

# APPENDIX I

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## APPENDIX I

### SECTION I-1- INTRODUCTION

#### INTRODUCTION

Traffic Barriers discussed in this appendix include w-beam guardrail, cable, and concrete median barrier and their associated terminals, do not prevent collisions or injuries from occurring and should only be used where the result of striking a fixed object hazard or leaving the roadway would be more severe than the consequence of striking the barrier. The roadway should be examined to determine the feasibility of adjusting site features so that the barrier will not be required (e.g. flattening a fill slope, removing a hazardous object such as a drainage headwall, etc.). The initial cost to eliminate the need for a barrier may appear excessive; however, the fact that a barrier installation will require maintenance costs for many years should not be overlooked.

When guardrail is wholly or partially within the project limits for any construction project, including heavy maintenance and RRR projects, the engineer shall perform a guardrail assessment on all existing guardrail systems and components including terminals. Refer to Traffic Engineering Division IIM-TE-366 for upgrade warrants. If warranted by IIM-TE-366, the existing guardrail shall be upgraded to the latest standard in accordance with the current VDOT Road and Bridge Standards for the following situations: \*

1. **When located within the project limits of a construction project.** When the line of rail extends outside the project limits with more than 60% of the existing substandard line of rail within the project limits, then the entire run shall be replaced including terminals and upgraded to meet the current Standards. If less than 60% is within the project limits, then only the rail within the project limits is to be upgraded. Consideration should be given to upgrading the entire line of rail even when less than 60% is within the project limits.
2. **When located within the project limits of transportation improvements associated with permitted land development projects.**
3. **When any road is accepted into the state roadway system, all guardrail must comply with current Standards and must include NCHRP 350 or MASH (Manual for Assessing Safety Hardware) approved terminals and rail systems. (For VDOT approved Developer Construction Plans, the Secondary Street Acceptance Requirements (SSAR) govern.)**

For definitions of RRR utilizing Federal Funding on National Highway System (NHS) Roadways, see VDOT's Road Design Manual, [Appendix A, Section A-4](#) Guidelines for RRR Projects.

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\* Rev. 1/18

## SECTION I-2- BARRIER SYSTEMS AND TERMINALS

### **W-BEAM GUARDRAIL GENERAL CRITERIA**

During NEW CONSTRUCTION, always install to the current Standard heights.

New and existing guardrail within the project limits must meet NCHRP 350 or MASH requirements.

All guardrail shall be replaced or upgraded in accordance with Section I-1.

All w-beam guardrail panels shall be lapped in the direction of traffic. With two-way traffic, the laps on the right side of traffic are to be in the direction of traffic or toward the downstream end.

Refer to the Road and Bridge Standards for transition designs between flexible and more rigid systems.

All roadside safety devices are to be equipped with identification numbers as per Code of Virginia [§33.2-274.1](#).\*

### **GR-2 STRONG POST W-BEAM GUARDRAIL**

For GR-2, the **minimum height is 27 3/4"** to the top of the rail with a **maximum height of 28 3/4"**. When checking the height on a length of GR-2, measure at increments of 50' where there is a rail splice at a post. Refer to the GR-INS Standard for measuring w-beam guardrail based on location on a slope.

The wood and composite blockouts can be used interchangeably within a single run of guardrail for new installations, replacements, and upgrades. When existing 6"x8" wood or composite blockouts are replaced, the blockouts shall include routing to prevent blockouts from rotating. When wood posts with wood blockouts are used, they shall have **TWO** nails (one on each side) to prevent rotation of blockouts. No metal blockouts are to be replaced in-kind or installed new, and no washers will be used.

When posts are **removed** and are to be **reused**, the Post shall meet the current standard length. They shall be reused only with Standard wood or composite blockouts. When resetting rail, the posts shall be removed and the holes backfilled prior to reinstalling the posts. The height of the rail shall be measured to ensure it meets the current VDOT [Road and Bridge Standards](#).

See Section 3 for guardrail installation adjacent to curb.

