

CHAPTER 7 CROSS SECTIONS

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INTRODUCTION

Cross sections define the configuration of a proposed roadway at right angles to the centerline. This chapter discusses the various cross section elements and provides guides for the application of standards in the design of typical sections.

See Chapter 18 – Plans Assembly for detailed Typical Grading Sections, Cross Section & Pipe Section illustrations.

Whenever possible, joints in the pavement should match the pavement markings which aids in nighttime driving/or wet conditions when the pavement markings are faint. In order to have consistency between typical sections, pavement markings and joint layouts, coordination needs to occur between the grading designer, the pavement markings designer and the surfacing designer.

LANES AND SHOULDERS

Refer to Table 7-1 for surfacing standards and Figure 7-1 for typical surfacing sections that includes the pavement for the traffic lanes, the shoulders, and the base and subbase courses that are placed on the graded roadbed.

The type of pavement usually is determined by analysis of the volume and composition of traffic, the soil conditions, the availability of materials, the initial cost and the estimated cost of maintenance.

Decisions on surface type and structural thickness normally will be made by the Office of Materials and Surfacing and the Surfacing Design Group. These determinations are to be incorporated in the typical sections prepared by the designers.

Lane Width

Minimal reduction in highway capacity occurs between 12 and 11 foot lanes but 10 foot lanes and narrower may have a significant loss in highway capacity.

Research indicates there is only a slight decrease in safety when providing 11 foot lanes compared to 12 foot lanes. However crashes can be expected to increase more significantly when 10 foot or narrower lanes are provided. There are three situations that should be avoided when considering narrower than 11 foot lanes:

- four-lane undivided arterials with 10 foot lane widths or less
- four-lane divided arterials with 9 foot lane widths or less, and
- approach to four-leg stop-controlled arterial intersections with 10 foot lane widths or less.

Because of higher speeds and the potential severity of a potential crash the basic policy is to provide 12 foot traffic lanes for all rural highways. For urban highways with low speeds,

11 foot traffic lanes should typically be provided as they do not have a negative effect on capacity and only a minimal effect on safety. Narrower lanes in urban areas can provide benefits such as shorter pedestrian crossings and reduction in right-of-way and property impacts. Combined high ADT with high truck volumes may be justification for the use of 12' lanes for urban highways.

Standard lane widths are as follows:

- Rural Highways – 12 foot lanes
- Urban and Suburban Highways (moderate speeds 45 – 50 mph) – 12 foot lanes, however 11 foot outside lanes may be considered when a shoulder is provided
- Urban Highways (low speeds \leq 40 mph) – 11 foot lanes

A review of a wider lane width is required for the tracking of larger vehicles when on sharp horizontal curves.

Shoulder Width

The shoulder widths on rural highways depend on the traffic volume as seen in Table 7-1.

Where pedestrians and bicyclists are to be accommodated on the shoulders, a minimum usable paved shoulder width, clear of rumble strips, of 4 foot should be used. See Chapter 16 – Miscellaneous for information on ADA requirements.

For urban highways shoulders may not be provided, however consideration is made to provide shoulder widths to accommodate parking and/or shared use/bike lanes. See Chapter 16 – Miscellaneous for additional information regarding parking and bicycle lanes. Where unequal lane widths are used, locating the wider lane on the outside provides more space for large vehicles that usually occupy that lane, provides more space for bicycles, and allows drivers to keep their vehicles at a greater distance from the right edge. The basic design decision is the total roadway width, while the placement of stripes actually determines the lane widths.

Standard shoulder widths are as follows:

- for high speed (\geq 55 mph Design Speed) highways – See Table 7-1
 - Shoulders may be reduced to 4 foot on undivided highways with 4 or more lanes, the posted speed limit is 55 mph, and is located near suburban or urban areas where it is anticipated the speed limit will be reduced as development occurs.
- for moderate speed (45 – 50 mph Design Speed) highways

- 2 lanes (w/ or w/o curb & gutter) – See Table 7-1
 - 3 lanes (w/o curb & gutter) – See Table 7-1 and use 2 lane standards
 - 4 or more lanes (w/o curb & gutter) – 4 foot – A wider shoulder should be considered on asphalt concrete roadways to allow for overlays and maintain a 4 foot shoulder to accommodate bicyclists.
 - 3 or more lanes (w/ curb & gutter) – 3 foot^{1,2} width plus gutter pan adjacent to outside lane for shared use/bike lane or provide a separate bike facility based on traffic volumes, number of bike commuters, number of access points, etc.
- for low speed (≤ 40 mph) highways
 - 2 lanes (w/ or w/o curb & gutter) – See Table 7-1
 - 3 or more lanes (w/o curb & gutter) – 4 foot
 - 3 or more lanes (w/ curb & gutter) – 3 foot^{1,2} width plus gutter pan adjacent to outside lane for shared use/bike lane or provide a separate bike facility based on traffic volumes, number of bike commuters, number of access points, etc
- ¹ Consideration of not providing a 3 foot shoulder may be made on a project by project basis when 4 or more lanes are provided, there is a sufficient grid network for bike commuters to share lanes with vehicles on adjacent streets, and/or the existing corridor is narrow and expanding the roadway may result in significant environmental or ROW impacts.
- ² Striping or signing the 3 foot width adjacent to the outside lane as a shoulder or bike lane will be on a project by project basis.

Median Shoulders -- Divided Highways

Since most stopped or disabled vehicles use the outside shoulder, the left shoulder need not be quite as wide.

The minimum left shoulder width is 4 feet for all types of medians without curb and gutter (including Interstate). Refer to Table 7-1 for additional guidance on use of wider shoulders when abutting shoulders are 6' and when 3 or more through lanes per direction are provided. For highways with curb and gutter, no additional left shoulder is required beyond the 2 foot shy distance provided by the gutter pan of the curb and gutter.

Where a median barrier is installed, provide a shy distance between the traveled way and the barrier. For moderate (45 – 50 mph) and high speed (≥ 55 mph) highways use the shoulders widths as provided in Table 7-1. For low speed (≤ 40 mph) highways provide a minimum 2 foot shy distance.

