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MINNESOTA DEPARTMENT OF TRANSPORTATION	**TRANSMITTAL LETTER NO. (19-04)**
DEVELOPED BY: Design Standards Unit	**MANUAL:** Road Design Manual
ISSUED BY: Office of Project Management and Technical Support	**DATED:** November 19, 2019
SUBJECT: Sections 4-3 and 4-4	

A list of changes is attached to this update.

INSTRUCTIONS:

1. Record this transmittal letter number, date and subject on the transmittal record sheet located in the front of the manual. The last Transmittal Letter was 19-03, dated September 17, 2019.

2. Remove from the manual: Section 4-3(1-2)
Section 4-4(1-11)

3. Insert into the manual: Section 4-3(1-2)
Section 4-4(1-4)

4. The Road Design Manual and associated Transmittal Letters are available online in PDF format at. http://roaddesign.dot.state.mn.us/roaddesign.aspx

5. Any technical questions regarding this transmittal should be directed to Mike Elle, Design Standards Engineer, at (651) 366-4622, or by email to DesignStandards.DOT@state.mn.us

Michael Elle

Michael Elle, P.E.
Design Standards Engineer

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Summary of Changes
MnDOT Road Design Manual
19-04

Section 4-3 TRAVEL LANES

- 4-3.01.02 Width
  - Remove superseded lane width content in favor of references/links to governing tech memo and PBPD guidance document
- 4-3.01.03 Surface Types
  - Update the title of the Pavement Design Manual
  - Remove paragraphs referencing outdated surface types (i.e. high, intermediate and low)
- 4-3.01.04 Cross Slopes
  - Editorial adjustments to first and third paragraphs
  - Relocate second paragraph for more logical flow
  - Divided highway bullets:
    - Bullet 1: editorial adjustments
    - Bullet 2: limit recommendation to crown each direction of travel to high-speed facilities
    - Bullet 3:
      - Suggest unidirectional slope for low-speed facilities
      - Recommend capturing median drainage for 40+ mph design speeds
      - Reword to avoid characterizing not capturing median drainage as a safety problem
  - Cross slope rate (relocated second paragraph):
    - Eliminate Table 4-3.01A in lieu of more nuanced discussion in bulleted text
    - Adopt Green Book / cross slope tech memo criteria (i.e. 0.015 minimum)
    - Confine controlling criteria applicability to first lane out from crown / top of unidirectional slope (consistent with AASHTO/FHWA intent)
    - Create separate subsections for rural/high-speed and urban low-speed facility types
    - High-speed/rural
      - Provide common examples of where 0.015 may be appropriate
      - Clarify how wide sections should be steepened on the outer lanes
    - Urban low-speed
      - Encourage uniform cross slope as desirable practice
      - Encourage flexibility in constrained areas, i.e. outside-in design
- 4-3.02 Auxiliary Lanes
  - Update definition to match newer Green Books
  - Add flexibility to lane width guidance
  - Add guidance on speed basis for design
  - Remove freeway aux lane shoulder width criteria in lieu of reference to Chapter 6; add references to truck climbing and turn lane sections of Chapters 3 and 5 respectively
  - Revise cross slope criteria to not require steepening from adjacent lane unless judged necessary

Section 4-4 SHOULDERS AND CURBS

- 4-4.01.01 Width
  - Remove superseded shoulder width content in favor of references/links to governing tech memo and PBPD guidance document
- 4-4.01.02 Cross Slopes
  - Table 4-4.01D: revise to reflect surface types and standard ranges in the AASHTO Green Book
  - Bullet 1:
    - Editorial adjustments
    - Reflect the established practice of sloping narrow paved shoulders with the adjacent lane
  - Bullet 2:
    - Add statement about flexibility
    - Simplify discussion by eliminating superfluous noise
  - Bullet 3:
    - Some editorial adjustments
    - Reflect the established practice of sloping narrow paved shoulders with the adjacent lane
    - Add allowance for up to 9 percent slope rollover where necessary to accommodate up to 8 percent lane superelevation (greater than 8 percent through design exception)

- 4-4.02.01 Shoulder Rumble Strips
    - Remove shoulder rumble strip content in favor of references/links to governing tech memo
- 4-4.03.01 Design Criteria (Shoulder Use by Buses)
    - Update Metro District name
    - Table 4-4.03A:
        - Remove criteria that are no longer controlling criteria for design and update nomenclature
        - Update standard design values for criteria and provide/update references
        - Clarify/correct policy on vertical clearances