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\* Rev. 7/15

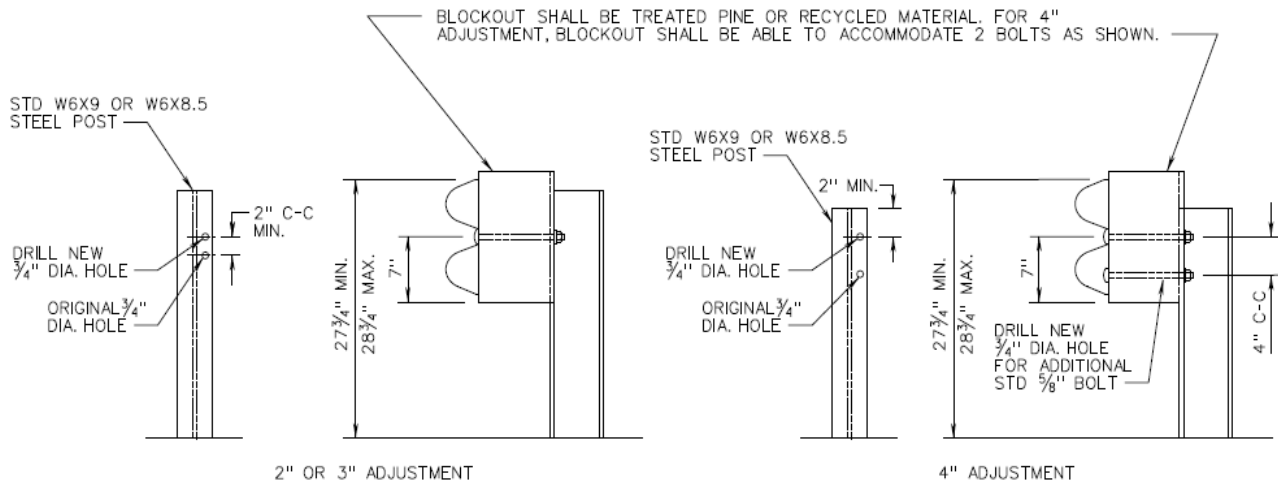
**MB-3 STRONG POST MEDIAN BARRIER W-BEAM GUARDRAIL**

MB-3 is double sided GR-2 that consists of a line of single posts with a blackout and w-beam guardrail on each side designed for use in the median when the back side of the system is within the clear zone of the opposing traffic.

**MB-5 WEAK POST MEDIAN BARRIER W-BEAM GUARDRAIL**

MB-5 is double sided GR-8 that consists of a line of single posts with a w-beam guardrail on each side designed for use in the median when the back side of the system is within the clear zone of the opposing traffic. MB-5 must be transitioned to MB-3, per the Standards, prior to a terminal or attaching to an FOA.

**For raising existing GR-2 rail height only**, a 2", 3" or 4" vertical adjustment of the GR-2 (steel post only) rail is allowed by adjusting the blackout and redrilling the post provided the post is acceptable to use. Centerline of holes shall be no closer than 2" to another hole and no less than 2" from top of post. Hole diameter shall be 3/4". For 4" adjustment, 2 bolts shall be used; one above the other with centerlines of holes 4" apart. Blockouts must be able to accommodate the additional bolt for a 4" adjustment. See detail below. If the GR-2 rail cannot be adjusted to the current Standard GR-2 height, then the guardrail is to be reset.



ONE TIME 2", 3" OR 4" ADJUSTMENT OF GR-2 BLOCKOUT FOR STANDARD GR-2 STEEL POST ONLY

FOR RAISING EXISTING GR-2 RAIL HEIGHT ONLY

### **GR-3 LOW TENSION CABLE GUARDRAIL**

For GR-3, the minimum height is 27" to the top cable with a **maximum height of 28"**. Measure the height at the posts in increments of 48 feet.

When GR-3 is hit, the cable will typically drop rendering the entire run nonfunctioning until it is repaired. GR-3 should be placed to avoid nuisance hits.

Cable guardrail should normally be used only on Limited Access projects which provide "Recoverable Areas" exceeding 14 feet in width.

