CHAPTER D

CROSS SECTION ELEMENTS

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CROSS SECTION ELEMENTS

FIGURES

D.1 INTRODUCTION

D.1.1 NOMENCLATURE

The cross section of a road is the view of a vertical plane perpendicular to the horizontal alignment. It is normally illustrated in the direction of increasing stationing. Only the visible cross section elements are dealt with in this chapter. Non-visible dimensions, such as depths of asphalt and granular base are geotechnical matters and are beyond the scope of this manual. The elements of cross section described in the following paragraphs are illustrated in Figures D1-1 and D1-2.

The term *road* refers to the right-of-way or strip of land reserved for public travel.

The term *roadway* refers to those elements intended for vehicular use, including the shoulders.

Travelled way refers to that part of a roadway intended for vehicular use excluding shoulders. It may have a variety of surfaces but is most commonly hard surfaced with asphalt or concrete or gravel surfaced.

Traffic lane is a through lane or auxiliary lane for the movement of a single line of vehicles.

Through lanes are those lanes intended for normal through travel of vehicles.

Auxiliary lanes are lanes in addition to and placed adjacent to through lanes, intended for specific manoeuvres such as turning, merging, diverging and weaving, or to accommodate slow-moving vehicles, but not parking.

Shoulders are areas of pavement, gravel or hard surface placed adjacent to through or auxiliary lanes. They are intended for emergency stopping and travel by emergency vehicles only. They also provide structural support for the pavement.

A *median* is the area that laterally separates traffic lanes carrying traffic in opposite directions. A median is described as flush, raised or depressed, referring to the general elevation of the median in relation to the adjacent edges of traffic lanes. The terms wide and narrow are often used to distinguish different types of median. A wide median generally refers to depressed medians sufficiently wide to drain the base and subbase into a median drainage channel. Flush and raised medians are usually narrow medians.

An *outer separation* is a reserve which separates traffic travelling in the same direction, and includes shoulders, if any.

A *sidewalk* is a travelled way intended for use by pedestrians only, and normally follows an alignment generally parallel to that of the adjacent roadway.

A *bikeway* is that part of a right-of-way set aside for the preferential treatment of bicycle traffic and is made up of one or more bicycle lanes.

A *boulevard* is a reserve which separates the roadway and sidewalk. It provides some protection to the pedestrian and can accommodate street accessories such as traffic signs and fire hydrants. It is a suitable location for underground utilities and may be used for illumination poles. It also provides 'an area' for snow storage.

Curb and gutter is placed adjacent to an outside lane or shoulder and is intended to control and conduct storm-water and also provides delineation for traffic. In some instances, curb is introduced without a gutter.

A *drainage channel* is placed adjacent to an outside lane or shoulder and is intended to control and conduct storm-water runoff. A shallow drainage channel is sometimes referred to as a *swale.*

A roadway located above the natural ground elevation is said to be in fill, and a roadway located below natural ground elevation is said to be in cut. Where the roadway is in fill, the slope between the roadway and the natural ground is referred to as the *fill side slope* or sometimes the *fill slope*. Where the roadway is in cut there is normally a drainage channel adjacent to the roadway. The slope between the roadway and channel is referred to as a *cut side slope* and the slope between the channel and the natural ground is referred to as a *back slope.*

Traffic barriers are placed adjacent to a roadway to protect traffic from hazardous objects either fixed or moving (other traffic).

Traffic barriers placed in a median are referred to as *median barriers* and may be placed in flush, raised or depressed medians.

Two-lane roads and *four-lane* roads have one and two through lanes of traffic in each direction respectively.

Multi-lane roads have more than two through lanes of traffic in each direction.

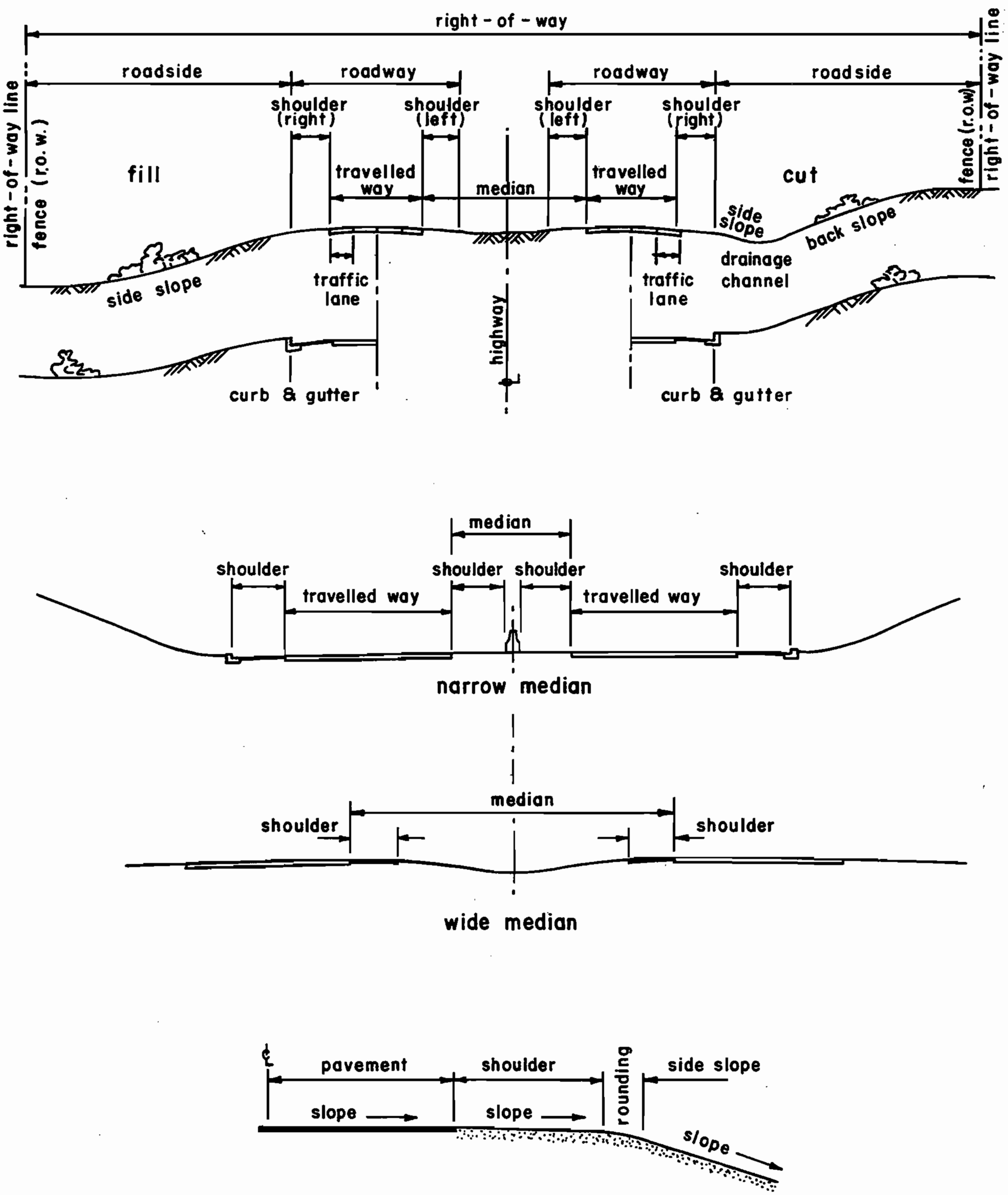


Figure D1-1

Nomenclature for Rural Road Cross Section Elements

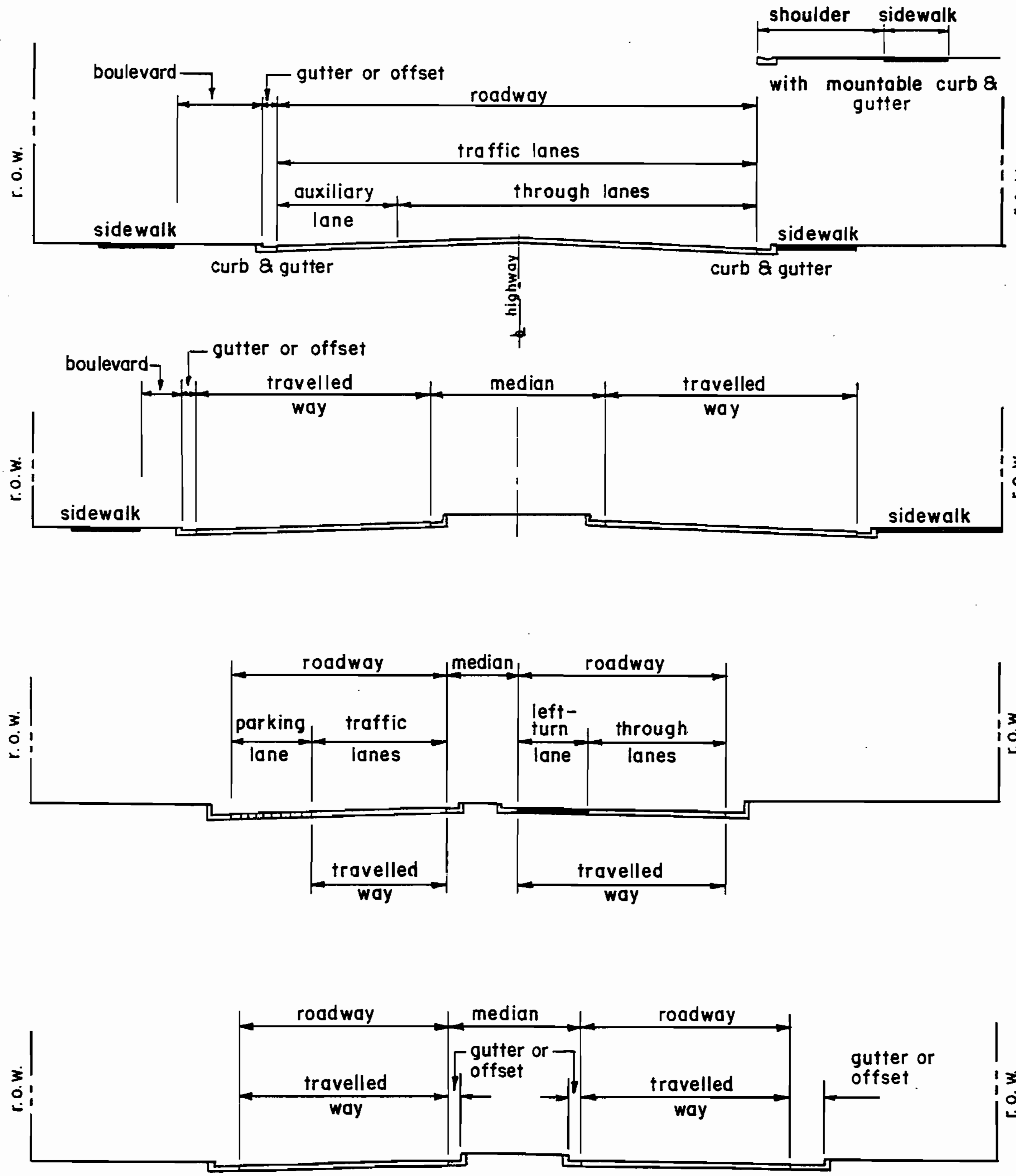


Figure D1-2

Nomenclature for Urban Road Cross Section Elements

D.1.2 STAGE CONSTRUCTION

It is good design practice to consider the need for future expansion of a road facility to provide additional capacity or, perhaps, to convert a road to a different classification. This is particularly important in the design of a cross section and selection of cross section elements and their dimensions.

Recognition should also be given to a change in land use of the area during the foreseeable life of the road, that might affect the classification of a road; for example, a road may be classified as rural initially but may become urban several years later.

In selecting cross section elements it is prudent to approach the design in two ways:

1. Determine the ultimate requirements of the road in terms of classification, design speed, level of service and service volumes, and design a suitable cross section. For the first and any intermediate stages, the cross section consists only of those elements of the cross section that are required to meet immediate needs. Additional elements can then be added in the future as required without wasting capital expenditures made initially.

2. Determine initial requirements and adjust the dimensions so as to allow for future expansion should it be required.

Approach 1 is the better approach, but depends on knowing what the ultimate requirements will be at the outset. This is often not known or may be known in general terms only, in which case the designer should use Approach 2. Often in practice, knowledge of future requirements is limited and the designer may consider both approaches in selecting cross section elements.

To illustrate the above by an example, consider the design of a 4-lane rural freeway. If this road is to be built in an area that is rural and could never conceivably become urban, the appropriate design is a 4-lane rural freeway cross section. Alternatively, if the area is presently rural but is on the fringe of a major metropolitan area, a different planning approach is appropriate. If sufficient right-of-way is being protected for a future urban freeway having six or more lanes, the ultimate design should be that of an urban freeway, providing the appropriate number of lanes for the ultimate requirement. For the first stage all but four lanes are omitted. The first stage design may well be similar to a rural freeway cross section. Cross section considerations for the first and subsequent stages of a facility are dependent on the expected growth of traffic demands in each time frame.

In some cases it may be economical to provide the earth grading for the ultimate cross section at the first stage of construction.

Most urban freeways will ultimately require six or more lanes and 4-lane urban freeways are rare. Nevertheless, standards for 4-lane urban freeways are shown in this chapter in the event that they will be required.

Widening of 2-lane rural arterial roads to multi-lane undivided or divided highways usually takes place on the outside and culverts are extended at the time of widening. Bridges at underpasses may be built to the ultimate design in the initial stage. Sometimes a 2-lane rural arterial is converted to a 4-lane divided arterial or rural freeway by twinning the existing 2-lane roadway. In this case the dimensions of the future cross section should be determined so that the initial roadway can be properly located within the right-of-way to accommodate future expansion.

Freeways are usually widened in the median so that ramps and bridge structures are unaffected at later stages. This means that the critical dimensions in the cross section in allowing for future expansion are lane width, shoulder width, and median width.

In the case of urban arterial roads, provision for future lanes is usually made in the median. Existing arterial roads for which provision was not made are normally widened on the outsides.

D.1.3 DIMENSIONING

For cross section elements horizontal dimensions are multiples of 0.25 m.

There are some minor exceptions to this practice when using curb with gutter and/or concrete median barriers. Standard gutter widths include 300 mm and 400 mm. The existing concrete median barrier widths are 600 mm and 800 mm; the new 'F' shape standard concrete barrier widths are 630 mm and 820 mm, while the Tall Wall is 800 mm in width. In these cases it is advantageous to select the dimension of an adjacent element so as to make the two added together a multiple of 250 mm. For example, if a curb and gutter having gutter width of 400 mm is used in an urban cross section adjacent to a boulevard, the boulevard dimension could be 1.6 m to make the total width of curb and gutter plus boulevard 2.0 m.

Horizontal cross section dimensions greater than one metre are stated in metres and decimals of metres. Dimensions less than one metre are stated in millimetres for standard details such as curb and gutter dimensions. Dimensions should be stated to two decimal places unless the second decimal place digit is zero, in which case the second decimal place digit is omitted.

Vertical cross section dimensions greater than one metre are stated in metres and those less than one metre are stated in millimetres.

Cross-fall and superelevation are normally stated in terms of vertical rise in metres over a horizontal distance of one metre, for example, 0.02 m/m. However, on Ontario Peovincial Standard Drawings (OPSD) and in contract documents, crossfall and superelevation are stated as a percentage, for example, 2%.

D.2 LANE WIDTHS

D.2.1 INTRODUCTION

Lane width and condition of the road surface have a significant influence on the safety and comfort of the travelling public.

Studies on 2-lane two-way highways have shown that inadequate vehicle lanes less than 3.5 m wide when carrying even moderate volumes of mixed traffic. To provide desirable clearance between trucks, lane widths of 3.75 m may be required. It is generally desirable to maintain this width in higher speed 2-lane roads. Traffic volumes and composition are considerations.

The capacity of a road is markedly affected by lane width. For example, on 2-lane rural roads the capacities of 3.0 m and 3.25 m lanes are reduced to 77% and 83% respectively of the capacity provided by a lane width of 3.75 m. For 4-lane undivided highways these ratios are 88% and 94% respectively. on terms of capacity the effective width is further reduced by lateral obstruction less than 2.0 m from the edge of pavement or narrow shoulders.

D.2.2 THROUGH LANES

POLICY

STANDARD MINISTRY LANE WIDTHS ARE MULTIPLES OF 0.25 M AND GENERALLY RANGE FROM 3.0 M TO 3.75 M DEPENDING ON A NUMBER OF FACTORS.

Values for lane widths for various classification of roads are set out in the following paragraphs and are also shown together with other cross section elements in A. These are general guidelines to be followed when considering the selection of lane widths. Deviations from desirable design standards may be appropriate as outlined below, particularly for secondary highways.
In general, higher design speeds warrant wider lanes. In addition wider lanes are normally appropriate:

- for major highways which typically carry high volumes over long distances between important regional centres;
- where warranted by type, size and volume of commercial traffic.

Narrower lanes are appropriate for manor highways, which are typically laical, low volume, short distance roads and provide access to recreational or resource areas.

On new construction and reconstruction projects, lane widths from the tables should be applied.

In rugged terrain narrower lanes may be appropriate by reason of cost and this consideration is reflected in the selection of design speed.

When a highway is to be resurfaced, consideration should be given to retaining the existing cross section dimensions where the dimensions in the tables cannot be accommodated within the existing roadway. Alternatively, standard lane widths may be applied together with reduced shoulder width of 1.0 m gravel or 0.5 m paved is maintained for pavement support.
Where the existing pavement is either fully ir partially reclaimed and recycled , lane widths are determined as follows:

- reclaimed to full depth and recycled:
  - the new pavement width should be the design standard.
- reclaimed to partial depth and recycled:
  - if the design standard is less than the new existing width, the new pavement width should be identical to the existing width.
  - where partially or fully paved shoulders are required, consider providing the paved portion of the shoulder.
  - if the design standard is greater than the existing width, the design standard should be used. This practice should be applied regardless of shoulder surface treatment.

Where adjacent sections off secondary highways are to be resurfaced and reconstructed, different lane and shoulder widths are acceptable. Transition section may be warranted where changes in width appear to be about.

2-Lane Rural Roads

Lane width for 2-lane King's Highways are shown in Tables D2-1 and D2-2 for a range of fdic volumes stated in terms of Annual Average Daily Traffic (AADT)and Design Hour Volume (DHV). If both are known, DHV should be used for design. Width adjustments for truck percentages are indicated.

The selection of lane width for 2-lane rural roads is dependent primarily in design speed, traffic volume and traffic compassion. Service function and topography influence the selection of design aped and therefore have a bearing on lane width.

Lane and shoulder widths may be designated on important long distance highway to ensure continuity, regardless of traffic volumes.

Table D2-1
LANE WIDTH FOR 2-LANE RURAL KING'S HIGHWAYS

Design Speed km/h	Traffic Volume for Design Year					
	AADT					
	>4000	3000-4000	2000-3000	1000-2000	400-1000	<400
	DHV					
	>600	450-600	300-450	150-300	60-150	<60
120	3.75	-	-	-	-	-
110	3.75	3.75	3.75	3.5C	-	-
100	3.75	3.5A	3.5B	3.5	3.5	-
90	3.5A	3.5A	3.5	3.25	3.25	-
80	3.5	3.5	3.25	3.25	3.25	3.25D
70	-	3.25	3.25	3.0	3.0	3.0
60	-	-	-	3.0	3.0	3.0
50	-	-	-	-	-	2.75

Notes:
- ° Minimum lane width for all paved 2-lane King's Highways is 3.5 m.
- ° For design use DHV if available.
- ° Highway 11 in Northern and Northwestern Regions, 3.5 m minimum lane width.
- ° Highway 17 in Northwestern Regions, 3.75 m minimum lane width.

A. If truck percentage exceeds 10% increase by one increment.
B. If truck percentage exceeds 15% increase by one increment.
C. of truck percentage exceeds 25% increase by one increment.
D. 3.0 m may be acceptable where the type, size, and volume of trucks ate not significant.

Table D2-2
LANE WIDTH FOR SECONDARY HIGHWAYS

Design Speed km/h	Traffic Volume for Design Year		
	AADT		
	>1000	400-1000	<400
	DHV		
	>150	60-150	<60
100	3.5	-	-
90	3.25	-	-
80	3.25	3.25*	3.25*
70	3.0	3.0	3.0
60	3.0	3.0	3.0
50	-	-	2.75

Notes:
- ° Major secondary highways shall have a minimum lane width of 3.5 mm.
- ° For design use DHV if available.
- ° Lane width may be increased by 0.25 m to a maximum of 3.5 m if warranted by type, size and volume of trucks.
- * 3.0 m may be acceptable where the type, size and volume of trucks are not significant.

Table D2-3
LANE WIDTHS FOR UNDIVIDED & DIVIDED HIGHWAYS

4-LANE UNDIVIDED AND DIVIDED RURAL ROADS

Lane widths for 4-lane rural roads depend primarily on design speed and to a small degree on traffic volume or truck percentages. Widths for 4-lane rural roads are:

Design Speed	Width
≥ 100 km/h	3.75 m
< 100 km/h	3.50 m

2-LANE AND 4-LANE UNDIVIDED URBAN ROADS

Lane widths for 2-lane and 4-lane undivided urban roads are shown in Table D2-4 for a range of design speeds from 40 km/h to 80 km/h and for ranges of traffic volumes stated in terms of AADT and DHV. No adjustment for truck percentages is required for the use of this table.

MULTI-LANE DIVIDED RURAL AND URBAN ROADS

For multi-lane divided roads the width of the median lane is 3.50 m and all other lanes 3.75 m, to minimize the overall pavement width. The pavement may be striped in equal lane widths.

4-LANE DIVIDED URBAN ROADS

Lane widths for 4-lane divided urban roads depend only on design speed and not on traffic volume or truck percentages. Widths for 4-lane divided roads are:

Design Speed	Width
≥ 80 km/h	3.75 m
< 80 km/h	3.50 m

Table D2-4
LANE WIDTH FOR UNDIVIDED URBAN ROADS

Design Speed km/h	Traffic Volume for Design Year				
	AADT				
	>6000	3000-6000	2000-3000	1000-2000	<1000
	DHV				
	>600	300-600	200-300	100-200	<100
80	3.5 - 3.75*	3.5 - 3.75*	3.5	-	-
60 - 70	3.5	3.5**	3.25	3.25	-
50	-	-	3.0	3.0	-
40 - 50	-	-	-	-	2.75 - 3.0*
No. of lanes	4	2 - 4**	2	2	2

Notes:

Minimum lane width for all paved 2-lane King's Highways is 3.5 m.

