

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.

SURFACING

The typical surfacing section (Figure 7-1) 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 and Shoulder Width

The basic policy is to provide 12-foot traffic lanes for all rural principal arterial highways, and for all new construction on lower classes of rural roads. In urban areas where right-of-way and existing development become stringent controls, the use of 11 foot lanes is not typical, but may be acceptable.

The shoulder widths depend on the traffic volume as shown in Chapter 3 – Scope Summary. Under certain conditions of long steep grades, a climbing lane should be provided. Usually the determination cannot be made until the profile grade has been established. Guidelines and criteria are presented in Chapter 6 - Vertical Alignment to help the designer evaluate the need for climbing lanes.

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

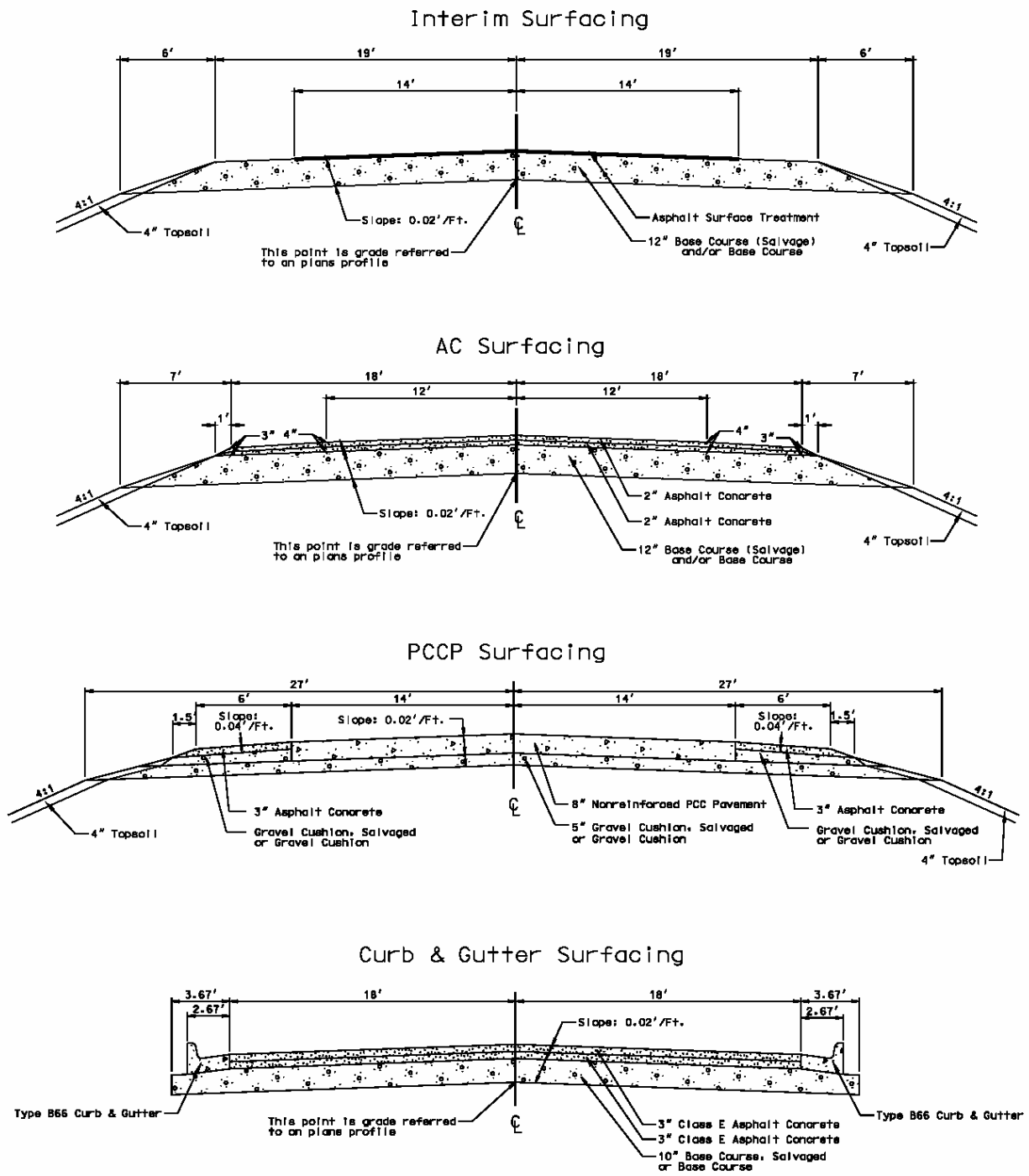


Figure 7-1. Typical Surfacing Sections

Median Shoulders -- Divided Highways

Chapter 3 – Scope Summary is to be referred to for shoulder widths. Since most stopped or disabled vehicles use the outside shoulder, the left shoulder need not be quite as wide. With a barrier type median the shy distance may require more than the minimum shoulder width. The minimum shoulder width is 4 feet for all types of medians (including Interstate).