Rural Highway Type	Projected 20 Year Average Daily Traffic (ADT)	Lane Width Ft.	Ultimate Surfaced Shoulder Width ³ Ft.	Project's Surfaced Shoulder Width Ft.	Project's Total Surfaced Width Ft.	Project's Bridge Width ⁴ Ft.	Shoulder Type	Comments on Different Mainline Surfacing		Pads for Intersecting Roads and Entrances (Width of Pad for Ent)
								Asphalt Concrete (AC)	Portland Cement Concrete Pavement (PCCP)	
2 LANE	0-250	12	6	2	28	32	Same as Mainline	Pave Mainline 28'	NA	Minimum 2" AC (4')
	251-550	12	6	4	32	32	Same as Mainline	Bottom Lift Full Width Top Lift 28' w/12:1 slope	NA	Minimum 2" AC (4')
	551-1500	12	6	6	36	36	Gravel ⁵	Pave Mainline 28'	Pave Mainline 28'	Minimum 2" AC (4')
	1501-2500	12	8	8	40	40	Gravel ⁵	Pave Mainline 28'	Pave Mainline 28'	Minimum 2" AC (6')
	2500+	12	8	8	40	40	Minimum 2" AC	Bottom Lift Full Width Top Lift 28' w/12:1 slope	Pave Mainline 28'	Minimum 2" AC (6' w/ AC Mainline) (NA w/ PCCP Mainline)
4 LANE DIVIDED	<4000 Combined	12	4 Inside 8 Outside	4 Inside 8 Outside	36	36	Gravel Outside ⁵ & Minimum 3" AC Inside	Pave Mainline 26' (includes 2' outside shoulder)	Pave Mainline 26' (includes 2' outside shoulder)	Minimum 2" AC (6' w/ AC Mainline) (NA w/ PCCP Mainline)
	>4000 Combined	12	4 Inside 8 Outside	4 Inside 8 Outside	36	36	Minimum 3" AC ⁶	Pave Mainline 26' (includes 2' outside shoulder)	Pave Mainline 24' ⁷	NA
INTERSTATE ⁸	<30,000 ⁹ Combined	12	4 Inside ¹⁰ 10 Outside ¹¹	4 Inside ¹⁰ 10 Outside ¹¹	38	40	Minimum 3" AC ⁶	Pave Mainline 26' (includes 2' outside shoulder)	Pave Mainline 24' ⁷	NA
	>30,000 ⁹ Combined	12	10 Inside ^{11,12} 10 Outside ¹¹	10 Inside ^{11,12} 10 Outside ¹¹	56	56	Minimum 3" AC ⁶	Pave Mainline 38' (includes 2' outside shoulder)	Pave Mainline 36' ⁷	NA
RAMP ^{8,13}	ALL	15	2 Inside 8 Outside	2 Inside 8 Outside	25	28	Same as Ramp			NA
LOOP RAMP ^{8,13}	ALL	19	2 Inside 4 Outside	2 Inside 4 Outside	25	28	Same as Ramp			NA

¹ Design Exceptions shall be provided when these standards are not met (i.e. for Black Hills Park, Scenic Roads, etc.) when applicable.

² For Service Roads refer to the current AASHTO publication *A Policy on Geometric Design of Highways and Streets*.

³ Used to determine subgrade width. For shoulder widening projects, an 8' subgrade shoulder width will be used for constructability.

⁴ Review of width should be considered based on long term growth area impact for potential additional lanes before the life of the structure ends. For remove/replace, resurfacing, restoration, and rehabilitation projects on the interstate, the minimum structure width is 37.5'.

⁵ Gravel shoulders should not be used over 5% grades, adjacent to guardrail, on superelevated curves, adjacent to curb and gutter or as determined by the Office of Materials and Surfacing.

⁶ PCCP shoulders may be considered on a project by project basis or as determined by the Office of Materials and Surfacing.

⁷ When AC shoulders are provided, widen the outside mainline surface 2'.

⁸ For Interstate Remove/Replace, Resurfacing, Restoration, and Rehabilitation projects refer to the Preface of the *SDDOT Road Design Manual*.

⁹ Traffic analysis to determine number of through lanes with or without auxiliary lane.

¹⁰ 6' if abutting sections are 6' or if future lane additions are anticipated. 6' on Bridges.

¹¹ Where truck traffic exceeds 250 directional design hourly volume (DDHV) a paved shoulder of 12' should be considered.

¹² 10' inside shoulder if 3 or more through lanes per direction are provided. 4' inside shoulder (6' on bridge) if 2 through lanes with or without auxiliary lane are provided.

¹³ Standards are for a single lane ramp. The minimum ramp width for a two lane ramp is 28' (2-12' driving lanes with 2' shoulders) per Chapter 13 – Interchanges of the *SDDOT Road Design Manual*. Refer to Chapter 12 – Intersections of the *SDDOT Road Design Manual* in Table 12-4 (Case III) for pavement width on a two lane ramp when on a horizontal curve.

Table 7-1. Lane / Shoulder Width and Surfacing Standards¹ for Construction, Reconstruction and Shoulder Widening Projects on Rural State Highways²

Lane and Shoulder Width Criteria for Resurfacing, Restoration, and Rehabilitation (3R) Projects

For the purposes of this chapter, 3R projects are defined as those that do not require additional subgrade widening. Projects that require subgrade widening for an auxiliary lane shall use the lane and shoulder width recommendations for construction, reconstruction, and shoulder widening projects as referenced on page 7-7.

CURRENT ADT	<551	551-1500	1501-2500	>2500
Minimum Lane Width (ft)¹	12	12	12	12
Combined Lane and Shoulder Width (ft)^{2,3}	14	15	15	18

- ¹ Traffic lanes may be 11 feet wide and the turning lanes 10 feet wide through cities and towns. The gutter pan is not considered part of the traffic lane.
- ² If Truck ADT is >100, minimum shoulder width = 3 feet
- ³ Where pedestrians and bicyclists are to be accommodated on the shoulders, follow guidance on page 7-4 and the AASHTO Guide for Development of Bicycle Facilities.

Table 7-2. Lane & Shoulder Widths for 3R Projects (Non-Interstate NHS)

CURRENT ADT	<551	551-1500	>1500
Minimum Lane Width (ft)¹	10	10	11
Combined Lane and Shoulder Width (ft)^{2,3}	12	12	13

- ¹ Desirable lane width is 11 feet. If feasible, 12 feet is preferable. Where truck volumes exceed 15%, a minimum of 11-foot lanes are to be considered.
- ² If Truck ADT is >100, minimum shoulder width = 3 feet
- ³ Where pedestrians and bicyclists are to be accommodated on the shoulders, follow guidance on page 7-4 and the AASHTO Guide for Development of Bicycle Facilities.

Table 7-3. Lane & Shoulder Widths for 3R Projects (Other than NHS)

Lane and Shoulder Widths for Auxiliary Lanes on Construction, Reconstruction, and Shoulder Widening Projects

Auxiliary lanes (left and right turn lanes, climbing lanes, passing lanes, acceleration lanes, etc.) should match the widths for through lanes as referenced on pages 7-2 to 7-5.

Shoulders adjacent to auxiliary lanes should desirably be the same width as shoulders adjacent to the through lanes. However, shoulders may be reduced if right-of-way, environmental, or economic impacts justify a reduction in width. Shoulders may be omitted adjacent to auxiliary lanes in urban areas with curb and gutter.

Special design consideration is needed for shoulders where right turn lanes are adjacent to bike lanes (refer to AASHTO Guide for the Development of Bicycle Facilities and Chapter 9 of MUTCD for guidance).

Table 7-4 summarizes the recommended lane and shoulder widths for the various auxiliary lane types.

Auxiliary Lane Type	Lane Width (ft)			Shoulder Width (ft)	
	High Speed (≥55 mph)	Moderate Speed (45-50mph) ¹	Low Speed (≤40 mph)	Without Curb and Gutter	With Curb and Gutter
Left Turn	12	12	11	0 (undivided highways) 2 (divided highways)	0
Right Turn	12	12	11	4 (preferred) 2 (minimum)	See AASHTO Bike Guide (with bike lane) 0 (without bike lane)
Climbing	12	12	N/A	Table 7-1 (preferred) 4 (minimum)	N/A
Passing	12	12	N/A	Table 7-1 (minimum)	N/A
Acceleration	12	12	11	Table 7-1 (preferred) 4 (minimum)	See AASHTO Bike Guide (with bike lane) 0 (without bike lane)

¹ 11 ft lanes may be considered when a shoulder is provided.

