground is more than 1:5 then the ground should be cut with more than 2m wide horizontal steps.

Recommended values of side slopes in cutting are given in Table 11-5.

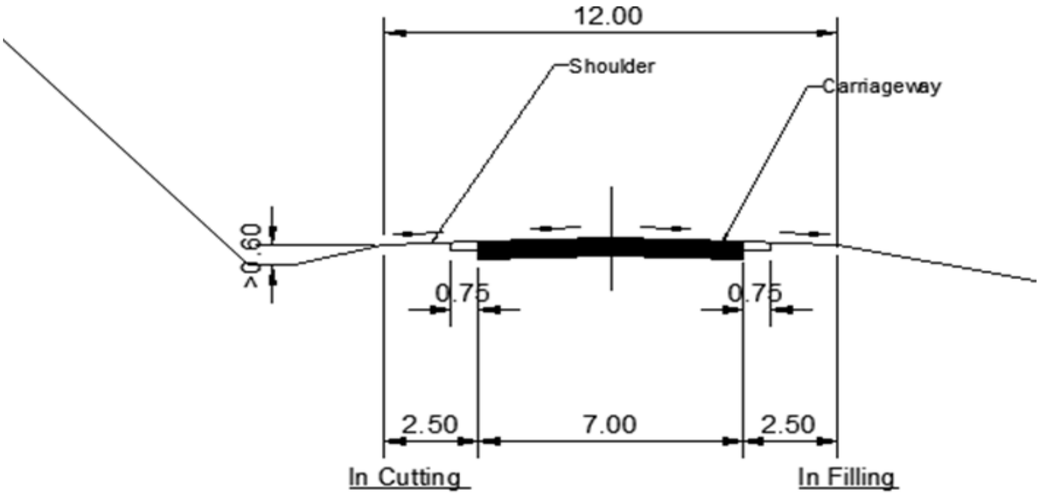
Table 11-5: Cuttings Side Slopes

Soil type	Side Slope (Vertical : Horizontal)
Ordinary Soil	1:2 to 1:1
Disintegrated rock or conglomerate	1:$^1/_2$ to 1: $^1/_4$
Soft rock, shale	1: $^1/_4$ to 1: $^1/_8$
Medium Rock	1: $^1/_{12}$ to 1: $^1/_{16}$
Hard Rock	Almost vertical

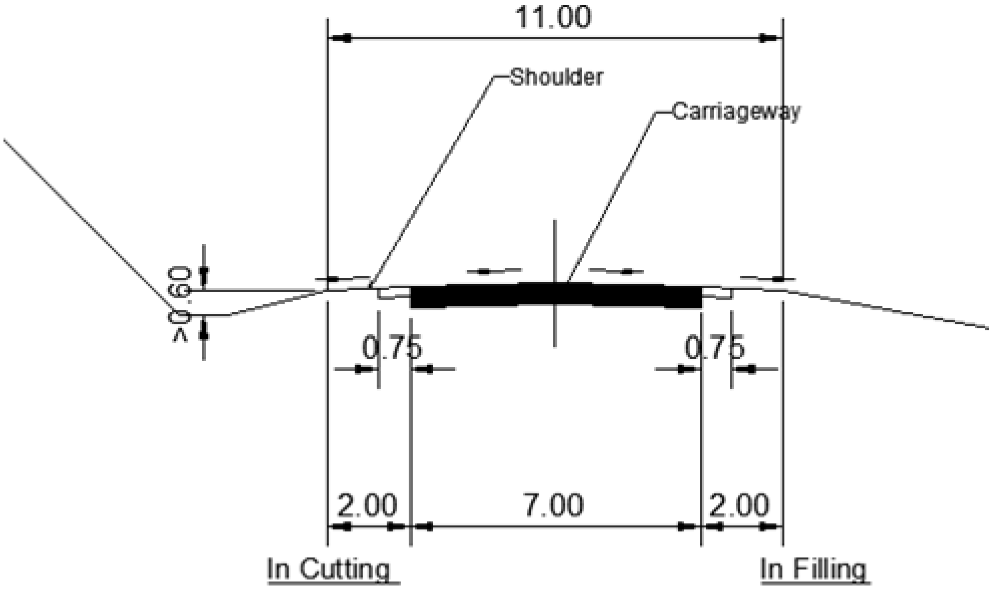
11.8 Typical Cross Section



CROSS SECTION OF CLASS I ROAD(n=2,3...)



CROSS SECTION OF CLASS II ROAD



CROSS SECTION OF CLASS III ROAD

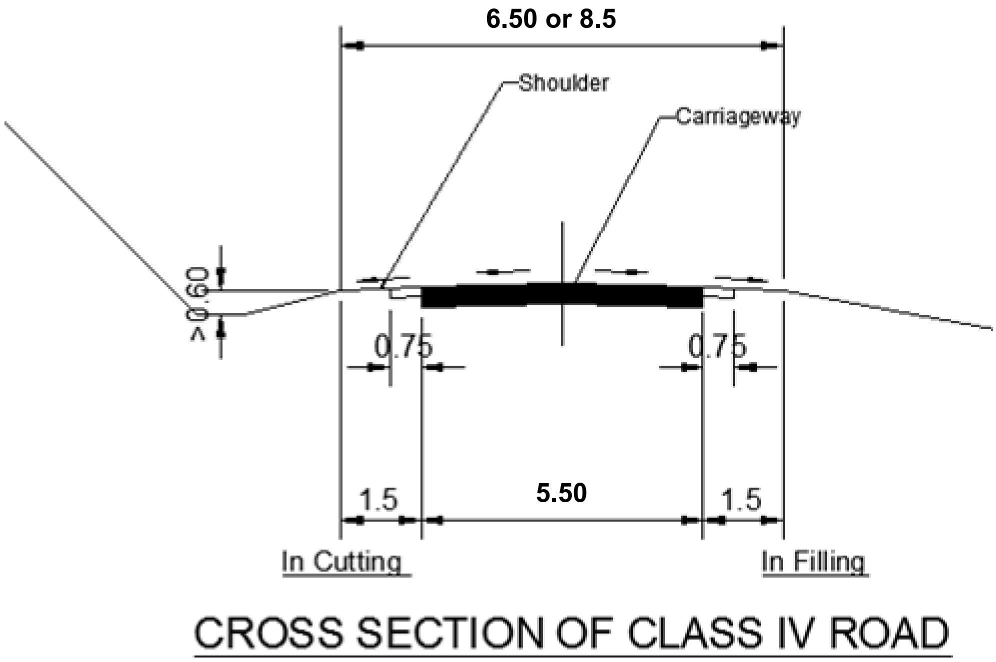


Figure 11-1: Cross Section of Roads

11.9 Right of Way and Clearance

11.9.1 Right of Way

Right of way for different types of roads shall be as follows:

Table 11-6: Right of Way

Road Class	Total Right of Way, m
Class I	42
Class II	30
Class III	24
Class IV	20

11.9.2 Lateral Clearances

a. For a single carriageway road that goes through an underpass, whole width of the roadway (carriageway plus shoulder widths) should be cleared in lateral direction.

b. If footpaths are provided minimum lateral clearance should be width of footpath plus 1.0 m.

On roads with divided carriageway, left hand side lateral clearance should be as given on (a.) and (b.) above.

Right hand side clearance should be 2.0 m (desirable) with 1.5 m minimum.

11.9.3 Vertical Clearances

A vertical clearance of 5.0 m measured from the crown of the road surface shall be provided for whole roadway width on all roads. No obstructions shall be made on this space.

Vertical clearance for high voltage electric cables from the road surface shall be as shown in Table 11-7.

Table 11-7: Vertical Clearances for Electric Wires and Cables

Voltage, kV	Minimum Vertical Clearance, m
1	6
110	7
132	7.5
220	8
330	8.5
550	9
720	16

12. Traffic Signs and Safety

All traffic signs and road markings shall be as per the prevailing guidelines of government agency (TID, DoR etc.).

13. Miscellaneous Road Appurtuances

13.1 Guard Rails and Safety Barriers

Guard Rails and safety barriers are provided in places where serious damage to vehicle and people may occur when an out of control vehicle may leave the roadway or hit other objects.