For design use DHV if available.

* Upper value is desirable, lower value is acceptable.

** Four lanes are appropriate in the upper part of this traffic range where there is a measurable capacity deficiency with only two lanes.

D.2.3 AUXILIARY LANES

Auxiliary lanes are traffic lanes provided in addition to those which are intended for normal through travel. They are usually relatively short, and each auxiliary lane is introduced for a specific function. Auxiliary lanes may be divided into the following groups:

- right-turn lanes
- left-turn lanes
- continuous left-turn lanes
- acceleration and deceleration lanes
- weaving lanes
- truck-climbing lanes
- passing lanes
- left-turn slip-around lanes

Widths for auxiliary lanes are shown in Table D2-5.

Standard widths for auxiliary lanes are the same for all types of highway and are as follows:

Right-turn lanes - are lanes added to the right of through lanes ahead of intersections to allow right-turning traffic to slow down before making the turn, without interfering with following through traffic, and to provide additional capacity at intersections. The lane may or may not lead directly into an exclusive right-turning roadway.

POLICY

THE WIDTH SHOULD NOT BE LESS THAN 0.25 m LESS THAN THE WIDTH OF THE ADJACENT THROUGH LANE AND IN NO CASE LESS THAN 3.25 m.

Left turn lanes - are lanes added to the left of through traffic lanes to provide a refuge for left-turning traffic waiting to make the turn and to avoid interference with following through traffic. Left-turning traffic typically will move into the left-turning lane, slow down and wait for a suitable gap in oncoming traffic to make the turn. Left-turn lanes are used with and without medians.

POLICY

THE WIDTH OF LEFT-TURN LANES NOT ADJACENT TO A MEDIAN SHOULD NOT BE LESS THAN 0.25 m LESS THAN THE ADJACENT LANE AND IN ANY CASE NOT LESS THAN 3.25 m. LEFT-TURN LANES ADJACENT TO A RAISED MEDIAN WITHOUT A GUTTER SHOULD HAVE THE CURB OFFSET BY 500 mm. LEFT-TURN LANES ADJACENT TO A RASED OR PAINTED MEDIAN SHOULD BE NOT LESS THAN 3.0 m WIDE.

Continuous left- turn lanes - are introduced between through lanes in both directions to provide storage for left-turning vehicles from either direction and are usually designated for left turns only throughout their length. This form of operation is well suited to 4-lane and multi-lane urban arterial roads where running speeds are relatively low, in the range of 40 km/h to 70 km/h.

POLICY

CONTINUOUS LEFT-TURN LANES SHOULD DESIRABLY BE 4.0 m WIDE. THE ADDITIONAL WIDTH OVER THE ADJACENT THROUGH LANE RECOGNIZES THAT VEHICLES ARE MAKING TURNING MANOEUVRES FROM BOTH DIRECTIONS SIMULTANEOUSLY, AND THE ADDITIONAL WIDTH ADDS A MEASURE OF SAFETY. LESSER WIDTHS TO A MINIMUM OF 3.0 m MAY BE APPLIED WHERE OPERATING SPEEDS ARE LESS THAN 60 km/h.

Acceleration and deceleration lanes - are auxiliary lanes adjacent to through lanes on freeways and arterial roads at interchanges for vehicles changing speed at entrances and exits.

POLICY

THE WIDTH OF THESE AUXILIARY LANES SHOULD BE 0.25 m LESS THAN THE WIDTH OF THE THROUGH LANE, BUT NOT LESS THAN 3.25 m.

Weaving lanes - are auxiliary lanes introduced between an entrance followed by an exit in close succession, usually less than 1000 m, to minimize turbulence in the traffic stream and to maintain adequate capacity.

POLICY

THE WIDTH DESIRABLY SHOULD BE 0.25 m LESS THAN THAT OF THE THROUGH LANE, BUT NOT LESS THAN 3.25 m.

Left-turn slip-around lanes - may be used on 2-lane highways at "T" intersections, where the left-turning traffic volumes do not warrant the standard left-turning treatment, but may pose a threat to the safety of through traffic, and where by-passing vehicles throw gravel from the shoulder onto the highway.

POLICY

THE WIDTH SHOULD BE 0.25 m LESS THAN THE WIDTH OF THE THROUGH LANES BUT NOT LESS THAN 3.25 m.

Truck-climbing lanes - are introduced on steep upgrades to provide a lane for trucks and other slow moving vehicles whose speed drops more than 15 km/h because of the grade. The through uphill lanes are kept free for faster traffic. Truck-climbing lanes increase capacity, improve travel times, and reduce accident rates.

POLICY

THE WIDTH OF TRUCK-CLIMBING LANES SHOULD BE NOT LESS THAN 0.25 m LESS THAN THE ADJACENT THROUGH LANES, AND IN NO CASE LESS THAN 3.25 m.

Passing lanes - are similar to truck-climbing lanes, but are not necessarily located on upgrades. Passing lanes are applied to 2-lane roads carrying large volumes of slow-moving vehicles (for example, recreational routes). A slow-moving vehicle will cause a queue to form because of lack of passing opportunity, sight distance restrictions or large volumes of opposing traffic. Passing lanes are introduced at intervals to allow following vehicles to overtake.

POLICY

THE WIDTH OF PASSING LANES SHOULD BE NOT LESS THAN 0.25 m LESS THAN THE ADJACENT THROUGH LANE, AND IN NO CASE LESS THAN 3.25 m.

Table D2-5
AUXILIARY LANE WIDTHS

Auxiliary Lane	Width
Right-turn lane	- not less than 0.25 m less than adjacent lane - not less than 3.25 m
Left-turn lane not adjacent to a median	- not less than 0.25 m less than adjacent lane - not less than 3.25 m
Left-turn lane adjacent to a median	- 3.0 m minimum
Continuous left-turn lane	- 4.0 m where design speed is greater than 60 km/h - 3.0 m where design speed is equal to or less than 60 km/h
Acceleration and deceleration lanes	- not less than 0.25 m less than adjacent lane - not less than 3.25 m
Weaving lane	- not less than 0.25 m less than adjacent lane - not less than 3.25 m
Truck-climbing lane	- not less than 0.25 m less than adjacent lane - not less than 3.25 m
Passing lane	- not less than 0.25 m less than adjacent lane - not less than 3.25 m
Left-turn slip-around lane	- not less than 0.25 m less than adjacent lane - not less than 3.25 m

D.2.4 RAMPS AND TRANSFER LANES

An interchange is an intersection of two (or more) roadways separated vertically, with at least one roadway for travel between them. These interconnecting roadways are called ramps. A ramp is also applied to separate right turn lanes at channelized at-grade intersections. Transfer lanes are roadways to provide for travel between freeway express lanes and a collector-distributor road or a service road.

POLICY

THE PAVEMENT WIDTH FOR SINGLE-LANE RAMPS AND TRANSFER LANES IS 4.75 m. THE PAVEMENT WIDTH FOR RAMPS AND TRANSFER LANES OF TWO OR MORE LANES SHOULD BE 3.75 m AND ADJUSTED FOR CURVATURE.

The pavement width of 4.75 m is based on the premise that interchanges carry sufficient single unit and semitrailer vehicles to govern design requirements. It also provides for widening on curves of radius greater than 50 m. For 50 m and smaller radii the width should be increased. Refer to Chapter E, Table E8-8 for pavement widths.

D.2.5 PARKING LANES

Cross section design may include provision for parking. This is normally limited to urban roads. Parking facilities should offer safe and convenient access and egress for parking users and at the same time maintain safe and convenient operation for other traffic.

Parking dimensions depend on the vehicle dimensions and steering geometry of vehicles to be parked, and on the form of parking provided. Although there is a marked trend toward smaller cars in recent years which would suggest smaller parking dimensions, parking facilities should be able to accommodate most cars and dimensions should be adequate for all but the larger passenger vehicles.

On-street parking is normally parallel or angled to the alignment of the roadway. Parking at right angles to the alignment offers the most efficient use in terms of parking area, but is seldom considered for on-street parking since it calls for a very wide cross section and is very interruptive to the flow of through traffic.

For parallel parking the parking lane width for design speeds up to 40 km/h should be 2.5 m and for higher design speeds the width should be 3.0 m.

In selecting a suitable stall length for parallel parking, consideration should be given to either individual stalls or to paired parking stalls, as shown in Figure D2-1. The individual stall provides for manoeuvring within its own length, whereas in the paired stall a manoeuvring area is delineated by paint, and can be used by either of the two vehicles entering or leaving the two adjacent areas.

For individual parking stalls the length should be 7.0 m to 8.0 m to allow for a 6.0 m vehicle. The smaller dimension may be used but may be false economy. Shorter stalls cause drivers to take more time manoeuvring and cause additional delay and turbulence to through traffic.

For paired parking stalls, the stall should be from 5.5 m to 6.0 m and the manoeuvre length from 2.5 m to 3.0 m. Since the manoeuvre area is used for two stalls, the average length of roadway per stall is 6.75 m to 7.5 m, a saving over the individual stall of 3.5% to 6%. Angle parking allows more vehicles to be parked in a given length of roadway than parallel parking; the higher the angle the more vehicles parked. Typical dimensions for angle parking are shown in Figure D2-2.

The choice of angle is usually governed by available width. However, although a higher angle permits more vehicles to be parked in a given length of roadway and reduces wasted area, the higher angle increases manoeuvre time and, consequently, generates more turbulence and delay in the through traffic flow. For in-street angle parking, angles in the 45° to 60° range are normally used.

D.2.6 BUS BAYS

Bus bays have the advantage of separating buses from other traffic during loading and unloading of passengers, however, they sometimes require additional right-of-way.

To be fully effective a bay should include: a deceleration lane or taper to permit convenient entrance to the loading area, a standing space sufficiently long to accommodate the maximum number of buses expected at one time, and a merging lane to provide convenient re-entry into the through traffic lanes. The dimensions of these elements should encourage the bus driver to position the bus completely clear of the through lane of traffic. Ideally the deceleration and acceleration lanes should be sufficiently long so that all acceleration and deceleration is contained within them, however this is normally not feasible.

Taper lengths for deceleration and acceleration should be 25 m each. The loading area should be about 15 m per bus and the width should be 3.0 m to the edge of curb. For details refer to OPSD 501.01.

D.2.7 SUMMARY

Lane widths are summarized in the Appendix to this chapter.

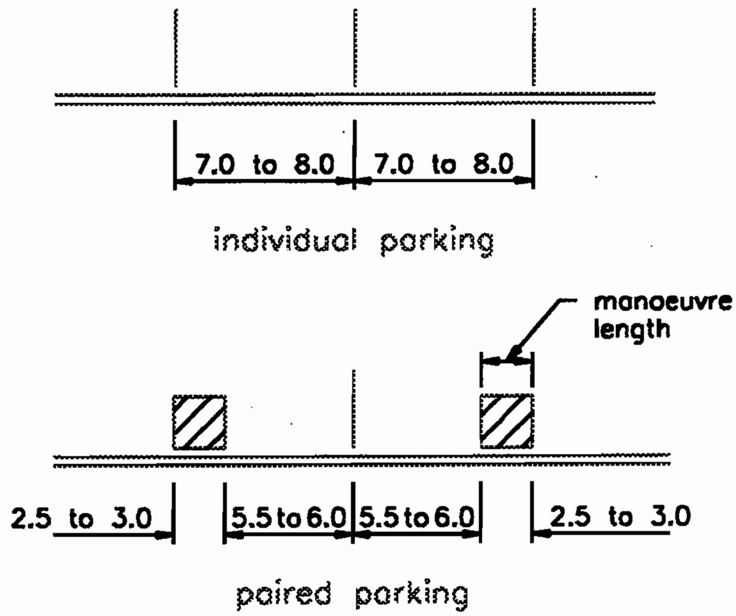
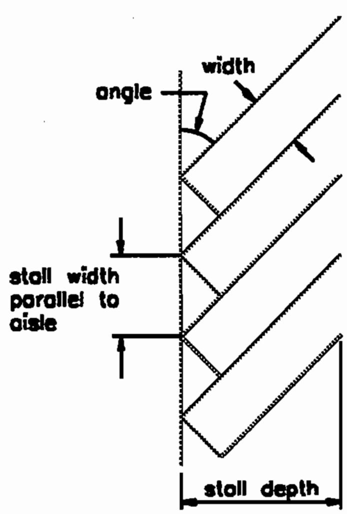


Figure D2-1

Parallel Parking Dimensions



Angle	Width m	Stall width parallel to aisle m	Stall depth m
45°	2.5	3.5	3.9
45°	2.75	3.9	3.9
45°	3.0	4.2	3.9
60°	2.5	2.9	4.8
60°	2.75	3.2	4.8
60°	3.0	3.5	4.8
75°	2.5	2.6	5.3
75°	2.75	2.8	5.3
75°	3.0	3.1	5.3
90°	2.5	2.5	5.5
90°	2.75	2.7	5.5
90°	3.0	3.0	5.5

Figure D2-2

Angle Parking Dimensions

D.3 PAVEMENT WIDENING ON CURVES

D.3.1 BASIS OF DESIGN

Pavement widening on curves is carried out to provide additional load-bearing surface to form part of the traffic lane.

Vehicles travelling on a curve occupy a greater width of roadway than they do on tangent sections as a result of the rear wheels tracking inside the front wheel path. The amount of this increase in roadway occupation is dependent on the curve radius and the length and type of vehicle. For the range of radii used on open highways, this additional amount is negligible for passenger cars. However, for trucks it is significant and it is necessary to provide an additional width of pavement to ensure adequate clearance between opposing trucks on curves.

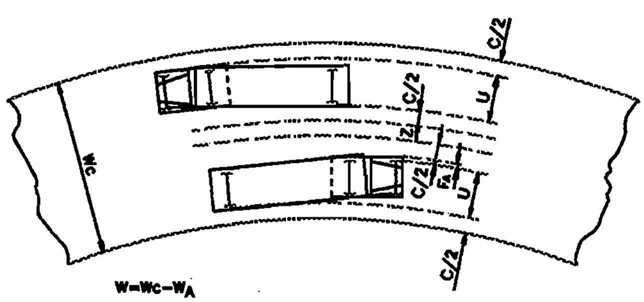
Maintaining a vehicle centrally located on the lane is more difficult on a curve than on a tangent section. To compensate for this, an additional clearance is provided on curves to reduce driver apprehension should a vehicle deviate from the centre of its lane. This amount is dependent on the vehicle speed, as well as curve radius.

The amount of widening required is the difference between the width required when two trucks meet on the curve and the approach width. The basis of determining the amount of widening is illustrated in Figure D3-1.

Pavement widening should not be confused with partially paved shoulders which are not intended for normal travel.

D.3.2 DESIGN VALUES

Tables D3-1, D3-2 and D3-3 indicate values of pavement widening for single unit trucks (SU) and semi-trailer combinations (WB-15 and WB-17.5). The range of values for curve widening extends to curve radii corresponding to 30 km/h less than the design speed indicated . This provides widening values for conditions where the overall highway design speed and the operating speed are known to exceed the design speed of an isolated curve.



$W = W_C - W_A$

where: W = amount of widening
W_C = pavement width on curve
W_A = pavement width on tangent

$W_C = 2(U+C) + F_A + Z$

where: U = vehicle track width on curve in metres
C = nominal clearance between vehicles
0.4572m for 6.0m wide pavements
0.6096m for 6.5m wide pavements
0.7620m for 7.0m wide pavements
0.9144m for 7.5m wide pavements
F_A = front overhang in metres
Z = additional clearance in metres to compensate for difficulty of driving on curves where

$$Z = \frac{0.10456\ V}{\sqrt{R}}$$

V = design speed of highway in kilometres per hour
R = curve radius in metres

Figure D3-1
Basis forPavement Widening

Table D3-1

PAVEMENT WIDENING VALUES ON CURVES FOR SINGLE UNIT (SU) VEHICLES

PAVEMENT WIDTH 7.5 m								
Design Speed								
km/h	50	60	70	80	90	100	110	120
W	R	R	R	R	R	R	R	R
1.25	50	50-55	55-65					
1.00	55-65	60-70	70-80					
0.75	70-85	75-95	85-110	90-125	130-140			
0.50	90-120	100-140	115-160	130-190	150-210	190-240	250-280	
0.25	125-200	150-240	170-280	200-320	220-380	250-450	300-500	340-550
PAVEMENT WIDTH 7.0 m								
1.50	50	50-55	55-60					
1.25	55-60	60-70	65-75					
1.00	65-80	75-90	80-105	90-115	130			
0.75	85-110	95-130	110-150	120-170	140-190	190-220	250	
0.50	115-170	140-200	160-240	180-280	200-320	230-380	280-420	
0.25	180-350	210-450	250-500	300-650	340-750	400-900	450-1050	
PAVEMENT WIDTH 6.5 m								
1.75		50	55-60					
1.50	50-55	55-65	65-75					
1.25	60-75	70-85	80-95	90-110				
1.00	80-100	90-115	100-130	115-150	130-170	190-200		
0.75	105-150	120-180	140-210	160-250	180-280	210-320		
0.50	160-280	190-350	220-420	280-500	300-600	340-700		
0.25	300-1050	380-1300	450-1700	525-2000	650-2500	750-2500		
PAVEMENT WIDTH 6.0 m								
1.75	55	55-60						
1.50	60-70	65-80	90					
1.25	75-95	85-110	95-125	130-140				
1.00	100-140	115-160	130-190	150-220	170-250			
0.75	150-250	170-300	200-350	230-420	280-500			
0.50	280-700	320-850	380-1100	450-1300	525-1600			
0.25	750-10000	900-10000	1150-10000	1400-10000	1700-10000			

Notes:

- W - widening values in metres are based on SU design vehicles travelling at the design speed.
- R - denotes centreline radius in metres.

- For methods of widening see Standards OPSD 213.01 and OPSD 213.02.
- Not to be used for interchanges.

Table D3-2

PAVEMENT WIDENING VALUES ON CURVES FOR TRACTOR-SEMI-TRAILER (WB-15) VEHICLES

PAVEMENT WIDTH 7.5 m								
Design Speed								
km/h	50	60	70	80	90	100	110	120
W	R	R	R	R	R	R	R	R
2.00	65-70	75	75-80					
1.75	75-80	80-85	85-90	90-95				
1.50	85-90	90-95	95-105	100-110				
1.25	95-105	100-115	110-125	115-130	130-140			
1.00	110-130	120-140	130-150	140-170	150-180	190-200		
0.75	140-170	150-180	160-200	180-220	190-240	210-250	250-280	
0.50	180-230	190-250	210-280	230-300	250-340	280-380	300-400	340-450
0.25	240-350	280-400	300-450	320-525	350-575	400-650	420-700	475-800
PAVEMENT WIDTH 7.0 m								
2.00	75	75-80	75-85					
1.75	80-85	85-95	90-100	90-105				
1.50	90-105	100-110	105-120	110-130	130-140			
1.25	110-125	115-130	125-140	140-160	150-170			
1.00	130-160	140-170	150-190	170-210	180-230	190-240	250	
0.75	170-210	180-240	200-250	220-280	240-300	250-340	280-380	
0.50	220-320	250-350	280-400	300-450	320-500	350-550	400-600	
0.25	340-600	380-700	420-800	475-950	525-1050	575-1200	650-1300	
PAVEMENT WIDTH 6.5 m								
2.00	80-85	85-90	90-95	90-105				
1.75	90-100	95-105	100-115	110-125	130			
1.50	105-120	110-130	120-140	130-150	140-160			
1.25	125-150	140-160	150-180	160-190	170-210	190-230		
1.00	160-200	170-220	190-240	200-250	220-280	240-320		
0.75	210-280	230-320	250-350	280-400	300-450	340-450		
0.50	300-500	340-575	380-650	420-750	475-850	475-950		
0.25	525-1600	800-1800	700-2200	800-2500	900-3000	1000-3500		

Notes:

- W - widening values in metres are based on WB-15 design vehicles travelling at the design speed.
- R - denotes centreline radius in metres.

- For methods of widening see Standards OPSD 213.01 and OPSD 213.02.
- Not to be used for interchanges.

Table D3-3

PAVEMENT WIDENING VALUES ON CURVES FOR TRACTOR-SEMI-TRAILER (WB-17.5) VEHICLES

PAVEMENT WIDTH 7.5 m								
Design Speed								
km/h	50	60	70	80	90	100	110	120
W	R	R	R	R	R	R	R	R
2.00	115-125	120-130	125-140	130-150	140-150	150-160	160-170	160-180
1.75	130-150	140-160	150-170	160-180	170-190	170-200	180-210	190-230
1.50	160-180	170-190	180-210	190-220	200-240	210-250	220-250	240-280
1.25	190-240	200-250	220-250	230-300	250-320	280-340	280-300	300-380
1.00	250-320	280-350	280-380	320-420	340-450	350-500	380-550	400-575
0.75	340-525	380-600	400-650	450-700	475-800	525-850	575-950	600-1050
0.50	550-1250	150-1400	700-1600	750-1800	850-2000	900-2200	1000-2500	1100-3000
0.25	1300-10000	1500-10000	1700-10000	2000-10000	2200-10000	2500-10000	3000-10000	3500-10000
PAVEMENT WIDTH 7.0 m								
2.00	105-120	115-125	120-130	125-140	130-140	140-150	150-160	
1.75	125-140	130-140	140-150	150-160	150-170	160-180	170-200	
1.50	150-170	160-180	160-190	170-200	180-220	190-230	210-240	
1.25	180-210	190-230	200-240	210-250	230-280	240-300	250-320	
1.00	220-280	240-300	250-340	280-350	300-380	320-420	340-450	
0.75	300-420	320-475	350-525	380-575	400-600	450-650	475-750	
0.50	450-800	500-900	550-1050	600-1150	650-1300	700-1400	800-1600	
0.25	850-3500	950-4500	1100-5000	1200-6000	1400-7000	1500-8000	1700-10000	
PAVEMENT WIDTH 6.5 m								
2.00	100-110	105-115	110-125	120-130	125-140	130-140		
1.75	115-130	120-130	130-140	140-150	150-160	150-170		
1.50	140-150	140-160	150-170	160-180	170-200	180-210		
1.25	160-190	170-200	180-220	140-230	210-250	220-250		
1.00	200-250	210-250	230-280	240-320	280-340	280-350		
0.75	280-350	280-380	300-420	340-450	350-500	380-550		
0.50	380-600	400-650	450-750	475-800	525-900	575-1000		
0.25	650-1600	700-1800	800-2200	850-2500	950-2500	1050-3000		

Notes:

- W - widening values in metres are based on WB-17.5 design vehicles travelling at the design speed.
- R - denotes centreline radius in metres.