- 4-4.04 Curbs
    - Qualify statement on rural highway use
    - Add curb functions to include those listed in newer Green Books
    - Update curb characterizations to match contemporary AASHTO classifications
    - Clarify, expand and provide reference for curb reaction definition and criteria
    - Rewrite curb type usage paragraph:
        - Clearly specify MnDOT standard curb designs in the discussion
        - Include the new Design R
        - Add guidance and wordings from AASHTO Green Book and Roadside Design Guide
    - Second-to-last paragraph
        - Clarify and update discussion to be consistent with AASHTO curb classifications
        - Remove extraneous discussion pertaining to interchange design and operation
    - Last paragraph
        - Shorten and defer to Chapter 10 (where this discussion is more appropriate)
        - Remove characterization of curbs used with barriers as a “safety problem”

4-3.0 TRAVEL LANES

4-3.01 Through Lanes

4-3.01.01 Number

The number of travel lanes is determined, in part, through capacity and quality of service analyses. The analysis should include an evaluation of traffic types and volumes, traffic composition, space availability, economy, and contextual and environmental considerations. Refer to Chapter 2 for parameters and controls related to capacity and level of service.

4-3.01.02 Width

Refer to Technical Memorandum No. 18-08-TS-06 as supplemented by the Performance-Based Practical Design guideline document for MnDOT's current design policy and guidance on travel lane width.

4-3.01.03 Surface Types

The selection of surface type is determined based on the volume and composition of traffic, soil characteristics, weather, performance of pavements in the area, initial cost, and overall maintenance and service-life costs. Refer to the Pavement Design Manual for pavement determination and design procedures.

4-3.01.04 Cross Slopes

Surface cross slopes are necessary to facilitate drainage because of the detrimental effects of wet pavements and standing water on vehicular operation and pavement durability. Such conditions reduce the friction between tire and pavement and increase the distance needed for stopping. This need must be balanced, however, against the effects of the cross slope on driving comfort and safety, as cross slopes require that drivers continuously steer their vehicles counter to the down slope to stay within their lane. Drivers also need to make steering corrections to change between lanes of opposite-direction cross slopes.

On multi-lane divided highways, each directional roadway may be crowned separately, or all lanes of each roadway may flow in one direction. The designer should consider the following when selecting cross slope direction.

1. Crowning each directional roadway will drain the pavement more efficiently and minimize the elevation difference across the cross section. This treatment requires drainage facilities for both sides of each roadway and complicates at-grade intersection design. This treatment is best suited for divided highways with wide depressed medians, especially those with full or partial control of access.
2. For high-speed facilities, the preferred design is a crowned cross section for each direction of travel, even for roadways with narrow raised medians.
3. Sloping each directional roadway toward the outside is typically suitable for low-speed facilities with narrow raised medians. This approach minimizes complications in at-grade intersections and lends itself well to a single centerline and profile controlling the entire roadway.
    a. With design speeds of 40 mph and higher, median runoff is often captured with drainage structures, preventing snow melt and low flows from streaming across travel lanes.
    b. Allowing drainage from raised median areas to cross travel lanes is common practice for design speeds less than 40 mph. Such designs are simple and economical—requiring drainage inlets only at the outside of the overall roadway—but can be susceptible to refreezing of snow melt under certain weather conditions.

Design cross slope rates vary with surface type, as paved surfaces require less cross slope than unpaved surfaces to sufficiently drain. The range of design for unpaved roads is 0.02 (ft/ft) to 0.06, with 0.04 a common typical value. On paved surfaces, cross slopes up to 0.02 are barely perceptible to the driver; rates steeper than 0.02 are noticeable and require a conscious counter-steering effort. For these reasons, the accepted range of design is 0.015 to 0.02 for the first lane out from a crown line or top of a unidirectional surface. Of these values, 0.02 is considered optimal, offering satisfactory driver comfort, lower potential for hydroplaning at high speeds, and reduced potential for ponding of water on irregular or rutted surfaces. Cross sectional design approach varies depending on speed and rural/urban context, as discussed below.

4-3.01.04.01 Rural and High-Speed Urban Facilities

The following specific criteria apply for through travel lanes. As noted above, the controlling criterion for normal cross slope applies to the first lane out from the crown line or top of the cross section. Cross slopes in the outer lanes of wide pavements should be steepened to better drain the cumulative flow. Refer to 4-3.02 for auxiliary lane criteria.