Road edge barriers are provided near the edge of the road with steep slopes (more than 1:4) or there is a drop of more than 3 m or on the outer edge of sharp horizontal curves to protect the vehicles from falling off.

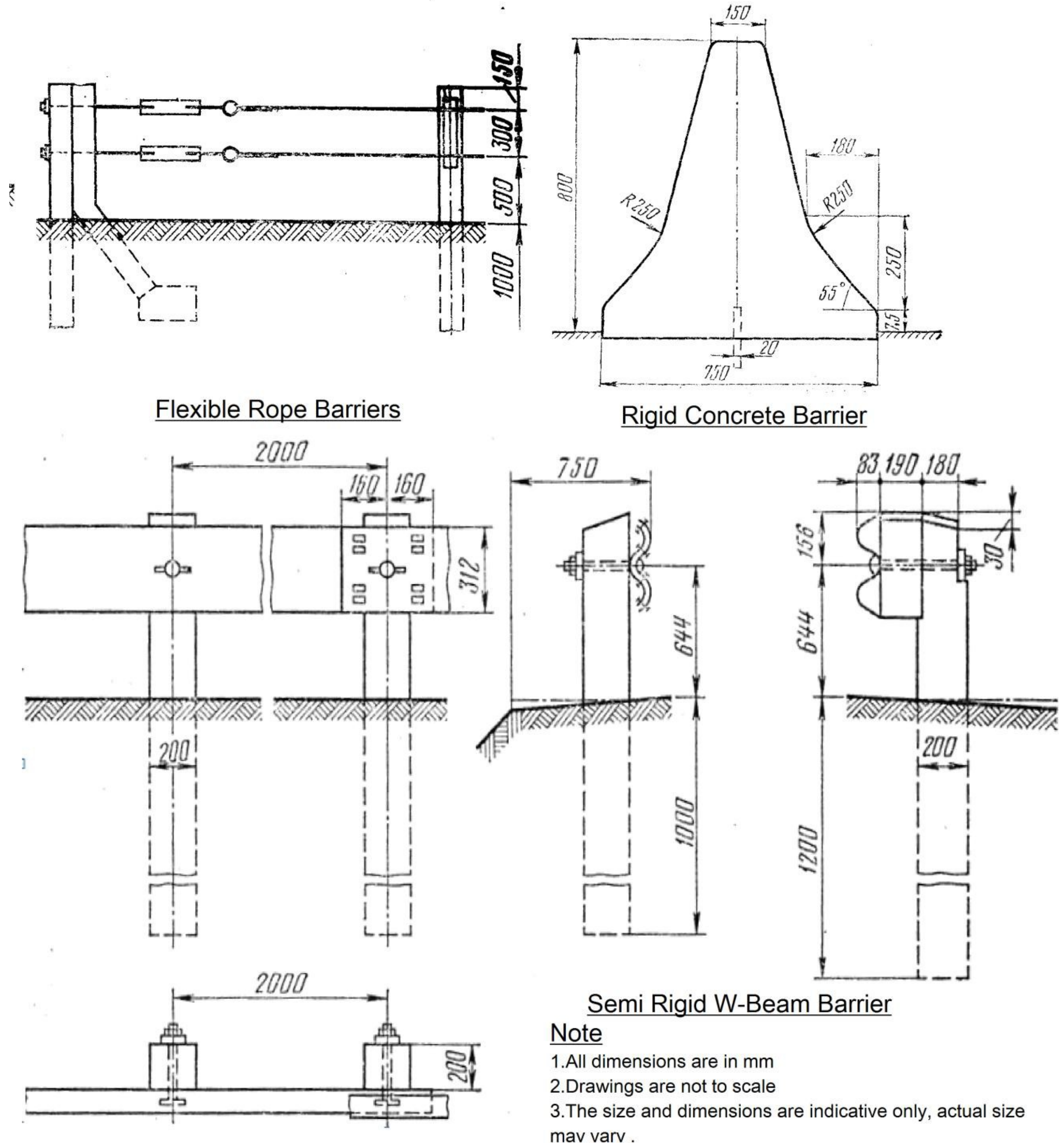


Figure 13-1: Safety Barriers

They are provided to protect the vehicle from hitting roadside objects e.g. overhead bridge piers, large sign posts, large trees, walls, ends of bridge parapets located near the edge of the carriageway.

Usually flexible type steel wire rope barriers or semi-rigid type steel beam barriers or rigid type RCC barriers are used as barriers.

Median Barriers are provided along the edge of medians on divided highways to protect the traffic on both carriageways to cross-over the median and prevent head-on collisions or hitting other objects on the medians.

Road Safety Notes published by the Government Agencies of Nepal should be consulted for selection and installation of safety barriers.

13.2 Road Humps

No road humps shall be provided on road located in non urban areas. They can be provided on slow speed roads (speed <30 kmph, only on class IV roads) on some urban areas if their necessity is justified.

The width of the hump shall not be less than 3.7m.It should have a parabolic shape as shown on the figure with maximum height of 0.1m at the crown.

The faces of the humps shall be painted with 200 mm wide alternating black and white stripes at 45 deg slopes.

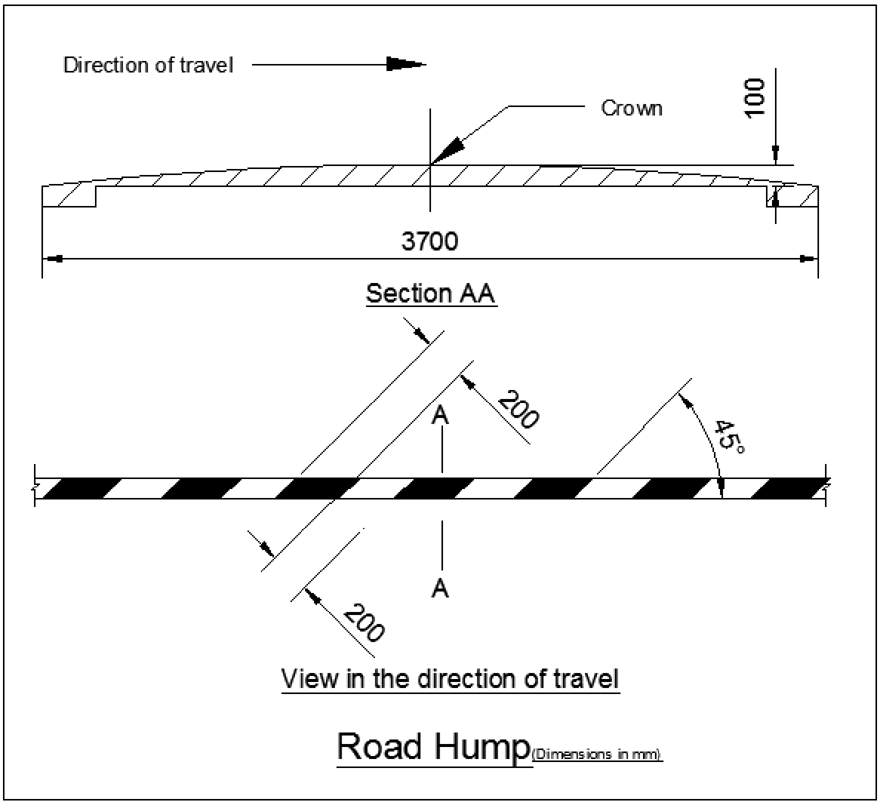


Figure 13-2: Road Hump

13.3 Bicycle Tracks

In all roads with ADT of more than 4000 PCU and movement of bicycles more than 1000 nos/day bicycle tracks should be constructed. The minimum width of each lane of the bicycle track should be 1.2m for each direction of movement.

The track should be constructed on a separate formation or at least 1 m away from the edge of the roadway.

13.4 Pedestrian Facilities

13.4.1 Footpaths

Provision of footpaths should be made on all roads passing through populated areas.

On high traffic non-urban roads footpaths should be constructed outside of the roadway on separate formation or buffer areas should be established so as to separate them from the carriage way.

