Government of the People's Republic of Bangladesh
Ministry of Communications
Roads and Railways Division

Geometric Design Standards
for
Roads & Highways Department

Draft Version 4
October 2000

Contents

Glossary

AADT Annual average daily traffic volume.

Adverse crossfall (on a horizontal curve) Crossfall that tilts away from the centre of the curve and thus adds to the amount of friction needed to stop a vehicle from moving sideways as it traverses the curve.

Axis of rotation The line along which the carriageway is rotated on curves in order to develop superelevation – it is recommended that this be the inner edge of the carriageway.

Carriageway That part of the road for use by moving traffic, and normally divided into traffic lanes.

Clear zone A strip of ground alongside the road that is kept free of hazardous objects.

Crest curve A convex vertical curve with a peak (summit).

Crossfall The transverse slope that helps the carriageway to drain properly.

Crown The highest point on the cross-section of the carriageway.

Design Type One of six standard road types (cross-sections). Each Type is associated with a specific traffic volume range.

Design Year (DY) The year for which the road is designed. It is usually the 10^{th} year after the road is opened to traffic.

Design Speed The speed of traffic for which the road or road section is designed. This is taken to be the 85^{th} percentile speed of the traffic on the road.

Dual carriageway A road having two separate carriageways for travel in opposite directions.

Footway A pedestrian pathway alongside a road.

Horizontal alignment The direction and course of the road in plan view – comprising tangents and curves.

K value The ratio of the minimum length of vertical curve in metres to the algebraic difference in percentage gradients adjoining the curve. It is effectively an expression for degree of curvature and is the main design parameter for vertical curves.

Level of Service A road performance classification used in the U.S. Highway Capacity Manual.

Median The strip of ground or structure between the two carriageways of a dual carriageway road.

MV Motor vehicle.

NMV Non-motorised vehicle, e.g. cycle rickshaws, bicycles, hand carts.

Passenger car unit (PCU) A measure of traffic flow which takes account of the time /space taken up by different vehicle types. Each type of vehicle has a passenger car unit equivalent – for cycle rickshaws it is 2.0 (see Table 2.4).

kPavement That part of the road designed and constructed to withstand the weight of vehicles.

Percentile A value below which the given percentage of values fall. If the 85^{th} percentile speed is 70km/h it means that 85% of vehicles were travelling at a speed of less than 70km/h.

Road Classification The official classification of RHD roads based loosely on road function (National, Regional, and Feeder).

RHD Roads and Highways Department.

RMSS Road Materials and Standards Study.

Sag curve A concave vertical curve.

Shoulder That strip of ground along the edge of the carriageway that is for emergency stopping and for general use by slow-moving vehicles, NMVs and pedestrians.

Sight distance The distance ahead that a driver must be able to see in order to safely carry out a manoeuvre. There are three sight distances referred to here: the **Stopping Sight Distance (SSD),** the **Overtaking Sight Distance (OSD)**, and the **Intermediate Sight Distance (ISD).**

Superelevation The inward tilt given to the cross-section of a carriageway throughout the length of a horizontal curve to reduce the frictional requirements between the vehicles’ tyres and the road surface.

Tangent A straight section of road.

Thermoplastic A hot-melt plastic used to form durable road markings.

Traffic calming Self-enforcing engineering measures that reduce the speed of motor vehicles.

Transition curve A curve in which the radius changes continuously along its length. A transition curve is often used for the purpose of connecting a straight with a circular curve.

Verge The grassed strip at the edges of the road formation.

Vertical alignment The direction and course of the road in profile.

Vulnerable road users Pedestrians, cyclists, cycle rickshaw riders, autorickshaw riders, and motorcyclists.

1 Introduction

1.1 Purpose of this Manual

This manual aims to promote good, consistent practice in the geometric design of the Roads and Highways Department's roads. It has been written for RHD staff and their consultants and assumes that they have some knowledge of highway design. All RHD road projects should be designed in accordance with the design approach, standards, assumptions, etc., that are set out in this manual. It is hoped that this will lead to better designed roads –roads that are operationally effective, economic to build and maintain, and are as safe as we can afford to make them. A simple manual like this cannot cover all possible circumstances, and there is nothing to stop designers from doing something different if they can make a good case for it.

1.2 Road Materials and Standards Study, 1994

The standards set out in this manual are mostly derived from RHD's Road Materials and Standards Study (RMSS). Readers who are interested in how the standards were derived should refer to the RMSS report, principally Vol. V11A "Development of Geometric Design Standards".

1.3 Design Approach

Geometric design of roads is a complex task. Getting to a satisfactory design that meets all the constraints calls for much skill and experience. There is often a lot of trial and error, and the final design is likely to be a compromise. The standards in the manual are defined precisely but there is some scope for modifying them in order to achieve an appropriate design for a specific problem. It is hoped that by following the design process set out in this manual the task will be made easier.

One of the basic assumptions is that driver behaviour can be influenced by the appearance of the road and the road environment. It is vital that everything be done to give drivers clear clues and messages about how they should negotiate each section of road – and, particularly, how fast they should travel.

1.4 Acknowledgements

The manual makes extensive use of material from two design guides: "A guide to geometric design", Overseas Road Note 6, Transport Research Laboratory, UK, 1988, and "Rural Road Design", Austroads, 1989. The co-operation of TRL and Austroads in permitting the use of their work is gratefully acknowledged. A full list of references appears at the end of the manual.

2 Design Standards

2.1 Design Types and Standards

The geometric design standards are summarised in Table 2.1 (Cross-Sections) and Table 2.3 (Speed Related Design Parameters). There are six standard cross-sections (Design Type 1 to 6) each of which is suitable for a specific range of traffic volumes. The traffic volume levels at which the cross-sections change have been selected largely on the basis of economic analysis, and must be treated as approximate, because of the many uncertainties. The Design Year is normally the 10th year after the road is open to traffic. However, the Design Type should not be more than one Type higher than that for the traffic volume in the year the road opens.

Other design standards relate to horizontal and vertical curves, and these are largely derived from the design speeds and sight distances. Table 2.2 gives a guide to appropriate design speeds for different combinations of Design Type and terrain type – see also Section 2.5. Table 2.3 gives the sight distance and curvature standards.

Note that Tables 2.1 and 2.3 only provide summaries of the standards. It is essential to refer to Section 4 – Cross-Sections, Section 5 – Horizontal Alignment, and Section 6 – Vertical Alignment to get a proper understanding of what is required.

2.2 Road Classification

The RHD road network is divided into three Classifications (National, Regional and Feeder) based on functions defined in the 1980's. The classification has become distorted over the years and no longer reflects the actual usage being made of each road. Some feeder roads for example carry much more traffic than many national roads. To make optimum use of resources the standards to be adopted in road design must be based wholly on traffic volume, regardless of Road Classification. Hence Design Types are based on traffic volume and have no direct relationship with functional classifications.

2.3 Traffic Volume and Composition

Good traffic data is critically important in the design of roads. RHD has some data but it will generally need to be supplemented. Investing in traffic surveys will pay for itself many times over. Traffic surveys must cover NMVs and pedestrians as well as motorised vehicles, and be designed to show how traffic flows vary along the route. Data on NMV flows in the vicinity of towns and villages will be particularly useful in determining when to start and finish NMV lanes. For new roads on completely new alignments it will be necessary to assign traffic to them from existing roads and then make an allowance for generated traffic.

Table 2.1 Road Cross-Section Standards

Design Type	Design year traffic volume PCU / peak hour (typical MV AADT)	Cross-section widths in metres			Indicative Road Classification
		Crest width	Carriageway (no. of lanes)	Paved shoulders	
1	4500 – 8500 (19,000–36,000)	36.2	2 x 11 (6)	1.8	
2	2100 - 4500 (7,000 – 19,000)	21.6	2 x 7.3 (4)	1.8	National
3	1600 – 2100 (5,000 – 7,000)	16.3	7.3 (2)	1.5	Regional
4	800 – 1600 (1,000 – 5,000)	12.1	6.2 (2)	1.5	
5	400 – 800 (500 – 1,000)	9.8	5.5 (2)	1.2	Feeder
6	<400 (<500)	9.8	3.7 (1)	1.2	

Notes
This is a summary table – refer to Section 4 before using these standards

Table 2.2 Typical Design Speeds

Design Type	Design Speed (km/h)		
	Plain	Rolling	Hilly
1 - 2	80 –100	80	-
3	80	65	50
4	65	50	40
5 - 6	50	40	30

Notes
Terrain: typical cross-slopes
Plain: 0 – 10%
Rolling: 11 – 25%
Hilly: >25%

Table 2.3 Speed Related Design Parameters

Design Speed (km/h)	Sight Distance (m)			Minimum Curvature Values	
	SSD	ISD	OSD	Horizontal curve (radius (m))	Vertical curve (K value)
Two lane roads					
30	30	60	120	35	2
40	45	90	180	65	4
50	60	120	250	120	9
65	90	180	360	250	18
80	120	250	500	500	35
100	180	360	720	1000	70
Single lane roads					
30		60		120	4
40		90		250	9
50		120		500	18
65		180		1000	35

Notes:
1. This is a summary table – refer to the appropriate sections of the manual before using these parameters
2. Sight distances (see Section 2.6) SSD – Stopping Sight Distance; ISD - Intermediate Sight Distance; OSD – Overtaking Sight Distance
3. Horizontal curves (see Section 5) The radii are those needed to achieve SSD with 5% superelevation (3% for the 1000m radius curve)
4. Vertical curves (see Section 6) Two lane roads: K values are those needed to achieve SSD; Single lane roads: K values are those needed to achieve ISD
5. For parameters relating to dual carriageway roads refer to the appropriate sections of the manual

The wide variety of vehicle types in use on Bangladesh roads makes it appropriate to define traffic flow in terms of passenger car units (PCUs) rather than vehicles. The PCU values are given in Table 2.4.

Table 2.4
Passenger Car Unit (PCU) Values

Vehicle Type	PCU Value
Truck	3.0
Bus	3.0
Minibus	3.0
Utility	1.0
Car	1.0
Baby taxi	0.75
Motorcycle	0.75
Bicycle	0.5
Cycle Rickshaw	2.0
Bullock Cart	4.0

Source: p72, RMSS, Vol. V11A

Table 2.5 Generalised Traffic Flow Characteristics

Road Classification	Peak hour flow as % of daily flow	No. of MVs as % of total PCU flow	NMV / MV ratio (PCU)
National	8	34	0.15
Regional	10	33	0.3
Feeder	10	13	2.5

Source: Tables 3.13 , 3.20, 3.22, derived from RMSS, Vol. V11A

All traffic flows specified in this manual refer to two-way flows. Traffic flow characteristics vary considerably, but some broad generalisations are possible and these are set out in Table 2.5.

2.4 Traffic Capacity

Table 2.1 gives the traffic flow ranges for each of the six Design Types, expressed in terms of PCU / peak hour. The upper end of the range is the design capacity. Given the uncertainties involved in predicting how roads will perform under mixed traffic conditions the values must be regarded as approximate. For Design Types 1 to 5 the design capacity is broadly equivalent to Level of Service "E" in the U.S. Highway Capacity Manual. In general terms Level of Service "E" implies a heavily congested road, where overtaking is impossible and where any interruptions, such as vehicles turning, will cause the flow of traffic to break down completely. The adoption of these high design capacities reflects the need to optimise the economic returns from road investment in a situation where traffic forecasts are uncertain. Road user costs in Bangladesh are low and this means that high levels of congestion have to be reached before road user costs are high enough to justify upgrading a road to a higher standard. For Type 6 roads the design capacity of 400 PCU / peak hour is equivalent to Level of Service "C" and this reflects safety and operational concerns specific to single lane roads.

2.5 Design Speed

The design speed is the expected 85th percentile speed of the motorised traffic on the new road in the design year. The 85th percentile speed is the speed which only 15% of vehicles will exceed. The choice of design speed has a big influence on key aspects of highway design, especially curvature.

Table 2.2 gives typical design speeds for each Design Type and terrain type. This is just a general guide. In practice it is rarely possible to adopt a uniform design speed for the whole road - design speeds need to vary from section to section to reflect differences in the road environment, terrain, etc.

The highest permissible design speed is 100km/h. Although it is evident that car drivers and passengers want to travel at this speed, it is questionable whether this is an appropriate design speed for Bangladesh because of the large numbers of slow-moving vehicles and pedestrians, and the general lack of road user discipline. Hence for normal design purposes the highest permissible design speed would be 80km/h

Where a case can be made for building 100km/h roads it will be essential to give great attention to the safety issues, such as the feasibility of prohibiting NMVs and pedestrians.

2.6 Sight Distance

The need to achieve minimum sight distance standards (given in Table 2.3) sets limits on how sharp the curves can be. These standards are of course speed-related – they are the link between design speed and curvature. There are three main types of sight distance to consider:

Stopping Sight Distance (SSD)
Overtaking Sight Distance (OSD)
Intermediate Sight Distance (ISD)

Stopping Sight Distance. This is the visibility necessary for a driver to be able to see an obstruction in time to bring the vehicle to a halt without a collision. This is a basic minimum standard for two-lane single carriageway roads. It is assumed that the driver's eye height is 1.2m and the height of the obstruction is at least 0.15m above the road surface.

Overtaking Sight Distance. This is the visibility necessary for a driver to be able to see whether the road ahead is sufficiently clear to enable him to overtake a vehicle in front – even if an oncoming vehicle appears after he has started the overtaking manoeuvre. It is a very long distance, especially at the higher speeds, and it can be difficult to achieve.

Intermediate Sight Distance. This is the visibility necessary for a driver to be able to see whether the road ahead is sufficiently clear to enable him to overtake, assuming that he will abort the manoeuvre if an oncoming vehicle appears before he has got level with the slower vehicle. ISD is much less than OSD yet it permits reasonably safe overtaking. ISD is about twice SSD. It is assumed that the observer and the obstruction are at eye height (1.2m).

Two-lane roads should have a high proportion of sections with ISD, or better still OSD. SSD must always be available even on the most difficult sections. Single lane roads should be designed to ISD standards, because opposing vehicles occupy the same lane. This enables drivers to avoid a collision if they see an oncoming vehicle, even if the other vehicle does not slow down. Dual carriageway roads should be designed to provide ISD.

3 The Design Process

3.1 General

The geometric design of roads is a complex task and it is advisable to approach it in a structured way. Figure 3.1 illustrates the recommended design process. It is presented here in a generalised form and in practice there are many possible variations.

3.2 Basic Parameters

The starting point is to determine the design year traffic volume (usually the traffic in the 10^{th} year after opening), the type of terrain, the High Flood Level and other basic parameters. RHD's Economics Circle can provide advice on traffic forecasts.

3.3 Select Design Type and Design Speed

A Design Type is selected from Table 2.1 on the basis of the design year traffic volume. Values of Design Type boundaries are approximate, and the lower Design Type should be used in borderline cases. Normally the Design Type should not be more than one Type higher than that for the traffic volume in the first year of operation. A design speed should then be chosen which reflects the road environment (terrain, frequency of towns and villages, etc) and the level of service expected from the road. The design speed may differ from section to section.