- For methods of widening see Standards OPSD 213.01 and OPSD 213.02.
- Not to be used for interchanges.

D.3.3 WARRANTS

The necessity of widening the pavement on a curve is dependent upon one truck meeting another on a curve, the frequency of which is dependent on truck volumes and distribution, curve radius and design speed. Failure to provide widening on a curve will result in a higher degree of concentration required by the driver and possible reduction in speed.

On a curvilinear section of road in which the majority of the alignment is on curve, the probability that two trucks will meet on a curve is greater than the case where most of the alignment is on tangent. However, the probability that two trucks will meet on any particular curve is independent of the configuration of the alignment on either side of the curve. The need for pavement widening on a curve is not dependent on the frequency of curves.

D.3.3.1 Undivided Roadways

POLICY

FOR 2-LANE ROADWAYS WHERE THE NUMBER OF TRUCKS IN BOTH DIRECTION IS LESS THAN 15 PER HOUR, PAVEMENT WIDENING IS NOT REQUIRED. WHERE THE NUMBER OF TRUCKS IS 15 PER HOUR OR MORE PAVEMENT WIDENING SHOULD BE APPLIED AS FOLLOWS:

- **WHERE SU TRUCK VOLUME IS 15 PER HOUR OR MORE, USE TABLE D3-1**
- **WHERE WB-15 TRUCK VOLUME IS 15 PER HOUR OR MORE, USE TABLE D3-2**
- **WHERE WB-17.5 TRUCK VOLUME IS 15 PER HOUR OR MORE, USE TABLE D3-3**

Theoretically widening of a 4-lane undivided roadway should consist of the additional clearance required for the physical occupation of the roadway. Since the additional clearance is required to compensate for opposing vehicles only, this component need not be included twice for a 4-lane highway where some of the vehicles are travelling in the same direction. The possibility of trucks occupying all lanes at a given location on a curve is so remote that the absence of the small amount of widening required to compensate for the physical roadway occupation of the extra vehicles is not significant.

Pavement widening values given in Tables D3-1, D3-2 and D,3-3 should therefore be applied to all undivided roadways regardless of the number of lanes. These values should not be applied to divided highways or interchange ramps. For widths of pavement of interchange ramps refer to Chapter E, Table E8-8.

D.3.3.2 Divided highways

On divided highways vehicles only encounter other vehicles moving in the same direction. The relative speeds are such that the additional clearance (Z) is not required. Furthermore, due to the relatively flat curves utilized on highways of this type, the effects of vehicular off-tracking are usually sufficiently small to be insignificant. Pavement widening on divided highways therefore is not required.

D.3.3.3 Ramps

Ramp pavement widths for channelized intersections and interchange ramps are based on vehicle off-tracking and clearance requirements similar to the pavement widening considerations for open highways. However, due to the relatively small radius curves associated with this type of design the width requirements are considerably larger. Pavement widths of 4.75 m on single lane ramps do not require widening to accommodate off-tracking, providing the radius is greater than 50 m.

Design considerations include provision for passenger cars, single unit and tractor semi-trailer design vehicles, together with operating conditions which assume one-way traffic with provision for passing stalled vehicles and two-way traffic.

Design values for ramps and transfer lanes pavement widths are indicated in Section D2.4 and values for widening are given in Chapter E, Table E8-8.

D.3.4 APPLICATION

The pavement widening values given in Tables D3-1, D3-2 and D3-3 represent the total amount of widening required.

For new construction and reconstruction projects, curve widening should be applied by adding half of the total requirement to each side of the highway. Equal division of the widening is not practical however, with values ending in 0.25 or 0.75. A preferred treatment is to round the total widening value to a higher even digit before dividing in half. The normal shoulder width should be maintained over the length of curve widening.

Curve widening on resurfacing projects should be carried out with a corresponding reduction in shoulder width to maintain the existing subgrade. A minimum shoulder width of 1.0 m gravel, or 0.5 m paved, must be maintained to provide the pavement with adequate lateral support.

An exception to the minimum shoulder width requirement may be considered in the application of resurfacing and curve widening to secondary highways, particularly those with low traffic volumes. Where the required curve widening closely approaches or exceeds the existing shoulder width, an acceptable and cost-effective design alternative to road widening is to utilize the entire shoulder width to achieve the curve widening.

For resurfacing projects with no recycling, or with partial-depth recycling, widening values of 0.25m may be ignored. If the widening requirement is 0.5m or less, the total widening may be applied to the inside of curve to avoid application of a narrow strip of base pavement to both sides of the highway prior to resurfacing.

For resurfacing projects with full-depth recycling, curve widening should be applied by adding one half of the total requirement to each side. Widening values ending in 0.25 or 0.75 should be rounded to a higher even digit before dividing in half.

Since the amount of pavement widening is a function of the curve radius, the widening should be applied over the length of the spiral curve in such a fashion that a smooth edge of pavement is produced. For unspiralled curves the widening should be applied over the corresponding spiral length had the spiral been applied. The method of attaining the pavement widening is illustrated in Ontario Provincial Standards Drawings OPSD 213.01 and OPSD 213.02.

Pavement widening may be warranted on several successive horizontal curves so that a significant length of highway has a continuous variation in pavement width. In such a situation of a wider pavement over the total section of highway should be considered. The amount of widening should be representative of the required widening on individual curves and not necessarily the widening required by the smallest radius curve. Alternatively, less widening could be applied over the total section with additional widening on the smaller radius curves.

Each situation should be assessed independently considering how closely the warrants are met, the length of the highway section under consideration, the frequency of curves and the amount of widening required for each curve, A uniform pavement width is desirable but may not always be economically practical.

D.4 PAVEMENT CROSSFALL AND SUPERELEVATION

D.4.1 CROSS-FALL REQUIREMENTS

POLICY

ON 2-LANE HIGHWAYS THE PAVEMENT IS NORMALLY CROWNED AT THE CENTRELINE AND THE PAVEMENT SLOPES DOWN TO EITHER EDGE AT A CROSS-FALL RATE OF 2%.

ON 4-LANE UNDIVIDED HIGHWAYS AND 4-LANE DIVIDED HIGHWAYS WITH A FLUSH MEDIAN, THE CROWN IS NORMALLY PLACED IN THE CENTRE OF THE PAVEMENT OF MEDIAN, AND CROSS-FALL TO EITHER PAVEMENT EDGE IS 2%.

ON A 4-LANE DIVIDED HIGHWAY WITH A DEPRESSED MEDIAN, THE CROWN IS NORMALLY PLACED AT THE CENTRE OF EACH ROADWAY WITH A CROSS-FALL OF 2% TO EACH EDGE. FOR ROADWAYS ON STRUCTURES, THE CROSS-FALL SHOULD BE A MINIMUM OF 2%.

There are two reasons for this: the first is to permit storm-water to drain to either side of the roadway; the second is to facilitate the treatment of the roadway with de-icing chemicals which are spread in a narrow strip about the crown line, allowing the action of traffic and cross-fall to further spread the chemicals across the entire pavement. If the road eventually requires expansion to six lanes by adding two lanes in the median, the additional lanes will slope toward the median.

If a 4-lane divided highway is to be expanded to six lanes within a short period of time of initial construction, it should be designed for six lanes and built without the median lanes initially, in this case both lanes of each roadway will slope towards the outer edge.

For 6-lane divided highways, the crown for each roadway is applied to the common edge of the centre and median lanes, the two outside lanes having a cross-fall of 2% towards the outside edge, and the median lane having a cross-fall of 2% draining towards the median. If this cross section is expanded to an 8-lane cross section with the additional lanes in the median, the additional lanes have 2% cross-fall applied draining towards the median.

The above cross-fall requirements are illustrated in Figure D4-1.

Cross-fall on auxiliary lanes is the same as that of the adjacent through lane.

At intersections where two roads on tangent intersect, normal cross-fall is maintained on the major road, and cross-fall on the minor road is run out on the approaches to the intersection to match the profile of the major road. This treatment is typical of intersections controlled by a stop sign on the minor road. In the case of an intersection where the two roads are of equal importance, or where the intersection is signalized, the normal cross-fall is run out on all four approaches so that the cross-fall on each road matches the profile of the crossing road. Simply put, the pavements are warped to maintain smooth profiles for traffic on both roads. This topic is dealt with in more detail in Chapter E, Section E.4.

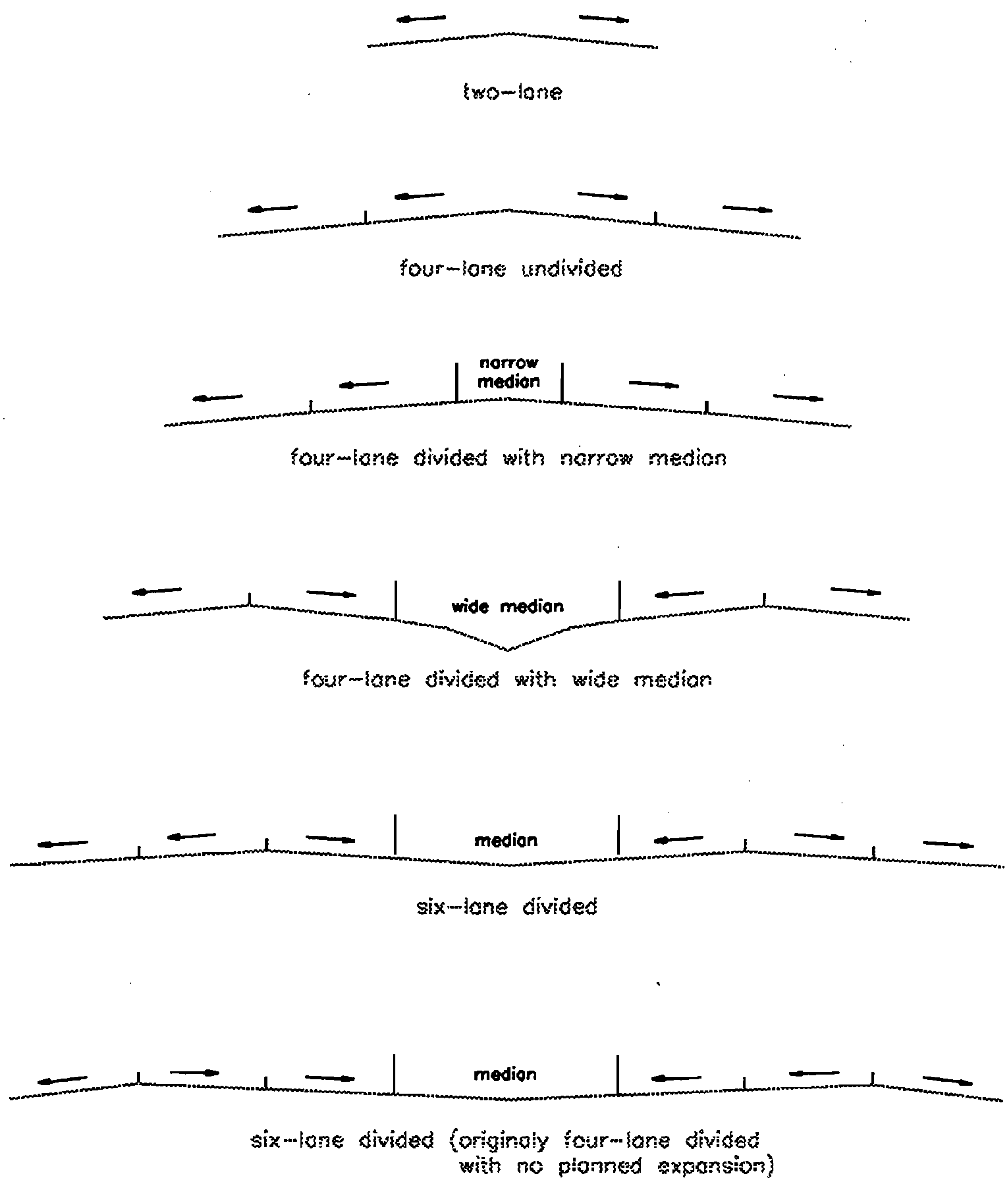


Figure D4-1
Application of 2% Cross-Fall on Tangent Section

D.4.2 SUPERELEVATION REQUIREMENTS

Superelevation is the practice of tilting the pavement on circular curves, such that the pavement drains towards the centre of the curve. The objective is to assist the driver in safely manoeuvring the vehicle through the curve without an undue reduction in speed.

As a vehicle travels along the circular curve it experiences radial acceleration towards the centre of the curve produced by centripetal forces acting on the vehicle. If no superelevation were applied the centripetal force would be supplied solely by friction between pavement and tires. If superelevation is applied, a component of the force of gravity acting on the vehicle will contribute towards the centripetal force reducing reliance on friction and providing a safer condition. The total friction and superelevation requirement to negotiate a curve is a function of speed and radius. This relationship is explained in detail in Chapter C, Alignment, Section C.3.2.2.

POLICY

MAXIMUM SUPERELEVATION RATE FOR DESIGN IS:

- **FOR URBAN FREEWAY INTERCHANGE RAMPS WHERE A HIGH LEVEL OF MAINTENANCE PREVAILS AND LITTLE ICE OR SNOW ACCUMULATION IS ANTICIPATED: 8%.**
- **FOR ALL OTHER ROADWAYS: 6%.**

A more detailed explanation of these values is discussed in Chapter C, Alignment, Section C.3.2.3. Distribution of superelevation for curves of radius greater than minimum is discussed in Chapter C, Alignment, Section C.3.2.6. Design values for superelevation are given in Chapter C, Alignment, Tables C3-3 and C3-4.The transition from normal cross-fall on a tangent to full superelevation on a circular curve is normally applied over a length referred to as the transition length. Its purpose is to provide a natural manoeuvre between a tangent and circular curve to avoid a rapid change in cross-fall, or a jerk, and to maintain the natural position of the vehicle on the lane. The transition length is normally applied over a spiral on the horizontal alignment. Design values for spiral lengths are explained in Chapter C, Section C.3.3.5 and the basis of spiral design is discussed in Section C.3.3.4. Methods of attaining superelevation between tangent and circular curve are discussed in Chapter C, Alignment, Section C.3.3.6 and are shown in Figure C3-6.

The removal of normal cross-fall before and after superelevated cross section is referred to as tangent runout. This is explained in Chapter C, Alignment, and is illustrated in Figures C3-2 and C3-6. Tangent runout is usually a maximum of 1:400.

Where the horizontal alignment does not include a spiral transition curve between tangent and circular curve, transition between normal cross-fall and super-elevation should be applied partly on the tangent and partly on the circular curve. The method of attaining this superelevation transition is described in Chapter C, Alignment, Section C.3.2.7.

On bridge structures the roadway surface standards should match those for the approach roadway.

D.4.3 APPLICATION OF SUPERELEVATION

D.4.3.1 Rate of Change

The basis for acceptable rates of change of superelevation are comfort, safety and convenience of operation. Changes in the rate of superelevation occur on mainline design at the beginning and end of circular curves and other areas where changes in direction of vehicle travel occur; for example, on turning roadways at intersections and at interchanges on ramps and ramp terminals.

Acceptable rates of change are a function of design speed and radius of curve.

(i) Two-lane Roadways

Relative slope is the slope or profile of the outer edge of the pavement in relation to the profile of the centreline. It is dependent on the rate of superelevation being developed, the length over which it is developed, and the width of the pavement. It is therefore an expression of rate of change of superelevation. The maximum permissible relative slope varies with design speed and acceptable values are shown in Table D4-1.

(ii) Turning Roadways

The term turning roadways refers to separate roadways to provide for right-turning traffic at intersections and curvilinear sections of interchange ramps.

The rate of change of cross-fall on intersection curves, ramp curves and ramp terminals varies with the design speed. As the design speed is increased the length over which the change in superelevation can be made is reduced.

Design values for rates of change of cross-fall are shown on Table D4-2. These values are suitable for single-lane ramps. For 2-lane ramps lower values should be used. Theoretically the maximum rate of change for 2-lane roadways should be 50% of that for single lane roadways, however, this may generate transition lengths which cannot be achieved at an acceptable cost and values of 75% are acceptable.

D.4.3.2 Difference in Pavement Cross-Fall

The phenomenon of adjacent traffic lanes having different rates of cross-fall or superelevation gives rise to a ridge at the common edge, referred to as algebraic difference or roll-over.

Where the design of the superelevation meets speed/radius requirements and the minimum design values for rate of change of cross-fall, but exceeds the maximum algebraic differences in pavement cross slope, the alignment design should be re-examined.

Figure D4-2 illustrates the development of superelevation at a turning roadway exit terminal for alternative alignments and auxiliary lane treatments.

Too great a difference in cross-fall may cause vehicles travelling between lanes to sway, giving rise to some discomfort, and possible hazard. Significant differences in cross-fall can occur in the vicinity of ramp exit terminals and ramp entrance terminals. The maximum algebraic difference in the cross-fall between adjacent lanes is given in Table D4-3.

D.4.3.3 Undivided Roadways

On 2-lane highways and 4-lane undivided highways superelevation is normally applied between a tangent section and a fully superelevated curve by revolving the pavement about either the centreline or one of the edges of the roadway. These methods are described in Chapter C, Alignment, Section C.3.3.6 and are illustrated in Figure C3-6.

Table D4-1

MAXIMUM RELATIVE SLOPE BETWEEN OUTER EDGE OF PAVEMENT AND CENTRELINE FOR 2-LANE ROADWAY

Design Speed, km/h								
40	50	60	70	80	90	100	110	120
Relative Slope, %								
0.70	0.65	0.60	0.55	0.51	0.47	0.44	0.41	0.38

The minimum length (L) is given by the equation:

$$L = \frac{100\,we}{2s}$$

where w is the width of pavement in metres

e is the superelevation being developed in metres per metre

s is the relative slope, percentage

Table D4-2

DESIGN VALUES FOR RATE OF CHANGE OF CROSS-FALL FOR SINGLE-LANE TURNING ROADWAYS

Design Speed km/h			
25 and 30	40	50	55 and more
Rate of Change of Superelevation, %/m length			
0.25	0.23	0.20	0.16

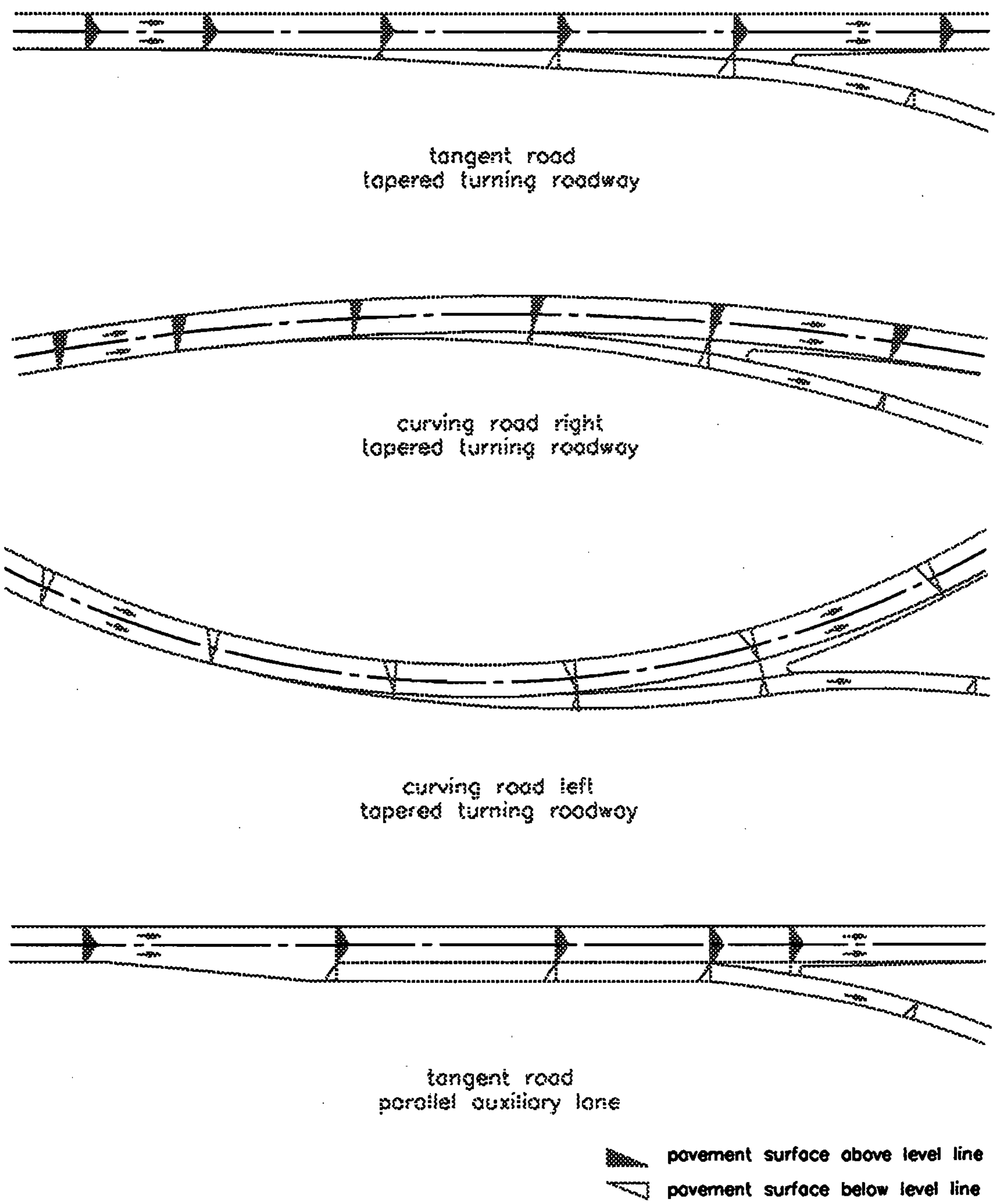
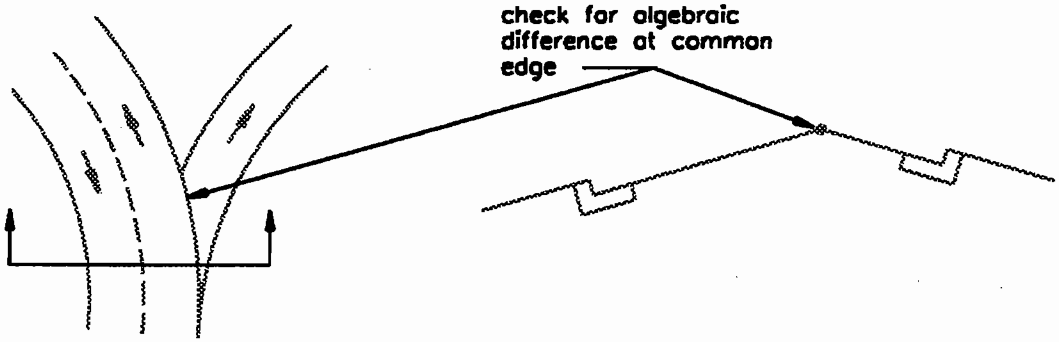


Figure D4-2
Development of Superelevation at Turning Roadway Exit Terminals

TABLE D4-3

MAXIMUM ALGEBRAIC DIFFERENCE IN PAVEMENT CROSS-FALL AT TURNING ROADWAY EXIT TERMINALS



Design speed of exit or entrance curve km/h	Maximum algebraic difference in cross-fall m/m
up to 30	0.06
30 to 50	0.05
50 & over	0.04

D.4.3.4 Divided Roadways

On divided roadways with wide medians, the median pavement edges are usually maintained at the same elevation as shown in Figure D4-3 and, each pavement is revolved about the median edge as illustrated in Chapter C, Alignment, Figure C3-6.