Width of the footpath depends on the volume of anticipated pedestrian traffic. But a minimum width of 1.5 m is required.

In case of narrow footpaths(<1.8m wide) a passing zone of a minimum width of 1.8m and length of 2.0 m is to be provided at every 50m or less for passing of two wheelchairs.

The minimum width of footpaths for various volumes of pedestrian traffic should be as shown in Table 13-1

Table 13-1: Width of Footpath

Hourly Design Flow (both ways) of 15 min peak period	Footpath width, m
Upto 500	1.5
500-1500	2.0
1500-2500	2.5
2500-3500	3.0

13.4.2 Pedestrian Crossings

Grade separated pedestrian crossings should be provided where pedestrian volume, traffic volume, intersection capacity, and other conditions favour their use, although their specific location and design require individual study.

They may be warranted where there are heavy peak pedestrian movements, such as at central business districts, factories, schools, or athletic fields, in combination with moderate to heavy vehicular traffic or where unusual risk or inconvenience to pedestrians would otherwise result.

Overpass/underpass crossings should be easier to use (than directly crossing the road), well lighted to enhance the sense of security and well ventilated (especially on long underpasses).

Walkways for pedestrian separations should have a minimum width of 2.5 m. Greater widths may be needed where there are exceptionally high volumes of pedestrian traffic.

Overpasses should have a minimum vertical clearance of 5.0m and underpasses 2.5m.

All overpass/underpass pedestrian crossings should be provided with ramp for wheelchairs or other alternative measures (e.g. lifts) for comfortable movement of disabled people. Maximum grade on the ramps should not be steeper than 8%.

13.5 Bus Lay Bys

To be fully effective, bus lay bys should incorporate

- a deceleration lane or taper to permit easy entrance to the loading area,
- a standing space sufficiently long to accommodate the maximum number of vehicles expected to occupy the space at one time, and
- a merging lane to enable easy re-entry into the carriage way.

A taper of about 5:1, longitudinal to transverse, is a desirable minimum for deceleration lane

The standing space should provide about 15 m of length for each bus.

The width of standing space should be at least 3.0 m and preferably 3.75 m.

The merging or re entry taper may be somewhat more abrupt than the deceleration taper but, preferably, should not be sharper than 3:1.

If bus lay bys are located near the intersections, it is preferable to locate them on departure side (far side) of the intersection.

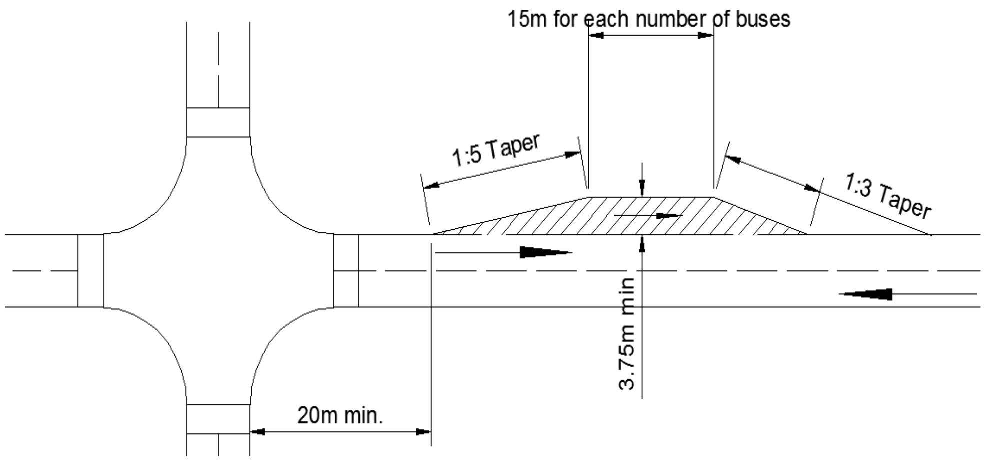


Figure 13-3: Bus LayBys Plan

13.6 Curbs

Curbs are classified as "Barrier" or vertical type (with vertical road side face) and "Mountable" or sloping type (with sloping roadside face).

The height of curbs ranges from 10 to 20 cm.

Barrier curbs are designed to discourage vehicles leaving the pavement. Mountable curbs are provided at medians or channelizing islands.

Vertical curbs should not be used along freeways or other high-speed roads.

Design may vary in shape or size. But they should be good in appearance and strong.

Some recommended designs are shown in Figure 13-4

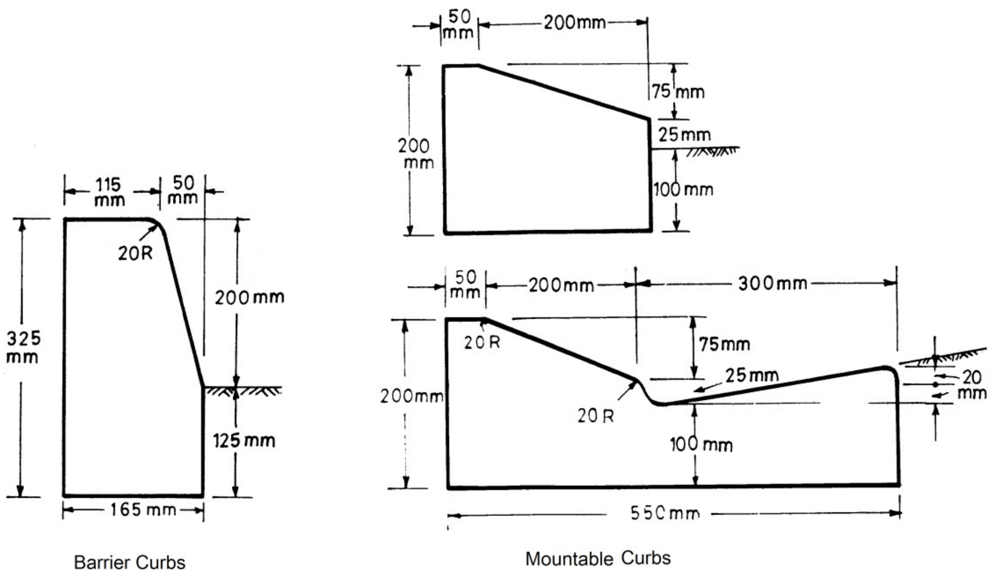


Figure 13-4: Typical Curb Designs

13.7 Road Lighting

Rural highways should be designed with an open cross section and horizontal and vertical alignment of a fairly high type. Accordingly, they offer an opportunity for near maximum use of vehicle headlights, resulting in reduced justification for fixed highway lighting.

Provision of artificial lighting should be made on all roads near populated areas, on major bridges, bus stops, roads and railroads intersections (up to a distance of 250m from the point of intersections), tunnels and approaches to them and toll plazas.

Light mounting poles should be at least 9m high (but mounting heights of 10 to 15 m are usually preferable). They should be located outside the edge of the roadway or on wide central medians.

Level of illumination should be 30 lux on important high speed roads and 15 lux on other main roads.

The ratio of minimum to average illuminations should be about 0.4.

13.8 Road Drainage

For long life of pavement and other components of a highway system, the sub grade should be kept at optimum moisture level and avoided to be over wetted.

Water should be drained away from the road and ground surface as well as under the surface by a system of surface and subsurface drainage.

Surface Drainage

Water is drained from the road surface with adequate camber of both the carriageway and the shoulder.

Road side drains are provided in all cut sections to remove water in the longitudinal direction.

Toe-of-slope road side drains are constructed in low fill (<0.8m filling height) sections to convey water away to water courses

Intercepting or catch water drains are placed on back of the top of cut slopes to intercept surface water. Distance of these drains from the edge of the cutting should not be less than 5m.

Flumes are provided to carry collected water down deep cuts or high fill slopes.

Drains should be provided with minimum 0.5% longitudinal grade.

Trapezoidal shape of drains is preferred.

For calculating design discharge on roadside drains following return periods should be taken.

Table 13-2: Return Periods for Calculating Design Discharges

Road Class	I and II	III	IV
Return Period in years	50	33	25

Outlets from the side drains should be provided at no more than 500m intervals.