1. 0.02 (ft/ft) is the typical design cross slope for new construction and reconstruction.
2. 0.015 is the minimum design value.
   a. 0.015 (ft/ft) cross slopes are commonly applied in pavement preservation to minimize cost and complication when overlaying existing surfaces having cross slopes of 0.015 or flatter. On rare occasions 0.015 may be considered for a reconstruction project with severe or unusual constraints.
   b. Investigate existing performance problems that may be attributable to pavement drainage when considering perpetuation of existing cross slopes less than 0.02.
   c. 0.015 cross slopes are appropriate for roundabout circulatory roadways or other low-speed situations where curvature is adverse to the cross slope
3. Slope the second lane out from the crown or top of cross section at 0.02 regardless of the first-lane cross slope.
4. Increase the slope of each successive pair of lanes by 0.005—e.g. slope the third and fourth lane out from the crown at 0.025.
5. Avoid cross slopes steeper than 0.03 on tangent roadways wherever practical.

4-3.01.04.02 Low-Speed Urban Facilities

A uniform, constant cross slope from the high point to edge of the cross section is desirable from the standpoint of design and construction simplicity and is suitable for low-speed vehicular operation. In constrained environments, a flexible design approach is often needed in order to match curb and/or sidewalk elevations to those of adjoining properties, particularly where doorways and pedestrian accessibility are in play. The following general criteria and framework apply.

1. 0.02 (ft/ft) is typically preferred for new construction and reconstruction.
2. The minimum design value of 0.015 can be appropriate in various circumstances, including:
   a. Where beneficial in a constrained location to match streetside features or properties
   b. Where parallel parking areas are or have the potential to be designated as accessible for disabled users
   c. For roundabout circulatory roadways or similar circumstances where cross slope adverse to restrictive curvature could cause operational problems, especially for trucks
3. A standard range of cross slope between 0.015 and 0.03 should generally be observed, but non-standard values can be considered where necessary to fit constrained locations.
4. Although a uniform cross slope across a cross section is ideal, varying cross slopes by lane can be useful to best fit constraints.
   a. Avoid inverted-crown arrangements (i.e. cross slopes of decreasing pitch in the down-slope direction).
   b. Variable lane slopes may be designated but add complication to design and construction, often necessitating independent curb grades, multi-stage paving, or other measures.

4-3.02 Auxiliary Lanes

An auxiliary lane is defined as the portion of the roadway adjoining the through travel lanes for speed change, turning, storage for turning, weaving, truck climbing, and other purposes supplementary to through-traffic movements. Travel speeds in auxiliary lanes are typically somewhat less than in the adjacent through lane(s) and often variable; the design of speed-dependent design elements and parameters should take this into account. The width of an auxiliary lane should generally be based on the same criteria that governs through lanes, although additional flexibility may be called for. Refer to Chapter 3 for information on the design of truck climbing lanes; design criteria and details for turning lanes are provided in Chapter 5; discussion of freeway auxiliary lanes can be found in Chapter 6.

The normal cross slope of an auxiliary lane should typically match that of the adjacent through lane. Freeway auxiliary lanes longer than a half mile that exhibit usage and operational characteristics of through travel lanes may be steepened consistent with the design criteria in 4-3.01.04.02.

4-4.0 SHOULDERS AND CURBS

4-4.01 Shoulders

Shoulders serve many functions and offer many advantages, including:

1. Providing an area for emergency parking
2. Providing room for evasive action and recovery in the case of lane departure
3. Improving highway capacity and driver comfort
4. Improving lateral support and drainage for the pavement
5. Providing lateral clearance for highway appurtenances and for snow removal
6. Providing an area for pedestrians and bicyclists
7. Providing an area that can function as a turn lane or bypass lane, if so designated
8. Providing an area for maintaining roadway lights, signs or signals

Well-designed and maintained shoulders, regardless of width, prevent failure and progressive deterioration of the pavement edge due to lack of lateral support. Shoulders on roads with very low traffic volumes and on temporary roadways with limited use or life may be designed primarily for such support. A well-designed shoulder will be sufficiently stable to provide lateral support and will also support an occasional vehicle in all kinds of weather without rutting.

The outer strip of shoulder between the surface portion and the side slope plane is of critical importance for carrying lateral drainage off the roadway. When a side strip is placed adjacent to the surfacing, it should be placed at the same or at a lower elevation than the surfacing to avoid impeding the flow of water. Should the lateral drainage be impeded, accumulations of sanding residue and other debris will build up at the juncture of the shoulder surface and the sod. The topsoil underlying the sod should therefore be placed to accommodate the sod strip at the appropriate elevation. The potential for drainage obstruction and damage to vegetation from spray and residues from snow and ice removal chemicals may suggest alternates to sodding the outer strip of shoulders.

