Chapter Four

Cross Section Elements

Many of the basic geometric criteria for design of the various cross section elements were described as design standards in Chapter Three. This chapter provides more detailed instructions for practical application of these criteria, along with guidelines for cross section elements not previously discussed.

The term "cross section" is used to define the configuration of a proposed roadway at right angles to the centerline. Typical sections show the width, thickness and descriptions of the pavement section, as well as the geometrics of the graded roadbed, side ditches, and side slopes.

Criteria are presented in two general categories: (1) those related to surfacing elements, and (2) those related to grading elements.

4.1 SURFACING ELEMENTS

The surfacing cross section includes the pavement for the traffic lanes, the shoulders, and the base and subbase courses that are placed on the graded roadbed, as well as curbs that may be used adjacent to the pavement.

4.1.1 SURFACE TYPE

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, the desired service life and the estimated cost of maintenance.

Recommendations on surface type and structural thickness are prepared by the Materials and Research Section and are used in the typical sections prepared by designers. A general discussion of criteria and procedures for selecting the type of pavement, structural design of the various surfacing courses and different pavement rehabilitation techniques can be found in Chapter Nine-Pavement Selection.

The texture of the type of surface to be used has an influence on the prescribed cross slopes for pavement surfaces and for shoulders. For this reason, three general types of surfacing are recognized:

- **High type**–hot-mixed asphalt concrete or Portland cement concrete on a prepared subbase with an improved subgrade;
- **Intermediate type**–hot-mixed asphalt concrete on a prepared subbase; and
- **Low type–**surface treatment on prepared subbase material.

4.1.2 LANE AND SHOULDER WIDTHS

Criteria for widths of traffic lanes and shoulders are in Chapter Three. The basic policy is to provide 12 ft [3.6 m] traffic lanes on all arterials and collectors. This lane width is desirable in that it provides sufficient clearances between large commercial vehicles in the opposite lane on two lane roadways or four-lane undivided roadways. Lane widths affect level of service, operating speeds, and driver comfort. If the lanes are too narrow for the traffic volume and composition, it can result in reduced driver comfort and create erratic operations. Narrower lanes are permitted on some lower classifications of roads with relatively low traffic volumes. Narrower lanes may also be permitted on some higher level roadways where the scope of work is limited, right-of-way is restricted, there is extensive adjacent development, significant pedestrian traffic is present, and other constraints may apply.

Prescribed shoulder widths vary widely, depending on the functional classification of the highway, the traffic volume, and the type of improvement. For new construction on most arterial highways, the shoulder should have a width of 10 ft [3.0 m], while narrower shoulders may be acceptable for lower class roadways having lower traffic volumes and a low percentage of trucks. Unless local conditions significantly increase costs, designers should provide at least a 4 ft [1.2 m] shoulder and preferably an 8 ft [2.4 m] shoulder. Shoulders provide safety benefits, protection of the structural integrity of the edge of the travel lane pavement, and accommodate bicycle and pedestrian use.

Shoulders are usually not required adjacent to auxiliary turning lanes.

4.1.3 MEDIAN SHOULDERS–DIVIDED HIGHWAYS

In the case of divided highways, left shoulders (or median shoulders) are also to be provided but the criteria are different. The left shoulder need not be quite as wide since the purpose is to keep vehicles from rutting the edge of the traveled way and aid in recovery if the driver leaves the traveled way.

- The inside shoulder width for a depressed median should be at least 4 ft [1.2 m];
- The inside shoulder on six lane facilities should be 10 ft [3.0 m]
- Where there is a concrete or guardrail barrier in the median, an additional 2 ft [0.6 m] clearance from the outer edge of the shoulder to the face of the barrier is needed.
- A minimum of 1 ft [0.3 m] and preferably 2 ft [0.6 m] clearance from the edge of the traffic lane to the face of the curb is needed with curbed medians.
- If drainage inlets are to be installed, the shoulder may have to be widened to keep the basins/grates out of the running path. Since this is a major design and economic decision, the designer should obtain approval early in the design process.

4.1.4 CROSS SLOPES

It is important to enable surface water to drain from traffic lanes and shoulders as quickly as possible. Accumulations of water (ponding) cause hazards by reducing surface friction and vehicle stability. Sufficient cross slope is needed for adequate drainage, but too great a slope adversely affects vehicle operation. In addition, good drainage minimizes moisture penetration at the pavement/shoulder joint thus increasing stability and ensuring the mainline pavement will meet its projected service and design life.

The type of surface greatly influences surface drainage characteristics. Dense, smooth surfaces (concrete or high-type asphalt) require a lesser

Figure 4-1
Pavement Cross Slopes for Traveled Way

	Pavement Cross Slope (%)	
Surface Type	**New Construction/ Reconstruction**	**Preventive Maintenance**
Portland Cement Concrete or Asphaltic Concrete	2.0	1.0–3.0
Surface Treatment	N/A	2.0–4.0

slope for adequate cross drainage than is required for gravel or a coarse-textured, intermediate-type asphalt surface. The Department has adopted the cross-slope values shown in Figure 4-1 for standard practice on tangent sections of highways.

The range of cross slope values for projects other than "new construction" permits slight variations in the slope where the scope of work is primarily resurfacing. If surface drainage is a problem, cross slopes up to 2.5% on high-type pavements may be justified. However, new construction slopes should be provided wherever practical. For two-lane highways or multi-lane undivided highways, the cross slope normally goes downward both ways from a crown point at the highway center line.

On divided highways, each one-way pavement may be crowned separately, as on two-lane highways, or each may have a one-direction cross slope across the entire width of pavement-usually downward to the outer edge. Surface drainage on roadways with three or more lanes in one direction can cause problems if the pavement slopes uniformly in one direction at the rate of slope recommended for one- and two-lane roadways. The designer has two options for cross slopes on a three-lane roadway: (1) slope the inside lane to the median and the other two lanes to the outside, or (2) slope all three lanes to the outside and increase the slope of the outside lane.

A cross section with each roadway crowned separately, such as the first option above, has an advantage in rapidly draining the pavement during rainstorms. Disadvantages are that more inlet and underground drainage lines are required, and treatment of at-grade intersections is more difficult because of several high and low points on the cross section. Sections having no curbs and a wide depressed median are particularly well suited for this design. With a crowned section, cross slopes should not exceed 2% because the rollover effect, when changing lanes, is then 4%. "Rollover" is the algebraic difference between the two slopes.