On divided roadways with narrow medians consisting of a median barrier and paved shoulders, the median barrier edges at the two shoulders desirably should be at the same elevation, as shown in Figure D4-3.

On divided roadways where additional lanes are being added to the median and provision for the above treatment was not made in the original design, median shoulder edges will not be at the same elevation. This difference in elevation can be taken up with an asymmetric concrete median barrier, as shown in Figure D4-3.

The use of curb and gutter with any guide rail system is not recommended. Refer to section D.6, Medians and Outer Separations for the recommended procedure.

D.4.3.5 Cross-Fall and Superelevation for Resurfacing Projects

POLICY

ON RESURFACING AND/OR RE-ALIGNMENT PROJECTS, CROSS-FALL AND SUPERELEVATION SHOULD BE RESTORED TO DESIGN STANDARDS.

On resurfacing projects restoration to acceptable standards should only be made if it can be justified. These justifications must be clearly stated in the Design Criteria and documented in detail in the project file.

The following justification guidelines are suggested, but should be used with care and judgement on the part of the designer:

(i) Cross-fall

During the preliminary design stage, the costs to restore a section of pavement to both acceptable tolerances and design cross-fall standards must be determined and carefully assessed.

Resurfacing of a pavement is normally undertaken to strengthen the pavement structure and restore ride and/or skid resistance. This resurfacing can be carried out by a conventional overlay on the existing surface with some padding, by partial depth removal, or by an in-place recycling process including hot/cold in-place recycling. In conjunction with resurfacing to improve ride and pavement structure, cross-fall and superelevation correction may be incorporated to improve rideability and safety.

Minimum acceptable standards are provided in Table D4-4.

Where a conventional resurfacing or in-place recycling project is undertaken, the conventional or recycled binder course must be thick enough to allow for cross-fall correction to an acceptable tolerance. Where partial depth removal of the pavement is undertaken, milling can be utilized to correct cross-fall or superelevation to an acceptable tolerance. The average cross-fall rate selected for a specific resurfacing project must be reasonably consistent throughout and within the acceptable tolerances outlined above.

Restoration to acceptable standards should be justified in terms of the service to high speed traffic, potential reduction in accident experience and anticipated life expectancy of the project.

For example, resurfacing is occasionally programmed as a short-term improvement with the intention of carrying out more extensive work, such as road widening, in 5-10 years.

Restoration to acceptable standards may also be justified where new procedures with limited correction capabilities are being used.

(ii) Superelevation

In many cases design speed and posted speed are the same, particularly for low volume roads. To determine the need for superelevation correction, the following data should be obtained for each horizontal curve:

- existing superelevation
- accident experience
- 85th percentile average running speed
- maximum safe speed as determined by Table C3-5 of Chapter C.

The existing superelevation on curves may remain less than that shown in Tables C3-3 and C3-4 of Chapter C, provided the following conditions are met:

- There is no unusual accident experience, such as loss of control type, that can be related to inadequate superelevation.
- The maximum speed given by Table C3-5 of Chapter C based on the prevailing rate of superelevation and the maximum friction factor is at least 10 km/h higher than the 85th percentile operating speed. (Generally the 85th percentile operating speed will be close to the posted speed limit, but can be significantly higher.)

Where the above conditions are not met, corrections should be applied to make the superelevation as shown in Tables C3-3 and C3-4 of Chapter C as follows:

- design standard, based on design speed, or
- acceptable standard, based on posted speed, or the 85th percentile operating speed plus 10 km/h, whichever is greater.

The cost of correction based on design and acceptable standards must be determined and taken into account in selecting the course of action to be followed.

Table D4-4

PAVEMENT CROSS-FALL FOR RESURFACING PROJECTS

Design Speed km/h	Cross-Fall Design Standard %	Cross-Fall Acceptable Range %	Maximum Alebraic Difference (driving lanes) %
120	2	1.5 - 2.5	5
100	2	1.5 - 3.0	6
80	2	1.5 - 3.5	7

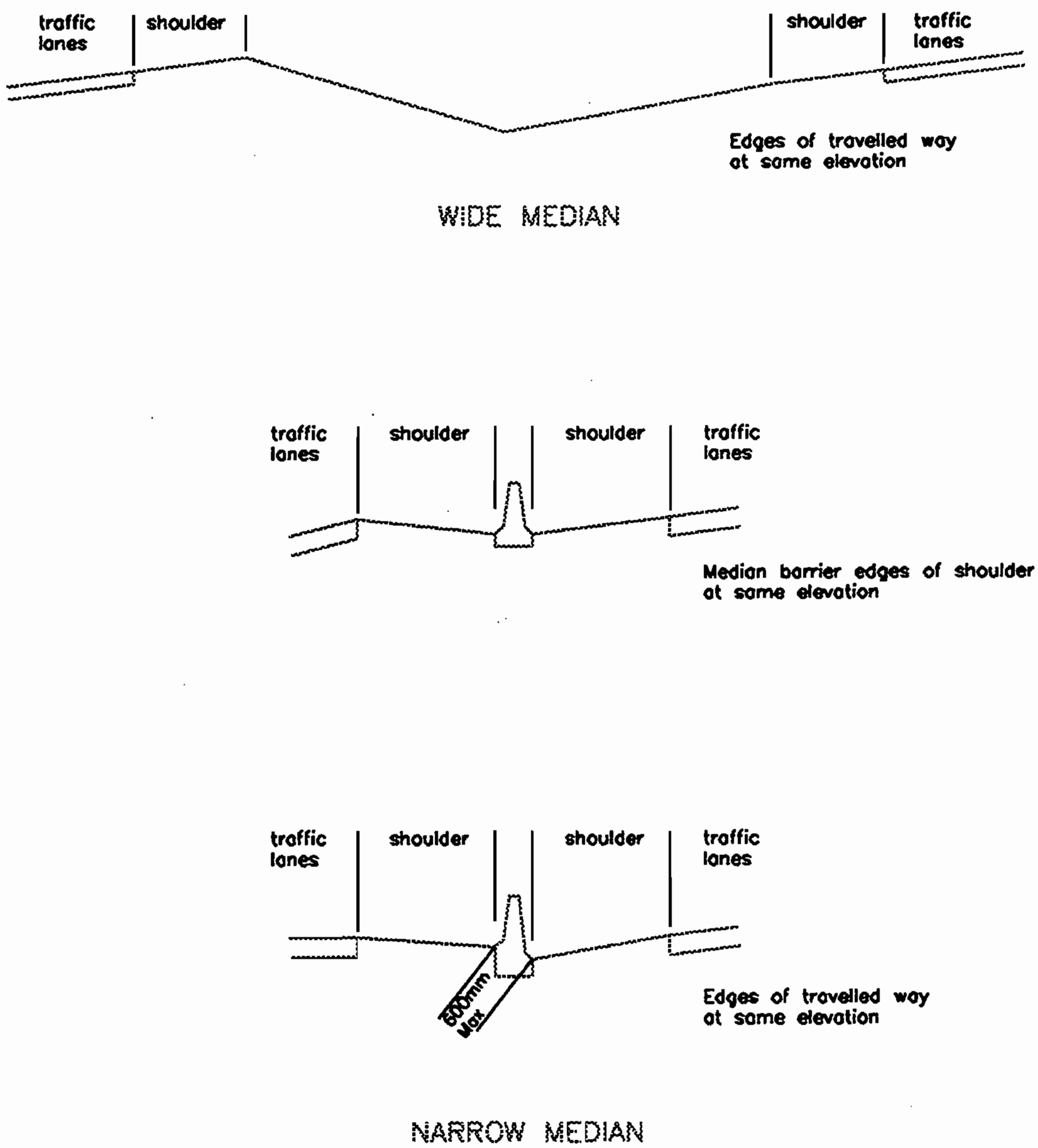


Figure D4-3
Application of Superelevation on Divided Roadways

D.5 SHOULDERS

D.5.1 FUNCTION

A shoulder is the part of the roadway adjacent to traffic lanes provided as refuge for stopped or disabled vehicles, for travel by emergency vehicles and for lateral support for the roadway structure.

Shoulders are normally provided on rural highways, and all freeways.

On highways in urban areas, shoulders are usually omitted, except on freeways, since speeds are lower and it is less hazardous for a stalled vehicle to be on the travelled way. Also, property cost in urban areas is usually too high to justify the provision of shoulders.

Shoulders provide an area that may be used to avoid a potential accident or to minimize the severity of an accident. Shoulders improve highway capacity and provide a storage area for snow removal. Shoulders may also be used for bus bays to allow buses stopping, to load and unload while remaining clear of traffic in the adjacent lane.

Most 2-lane highways have paved traffic lanes and gravel shoulders, in which case the driver recognizes the shoulder for what it is and is not encouraged to treat it as a traffic lane. Where shoulders are paved for reasons such as traffic volume, reduction in shoulder-related accidents, maintenance or drainage, the shoulder can be delineated by means of a contrasting colour and/or texture.

It is important for the operation of the road to make a clear distinction between traffic lanes and shoulders so that the use of a shoulder as a traffic lane is not encouraged. This can be accomplished in a number of ways.The shoulder may be treated with a coarser surface than that of the traffic lane, so that if a vehicle inadvertently leaves the lane and travels onto the shoulder, the change in tone of tire noise will alert the driver.

Pavement edge striping is an important device for delineating the shoulders, particularly where the shoulder is partially paved with the same mix as the through travel lane. Shoulders usually have a steeper cross-fall than the adjacent travel lane and this further assists the driver in distinguishing between the two.

D.5.2 TREATMENT OF SURFACE

Shoulders are gravel surfaced, unless partial paving or full paving is warranted.

D.5.2.1 Partially Paved Shoulders

POLICY

PARTIALLY PAVED SHOULDERS SHOULD BE INCLUDED ON ALL KING'S HIGHWAYS UNLESS OTHERWISE RECOMMENDED BY THE REGIONAL MANAGER OF ENGINEERING AND RIGHT-OF-WAY.

Partially paved shoulders are not normally used on secondary highways, however, at the discretion of the Regional Manager of Engineering and Right-of-Way, and based on engineering evaluation, they may be provided. Appropriate documentation of the shoulder treatment and rationale should be included in the Design Criteria. Where a shoulder is partially paved, a width of 0.5 m closest to the adjacent travel lane is hard surfaced, usually with asphalt, and the remaining shoulder surface is gravel.

On existing highways having a median shoulder width and/or outside shoulder width $\leq$ 1.0 m, the full shoulder width should be paved to avoid the existence of a narrow gravel strip which is extremely difficult to maintain.

Partially paved shoulders should preferably be constructed in conjunction with resurfacing, reconstruction or new construction. In order to avoid a joint at the interface, partially paved shoulders are not normally placed adjacent to the existing pavement without resurfacing. A stand-alone partially paved shoulder retrofit may be justified, at the discretion of the District/Region, based on continuity, median safety or maintenance considerations.

Partially paved shoulders should be carried through on passing lanes and truck-climbing lanes.

The beginning and termination points of 0.5 m wide partially paved shoulder sections should be tapered to the through pavement edge over a distance of 10 m. Exceptions to this are at speed-change lanes where the partially paved shoulder should be feathered into the auxiliary lane taper, or where the presence of curves would create discontinuity of the edge of paved surface.

As a general rule, continuous partially paved shoulders should terminate either at an intersection where there is a significant change in traffic volume or at locations where changes in the characteristics of roadside developments occur, such as the beginning of an urban cross section.

D.5.2.2 Fully Paved Shoulders

POLICY

FULL SHOULDER PAVING IS WARRANTED:

- **ON ALL FREEWAYS HAVING THREE OR MORE LANES IN ONE DIRECTION;**

- **ON 4-LANE DIVIDED HIGHWAYS FOR THE MEDIAN SHOULDER;**

- **IN URBAN AREAS:**

  WHERE THE SIDEWALK IS LOCATED 3 m OR LESS FROM THE THROUGH LANES, AND WHERE REVERSE SHOULDERS ARE UTILIZED TO SUIT EXISTING CONDITION;

  WHERE THREE OR MORE ADJACENT COMMERCIAL ESTABLISHMENTS ARE PRESENT, OR

  WHERE THE TOTAL DENSITY OF ENTRANCES (ALL TYPES) EXCEEDS 10 PER 300 m PER SIDE.

  ON 2-LANE HIGHWAY SECTIONS, SHOULDER PAVING SHALL BE APPLIED ON BOTH SIDES OF THE HIGHWAY

  ON HIGHWAYS WITH MORE THAN TWO LANES, SHOULDER PAVING SHALL APPLY ONLY TO THE SIDE ON WHICH THE ENTRANCES ARE LOCATED;

- **AS PROTECTION AGAINST SHOULDER EROSION ON GRADIENTS. THE CONDITIONS UNDER WHICH PROTECTIVE MEASURES ARE WARRANTED ARE:**

  GRADIENTS LESS THAN 3%; NO TREATMENT IS REQUIRED,

  GRADIENTS OF 3% TO 5%; TREATMENT SHOULD BE BASED ON LOCAL CONSIDERATIONS,

  GRADIENTS GREATER THAN 5%; TREATMENT ADVISABLE.

To prevent excessive shoulder erosion caused by storm-water, steep grades and superelevation, shoulder paving is an acceptable alternative to the application of curb and gutter. The entire width of shoulder should be paved.

D.5.3 WIDTH

POLICY

FOR HIGH-SPEED HIGHWAYS THE NORMAL SHOULDER WIDTH IS 3.0 m.

FOR HIGHWAYS OF LOWER SPEED AND/OR LOWER VOLUME, THIS WIDTH OF SHOULDER IS NORMALLY NOT JUSTIFIED AND A NARROWER SHOULDER MAY BE APPLIED.

THE MINIMUM SHOULDER WIDTH ACCEPTABLE FOR PAVEMENT SUPPORT IS 0.5 m IF THE SHOULDER IS PAVED, AND

1.0 m IF THE SHOULDER IS GRAVEL SURFACED.

IT IS DESIRABLE THAT A VEHICLE STOPPED ON A SHOULDER FOR EMERGENCY REASONS BE CLEAR OF THE PAVEMENT BY AT LEAST 0.25 m AND PREFERABLY 0.5 m.

The minimum usable shoulder width required to accommodate a disabled vehicle is 2.0 m.

Where curb and gutter is placed at the outside edge of a shoulder, the gutter width is regarded as part of the usable shoulder width. Where a mountable curb and gutter is placed between the traffic lane and the shoulder, the entire unit is treated as part of the usable shoulder.

Where guide rails, walls or other obstructive elements are introduced adjacent to a shoulder, it is desirable that the shoulder be wide enough to allow for opening of a vehicle door. However, it is not always practical or economical to do so.

Shoulders desirably should be continuous so that at any location along the roadway a driver can leave the traffic lanes to use the shoulder. If the shoulder is intermittent some drivers may find it necessary to stop in the traffic lane, precipitating a hazardous condition. However, it may not always be economical to maintain shoulder width in all cases as for example in deep rock cuts.

Shoulder widths are normally multiples of 0.5 m. Shoulder widths for undivided rural highways are given in Table D5-1. Shoulder widths on bridge decks for various conditions are given in Section D.7.3.2.

For 4-lane divided highways the width of the shoulders are as follows:

- right shoulder is the same as for undivided highways, see Table D5-1.
- left or median shoulder is 1.0 m.

For multi-lane divided highways the width of the shoulders are as follows:

- right shoulder is 3.0 m.
- left or median shoulder is 2.5 m.
  Where a median barrier system is placed, the median shoulder width varies according to the type of barrier used, see section D.6.

For all interchange ramps the right shoulder width is 2.5 m.

The right shoulder on a single-lane ramp may be gravel, partially paved, or paved depending on rural or urban locations and maintenance considerations.

The right shoulder of a ramp with two or more lanes is normally paved.

For interchange ramps the left shoulder width is as follows:

• single-lane ramp	- 1.0 m
• 2-lane ramp	- 1.0 m
• ramps of more than two lanes	- 2.5 m

The left shoulder is normally paved.

The shoulder width for collector-distributor roads on urban freeways should be the same as those for express lanes.

The shoulder widths adjacent to acceleration, deceleration and weaving lanes on freeways are the same as those of the adjacent ramps.

For speed-change lanes at entrances and intersections on roads other than freeways, the shoulder width is 1.0 m . The transition in shoulder width should take place over the length of taper of the speed-change lane.

For truck-climbing and passing lanes the shoulder width should be the same as the shoulder width on the typical cross section for the roadway, but may be reduced to not less than 1.0 m where the cost of maintaining the shoulder width is considered prohibitive, in which case the shoulder should be fully paved.

D.5.4 CROSS-FALL AND SUPERELEVATION

Standard values for cross-fall and superelevation of shoulders on undivided and divided highways are listed and illustrated in Figures D5-1, D5-2, and D5-3:

• on tangent, unpaved, partially paved or paved	-0.06 m/m
• on the high side of superelevated sections, unpaved, partially paved or paved	as noted in Table D5-2
• on paved part of partially paved shoulder on high side of superelevated section	same as adjacent superelevation
• on the low side of superelevated sections, unpaved, partially paved or paved	- 0.06 m/m

Table D5-1

SHOULDER WIDTH FOR UNDIVIDED KING'S HIGHWAYS AND SECONDARY HIGHWAYS

Design Speed km/h	Traffic Volume for Design Year					
	AADT					
	>4000	3000-4000	2000-3000	1000-2000	400-1000	<400
	DHV					
	>600	450-600	300-450	150-300	60-150	<60
120	3.0	-	-	-	-	-
110	2.5[1]	2.5[1]	2.5	2.5	-	-
100	2.5[1]	2.5	2.5	2.0[3]	1.0	-
90	2.5	2.5	2.0[2]	2.0	1.0	-
80	2.5	2.5	2.0	2.0	1.0	1.0[4]
70	-	2.0	2.0	1.0	1.0	1.0[4]
60	-	-	-	1.0	1.0	1.0[4]
50	-	-	-	-	-	1.0[4]

Notes:

1. If truck percentage exceeds 10% increase by 0.5 m.
2. If truck percentage exceeds 15% increase by 0.5 m.
3. If truck percentage exceeds 25% increase by 0.5 m.
4. Shoulder width of 0.5 m is acceptable on King's Highways where there is no foreseeable possibility of the road being paved within a 20-year period. Where guide rail is installed, shoulder width must be 1.0 m.

Minimum width for pavement support: 0.5 m paved, 1.0 m gravel surfaced.

Minimum usable width for disabled vehicle: 2.0 m.

Highway 11 in Northern and Northwestern Regions, 2.0 m minimum shoulder width.

Highway 17 in Northern and Northwestern Regions, 2.5 m minimum shoulder width.