In situations with 3 or more lanes in one direction, provide a shoulder wide enough to accommodate a stranded vehicle on each side of roadway.

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>
Portland Cement Concrete	2
Asphalt Concrete	2
Other Asphalt Surfacing	2
Gravel	3

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.

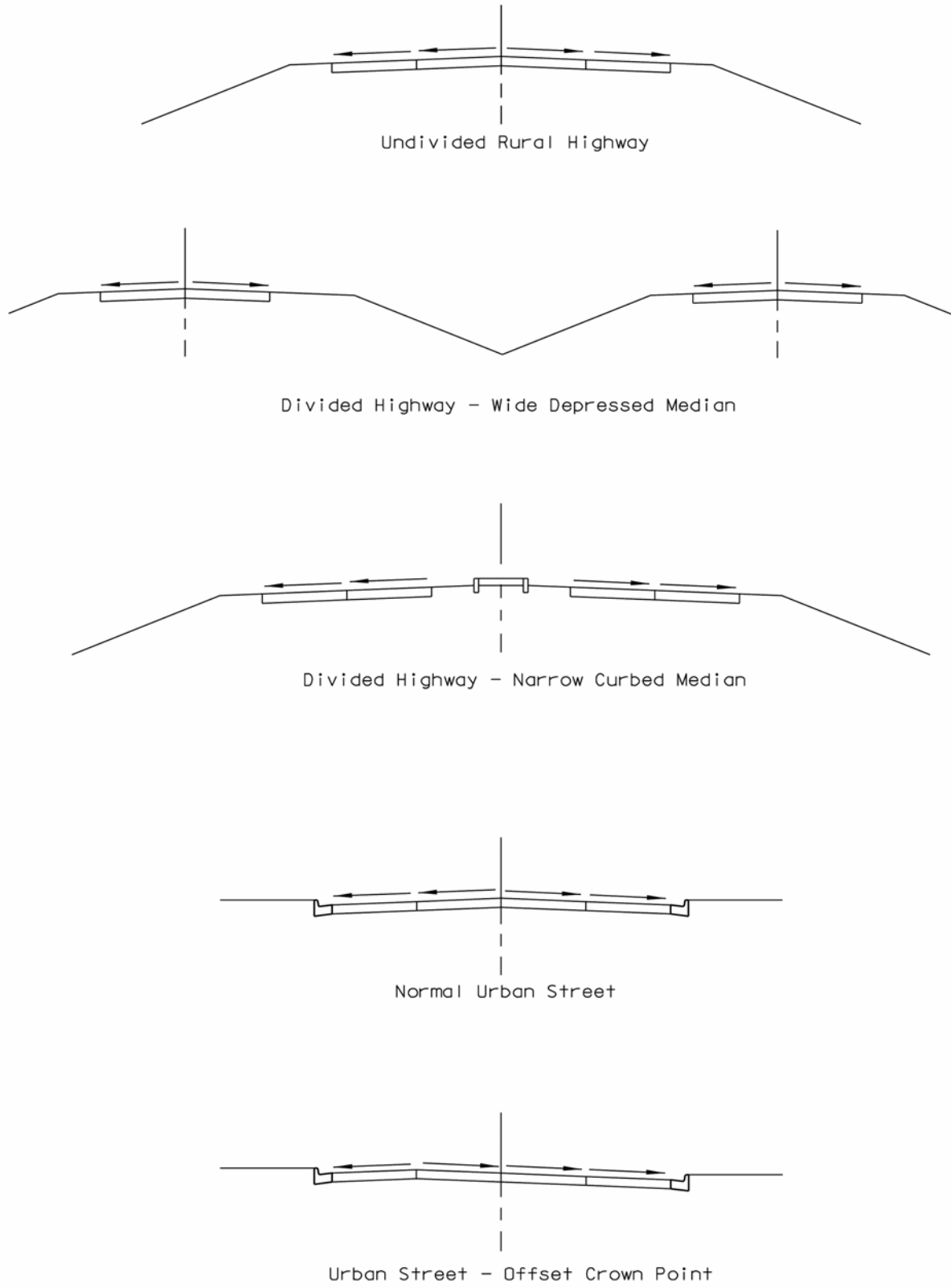


Figure 7-2. Typical Cross Slopes

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 7-1 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 7-1. 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 7-1.

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 7-2. 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%. Any portion of the paved shoulder which is constructed monolithically with the traffic lanes, should be sloped the same as the traffic lanes.
- 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 gradelines over 5%, adjacent to guardrail, and on superelevated curves.

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.

Width

The design width of the subgrade 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 the table for “SDDOT Highway Width Standards” found in Chapter 3 – Scope Summary. Table 7-3 can be used to determine the width of the surfacing sluff. Typical median widths are outlined in the section for Medians beginning on page 7-16.