Roadways that slope in only one direction are more comfortable to drivers because vehicles tend to be pulled in the same direction when changing lanes. This design is generally desirable for divided highways with a narrow curbed median. The cross slope of the third lane (outside lane) of a three-lane roadway where the cross slope is all one direction should be increased by 0.5% to 1.0% to improve surface drainage.

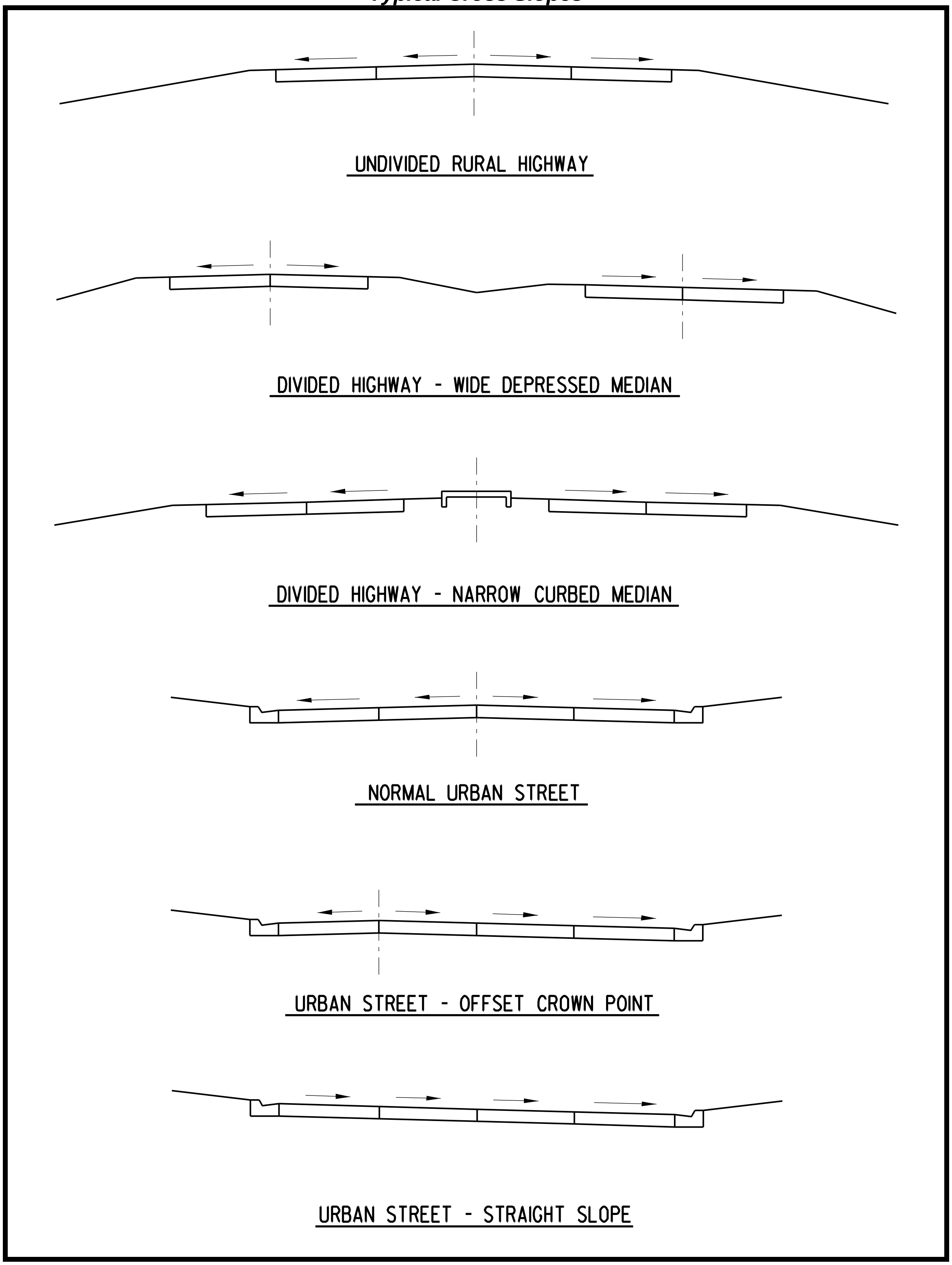
In the design of urban highways and streets, it may sometimes be found that adjacent property developments dictate that the curb on one side must be higher than the curb on the other. Two options are available. The cross slope can be in one direction for the full width of the street, or the crown point can be offset from the centerline toward the high side of the street. The latter option usually is preferable with the offset crown point corresponding to an edge of travel lane, out of the wheel path and with a maximum of 4% rollover.

Typical cross slope designs are illustrated in Figure 4-2.

4.1.5 SHOULDER CROSS SECTIONS

Shoulders should be flush with the roadway surface and should abut the edge of the traffic lane. All shoulders, including median shoulders on divided highways, normally should be sloped to drain away from the traveled way. However, in the case of a raised narrow median, the median shoulders may slope in the same direction as the traffic lanes, but consideration should be given to sloping the shoulders toward the median and providing inlets and underground drainage to alleviate problems with snow and ice. Slightly sloping shoulders steeper than the traffic lanes assure rapid surface drainage, reduce the chance of ponding, and minimize subgrade penetration of moisture through the edge joint. Paved shoulders normally should slope at a rate of 4%, and unpaved shoulders should be sloped at a rate of 6%.

Figure 4-2
Typical Cross Slopes



Special attention must be given to shoulder slopes in relation to superelevation on curves. Shoulder slopes that drain away from traffic lanes on the outside (high side) of a superelevated curve should be designed to avoid too great a cross slope break at the pavement edge. The rollover should not exceed 8%; differences greater than this tend to pull the vehicle toward the shoulder and may result in difficulty for the driver to regain control. For example, with a superelevation rate of 6% and a shoulder slope of 4%, the rollover would equal 10% which is unacceptable. The shoulder slope should be reduced to 2% but not less than 1% along the high side of the curve; this is acceptable since there is no stormwater discharge to the shoulder from the pavement and there is little opportunity for ponding or shoulder erosion damage.

Standard shoulder slopes should be used on the inside (low side) of superelevated curves unless the rate of superelevation exceeds the rate of normal shoulder slope. In this case, the shoulder slope should be the same as the superelevation slope.