### **GR-8 WEAK POST W-BEAM GUARDRAIL**

For GR-8, the minimum height is 31 1/2" to the top of the rail with a **maximum height of 33"**. When checking the height on a length of GR-8, measure at increments of 50' where there is a rail splice. Refer to the GR-INS Standard for measuring w-beam guardrail based on location on a slope.

When resetting or reusing rail, the height of the rail shall be installed to meet the current VDOT Road and Bridge Standards. If the particular site conditions are appropriate, a Standard GR-2 system can be used.

The latest GR-8 design can be used even for speeds greater than 45 mph.

When upgrading existing weak post guardrail to the current weak post Standard GR-8, curb shall be removed. If curb cannot be removed see Section 3 for guardrail installation adjacent to curb.

Proper transitions **MUST** be incorporated when GR-8 transitions to the current standard height. Splice locations and backup plates for the GR-8, and for the GR-2 transitions from GR-8, 8A, 8B to the GR-2 must be done in accordance with current Standard designs.

At transitions, measure the height at the posts at the beginning and end of the transition between standard systems.

### **GR-10 GUARDRAIL OVER CULVERT IN LOW FILLS**

For GR-10, the height is the same as GR-2.

Standard GR-10, Type I, II, or III is the preferred method of installing guardrail over culverts where fills are less than 4'-0" above the culvert top slab.

Type I is adaptable to culverts with a perpendicular width of 10'-6" or less. A 25' section is used with the rail double nested and one post omitted. Type II is adaptable to culverts with a perpendicular width of 18'. A length of 37'-6" is used with the rail double nested and two posts omitted. Type III is for use with a perpendicular width of 23'. A length of 100' is used with the rail double nested and three posts omitted.

In situations where the use of Standard GR-10 is not feasible, an allowable alternative may be the TEXAS T-6 (BGR-01) for speeds  $\leq$  45 m.p.h.

## **HIGH TENSION CABLE**

Currently, there is no standard for high tension cable since each available proprietary system is unique. Therefore, a Special Provision is needed when used on a project. Drawings of the proposed system must be submitted for approval prior to installation.

## **CONCRETE BARRIER**

The "F" shape of Standard MB-7D, E, F Concrete Median barrier will be the only configuration allowed. Testing conducted using small cars proved that reducing the height of the break between the upper and lower slopes from 10" (old Standard MB-7A, B, C Jersey shape) to 7" decreases the probability of a vehicle overturning.

Only Traffic Barrier Service with a positive connection and "F" shape or VDOT approved steel barrier will be allowed. See Standard MB-INS for positive connection details.

MB-12A, B, C 50" Concrete Median Barrier (Tall Wall) is for glare control where there is a high volume (10% or greater)\* of truck traffic or other warrants as noted below. This barrier is designed with the same shape as MB-7D, E, F and extended to the 50" height.

Conditions to keep in mind when considering concrete median barrier for glare control are median width, vertical grades and horizontal curvature (especially to the left). Since warrants are not available for determining the need for glare screens, a recommendation from the District Traffic Engineer based on existing accident data would be the typical factor determining a need.

When a double-faced median barrier is used to separate roadways with minimal width medians and the barrier faces are at different elevations due to the roadway elevations, superelevation, etc., the designer can specify Concrete Median Barrier MB-8A, Type I, II, or III for grade differentials varying from zero to 3'0" maximum. Grade differences exceeding the 3'0" maximum will be submitted to the Standards and Special Design Section for design.

Concrete Median barrier (Tall Wall), MB-13 (TYPE. I, II, or III) is for use with the same conditions that govern the use of MB-12A, B, C, 50" MB-13 is designed with the same shape as MB-8A and extended to the 50" height on the roadway with the highest elevation.