4-4.01.01 Width

Refer to Technical Memorandum No. 17-12-TS-05 as supplemented by the Performance-Based Practical Design guideline document for MnDOT's current design policy and guidance on shoulder width.

4-4.01.02 Cross Slopes

1. As with travel lanes, shoulders are sloped to provide adequate cross drainage. They are usually sloped away from the travel lanes and at a somewhat higher rate; however, narrow paved shoulders constructed with the same pavement section as the travel lane(s) may be sloped to match the adjacent lane.
2. Table 4-4.01A presents the standard range of shoulder cross slopes, which vary with surface type. Values outside these ranges may be considered in unusual or constrained situations.
3. On superelevated highways, the shoulder cross slope is governed by the superelevation rate of the travel lanes. The following will apply:
   a. Shoulders should generally slope away from the traveled lanes, although narrow paved shoulders may slope with the adjacent lane if constructed with the same pavement section.
   b. On superelevated highways, slope the high-side shoulder away from the through lanes at a minimum slope of 0.01 (ft/ft). Slope the low-side shoulder at the same rate as the through lanes where the superelevation rate exceeds the typical shoulder cross slope.
   c. The algebraic difference between the travel lane slope and the high-side shoulder slope should normally not exceed 0.07. However, where the travel lane superelevation rate exceeds 0.06, the algebraic difference needs to vary to greater than 0.07 in order for the shoulder to slope away. AASHTO currently limits the difference to 0.08, but NCHRP Project 03-105 suggested that this allowance could be increased to 0.10. For this reason, designers should consider algebraic differences up to 0.09, which corresponds to a lane superelevation rate of 0.08. Design values greater than 0.08 would necessitate informal design exception documentation.

Table 4-4.01A
NORMAL SHOULDER CROSS SLOPE

SURFACE TYPE	RANGE IN SHOULDER CROSS SLOPE, ft/ft	TYPICAL VALUE
PAVED	0.02 - 0.06	0.04
GRAVEL	0.04 - 0.06	0.04
TURF	0.06 - 0.08	0.06