4.1.5.1 GRASS SHOULDER

Vehicles often drift off the roadway and cause rutting of the shoulder edge. This is particularly noticeable at intersections and on the inside of sharp curves. Several options of grass shoulders are available. Vehicles may also park on the grass shoulder. Grass shoulders should be used only for special project needs. A grass shoulder shall not be used directly under a bridge overpass. Consider the following:

1. Use inground pavers, geogrid or a combination, which provide stability and allow grass to grow up through them. This is suitable for the area where parking is anticipated. Consider this where trash pick-up or mail delivery could rut the shoulder.
2. Provide a two foot wide paved shoulder adjacent to the grass shoulder, which may or may not be stabilized.
3. Provide a pavement edge line to determine the edge of the travel lane.
4. In a heavily salted area, alkaligrass may be used. Contact the Roadside Environmental Administrator.
5. The time of year for seeding and the length of time after seeding before the shoulder is subject to traffic are important. Phasing work should provide time for growth after seeding, and the shoulder should be protected until the grass is firmly established.

4.1.6 CURBS

Curbs are closely related to other surfacing cross section elements. They generally serve several purposes including drainage control, pavement edge delineation, delineation of pedestrian walkways, and control of entrances to roadside development. Curbs are used extensively on various types of urban highways and streets. In the interest of safety, curbs should be omitted on high-speed rural highways when the same objectives can be attained by other acceptable means. Curbs may be considered an obstruction, increase project cost and design effort. When using curbs, positive drainage of paved areas, particularly the traveled way, is necessary. This normally requires the installation of a closed drainage system with drainage inlets, positive outfalls and extensive ditching. Therefore, the need and use of curbs should be given appropriate study.

Curbs may be designed as a separate unit or integrally with the pavement structure. 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 barrier curbs and mountable curbs. Barrier curbs tend to, but do not always, prevent vehicles from crossing the curb line; mountable curbs permit such vehicle crossings without much difficulty. The types of curbs used most commonly are in DelDOT's *Standard Construction Details*. Refer to Chapter Ten for criteria for curb installations.

4.2 GRADING CROSS SECTION

The geometric elements of the grading cross section include the width and shape of the graded roadbed that consists of either suitable natural material or specified imported material. The top surface of the roadbed soil is defined as the subgrade. The pavement structure is placed on the prepared roadbed. The pavement structure includes any required selected subbase materials, base materials and the various layers of paving courses. The subgrade includes the various cut and fill slopes related to grading operations, including side ditches, to prepare a surface for constructing the pavement structure.

4.2.1 SUBGRADE CROSS SLOPES

The cross slope of the bottom of pavement box (top of subgrade) should parallel the cross slopes of the finished traffic lanes for the full width of the roadbed, including shoulders. This allows the pavement structure to drain through the porous material into side ditches or, if necessary, an underdrain system. The subgrade slope should not be broken to parallel the steeper finished shoulder slope. The parallel relationship between the subgrade and the finished traffic lanes applies to both normal crown slopes on tangent sections of highways and superelevated sections on curves.

4.2.2 SUBGRADE WIDTH

The design width of the subgrade should be shown on the roadway typical section(s). The total subgrade width should be the sum of the widths required for travel lanes, shoulders, median area, and any side slopes necessary to meet the subgrade.

For ease of computation and field staking, the design width may be rounded off to the nearest 1 ft [0.3 m]. This will result in a slope from the outside of the finished shoulder to the subgrade shoulder slightly different from the slope prescribed by the standards, but the variations will be negligible.

4.2.3 SUBGRADE WIDENING FOR GUARDRAIL

The subgrade should be widened at locations where guardrail is to be installed. The purpose is to provide the required horizontal clearance from the edge of the normal shoulder to the face of the guardrail, ensure the stability of the guardrail posts when placed in the embankment, and reduce maintenance.

Normally, 6 feet [1.8 m] of widening is required. This width includes 2 feet [0.6 m] from the normal shoulder line to the face of rail and 4 feet [1.2 m] behind the face of rail to a newly established edge of shoulder (the point of intersection of the front slope with the stabilized shoulder subgrade). Widening requirements are shown in DelDOT's *Standard Construction Details* for guardrail including special details for tapered flares for end treatments.

Refer to Chapter Ten for criteria for guardrail installations for various conditions relating to high embankments, non-traversable hazards and bridge ends.

4.2.4 SIDE SLOPES

A roadway's cross section includes side slopes as illustrated and identified in Figure 4-3. Side slopes are important in maintaining the stability of the roadbed and pavement structure as well as providing an area for the safety of errant vehicles. Side slopes are constructed in both fill (embankment) areas (those falling above the natural ground level) and cut areas (those falling below the natural ground level). As a general reference, slopes in embankment areas are commonly referred to as fill slopes or front slopes. When it is determined that no parallel ditch section is needed the front slope is graded to meet natural ground. In cut areas, side slopes are referred to as front slopes and back slopes, the back slope being necessary to bring the roadway cross section back up to meet the natural ground level. Ditch sections included as part of either fill or cut sections have a front slope, a ditch bottom with a defined shape and width, and a back slope. Criteria for rates of these slopes (by road classes) are shown in Figure 4-4. The application of the criteria is very important in selecting a safe cross section. This application is discussed in this section; a full understanding of the concepts presented in AASHTO's *Roadside Design Guide* is critical to the proper application of the criteria.

All three slopes depend upon a lateral horizontal area measured from the edge of outside travel lane, called "clear zone". Consideration must be given to the lateral clear zone requirements when applying the criteria in selecting all side slope and ditch sections for the design cross section.

4.2.4.1 SIDE SLOPES WITHIN THE CLEAR ZONE

A roadway's "clear zone" is the total roadside border area, starting at the edge of the inside traveled way, that is considered available for safe use by errant vehicles. In addition to any shoulder area, the clear zone area may consist of a combination of a recoverable slope, a non-recoverable slope, a traversable slope, a clear run-out area and a critical slope. These slopes are defined as follows:

- A recoverable slope is flatter than 4:1 and an errant driver has a high probability of being able to recover control of the vehicle.
- Non-recoverable slopes are embankment areas with slope ratios from 3:1 to 4:1 on which the vehicle will continue to the bottom of the slope.
- A traversable slope has a slope ratio between 3:1 and 4:1. Slopes in this range, if properly graded and clear of obstructions, will not allow the driver to recover control and steer back onto the roadway but will permit the vehicle to slow down and stop safely.
- A clear runout area follows a non-recoverable slope and is graded, shaped and made free of hazards (traversable) wide enough to allow an errant vehicle to safely stop.
- Critical slopes have a slope ratio of 3:1 or steeper and will require barrier treatment to protect an errant vehicle

Please note that in the Department's presentation of slope ratios it uses horizontal to vertical while the *Roadside Design Guide* uses the ratio of vertical to horizontal, e.g. DelDOT's 4:1 versus the *Roadside Design Guide's* 1:4.