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\* Rev. 7/16

Temporary Concrete Barriers are referred to as Traffic Barrier Service Concrete (TBSC) and are used to prevent errant vehicles from entering a work zone when site conditions warrant their use. Requirements for anchoring TBSC are described in Appendix A of the Virginia Work Area Protection Manual. When a project requires the use of an anchored barrier the designer shall label and quantify the barrier as Standard MB-10A or MB-11A. The Standard MB-10A Traffic Barrier Service Concrete Parapet (Single Face) is for use on bridge decks only. The Standard MB-11A Traffic Barrier Service Concrete (Double Face) is intended for use on bridge decks and roadway pavements. See the current Road & Bridge Standards MB-10A and MB-11A for installation details.\*

## **BARRIER TERMINALS GENERAL CRITERIA**

Guardrail/barrier terminals are to be provided for all installations regardless of "Functional Classification". Terminals develop the necessary tension at the end of the system in order to redirect a vehicle and, if hit, minimize the damage to a vehicle and its occupants. The termini of guardrail/barrier must be designed and located so there are no exposed rail element ends within the clear zone which a vehicle could impact.

New and existing terminals within the project limits must meet NCHRP 350 or MASH requirements. Those that are not within project limits but are part of a length of barrier that has 60% within the project limits (see Section 1) must also meet NCHRP 350 or MASH requirements. All terminals shall be installed as they were tested in accordance with NCHRP 350 or MASH. Lapping of guardrail terminals must be per the Standards.

A site investigation shall be made to determine whether a terminal should be upgraded, or eliminated. For gaps between two runs of guardrail  $\leq 200' \pm$ , closing the gap by continuing the run of guardrail is recommended, thereby eliminating the need for a terminal. If a cut slope is within approximately  $200' \pm$  longitudinal distance from the location of the terminal and is sufficient to install a Standard GR-6, the guardrail shall be extended to the cut slope and a cut slope terminal (Standard GR-6) shall be used.

Radial guardrail not to be used in place of a MASH or NCHRP 350 approved terminal section. Radial terminal sections that exist within the project limits shall be upgraded to an approved terminal section. For guidance on the use of radial guardrail, see Radial Guardrail in Section 3 or contact the Central Office Standards and Special Design Section.

If the w-beam terminal installation site does not provide at least 75' of clear run-out path in addition to the length of need required for the barrier (exclusive of the terminal), a parallel terminal (Standard GR-9) shall be used instead of a flared terminal (Standard GR-7). If an extensive amount of grading would be required for site preparation to install a flared terminal (Standard GR-7), consideration should be given to using a parallel terminal (Standard GR-9) that does not require as much site preparation. Before replacing a substandard terminal, the location of the existing terminal shall be checked to ensure sufficient length of need has been provided in the run of guardrail to adequately shield the hazard for which it was installed.

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\* Rev. 11/15



In some cases it may be necessary to extend the guardrail to better shield the hazard or to provide for a more suitable site that would not require grading.

The site preparation for all installations shall be in accordance with current Standards and manufacturers' requirements.

### **GR-3 LOW TENSION CABLE TERMINAL**

If the introduction of cable guardrail is in close proximity to an adequate cut section, it should be extended and terminated in the back slope of the cut ditch. (Use 15:1 transition for Design Speeds of 70 MPH or 13:1 transition for design speeds of 60 MPH or less). GR-3 is terminated on both the run-on and run-off ends with an NCHRP 350 anchor assembly as detailed in Standard GR-3.

### **GR-6 W-BEAM BURIED IN THE CUT SLOPE TERMINAL**

The Standard GR-6 terminal is used as a means of terminating run-on or run-off ends of GR-2 or GR-8 guardrail on divided or undivided roadways by burying the end of the guardrail into the cut slope. This terminal treatment requires enough right of way to extend the guardrail beyond the ditch line per the standards. The guardrail should terminate a minimum of 1' below the ground elevation of the backslope. The rail preceding the GR-6 terminal is to maintain a consistent height relative to roadway profile grade to prevent errant vehicles from impacting at an improper height. If more than a 200 foot extension of GR-2 is necessary to tie GR-6 terminal into the back slope, cost-effectiveness would justify use of a GR-9.

When terminating GR-8, a transition to GR-2 (In accordance with the current Road and Bridge Standards) must be used prior to rail flaring away from roadway.