Sides and bottoms of the drains should be lined according to the longitudinal slope of the drain as shown in Table 13-3.Size of the drain should be worked out based on the discharge, longitudinal slope and type of lining.

Table 13-3: Type of Lining of Side Drains

Type of lining	Longitudinal slopes,%	
	Sandy Soil	Clayey Soil
No lining required	<1	<2
Grass turfing	1~3	2~3
Stone Rip Rap, masonry, concrete	3~5	3~5
Stepping	>5	>5

Subsurface Drainage

Subsurface water table should always be kept 1 to 1.2 m below the subgrade level to protect pavement layers from excessive moisture.

If it is difficult to achieve the above difference in levels, subsurface drains need to be provided.

To save road subgrade from detrimental effects of moisture from the capillary rise of water a layer of granular materials is provided between the subgrade and the highest level of subsurface water.

Sometimes geotextiles are laid over the subgrade soil to stop the migration of small clay particles upwards that increase the capillary rise of water to the pavement.

Subsurface drains are constructed with 150 mm-200 mm dia perforated pipes with well designed filter material around them and subsequently wrapped by geotextile with adequate longitudinal slopes. Numbers and spacing of subsurface drains should be decided by the design.

14. Access Control

For smooth flow of traffic and reducing ribbon development on non-urban highways number of accesses to it from side roads should be restricted.

No direct access is allowed on class I roads.

If parallel service road (frontage road) is provided the connection from these roads to highways should not be at less than 750m interval.

15. Pavement

The selection of pavement type is determined based on the traffic volume and composition, soil characteristics, weather, performance of pavements in the area, availability of materials, energy conservation, initial cost, and the overall annual maintenance and service-life cost.

Pavement surface type provided should be consistent with the selected design speed for the highway.

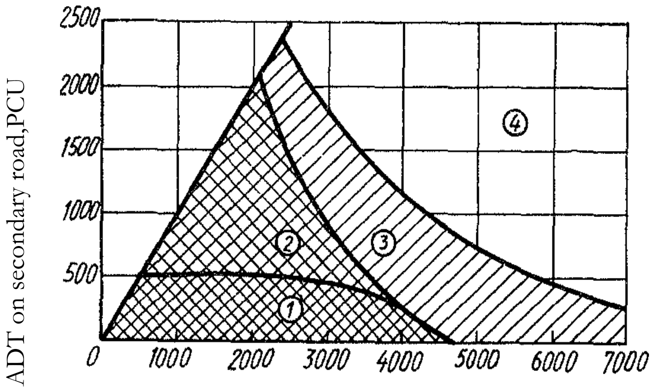
16. Road Intersections

16.1 Types of Intersections

Intersections may be at grade (roads crossing at the same level) or grade separated (roads crossing at different levels).

Grade separated intersections with ramps are called interchanges. They may be simple without any ramps.

- Type of intersection depends on the volume of traffic on crossing roads and angle of crossing.
- Intersection at grade is not allowed when one of the crossing roads is a class I road.
- Roads should cross each other at right angle as far as possible
- Approach sections of intersecting grades should not be steeper than 4%.
- Detailed design for each intersection should be carried out separately.
- For a general guidance following graph can be used to select the type of intersections.



Simple intersection with channelizing islands on secondary road With channelizing islands on both roads Grade separated intersections.

Figure 16-1: Intersection Type Selection

17. Structures

17.1 Bridges, Culverts and Other Cross Drainage Structures

- Cross drainage structures having length of more than 6 m are called bridges. For provincial highways, the total width of bridge shall be 10.5 m(Carriageway width 7.5m +2*1.5m footpath) and for provincial roads, the total width of bridge shall be 8.4 m (Carriageway width 6m +2*1.2m footpath) In the urban area and local roads, the width shall be fixed as per traffic.
- Other cross drainage structures are culverts, causeways (simple) and vented causeways.
- These structures shall be designed and constructed as per prevailing Bridge Standards of government agency (TID, DoR etc.) with revisions, if any.
- The full width for the approach roadway should be provided across all new bridges.

17.2 Retaining Walls

On steep cross slopes of hills, volume of filling may be considerably high and cutting slopes are unstable.

To minimize the volume of fillings and to stabilize the slopes retaining walls are constructed.

Retaining walls are designed to withstand the lateral pressure from the soil or the filling materials so as to be stable against overturning, sliding, foundation failure due to excessive bearing pressure with adequate structural strength.

Vehicle load is replaced by an equivalent surcharge of additional height of filling materials for design.

When the height of retaining walls becomes large, overpass or half-bridges are constructed.

17.3 Road Tunnels

Although road tunnels are very costly, they are often constructed if after rigorous economic analysis they substantially reduce the cost of construction, maintenance and vehicle operation costs of roads especially on hilly areas.

Highway tunnels are usually constructed either by mining method or cut and cover method.

Tunnels are usually constructed with two lanes. In four lane roads two separate two lane tunnels are constructed.

The minimum roadway width between curbs should be at least 0.6 m greater than the approach carriageway, but not less than 7.2 m.

The curb or sidewalk should be 0.5 m minimum on either side of the pavement.

The total clearance between walls of a two lane tunnel should be a minimum of 9 m.

Minimum vertical clearances inside the tunnels should be 5.0m.

Tunnels should be as shortest as possible.

As far as possible tunnels should be constructed with straight horizontal alignment which simplifies the construction, reduces the cost and it is easy to provide adequate sight distance on tunnels.

Vertical alignment of the tunnel should be decided based on the economic balance between construction costs and operating and maintenance expenses.

Ventilation costs depend on length, grades, natural and vehicle-induced ventilation, type of system, and air quality constraints.

Maximum gradient of the road in tunnels should be 4% and minimum 0.4% (From drainage consideration)

Tunnels of length less than 300 m are constructed with one directional gradient and more than 300 m with two way grades with maximum height at the centre.

Tunnels of more than 150m length should be provided with artificial ventilation.

Maximum speed of air inside the tunnels (without considering the motion of air due to movement of vehicles) from artificial ventilation should be 6 m/s.

Tunnels of more than 300 m length on straight sections or 150 m on curved sections of non-urban roads or all tunnels on urban roads should be illuminated with artificial lighting.

Illumination of tunnels at the level of carriageway should not be less than:

30 lux at night ; 400-750 lux during day time near the portals and 30 lux at the middle.

Illumination of tunnels should be changed gradually from entrance to the interior so as to provide smooth light adaptation. To achieve this, sometimes the entrance of the tunnel is located on slight horizontal curvature or covered by gratings.

Minimum and desirable clearances for tunnel are shown in Figure 17-1.