3.4 Determine Trial Alignment

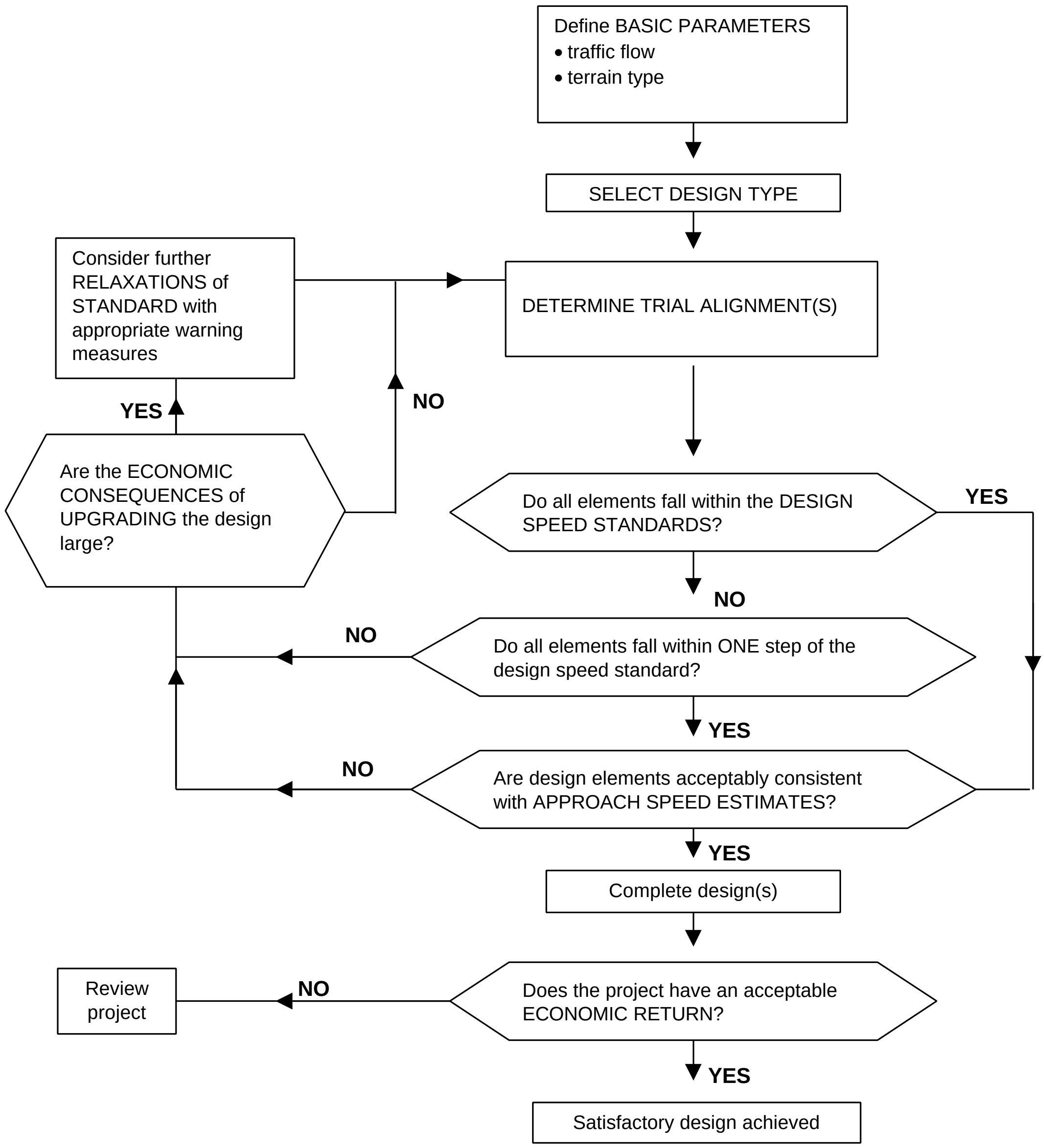
The first step in selecting an alignment for a new road is to sketch a route on a map or aerial photograph. A similar process can be followed when upgrading an existing road. At this stage there is no need for detailed design of curves but the radii should be broadly consistent with the chosen design speed. Several alternative alignments should be tried and the route should be inspected to get a better understanding of the constraints and opportunities. Where a road is to be upgraded the structural elements of the existing road, such as bridges and embankments, may still be worth using and this will influence the alignment.

The aim is to find an alignment which is the economic, operational and safe optimum. There are always many route constraints, such as building development, deep borrow pits, awkward river crossings, rail crossings, power lines, and many others. Safety can best be achieved through provision of facilities for vulnerable road users, consistency between successive road sections, and maximising safe overtaking opportunities. Long, continuous curves provide dubious overtaking opportunities (unless the radius is very large) and should be avoided. Excessively long straights are also unsafe. A succession of curves and straights provides a more interesting driving task and is more easily fitted into the terrain (see Section 5.1).

Other major considerations at this stage include hydrology, environmental impact, land acquisition and resettlement. All these have significant financial and technical implications and can be expected to influence the alignment of the road. During the monsoon season many roads in Bangladesh become dams, so it is essential that good hydrological studies and plans be prepared. In the past many roads have been built without sufficient culverts. The RHD's Environment and Resettlement Division can provide further advice.

Figure 3.1 The Design Process

Source: adapted from " A Guide to Geometric Design", Overseas Road Note 6, Transport Research Laboratory, UK



3.5 Check the Trial Alignment Against Design Speed Standards

Consistency of design elements is important for safety and efficiency. As a first check look at whether all the elements in the trial alignment conform to the design speed standards for the road (or section as appropriate). At difficult sites standards can be relaxed by one design speed step provided that the sub-standard section is well signed. Where site constraints mean that even lower standards must be adopted it will be best to achieve this by successive reductions in design speed, e.g., a 50km/h bend on an 80km/h road should be “protected” by 65km/h sections on either side of it. If this is not possible consideration must be given to either redesigning the problem element or installing very prominent signing, safety barriers, etc. On low flow roads grossly sub-standard elements will probably not cause accidents because most of the drivers will be regular travellers. Greater care and consideration is needed before relaxing standards on high flow / high speed roads.

Reduction in standards should only apply to stopping distances and curvature. Carriageway and shoulder widths should not be reduced because this could seriously affect capacity and safety.

3.6 Do a Detailed Consistency Check

Conformity to design speed standards ensures an overall level of consistency but design speeds are not a precise indicator of actual speeds on a particular section of road. A second more detailed check is needed to ensure that actual speeds do not differ by more than about 15km/h on successive sections of the road. When estimating actual speeds take account of the geometry as well as the speed characteristics of the preceding few kilometres – sometimes called the “speed environment”. Actual speeds on a 500m radius curve in a 80km/h speed environment may be close to 80km/h but speeds on the same radius curve in a 60km/h environment will be very much lower. Note too that long straights can induce very high speeds that may be well in excess of the overall design speed for the road. Design speeds of the first curves at the ends of such long straights should not be more than 10km/h below the estimated speeds on the straights.

3.7 Amend the Alignment

Where elements of the design are seriously sub-standard the cost-benefits of upgrading the alignment need to be assessed. The alternative to upgrading is to accept the sub-standard element and try and do everything possible to reduce the risk of accidents – through prominent signing, installation of safety barrier, etc. On the higher-volume higher-speed roads it will almost always make economic sense to upgrade the alignment.

3.8 Safety, Environment, Land and Resettlement

Roads and Highways Department (RHD) is committed to following good practice with regard to the safety and environmental impact of its roads and the way it acquires land and resettles affected persons. It is RHD policy that all major road projects be given a road safety audit before they are finalised (see Section 9). RHD ensures that all the Government’s environmental regulations are complied with, and for major projects this will usually involve the preparation of environmental impact assessments and environmental management plans. Land acquisition and resettlement is a major task for most road projects and RHD has much experience of this. RHD’s Environment and Resettlement Division can provide advice. All of this work can give rise to changes in the geometric design of the road.

3.9 Check the Economic Assessment

The full economic assessment of the project will have been done at the feasibility study stage. During the design process any alignment options that could improve the economic returns will need to be investigated. Once the design is firmed up check that the project cost has not altered sufficiently to significantly affect the economic return. If the economics of the project are not good then the project will have to be reviewed.

4 Cross-Sections

4.1 Carriageways and Shoulders

The choice of cross-section is crucial to obtaining a cost-effective solution to meeting traffic needs. Most of our roads are built on embankments and every extra metre of crest width adds considerably to the cost. The principal cross-sectional elements are:

- carriageway – the part of the road formation carrying moving vehicles – divided into one or more traffic lanes
- shoulder – the strip along the edge of the carriageway for use by stopped vehicles and often NMVs and pedestrians
- embankment side slopes.

Carriageway and shoulder widths should be the minimum necessary to carry the traffic volume efficiently and safely. The cross-sections set out in this manual are based on a comprehensive evaluation of many alternatives and they represent the economic optimum. Operational and safety considerations have also been taken into account.

There are five basic carriageway widths within the six Design Type configurations:
3.7m wide - This is the standard single lane carriageway width, and is suitable for the more lightly-trafficked Feeder Roads. Vehicles travelling in opposing directions can pass each other by putting their outer wheels on the shoulder.
5.5m wide - This is a minimum width two-lane carriageway. Large vehicles can pass each other at slow speed.
6.2m wide - This is the lowest economic cost option for a very wide range of traffic volumes. It allows most vehicles to pass with sufficient clearance to avoid the need to slow down or move aside.
7.3m wide single - This is a high standard two-lane single carriageway.
7.3m wide dual - This is a high standard carriageway as one half of a dual 2-lane road.
11m wide dual - This is a three-lane carriageway as one half of a dual 3-lane road.

The option of an 11m wide single carriageway road, as proposed in RMSS, has not been adopted because of concerns that the wide carriageway would encourage unsafe overtaking. British experience with 11m single carriageway roads is that, whilst their overall safety record is good, they do have a higher-than-average proportion of overtaking accidents.

Shoulders are essential for safety and capacity, and must be provided on all roads. Optimum widths for shoulders are 1.2m, 1.5m, and 1.8m. All shoulders must be paved in order to be durable and perform effectively in all weathers. This can be achieved either by extending the main pavement or using a different construction, such as double bituminous seal treatment. Factors to consider when designing shoulders include:

- the shoulder needs to be strong enough to take all vehicles in any weather and without needing much maintenance

- shoulders that are to be used by NMVs and pedestrians must have a good-quality smooth surface – otherwise NMVs and pedestrians will use the carriageway instead
- using a different surface to that of the carriageway makes the shoulder look different and this helps emphasise that it has a different function
- it is essential to use edge lines (preferably made of thermoplastic) to mark the divide between carriageway and shoulder
- there should be no difference in level between the carriageway and the shoulder – an edge drop could discourage NMVs, baby taxis and tempos from using the shoulder and could be hazardous, especially for motorcyclists.

On dual carriageway roads (Type 1 and 2) there must be a 0.3m wide shoulder on the right-hand side of the carriageway next to the median. The divide between the carriageway and shoulder must be marked with an edge line.

4.2 Design Type Cross-Sections

Figure 4.1 gives an overview of the cross-sections and shows the progression from single lane road (Type 6) to dual 3-lane road (Type 1). Figures 4.2 – 4.7 repeat the standard cross-sections but give further information, including the design capacity and the options available for handling NMVs.

The design capacities are very much the maximum possible and in practice roads may be upgraded to the next highest standard some time before these capacities are reached. All widening works (or new construction) to Type 4, 5, and 6 standards involve overwidening the embankment to the next highest design category, so that, if traffic grows faster than forecast, the road can be upgraded by just widening the pavement. The validity of the design capacities is partly dependent on the validity of the assumptions on NMV/MV mix (indicated in the notes below the figures). Where there is good reason to believe that these assumptions will not apply the cross-section may need to be adjusted – this is particularly the case with Type 6 where it is assumed that over 70% of the PCU capacity will be taken up by NMVs.

4.3 Provision for NMVs and Pedestrians

One of the particular characteristics of Bangladesh roads is the large number of non-motorised vehicles and pedestrians. This has many implications for road design. Local surveys of NMV and pedestrian flows are essential to provide a firm basis for deciding how to provide for these road users. Failure to provide properly for NMVs will significantly reduce the traffic capacity of the road and be a cause of accidents.

Shoulders are to be provided on all roads for use by NMVs. On heavily-trafficked sections, such as through towns and villages it will be necessary to provide separate NMV lanes. See below for more detailed guidance.

Separate NMV lanes should be provided on Type 2, 3 and 4 roads where the design year NMV PCU/hr exceeds 400 (50 PCU/hr for Type 2) or there are clear operational and safety benefits. Type 1 dual carriageway roads should always have separate NMV lanes, for capacity and safety reasons. They should only be omitted where it is feasible to prohibit NMVs entirely. Figure 9 shows three options for the layout of NMV lanes, depending on the road environment. The absolute minimum width of an NMV lane could be 2m where there is a hard surfaced shoulder to enable passing other slower or stationary NMVs. Normally 3m is needed as a minimum and this can accommodate a maximum of 513 PCU/hr. For the flows:width relationship see Table 4.1.

Table 4.1 NMV Lane Capacities

NMV lane width (m)	Flow per lane (PCU/hr)
3.0	513
3.6	645
4.2	732
4.8	794
5.4	901
6.0	1015

Source: Tables 6.40, 6.47, RMSS Vol. V11A
Note: Capacities are for Level of Service 'D'

The provision of an NMV lane on one side of the road only is not recommended, because it is unlikely that more than half the NMVs would use it.

Most towns and villages will have sufficient NMV traffic to warrant the provision of separate NMV lanes. A detailed traffic survey should be carried out to determine how far to extend the NMV lanes. As a guide, the RMSS found that on average the NMV flow dropped significantly after about 1km from the centre of the built-up area. Note though that on roads with villages every few kilometres the NMV traffic is likely to be fairly constant.

Care is needed with the design and layout of NMV lanes in order to make them as convenient and easy to use as possible. They must be well constructed with a smooth durable surface, and should be marked with the rickshaw symbol (sign F19).

In most situations pedestrians can share the paved shoulder or NMV lane with the NMVs. However, where there are a lot of pedestrians and near-capacity NMV flows or high-speed traffic it may be necessary to provide a separate footway. Typically this could be a 1.5m wide footway benched into the embankment side slope about 0.5m below carriageway level. It should be designed for ease of use and must connect with footways across bridges and culverts. The footway surface must be smooth, durable and well-drained.