Table 7-4. Lane / Shoulder Width for Auxiliary Lanes on Construction, Reconstruction and Shoulder Widening Projects

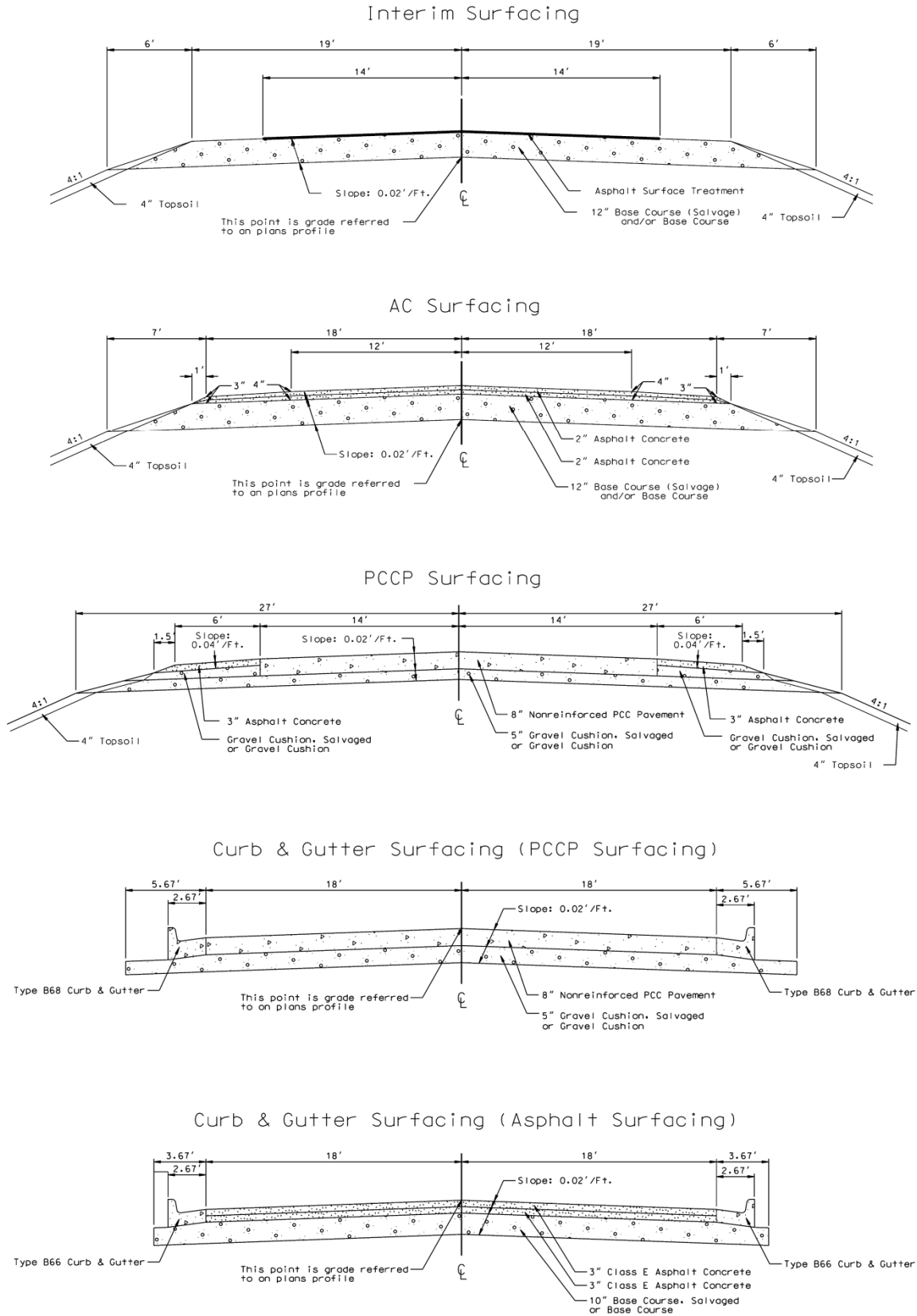


Figure 7-1. Typical Surfacing Sections

Cross Slopes

It is important to enable surface water to drain from the traffic lanes and shoulders as quickly as possible. Accumulations of water cause hazards by reducing surface friction and vehicle stability. Sufficient cross slope is needed for adequate drainage, but too much slope adversely affects vehicle operating characteristics.

The type of surface greatly influences surface drainage characteristics. Dense, smooth surfaces (PCC or densely grading asphalt concretes) require less slope for adequate cross drainage than is required for a gravel or a coarse textured open graded asphalt surface. AASHTO recommends a range of values for cross slope for traffic lanes. The Department has adopted the values shown below for standard practice on tangent sections of highways.

<u>Surface Type</u>	<u>Cross Slope (%)</u> ¹
Portland Cement Concrete	2
Asphalt Concrete	2
Other Asphalt Surfacing	2
Gravel	3

¹ For urban roadways the cross slope may be increased to 3% to better match the existing terrain in an effort to minimize impacts to adjacent property.

The several different types of cross slope design are illustrated in Figure 7-2.

For two-lane highways or multilane undivided highways, the cross slope normally goes downward toward both edges from a crown point at the highway center line.

On high-speed facilities when 3 or more lanes are inclined in the same direction the cross slope may be increased to 2.5% to facilitate roadway drainage.

On divided highways, the standard practice is to crown each one-way traveled lane separately, as on two-lane highways. The other option is to have a one-direction cross slope across the entire width of pavement, typically sloping downward to the outer edge.

For resurfacing projects, maintain the existing cross slopes. Correcting cross slopes to current AASHTO criteria per publication *A Policy on Geometric Design of Highways and Streets* should be considered when cost effective.

Crown shift occurs when the crown point of a section needs to be shifted from where it is originally located in the cross section. Crown shift may be incorporated into the designed typical section with the addition of a travel lane or left turn lane in urban projects to tie into existing terrain or to tie into existing crown.

The length of crown shift transition varies depending on the operating speeds. Guide lines for determining lengths to transition when adding a left turn lane or an additional lane are:

For speeds of 45 mph and over: $L = WS$

For speeds under 45 mph: $L = WS^2 / 60$

where: L = Length of entering taper, ft.

W = Width to be tapered, ft.

S = Design Speed, mph

For low speed urban sections the crown may be shifted across an intersection. If the crown point of a section is shifted to tie into existing terrain or existing crown superelevation, the appropriate superelevation table should be used to design the crown shift. If the shift is over multiple lanes on a wide section (and/or the cross-road is narrow) the length of shift may need to be increased.