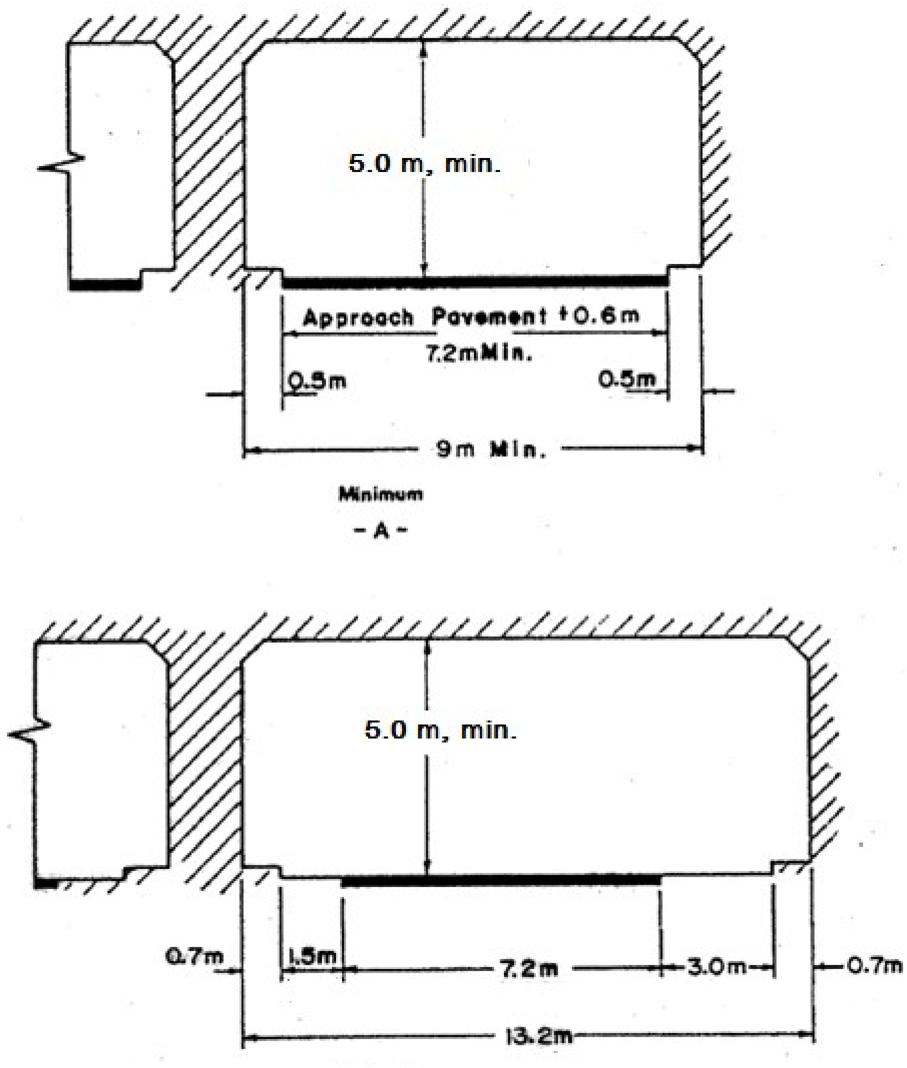


Figure 17-1: Typical Tunnel Clearances

18. Aesthetics and Landscape Design

Following rules for aesthetic and landscape design of highways should be followed during design:

Road alignment should be consistent throughout without any sudden change of design standards.

Radii of curves should be selected as high as possible. Sharp curves should be avoided on high, long fills.

Length of horizontal curves should be long enough to avoid the appearance of a kink.

Parameter A (where A^2=RL, R- radius of horizontal curve, L- length of transition curve) of the clothoid for transition curve should be within 0.4R to 1.4R. Length of transition curve should not be less than ¼ of the length of the circular curve.

Horizontal and vertical alignments of the road should not be designed independently but in coordination with each other so as to produce a smoothly flowing line that is nicely blended with the surrounding ground contour. Proper coordination in this respect will ensure safety, improve utility of highway and contribute to overall aesthetics.

Length of straight sections and curved sections in the plan must be almost equal.

Maximum length of straight sections in plan should be limited to 3-5 km.

Two curves in the same direction separated by a short straight should be avoided.

Compound curves should be avoided as far as possible.

As far as possible horizontal and vertical curves should be overlapped. It is desirable that horizontal curve be slightly longer than vertical curve. The IP"s of horizontal and vertical curves should be offset to a distance not more than ¼ of the length of shorter of these curves.

Sharp horizontal curve should be avoided at or near the apex of the pronounced vertical curves. The minimum radius of the sag vertical curve (100 times K-value) should be at least 6 times the radius of overlapping horizontal curve.

Ends of horizontal curves should not coincide with the beginnings of vertical curves.

Sharp vertical curves at the end of long straight sections or curved sections of large radius should be avoided.

It is recommended to evaluate the spatial smoothness of the designed road by constructing the perspective views simulating the views that would be seen by the driver on the road after construction.

A general rule for the designer is to achieve a "flowing" line, with a natural and smooth appearance on the land, and a sensuous, rhythmic continuity for the driver. This effect results from following the natural contours of the land, using graceful and gradual horizontal and vertical transitions, and relating the alignment to permanent features of the landscape such as rivers or mountains.

In many multilane hill roads, there is a potential for designing a divided highway with independent horizontal and vertical alignments for each direction of traffic with minimization of adverse effects on environment.

19. Roadside Arboriculture

Roadside plantation of trees and shrubs should be encouraged as far as possible on all urban and non-urban roads.

For roadside plantation, ornamental and flowering species are selected.

Trees are usually planted on roadsides and shrubs are planted on medians for good visibility.

Wide crowned trees are not preferred for roadside plantation.

Crown of the trees planted on roadsides should not go beyond the edges of the pavements.

In rural open areas it is desirable to plant trees at a distance of 12 m from the edge of carriageways.

Selection of species and their architectural composition with the surrounding landscape should be entitled to specialized landscape designers, architects and professionals in this field.

20. Environmental Consideration

All roads should be designed and constructed with proper assessment of all Environmental and Social aspects and their impacts.

Environment Protection Acts and Rules of Bagmati Province and Government of Nepal should be followed.

All design elements of highways and roads should properly blend with the surrounding elements of nature.

Road alignment should avoid preserved zones like national parks, historical monuments and other sensitive to flora, fauna and people.

Highways should be located away from the populated areas so as to minimize the disturbance to people from construction activities and noise from moving vehicles.

As far as possible road alignments should be located on wind leeward (opposite to windward) side of the populated areas so as to minimize the effect of dust and smoke pollution during construction and vehicle movement.

Proper provisions of path should be made for migration of animals across the roads located in forest areas. In access controlled highways provisions of under/overpass bridges for movement of people should be made at required intervals.

Provisions of sound barriers should be made on roads passing through populated areas.

Removal of top soil before road construction should be done and used for land recultivation, reclamation and road slope stabilizations.

Bio-engineering techniques should be applied on road slope stabilization.

Road side arboriculture should be implemented.

Road embankments should be constructed using imported materials as far as possible. Road side excavation and burrow pits should not be encouraged especially on highly fertile lands.

Quarries for construction materials should be properly managed and provisions for reinstatement to an acceptable condition should be made in the project.

Dust/smoke producing pavement technology shall not be adopted near populated areas.

21. Roadside Service Facilities

Location and general design of gas filling stations and vehicle charging station along the highways and their spacing should be as per the prevailing government guidelines.

Highway motels, camping stations and technical service centres should be provided preferably at 50-100km distances.

Telephone booths should be provided at least at 20 km distance.

Highway police control rooms, and emergency medical service centres should be provided on highways.

In order to permit the motorists to easily leave the roadway for vehicle inspection, scenic lookouts and rests, a number of lay-bys, parking lots and recreational areas should be provided on highways.

Recreational areas should be set out away from the main highway separating by a dividing strip planted with tall trees that attenuate the vehicular noise from the adjacent highway. They should be located on scenic sites e.g. mountain pass, top of a hill or other sites with pleasant view of nature. They should be provided with wash rooms, public toilets and drinking water facilities.

Annexes

Annex-1. Recommended Design Parameters for Provincial Road Standards

Table A-1: Recommended Design Parameters for Provincial Road Standards

Design Parameter	Province Roads				Remarks
	I	II	III	IV	
Design Capacity, PCU day	>10000	5000-10000	1000-5000	<1000	
Design speed, kmph	P-120 R-100 M-80 S-60	P-100 R-80 M-60 S-40	P-80 R-60 M-40 S-30	P-60 R-40 M-30 S-20	
No. of lanes	4 min	>=2	2	1	
Lane width, m	3.75	3.5	3.5	5.5	
Shoulder width (minimum), m	P,R-3.75 M,S-2.5	P,R-2.5 M,S-2.0	P,R-2.0 M,S-1.0	P,R-1.5 M-0.75 S-0.50	
Median Strip, m	3.50	-	-	-	
Minimum radius of hor. Curve (when super elevation is not provided), m	P-800 R-500 M-300 S-200	P-400 R-250 M-150 S-60	P-250 R-150 M-60 S-30	P-150 R-60 M-30 S-15	
Minimum K- value for vertical curves(Summit/Valley)	P-807/441 R-427/236 M-231/111 S-94/42	P-427/236 R-231/111 M-94/42 S-29/17	P-231/111 R-94/42 M-29/17 S-4/6	P-94/42 R-29/17 M-4/6 S-2/3	
Minimum Gradient	0.5	0.5	0.5	0.5	
Maximum longitudinal gradient,%	P-4	P-5	P-6	P-7	
	R-5	R-6	R-7	R-9	
	M-6	M-7	M-9	M-10	
	S-7	S-9	S-10	S-12	
RoW in both side from Cl	21	15	12	10	
Maximum Super elevation	P,R- 7%, SB-7%, Hill not bound by snow-10%				
Critical Length of Maximum Gradient	P-600	P-450	P-400	P-300	
	R-450	R-400	R-300	R-200	
	M-400	M-300	M-200	M-150	
	S-300	S-200	S-150	S-150	
Cross Slope	As per Pavement Type				