4.4 Bus Bays and Stopping Places

Buses stopping on the carriageway to pick up or set down passengers will interfere with traffic flow and can be a cause of accidents. Bus bays which enable buses to pull off the carriageway can be of benefit provided that they are used. Proper surveys and studies must be carried out to determine exactly where the buses will stop. Experience shows that it is very difficult to make drivers use bus bays unless they are located exactly at the point of maximum passenger demand. RHD's Road Safety Division can provide design advice. When building or rehabilitating roads through towns it is essential to consider the needs of buses, some of which may remain stopped for a considerable period of time. If suitable hard standing areas are not provided the buses will wait on the carriageway causing congestion and accidents.

4.5 Traffic Calming Through Towns and Villages

Most accidents on rural roads in Bangladesh happen in towns and villages, and the accidents almost always involve a vehicle which is speeding through the centre. Projects which improve roads through towns and villages may make the accident situation worse because speeds will increase. In order to prevent this it is essential that traffic calming be applied. Traffic calming is the term used to describe self-enforcing engineering measures that reduce the speed of motor vehicles. Lower speeds reduce both the likelihood of an accident happening and the severity of injuries if it does occur. Effective traffic calming results in a better environment for all and improved safety for vulnerable road users (pedestrians, cyclists, rickshaw users). The engineering measures that can be used to calm traffic include:

- false roundabouts (a roundabout where there is no junction)
- speed humps
- road narrowings and deflections
- footway widening
- using upright signs / kerbs / planting / carriageway markings to form “gates” at the entrance to the town or village
- rumble strips that make a noise and give a slight jolt when vehicles go over them.

To have any chance of being effective the individual measures must be implemented as part of an overall traffic calming plan for each town and village. Preparing these plans requires specialist experience, and assistance should be sought from RHD’s Road Safety Division.

4.6 Lateral and Vertical Clearances

Trucks are typically just over 4m high. To allow for adequate vertical clearance and the transport of abnormal loads 5.7m headroom should be provided when designing new roads and structures. This also makes some allowance for headroom being lost when road pavements are given overlays. The headroom must be available over the full width of the road formation. There may be special requirements on some roads and this should be checked with the RHD’s field divisions.

The lateral clearance, measured between the outer edge of the shoulder and roadside objects should be a minimum of 1m. In difficult situations an absolute minimum clearance of 600mm can be accepted. Where there is no shoulder, the respective clearances are 1.5m and 1m.

Many accidents happen when vehicles run off the road and hit a roadside object. Collisions with trees are commonplace and often result in death or serious injury. Ideally there should be a 4m wide clear zone beyond the shoulder that is kept free of roadside hazards. For curves with a radius of less than 600m the clear zone width on the outside of the curve should be doubled.

It is also important to check that roadside signs, poles, bridge abutments, trees etc., do not interfere with sight distances on curves. Tree planting alongside new roads is beneficial but care should be taken to reduce the hazard risk.

4.7 Crossfall

Crossfall is the slope of the carriageway or shoulder that enables water to drain away. Carriageway crossfall must be sufficient to provide good surface drainage but not so steep as to cause problems for drivers. On two-way single carriageway roads the carriageway is normally cambered to form an inverted ‘V’ which may be rounded at its highest point, the crown. On dual carriageway roads the carriageway normally slopes away from the median. At curves the carriageway and shoulder profile may change – see Section 5.3. The standard crossfall for paved carriageways is 3%.

Shoulders having the same surface as the carriageway may have the same crossfall, but generally shoulder crossfalls will be a little steeper - normally 5%. See Section 5.3 for advice on shoulder crossfall on curves with superelevated carriageways.

4.8 Drains

Detailed advice on the design of road drains is outside the scope of this manual. However, key points to consider in the design are:

- The need for cross drainage, road surface drainage, and sub-surface drainage
- Drain design should prevent siltation (too shallow a fall) and excessive scour (too steep a fall)
- The side slopes next to the road should be flat enough to reduce the risk of errant vehicles overturning (maximum slope of 5 horizontal to 1 vertical)
- Open lined drains should be in the form of shallow dishes rather than steep-sided U or V-sections
- In built-up areas channel drains deeper than 250mm should be covered for the safety and convenience of both pedestrians and vehicles
- The drain should terminate or run-out in a satisfactory manner without risk of causing erosion or other problems
- The drain should be capable of being cleaned and maintained easily.

It is not easy to design drains that can cope with the expected flow and yet are safe, affordable and easy to maintain, so compromises are usually required.

4.9 Embankments

Rural roads in Bangladesh are typically on high embankments. The standard side slope for embankments is 2 horizontal and 1 vertical. These have proved to be quite stable when covered in vegetation. The slope is dangerous however and any vehicle going down it will almost certainly overturn. Every year many people are killed and injured in accidents of this kind. Low embankments up to 1.5m in height should ideally have flatter side slopes (3 horizontal / 1 vertical, or flatter). Unfortunately it would be enormously expensive to provide these forgiving slopes on higher embankments, and instead efforts should be made to try and contain out-of-control vehicles. The installation of safety barrier may be cost-effective at very hazardous sites, but it is too expensive for general use. The planting of soft trees and bushes near the top of the side slope may help to slow down and contain runaway vehicles. Road Safety Division can provide advice on this.

4.10 Design Levels

It is normal practice to build roads so that the carriageway surface will have a freeboard of 1.0m above the highest flood level recorded in the locality. Information on local flood levels can be obtained from RHD field divisions or the district administrations.

4.11 Cross-Sections at Bridges and Culverts

The design of bridges and culverts is outside the scope of this manual, but it is obvious that safety and capacity will be affected if the road cross-section is not maintained across these structures. The key points to consider are:

- Carriageway and shoulder narrowings are particularly dangerous on high-speed roads;
- If the shoulder is not continued across the structure, NMVs will move out onto the carriageway in front of fast-moving vehicles and there may be accidents;
- Footways are conventionally provided on structures with parapets, but the accident risks at the site need to be assessed carefully especially where footways can only be provided by omitting the shoulders; take account of the relative volumes of pedestrian and NMV traffic, the speed and volume of motorised traffic and the length of the span;
- Where there are significant pedestrian and NMV flows the best solution is to separate them from fast-moving vehicles with a safety barrier – see Figure 4.10;
- Where there are very high pedestrian and very high NMV flows separate footways and NMV lanes should be considered;
- It is RHD policy to design new bridges for a minimum of two lanes on all roads including feeder roads - where, exceptionally, a single lane bridge is planned the carriageway should be a maximum of 3.7m wide between kerbs in order to avoid confusion over whether the bridge is for one-way or two-way traffic.

Figure 4.10 Segregated NMV Lane or Footway on Bridges

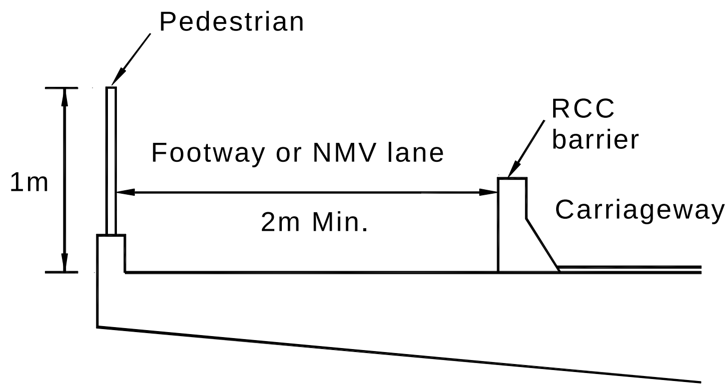


Figure 4.1 Overview of cross-sections

Notes

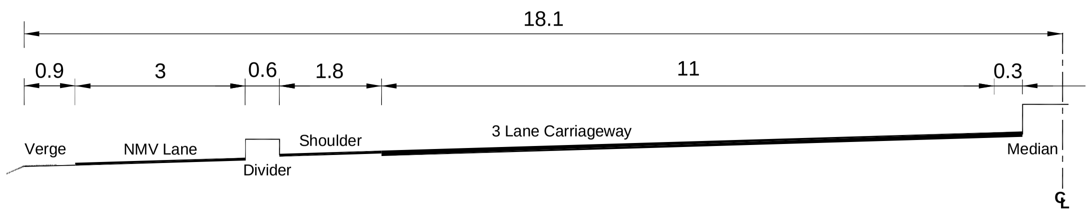
These are RHD standards and other cross-sections are only permissible in exceptional circumstances and with the approval of the Chief Engineer.

The cross-sections for Design Types 3 - 6 have extra-wide embankments in order to enable the road to be easily upgraded as traffic volumes grow.

Refer to Figures 4.2 - 4.7 for details of design capacities.

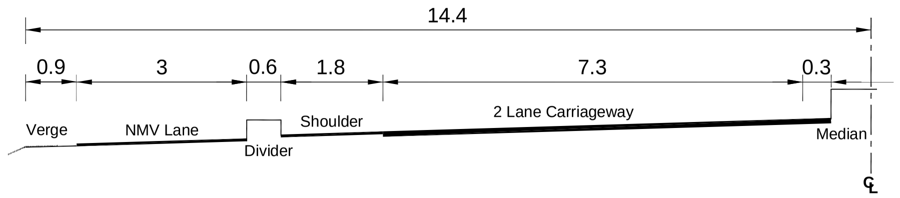
Type 1 Dual 3 lane carriageway with NMV lanes

Class 1 roads must always have NMV lanes

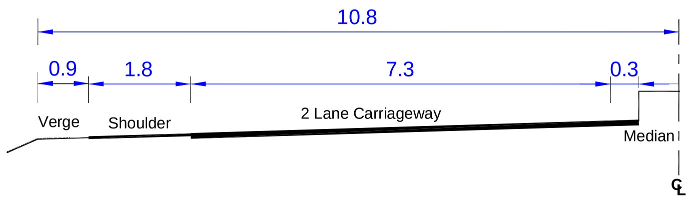


Type 2a Dual 2 lane carriageway with NMV lanes

For use where there are many NMVs, such as through towns and villages

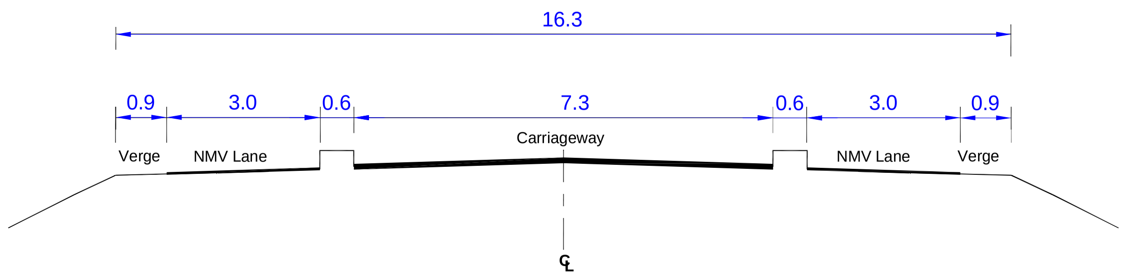


Type 2 Dual 2 lane carriageway



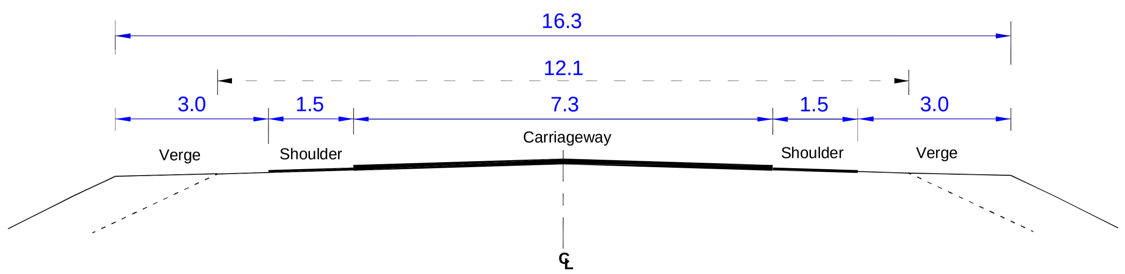
Type 3a 7.3m carriageway with NMV lanes

For use where there are many NMVs, such as through towns and villages



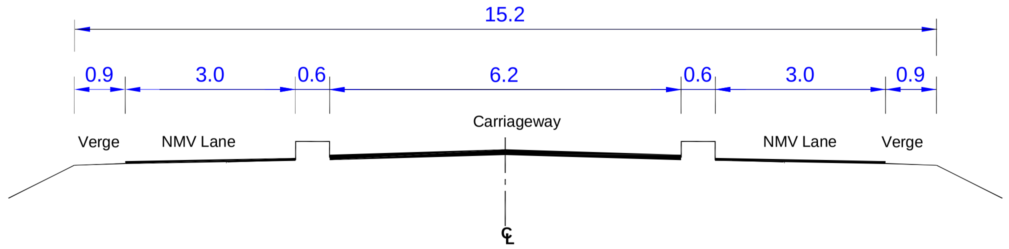
Type 3 7.3m carriageway

If it is unlikely that NMV lanes will ever be needed the road can be built with a crest width of 12.1m.