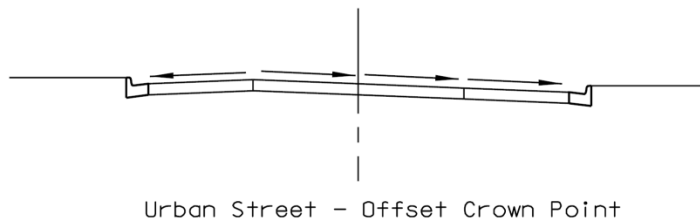
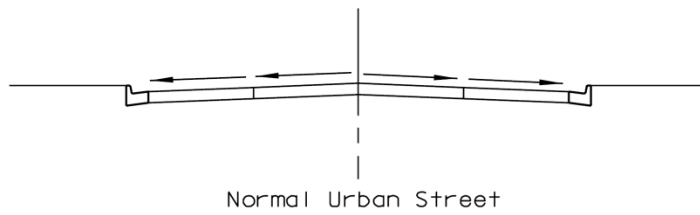
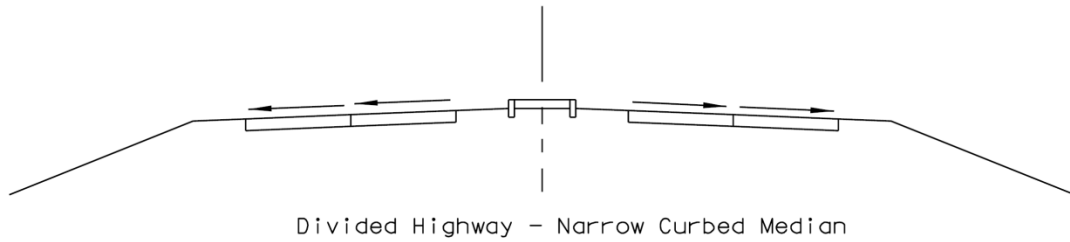
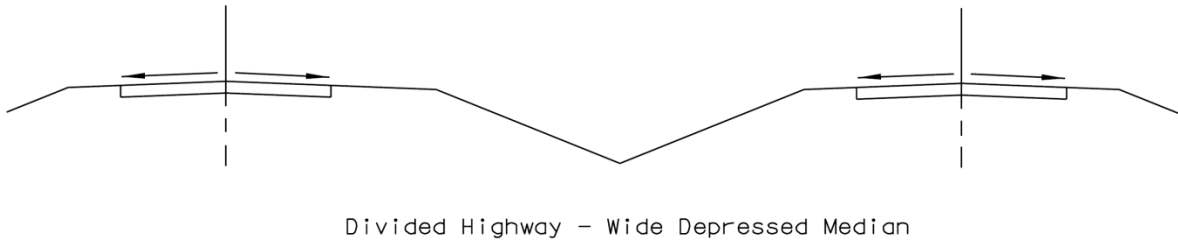
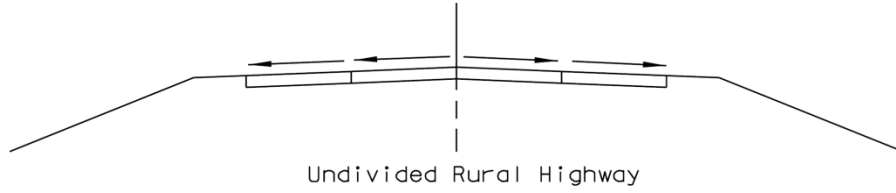


Figure 7-2. Typical Cross Slopes

In the design of urban highways and streets adjacent property developments may dictate that the curb on one side must be higher than the curb on the other. Two options are available. The cross slope can be in one direction for the full width of the street or the crown point can be offset from the centerline toward the high side of the street. The latter option usually is preferable when considering snow melt and drainage.

For major intersections, it may be desirable to reduce the cross slope of the major highway from the normal 2% to a 1% crown. Minimum transition distance shall be 50'. Refer to Table 7-5 for situations that may require a greater transition distance. The transition shall end at the edge of pavement of the intersecting road. Designer will need to ensure that drainage is not compromised in the transition area.

Design Speed (mph)	Number of Lanes Rotated										
	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6
	Transition Distance for Number of Lanes Rotated										
45	50	50	50	50	50	50	60	65	70	75	80
50	50	50	50	50	50	55	60	70	75	80	85
55	50	50	50	50	55	60	65	75	80	85	90
60	50	50	50	50	55	60	70	75	80	90	95
65	50	50	50	50	60	65	70	80	85	95	100
70	50	50	50	55	60	70	75	85	90	100	105

Table 7-5. Transition Distance from 2% to 1% Cross Slope at Major Intersections

The criteria for roll-over rates between adjacent roadways (i.e. interstate and ramp driving lanes) varies depending on the design speed. A desirable maximum algebraic difference at the crossover line is 4 or 5 percent, but it may be as high as 8 percent at low speeds and where there are few trucks. The recommended maximum difference in cross slope rate at a crown line, related to the speed of turning traffic is shown in Table 7-6.

ENGLISH UNITS		METRIC UNITS	
Design speed of exit or entrance curve (mph)	Maximum algebraic difference in cross slope at crossover line (%)	Design speed of exit or entrance curve (km/h)	Maximum algebraic difference in cross slope at crossover line (%)
20 and under	5.0 to 8.0	30 and under	5.0 to 8.0
25 to 30	5.0 to 6.0	40 to 50	5.0 to 6.0
35 and over	4.0 to 5.0	60 and over	4.0 to 5.0

Table 7-6. Maximum Algebraic Difference in Cross Slope at Turning Roadway Terminals

Within a superelevated roadway section, the maximum “roll-over” algebraic difference in rate of cross slope, shall not exceed 8% between the traveled way and usable shoulder.

Shoulder Slopes

In order to rapidly drain surface water, the shoulders surface should be sloped slightly steeper than the traffic lanes. Criteria to be followed are shown below.

- Paved Shoulders normally should slope at a rate of 4%. When shoulders are used for pedestrian traffic the shoulder slopes should not exceed 2% to meet ADA guidelines. Refer to Chapter 16- Miscellaneous for ADA guidelines.
- Gravel Shoulder should be sloped at a rate of 4%.

On divided highways with a depressed median, all shoulders should be sloped to drain away from the traffic lanes. With a raised, narrow median, the median shoulder normally should slope in the same direction as the traffic lanes -- but consideration should be given to sloping the median shoulder toward the median and providing inlets and underground drainage to alleviate problems with snow and ice.

Gravel shoulders are not to be used on grades over 5%, adjacent to guardrail, and on superelevated curves.

RUMBLE STRIP/STRIPES

Research as identified in NCHRP Report 641, *Guidance for the Design and Application of Shoulder and Centerline Rumble Strips*, recognizes the safety benefits and subsequent reduction of single-vehicle run-off-the-road crashes through the installation of shoulder rumble strips.

The use of rumble strips has been proven to enhance the visibility of pavement markings not only during night time conditions but also during wet weather. The use of rumble strips should be coordinated with the respective Region Traffic Engineer.

Rumble strips/strips should be considered on rural sections with posted speed limits 50 mph or greater. Typical crash types that have the potential to be reduced by shoulder rumble strips/strips include roll-over on roadway, roll-over off roadway, and fixed object off roadway. The adjacent land use and road functionality should also be a consideration in determining whether to install rumble strips/strips.