Annex-2. Sight Distance Formulas

a. Stopping Distance

Stopping distance is calculated as a sum of the distance travelled by the vehicle during perception and brake reaction time (first term in equation A- 1) and the braking distance (second term in equation A- 1)

$$s=\frac{Vt}{3.6}+\frac{V^2}{254\varphi}+ \quad \ldots \qquad \textbf{A- 1}$$

Where,

V - Design speed

t - Perception and brake reaction time, taken as 2.5 s

φ - co-efficient of longitudinal friction, depends on the speed (taken as per Table A-2)

Table A-2: Coefficient of Longitudinal Friction

Speed (kmph)	f
20	0.40
30	0.39
40	0.39
60	0.38
80	0.36
100	0.35
120	0.34

b. Overtaking Distance

Overtaking distance is calculated considering the optimum condition in which the overtaking driver can follow 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 of the highway, and returns to his own lane before meeting any oncoming vehicle from the opposite direction travelling at the same speed.

Time components for various maneuvers and corresponding overtaking distances are given below in Table A-3: Overtaking Distance Calculations

Table A-3: Overtaking Distance Calculations

Speed, kmph	Time Components, s			Overtaking Distance, m
	For Overtaking Maneuvers	For Opposing Vehicle	Total	
40	9	6	15	165
60	10.8	7.2	18	300
80	12.5	8.5	21	470
100	14	9	23	640
120	16	10	26	880

Annex-3. Horizontal Curve

Radius of horizontal curve is selected based on the following criteria:

- The centrifugal force developed on the vehicle negotiating a horizontal curve should not be more than the balancing force of friction and superelevation.
- The vehicle should be stable against overturning.
- The road should be visible to a sufficient distance that is illuminated in a horizontal plane by the headlight of the vehicle during night driving time.
- The visibility of the road ahead should not be obstructed by objects on the inner side of the horizontal curve.
- The wear and tear of vehicle tires should be minimum.
- Passengers and drivers of the vehicle should not feel excessive lateral force from the view point of comfort of travel.
- Among all above criteria the first one usually governs in the road design.
- Radius of horizontal curves is decided in such a way that the centrifugal force acting on the vehicle is balanced by superelevation and side friction.

Basic equation for finding the radius of horizontal curve from the condition of equilibrium of centrifugal force, superelevation and friction is given below:

$$\boldsymbol{R} = \frac{\boldsymbol{V^2}}{\boldsymbol{127(e+f)}} \quad \text{A- 2}$$

Where, R-Radius of Horizontal Curves, m

V-Design speed in kmph

Superelevation provided

Co-efficient of lateral friction, depends on the speed (taken as per Table A-4:)

Table A-4: Coefficient of Lateral Friction

Speed (kmph)	f
120	0.09
100	0.12
80	0.14
60	0.17
40	0.23
30	0.28

Speed (kmph)	f
20	0.33

Radius of curve calculated from the above consideration usually gives a very sharp curve. As a consequence passengers travelling on such curves experience discomfort with high lateral force acting on their body.

So where site conditions permit it is recommended that radius of horizontal curve be decided based on the lateral force acting on the passenger caused by the centrifugal force thereby limiting the ratio of lateral to vertical forces to 0.15.

From the consideration of passengers comfort

$$R=\frac{V^2}{20} \quad \text{A- 3}$$

Where,

R - Radius of Horizontal Curve, m

V - Design speed in kmph

a. Elements of a Clothoid

Length of transition curves is decided based on the allowable rate of change of centrifugal acceleration acting on the vehicle so that the driver can steer the vehicle easily from straight section to a circular curve section of the road.

$$\boldsymbol{L = \frac{V^3}{47CR}} \quad \text{A- 4}$$

Where,

L = minimum length of spiral, m;

V = speed, kmph;

R = curve radius, m;

C = rate of increase of lateral acceleration, m/s^3 ($C = \frac{80}{75+V}$, subject to the condition $0.5<C<0.80$)

It is not possible to place a transition curve between straight and circular sections if following condition is not fulfilled

$$\boldsymbol{L \leq \Delta R} \quad \text{A- 5}$$

L - length of the spiral, m

Δ - Deflection angle, in radians

R - Radius of circular curve, m

SinceΔ is always less than π, from the above it follows that

$$L \leq \pi R \quad \ldots \qquad \textbf{A- 6}$$

i.e L cannot be more than πR .

No transition curve is required if the lateral shift (S in Figure A-1) of the circular curve due to transition curve is less than 0.25 m.i.e.

$$\frac{L^2}{24R} \geq 0.25 \quad \ldots \qquad \textbf{A- 7}$$

Where,

L-Length of the, m

R-Radius of circular curve, m

Notations to Figure A-1: Elements of a Transition or Spiral Curve

BC-Beginning of the curve

EC-End of the curve

BCC - Beginning of the circular curve

ECC - End of the circular curve

R - Radius of the circular curve

x_s,y_s - abscissa and ordinate of any point on the spiral(origin of coordinates at tangent point or BC with direction of abscissa towards IP)

l - Length of the spiral from BC to the current point (x_s,y_s)

x_c,y_c - abscissa and ordinate of any point on the circular curve(origin of coordinates at the BCC with direction of abscissa along the tangent at that point)

L-length of the spiral T- tangent length

IP - Intersection point

L_c - length of the circular curve s-shift of the spiral

Δ - Deflection angle

φ - Angle of the spiral

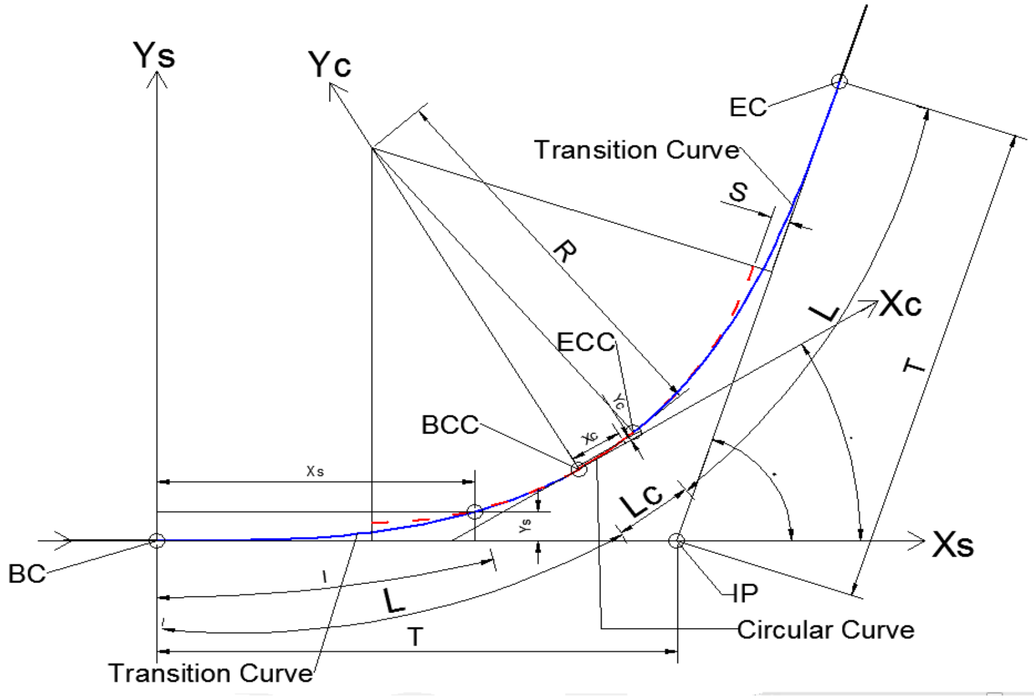


Figure A-1: Elements of a Transition or Spiral Curve

Coordinates of points along the spiral are found as follows:

$$x_s = ll - \frac{l^4}{40A^4} + \frac{l^{94}}{3456A^8} \quad \text{A- 8}$$

$$Y_s = \frac{l^3}{6A^2} - \frac{l^7}{336A^6} + \frac{l^{11}}{42240A^{10}} \quad \text{A- 9}$$