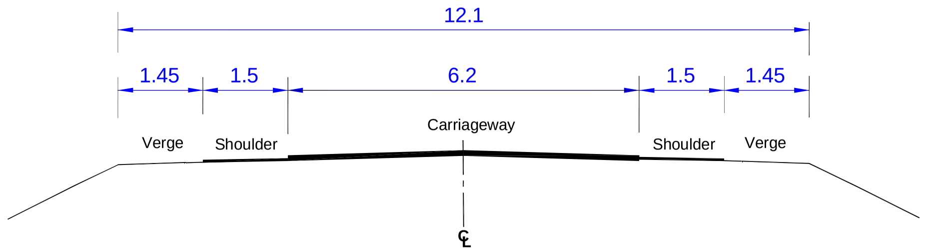


Type 4a 6.2m carriageway with NMV lanes

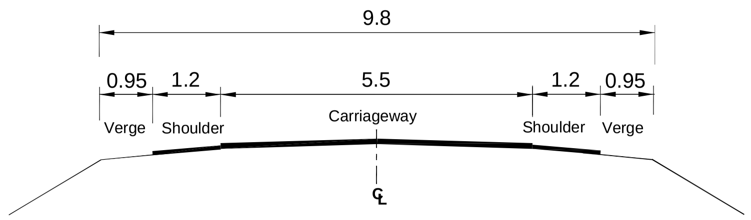
For use where there are many NMVs, such as through towns and villages



Type 4 6.2m carriageway with 1.5m shoulders



Type 5 5.5m carriageway



Type 6 3.7m single lane carriageway

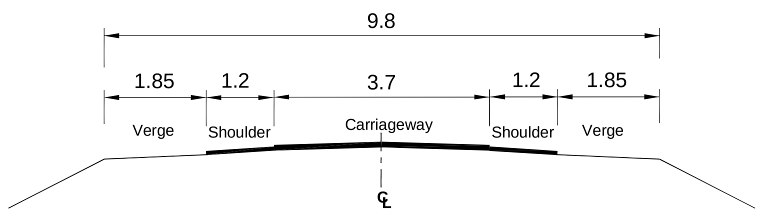
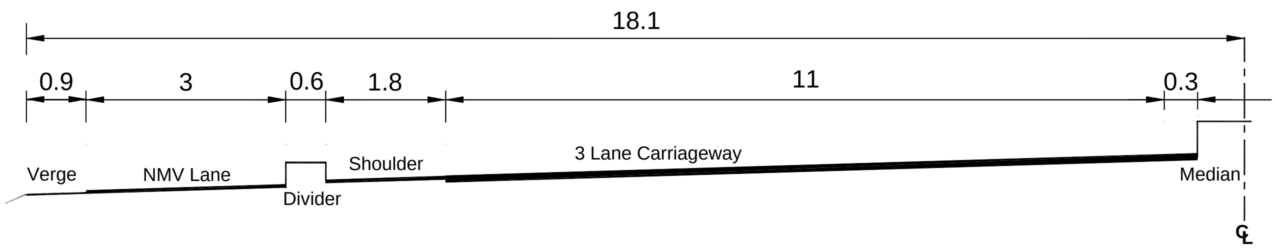


Figure 4.2 Design Type 1 Dual 3-lane 11m carriageway



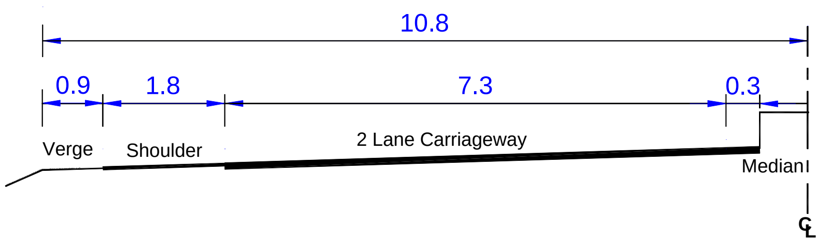
<u>Width of sectional elements (m)</u>

Crest	36.2
Median	1.0
Carriageway	11.0
Shoulder (L) – paved	1.8
Shoulder (R) – paved	0.3
Divider	0.6
NMV lane	3.0
Verge	0.9

<u>Design Capacity</u>
Maximum capacity: 8500 PCU/hr
(assumed NMV/MV ratio of 0.13)

<u>NMV provision</u>
NMVs will use the separate NMV lane. Separation can be achieved in any of the three ways indicated in Figure 4.8. A standard width NMV lane is shown but this may need to be wider if NMV flows are high – see Section 4.3. Exceptionally the NMV lane may be omitted where it is thought to be feasible to prohibit NMVs from using the road.
<u>Median</u>
See Figure 4.9 for alternative designs.

Figure 4.3 Design Type 2 Dual 2 lane 7.3m carriageway



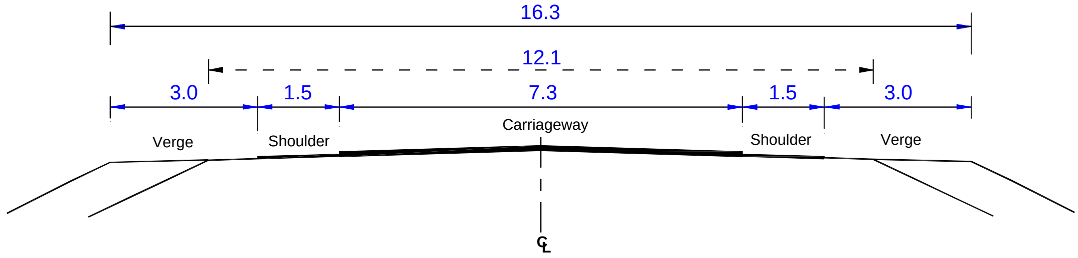
<u>Width of sectional elements (m)</u>

Crest	21.6
Median	1.0
Carriageway	7.3
Shoulder (L) – paved	1.8
Shoulder (R) – paved	0.3
Verge	0.9

<u>Design Capacity</u>
Maximum capacity: 4500 PCU/hr
(assumes that NMVs are either prohibited or are less than 50 PCU/hr)

<u>NMV provision</u>
NMVs will use the shoulder. If the Design Year NMV PCU/hour exceeds 50 adopt the Type 2a cross-section which incorporates separate NMV lanes.
<u>Median</u>
See Figure 4.9 for alternative designs.

Figure 4.4 Design Type 3 7.3m carriageway



<u>Width of sectional elements (m)</u>

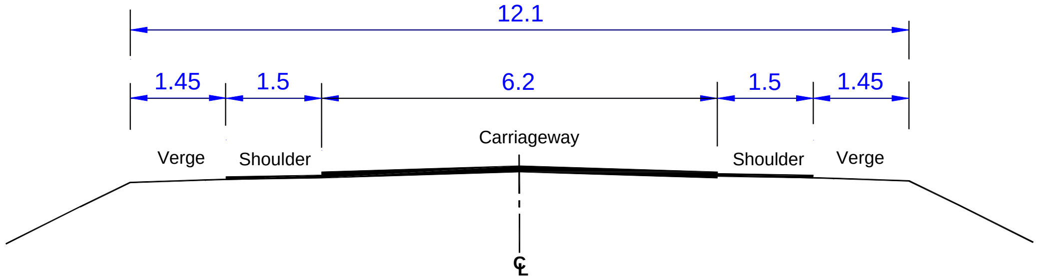
Crest	16.3
Carriageway	7.3
Shoulder – paved	1.5
Verge	3.0

<u>Design Capacity</u>
Maximum capacity: 2100 PCU/hr
(assumed NMV/MV ratio of 0.2)

<u>NMV provision</u>
NMVs will use the paved shoulder. Consider providing separate NMV lanes (Type 3a cross-section) if the DY NMV PCU/hr exceeds 400 – see Figure 4.8.

<u>Crest width</u>
The extra-wide embankment permits the future addition of NMV lanes. If it is unlikely that these will ever be needed the verge need only be 0.9m wide, making the crest width 12.1m.

Figure 4.5 Design Type 4 6.2m carriageway



<u>Width of sectional elements (m)</u>

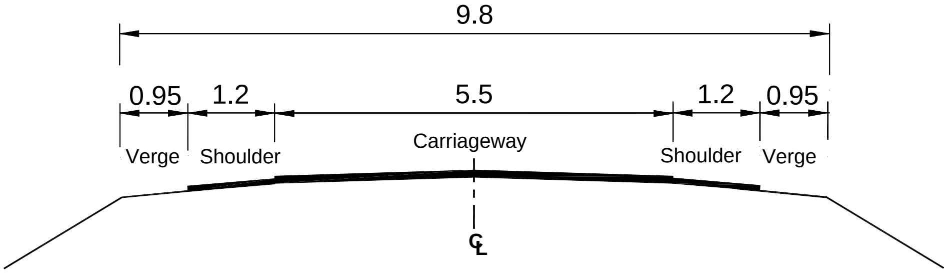
Crest	12.1
Carriageway	6.2
Shoulder – paved	1.5
Verge	1.45

<u>Design Capacity</u>
Maximum capacity: 1600 PCU/hr
(assumed NMV/MV ratio of 0.14)

<u>NMV provision</u>
Where DY NMV PCU/hr exceeds 400 consider providing separate NMV lanes (Type 4a cross-section) – see Figure 4.8.

<u>Upgrading</u>
The extra-wide embankment permits upgrading to Type 3 standard.

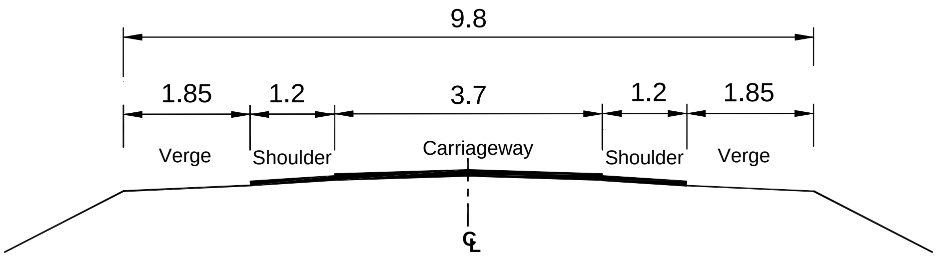
Figure 4.6 Design Type 5 5.5m carriageway



Width of sectional elements (m)		Design Capacity
Crest	9.8	Maximum capacity: 800 PCU/hr
Carriageway	5.5	
Shoulder – paved	1.2	
Verge	0.95	

NMV provision
NMVs will use the carriageway and the shoulder, so it is essential that there is no difference in level between the two.
Upgrading
The extra-wide embankment permits upgrading to Type 4 standard.

Figure 4.7 Design Type 6 3.7m single lane carriageway



Width of sectional elements (m)		Design Capacity
Crest	9.8	Maximum capacity: 400 PCU/hr
Carriageway	3.7	(assumed NMV/MV ratio of 2.5)
Shoulder – paved	1.2	
Verge	1.85	

NMV provision
NMVs will use the carriageway and the shoulder, so it is essential that there is no difference in level between the two.
Upgrading
The extra-wide embankment permits upgrading to Type 5 and Type 4 standards.
Capacity
The design capacity of 400 PCU/hr is only achievable with good, well-maintained shoulders and when most of the vehicles are NMVs.

Figure 4.8 Typical NMV Arrangements at Bazar & Hats

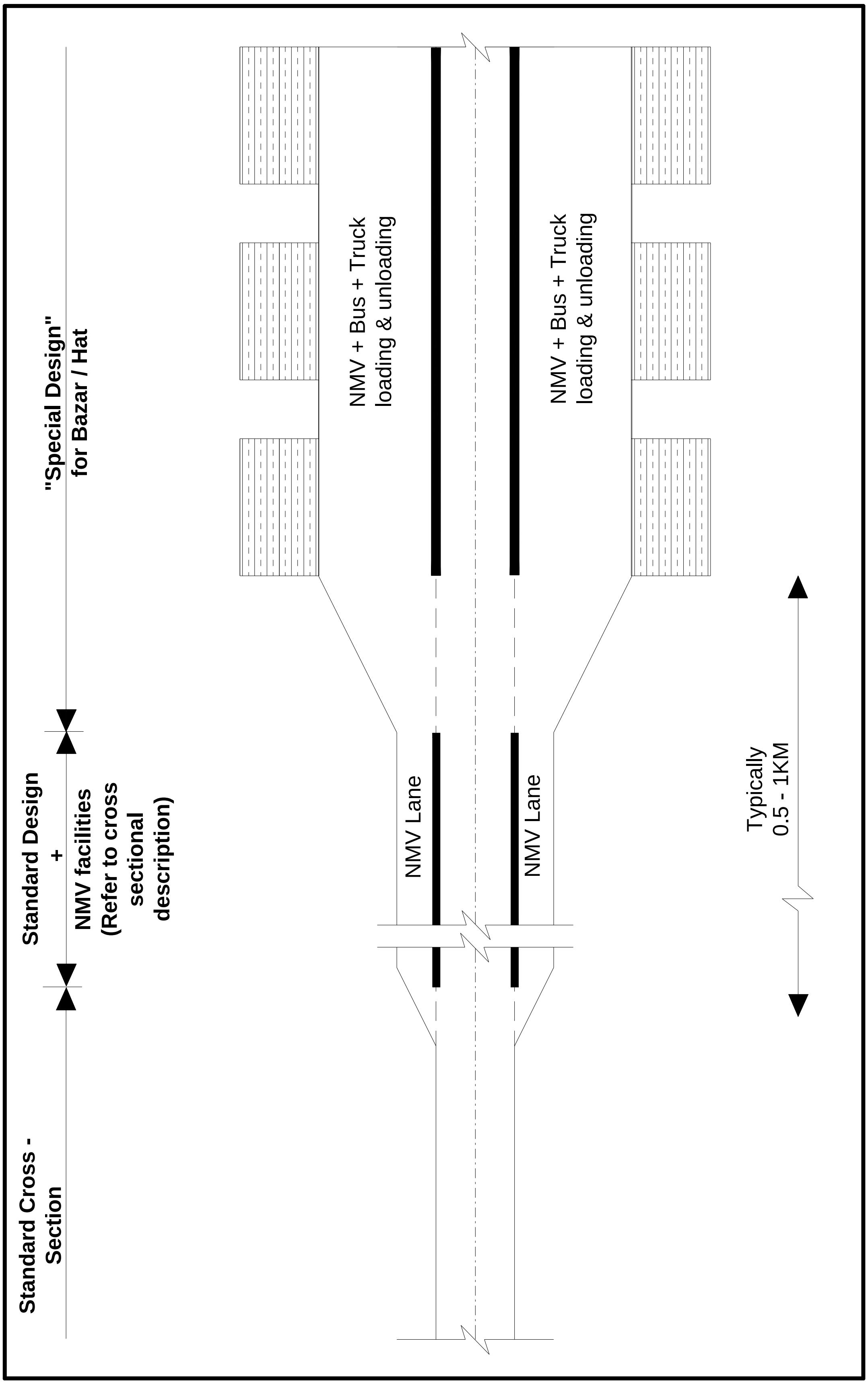
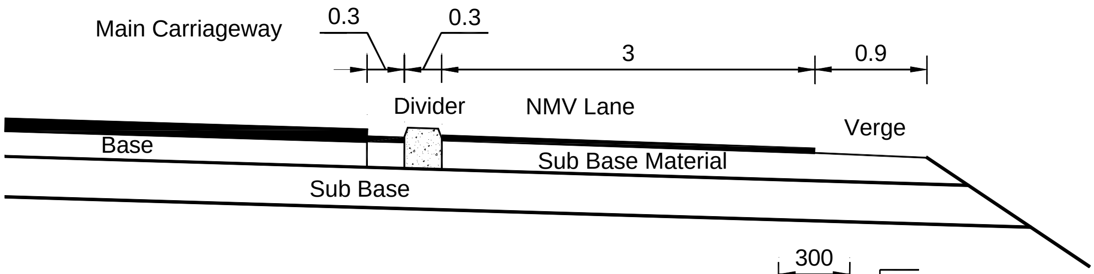


Figure 4.8 NMV Lane Designs

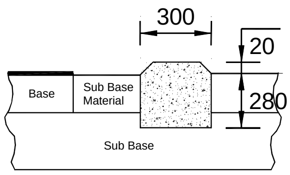
Shown are generalised designs – other designs may be acceptable

A. Rural sections – between towns and villages

Cross Section

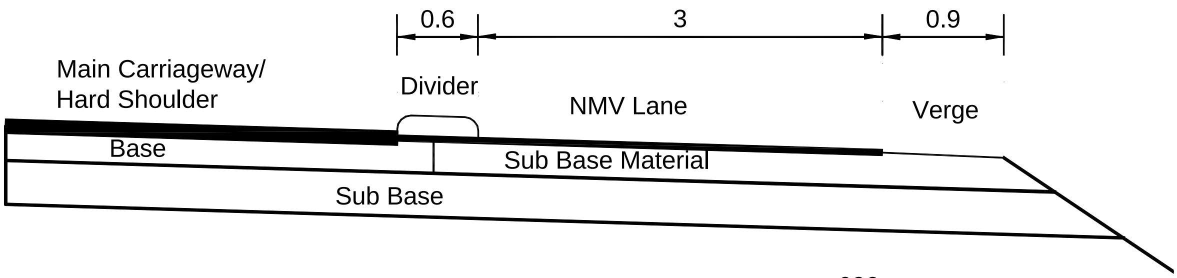


Divider Detail
Divider is a concrete cube 300x300x300
set in the pavement at 1m intervals.