The "forgiving roadside" concept recognizes that motorists do run off the roadway and that serious accidents and injuries can be lessened if at least a traversable recovery area is provided. The concept calls for a clear, unobstructed, relatively flat roadside area providing drivers an opportunity to recover control if their vehicle accidentally leaves the pavement surface. It may not be possible or practical to provide an area with flat slopes large enough to permit the driver to regain control of the vehicle. Where these areas can not be provided every attempt should be made to have an appropriate area clear of obstructions. The desired width of a project's clear zone varies based on several factors: (1) operating speeds, (2) traffic volume, (3) the steepness of slopes, (4) changes in slopes, (5) horizontal curvature, and (6) the accident history.

Any decisions on clear zone width obviously will influence the geometrics of the cross-section design, including design of side slopes. Since funds available for roadway improvements are limited, designers must consider the benefits and costs of alternate design treatments to provide the optimum clear zone design for any specific location. The proposed improvements for some projects do not take into consideration the clear zone based on the scope of work, such as minor improvements projects like pavement rehabilitation.

Table 3.1 of the *Roadside Design Guide* was developed to determine suggested roadside recovery area or clear zone distances for selected traffic volumes and speeds. The numbers are not precise since they are based on limited empirical data extrapolated to provide information for a wide range of conditions. Keep in mind site-specific conditions, design speeds, rural versus urban locations, project scope and practicality. The clear-zone distances from Table 3.1 for horizontal curvature may be modified by using Table 3.2. These modifications are normally considered where accident history indicates a need or a specific site investigation shows definite accident potential which could be significantly lessened by increasing the clear zone width in a cost effective manner.

For relatively flat and level roadways, the clear-zone concept is simple to apply. However, it becomes somewhat less clear when the roadway is in a fill or cut section where roadside slopes may be either positive, negative, or variable, or where a ditch exists near the traveled way. Consequently, these features must be discussed before a full understanding of the clear zone concept is possible.

A basic understanding of the clear zone concept is critical to its proper application. As previously mentioned, the numbers obtained from Table 3.1 of the *Roadside Design Guide* are based on limited empirical data and extrapolated to provide information for a wide range of conditions. Thus, the numbers represent a reasonable measure of the degree of safety suggested for a particular roadside, but they are neither absolute nor precise. In some cases, hazards outside the clear zone may require removal or shielding depending on the severity of the hazard, the projected ADT, projected construction costs, and the classification of the roadway. The selection of an appropriate clear zone distance amounts to reaching a compromise between balancing user safety, construction costs, land use and social impacts, environmental concerns and the many other constraints that influence project decisions. Appropriate application of the clear zone concept will often result in more than one possible solution.

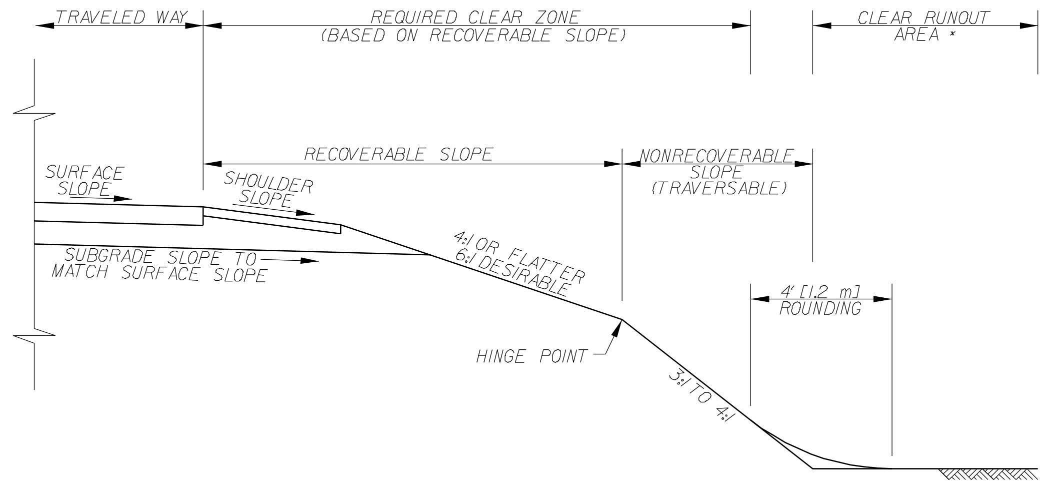
Chapter 3 of the *Roadside Design Guide* states: “The guidelines found in this chapter may be most applicable to new construction or major reconstruction.” For other types of projects the guide recognizes that it may be not within the scope, not within the available funding, too environmentally disruptive, or impractical to achieve the recommended clear zone widths. Projects at this level are evaluated on an historical basis, identifying safety problems and obvious obstructions with emphasis placed on correcting these, if clear-zone related. TRB’s *Special Report 214 Designing Safer Roads* should also be referred to when designing these types of projects.

In Delaware, experience has shown that the amount of lateral clear zone that should be provided varies from location to location. For each specific project a lateral clear zone is established by considering the following factors:

- Run-off-the-road accident experience,
- Design speed,
- Operating speed,
- Traffic volume,
- Steepness of side slopes,
- Profile grade,
- Horizontal curvature,
- Amount of roadside development,
- Sight distances,
- Level of improvement,
- Policy on removal and/or preservation of trees,
- Policy on installation of above ground utilities and
- Severity and location of the hazard.

After consideration of these factors and the clear zone requirements, the designer recommends a lateral clear zone or zones for each project. Clear zone widths generally will be uniform throughout the project except where widened for curvature. Lateral clear zone width decisions are an important design issue and are fully documented as described in Chapter 3.