The installation of rumble strips/strips will be decided on a case by case basis after analyzing all pertinent data and utilizing engineering judgment.

Centerline Rumble Stripes

Centerline rumble stripes (CLRS) may be installed on undivided highways as a countermeasure to prevent road departure left crashes, head-on collisions, and opposite direction sideswipe crashes. Where installed, CLRS should be continuous through passing and no passing zones. Recommendations to install CLRS should be coordinated with Department's Highway Safety Engineer and the respective Region Traffic Engineer. CLRS should be installed according to current standard plates for both AC and PCC mainline pavements. The following criteria should be considered prior to installing CLRS:

- 1) Undivided roadways only, 2 lanes or 4 lanes.
- 2) Minimum lane plus shoulder width of 28'.
- 3) Pavement condition shall be reviewed by pavement design engineer if installation is done on existing pavement.
- 4) Route should be reviewed for location of houses and businesses. Recommend at least 650' of separation. Sinusoidal CLRS should be considered if noise is a concern.
- 5) ADT > 2,500 or if an average of two road departure left crashes, head-on collisions, or opposite direction side swipe crashes per mile have occurred through the prior 5 years of crash history for the length of the project.

Transverse Rumble Strips

Transverse Rumble Strips (TRS) are grooved into the pavement across the width of the lane and alert approaching traffic of a stop sign. Research¹ has shown that TRS placed in advance of a minor leg stop sign at rural intersections reduces fatal and serious injury crashes by 21%. Intersection crashes account for 15% of fatal and serious injury crashes on rural state system roads. TRS are a low-cost safety improvement that can be implemented systematically to reduce intersection crashes.

TRS will be placed on all state highway system approaches to stop-controlled intersections in rural locations. Sinusoidal TRS should be considered when houses are located within 500' of the proposed TRS.

TRS can also be considered as a safety countermeasure to alert drivers to the advance warning of reduced speed limit, advisory speeds, and horizontal curves. This use of TRS should be based on a crash analysis.

Reference Material:

¹ Srinivasan, R., Baek, J., and Council, F., "Safety Evaluation of Transverse Rumble Strips on Approaches to Stop-Controlled Intersections in Rural Areas."

Shoulder and Edge Line Rumble Strip/Stripe Guidelines for Asphalt Mainline Surface

Table 7- 7 provides shoulder and edge line rumble strip/stripe guidelines for asphalt mainline surface.

Functional Classification	Shoulder Width ^{1,2,3}	Mainline Width	Strip Width	Rumble Type	Continuous or Intermittent
Interstate	4' inside 10' outside	28'	12"	Rumble Strip	Continuous
Non-Interstate	4'	24'+shld	8"	Rumble Stripe	Intermittent
	> 4'	28'	12"	Rumble Strip	Intermittent

¹ The use of rumble strips/stripes on sections with shoulders less than 4 foot should be reviewed with the Region Traffic Engineer and the Department’s Traffic and Safety Engineer after an analysis of historical crash data, inslope, fixed objects, horizontal/vertical alignment, current and future bicycle use, and other design elements.

² For sections of roadway with 4 foot shoulders, the engineer should use 8 inch rumble stripes in lieu of rumble strips in order to provide adequate lateral clearance for bicycle use. The engineer should also consider the inslope rate, location of fixed objects as compared to the edge of traveled way, horizontal/vertical alignment and other design elements.

³ For sections of roadway with greater than 4 foot shoulders the shoulder type may be asphalt, concrete, or gravel (except interstate). A 28 foot mainline top for asphalt paving should be constructed to accommodate the use of rumble strips on the mainline pavement. The use of 12 inch rumble stripes can be considered as an effort to increase visibility of pavement markings upon recommendation from the respective Region Traffic Engineer.

Table 7- 7. Shoulder and Edge Line Rumble Strip/Stripe Guidelines for Asphalt Mainline Surface

Bicycle Use

The engineer should take into consideration the amount of bicycle use on a facility and its relation to shoulder width and lateral clearance. A minimum of 4 foot shoulder is required to accommodate bicycle use. If rumble strips/stripes are recommended on sections with less than 4 foot shoulders, a thorough analysis of bicycle use should be completed. Information pertaining to bicycle use can be obtained by contacting local bicycle shops and user groups.

Shoulder and Edge Line Rumble Strip/Stripe Guidelines for PCCP Mainline Surface

The installation of rumble strips on PCCP shall be spaced consistent with two times the joint spacing or a 40 foot maximum spacing. If for example, joint spacing is 15 foot, the rumble strip should be placed 30 foot center to center and shall not coincide with any transverse contraction joint. If the proposed lane width is 14 foot, the rumble strip should be installed on the PCCP.

For the installation of rumble strips on existing 14 foot wide PCCP lane(s), every effort should be made to grind rumble strips on a basis consistent with asphalt pavement rumble strip design, on the existing concrete pavement.

For existing PCCP two lane rural highways with 12 foot wide lanes, the rumble strip should be installed a maximum of 2 foot from the edge of concrete lane on the shoulder.

For divided highways, if the existing outside lane PCCP is 12 foot, the rumble strip should be installed a maximum of 2 foot from the edge of concrete lane on the outside shoulder. Rumble strips should be placed a maximum of 12 inches from the edge of concrete lane on the inside shoulder.

Rumble strip widths for grinding on existing PCCP surface shall be 12 inches. Prior to the design and installation of ground in rumble strips on PCCP, the designer should contact the Office of Project Development and Materials and Surfacing to determine anticipated life of existing PCCP.

Reference Material:

South Dakota Department of Transportation Bicycle & Pedestrian info,
<http://sddot.com/travelers/bicycle/Default.aspx>

South Dakota State Park Bicycle Tours, <https://gfp.sd.gov/things-to-do/>

FHWA Technical Advisory for *Roadway Shoulder Rumble Strips*,

T 5040.39, Revision 1 November 7, 2011

http://safety.fhwa.dot.gov/roadway_dept/pavement/rumble_strips/t504039/t504039.pdf

CURBS

Curbs are closely related to other surfacing cross section elements. Curbs generally serve one or more of several purposes:

1. drainage control,
2. pavement edge delineation,
3. delineation of pedestrian walkways, and
4. assistance in orderly roadside development.

Curbs are used extensively on all types of urban highways and streets. In the interest of safety, curbs should be omitted on high-speed rural highways when the same objective can be attained by other acceptable means.

Curbs may be designed as a separate unit or integrally with the pavement. Separate curbs usually are a combination curb and gutter. Sometimes the curb is constructed alone without the gutter section.

The two general classes of curbs are vertical curbs and sloped curbs. As the names imply, vertical curbs tend to prevent vehicles from crossing the curb line, and sloped curbs permit such vehicle crossing without much difficulty. The types of curbs used most commonly are included in the Department's Standard Plates. All curbs used by the department are sloped curbs.

Type B curbs usually are limited to urban areas for typical street sections with speeds of 40 mph or less. Type F curbs can be used at median edges to outline channelizing islands in intersection areas, with speeds greater than 40 mph. They also may be used at the outer edge of a shoulder to control drainage, improve delineation, and reduce erosion.

For curb and gutter used adjacent to railroad crossings, see Chapter 16 – Miscellaneous.