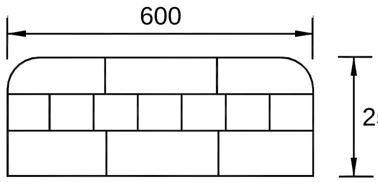


B. Towns and villages (low pedestrian and NMV flows)

Cross Section



Divider Detail
Brick divider to be constructed on a mortar pad directly on the road surface. Gaps are to be left in the brick work to let the carriageway drain through to the NMV lane. Width of divider should be increased if there are many pedestrians.



C. Towns and villages (high pedestrian and NMV flows)

Cross Section

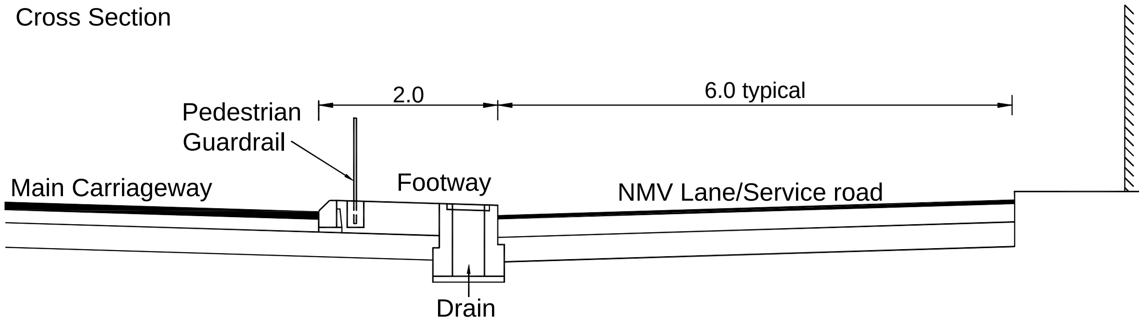
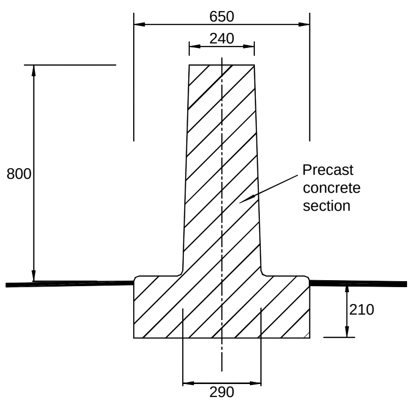


Figure 4.9 Median Designs

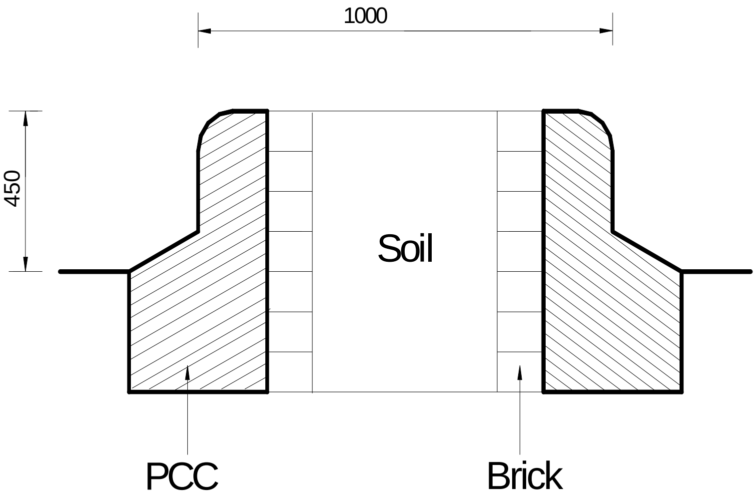
The New Jersey Safety Barrier is the prefered divider on RHD roads. Two alternative types of median are illustrated below. These are generalised designs and other designs may be acceptable. The reinforced concrete safety barrier (such as the New Jersey Safety Barrier) is the safest option for busy, high-speed roads, because it will stop any out-of-control vehicle from crossing into the opposite carriageway. The island divider will stop some but not all vehicles – however it is much cheaper and does provide a refuge for pedestrians when they are crossing the road.

Medians should begin only in low-speed situations such as just after roundabouts or at the start of the minor arm of a T-junction. Adequate warning signs and hazard markers must be provided. The number of openings in the median must be kept to an absolute minimum for safety reasons. Where openings cannot be avoided a separate lane should be provided for turning traffic, and drivers of turning vehicles must be given a good view of oncoming traffic.

RCC Safety Barrier



Island divider



5 Horizontal Alignment

5.1 General

The horizontal alignment of single carriageway roads will normally consist of a series of straights (tangents) or very large radius curves, linked by smaller radius curves. Continuous curving alignments with few or no straight sections are not recommended, because unless the curve radii are very large they will not provide sufficient sight distance to allow drivers to clearly see whether it is safe to overtake. Instead, relatively short curves, at or near the minimum radius for the design speed should be used in conjunction with straights or very large radius curves. Maximising safe overtaking conditions is one of the key objectives of alignment design. This is especially important in Bangladesh where there is a large proportion of slow-moving vehicles.

Excessive lengths of straight should be avoided as these could encourage dangerously high speeds. Very large radius curves (>5000m radius) are safer than long straight sections. A succession of curves and straights makes for a more interesting driving task, and helps the driver stay in control. Drivers are better able to assess the distances and speeds of other vehicles, they are more likely to remain alert, and there is less headlight glare at night.

Continuous curving alignments are more acceptable on dual carriageway roads because there is no need to provide overtaking sight distance.

5.2 Determining the Curve Parameters

The key design parameter for circular curves is the radius, and the main factors that help determine the appropriate value are the design speed and the required sight distance. A step by step guide to determining curve radius and related design parameters is given below:

1. Decide what sight distance to use

The Intermediate Sight Distance (ISD) provides a good starting point for curve design. It avoids the need for superelevation and makes future upgrades much easier. Single lane roads and dual carriageway roads must always be designed to provide Intermediate Sight Distance.

2. Use Table 5.1 to determine the minimum curve radius

Knowing the road type and the design speed, and having selected a sight distance, read off the appropriate value for curve radius.

3. Check for feasibility – amend if necessary

If site constraints prevent a curve of this radius being provided, check whether a curve to Stopping Sight Distance (SSD) requirements will be feasible. Do not use curves whose radius is between the ISD and SSD standards as these could tempt drivers to overtake when there is not enough visibility – curves must be clearly non-overtaking (SSD standards) or clearly overtaking (at least ISD standards and preferably Overtaking Sight Distance standards).

4. Use Table 5.2 to determine the minimum superelevation requirements

Knowing the design speed and the curve radius the appropriate value of superelevation is read off from Table 5.2. In some cases no superelevation will be required. Refer to Section 5.3.

5. Use Table 5.3 to determine minimum transition lengths
Knowing the design speed and the superelevation the appropriate transition length is read off from Table 5.3. Refer to Section 5.4. If transition curves are not being used Table 5.3 can be used to find the superelevation development length (*Lp + Lc).*
6. Use Table 5.4 to determine whether there are any curve widening requirements
Knowing the road type and the curve radius the appropriate curve widening (if any) is read off from Table 5.4. Refer to Section 5.5.

Table 5.1 Minimum Curve Radii (metres)

Design Speed (km/h)	Single Lane Roads (3.7m carriageway)	Two Lane Single Carriageway Roads (6.2 and 7.3m carriageway)			Dual Carriageway Roads (2 x 7.3)
	ISD	SSD	ISD	OSD	ISD
30	120	35	120	500	-
40	250	65	250	1000	-
50	500	120	500	2000	500
65	1000	250	1000	4000	1000
80	-	500	2000	8000	2000
100	-	1000	4000	-	4000

Notes:
It is generally assumed that visibility will only be available within the limits of the cross-section (i.e. the top of the embankment).
Source: adapted from Table 7.54, RMSS, Vol. V11A

Table 5.2 Minimum Superelevation Requirements (%)

Design Speed (km/h)	Sight Distance (m)								
	25	30	45	60	90	120	180	250	360
	Curve Radii (m)								
	20	35	65	120	250	500	1000	2000	4000
	Minimum Superelevation Requirements (%)								
30	7	5	3	Nil	Nil	-	-	-	-
40	-	7	5	3	Nil	Nil	-	-	-
50	-	-	7	5	3	Nil	Nil	-	-
65	-	-	-	7	5	3	Nil	Nil	-
80	-	-	-	-	7	5	3	Nil	Nil
100	-	-	-	-	-	7	3	3	Nil

Source: adapted from Table 7.55, RMSS, Vol. V11A

Table 5.3 Minimum Design Transition Length (m)

Design Speed (km/h)	Superelevation *e*			Straight Transition Length (m) *Lc*
	7%	5%	3%	
	Plan Transition Length (m) *Lp*			
30	25	15	10	10
40	35	20	13	13
50	45 [55]	25 [35]	15 [20]	15 [20]
65	55 [65]	35 [45]	20 [25]	20 [25]
80	65 [75]	45 [55]	25 [35]	25 [35]
100	75 [95]	55 [65]	35 [45]	35 [45]

Notes:
1. Values in brackets refer to dual carriageway roads
2. Figure 5.1 illustrates the two types of transition *Lp* and *Lc*
3. To allow scope for future road upgrades and higher design speeds it is desirable to select Lp values for one design speed and one 'e' value larger than the values given by input.

Source: adapted from Table 7.58 and 7.59, RMSS, Vol. V11A

Table 5.4 Extra Carriageway Width On Curves (m)

Radius (m)	Single Lane Roads	Two Lane Roads	
	3.7m wide	6.2m wide	7.3m wide
15	1.8	2.4	2.1
16 to 20	1.5	2.1	1.8
21 to 35	1.2	1.8	1.5
36 to 65	0.9	1.5	1.2
66 to 120	0.6	1.2	0.9
121 to 200	Nil	0.9	0.6
201 to 350	Nil	0.6	Nil
351 to 600	Nil	0.6	Nil
601 to 1000	Nil	Nil	Nil

Notes:
1. For transitioned curves half the widening is applied on each side of the centreline, and it is developed uniformly over the length of the transition curve.
2. For curves without transitions the widening is applied on the inside of the curve, and it is developed uniformly over a 20m length leading up to the start of the circular curve.

Source: adapted from Table 7.56, Vol. V11A. RMSS

Worked Example

- Assumptions: Design Class C; 6.2m carriageway; 65km/h design speed

- Table 5.1 indicates that the minimum curve radii needed to provide Intermediate Sight Distance is 1000m. On the section that is being designed it is not possible to fit in a curve of more than 850m radius because of site constraints (buildings, deep borrow pits, etc.). So the Stopping Sight Distance curve is used instead. Table 5.1 indicates that this is 250m radius.

- Table 5.2 indicates that a 250m radius curve on a 65km/h road will need 5% superelevation.

- Table 5.3 indicates that a 5% superelevated curve on a 65km/h road will need a plan transition curve 35m long, but to allow for upgrades the next highest value (for both speed and superelevation) is taken – which is 65m. The superelevation will start to be developed 25m before the transition curve starts.

- Table 5.4 indicates that a 250m radius curve on a 6.2m wide road will need to be widened by 0.6m (0.3m each side).

5.3 Superelevation

The normal crossfall on a road will result in vehicles on the outside lane of a horizontal curve needing to develop higher than normal levels of frictional force to resist sliding. In many cases it will be necessary to remove this adverse crossfall, for safety and comfort reasons. For small radius curves and at higher speeds the removal of adverse crossfall will not be enough to reduce the frictional needs to an acceptable level and a steeper crossfall (superelevation) must be provided.

Table 5.2 gives the minimum superelevation requirements for the various design speeds and curve radii. Values of 3% indicate that only removal of adverse crossfall is required. Maximum permitted superelevation is 7% but it is desirable to avoid using curves that need this amount of superelevation unless site constraints make it really necessary. Use of lower superelevation levels allows the alignment to be upgraded to a higher design speed in the future by increasing the superelevation.

Figure 5.1 illustrates the standard way of developing superelevation on curves which have plan transitions (see Section 5.4). Adverse crossfall is removed over a tangent section (*Lc* “Straight Section”) and the full superelevation is developed over the length of the transition curve (*Lp* “Plan Transition”). The transition lengths to be used are given in Table 5.3 – see also section 5.4.

The axis of rotation (the point about which the crossfall is rotated to develop superelevation) shall be the inner curve carriageway edge – see Figure 5.1. This has been chosen to make sure that the whole carriageway always has the necessary freeboard above High Flood Level. It also avoids the drainage problems that sometimes occur at the low point on the inner edge.

Where transition curves are not used the superelevation should be developed uniformly so that two-thirds is applied prior to the start of the circular curve. The length over which the superelevation is developed shall be $Lc + Lp$ (Table 5.3).

The treatment of shoulders on superelevated curves needs care. Shoulders having the same surface quality as the carriageway may be in the same plane, but normally the outer shoulder will slope outwards. In order to avoid too sharp a change in slope from carriageway to outer shoulder the shoulder crossfall should be as follows:

2% with carriageway superelevation of 5 - 7%
4% with carriageway superelevation of 3%

The join between carriageway and outer shoulder must be smoothed off so that it is not hazardous to vehicles such as motorcycles.

The crossfall on the inner shoulder will either be 5% or the same as the carriageway superelevation, whichever is the greater .