Figure 4-3
Cross Section Side Slopes

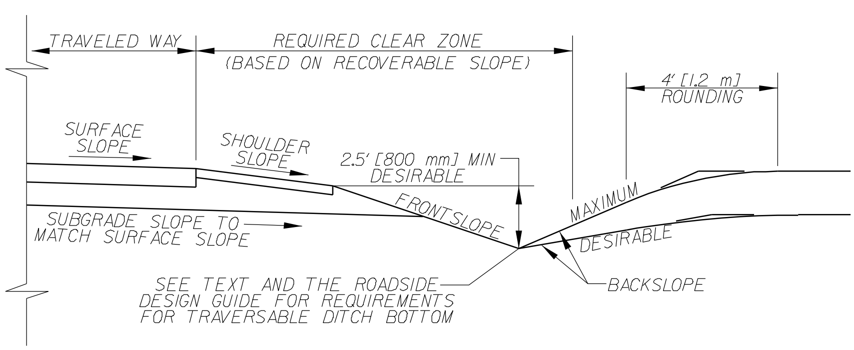


FILL SLOPES

* - THE CLEAR RUNOUT AREA IS ADDITIONAL CLEAR ZONE SPACE THAT IS NEEDED BECAUSE A PORTION OF THE REQUIRED CLEAR ZONE FALLS ON A NON-RECOVERABLE SLOPE. THE WIDTH OF THE CLEAR RUNOUT AREA IS EQUAL TO THAT PORTION OF THE CLEAR ZONE DISTANCE THAT IS LOCATED ON THE NON-RECOVERABLE SLOPE. THE CLEAR RUNOUT AREA SLOPE SHOULD BE RECOVERABLE OR AT LEAST TRAVERSABLE.

NOTES:

1. SEE TEXT SECTION 4.2.4.1 FOR DEFINITIONS OF CLEAR ZONE COMPONENTS.
2. A FILL SECTION USING A FRONTSLOPE CROSS SECTION THAT INCLUDES A NON-RECOVERABLE BUT TRAVERSABLE SLOPE WITHIN THE REQUIRED CLEAR ZONE IS COMMONLY REFERRED TO AS A "BARN ROOF DESIGN."



CUT SLOPES

Figure 4-4
Side Slope Criteria

Cut Slopes						
Road Class	**Front Slopes**		**Back Slopes**			
	Desirable	**Maximum**	**Desirable**	**Maximum** [1]		
				Depth of Cut		**Slope Ratio**
				US Customary	**Metric**	
Arterial	6:1	4:1	6:1	0 to 5 ft 5 to 10 ft 10 ft+	0 to 1.5 m 1.5 to 3 m 3 m +	4:1 3:1 2:1
Collector	6:1	4:1	4:1	0 to 5 ft 5 to 10 ft 10 ft +	0 to 1.5 m 1.5 to 5 m 3 m +	4:1 3:1 2:1
Local	6:1	4:1	4:1	0 to 5 ft 5 to 10 ft 10 ft +	0 to 1.5 m 1.5 to 5 m 3 m +	4:1 3:1 2:1

Fill Slopes						
Road Class	**Within Clear Zone**		**Outside Clear Zones**			
	Desirable	**Maximum**	**Desirable**	**Maximum**		
				Depth of Fill		**Slope Ratio**
				US Customary	**Metric**	
Arterial	6:1	4:1	6:1	0 to 5ft 5 to 10 ft 10 to 15 ft 15 ft +	0 to 1.5 m 1.5 to 3 m 3 to 5 m 5 + m	6:1 4:1 3:1 2:1
Collector	6:1	4:1	6:1	0 to 5 ft 5 to 10 ft 10 to 15 ft 15 ft +	0 to 1.5 m 1.5 to 3 m 3 to 5 m 5 m +	6:1 4:1 3:1 2:1
Local	4:1	3:1	4:1	0 to 3 ft 3 ft +	0 to 1.5 m 1.5 m +	3:1 2:1

Note:

Refer to the text and Tables 3.1 and 3.2 in the *Roadside Design Guide* for proper application of side slope design and clear zone requirements.

[1] The maximum back slope ratio outside the clear zone may be increased because of right-of-way restrictions.

In urban areas where curbs are often utilized, the space available for clear zones is generally restricted. In areas where barrier curbs are used, the clear zone shall extend to a minimum of 2 ft [0.6 m] beyond the face of curb, with wider clear zones provided where possible. In locations with mountable curbs, the clear zone width provided shall be as determined in *Roadside Design Guide*'s Table 3.1 as adjusted by Table 3.2.

If the clear zone width requirements, as determined by the above procedure, are not practicable because of local conditions or are inadequate because of specific safety problems, the designer should consider adjustments to the highway geometry or the installation of barriers. Refer to Chapter Ten for policies and criteria for barriers.

Utility poles are considered an obstruction and are not permitted within the clear zone without an engineering study, including accident history, and proper documentation. A design exception may be necessary. The use of breakaway utility poles can be considered as an alternative to moving or burying the utility where there is documented accident history.

4.2.4.2 FRONT SLOPES

Slopes within the selected clear zone must have a slope rate that is relatively flat. Normally a 6:1 slope (or flatter) should be used outward and downward from the edge of the finished shoulder to the outer limits of the lateral clear zone. Steeper slopes, up to a maximum of 3:1, may be used for low traffic volume roads and for conditions where flatter slopes would cause inordinately high costs. With slopes steeper than 4:1 the horizontal distance of the steeper slope cannot be used to meet the clear zone requirements.

For relatively low embankment heights, fill slopes extending outward and downward from the outer limits of the lateral clear zone to the natural ground normally should be the same.

Under conditions of high fills and/or right-of-way restrictions, steepening the fill slopes to a maximum of 2:1 beyond the clear zone may be considered, but they should be designed as flat as practical within the constraints of local right-of-way conditions. Slopes steeper than 3:1 cannot be mowed with conventional mowers. The cost of flattening slopes versus the cost of guardrail is also a consideration as guardrail is deemed a roadside obstruction and can be a continuing maintenance problem.

Slopes that parallel the traveled way can be recoverable, non-recoverable, traversable or critical. For recoverable slopes that are smooth and traversable with slopes of 4:1 or flatter, the suggested clear zone may be taken directly from the *Roadside Design Guide*'s Table 3.1, adjusted by Table 3.2 as necessary. Motorists who encroach on recoverable slopes can generally stop their vehicles or slow them enough to safely return to the roadway. Fixed object hazards, such as culvert headwalls, should not extend above the embankment either within the clear zone or beyond if the embankment is traversable to the bottom.