SUBGRADE

Cross Slopes

The subgrade cross slopes should parallel the cross slopes of the finished traffic lanes for the full width of the roadbed. When the finished shoulders are at a steeper cross slope than the traffic lanes, the result is a slightly tapered section of surfacing courses, thicker at the edge of the traffic lane than at the outside edge to the shoulder.

The parallel relationship between the subgrade and the finished traffic lanes applies to both normal crown slopes on tangent sections of highway and to superelevated sections on curves.

Urban Width

The design width of the subgrade in urban areas depends on several factors:

1. width of traffic lanes,
2. width of finished shoulders,
3. pavement type
4. width of median (if any)

The total subgrade width should be the sum of widths of the four items above. For any project, the first and second factors are set forth in Table 7-1. Typical median widths are outlined in the section for Medians.

Subgrade width in sections of curb and gutter is dependent on the pavement type. For constructability in sections of Asphalt Concrete Pavement the subgrade extends 1' behind the curb and gutter. In sections of Portland Cement Concrete Pavement the subgrade extends 3' behind the curb and gutter.

When possible a 2% slope should continue 1 foot behind the back edge of the sidewalk to eliminate the potential for a drop off at the edge of the sidewalk. When a path is designated for shared or bicycle use a minimum 2 foot wide graded area with a 6:1 maximum slope should be maintained adjacent to the sides of the path. See the section on Bicycle Accommodations in Chapter 16 – Miscellaneous.

Rural Width

The design width of the subgrade in rural areas depends on several factors:

1. width of traffic lanes,
2. width of finished shoulders,
3. width of the surfacing sluff, and
4. width of median (if any)

The total subgrade width should be the sum of widths of the four items above. For any project, the first and second factors are set forth in Table 7-1. Table 7-8 can be used to determine the width of the surfacing sluff. Typical median widths are outlined in the section for Medians.

Surfacing sluff is the width from the subgrade shoulder to the finished shoulder.

MAINLINE THICKNESS	SURFACING SLUFF WIDTH	
	4:1 Inslopes	6:1 Inslopes
5" to 7"	3'	4'
7.5" to 9.5"	4'	5'
10" to 12"	5'	7'
12.5" to 14.5"	6'	8'
15" to 17"	7'	9'
17.5" to 19.5"	8'	10'
20" to 22"	9'	11'

Table 7-8. Surfacing Sluff Width on Construction/Reconstruction Projects

The above tables apply to portland cement concrete pavement or asphalt concrete pavement with concrete, asphalt, or gravel shoulders.

Widening

The following are details for subgrade widening of a typical roadway section:

- Embankment and Surfacing for W Beam Guardrail Flared End Terminal
(See Standard Plate 630.45)
- Embankment and Surfacing for W Beam Guardrail Tangent End Terminal
(See Standard Plate 630.46)
- Embankment and Surfacing for Typical Median Protection
(See Standard Plate 630.99)
- Mailbox Turnout
(See Standard Plate 900.01)
- Historical Marker Turnout
(See Standard Plate 120.20)

Undercut

Design of cross section elements sometimes is affected by certain subgrade conditions and requires the need to take corrective actions. The Materials and Surfacing Engineer will identify locations of unsatisfactory subgrade materials and will recommend designs to improve the roadbed, including sources of selected material. Normally, the corrective action will consist of undercutting the subgrade to a recommended depth and replacing the unsatisfactory material with designated selected material. This special subgrade treatment should be clearly documented on the contract plans with (1) typical section of the geometrics of the undercutting, (2) the stationing limits of the undercutting, (3) depth of undercutting at each location, (4) the quantities of required select materials, and (5) the source of select replacement material.

SIDE SLOPES

The various slopes related to typical sections are illustrated in Figure 7-3. Application of the criteria is discussed as follows.

Fill Slopes

All fill slopes begin at the outside subgrade shoulder and extend outward and downward to the natural ground. 4:1 slopes (6:1 interstate) are extended to the clear zone and then are broken to a 3:1 to catch natural ground. When the 3:1 segment is less than 10' above the natural ground, extend the 4:1 (6:1 interstate) to natural ground. A shorter 3:1 segment may be used if there are other considerations such as a pipe or ROW restrictions.

Fills with fence berms shall begin at the outside subgrade shoulder and extend outward and downward to the ROW line and then are broken to a 20:1 and extended horizontally 10', and then are broken to a 3:1 to catch natural ground. To minimize the length of box culvert, a fence berm should not be placed over large box culverts.

When extreme conditions exist (high fill, environmental impacts, etc.) the designer may use fill slopes steeper than 3:1, however should contact the Geotechnical Office for guidance.

Inslopes

In cut sections, the inslope extending outward and downward from the subgrade shoulder to the side ditch should normally be 4:1 (6:1 interstate).

On construction/reconstruction projects the inslopes within the median section of a divided highway shall be 6:1 for interstate and expressways. For expressways under conditions where right-of-way is restrictive, design speeds are slower, etc. the inslope may be steepened to a 4:1.

For interstate resurfacing projects the acceptable inslopes are in Table 7-9.

	Median Inslope	Outside Inslope
Desirable	6:1	6:1 to clear zone ¹
Minimum	4:1 ²	4:1 to clear zone ^{1,3}
Consider Guardrail	3:1 to 4:1 ³	3:1 to 4:1 ³

¹ 30 feet from edge of driving lane

² Cost and capability to grade to 5:1 or 6:1 should be reviewed for feasibility.

³ To be reviewed with documented justification to leave without guardrail. A 3:1 inslope or flatter which is free of obstacles and provides recovery of an errant vehicle does not require a design exception or guardrail protection per the current AASHTO publication *Roadside Design Guide*.

Table 7-9. Interstate Inslopes for Resurfacing Projects

Inslope Transition

The intent is to have a relatively gradual slope change when extending the pipe or RCBC to the clear zone distance (See Standard Plate 120.05). Sloped end sections are recommended for all 24" and 30" cross pipe. Cross pipe larger than 30" should use flared ends which are required to be extended outside the clear zone per Chapter 10 – Roadside Safety. Reinforced concrete box culverts (RCBC) should be extended to the clear zone also and utilize the same inslope transition. Cost estimates and engineering judgment should be considered to determine if multiple pipes of 24" or 30" that match the inslope with sloped ends are more economical than lengthening a pipe larger than 30" to the clear zone distance and providing an inslope transition.

Ditch Bottom

The principal purpose of ditch bottoms is to control surface drainage through cut sections. If the excavated material is of adequate quality it usually is used in the construction of adjacent fill sections.

The ditches generally should be 3.5 feet below the elevation of the subgrade shoulder. This means that a standard 4:1 inslope should extend 14 feet outward from the subgrade shoulder. The objective is to prevent the upper portions of the roadway subgrade from becoming saturated with water.

The slopes into and out of ditches are an important design consideration. They should be as flat as possible for two reasons: (1) flatter slopes provide a safer recovery area for errant vehicles leaving the roadway surface; and (2) problems from drifting snow are reduced by flatter slopes. But very flat slopes usually are not economically practical in areas of deep cuts or extensive roadside development.