Existing GR-6 installations that are not NCHRP 350 or MASH compliant shall be upgraded the current Standard per policy to ensure the following:

1. Proper Height per current standards. Where existing GR-6 terminals were installed with the height of rail following the ground line at a height of 27" to 28", this installation method caused the terminals to be low, both in front of and behind the ditch line. These low installations may allow an errant vehicle to vault over the top rail and go behind the guardrail, failing its intended protection from hazards.
2. The end anchorage is sufficiently buried in the slope with 1' min. cover.

### **GR-7 W-BEAM FLARED TERMINAL**

When using the Standard GR-7 terminals on standard shoulders, the 4-foot flare as specified in the standard drawing or manufacturer's specifications must be provided for the installation to function as tested. This is considered essential to proper performance for end-on impacts to eliminate the potential of spearing.

In consideration of the 4-foot flare requirement to construct the terminal treatment for GR-7, the shoulder in the terminal area must be widened sufficiently to accommodate site preparation for the terminal. The terminal should be located, or the barrier may need to be extended as needed, to provide a clear run-out path behind the terminal. The total length of the terminal is typically 37.5 feet. The length of need (LON) typically begins at the 3<sup>rd</sup> post.

On bridge replacement projects and other projects (involving guardrail upgrades) on which existing shoulders are of insufficient width and for which there are no provisions for widening such shoulders, additional fill material is required to be placed to ensure that the flare can be correctly installed. Typical installation details are shown in the Standard GR-7. Projects with paved shoulders - Details are shown on Standard MC-4).

When this situation occurs for the GR-7 terminals on projects without normal grading operations, a pay item [Guardrail Terminal site preparation (GR-SP) - Item Code 13349 with pay unit of Each] is to be used to cover the required embankment, benching and reseeding. (A Special Provision Copied Note is available for use in contracts involving this pay item.)

New construction projects provide the necessary shoulder widening for the required guardrail terminals; therefore, the separate pay item for site preparation is not applicable.

### **GR-8 WEAK POST W-BEAM GUARDRAIL RUN-OFF ONLY TERMINAL**

For run-off terminal treatment with Standard GR-8 (weak post guardrail), the GR-8, Type II terminal is acceptable only for divided roadways outside of the opposing traffic clear zone or one-way traffic situations. The guardrail is to be flush with the concrete anchor throughout the length of the anchor assembly in order for the installation to function properly without shearing the bolts.

Two-way traffic on an undivided facility would introduce the possibility of opposing traffic impacting an intended run-off terminal for another lane. Therefore, a GR-6, GR-7 or GR-9 terminal must be used with the proper transition to GR-2.

### **GR-9 W-BEAM TANGENT TERMINAL**

The GR-9 terminal is intended solely for use on the end of a tangent w-beam installation. Typically, a 1 foot offset (50:1 over the 50 foot terminal length) is provided at the impact head to reduce nuisance hits.

The total length of the terminal is typically 50 feet. The length of need (LON) typically begins at the 3<sup>rd</sup> post from the end. For GR-9 installations used to terminate GR-8 (weak post guardrail), an additional transition of GR-2 is required.

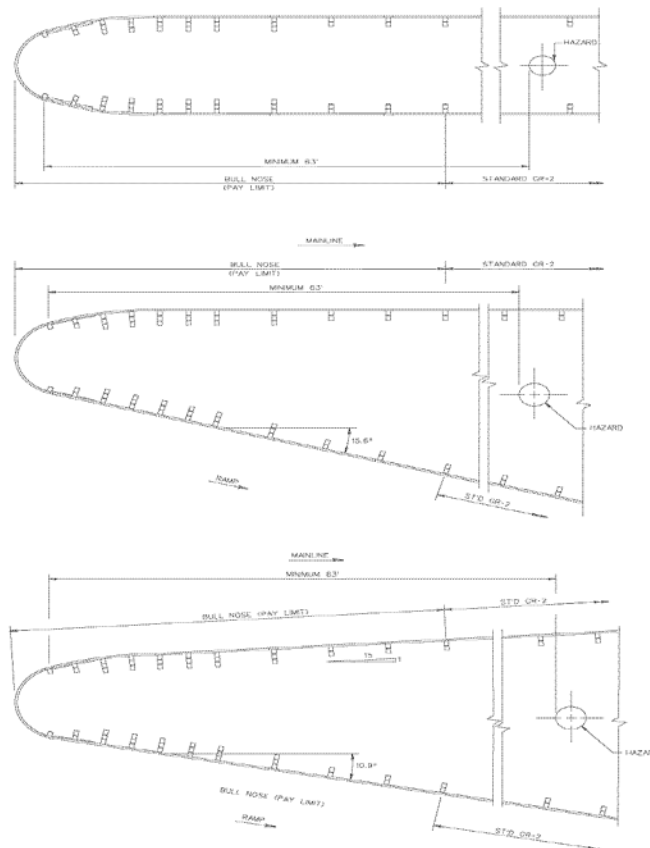
Guardrail terminals for use with median guardrail (MB-3) are designed to be hit from either side.