5.4 Transition Curves

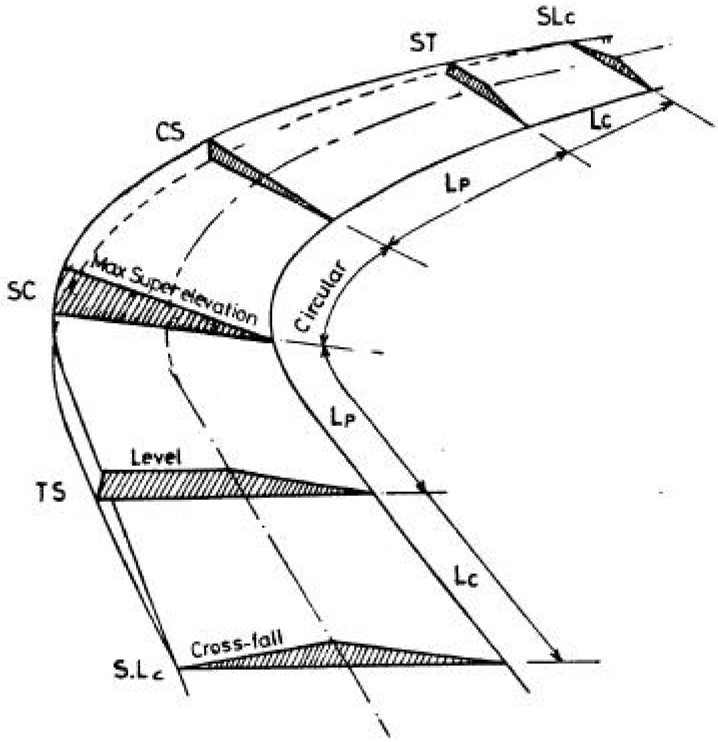
A transition curve (also called a plan transition curve) is one which has a constantly changing radius, as in a spiral. It is common practice to insert transition curves between tangents and circular curves to make it easier for drivers to steer smoothly into the curve. The transition is a convenient section over which superelevation and pavement widening can be applied. And by smoothing out the edge of the carriageway the transition can make the road look better. Although some national road authorities are unconvinced about the benefits of transitions, and do not use them, there is evidence of safety benefits, especially for high-sided articulated trucks. The general advice is to continue with the practice of using transitions on the higher-speed roads. Very large radius curves do not need plan transitions.

The usual geometric form adopted for transitions is the clothoid, where curvature changes at a uniform rate along the curve. The length of the transition curve is dependent on the superelevation requirements. The transition curve is used to develop the superelevation from where the outer lane is level to full superelevation at the start of the circular curve – see Figure 5.1. Table 5.3 gives the minimum lengths to be used. It is desirable to use a transition curve length that is one design speed and one superelevation value higher than indicated by the input values in order to allow for future road upgrades.

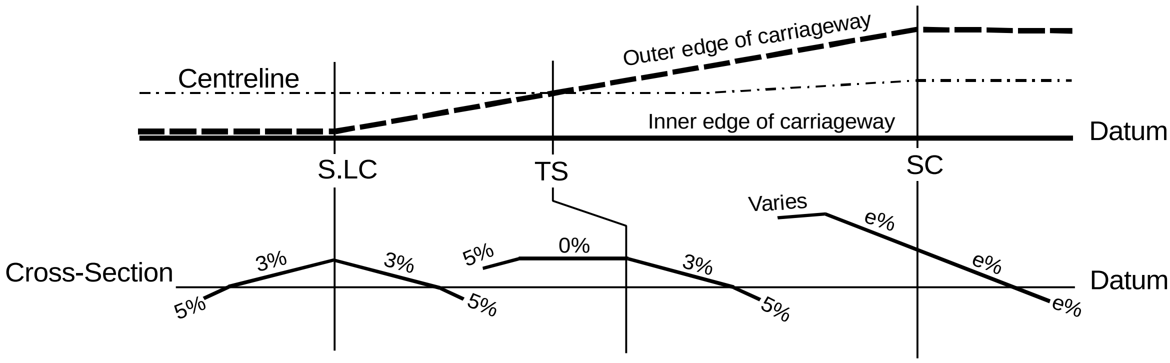
Figure 5.1 Development of Superelevation on Transitioned Curves

A. Perspective

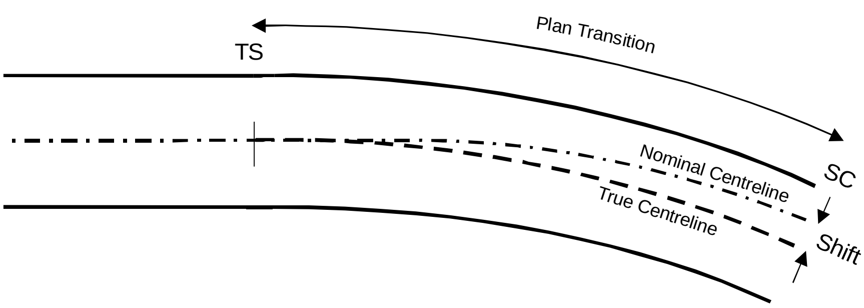
S.LC = Start of superelevation development
TS = Tangent to spiral point
SC = Spiral to curve point



B. Elevation



C. Plan



The amount by which either end of the circular curve is shifted inwards from the tangent is called the *shift* – see part C of Figure 5.1 For the clothoid the value of the shift can be taken as $L^2/24R$ where L is the length of the transition curve, and R is the radius of the circular arc. Where the shift is less than 250mm it serves no purpose and the transition curve can be omitted.

Long transition curves can sometimes hide the true sharpness of the curve ahead, and this is dangerous. Shorten the transition length and, if possible, improve the view of the curve. Do not make transitions longer than necessary for superelevation development, and always ensure that the nature of the circular curve is fully evident to the approaching driver.

5.5 Curve Widening

It is necessary to widen the carriageway on small radius curves in order to enable vehicles to pass each other safely. The lateral positioning of vehicles varies more on a curve than on a straight. Moreover long vehicles occupy a greater width of pavement on a curve. The amount of widening needed is dependent on the curve radius, the width of the carriageway, and the type of the vehicle. Table 5.4 sets out the extra carriageway widths that are required. These are appropriate for rigid two-axle vehicles similar to the buses and trucks widely used in Bangladesh. Where there is a transition curve the widening should be introduced gradually along the transition; half the widening is applied on each side of the centreline. On plain circular curves with no transitions the widening is added to the inside of the curve, in which case the same effect as a transition is achieved. The widening should be introduced gradually over a 20m length leading up to the start of the circular curve.

Where Type 5 and 6 roads have stretches with a lot of curvature that requires local widening it may be better to increase the carriageway width over the whole section. This will make the road easier to drive, and could have benefits for construction and maintenance.

5.6 Other Considerations

Other points to consider when designing horizontal alignments include:

- When the road is to change direction by only a very small amount it is desirable to use a large radius curve rather than omit the curve entirely;
- A straight section should be inserted between two curves that go in opposite directions (reverse curves) – this will help drivers to adjust to the changed direction and make it easier to alter the superelevation;
- Compound curves (two or more curves of differing radii going in the same direction) should be avoided unless the curves are of large radius – it is best to separate the successive curves by a straight section, for the same reasons as above
- Sharp bends at the end of long straights are highly dangerous and must be avoided – always check the consistency of adjacent design elements (see Section 3.6) – where there is no option but to include a very sub-standard curve bring the approach speeds down gradually by introducing curves of decreasing radii until the critical point is reached;
- Always check that the design produces a pavement which has no flat spots where water will collect.

6 Vertical Alignment

6.1 General

The vertical alignment of a road consists of a series of straight grades and vertical curves. The vertical curves smooth the passage of vehicles from one grade to another and enable sight distance to be maintained over the summit of a rise. Convex vertical curves are called summit or crest curves, and concave vertical curves are known as sag curves. At crest curves the minimum length is determined principally by the need to provide the required sight distance, though appearance is also a consideration. On sag curves sight distance is generally not a problem, at least in daylight, but satisfactory results can be obtained by designing them in the same way as crest curves.

6.2 Type of Curve

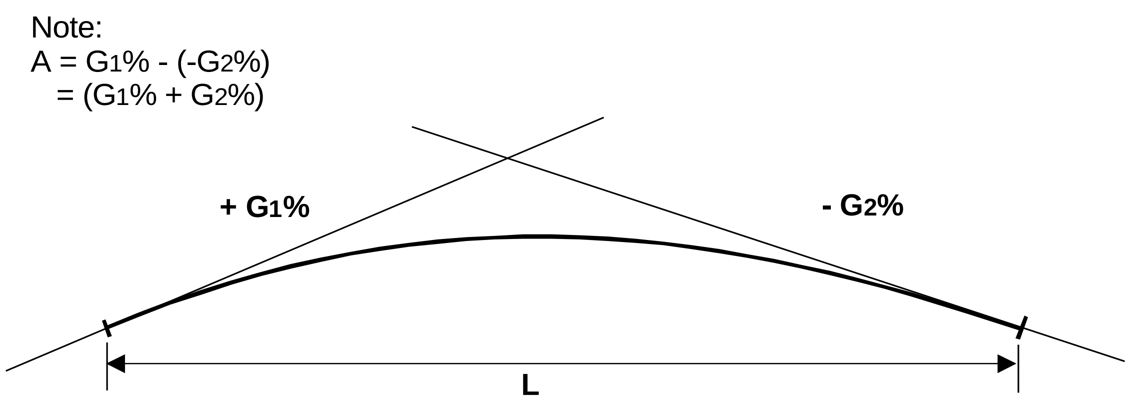
The recommended form of vertical curve is the parabola (see Figure 6.1). It is convenient to define parabolic vertical curves by the length of curve required for a change of grade of 1%, this being a constant for the parabola:

K = L/A

where:
K = length required for a 1% change of grade
L = length of vertical curve (assumed to equal length in plan)
A = change of grade in %

The K value is effectively an expression for degree of curvature (multiplying K by 100 gives the "equivalent radius" of the vertical curve). Table 6.1 contains the K values for each combination of road type / design speed / sight distance. Knowing K and A it is a simple matter to calculate L (see next section).

Figure 6.1 General Form of Parabolic Vertical Crest Curve



6.3 Determining the Curve Parameters

Vertical curves are specified in terms of their length L (or LVC - Length of Vertical Curve). A step by step guide to determining L is set out below:

1. Decide what sight distance to use

The Intermediate Sight Distance (ISD) provides a good starting point for curve design. In hilly terrain it is advisable to use the Stopping Sight Distance (SSD), as this will be more economic and will maximise the overtaking sight distance available on the gradients either side of the curve. Single lane roads and dual carriageway roads should always be designed to provide ISD.

2. Use Table 6.1 to determine the 'K' value

Knowing the road type and the design speed, and having selected a sight distance, read off the appropriate value for K in Table 6.1

3. Calculate 'A'

Knowing the gradient of the road on each side of the vertical curve calculate A (the change in grade in % - see Figure 6.1). Refer to Table 6.2 to determine whether the change in grade is sufficient to make a vertical curve necessary

4. Calculate the length of the curve

In most cases L = K x A (but see next step for exceptions)

5. Carry out cross-checks

Compare L with the minimum length of vertical curve required for acceptable appearance (Table 6.2) and increase L if necessary. If the sight distance might be longer than the vertical curve (such as could occur with the higher design speeds or the use of OSD) recalculate the curve length using L = 2S – 960/A where S = sight distance (sight distances are given in Table 2.3). Use the curve length which is the longest.

6. Check for feasibility – amend if necessary

If site constraints or costs prevent a vertical curve of this length being provided, check whether a curve to SSD requirements will be feasible. Do not use curves whose radius is between the ISD and SSD standards as these could tempt drivers to overtake when there is not enough visibility – curves must be clearly non-overtaking (SSD standards) or clearly overtaking (at least ISD, and preferably OSD).

Table 6.1 Minimum Vertical Curve 'K' Values

Design Speed (km/h)	Single Lane Roads (3.7m carriageway)	Two Lane Single Carriageway Roads (6.2 and 7.3m carriageway)			Dual Carriageway Roads (2 x 7.3)
	ISD	SSD	ISD	OSD	ISD
30	4	2	4	18	-
40	9	4	9	35	-
50	18	9	18	70	18
65	35	18	35	140	35
80	-	35	70	270	70
100	-	70	140	540	140

Notes:
1. To calculate curve length use equation L = K x A where A is the algebraic difference in gradients
2. For the higher design speeds and OSD recalculate the curve length using L = 2S – 960/A where S = sight distance (from Table 2.3) and then use the higher of the two curve lengths
3. Use Table 6.2 to check that the curve length exceeds the minimum length required for a good appearance – increase the curve length as necessary

Source: adapted from Table 7.47, RMSS, Vol. V11A

Table 6.2 Vertical Curve Appearance Criteria

Design Speed (km/h)	Maximum Change of Grade Permitted Without Use of a Vertical Curve (%)	Minimum Length of Vertical Curve for Good Appearance (m)
30	1.5	15
40	1.2	20
50	1.0	30
65	0.8	40
80	0.6	50
100	0.5	60

Source: adapted from Table 7.42 & 7.43, RMSS, Vol. V11A

Worked Example

1) Assumptions: Design Class C; 6.2m carriageway; 65km/h design speed; at the summit where the curve is needed the grade goes from +6% to –4%; ISD requirements.

2) Table 6.1 indicates that the minimum K value for ISD on 65km/h 6.2m roads is 35.

3) A = 6% – (-4%) = 10% This is well in excess of the maximum change of grade specified in Table 6.2, so a vertical curve is needed.

4) L = 35 x 10 = 350m

5) L is well in excess of the minimum length of curve for good appearance, so it is acceptable [Table 6.2]. Recalculating L in case sight distance is longer than the curve gives L = (2 x 180) – 960/10 = 264. [Table 2.3 indicates that ISD for a 65km/h design speed is 180m]. A curve length of 350m is selected.

6.4 Gradients

Table 6.3 sets out the maximum limits on gradients. In flat terrain (most of Bangladesh) the 3% grade limit will ensure that the roads provide a good level of service for all types of traffic including non-motorised vehicles (NMVs). The choice of grade limits for rolling and hilly terrain reflects the fact that there is a high proportion of overloaded trucks and buses on our roads. There is generally very little NMV traffic in these areas.

Table 6.3 Maximum Gradients

Design Type	Design Speed	Maximum Gradient %		
		Plain	Rolling	Hilly
All Design Types	All Design Speeds	0 - 3	1 - 5	1 – 7

Source: adapted from Table 7.41, RMSS, Vol. V11A

7 Appearance

7.1 General

The visual aspects of geometric design are of considerable importance for safety and amenity. The roadside view gives drivers important clues as to how to cope with the road ahead, and it should also be pleasant and interesting for passengers. Roads tend to disrupt rural views, but with careful design and supplementary landscaping the impact can often be softened, and everyone benefits.

Designers need to think how the road will look, right from the beginning of the design process. The traditional method of working with plans, longitudinal profiles and cross-sections makes this a little difficult, but a three-dimensional view of what is being designed is essential. This is the view that drivers will see and act upon. Computer graphics software can now produce these views from the alignment drawings, and can simulate a drive along the road.

7.2 The Driver's View

The designer must provide the driver with as many clues as possible as to what lies ahead, and some of the ways of doing this include:

- Using trees and planting to highlight where the road changes direction or where there is a junction
- Blocking off disused roads or tracks with mounding and planting to ensure that they do not distract or mislead drivers
- Using roadside planting at the entrance to villages to give the impression that the road is narrowing, so that drivers slow down
- Locating major junctions and other critical points on shallow sag curves where the visibility will be good – never at sharp crests

It is also important to ensure that the roadside view will not give any false or misleading messages.