Several options are available for the geometric configuration of ditch bottoms. The type of ditch bottom to be used will be given in the scope summary. These are illustrated in Figure 7-3.

- Standard Ditch The flat slopes into and out of the ditch bottom alleviate safety problems by making the ditch more easily traversable by out-of-control vehicles. But the design requires more right-of-way width than the alternate ditch bottom designs. The standard ditch is typically used by SDDOT.
- Slope Ditch This design requires less right-of-way width and still retains the safety characteristics of a relatively flat bottom without a sharp break at the intersection with the backslope.
- V - Ditch The V-ditch is typically used where rock excavation exists because it requires the least amount of excavation. The use of a V - ditch is common in the Black Hills and other scenic routes. Their application is generally a function of existing terrain and impacts to the adjacent environment. The backslope of a V - ditch is allowed within the clearzone unless their potential for snagging, pocketing, or overturning a vehicle is high.

Details of the selected ditch configuration should be clearly shown on the typical section. If more than one type of ditch is selected for a particular project, the non-typical section should be clearly detailed on the cross section plots.

To reduce or eliminate the amount of borrow material needed on a project, consideration should be given to wider or deeper ditch bottoms in cut areas where feasible. Note that it may be more economical to borrow material than to attempt to balance a project. Borrow material should be limited to no more than one mile haul from the borrow area.

Backslopes

Backslopes extending upward and outward from ditch bottoms to intersect the natural ground normally should be 5:1. Under conditions of deep cuts and/or right-of-way restrictions, the backslopes may be steepened to a maximum of 3:1.

Backslopes of 7:1 are used when snow problems exist or are created. Snow problems occur when natural ground is higher than the subgrade. When the subgrade shoulder is greater than or equal to 2' higher than natural ground the designer can assume that no snow problems exist. 7:1 backslopes should be used on areas with snow problems longer than 500'.

General practice is the use of 7:1 backslopes on the left of centerline (north & west sides) and 5:1 backslopes on the right of centerline (south and east side).

To reduce or eliminate the amount of borrow material needed on a project; consideration should be given to flattening or daylighting the backslopes in cut areas where feasible. Note that it may be more economical to borrow material than to attempt to balance a project. Borrow material should be limited to no more than one mile haul from the borrow area.

When using an inslope or backslope that is non-typical (something other than what is shown on the typical section), it must be labeled and transitioned.

Length of Transition

1. For every 1:1 slope you need 100' transition.
For example: 7:1 to 5:1 requires a 200' transition.
2. Backslopes may be changed at intersecting roads or entrances.

Recommendations for slopes in rock cuts will be made by the Geotechnical Office for individual projects based on studies of local conditions. A typical backslope recommendation is as follows and is shown in Chapter 18 – Plans Assembly.

Sta. 252+80± to 257+50; Left of Centerline.

Excavation material is Pahasapa Limestone with a small amount of soil cover. Blasting will be necessary to remove this material.

Design a 1/2:1 presheared backslope with the top 10 to 15 feet at 1 1/2:1.

Typical applications of slope criteria are illustrated in Figure 7-3.

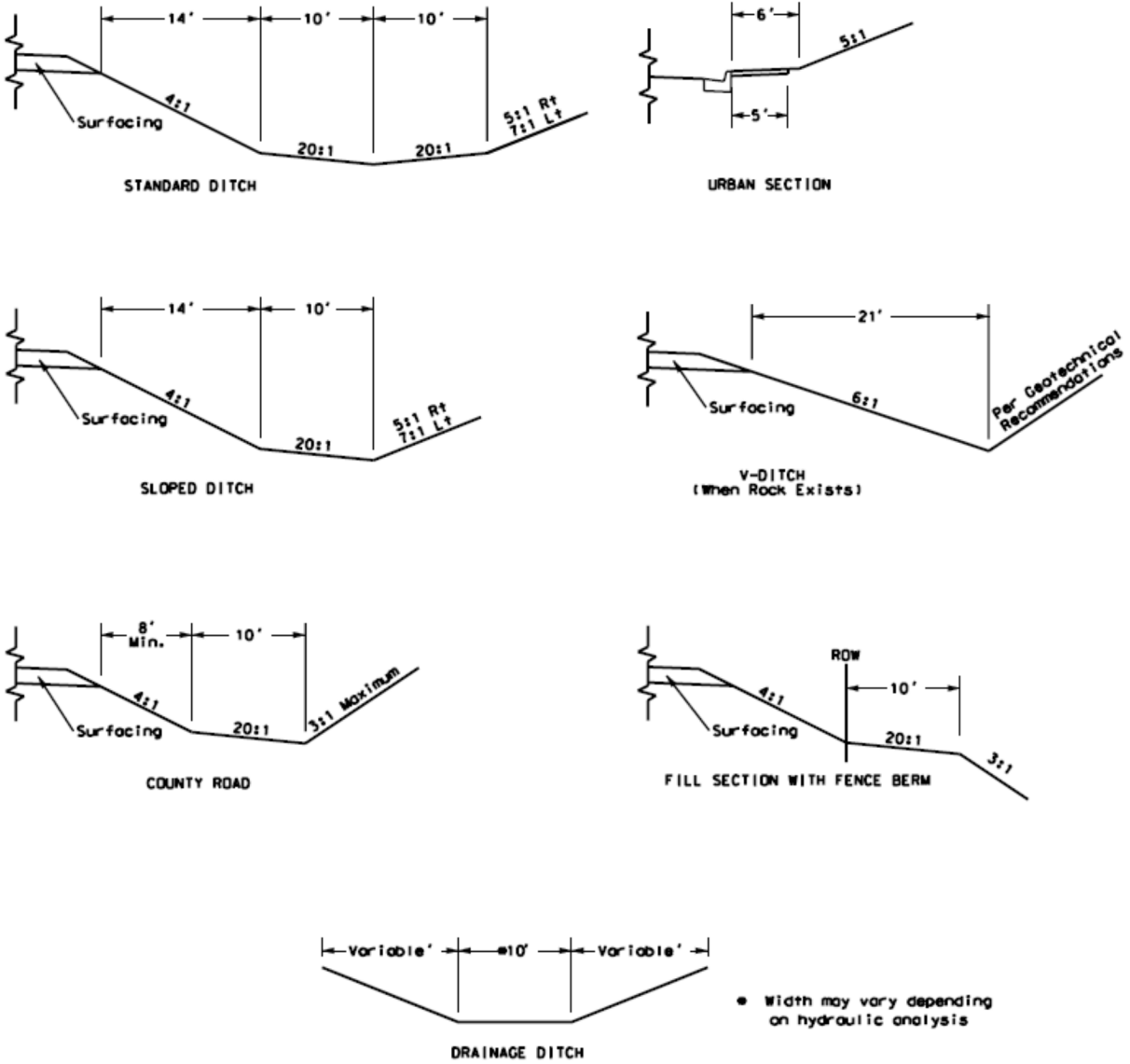


Figure 7-3. Typical Ditch Bottoms and Slope Criteria

TOPSOIL

Topsoil should be provided to cover all newly graded areas within the permanent ROW take (except top of roadbed) to a depth of 4± inches or as recommended by Roadside Development. Place topsoil on temporary easements outside of the permanent ROW take to a depth of 6± inches.