Table D5-2

SUPERELEVATION FOR SHOULDERS ON HIGH SIDE OF SUPERELEVATED SECTIONS
(For Urban Ramp Design, See Figure D5-4)

Adjacent Traffic Lane	+0.06	+0.05	+0.04	+0.03	+0.02	+0.01	0.00	-0.01	-0.02
Shoulder	-0.02	-0.02	-0.02	-0.03	-0.03	-0.03	-0.04	-0.05	-0.06

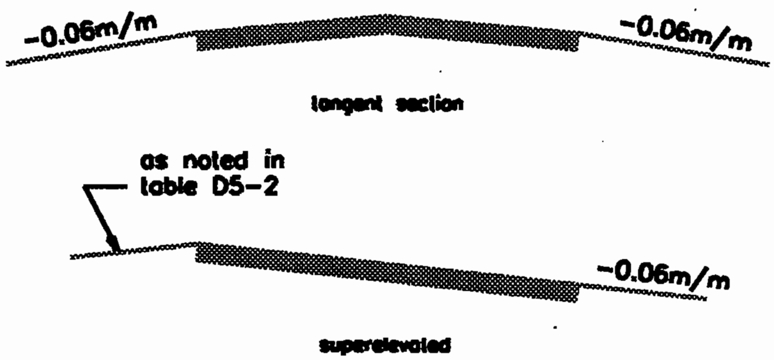


Figure D5-1
Unpaved Shoulder Cross-Fall

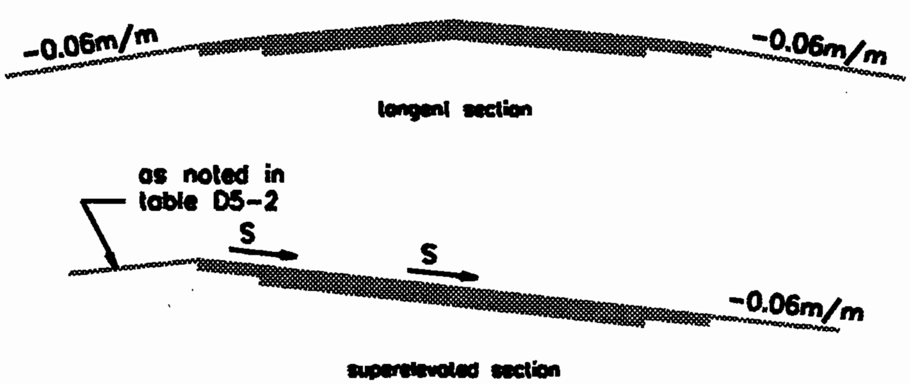


Figure D5-2
Partially Paved Shoulder Cross-Fall

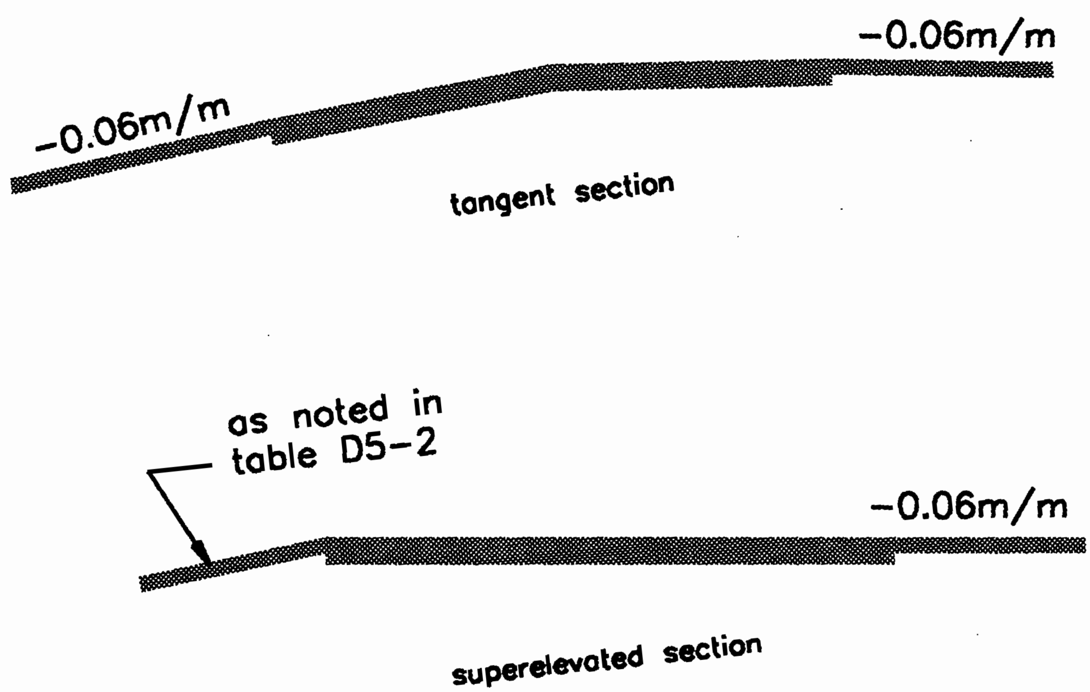


Figure D5-3

Paved Shoulder Cross-Fall

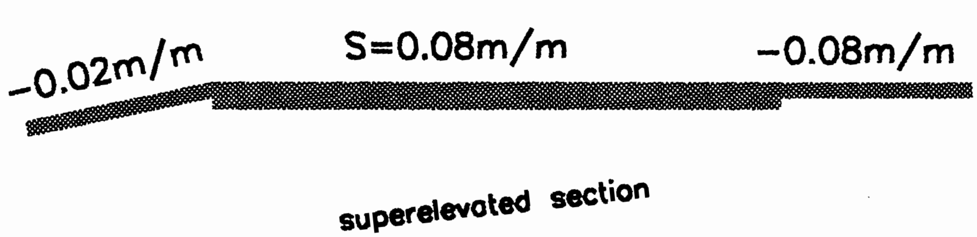


Figure D5-4

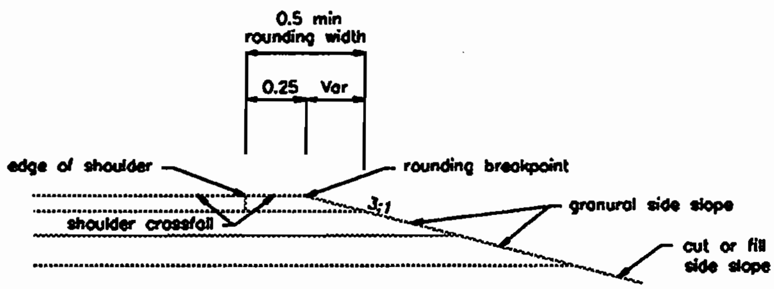
Paved Shoulder Cross-Fall
Superelevated Section - Urban Ramp

D.5.5 SHOULDER ROUNDING

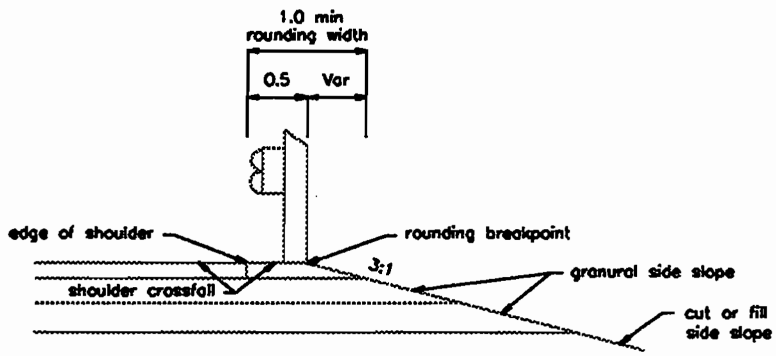
Shoulder rounding is a transition between the shoulder cross-fall and the granular side slope. It provides additional material beyond the shoulder for lateral support of the shoulder and provides a smooth transition for control of an errant vehicle leaving the roadway. Therefore, at higher speeds, the transition should be extended over a greater distance.

To provide additional stability for steel beam guiderail, roundings of 1.0 m minimum with 0.5 m from edge of shoulder to rounding break point should be used.

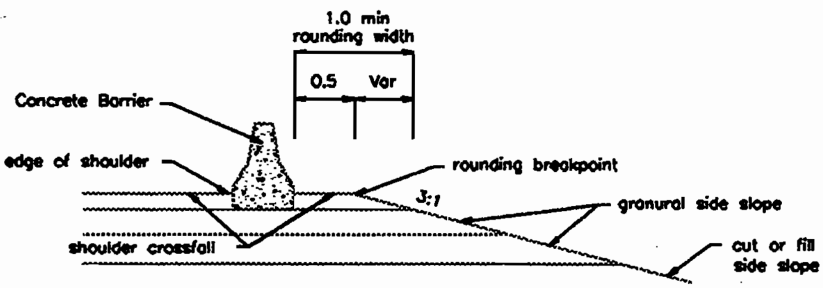
In some conditions the granular material within the rounding transition and on the granular side slope may require a granular sealant treatment to control erosion.



Standard Shoulder Rounding for Design Speed ≤ 100km/h



Standard Shoulder Rounding for Design Speed > 100km/h
or with Steelbeam Guiderail Installation



Standard Shoulder Rounding with Concrete Barrier Installation

Figure D5-5

Shoulder Rounding

D.5.6 GUIDELINES FOR SHOULDER DESIGN ON RESURFACING PROJECTS

On resurfacing projects, the shoulder cross-fall or superelevation should be improved to the design standard regardless of the treatment of cross-fall and superelevation to the adjacent traffic lanes.

For resurfacing shoulders without adjacent curbs the fill slope or cut side slope should be maintained. The increased depth of shoulder will necessitate a reduction in shoulder width as shown in Figure D5-6.

The resultant reduced shoulder width is acceptable provided both the following guidelines are met:

- the reduction in width is not more than 0.5 m
- the usable shoulder width is not less than 1.0 m

Where these guidelines are not met the shoulder should be widened to provide either:

- an acceptable shoulder width equal to the width occurring on most of the project, or
- the standard width noted in Section D.5.3.

The cost of widening to either of the above criteria should be compared.

If the shoulder requires widening over more than 10% of the project length excluding intersection improvement, application of the standard width should be considered.

Resurfacing of full or partially paved shoulders should be dealt with on a project-specific basis. The cross-fall or superelevation desirably should be as shown in Section D.5.4.

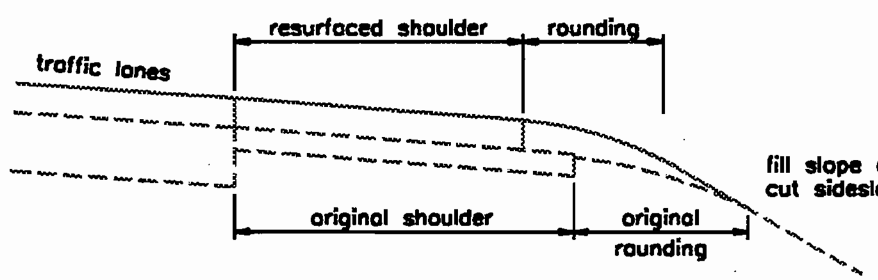


Figure D5-6

Shoulder Treatment on Resurfacing Projects

D.6 MEDIANS

D.6.1 GENERAL

Where opposing traffic lanes are separated laterally, that part of the cross section between opposing traffic lanes is referred to as the median. A median where uni-directional traffic lanes are separated, is referred to as an outer separation. The median and outer separation generally includes shoulders. The width of the median and outer separation is the distance between the edges of the through traffic lanes.

A median functions as a safety device which provides some measure of freedom from interference of opposing traffic. Medians of sufficient width also provide a recovery area for out-of-control vehicles, storage area for emergencies, speed-change lanes for left-turn and U-turn traffic, and reduction in headlight glare.

Medians should be visible day and night and should be in definite contrast to adjacent traffic lanes. Medians may be flush, raised or depressed in relation to, adjacent traffic lanes.

Medians should be as wide as possible, however, economic conditions may preclude such designs. In any case, the median width should be in balance with the other elements of the cross section and the character of the area.

Median widths may be as narrow as 1 m and as wide as 30 m. Widths above 30 m are usually associated with independent alignments, in which case the roadways are designed separately, and the area between is left in its natural state. A median width between 10 m and 15 m with 10:1 slopes does not usually require a traffic barrier and is considered to be the optimum median concept.

A median separating traffic moving in the same direction, known as an outer separation, forms a physical barrier between adjacent traffic lanes. There is little advantage in wider outer separations. They need only be wide enough to provide for elements such as shoulders, curbs, barriers, bridge piers and lighting poles.

Warrants for median barriers are based on traffic volumes and median widths. They are presented in the "Median Barrier Warrant Guide" of the "Roadside Safety Manual". Refer also to the manual for barrier selection, curb design, etc.

On urban freeways when the capacity of a facility is reached and the freedom to manoeuvre within the traffic stream has become difficult the median shoulder may be replaced with a traffic lane. However, this option is not recommended and each location should be assessed for adverse consequences, such as pavement deterioration, inability of access for police or emergency vehicles and finding a refuge area for disabled vehicles.

D.6.2 FREEWAYS

Median and outer separation characteristics for freeways depend primarily on the basic number of freeway lanes, and whether the freeway is designed with a rural or urban type cross section.

Freeways in an urban environment would normally have:
10 year projected AADT greater than 75,000, 6 lanes or more, multiple interchanges spaced 1 to 2 km apart, freeway to freeway interchanges, urban drainage, complex signing requirements including FTMS, illumination, and a significant requirement for protection other than for medians.

D.6.2.1 Rural Freeways

Rural freeways are usually designed with a depressed median of sufficient width to allow the roadbed to drain into the median and to obviate the need for any form of median barrier. See Figure D6-1.

Median side slopes should not be steeper than 4:1. Flatter slopes are beneficial to safety in that a driver leaving the traffic lanes and travelling in the median is more likely to be able to regain control without incurring vehicle damage or occupant injury. Flatter slopes should be used where feasible in terms of cost and property.

When warranted, an appropriate longitudinal median barrier system shall be selected. The types of traffic barriers used are the concrete or IBC barrier, steel beam, box beam* or six cable guide rail. The median treatment may be sod, stabilized granular or pavement depending on the traffic barrier to be used.

It should be noted that when a barrier is used the median must have side slopes of 10:1 or flatter, or, a barrier may be installed on a 6:1 slope providing the barrier system is located at least 4.5 m from the rounding break point.

* Box beam may be used provided posted speed is less than 80 km/h.

A median width of 22.0 m allows for practical side slopes of 6:1 and normally allows the roadbed to drain without subdrains. It will also permit the addition of future lanes leaving a standard urban multi-lane median width of 7.5 m. See Figure D6-2.

Wider medians may be employed to:

- provide independent roadway alignments in rugged terrain,
- improve aesthetics.

D.6.2.2 Staged Freeway Construction

In urban fringe areas it may be appropriate to build a rural freeway with a depressed median, recognizing that the character of the area will become urban and that the future lanes will be required together with a flush or raised median. In this case the ultimate cross section should be designed and then components removed to give the depressed median width at the initial stage. For example, an ultimate 8-lane cross section may have a 7.5 m median consisting of a 630 mm concrete median barrier and two 3.435 m shoulders. The initial stage could be built as a 4-lane cross section with a 22.0 m depressed median which allows for the future lanes, shoulders and standard or high performance median barrier. The staging for this case is shown in Figure D6-2.

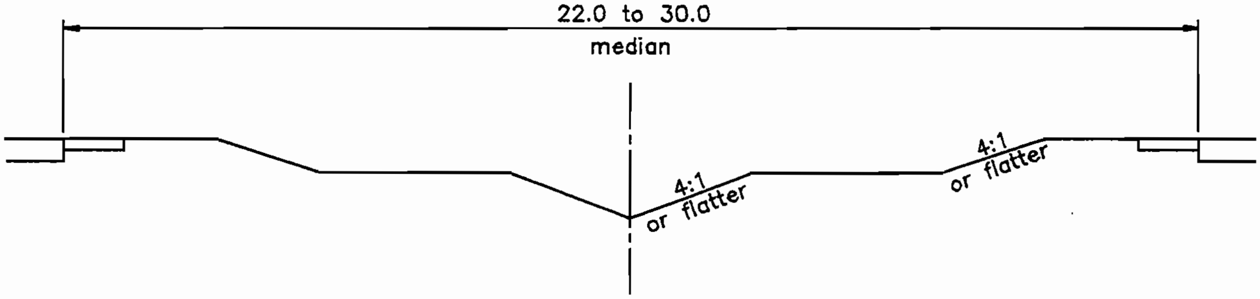
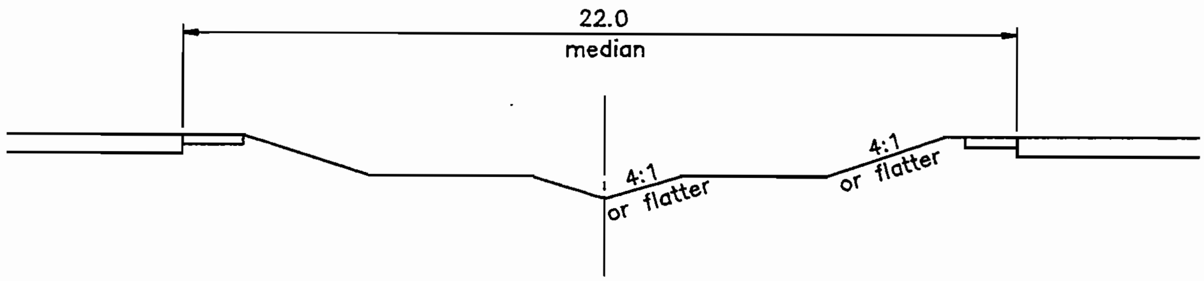
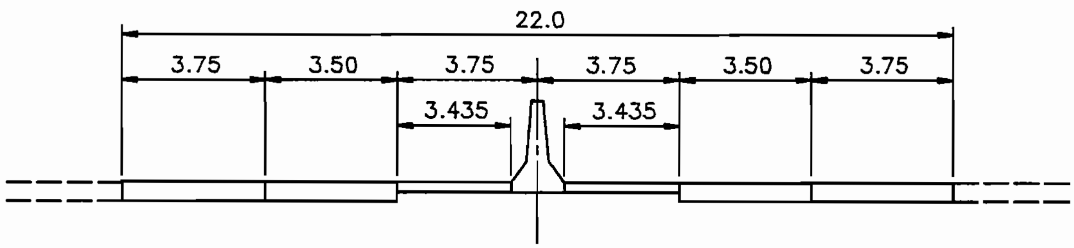


Figure D6-1
Median Width for Rural Freeways



Initial Stage - 4-Lanes



Ultimate Stage - 8-Lanes

Figure D6-2
Stage Construction for Freeway Medians

D.6.2.3 Urban Freeways

Medians for urban freeways are either flush or raised with some form of median barrier. Median width is dependent on shoulder width, barrier type, and whether or not there is provision for structure piers.

The standard median width of 6.0 m for a 4-lane urban freeway and 7.5 m for an urban multi-lane freeway should be maintained.

For a 10-lane or more urban freeway the standard median width may be increased to 8.5 m where multiple bridge pier intrusions would not provide for a minimum 3.0 m shoulder width. In isolated locations a smooth lane shift may be appropriate.

For 6 - 8 lane urban freeways the 3.0 m minimum shoulder width is also desirable but may, in isolated locations, such as bridge piers, be reduced to a minimum of 1.5 m.

(i) Flush Median

The 6.0 m median width will accommodate various median traffic barrier systems; however, a minimum shoulder width of 2.5 m should be maintained.

A wider left-hand shoulder width of 3.0 m is required on multilane freeways to provide additional safety. When the wider left-hand shoulder is provided on a multilane cross-section with three or more lanes in one direction, emergency stops may be facilitated for vehicles travelling in the lane adjacent to the median. In addition the driver's door can be opened without the vehicle encroaching into the adjacent lane.

A concrete barrier is commonly used on multi-lane urban freeways with a flush median. The shoulders are sloped to drain toward the barrier where catch basins are installed to collect the runoff. An IBC Mark VII may be considered as an optional design to a standard concrete median barrier where a minimum 3.0 m clearance is provided between the edge of the travelled lane and the barrier face. See Figure D6-3(a).

Where a Freeway Traffic Management System (FTMS) overhead sign structure, or high mast lighting is to be placed in a newly constructed multi-lane urban freeway median, high performance median barrier special design concrete footings are required. The shoulder thus produced will vary according to the type of barrier used.

Desirably a 3.0 m shoulder width should be maintained throughout. However, on projects where high mast lighting or FTMS overhead sign footings are to be located the minimum shoulder width may be reduced to 2.9 m; consequently the shoulder width varies and becomes narrower at each obstacle.

<u>High Performance Barrier</u>
Where a high performance median barrier is required either the Ontario 'Tall Wall' concrete barrier or an IBC Mark VII HV barrier system shall be placed. In a standard 7.5 m median both Ontario 'Tall Wall' concrete barrier and IBC Mark VII HV allow for an effective shoulder width in excess of 3 m. See Figure D6-3(b).

When applying the Ontario 'Tall Wall' or Mark VII HV barrier system a minimum clear shoulder width of 3.0 m should be provided, therefore, the required minimum median width must be 6.8 m for the Ontario 'Tall Wall' barrier and 7.12 m for the IBC Mark VII HV barrier system. For the application of high performance barriers refer to the Traffic Barrier Manual.
The above also applies to staged freeways.

An alternative design utilizing a twin concrete barrier system may be used to provide additional protection for a high mast light standard. The minimum median width required for this installation must be 9.0 m, thus producing a minimum shoulder width of 3.0 m on both sides of the concrete barriers. The twin concrete barrier design may be continuous or tapered at a rate of 40:1, into a single concrete median barrier. See Figure D6-3(c). Half sections next to bridge piers may also be utilized in confined conditions.

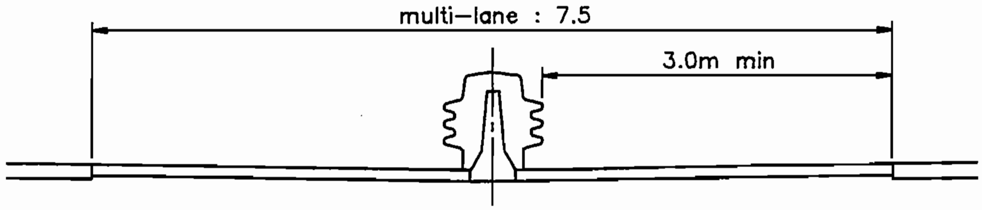
Box beam barrier may also be used with the flush median, but its use is restricted; installations are limited to highways where the posted speed is less than 80 km/h; see the Traffic Barrier Manual.

When applying box beam barrier in a flush median, the shoulder should be sloped and a drainage channel created 0.5 m from centreline. The drainage channel may be placed on either side of the centreline. See Figure D6-3(d).

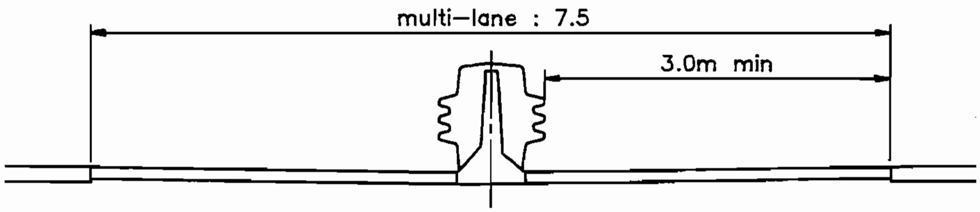
Double steel beam barrier may be used in flush medians where truck volumes are less than 9,000 per day. The shoulder slopes should intersect 0.5 m from the face of the barrier to create a drainage channel. See Figure D6-4 (a).