Slopes between 3:1 and 4:1 are considered non-recoverable slopes for which most motorists would be unable to safely stop or return to the roadway. It is very important that these embankments be traversable since a high percentage of encroaching vehicles will reach the toe of these slopes. The clear zone cannot logically end on the slope. Fixed object hazards should not be constructed along such slopes, and a clear runout area should be provided at the base of the slope. The runout area is a relatively flat clear area wide enough to allow the vehicle to stop. Figure 4-3 shows an example of such a clear zone. The clear zone width is the sum of the widths of the shoulder, any recoverable slopes, and the clear runout area, but excludes the non-recoverable slope.

Front slopes steeper than 3:1 are considered critical slopes and a driver will most likely lose control. If a slope steeper than 3:1 begins closer to the traveled way than the suggested clear zone for that specific roadway and the slope cannot readily be flattened, a barrier may be warranted. Barrier warrants are included in Chapter Ten-Miscellaneous Design.

In developing the proposed roadway cross section, the design cross section may consider a shape that resembles and is referred to as a "barn roof" section, (see Figure 4-3). This design provides a relatively flat recovery area adjacent to the roadway for some distance, followed by a steeper traversable down slope. This cross section may be more economical than providing a continuous flat slope from the edge of the traveled way to the original ground line and is generally perceived as safer than a continuous steeper slope.

In cut sections, the slope extending outward and downward from the finished shoulder to the side ditch should desirably be 6:1. For low traffic volume roads and unusual local conditions, the front slopes may be as steep as 3:1. On federal-aid projects the "desirable" criteria shown in Figure 4-4 shall be used. It is desirable that the front slope extend outward far enough to provide a side ditch flow line elevation at least 2.5 feet [800 mm] below the elevation of the paved or finished shoulder. The purpose of this minimum ditch depth is that it will place the ditch bottom below a normal pavement box allowing any moisture trapped under the pavement to travel through a porous subbase into the ditch. In addition, when combined with the proper slope, it will provide a depth that allows for some temporary ponding but will quickly remove any roadway runoff before it saturates the pavement structure.

4.2.4.3 BACK SLOPES

Back slopes extending upward and outward from side ditches to intersect the natural ground desirably should be 6:1 for principal arterials, but may be slightly steeper for lower classes of roads.

Under conditions of deep cuts and/or right-of-way restrictions, steepening the back slopes to a maximum of 2:1 may be considered, depending on the depth of cut and the class of road. Recommendations for slopes in rock cuts will be made for individual projects based on studies of local conditions.

When a roadway is in a cut section, the back slope may be hazardous depending upon its relative smoothness and the presence of fixed object hazards. If the slope is traversable (3:1 or flatter) and obstacle-free, it may not be a significant hazard. However, steep back slopes or those with obstacles such as rock cuts within the clear zone may require shielding if they cannot be flattened or the obstacle removed. Warrants for barriers are discussed in Chapter Ten.

4.2.4.4 TRANSVERSE SLOPES

Common obstacles along roadsides are transverse slopes created by median crossovers, drainage structures, driveways and intersecting side roads. These are generally more critical to errant motorists than front slopes or back slopes because they are typically struck by run-off-the-road vehicles travelling parallel to the roadway and impact the feature head on. Transverse cross slopes of 6:1 or flatter are suggested for high-speed roadways, particularly for the section of the embankment that is located immediately adjacent to traffic. This slope can then be transitioned to a steeper slope as the distance from the traveled way increases.

Embankment slopes (including the ends of any drainage structures) of 10:1 are desirable; however, their practicality is limited by width restrictions and the maintenance problems associated with long tapered pipe ends. Embankment slopes that are steeper than 6:1 may be considered for urban areas or for low-speed facilities. Safety treatments of drainage structures are discussed in Chapter Six-Drainage.

4.2.5 ROADSIDE DITCHES

The two principal functions of roadside ditches (hydraulically defined as open channels) are: (1) to drain water from the subgrade and (2) to collect surface water either from the roadway surface or adjacent roadside areas and remove it before entering the subgrade. Moisture in the subgrade and the frequency and magnitude of pavement loads are the most destructive forces to the roadbed and pavement structure. In addition, roadside ditches are an important element in reducing the environmental impact of a project on the adjacent landscape. Ditch designs can play a major role in managing stormwater runoff, removal of sediment, controlling erosion, and reducing the impact of roadway pollutants on watercourses.

Insofar as practical, ditch cross sections should be traversable within the clear zone. Figures 4-5 and 4-6 show preferred front slopes and back slopes for basic ditch configurations. Cross sections that fall within the shaded area of each figure are considered to have traversable cross sections. Ditch sections that fall outside the shaded area are considered less desirable; their use should be limited where high-angle encroachments, such as the outside of relatively sharp curves, can be expected. Ditch sections outside the shaded area may be acceptable for projects with one or more of these characteristics: restrictive right-of-way, rugged terrain, low traffic volume low, operating speed, or projects involving resurfacing, restoration, or rehabilitation, particularly if the ditch bottom and back slopes are traversable and free of any fixed objects. If practical, ditches with cross sections outside the shaded areas and in vulnerable locations may be re-shaped and converted to a closed system or shielded with traffic barriers.

Side ditches are particularly important to control surface drainage through cut sections in order to maintain the design integrity of a freely draining pavement structure. If the excavated material is of adequate quality it usually is used in the construction of adjacent fill sections. Figure 4-3 indicates that ditches may not be required at the toes of fill sections to drain the subgrade. However, in addition to the previously discussed environmental concerns, there may be other reasons to provide ditches to control runoff at the toes of fills to carry the flow to natural drainage channels thereby minimizing real or perceived damage to adjacent properties.

The two commonly used geometric configurations for side ditches are trapezoidal and v-ditch.

4.2.5.1 TRAPEZOIDAL DITCH

The preferred design is a ditch that is trapezoidal in shape with relatively flat front slopes and back slopes and a wide, flat bottom. (See Figure 4-5.) The general configuration of the trapezoidal ditch section does graphically show sharp breaks at the intersection points. However, constructing these breaks in the field is not always practical and they are normally graded in a more rounded shape making this ditch type more easily traversable than most other shapes.