Where,

$A = \sqrt{RL}$ - Parameter of spiral

Length of the circular curve equals (Δ in radians)

Coordinates of circular curve are calculated as follows

$$x_c = R\left(sin\frac{l_c}{R}\right) \quad \text{A- 10}$$

$$y_c = R\left(1 - cos\frac{l_c}{R}\right) \quad \text{A- 11}$$

$$L_c = R\left(\Delta - \frac{L}{R}\right) \quad \text{A- 12}$$

Shift equals

$$s = \frac{L^2}{24R} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \textbf{A- 13}$$

Angle of the spiral φ (in radians) equals

$$\varphi = \frac{L}{2R} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \textbf{A- 14}$$

Length of the tangent T equals

$$T = R\,tan\frac{\Delta}{2} + \frac{L}{2} - \frac{L^3}{1280R^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \textbf{A- 15}$$

Annex-4. Vertical Curve

a. Summit Curve

The length (L) and K-value of vertical summit curve should be selected based on

The required visibility of at least stopping distance as given on Table 8-1: Stopping Distance. For this purpose the driver's eye is assumed to be located at 1.2 m above the road surface and any object lying on the roads surface to be 0.15 m high.

The required visibility of at least overtaking distance as given on Table 8-2 or twice the stopping distance. For this purpose the driver's eye is assumed to be located at 1.2 m above the road surface.

When S<L

h1 = 1.2 m

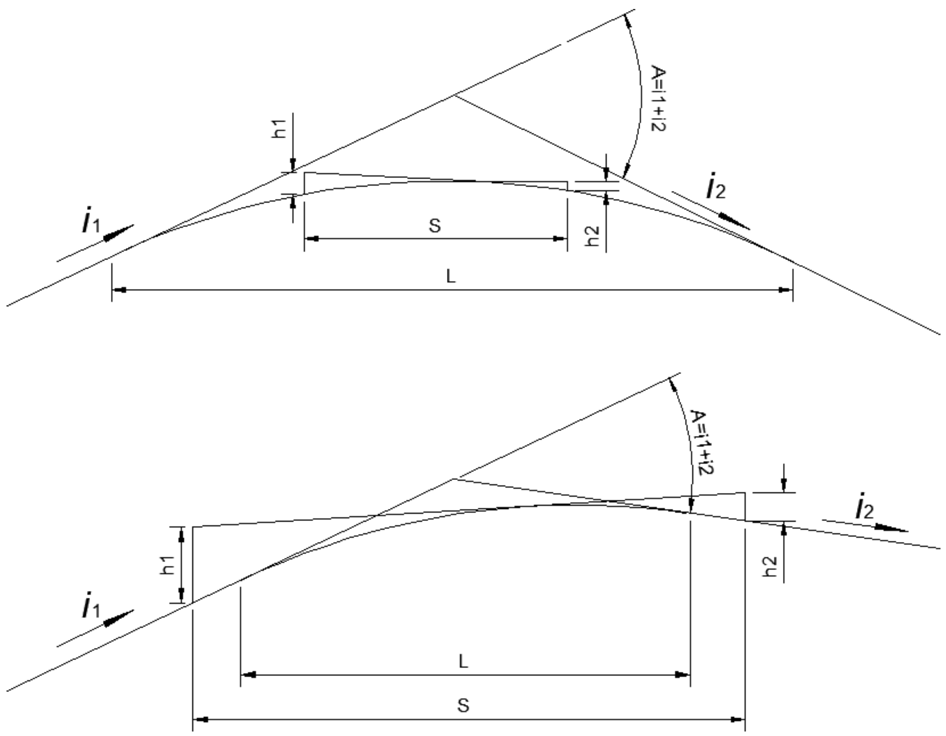


Figure A-2: Summit Curve

h2=0.15 m for stopping sight distance

h2=1.2 m for overtaking sight distance

When S>L

h1=1.2 m

h2=0.15 m for stopping sight distance

h2=1.2 m for overtaking sight distance

Minimum length of summit curve from the consideration of stopping distance is to be found as follows:

When stopping distance(S) is less than L

$$L = \frac{AS^2}{200(\sqrt{1}+\sqrt{2})^2}$$ …………………………………………………… **A- 16**

$$L = \frac{AS^2}{440}$$ …………………………………………………… **A- 17**

When stopping distance (S) is more than L

$$L = 2S - \frac{200\left(\sqrt{h_1}+\sqrt{h_2}\right)^2 AS^2}{A}$$ …………………………………………………… **A- 18**

$$L = 2S - \frac{440}{A}$$ …………………………………………………… **A- 19**

Where,

L - Length of summit curve, m

A - Algebraic difference in approach grades, %

S - Stopping distance, m

h_1 - Height of driver's eye above the pavement surface, m(taken as 1.0m)

h_2 - Height of object above the pavement surface, m(taken as 0.1m)

Minimum length of summit curve from the consideration of overtaking distance and twice the stopping distance is to be found as follows:

When overtaking distance or twice the stopping distance (whichever is higher)(S) is less than L

$$L = \frac{AS^2}{200\left(\sqrt{h_1}+\sqrt{h_2}\right)^2}$$ …………………………………………………… **A- 20**

$$L = \frac{AS^2}{960}$$ …………………………………………………… **A- 21**

When stopping distance(S) is more than L

$$L = 2S - \frac{200\left(\sqrt{1}+\sqrt{2}\right)^2 AS^2}{A}$$ …………………………………………………… **A- 22**

$$L = 2S - \frac{960}{A}$$ …………………………………………………… **A- 23**

Where,

L - Length of summit curve, m

A - Algebraic difference in approach grades, %

S - Stopping distance, m

h_1 and h_2 - Height of driver's eye above the pavement surface, m (taken as 1.2 m)

Minimum length of summit vertical curve can be found from the following graph (see Figure A-3: Minimum Length of Summit Curve) which is a plot of the above formulas.