The steel beam barrier system at bridge piers can also be placed in a flush median with provision of adequate slopes for drainage. See Figure D6-4(b).

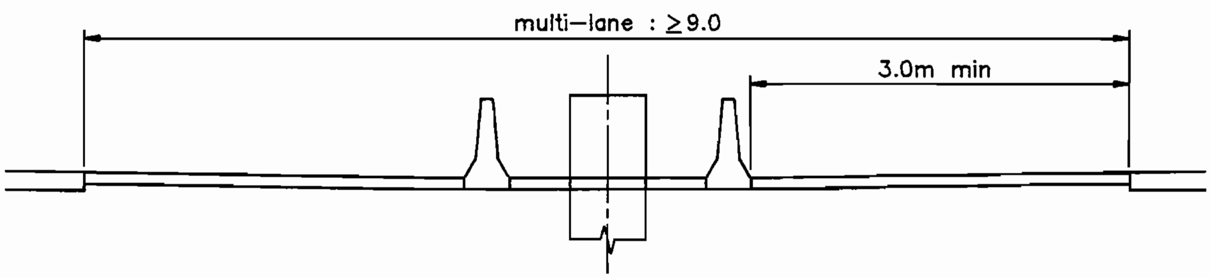
On existing facilities, where provision is required in the median for a bridge pier, a reduced shoulder width on the approaches to the pier may be acceptable, in which case the standard median width can be maintained.



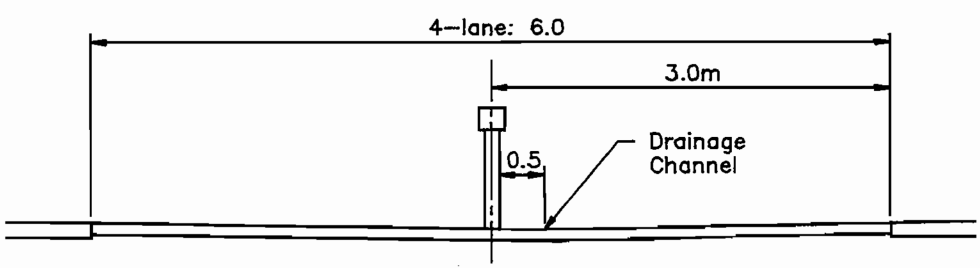
(a) Single Concrete Barrier or I.B.C. Barrier



(b) 'Tall Wall' or I.B.C. Barrier



(c) Twin Concrete Barrier



(d) Box Beam Barrier

Figure D6-3
Urban Freeway Flush Median Treatment

On reconstruction projects, at bridge pier locations the median width may be maintained and the shoulder width reduced. The type of barrier protection required is steel beam guide rail with channel. Steel beam barrier systems are desirably offset a minimum of 1 m from the face of the barrier to the pier to allow for barrier deflection. Where limited space precludes offsetting the barrier from the pier, the steel beam guide rail with offset blocks may be anchored directly to the pier. The offset distance 'd' from the bridge pier to the edge of the travelled lane is based on the hazard protection distance warrants for unprotected clearance and is shown in the table with Figure D6-4(b).

Whenever feasible and cost effective, the standard shoulder widths should be maintained.

(ii) Raised Median

Although a raised median design with guide rail is feasible, the performance of the traffic barrier system has proven to be adversely affected by the presence of curb and gutter. For this reason the flush median design is preferred when traffic barriers are required.

Raised medians may be used on urban freeways where double steel beam barrier is applied. A raised median consists of a mountable curb and gutter bordering a level area that is normally surfaced with asphalt or concrete. The standard median width for a 4-lane urban freeway is 6.0 m and 7.5 m for a multi-lane urban freeway.

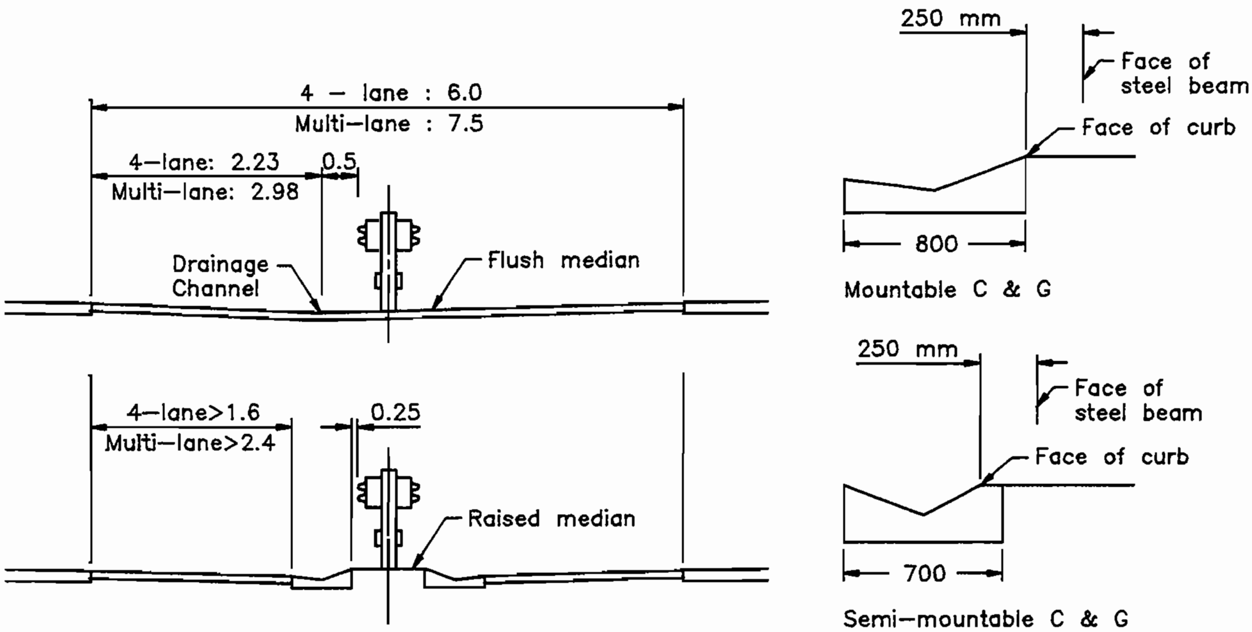
Double steel beam guide rail with channel shall be used adjacent to mountable or semi-mountable curb with wide gutter in all locations. The face of the steel beam guide rail shall be placed no more than 0.25 m from the face of curb.

The median shoulder width to the edge of curb and gutter shall not be less than 1.5 m for the 4-lane freeway and 2.5 m for the multi-lane freeway. See Figure D6-4(a).

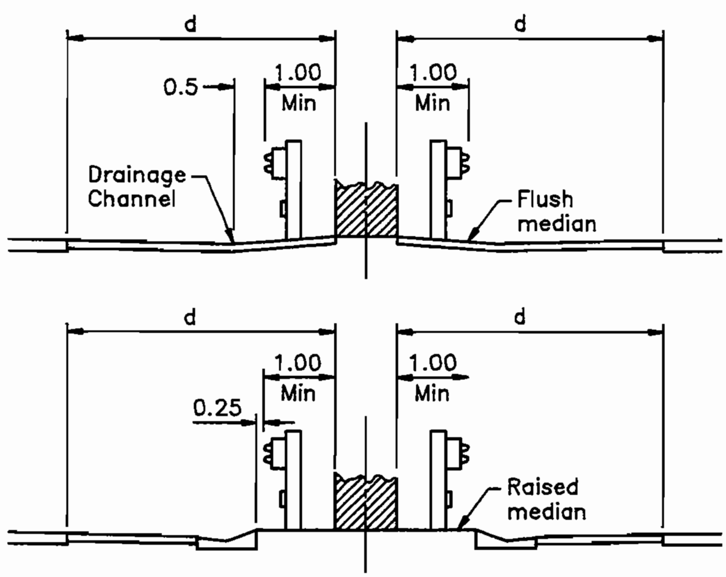
The desirable design is to place double steel beam barriers in a flush median and offset the intersecting slopes of the shoulder 0.5 m from the face of the barrier to create a drainage channel. The drainage channel may be placed on either side of the centreline. See Figure D6-4(a).

Where light poles or sign supports are placed in the median between the two rails, a barrier assembly with additional offset blocks are used to provide sufficient space.

The type of barrier protection required at piers or other median obstacles in raised medians with mountable curb and gutter is steel beam guide rail with channel. The face of the steel beam guide rail shall be placed no more than 0.25 m from the face of curb. The barrier system is desirably offset a minimum of 1.0 m from the face of the barrier to the pier to allow for barrier deflection. Steel beam barrier systems may be anchored directly to the pier where limited space precludes offsetting the barrier. See Figure D6-4(b).



Double Steel Beam Barrier
(a) Without Bridge Pier



Where offset distances are equal to or greater than 'd' barriers are not required

Design Speed km/h	Offset d m
120	10.0
110	9.0
100	7.0

Steel Beam Barrier
(b) With Bridge Pier

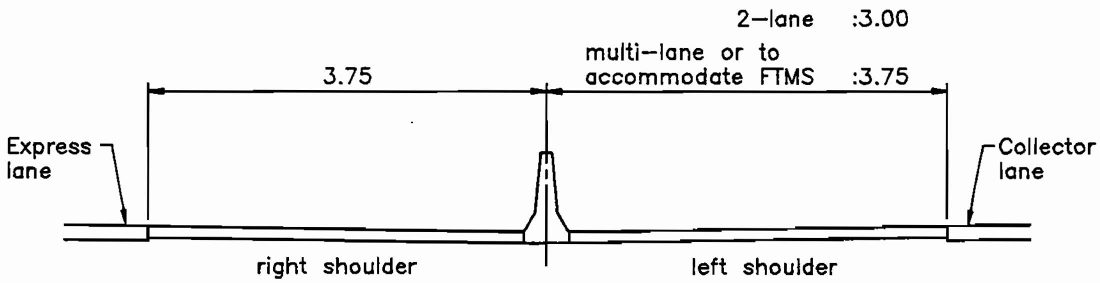
Figure D6-4
Urban Freeway Flush or Raised Median Treatment with Steel Beam Barrier

D.6.2.4 Outer Separations

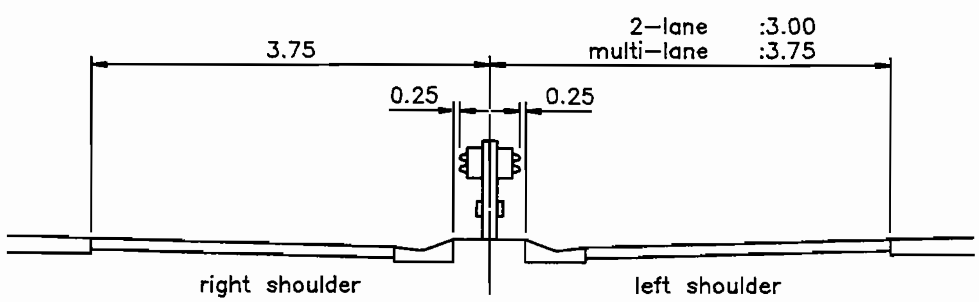
Outer separations separate express lanes from collector lanes. They usually contain some form of barrier and may accommodate bridge piers and lighting poles.

Viewed in the direction of the traffic, the outer separator consists of the right shoulder of the express lanes and the left shoulder of the collector lanes. Typical outer separations are shown in Figure D6-5.

Where an overhead sign structure for a Freeway Traffic Management System (FTMS) is to be placed in a newly constructed freeway/collector outer separation, this outer separation must be flush, and the FTMS sign structure must be mounted on a footing incorporating the concrete barrier design shape. The minimum width of the outer separation from the centre line of the barrier to the edge of the adjacent express lane is 3.75 m. The minimum width of the outer separation from the centre line of the barrier to the edge of the collector lane is shown below.



(a) Flush with Concrete Barrier



(b) Raised with Steel Beam Guiderail

Figure D6-5
Outer Separation Treatment

D.6.3 ARTERIAL HIGHWAYS

Divided arterial highways may have depressed, flush or raised medians. The selection of median type normally depends on whether the highway is urban or rural. Median barrier requirements are based on the Annual Average Daily Traffic (AADT) volumes and the type and width of median.

D.6.3.1 Rural Arterials

Rural arterials have a depressed or a flush median.

(i) Depressed Median

On rural divided arterial roads a depressed median is generally preferred. Design details and dimensions for depressed medians are the same as those for rural freeways presented in Section D.6.2.1.

(ii) Flush Median

Flush medians are usually narrow and used in rural and urban-fringe areas. A flush median without barrier may be appropriate for highways with higher volumes and lower speeds. This median is normally slightly crowned to assist drainage, and is normally paved, often in the same surface material as the adjacent lanes. It is advantageous, however, to surface the median in a contrasting texture and/or colour to alert the errant driver encroaching onto the median. The normal width is 1.0 m. See Figure D6-6(a).

The box beam barrier should be used with the flush median, but its use is restricted; installations are limited to highways where the posted speed is less than 80 km/h. The median width should be at least 3.0 m to allow for deflection of the traffic barrier after being struck without endangering or interrupting the passage of traffic in the opposite direction. The shoulder slopes should intersect 0.5 m from the centreline to create a drainage channel. The drainage channel may be placed on either side of the centreline. See Figure D6-6(b).

The wider flush medians with barriers normally apply to high speed rural arterial roads. In medians with a width less than 7.0 m, it is desirable to construct a concrete barrier, as it performs best at low angle, high speed impacts and requires a minimum of maintenance.

The minimum median treatment with concrete barrier should have a minimum shoulder width of 1.5 m plus the width of concrete barrier. See Figure D6-7(a).

Where provision is required for a bridge pier with concrete barrier, the median width should be 5.0 m plus the width of the pier. See Figure D6-7(b).

The steel beam barrier system may also be used at bridge piers and placed in a flush median with provision of adequate slopes for drainage. Steel beam barrier systems are desirably offset a minimum of 1 m from the face of the barrier to the pier to allow for barrier deflection or may be anchored directly to the pier. See Figure D6-9(a).

The offset distance 'd' from the pier to the edge of travelled lane is based on the hazard protection distance warrants and is shown in the table with Figure D6-9.

Whenever feasible and cost effective, the standard shoulder widths should be maintained.

For barrier selection consult the Traffic Barrier Manual.

(iii) Raised Median

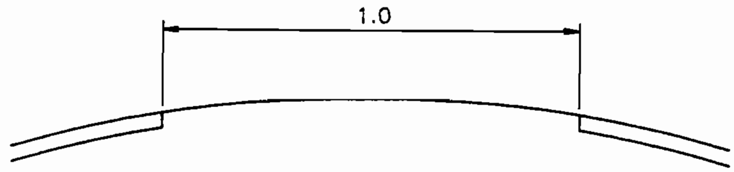
Although a raised median design with guide rail is feasible, the performance of the traffic barrier system has proven to be adversely affected by the presence of curb and gutter. For this reason the flush median design is preferred when traffic barriers are required.

Where a raised median is used on rural arterial highways double steel beam guiderail or box beam barrier is applied. A raised median normally consists of a mountable curb and gutter bordering a level area that is surfaced with asphalt.

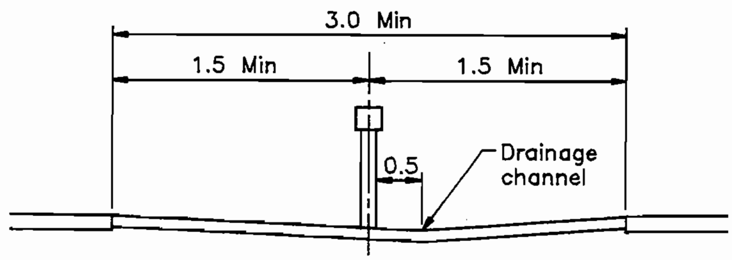
Double steel beam guide rail with channel shall be used adjacent to mountable or semi-mountable curb with wide gutter. The face of the steel beam shall be placed no more than 0.250 m from the face of curb. See Figure D6-4(a).

The box beam barrier application requires a mountable curb with wide gutter; however, the use of box beam is restricted to highways where the posted speed is less than 80 km/h. See Figure D6-6(c).

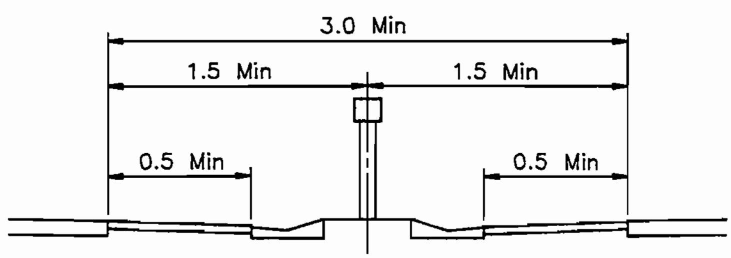
The type of barrier protection required at piers in raised medians with mountable curb and gutter is steel beam guide rail with channel. The barrier system may be anchored directly to the pier but desirably should be offset a minimum of 1.0 m to allow for barrier deflection. The face of the steel beam guide rail shall be placed no more than 0.25 m from the face of curb. See Figure D6-9(b). For detail of curb and gutter refer to Figure D6-4.



(a) Without Barrier



(b) Flush With Box Beam Barrier



(c) Raised With Box Beam Barrier

Figure D6-6
Rural Arterial Flush or Raised Median Treatment

D.6.3.2 Urban Arterials

Flush or raised medians may be used in urban and urban-fringe conditions.

(i) Flush Median

Design details for the flush median without barrier are given in the preceding subsection.

Where a flush median with barrier is required, it is desirable to construct a concrete type barrier as it performs best for low angle, high speed impacts and requires a minimal amount of maintenance. The minimum median treatment should have a minimum shoulder width of 1.5 m plus the width of the concrete barrier.

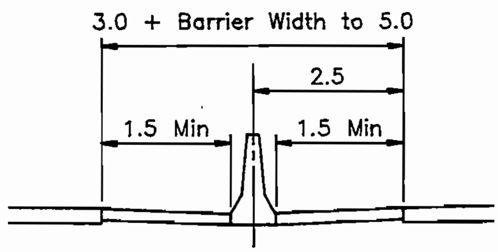
With a width of 2.5 m measured from the edge of travelled lane to the centre of the barrier, the median width becomes 5.0 m. See Figure D6-7(a).

Where provision is required for a bridge pier, the median width should be 5.0 m plus the width of the bridge pier. If the bridge pier width is not a multiple of 0.5 m, the shoulder widths should be adjusted to make the median width a standard multiple of 0.5 m. This practice simplifies design and construction.

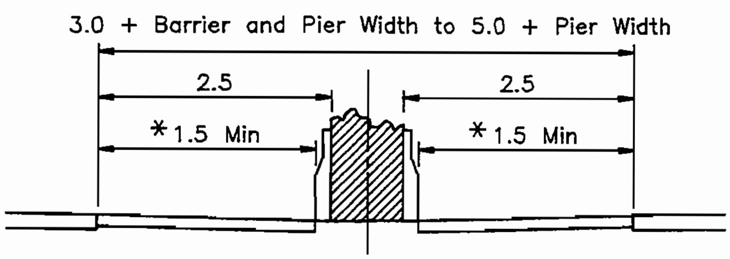
The steal beam barrier system at bridge piers may also be placed in a flush median with provision of adequate slopes for drainage. See Figure D6-9(a).

Whenever feasible and cost effective, the standard shoulder widths should be maintained.

* When the median width has to be reduced the required width from the edge of travelled lane to the face of the barrier wall is 1.5 m; however, this may be reduced to 0.5 m, subject to approval by the Executive Director, Highway Engineering Division. See Figure D6-7(b).



(a) Without Bridge Pier



(b) With Bridge Pier

Figure D6-7
Rural and Urban Arterial Flush Median Treatment with Concrete Barrier

(ii) Raised Median

Raised medians are normally applicable to urban areas and may be used on multi-lane urban arterial roads.

Raised medians have application on arterial streets to regulate left-turn movements. They usually include curb and gutter.

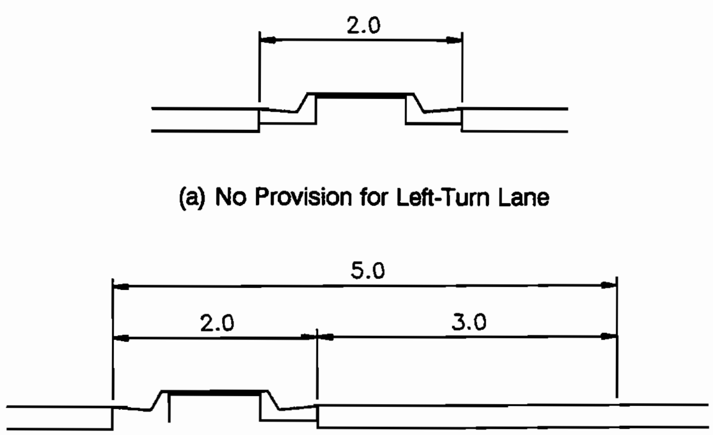
On urban arterial roads where a median barrier is not applied, a median width of 2.0 m is sufficient. Barrier curbs with gutter 400 mm wide are normally used, giving a width between faces of curb of 1.2 m. This is sufficient to allow the placement of traffic signs and other features without interference to the normal flow of traffic in adjacent lanes. See Figure D6-8(a).

If provision for a left-turn lane is required, the median width should be increased by the width of the left-turn lane, normally 3.0 m, giving a median width of 5.0 m. See Figure D6-8(b). For detail of left turn lanes see Chapter E, Section E10.1.

Where an arterial passes under a bridge structure, it may be necessary to make provision in the median for a bridge pier with barrier protection. The type of barrier protection required at piers or other median obstacles in raised medians with mountable curb and gutter is steel beam guide rail with channel. Steel beam barrier systems may be bolted directly to the pier but desirably should be offset a minimum of 1.00 m to allow for barrier deflection. The face of the steel beam guide rail shall be placed no more than 0.25 m from the face of curb. See Figure D6-9(b). For detail of curb and gutter refer to Figure D6-4.