Normally this operation consists of salvaging and stockpiling existing topsoil during grading operations and replacing the topsoil at designated locations after the grading is completed. The template lines of the cross sections represent the finished ground line after the topsoil has been placed. During construction all areas designated to be covered with topsoil must be left underbuilt or overexcavated to allow for the thickness of the topsoil to be placed.

The plans should show the estimated quantities of topsoil to be placed. When surfacing is to be accomplished under a separate contract, the grading contract should include provisions for placing the estimated required amount of topsoil for future use on the inslope or stockpiling.

MEDIANS

Medians are provided on divided multilane highways to provide a separation of opposing traffic lanes. Besides the obvious safety benefits, medians also provide space for:

- left-turn lanes
- snow storage
- collecting surface drainage
- adding future lanes
- refuge for pedestrians at crosswalks

Median widths are always measured between the inside edges of opposing traffic lanes. There are three basic types of medians:

- flush medians
- curbed medians
- depressed medians

Flush Medians

Flush medians consist of a relatively flat paved area separating the traffic lanes with only painted stripes on the pavement. This type is generally used for lower-speed urban arterials and is sometimes used as continuous two-way left-turn lanes (TWLTL).

To accommodate painted left-turn channelization, flush medians should be at least 12 feet wide. Flush medians should be either slightly crowned to avoid ponding of water in the median area or slightly depressed (with median drains) to avoid carrying all surface drainage across the driving lanes.

Curbed Medians

Curbed, raised medians are also most commonly used on lower-speed urban arterials. They have the same basic advantages and characteristics of flush medians except the separation is more clearly defined than for painted lines. Curbed medians may be used in areas where control of Access is desired.

Typical widths of raised medians range from 4 to 20 feet measured from edge of opposing driving lanes. A raised median with a 4 feet concrete island may be used on a city street, but it has limited advantages. Although it provides a positive separation between opposing traffic and an opportunity to collect drainage, it offers no opportunity to channelize left turns and is too narrow to provide a desirable pedestrian refuge. When a narrow raised island must be used, it is desirable to increase the width between the edge of the traffic lane and the face of curb. A raised island, at least 8 feet wide, should be used if traffic signs and signals are to be located on the island.

A 20 feet median width is desirable when left-turn channelization is to be provided. This width accommodates the left-turn lane, and an 8 feet wide island to provide space for traffic signs and signals. When dual left-turn lanes are warranted the median width should be increased to 32 feet to maintain the 8 feet wide island. See Figure 7-4 for examples of curb medians.

Depressed Medians

Depressed medians are most commonly used for high-speed expressways and freeways. Normally, the widths of depressed medians are considerably greater than for either flush medians or raised medians. Smoother traffic operations and improved traffic safety are observed advantages of wide, depressed medians.

Designing a relative narrow depressed median creates problems. The result is that the longitudinal drainage ditch in the center of the median is too shallow or the transverse slopes from the roadways to the ditch are too steep.

Side slopes in the median should be 6:1 or flatter for a distance of at least 30 feet from the edge of the traffic lanes. Other median slopes (for median crossovers, ditch blocks, etc.), which might be in the path of an out-of-control vehicle, should be 10:1 or flatter as a safety feature.

The desirable minimum width for a depressed median is 84 feet measured from centerline of opposing directions of traffic. This distance permits adequate drainage design with flat slopes and also permits placement of a median bridge pier with a horizontal clear distance in excess of 30 feet to the median edge of the traffic lanes. Wider medians are desirable where the additional right-of-way cost is not prohibitive, or where there is potential need for adding lanes in the median to provide capacity for larger future traffic volumes. See Figure 7-4.

Median Barriers

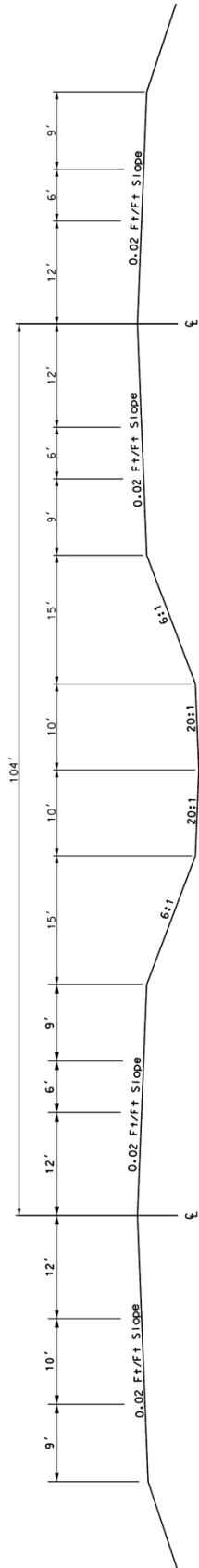
For divided highways with large traffic volumes and high operating speeds, a wide, depressed median is the best choice. Under some conditions this is not practicable, and a flush or raised median may be considered. With narrow medians on high operating speed facilities (i.e. interstate) consideration should be made to construct a physical barrier placed in the median to prevent out-of-control vehicles from crossing into opposing traffic lanes.

Several types of physical median barriers can be designed. Criteria for median barriers are discussed in Chapter 10 - Roadside Safety.

Median Openings

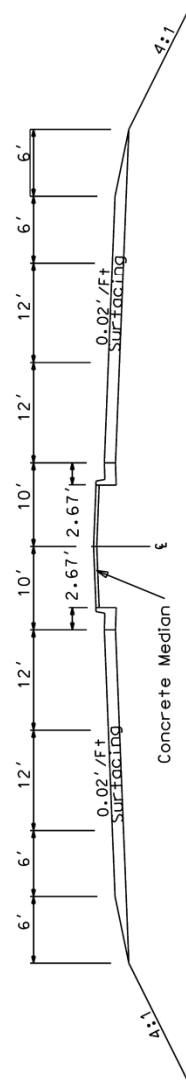
The designs of median openings and channelization for left turns are included with the discussion of intersections in Chapter 12- Intersections.

Depressed Median



Curbed Median

20' Median



Curbed Median

32' Median

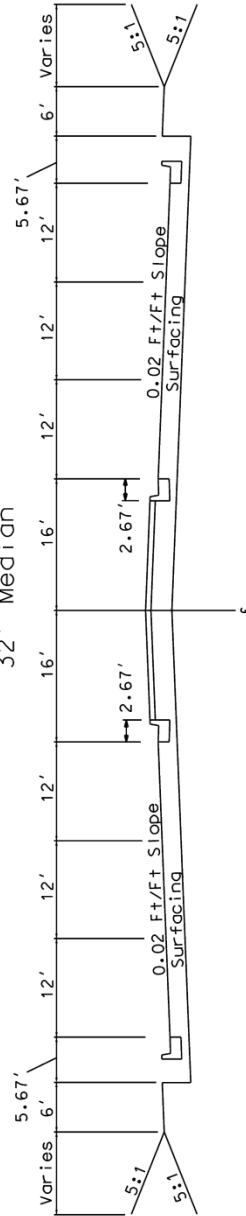


Figure 7-4. Typical Medians