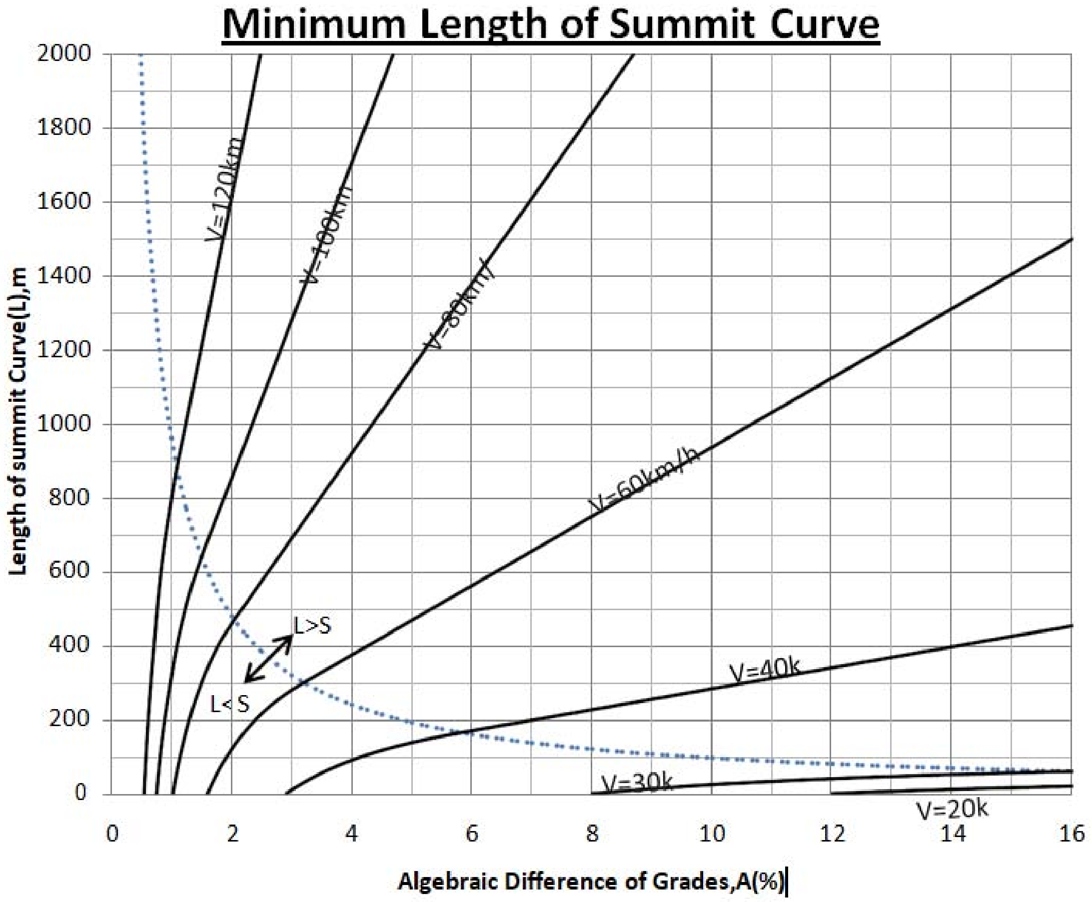


Figure A-3: Minimum Length of Summit Curve

b. Valley Curve

The length (L) and K-value of vertical valley curve should be selected based on the required night visibility by the headlight of the vehicle of at least stopping distance as given on Table 8-1 or based on the riding comfort of the passengers and overloading on the suspension system of the automobile.

On valley curves during night driving the top of the headlight beam should illuminate the road to a distance more than the stopping distance

For calculation of the distance illuminated by the headlights, the height of headlight above the road surface (H) is assumed to be 0.75 m and the total angle of the headlight beam (2α) is assumed to be 2 deg.

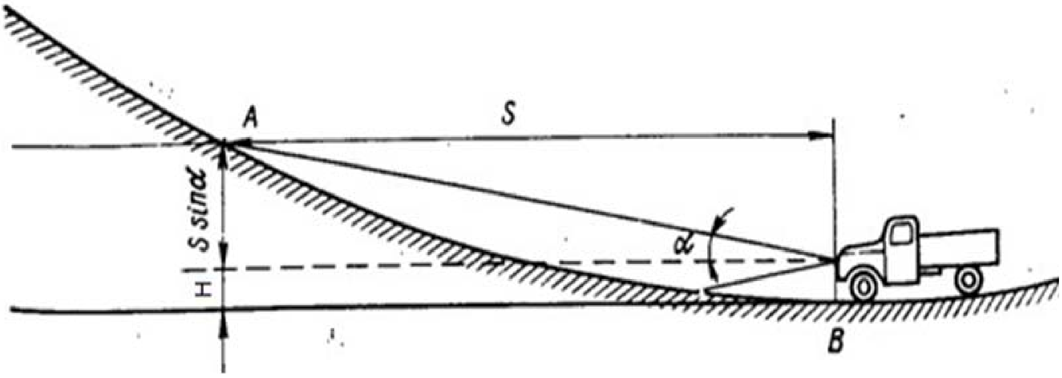


Figure A-4: Valley Curve from Headlight Illumination Criteria

$$L = \frac{AS^2}{200(H + S\sin\alpha)} \quad \text{……} \qquad \textbf{A- 24}$$

$$L = \frac{AS^2}{(150 + 3.5S)} \quad \text{……} \qquad \textbf{A- 25}$$

When stopping distance (S is more than L

$$L = 2S - \frac{200(H + S\sin\alpha)}{A} \quad \text{……} \qquad \textbf{A- 26}$$

$$L = 2S - \frac{(150 + 3.5S)}{A} \quad \text{……} \qquad \textbf{A- 27}$$

Where,

L- Length of valley curve, m

A- Algebraic difference in approach grades, % S-stopping distance, m

H- Height of headlight above the pavement surface, m (taken as 0.75 m)

α -half of the angle of the headlight beam, deg (taken as 1 deg)

Minimum length of valley curve (L) from the consideration of the riding comfort of the passengers and overloading on the suspension system of the automobile is found as follows:

$$L = \frac{AV^2}{1296a} \quad \text{……} \qquad \textbf{A- 28}$$

$$L = \frac{AV^2}{390} \quad \text{……} \qquad \textbf{A- 29}$$

L - Length of valley curve, m

A- Algebraic difference in approach grades, %

V-design speed in kmph

a- maximum allowable overloading coefficient (taken as 0.3 m/s^2)

Higher of the values obtained from the above considerations is taken for the design.

Minimum length of valley vertical curve can be found from the following graph (see Figure A-5:) which is a plot of the above formulas.

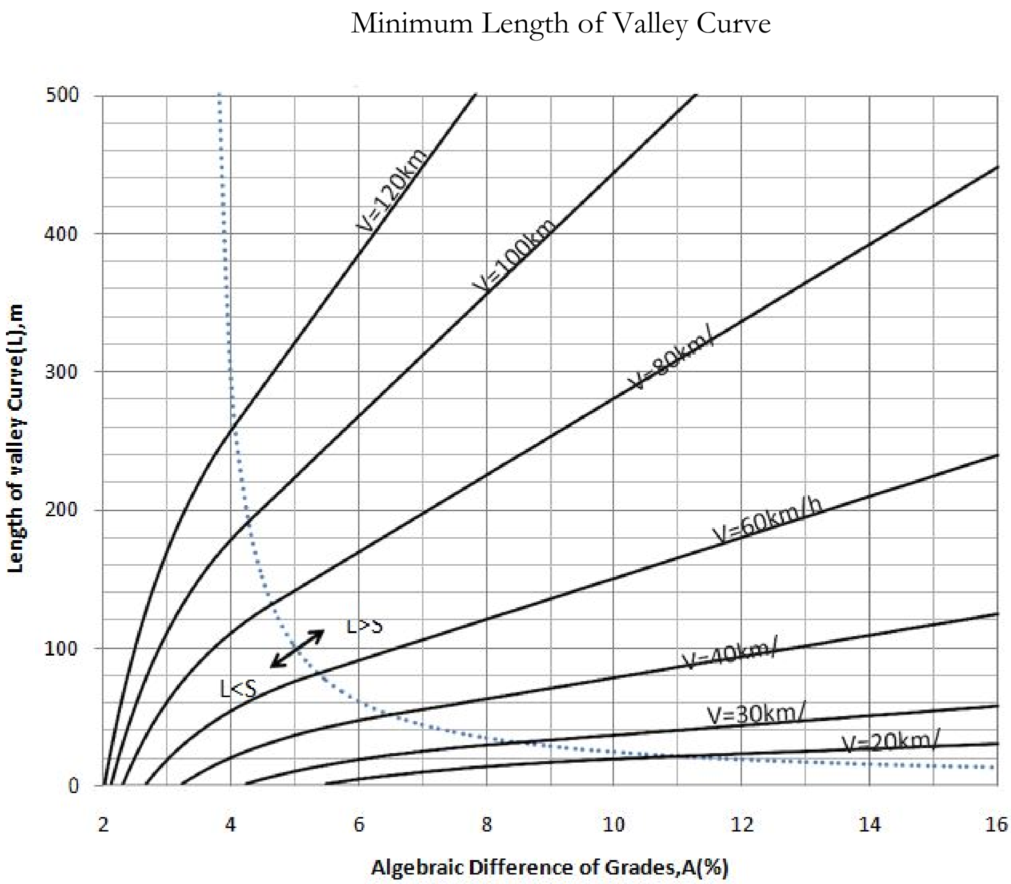


Figure A-5: Minimum Length of Valley Curve

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