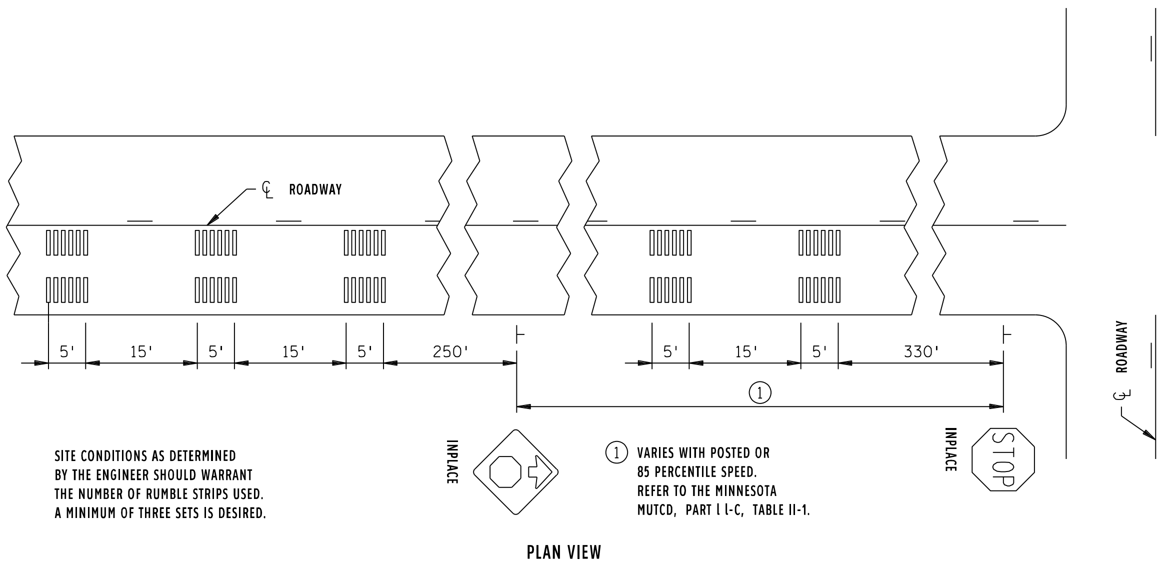
4-4.02 Rumble Strips

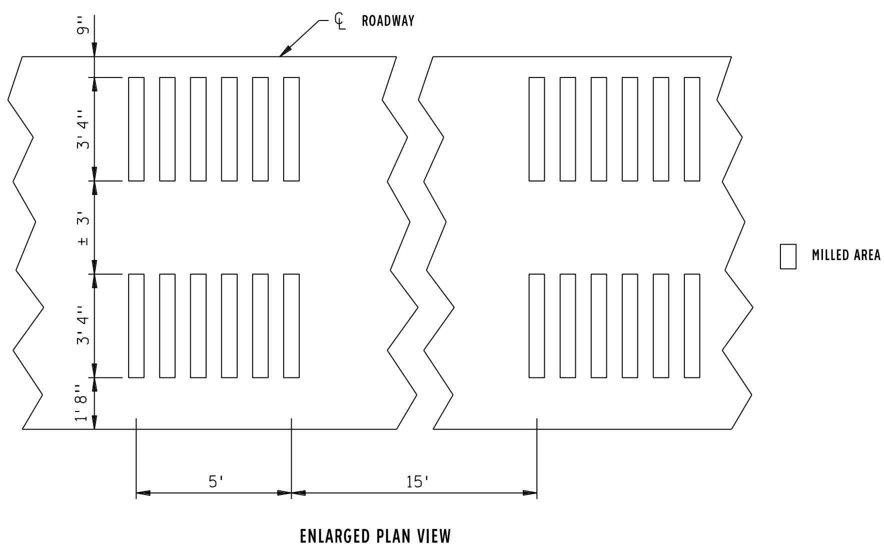
4-4.02.01 Shoulder Rumble Strips

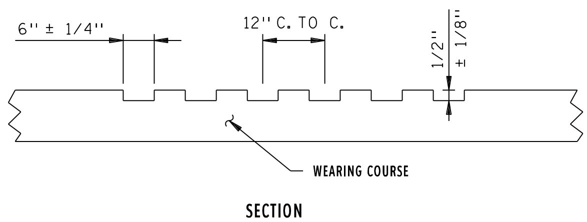
Refer to Technical Memorandum No. 17-08-T-02 for MnDOT's current policies and design criteria for shoulder rumble strip usage.

4-4.02.02 In-Lane Rumble Strips

In-lane rumble strips maybe installed before stop signs at the discretion of the designer. Figure 4-4.02A shows the standard detail in both plan and section views.







IN-LANE RUMBLE STRIPS, PLAN AND SECTION VIEWS
Figure 4-4.02A

4-4.03 Shoulder Use by Buses

Public transit buses are permitted to travel on designated shoulders of congested roadways during peak periods. This is done to encourage transit use and fully utilize the capacity of congested highways in urban areas. A number of criteria must be met in order for a roadway to be considered for bus shoulder use. The primary criterion is the presence of "predictable congestion delays," meaning the running speed of traffic must be less than 35 mph during peak periods and/or approaches to intersections must have continuous backups. Additional criteria that must be met for a roadway to be considered for bus shoulder use include:

1. Congestion delays must occur one or more days per week.
2. A minimum of six transit buses per week must use the proposed bus shoulder.
3. The expected time savings of using the shoulder must be greater than eight minutes/mile/week.
4. The proposed shoulder must have a continuous shoulder width of at least 10 ft.

Only right shoulders will be considered for bus use. Designated buses will be allowed to use designated shoulders only when traffic is moving at speeds less than 35 mph. When using a designated shoulder, buses shall not exceed the speed of traffic by more than 15 mph, the maximum speed being 35 mph. If traffic is stopped, bus speed shall not exceed 15 mph. If a shoulder is obstructed in any way, the bus driver must re-enter the mainline to avoid the obstruction. Bus drivers must yield to any vehicle that enters the shoulder as well as any vehicle merging or exiting at an interchange ramp. Buses can use designated shoulders while driving with an empty bus to the beginning of a new route.