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

ENGLISH UNITS		
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'

METRIC UNITS	
MAINLINE THICKNESS	SURFACING SLUFF WIDTH (4:1)
175 mm to 200 mm	0.9 m
215 mm to 225 mm	1.0 m
240 mm to 265 mm	1.2 m
275 mm to 300 mm	1.4 m
315 mm to 325 mm	1.5 m
340 mm to 365 mm	1.7 m
375 mm to 400 mm	1.9 m
415 mm to 425 mm	2.0 m
440 mm to 465 mm	2.2 m
475 mm to 500 mm	2.4 m
515 mm to 525 mm	2.5 m
540 mm to 565 mm	2.7 m

Table 7-3. Surfacing Sluff Width on Construction/Reconstruction Projects

The above tables apply to portland cement concrete 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. General criteria for these slopes are in the scope summary as described in Chapter 3 – Scope Summary. Application of the criteria is further discussed here.

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 7-4.

	Median Inslope	Outside Inslope
Preferred Ultimate	6:1	6:1 or 5:1 to clear zone*
Desirable Minimum	5:1	4:1 to clear zone*
Minimum	4:1**	3:1***
Minimum during interim season until other lane is completed	3:1	NA
Use Guardrail	Steeper than 3:1	Steeper than 3:1

* 30 feet from edge of driving lane

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

*** To be reviewed with documented justification to leave without guardrail. Some factors to be considered is if the bottom of the slope is obstacle free and/or shaped to allow recovery of an errant vehicle.

Table 7-4. 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 (when rock exists) Because the V-ditch requires the least amount of excavation, it may be used where rock excavation exists.

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.