Whenever feasible and cost effective, the standard shoulder widths should be maintained.

The offset distance 'd' from the travelled lane to the bridge pier is based on the hazard protection distance warrants for unprotected clearance and is shown in the table with Figure D6-9.



(a) No Provision for Left-Turn Lane

(b) Provision for Left-Turn Lane

Figure D6-8
Urban Arterial Raised Median Treatment Without Barrier

D.6.4 MEDIAN CROSSOVERS

Median crossovers are unacceptable on highways with median barrier protection.

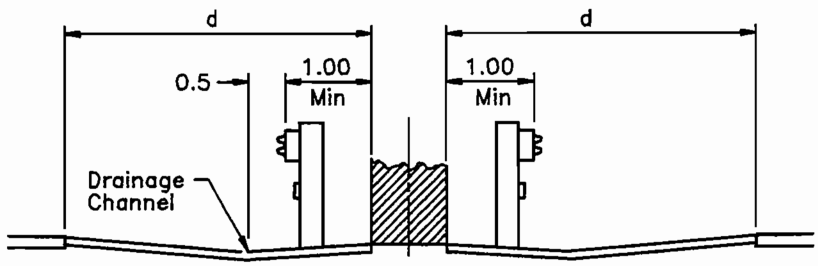
Median crossovers are acceptable on wide medians where guide rail is not required and are introduced on divided highways to allow police, emergency vehicles and maintenance vehicles to make U-turns to travel in the opposite direction. Their location depends on the distance between adjacent interchanges and the maintenance operation responsibilities. Median crossovers should be located where there is adequate sight distance for through traffic to be aware of accelerating and decelerating traffic using the crossover, as for example, in the vicinity of sag curves.

The design for median crossovers should be in accordance with the current Ontario Provincial Standard adopted by the Ministry.

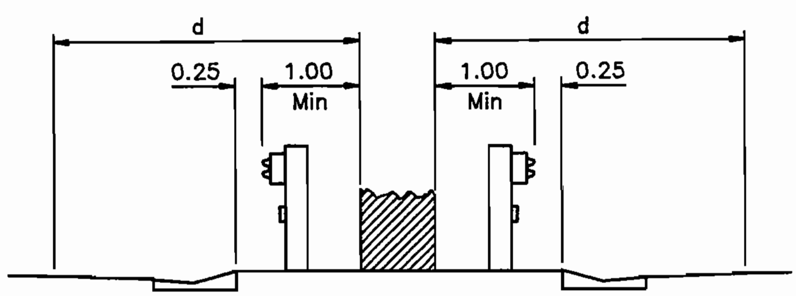
In the 6m to 20m median width range. It is necessary to widen out the opposite shoulder in order to provide sufficient room for snow plow manoeuvres. All crossovers, regardless of median width, are provided with deceleration tapers. It is important to keep crossovers inconspicuous to avoid their illegal use by motorists. Crossovers for snow plows, including tapers must not be paved.

Design speed km/h	Offset d m
100	7.0
80	5.0
60	3.0

Where offset distances are equal to or greater than 'd' barriers are not required



(a) Flush Median



(b) Raised Median

Figure D6-9
Rural and Urban Arterial Flush or Raised Median Treatment with Steel Beam Barrier at Bridge Pier

D.7 STRUCTURES AND CLEARANCES

D.7.1 GENERAL

The material contained in this section is intended to assist the designer when designing cross sections where bridges, retaining walls or other structures are required. This section gives direction in setting structure dimensions that influence geometric design of horizontal alignment, vertical alignment and cross sections.

In general:
- Bridges should be designed to match the geometric requirements of the roadway.
- Where practicable, the horizontal centreline alignment on bridges should be on tangent or of constant curvature.
- The cross section elements of roads on and under bridges should match those of the approach roadway.
- Sag curves on bridges should be avoided as much as possible.

D.7.2.1 – Deck Width and Traffic Lanes

The number and width of through lanes and auxiliary lanes should be the same on the bridge deck as on the approach roadway. Traffic lane widths should be in accordance with Section D.2.

In general, the minimum acceptable bridge deck roadway width for two way traffic is 8.5 m. Single lane bridges shall be a minimum 5.0 m roadway width except for single lane ramp bridges that shall be a minimum of 4.75 m roadway width.

Provision of narrower or single lane bridges may be permitted on low volume roadways in accordance with the Ministry's Guidelines for the Design of Bridges on Low Volume Roads.

D.7.2.2 – Side Clearances on Bridges

Side clearances on bridge decks, defined as the distance between the edge of the traveled way and the adjacent curb or barrier, should be in accordance with Table D7-1 and Figure D.7-1 for urban and rural structures. Where the side clearances from Table D7-1 are greater than the approach roadway shoulder width/side clearance as specified in D.5, the side clearance should match that of the approach roadway. Provision of wider side clearances may be considered to accommodate future rehabilitation or future widening requirements.

Where the approach roadway has continuous curb or continuous traffic barriers, the side clearances on the bridge deck should match the shoulders on the approaches but, should not be less than the minimum side clearance per Table D7-1.

On bridges greater than 50 m in length, reduced side clearances may be considered. Before the reductions are applied, the cost savings due to the reduced clearances as well as the implications for future rehabilitation, re-paving or the possible addition of an extra driving lane should be considered.
All clearances should meet requirements for sight distance. Side clearances may be increased to a maximum of 3.00 m where it is necessary to provide for minimum stopping sight distances.

D.7.2.3 – Sidewalks, Bikeways and Curbs

Where required, the widths of sidewalks and bikeways on bridge decks should meet the following requirements:
- The edge of a sidewalk adjacent to the roadway on a bridge should match that of the approach sidewalk.
- Where the approach roadway is not provided with a curb, the sidewalk width should be at least 1.5 m.
- Paved bike lane and bikeway widths should be in accordance with the Ministry's Ontario Bikeways Planning and Design Guidelines. Bikeways should be at least 1.5 m wide for one way traffic.
- The height of curbs should not be less than 150 mm above the adjacent roadway except to match the height of curbs on the approach roadway.
- Curbs should not be used in conjunction with barrier walls except where the curb and the barrier wall are separated by a sidewalk.

D.7.2.4 – Median Widths

The width of a median on a bridge should match that of the approach roadway.

D.7.2.5 – Horizontal Clearances at Underpasses

Where practicable, underpassing roadway cross-sections should match that of the approach roadway.

Horizontal clearances from the edge of the through traveled way to the face of an abutment or pier should meet or exceed the minimum clear zone widths specified in the Ministry's Roadside Safety Manual.

Where auxiliary lanes are present, the horizontal clearances from the edge of the traveled way to the face of an abutment or pier should also meet or exceed the minimum clear zone widths specified in the Ministry's Roadside Safety Manual based on the design speed on the auxiliary lane at the start of the structure.
Additional information on horizontal clearances and

grading at abutments is available in the Ministry's Roadside Safety Manual and Structural Manual.

D.7.2.6 – Vertical Clearances

For vertical clearances refer to section C.4.4.3 of this Manual.

Table D7-1
Minimum Side Clearances at Bridges

		Urban Roads			Rural Roads		
	Design Speed (km/h)	Left	Right		Left	Right	
			No Sidewalk	Sidewalk		No Sidewalk	Sidewalk
FREEWAY 4-LANE DIVIDED	100 to 120	2.5a	3.0 a		2.5a	3.0 a	
FREEWAY MULTI-LANE DIVIDED	100 to 120	2.5 a	3.0 a		2.5 a	3.0 a	
ARTERIAL DIVIDED	90 to 110	2.0 a	2.5 a	1.5	2.0	3.0 a	
	80	2.0 a	2.5 a	1.5	1.5	2.5 a	
ARTERIAL UNDIVIDED	90 to 110	-	2.0	1.5	-	3.0 a	2.5 a
	80	-	2.0	1.5	-	2.5 a	2.0 b
COLLECTOR UNDIVIDED	90 to 100	-	1.25 c	1.0	-	2.5 a	1.5 c
	70 to 80	-	1.25 c	1.0	-	1.5 d	1.25
	60	-	1.0	1.0	-	1.5 d	1.25
LOCAL UNDIVIDED	60 to 80	-	1.0	0.5	-	1.25	0.5 d

Notes:
1. If a barrier is to be placed between the sidewalk and roadway, then clearance should be the same as when there are no sidewalks.
2. All clearance should meet requirements for sight distance.
3. The width of a median on a bridge should match that of the approach roadway.
4. L = Length of bridge between centreline of abutment bearings.

a - For bridges with L>50 m, consideration can be given to decreasing the clearances to 1.5 m.

b - For bridges with L>50 m, consideration can be given to decreasing the clearance by up to 0.5 m.

c - For bridges with L>50 m, consideration can be given to decreasing the clearance by 0.25 m.

d - For bridges with L>50 m, consideration can be given to increasing the clearance by up to 0.75 m.

e – The values of the clearances given above are the minimum values. Consideration may be given to providing more than the minimum if justification is provided.

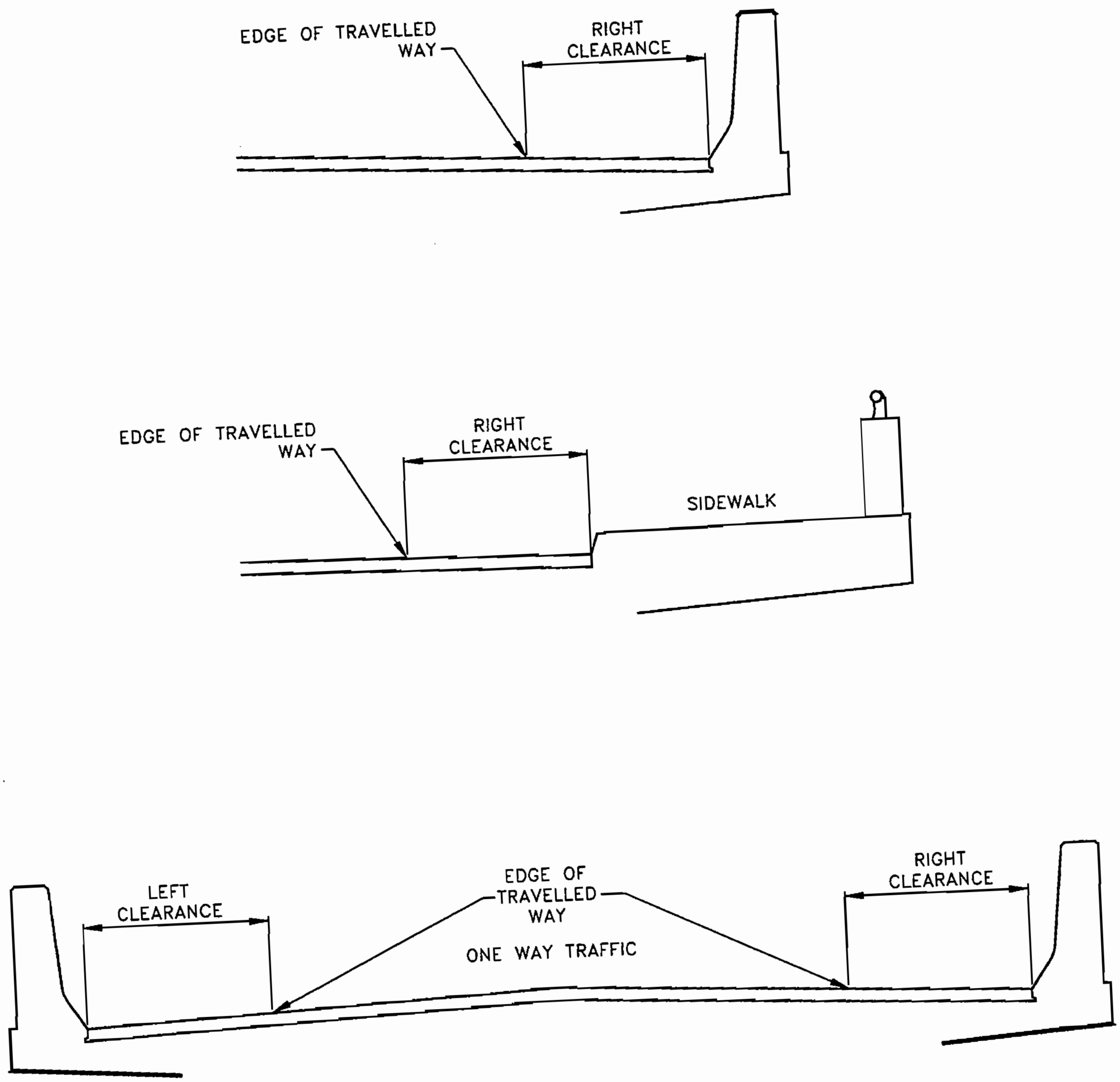


Figure D.7-1
Side Clearance on Bridges

D.8 OFF-ROADWAY ELEMENTS

D.8.1 CURB AND GUTTER

A curb is a raised element located adjacent to a traffic lane or shoulder. Curbs are normally introduced to control drainage and provide delineation of the pavement edge or pedestrian walkways.

The type and location of curbs can affect driver behaviour and the safety of a highway. Refer to the Roadside Safety Manual. They are extensively used on all types of urban highways, but only to a limited extent on rural highways where drainage is usually controlled by means of drainage channels.

There are two general types of curbs, namely, barrier curbs and mountable curbs, each type having a number of variations in design. Both barrier and mountable curbs may be designed integrally with a gutter to form a single unit. Generally curbs are not to be used in conjunction with traffic barrier systems.

Barrier curbs are relatively steep faced and intended to inhibit or at least to hinder vehicles from leaving the roadway. Typically, the height of the vertical face of the barrier curb is 150 mm. Most barrier curbs are not adequate to prevent a vehicle from leaving the roadway and, where positive containment is required, suitable concrete median barrier or guide rail should be provided. Barrier curbs should not be used adjacent to bridge parapets. A concrete parapet having a profile similar to that of a concrete median barrier is preferred. However, on urban roads where the cross section includes sidewalks on the approaches and the bridge, a barrier curb is carried across the bridge.

Mountable curbs have slightly inclined faces allowing vehicles to cross them readily. Semi-mountable curbs have somewhat steeper faces and are considered to be mountable under emergency conditions. Mountable curbs can be used at median edges. Where a median guide rail is installed, the gutter line of the curbs should be offset minimally from the face of the barrier, to ensure that the traffic barrier will perform properly. This also allows vehicles making emergency stops along the shoulder to do so without suffering body damage. Barrier curbs should not be placed adjacent to high-speed lanes, but may be placed adjacent to shoulders where they serve a definitive purpose.

Gutters may be provided adjacent to a curb to form the principal drainage system for the roadway. Generally the gutter is not considered to be a part of the adjacent traffic lane width, since with any form of curb there is some lateral shy distance accepted by drivers, particularly on their right, which reduces the effective lane width. For this reason, where a curb is provided without a gutter, the curb should be offset from the edge of the through traffic lane, a distance corresponding to a gutter width.

Where curb and gutter is placed at the outside edge of a paved shoulder, the gutter pan is regarded as part of the shoulder width.

Curb and gutter is usually formed with concrete, either precast or cast-in-place. Asphalt curbs are used for local drainage control, normally in rural areas where delineation is not a requirement. Temporary curbs are usually formed of asphalt.

Dimensions for the more commonly used standard ministry curb and gutter cross sections are shown on Figure D8-1. For further information refer to "Ontario Provincial Standards For Road and Municipal Services," Manual, Volume 3; Drawings, Roads-Barriers, Drainage, Sanitary Sewers, Watermains, and Structures.

D.8.2 TRAFFIC BARRIERS

For detailed information regarding traffic barriers refer to the Roadside Safety Manual.

Traffic barriers are used where errant vehicles leaving the roadway would otherwise be subject to undue hazard. Their purpose is to reduce the severity of accidents by restraining and redirecting or decelerating the vehicle without causing hazard to following, adjacent or opposing traffic. Since barriers are hazardous in themselves, emphasis should be placed on minimizing the number of such installations giving consideration to the social, environmental and economic factors as well as to safety.

The primary objective of traffic barriers is to protect the road user from potentially hazardous and not to protect roadway appurtenances from traffic.

A median barrier is used to prevent an errant vehicle from crossing the median of a divided highway and colliding with traffic travelling in the opposite direction. The probability of such a collision is a function of traffic volume, median type and median width. To determine the need for a median barrier, reference should be made to the Roadside Safety Manual.

Since a traffic barrier itself is a hazard, flattening an embankment slope and rounding the shoulder and toe to allow an errant vehicle to safely negotiate the embankment is preferable to installing a barrier. Where flattening the slope is not possible, for example, due to property limitations, a roadside barrier should be provided.

Roadside barriers should be located outside the shoulder so that the full shoulder width remains usable, and should have sufficient fill behind the post to provide lateral support.

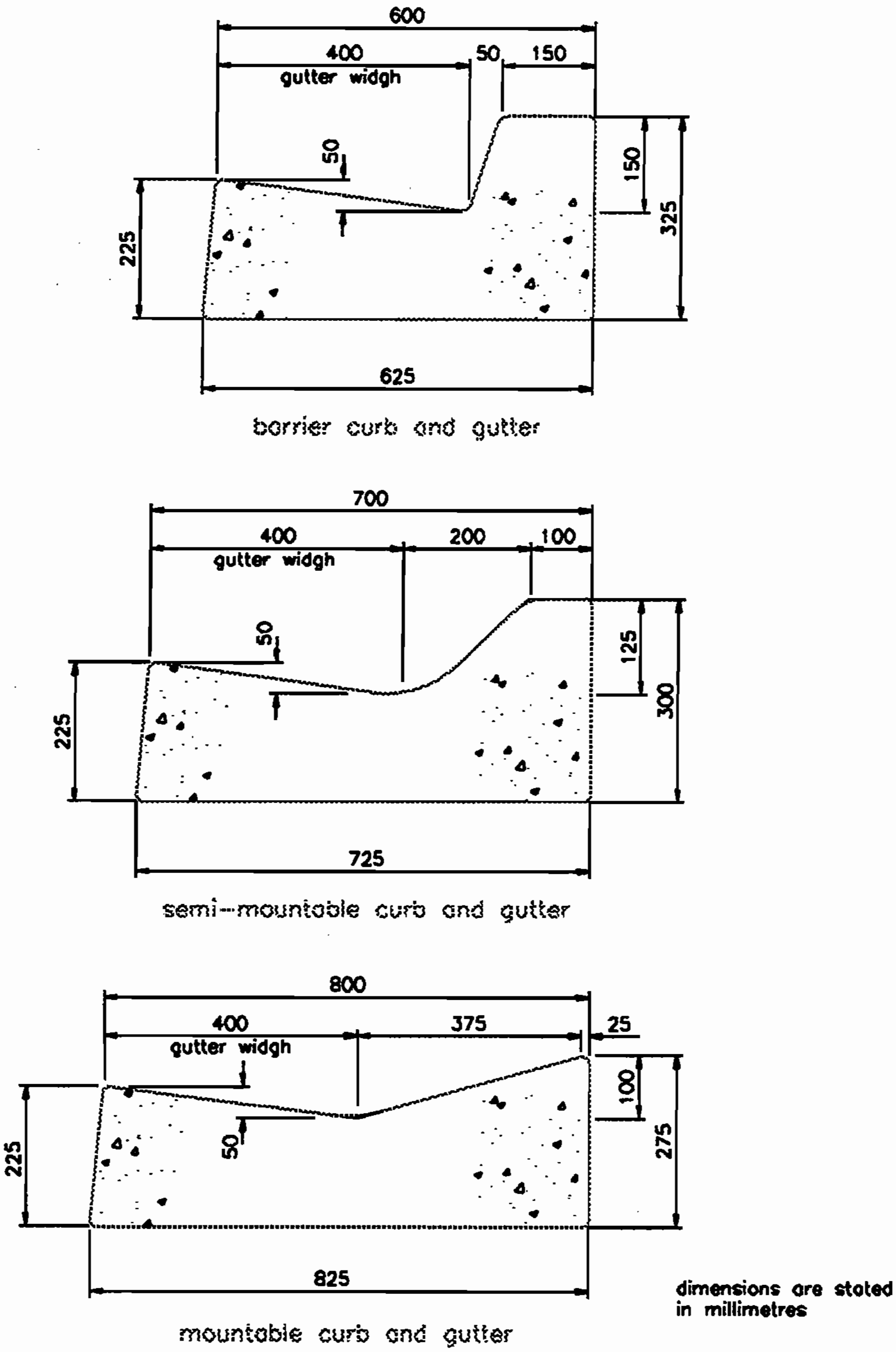


Figure D8-1
Concrete Curb and Gutter Dimensions

Since the end of a barrier facing oncoming traffic is a potential hazard, a series of barrier sections with short gaps between them should be avoided in favour of a singe continuous barrier. Judgement is required in each case.

Design details for longitudinal barriers and crash cushions are given in "Ontario Provincial Standards For Road and Municipal Services," Manual, Volume 3; Drawings, Roads-Barriers, Drainage, Sanitary Sewers, Watermains, and Structures."

Traffic barriers are generally denoted as one of three types: flexible, semi-rigid or rigid. The description reflects the degree of barrier deflection that occurs when a barrier is struck.

Flexible

Flexible systems undergo considerable dynamic deflection upon impact and are generally more forgiving than other types, because they impose lower impact forces on the vehicle. The most common forms of flexible barriers used are the cable guide rail and box beam guide rail. These systems are intended to restrain a vehicle rather than redirecting it. They require more lateral clearance from fixed objects due to increased deflection upon impact.

Semi-rigid

In semi-rigid systems the posts near the point of impact are intended to give but not break thereby distributing the impact force by beam action to adjacent posts. Posts outside the impact zone provide the resistance essential to control the deflection of the beam to an acceptable limit and thereby redirect the errant vehicle along the path of the traffic flow.

Rigid

Rigid systems do not deflect upon impact. During a collision energy is dissipated by raising and lowering the vehicle and by deformation of the vehicle. As the angle of impact increases, the barrier becomes less forgiving because of absence of barrier deflection.