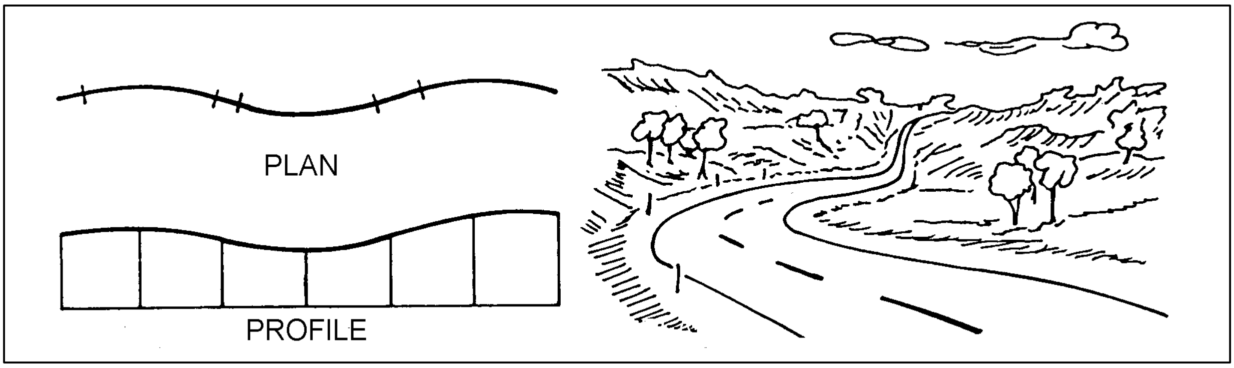
7.3 Fitting the Road to the Terrain

The aim should be to design the horizontal and vertical curvature so that it blends into the terrain in an aesthetically pleasing way and does not present any awkward surprises to the driver. The most effective way of achieving this is generally by keeping the horizontal and vertical curvature in phase, as this relates most closely to naturally occurring forms. This means that the vertical curves should be contained within the horizontal curves – see Figure 7.1. This enhances the appearance in sag curves, and improves the safety of crest curves by indicating the direction of curvature before the crest.

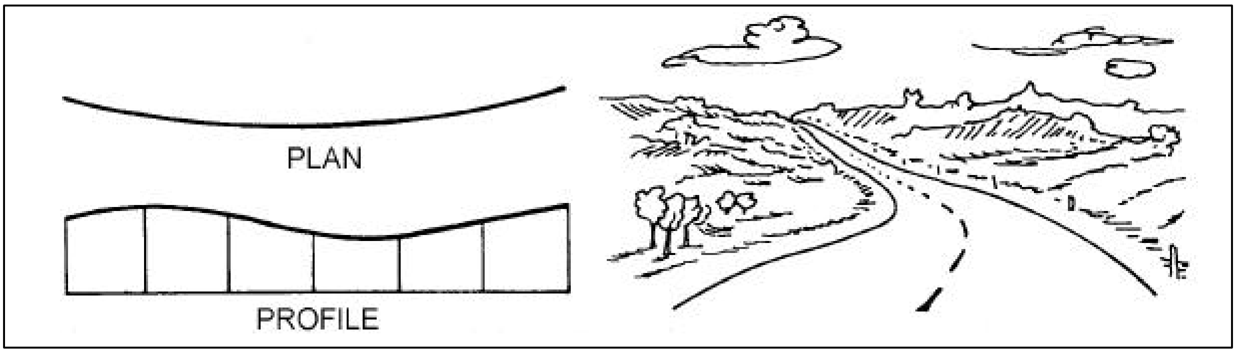
Figure 7.1 Co-ordination of Horizontal and Vertical Alignment

Source: Rural Road Design, Austroads, 1989

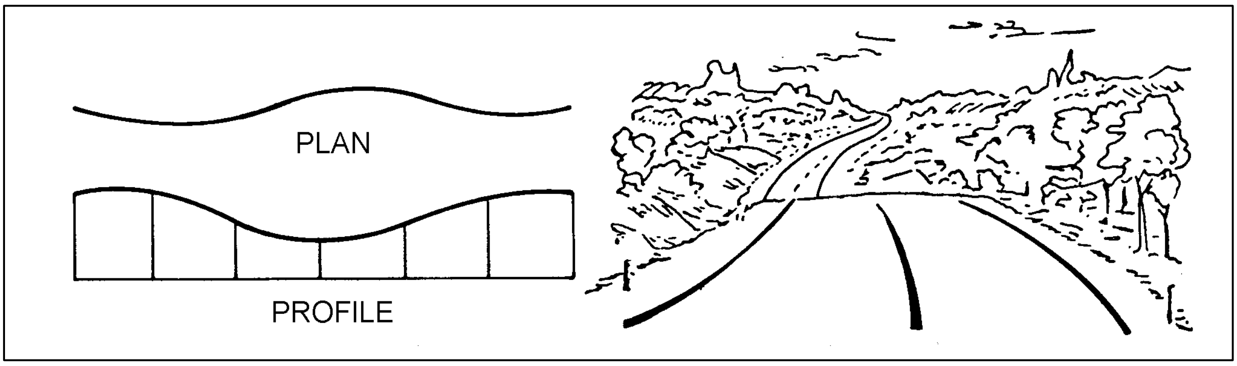
A. The ideal combination. The vertical and horizontal curves coincide and the result is a smooth flowing appearance. Ideally, horizontal curves should slightly overlap the vertical curves.



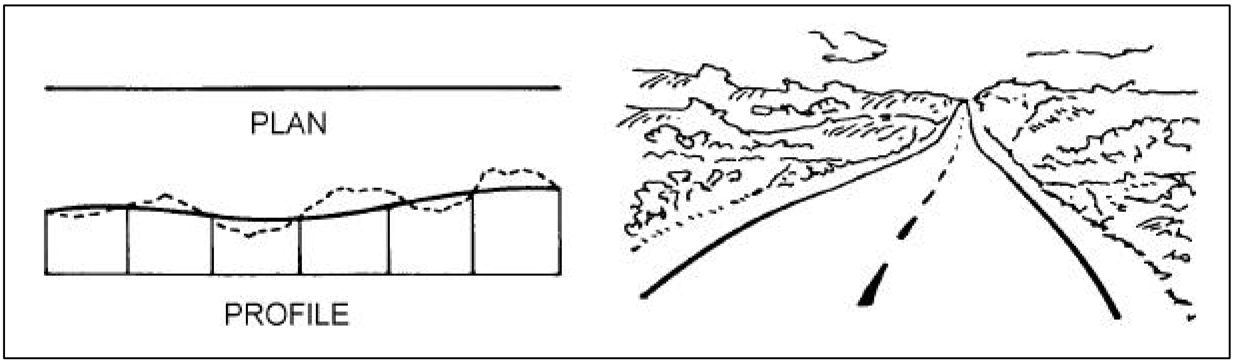
B. If the horizontal scale is large and the vertical scale is relatively small, it may be satisfactory to include two vertical movements on one long horizontal curve.



C. This is dangerous. The summit curve restricts the driver's view of the start of the horizontal curve.



D. This alignment shows lack of integration with the landform



8 Junctions

8.1 General

The design of junctions is a complex subject. More research and experimentation will be needed before we can confidently recommend junction designs that can handle Bangladesh's mixed traffic in a safe and efficient way. In the meantime some general advice can be given on the principles to be followed. This should be read in conjunction with the Road Safety Division's Design Advice Notes on junctions – these contain provisional designs for most types of junction.

8.2 Design Principles

The key requirements are:

- Design for all road users, including the NMVs and the pedestrians
- Minimise conflicts
- Ensure good visibility
- Keep the paved area to the minimum needed for manoeuvring – excessive space means higher speeds, less control over how vehicles move through the junction, and more danger for pedestrians
- Junction geometry should encourage appropriate speeds
- Ensure that the layout is clear and simple – define the vehicle paths clearly – ensure that it is obvious who has precedence - allow complicated manoeuvres to be carried out a step at a time
- Provide kerbed footways and pedestrian guardrail – to keep pedestrians out of the junction and channel them to safe crossing points – guardrail also discourages buses and rickshaws from stopping in the junction and keeps the carriageway clear of people selling things

8.3 Priority Junctions (e.g. T-junctions)

Key points to consider are:

- Cross-roads should not be used, because they tend to have a high rate of accidents – staggered T-junctions are much safer;
- Y-junctions (where one road joins another at a small angle) are also dangerous and should not be used;
- T-junctions work best when the minor road meets the major road at an angle of 90°;
- Corner radii at T-junctions can be between 6 and 10m depending on the turning traffic (buses and trucks need larger radii) and the amount of traffic on the main road – where the junction will be frequently used by buses it is best to use a larger, compound curve;
- At T-junctions put a channelising island in the minor road arm if there is a significant volume of minor road traffic or there are many pedestrians crossing (Figure 8.2);
- At busy T-junctions provide a right-turning lane in the main road – this must be created with physical islands not painted island markings, as the latter are likely to be ignored (Figure 8.3).

8 Junctions

8.1 General

The design of junctions is a complex subject. More research and experimentation will be needed before we can confidently recommend junction designs that can handle Bangladesh’s mixed traffic in a safe and efficient way. In the meantime some general advice can be given on the principles to be followed. This should be read in conjunction with the Road Safety Division’s Design Advice Notes on junctions – these contain provisional designs for most types of junction.

8.2 Design Principles

The key requirements are:

- Design for all road users, including the NMVs and the pedestrians
- Minimise conflicts
- Ensure good visibility
- Keep the paved area to the minimum needed for manoeuvring – excessive space means higher speeds, less control over how vehicles move through the junction, and more danger for pedestrians
- Junction geometry should encourage appropriate speeds
- Ensure that the layout is clear and simple – define the vehicle paths clearly – ensure that it is obvious who has precedence - allow complicated manoeuvres to be carried out a step at a time
- Provide kerbed footways and pedestrian guardrail – to keep pedestrians out of the junction and channel them to safe crossing points – guardrail also discourages buses and rickshaws from stopping in the junction and keeps the carriageway clear of people selling things

8.3 Priority Junctions (e.g. T-junctions)

Key points to consider are:

- Cross-roads should not be used, because they tend to have a high rate of accidents – staggered T-junctions are much safer;
- Y-junctions (where one road joins another at a small angle) are also dangerous and should not be used;
- T-junctions work best when the minor road meets the major road at an angle of 90°;
- Corner radii at T-junctions can be between 6 and 10m depending on the turning traffic (buses and trucks need larger radii) and the amount of traffic on the main road – where the junction will be frequently used by buses it is best to use a larger, compound curve;
- At T-junctions put a channelising island in the minor road arm if there is a significant volume of minor road traffic or there are many pedestrians crossing (Figure 8.2);
- At busy T-junctions provide a right-turning lane in the main road – this must be created with physical islands not painted island markings, as the latter are likely to be ignored (Figure 8.3).

8 Junctions

8.1 General

The design of junctions is a complex subject. More research and experimentation will be needed before we can confidently recommend junction designs that can handle Bangladesh's mixed traffic in a safe and efficient way. In the meantime some general advice can be given on the principles to be followed. This should be read in conjunction with the Road Safety Division's Design Advice Notes on junctions – these contain provisional designs for most types of junction.

8.2 Design Principles

The key requirements are:

- Design for all road users, including the NMVs and the pedestrians
- Minimise conflicts
- Ensure good visibility
- Keep the paved area to the minimum needed for manoeuvring – excessive space means higher speeds, less control over how vehicles move through the junction, and more danger for pedestrians
- Junction geometry should encourage appropriate speeds
- Ensure that the layout is clear and simple – define the vehicle paths clearly – ensure that it is obvious who has precedence - allow complicated manoeuvres to be carried out a step at a time
- Provide kerbed footways and pedestrian guardrail – to keep pedestrians out of the junction and channel them to safe crossing points – guardrail also discourages buses and rickshaws from stopping in the junction and keeps the carriageway clear of people selling things

8.3 **Priority Junctions** (e.g. T-junctions)

Key points to consider are:

- Cross-roads should not be used, because they tend to have a high rate of accidents – staggered T-junctions are much safer;
- Y-junctions (where one road joins another at a small angle) are also dangerous and should not be used;
- T-junctions work best when the minor road meets the major road at an angle of 90°;
- Corner radii at T-junctions can be between 6 and 10m depending on the turning traffic (buses and trucks need larger radii) and the amount of traffic on the main road – where the junction will be frequently used by buses it is best to use a larger, compound curve;
- At T-junctions put a channelising island in the minor road arm if there is a significant volume of minor road traffic or there are many pedestrians crossing (Figure 8.2);
- At busy T-junctions provide a right-turning lane in the main road – this must be created with physical islands not painted island markings, as the latter are likely to be ignored (Figure 8.3).

Figure 8.1 Simple Priority Junction

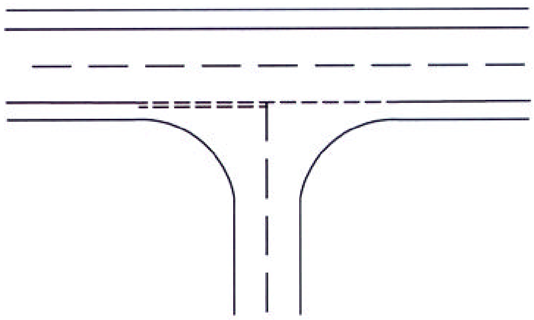


Figure 8.2 Priority Junction with Minor Road Channelising Island

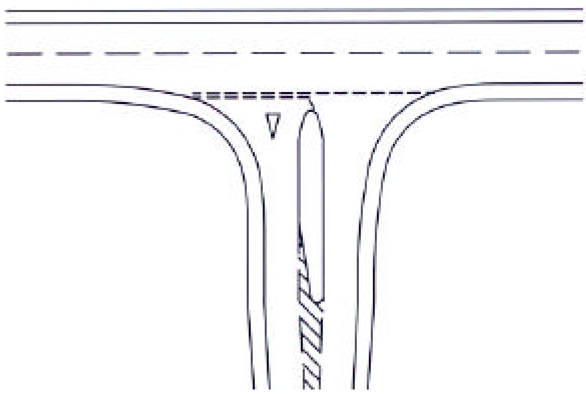


Figure 8.3 Priority Junction with Channelising Islands in Both Roads (Single Lane Dualling)