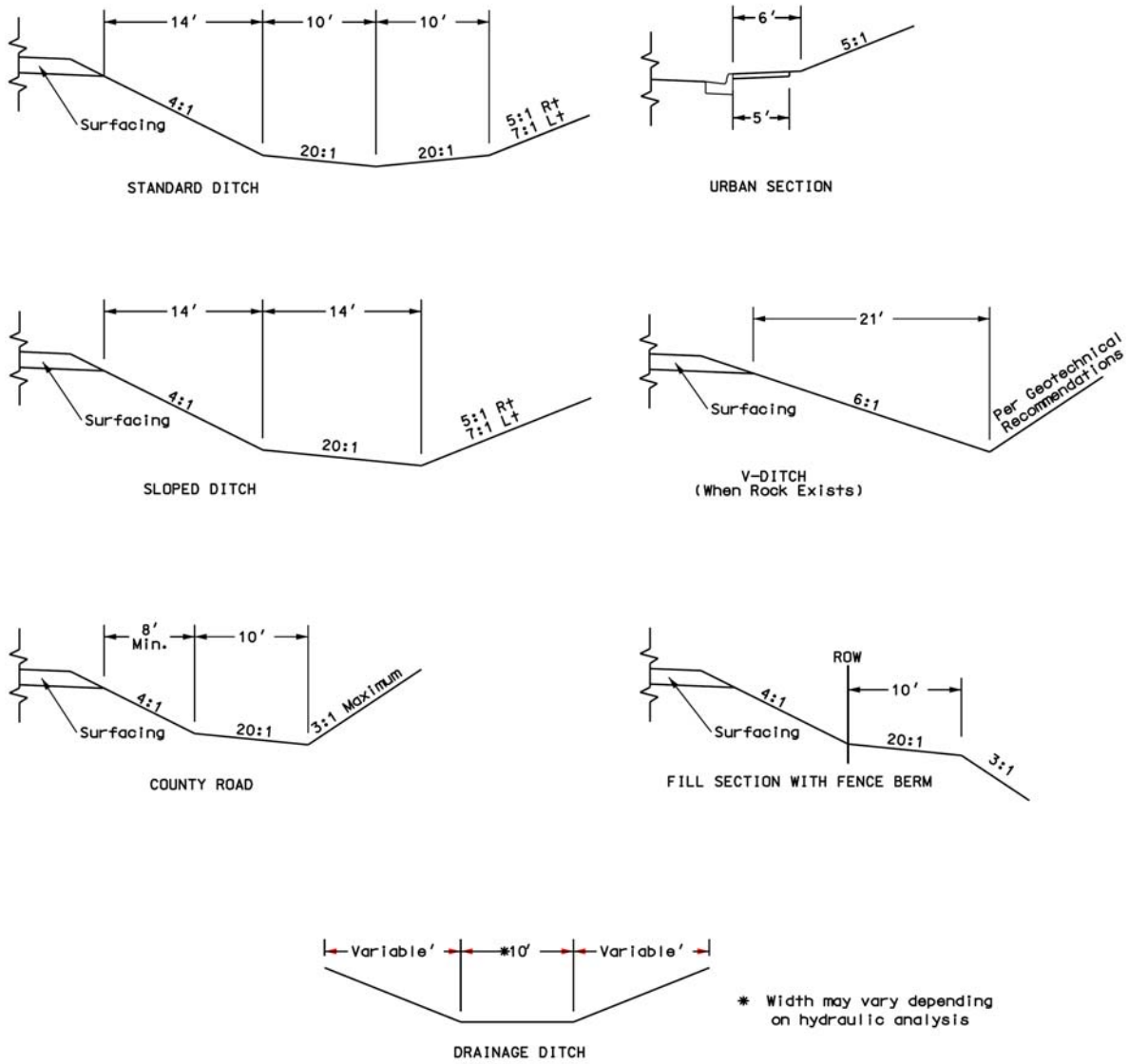


Figure 7-3. Typical Ditch Bottoms and Slope Criteria

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.

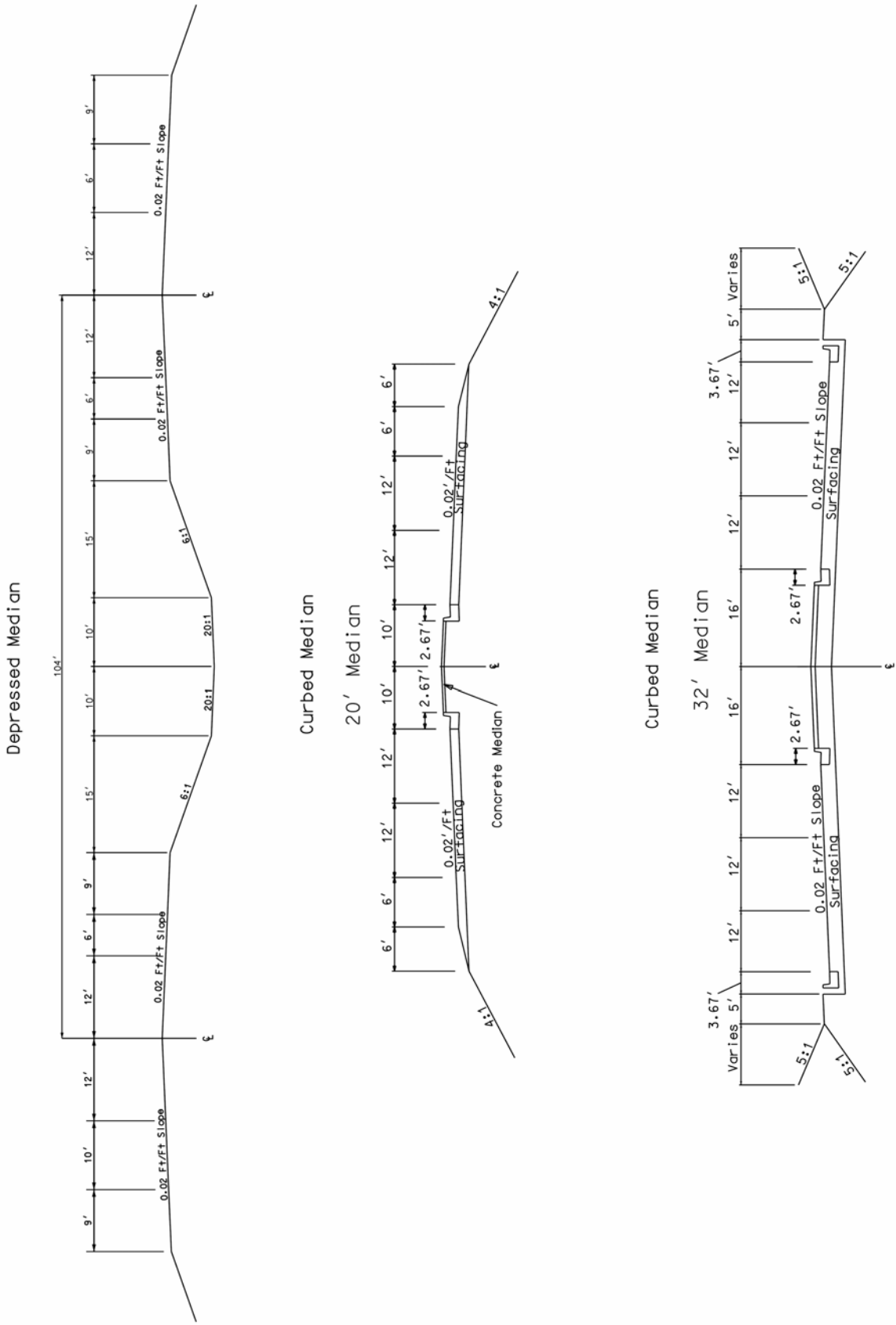


Figure 7-4. Typical Medians