Table 4-4.03A
SHOULDER USE BY BUSES: GEOMETRIC DESIGN CRITERIA
Type of Highway: Urban Multi-Lane Freeway and Expressways; Buses on right shoulders only

Geometric Design Criterion	Standard Value	Notes:
Design Speed, mph	35	Maximum speed for buses traveling on shoulder, as per operational policy
Shoulder Width, ft	10.0 12.0	10.0 ft minimum, 12.0 ft desirable 12.0 ft required in areas of new construction or reconstruction.
Bridge Width, ft	11.5 12.0	11.5 ft minimum, 12.0 ft desirable 12.0 ft required in areas of new construction or reconstruction
Maximum Grade %	N/A	Not applicable; match existing roadway
Design Loading Structural Capacity	HL-93	For new bridges. For existing bridges to allow shoulder use, the shoulder must be structurally adequate (capable of carrying legal loads); consult the MnDOT Bridge Office.
Horizontal Curve, Radius, ft	N/A	Not applicable; match existing roadway
Stopping Sight Distance, ft	250	Stopping Sight Distance based on 35 mph design speed
Cross Slope, ft/ft	0.02 - 0.06	Road Design Manual, Table 4-4.01A
Superelevation Rate (max), ft/ft	0.08	Road Design Manual, Section 3-2
Vertical Clearance, ft	Variable	Typically controlled by larger legal or oversize vehicles; refer to MnDOT LRFD Bridge Design Manual, Article 2.1.3 For bus-only facilities, a vertical clearance of 1 ft minimum above the design vehicle height may be appropriate; tallest bus vehicle is 10 ft -9 in.

4-4.03.01 Design Criteria

To qualify for bus shoulder use, existing roadways shall have a minimum roadway shoulder width of 10 ft, and a minimum bridge shoulder width of 11.5 ft. In areas of new construction or reconstruction where bus shoulder use is expected, 12-ft roadway shoulders and 12-ft bridge shoulders shall be constructed. Table 4-4.03A contains the design criteria for shoulder use by buses. All shoulders proposed for bus use must be of sufficient pavement strength and must be inspected by the District Materials Engineer prior to use. The decision to allow shoulder use by buses should be considered during the planning phase of construction or reconstruction projects on roadways that do not have bus shoulders.

On urban design type roadways, drainage structures should be evaluated for structural integrity before bus use is permitted on shoulders.

More information on shoulder use by buses can be obtained from the Metropolitan District Transit Advantages Coordinator.

4-4.04 Curbs

Curbs are used extensively at the outside of urban streets and highways; generally, they should be used on rural highways only in constrained situations; where median channelization is needed; or per standard bridge approach treatments. Curbs serve several functions. They allow the pavement surface drainage to be contained within the road and away from adjacent properties; provide pavement delineation; reduce grading limits; assist in channelization for orderly roadside development; and provide aesthetic value.

AASHTO categorizes curb configurations as vertical or sloping. Vertical curbs are defined as having a vertical or nearly vertical face and a height of 6 in. or greater, while sloping curbs are described as being “low with flat sloping faces” and depicted as being 4 in. to 6 in. in height. Standard Plates 7000 series provides details for standard curb designs. Of those, Design V having a 6 in. or greater height classifies as vertical in AASHTO’s definition, with all other designs having heights 6 in. and less classifying as sloping.

Curbs may be of concrete or bituminous construction and occasionally natural stone. Concrete curbs may be constructed as a separate unit – with or without gutter – or integral with or tied to an adjacent concrete pavement. A gutter section is often used to define the so-called curb reaction – a lateral shy distance exclusive of the traveled way. Where a shoulder is provided, the gutter is considered part of the shoulder width. Design criteria for curb reaction and shoulder width are provided in Technical Memorandum No. 17-12-TS-05.

Designs V and B are intended to discourage motorists from deliberately leaving the roadway, although Design B4 can be readily traversed when necessary. Designs V and B with heights of 6 in. and greater are thought to have limited vehicle redirection characteristics at low speeds and shallow impact angles, but for design purposes they should not be assumed to provide redirection. Designs D and R are intended to allow easy traversability and for that reason are standard along urban interchange ramps and roundabout truck aprons respectively. They are also commonly used along residential streets to allow driveway ingress/egress in the absence of aprons or curb cuts. Design S is more easily mountable and may be considered more aesthetically pleasing and bicycle friendly than Design B but also provides superior delineation to that of Design D, making it suitable for various urban and suburban uses. Design S is also occasionally used where curb is intermittently introduced along rural highways, subject to maintenance preference and site-specific judgment.

A curb can adversely affect vehicle behavior when struck, particularly curbs 6 in. or greater in height and especially at higher speeds. For this reason, where curbs are used along high-speed (50 mph design speed or greater) facilities, MnDOT’s practice is to construct only sloping configurations less than 6 in. high.

The use of curb in conjunction with traffic barrier is discussed in Chapter 10. Care must be exercised in design, as the effect curbs have on vehicle dynamics may or may not be consistent with the conditions under which barrier systems are tested and approved. Compatible combinations of curbs and barriers are typically subject to restrictions on their relative placement.