4.2.5.2 V-DITCH

The V-ditch is a less desirable ditch design. Safety features are reduced because of the sharp break in the slope between the front slope and back slope. (See Figure 4-6.) This type of ditch section is more easily constructed and requires less right-of-way. However, it is not the best choice for traversability or maintenance.

4.3 MEDIANS

Medians are provided on divided multi-lane highways to provide a separation of opposing traffic lanes, a recovery area for out-of-control vehicles and an area for emergency stops. Besides these safety benefits, medians also can provide space for:

- Left-turn lanes,
- Snow storage,
- Collecting surface drainage,
- Refuge for pedestrians at crosswalks,
- Installation of traffic control devices, and
- Adding future lanes.

Figure 4-5
Trapezoidal Ditch Section

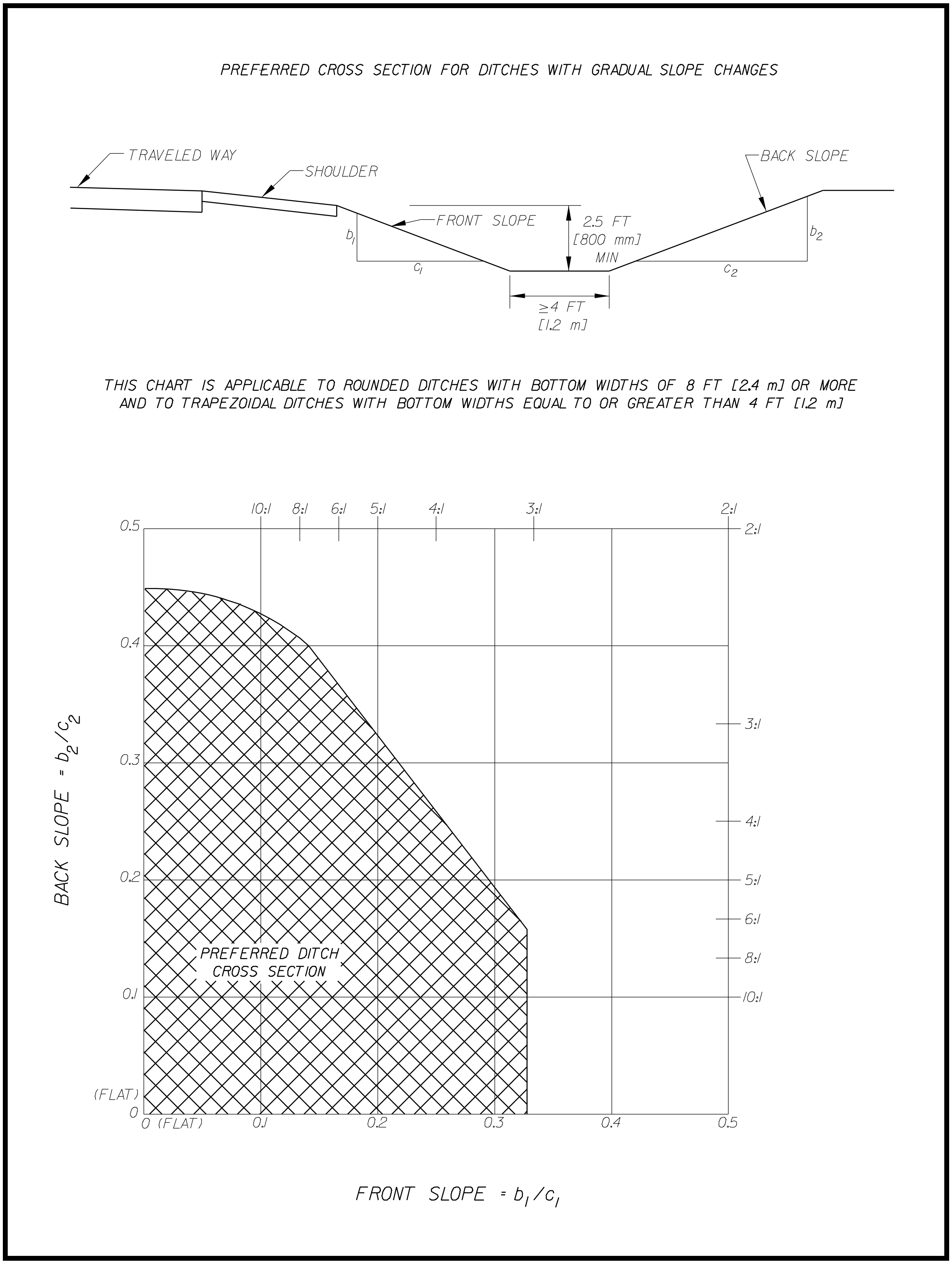
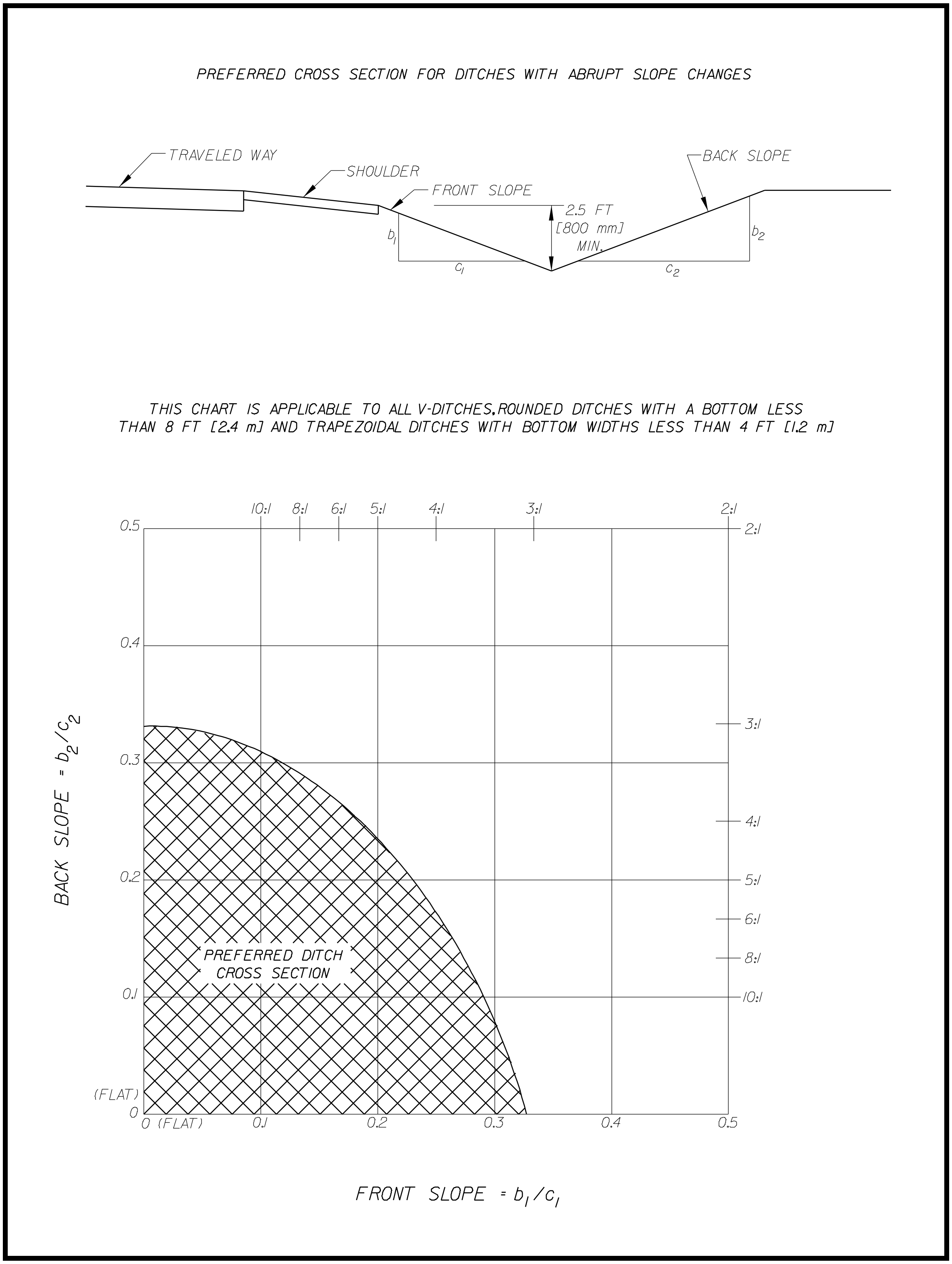