D.8.3 CRASH CUSHIONS

Crash cushions are devices placed in front of hazardous objects on the roadside or median to protect the road user, in the event that a vehicle leaves the roadway and strikes the object. Crash cushions reduce the rate of loss of a vehicle's kinetic energy on impact. Crash cushions are typically placed in front of bridge piers and exit signs.

A number of different crash cushions have been designed and evaluated for use. A detailed discussion on their operation is presented in the Roadside Safety Manual.

D.8.4 BOULEVARDS AND SIDEWALKS

The area between the roadway and the sidewalk is referred to as a boulevard. It serves as a safety separation, a location for overhead and underground utility lines and an area for snow storage. The boulevard may also be used to locate traffic signs, fire hydrants and lamp standards. However, it is generally preferred to locate utility poles, lamp standards and other objects potentially hazardous to an errant vehicle as far as possible from the travelled way, as for example, at the back of the sidewalk.

The standard widths for boulevards are:
- arterial roads 3.0 m
- collector and local roads 2.0 m

The desirable minimum width for boulevards is 1.5 m.

Where property is limited or where sidewalks have to be wider than usual to accommodate pedestrian traffic, boulevards may be narrower than the standard dimension and in some cases may be omitted entirely. Examples are in downtown areas or in areas fully developed with retail stores and offices.

Boulevards are usually sloped towards the roadway to facilitate drainage. They are normally surfaced with turf, in which case the cross-fall is 0.04 m/m. The area of the boulevard immediately adjacent to the roadway may be finished with a hard surface treatment to avoid deterioration of turf due to winter road clearing operations. This hard surface setback width is normally 0.75 m and is usually only applied to urban conditions where this problem is anticipated.

Materials commonly used for hard surface treatment are:
- granular
- asphalt
- concrete
- paving stone

In urban areas where the sidewalk is located 3.0 m or less from the traffic lanes and where a reverse shoulder is utilized as a boulevard to suit existing conditions, the shoulder should be fully paved.

Most urban roads other than freeways carry some pedestrian traffic and should be provided with sidewalks unless the pedestrian traffic volume is singularly light. Except for short residential streets, sidewalks should be provided on both sides of the road way unless motor vehicle traffic is expected to be very light.

Normal sidewalk width is 1.5 m and this is generally considered to be a minimum. In high density urban areas it may be necessary to increase the pedestrian capacity by widening sidewalks, using standard widths of 1.75, 2.0, 2.5. or 3.0 m. Where additional width is required and property is restricted, it may be necessary to reduce the boulevard width in favour of a wider sidewalk.

On rural roads sidewalks are usually not required except along sections where there is intensive residential or commercial development. In these cases sidewalks are generally located between the drainage channel and property line. Sidewalks should be provided on both sides of the roadway if motor vehicle traffic is heavy and if the development served is located on both sides of the roadway. Consideration should be given to reclassification of the facility from rural to urban in these cases.

Sidewalks are normally constructed with portland cement or bituminous concrete. The minimum cross-fall for paved surface is 0.02 m/m. Steeper cross-falls may be used but slopes n excess of 0.03 m/m are not desirable except at entrances where 0.05 m/m is acceptable.

Although 1.5 m is a normal width for sidewalks, in residential areas wider sidewalks may be required where the intensity of land use in terms of persons per unit area can cause higher volumes of pedestrian traffic. In determining sidewalk width the following guidelines should be considered:

- Near multiple family dwelling units a width of 1.75 m is adequate unless there is a possibility that the sidewalk may be used for many pedestrians from other sources.

- An extra width of sidewalk should be provided near schools, offices an industrial plants where large pedestrian volumes may occur for short periods.

- Where the adjacent land is used for shopping or entertainment, sidewalks should be at least 2.5 m wide and an additional width might be required.

- In general, pedestrians walk in pairs and in areas of heavy pedestrian traffic, sidewalk widths should permit two pairs to pass without restriction.

- On structures where a barrier wall or guide rail is placed to separate traffic and pedestrians, a 2.0 m sidewalk width is required for maintenance vehicles.

At driveway entrances, barrier or semi-mountable curbs should be replaced by a mountable curb to provide convenient access and egress for vehicle. The length of mountable curb for residential driveways should be equal to the width of driveway plus 1.5 m on either side. For residential parking lots, apartments and institutional developments the length should be the driveway width plus 3.0 m on either side. The slope of the driveway across the boulevard and sidewalk should desirably bot exceed 10%. Reference should be made to Ontario Provincial Standard Drawings (OPSD) 300 Series drawing.

When designing an urban highway proper consideration should be given to the requirements of the physically handicapped. The typical street intersection with a steep-faced curb is one form of obstacle that can be improved to aid the handicapped. Provision of sidewalk ramps of sufficient width for a wheelchair can readily be made at such intersections.

Dimensions of sidewalk ramps are given in Ontario Provincial Standard Drawings (OPSD) 300 Series drawing.

D.8.5 ROADSIDE APPURTENANCES

Attention should be given to safety in the design and location of sign supports adjacent to roadways. Every effort should be made to locate the supports where they are not likely to be struck by out-of-control vehicles. This can be accomplished by locating the support further away from the travelled way. Supports located where they are likely to be struck by an out-of-control vehicle should either be of the breakaway type or should be protected either by a guiderail or some form of impact attenuator.

Illumination poles should be located so as to meet acceptable standards of illumination for the driver while, at the same time, offering minimum potential hazard of equipment supports. Where possible these should be located away from the roadway or be of the breakaway type. Alternatively, some form of protection should be provided for the out-of-control vehicle.

Culvert headwalls and wingwalls that offer additional hazards to vehicles out-of-control on a fill slope should be avoided. Where possible the culvert opening should be flush with the fill slope.

D.8.6 NOISE ATTENUATION

The effect of traffic noise on adjacent existing or planned residential neighbourhoods is an important consideration in planning and designing freeways and limited access arterial roads. Traffic generated noise levels at the source or the receiver are determined by an acoustic study, in which the receiver is considered to be at the outside recreational area adjacent to residential units. The study also predicts the capability of alternative noise control measures to attenuate noise.

Noise control measures are acoustical devices or treatment to any feature of the highway facility intended to lower the impact of highway noise on the adjacent environment. Noise control may be addressed at the noise source, the receiver, and along the noise path. Measures to control noise include corridor location, corridor width, profile location, pavement surface type and acoustical barriers. The selection of the appropriate measure depends on the desired noise level and on the relative cost effectiveness of the alternative noise control measures.

In the design of a new freeway, there may be flexibility to employ any or all of the alternative noise control measures to achieve the most cost-effective design.

when reconstructing an existing freeway, the practical options for noise control are normally limited to those which can be contained within the existing right-of-way, such as pavement surface type or the introduction of acoustical barriers. Application of noise control measures to an existing freeway, normally referred to as a retrofit, further reduces options to a point where acoustical barriers generally the only practical method.

Acoustical barriers are devices installed between the highway and the residences to reduce sound transmission. Earth berms, walls, or combination berm and wall are the common barrier types. The location, height and material of the barrier is determined by an acoustic analysis.

Beams occupy substantially more right-of-way than barrier walls. Side slopes of berms should be 3:1 or flatter to facilitate maintenance and may be contour graded for aesthetic reasons. Where space in the right -of-way is available, a berm is generally preferred over a wall for aesthetic reasons and for its longevity. When right-of-way space is limited, for example in urban areas, the barrier wall or combination berm and wall are the most suitable acoustic devices.

Barrier walls are constructed from a variety of materials, the more popular being concrete and steel. Landscaping is normally provided to enhance the appearance of both berms and walls.

Where a noise barrier is installed, provision for access of maintenance vehicle to all areas of the right-of-way is required. Access may be provided by contour grading of berms and by gates or openings in walls.

The interaction of the noise barrier with traffic barriers, structural drainage and illumination facilities must be considered during design.

The mitigating measures described above apply to general cases and solutions to specific problem areas should be found through detailed study.

D.9 GRADING AND DRAINAGE CHANNELS

D.9.1 SLOPES

Earth cut and fill slopes should be flattened and generally rounded to be consistent with the topography and the type of highway. Effective erosion control maintenance costs and adequate drainage of the subgrade are largely dependent upon proper shaping of the side slopes. Overall economy depends not only on the element of first cost, but also on costs of maintenance of which slope stability is a factor. In addition to these reasons for gentle and rounded slopes on any highway, the proximity of any urban highway to the development and residents of the community call for additional attention to slope treatment and the overall appearance.

On freeways and arterial roads with reasonably wide roadsides, side slopes on embankments and in cuts should be designed to provide a reasonable opportunity for recovery of an out-of-control vehicle. Where the roadside, at the point of departure, is reasonably flat, smooth and clear of fixed objects, many potential accidents can be avoided. Embankments at a slope of 6:1 or flatter can be negotiated by a vehicle with a reasonable chance of recovery and should therefore be provided where feasible. Steeper slopes up to 4:1 may be traversible where the height is moderate and rounding at the bottom is generous. Where the height and slope of roadway embankments are such that an out-of-control vehicle cannot negotiate the slope with minimum hazard, the cross section should be designed for suitable guide rail.

POLICY

MAXIMUM SLOPES ARE DEPENDENT ON THE HEIGHT OF FILL OR DEPTH OF CUT, AND ON THE GRADING MATERIAL.
STANDARD MAXIMUM SLOPES ARE:

- **EARTH GRADING 2:1**
- **ROCK GRADING:**
  - **FILL SIDE SLOPE 1.25:1**
  - **CUT-BACK SLOPE VERTICAL**

FOR LOWER HEIGHTS OF FILL AND SHALLOWER CUTS, SLOPES SHOULD BE FLATTENED. THE STANDARD MINIMUM SLOPES ARE:

- **EARTH GRADING:**
  - **FILL SIDE SLOPE 4:1**
  - **CUT-BACK SLOPE 3:1**
- **ROCK GRADING:**
  - **FILL SIDE SLOPE 4:1**
  - **CUT-BACK SLOPE 1:4**

Further flattening of slopes may be considered in view of availability of material and property.

Flat and well-rounded side slopes simplify the establishment of turf and its subsequent maintenance. Usually grass can be readily established on side slopes as steep as 2:1.

In cut sections, side slopes of 6:1 or flatter can usually be negotiated by vehicles leaving the roadway if no obstruction is en countered. Back slopes flatter than 2:1 are desirable in the interest of safety and 3:1 in the interest of maintenance. In rock cut, economy generally requires steep slopes and slopes of 1:4, or vertical faces are commonly used.

D.9.2 SNOW IMPACT

Snow drifts occur where snow particles have been deposited in areas of reduced wind speed. Interruptions to the smooth flow of the wind by features such as changes of grade, fences, landscaping or buildings will cause a disruption of the wind flow and the formation of localized turbulent air zones on the leeward side of the interruption. These zones are usually low velocity regions precipitating snow accumulation. Conversely, less snow is deposited where higher velocities occur. When the low velocity region causing a snow drift has been filled with snow, the snow drift will not continue to increase in size and the depth of the snow draft will not be significantly affected by changes in the wind speed. However, wind speed will affect the rate at which the snow drift will increase.

Roadway cross sections in fill where the prevailing wind is blowing across the roadway will tend to keep reasonably clear of snow. On the other hand, roadway cross sections in cut will tend to precipitate snow drifting on the roadway up to the surrounding ground elevation.

Buildings, dense tree growth and rock faces close to roadways where the prevailing wind is across the road, will tend to generate snow drifting on the leeward side of the obstruction. If these obstructions are close to the road snow drifting may obstruct the roadway itself.

D.9.2.1 Mitigating Measures

Roadways in cut sections that are likely to precipitate snow drifting may be treated in one of two ways to minimize or eliminate the impact. The more desirable treatment is to raise the profile so as to bring the roadway above natural ground elevation. If this is not possible for other reasons, the back slopes of the cut section should be flattened to 7:1 and preferably flatter, so as to eliminate or minimize the area of low wind velocity where snow tends to deposit.

Where snow drifting occurs because of dense tree growth or rock cut, the length of the drift depends on the height of the obstruction. The impact can be minimized by increasing the distance from the obstruction to the roadway and will usually be eliminated by removing the obstruction back to a distance of 15 times the height of the obstruction.

D.9.3 CONTOUR DESIGN

Contour design is usually applied to residual areas of land in interchange areas between ramps, for noise berms and disposal areas. These areas can be graded with varying slopes to give undulating and natural looking appearance. Contour design is carried out in conjunction with drainage design with consideration for safety and, where appropriate in conjunction with landscaping. Residual pockets of land in interchange areas, particularly loop ramps, can be used to dispose of some surplus material and to minimize spoil. Conversely, they may be used to generate additional excavation and to minimize borrow.

D.9.4 DRAINAGE CHANNELS

Drainage channel cross sections must have adequate hydraulic capacity and should be designed to keep water velocities below the scour limits wherever possible. Generally additional capacity should be derived by widening channels. The depth must be a minimum of 0.5 m below the bottom of the subgrade to provide drainage of the pavement structure. The drainage channel therefore should be kept at an adequate depth below the pavement. Channels should have a streamlined cross section for safety, ease of maintenance and to minimize snow drifting. In areas of rock cut where fallen boulders can be expected, it may be desirable to provide a wider drainage channel to collect the boulders. This will reduce the possibility of the boulders resting on the shoulder or roadway, and will facilitate maintenance clean up. The design of drainage channels is dealt with in Chapter C of the Ministry Drainage Manual.

D.10 RIGHT-OF-WAY

D.10.1 CRITERIA

The right-of-way is that area property established to accommodate a road and its associated features and elements. The right-of-way width required for a facility is determined by establishing dimensions of each element such as roadway width, median sidewalk, boulevard, cut and fill slopes and including such items as provision for landscaping, noise attenuation devices and other environmental features. The dimensions of each of these elements is added together and the next largest right-of-way dimension is selected.

The right-of-way selected applying the above technique may be incompatible with existing property boundaries and may leave some undesirable residual severance, in which case adjustments should be made to the right-of-way and, in turn, this may necessitate some modification of dimensions of the components of the road and associated facilities.

In this way right-of-way becomes a design control and the process of determining cross section elements and right-of-way is iterative.

D.10.2 SELECTION

Standard values for right-of-way widths for urban and rural highways are as follows: 20, 26, 30, 35, 40, 45, 50, 55, 60, 70, 80, 90, and 100 m. The right-of-way for new or improved facilities should be selected from one of the above standard values. On reconstruction projects property acquisition is normally limited to that required for the improvement.

Rural local roads are generally at-grade and would require 20-m right-of-way unless significant cut and fill slopes were required. Rural collector roads would generally require 20-m or 26-m right-of-way and rural arterial roads would require a right-of-way in the range of 26 m to 40 m, plus provision for cut and fill slopes, and median width in the case of divided highways.

APPENDIX A

SUMMARY OF GEOMETRIC DESIGN STANDARDS

This section summarizes the more significant standard dimensions for cross section elements shown in this Chapter together with those for horizontal alignment shown in Chapter C - Alignment.

Standards are given for:

- Rural King's Highways
- Secondary Highways
- Undivided Urban Roads

Table DA-1

GEOMETRIC DESIGN STANDARDS FOR RURAL KING'S HIGHWAYS

DESIGN YEAR TRAFFIC VOLUME		DESIGN SPEED	MINIMUM CURVES (m)			MINIMUM STOPPING SIGHT DIST.	MAX. GRADE	WIDTH (m)	
			HORIZ.	VERTICAL					
AADT	DHV	km/h	Radius	K-Crest	K-Sag	m	%	Lane	Shoulder
Greater than 4000	Greater than 600	120	650	120	60	245	6-7	3.75	3.00
		110	525	90	50	215	6-7	3.75	2.50A
		100	420	70	45	185	6-8	3.75	2.50A
		90	340	50	40	160	6-8	3.50A	2.50
		80	250	35	30	135	6-8	3.50	2.50
4000 to 3000	600 to 450	110	525	90	50	215	6-7	3.75	2.50A
		100	420	70	45	185	6-8	3.50A	2.50
		90	340	50	40	160	6-8	3.50A	2.50
		80	250	35	30	135	6-8	3.50	2.50
		70	190	25	25	110	6-12	3.25	2.00
3000 to 2000	450 to 300	110	525	90	50	215	6-7	3.75	2.50
		100	420	70	45	185	6-8	3.50B	2.50
		90	340	50	40	160	6-8	3.50	2.00B
		80	250	35	30	135	6-8	3.25	2.00
		70	190	25	25	110	6-12	3.25	2.00
2000 to 1000	300 to 150	110	525	90	50	215	6-7	3.50C	2.50
		100	420	70	45	185	6-8	3.50	2.00C
		90	340	50	40	160	6-8	3.25	2.00
		80	250	35	30	135	6-8	3.25	2.00
		70	190	25	25	110	6-12	3.00	1.00
		60	130	15	18	85	6-12	3.00	1.00
1000 to 400	150 to 60	100	420	70	45	185	6-8	3.50	1.00
		90	340	50	40	160	6-8	3.25	1.00
		80	250	35	30	135	6-8	3.25	1.00
		70	190	25	25	110	6-12	3.00	1.00
		60	130	15	18	85	6-12	3.00	1.00
Less than 400	Less than 60	80	250	35	30	135	8	3.25E	1.00D
		70	190	25	25	110	12	3.00	1.00D
		60	130	15	18	85	12	3.00	1.00D
		50	90	8	12	65	12	2.75	1.00D

A - if number of trucks ≥ 10%
B - if number of trucks ≥ 15% increased by one increment
C - if number of trucks ≥ 25%
D - 0.5 m shoulders will be permitted where there is no foreseeable possibility of the road being paved within a 20-year period. A minimum of 1.0 m shoulder must be used where guide rail is installed.
E - A 3.0 m lane width may be acceptable where the type, size and volume of trucks are not significant.

Notes:

- Design Year should reflect the anticipated life span of the proposed improvement. Design Year is normally 10 years beyond the Program Year for resurfacing and reconstruction projects, and 20 years beyond for new construction projects.
- Use DHV if available for selection of design standards.
- Minimum Horizontal Curve Radius based on maximum superelevation of 0.06 m/m.
- Minimum desirable shoulder width for:
  - pavement support - 1.0 m gravel shoulder
    - 0.5 m paved shoulder
  - disabled vehicle - 2.0 m shoulder
- Standard lane width increment - 0.25 m.
- Standard shoulder width increment - 0.5 m.
- Shoulder rounding: 1.0 m for design speed greater than 100 km/h
  0.5 m for design speed less than or equal to 100 km/h.

Table DA-2

GEOMETRIC DESIGN STANDARDS FOR SECONDARY HIGHWAYS

DESIGN YEAR TRAFFIC VOLUME		DESIGN SPEED	MINIMUM CURVES (m)			MINIMUM STOPPING SIGHT DIST.	MAX. GRADE	WIDTH (m)	
			HORIZ.	VERTICAL					
AADT	DHV	km/h	Radius	K-Crest	K-Sag	m	%	Lane	Shoulder
Greater than 1000	Greater than 150	100	420	70	45	185	6-8	3.50	2.00
		90	340	50	40	160	6-8	3.25	2.00
		80	250	35	30	135	6-8	3.25	2.00
		70	190	25	25	110	6-12	3.00	1.00
		60	130	15	18	85	6-12	3.00	1.00
1000 to 400	150 to 60	80	250	35	30	135	6-8	3.25*	1.00
		70	190	25	25	110	6-12	3.00	1.00
		60	130	15	18	85	6-12	3.00	1.00
Less than 400	Less than 60	80	250	35	30	135	8	3.25*	1.00**
		70	190	25	25	110	12	3.00	1.00**
		60	130	15	18	85	12	3.00	1.00**
		50	90	8	12	65	12	2.75	1.00**

Lane width may be increased by 0.25 m to a maximum of 3.5 m if warranted by type, size and volume of truck traffic.

* A 3.0 m lane width may be acceptable where the type, size and volume of trucks are not significant.

** 0.5 m shoulders will be permitted where there is no foreseeable possibility of the road being paved within a 20-year period. A minimum of 1.0 m shoulder must be used where guide rail is installed.

Notes:

- Design Year should reflect the anticipated life span of the proposed improvement. Design Year is normally 10 years beyond the Program Year for resurfacing and reconstruction projects, and 20 years beyond for new construction projects.
- Use DHV if available for selection of design standards.
- Minimum Horizontal Curve Radius based on maximum superelevation of 0.06 m/m.
- Minimum Vertical Curve Standards based on stopping sight distance.
- Lower value in maximum grade range is desirable. Higher value is acceptable.
- Minimum desirable shoulder width for:
  - pavement support - 1.0 m gravel shoulder
    - 0.5 m paved shoulder
  - disabled vehicle - 2.0 m shoulder
- Desirable Shoulder Rounding - 0.5 m.

Table DA-3

GEOMETRIC DESIGN STANDARDS FOR UNDIVIDED URBAN ROADS

DESIGN YEAR TRAFFIC VOLUME		DESIGN SPEED	NO. OF LANES	LANE WIDTH	PARKING LANE WIDTH	MAXIMUM GRADE
AADT	DHV	km/h		m	m	%
Greater than 6000	Greater than 600	80 60 - 70	4 4	3.5 - 3.75 3.5		6 - 8 6 - 12
6000 to 3000	600 to 300	60 - 70 80 60 - 70	4* 2 2	3.5 3.5 - 3.75 3.5	 2.5 - 3.0 2.5 - 3.0	6 - 12 6 - 8 6 - 12
3000 to 2000	300 to 200	80 60 - 70 50	2 2 2	3.5 3.25 3.0	2.5 - 3.0 2.5 - 3.0 2.5 - 3.0	6 - 8 6 - 12 6 - 12
2000 to 1000	200 to 100	60 - 70 50	2 2	3.25 3.0	2.5 - 3.0 2.5 - 3.0	6 - 12 8 - 12
Less than 1000	Less than 100	40 - 50	2	2.75 - 3.0	2.5 - 3.0	8 - 12

* Four lanes may be appropriate toward the upper limits of this traffic range when there is a measurable capacity deficiency with only two lanes.

Notes:

- Design Year should reflect the anticipated life span of the proposed improvement. Design Year is normally 10 years beyond the Program Year for resurfacing and reconstruction projects, and 20 years beyond for new construction projects.
- Use DHV if available for selection of design standards.
- Lane widths and parking lane widths do not include width of gutter.