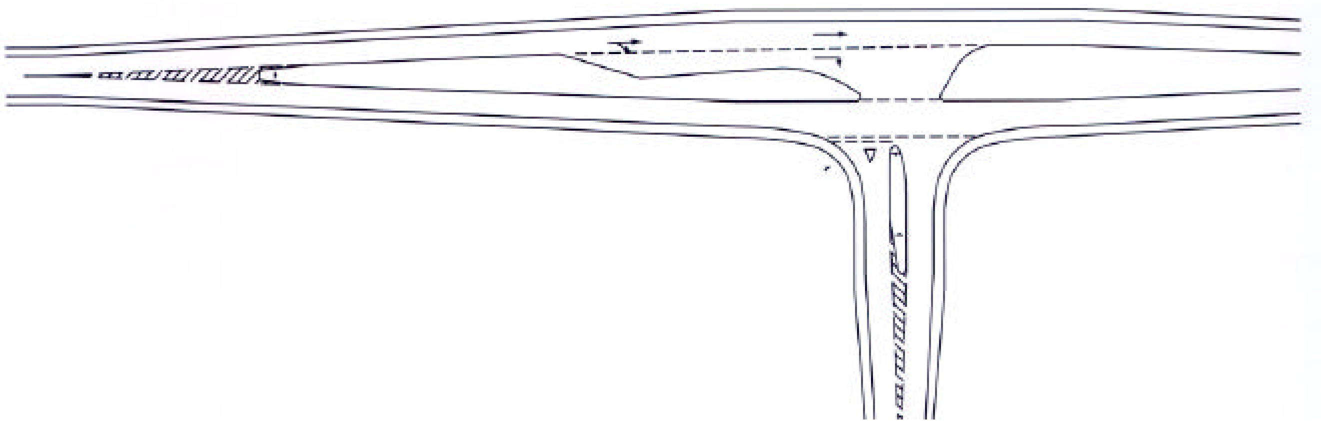
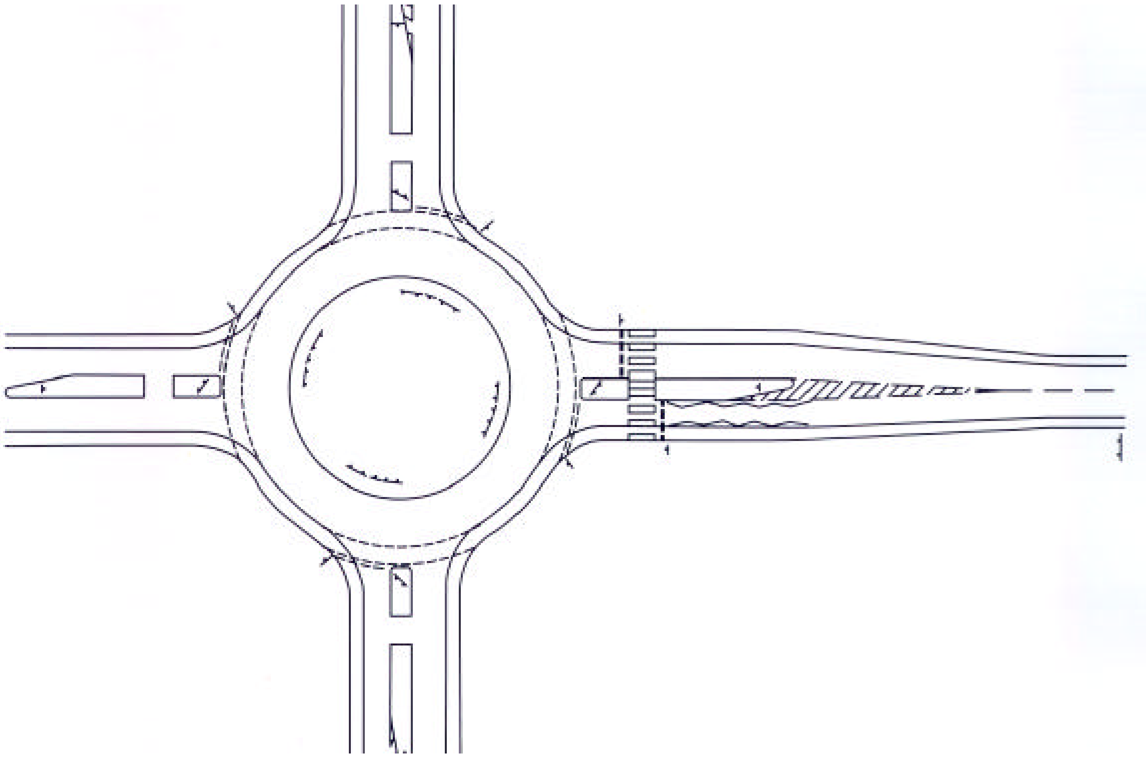


Figure 8.4 Roundabout



8.4 Roundabouts

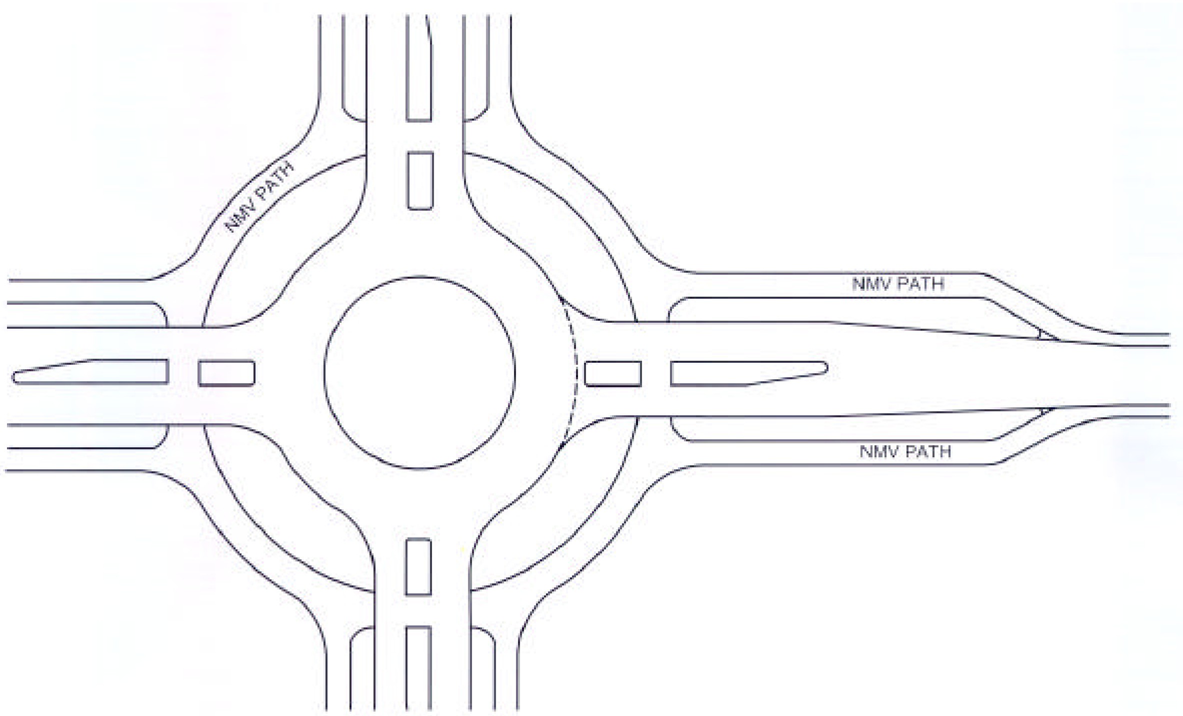
Well-designed roundabouts are a safe, effective form of junction. They can handle much higher volumes of turning traffic than T-junctions. Their safety benefits result primarily from the control they exercise on approach speeds, and this makes them ideal for junctions at the entrance to towns and villages. They are also one of the safest ways of handling the transition between dual carriageways and single carriageways.

The presence of mixed traffic, including NMVs and pedestrians, means that roundabouts must be designed primarily for speed control rather than high capacity – unlike in most developed countries. The layout must deflect entering vehicles sharply to the left in order to control speeds – this can be achieved by having a large centre island and single lane entries that point directly towards the island. The corner radius at the entrance to the circulating carriageway is to be no more than 10-15m in order to keep speeds low. There should normally be a channelising island in each entry road in order to separate entry and exit traffic and provide a refuge for crossing pedestrians. Turning circle templates should be used to check that the layout will accommodate trucks and buses.

Where there are many NMVs it is advisable to provide a separate network of paths around the outside of the roundabout, if there is enough space. The paths must provide a relatively quick and convenient route or the NMVs will not use them. Road Safety Division has a provisional design (see Figure 8.5) which can be adapted to suit the site.

Kerbed footways and pedestrian guardrail should be used at all roundabouts. This helps keep pedestrians out of the junction and discourages vehicles from stopping to let down or pick up passengers. Refer to the Road Safety Division's Design Advice Notes for suitable designs.

Figure 8.5 Roundabout with Segregated NMV Path



9 Designing Safer Roads

9.1 Road Accidents and Their Causes

Bangladesh has a serious road accident problem. In 1998 over 3,000 people were killed in road accidents, and the rate of death per 10,000 vehicles is one of the highest in the world. Apart from the human suffering involved there is a heavy cost to the nation's economy. About half of all the injury accidents occur on RHD roads. Road accidents are complex events and, although road user error is a major cause, there are almost always other contributory factors, including defective vehicles and problems with the road or the road environment. Road problems are rarely the principal cause of accidents, but it is very often the case that, if they had not been present, the accident would not have happened.

The National Road Safety Council is spearheading efforts to improve the skills and attitudes of drivers and other road users, but it will inevitably take a long time for these to produce results. Improving the engineering of our roads is much easier and in the short-term may be the quickest and most effective way of reducing the accident toll. The Roads and Highways Department is committed to this, and all highway designs produced for RHD must take full account of safety concerns. Moreover it is now RHD policy that all major projects be submitted to its Road Safety Division for a road safety audit prior to being finalised (see Section 9.3).

9.2 Safety Principles

Designing safer roads is not technically difficult but it does require a different approach and emphasis from that of traditional road design practice. There are five design principles to be followed:

- Design for all road users
- Reduce conflicts
- Encourage appropriate speeds and behaviour by design
- Avoid surprises and confusion
- Create a forgiving road

9.2.1 Design for All Road Users

In the past road designers have tended to concentrate on providing for motor vehicles to travel along the road as fast as possible. The needs of other road users including pedestrians, cyclists, and rickshaw riders were largely ignored – as were the needs of bus drivers and their passengers, and people who needed vehicle access to roadside property. This was short-sighted because the congestion and other problems caused by failing to provide for all road users meant that the benefits of constructing a good road pavement were partly lost. Designers are now taking a wider view but there is still not enough attention being given to how everyone will use the road.

9.2.2 Reduce Conflicts

Conflicts, whether between vehicle streams, or vehicle types, or vehicles and pedestrians, are always associated with accidents. Conflicts can often be reduced or designed out. Examples include:

- providing shoulders suitable for use by NMVs and stopped vehicles
- providing NMV lanes and service roads separate from the main carriageway
- substituting a roundabout or a staggered junction for a cross-roads
- using pedestrian guardrail to channel pedestrians to safe crossing points
- providing roadside space for markets, bus parks, etc.

9.2.3 Encourage Appropriate Speeds and Behaviour by Design

One of the biggest failings in past road projects has been the way in which roads have been improved through towns and villages without considering the safety implications. Speeds have increased because of the much better pavement, and this has resulted in more accidents. Local people on foot or in rickshaws are the main victims. In future all projects that improve roads through towns and villages must incorporate traffic calming measures. This might involve nothing more than altering the way the road looks as it enters the town or village. Where we want drivers to slow down we must give them clear visual clues, such as changing the shoulder treatment, providing a footway, and installing highly conspicuous signing and road marking. These measures can be supplemented by more aggressive traffic calming measures such as rumble strips, carriageway narrowings and, if absolutely necessary, road humps.

Speed control should also be a primary objective in junction design. This means keeping the amount of paved area to a minimum, using minimum corner radii, and limiting the number of lanes. Roundabouts must be designed so that vehicles are forced to slow down on entry.

9.2.4 Avoid Surprises and Confusion

Good highway design will result in a road which can be easily read and understood by the driver and presents him or her with no surprises. This is a particularly important consideration when designing the alignment – a sharp bend after a long straight or just beyond a crest curve is sure to produce accidents. The consistency check (see Section 3.6) should help prevent these problems. Junctions should be designed so that approaching drivers are faced with a clear, simple, familiar routine for getting through them. Avoid over-complicating the junction with too many islands, lanes and markings.

Traffic signs have a very important role in helping road users to make good, safe use of the road system. Drivers can be warned of difficult or potentially confusing situations and be guided through them. The general standard of traffic signing in Bangladesh is quite poor, but it should improve now that the Bangladesh Road Transport Authority (BRTA) has introduced a new modern traffic sign system. It is essential that the signs be used in a consistent way, and this can be ensured by following the technical advice contained in the BRTA Traffic Signs Manual.

9.2.5 Create a Forgiving Road

A safe road is one which recognises the realities and human limitations of the road user. To say that drivers are wholly to blame for their accidents is not helpful or constructive. Where possible we must build roads that allow for a margin of error – a forgiving road. This is of particular relevance for the design of the roadside, as many severe accidents happen when drivers lose control and the vehicle leaves the road, hits a roadside object, or overturns down a steep embankment. More needs to be done to reduce the severity of these loss-of-control accidents. This includes removing roadside hazards and, where this is not possible, shielding them with safety barrier and signing them. Bridge parapets and traffic islands need to be designed so as to minimise the consequences of vehicles hitting them.

9.3 Safety Audit

It is the policy of the Roads and Highways Department to undertake a safety audit of all its major road schemes prior to completion. A safety audit is a systematic check on the safety of a road scheme done by an independent team of safety experts. It is essential that the audit starts at an early stage in the design process when it is still easy to change things. The key stages for auditing a scheme are:

- the feasibility study – for checking the route, junction location and the road standard
- the engineering design – for checking the detailed design
- pre-opening - for checking signs and markings etc.

The audit procedure is broadly as follows:

- Project Director asks for a safety audit and provides a full set of drawings and reports
- Audit team examines the drawings to check for safety problems and is guided in this by established safety and traffic engineering principles
- Audit team visits the route / site and tries to imagine how the various road users will cope with the proposed road
- An audit report is produced which lists each safety problem together with the recommended solution
- Audit report is submitted to the Project Director who then decides whether to amend the design.

The Road Safety Division is responsible for road safety audits and they have staff with the necessary skills and experience. The schemes that have been audited so far were all about to go to tender, so the scope for changes was rather limited, but nevertheless in every case it has been possible to make worthwhile improvements. If just one injury accident has been prevented then the audit will have more than paid for itself.

The value of doing road safety audits is now being recognised by the donor community and it is probable that they will become a mandatory requirement for foreign-aided projects.

References

AUSTROADS (1989), *Rural Road Design: A Guide to the Geometric Design of Rural Roads,* Australia

HIGHWAYS AGENCY, *Design Manual for Roads and Bridges, Volume 6, Road Geometry,* UK

OGDEN, K.W. (1996), *Safer Roads: A Guide to Road Safety Engineering,* UK

ROADS AND HIGHWAYS DEPARTMENT (1994), *Road Materials and Standards Study Bangladesh, Final Report, Volume V11A, Development of Geometric Design Standards,* Ministry of Communications, Government of the People's Republic of Bangladesh

TRANSPORT AND ROAD RESEARCH LABORATORY (1988), *A Guide to Geometric Design, Overseas Road Note 6,* UK