Figure 4-6
V-Ditch Section



Median widths are always measured between the inside edges of opposing travel lanes. Medians operate best when they are highly visible during the day or night and are at a width that provides for the predominant usage. There are three basic types of medians:

- Flush medians,
- Curbed (raised) medians, and
- Depressed medians.

The use of medians in providing for U-turn movements, auxiliary lanes and intersection design is further discussed in Chapter Seven-Intersections.

4.3.1 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 only for lower-speed urban arterials. Painted medians need frequent repainting to maintain their visibility at night and under inclement weather conditions.

To accommodate painted left-turn channelization, flush medians should be at least 16 ft [4.8 m] wide and desirably 18 ft [5.4 m]. 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.

4.3.2 CURBED MEDIANS

Curbed raised medians are 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, do not need frequent repainting and are more easily seen at night and during inclement weather.

Typical widths of raised medians range from 4 to 22 ft [1.2 to 4.1 m]. A raised median of 4 to 6 ft [1.2 to 1.8 m] in width with a paved surface may be used under restricted conditions on urban streets, but they have limited advantages. Although they provide a positive separation between opposing traffic and an opportunity to collect drainage, they offer no opportunity to introduce left turn lanes, are too narrow to provide a desirable pedestrian refuge and do not adequately serve as an area for installing traffic control devices.

The absolute minimum median width is 12 ft [3.6 m] for introducing left-turn lanes on low-speed arterial streets with restricted conditions and minimal truck use. Any size truck (as well as many passenger car drivers) could not use this lane without infringing on the adjacent travel way. A median width of 16 ft [4.8 m] is the normally accepted minimum in urban areas to adequately serve a mix of drivers and vehicles without having erratic movements. This width provides for a 10 ft [3.0 m] turn lane and a 6-ft [raised median]. This width does not provide any curb offset so there will be a tendency for drivers to shy away from the median into the adjacent travel way.

The two preferred urban median widths, where frequent left turns are to be accommodated with a diverse traffic mix, are 20 ft [6.0 m] or 22 ft [6.6 m]. A 20 ft [6.0 m] median width allows for a 12 ft [3.6 m] left turn lane, 2 ft [0.6 m] clearance from the edge of traffic lanes to the face of the curbed island, and a 4 ft [1.2 m] wide island to provide space for traffic control devices. However, in high pedestrian use areas, the preferred width is 22 ft [6.6 m] that will allow for a 6 ft [1.8 m] raised median for pedestrian refuge.

4.3.3 DEPRESSED MEDIANS

Depressed medians are most commonly used for high-speed expressways, freeways and rural arterials. Depressed medians are uncurbed grass areas with flat slopes drained by open ditches and flush drainage inlets. 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 relatively 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.

Median side slopes of 6:1 or flatter, for a distance of at least 30 ft [9 m] from the edge of the traffic lanes, are preferred. Other median slopes (for median crossovers, ditch blocks, etc.), that might be in the path of an out-of-control vehicle, should be 6:1 as a minimum and preferably 10:1 or flatter as a safety feature.

A width of 40 ft [12.0 m] or more for depressed medians permits adequate drainage design with flat slopes. A median width of at least 50 ft [15.0 m] can safely store a school bus. Wider medians are desirable where right-of-way permits allowing for the placement of a median bridge pier or overhead sign structure without the need for barrier protection. Wider medians should also be considered where there is a potential for adding travel lanes in the median to meet future traffic demand. Also see the *Green Book* pages 460 and 461 for further discussion on this subject.

Where flat longitudinal slopes on the roadway are encountered, the cross slopes of the median may be varied to increase the longitudinal slope of the median ditch. For example, the cross slope may be kept very flat (10:1 or flatter) at the upper end of the drainage area and steeper (6:1) at the lower end.

4.3.4 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 must be provided. But in this case, some type of physical barrier must be 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. Refer to Chapter 10 and the *Roadside Design Guide* for criteria for median barriers.

4.3.5 MEDIAN OPENINGS

Refer to Chapter 7 for the design of median openings and channelization for left turns.