## GR-11 W-BEAM RUN-OFF ONLY TERMINAL

Use of a Standard GR-11 is required for trailing end terminal anchorage on divided or one-way roadways for run-off conditions only

## THRIE-BEAM BULL NOSE BARRIER

When the use of guardrail on depressed medians is being planned to shield bridge piers or other hazards, the designer should also consider the use of an NCHRP 350 Thrie-beam Special Design Bull Nose Barrier. (Pay Item - Bull Nose Barrier-Each - Computer Est. No. 13601.) Installation layout details will be furnished by the [Standards/Special Design Section](#) for each Bull Nose Barrier location for inclusion in the plans. Bull nose barriers must not be used behind or on top of curbs or raised medians. A 10:1 or flatter cross slope is required at least 60 feet before the installation and is carried through to the GR-2. See the below detail for median and gore area layouts.



SPECIAL DESIGN BULL NOSE BARRIER

## **MB-9A TURNED DOWN CONCRETE MEDIAN BARRIER TERMINAL**

For run-on treatment outside the clear zone with operating speeds of 40 mph or less and all run-off treatment, a concrete turned down terminal (MB-9A) can be used to terminate concrete barrier.

## **IMPACT ATTENUATORS**

During the preliminary design stages for new construction and for rehabilitation or reconstruction of existing highways, the need for and space requirements of impact attenuators to shield non-removable fixed objects should be considered. This will ensure compatibility with the final design and the impact attenuator that is to be installed. Since these devices are expensive to install and maintain, the hazard must be studied to determine if elimination is possible or its inherent hazard potential can be economically reduced to tolerable limits by less drastic safety treatments, such as guardrail, breakaway supports, set-back, safety shape, etc. Present procedure requires that the proposed site be selected by the roadway designer and reviewed by the [Standards/Special Design Section](#) for the type of impact attenuator to be used. When requesting the review and installation details from the [Standards/Special Design Section](#), submit a print of the plans with a transmittal slip giving the project number, UPC numbers, activity number, roadway design speed and advertisement date. In no case will attenuation devices be designed for placement behind curbed locations. For additional data, refer to the AASHTO's *Roadside Design Guide*.

Devices subjected to traffic speeds greater than 45 mph must meet Test Level 3 requirements per NCHRP 350 or AASHTO's MASH as appropriate.

Devices subjected to traffic speeds of 45 mph and less must meet Test Level 2 requirements per NCHRP 350 or AASHTO's MASH as appropriate.

## **TYPE 1 RE-DIRECTIVE LOW-MAINTENANCE IMPACT ATTENUATORS AND IMPACT ATTENUATOR SERVICE\***

Impact attenuators will be installed in areas that have a design speed (for permanent installations) or a posted speed (for temporary installations) of  $\geq 50$  mph and have an ADT more than 25,000 VPD. These devices must come from the "Type 1 (Re-Directive Low-Maintenance)" category of the VDOT's NCHRP 350 Approved Product List (See link below).

For a list of approved devices see VDOT's NCHRP 350 Approved Products List at: <http://www.virginiadot.org/business/locdes/nchrp350-index.asp>

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\* Rev. 7/16

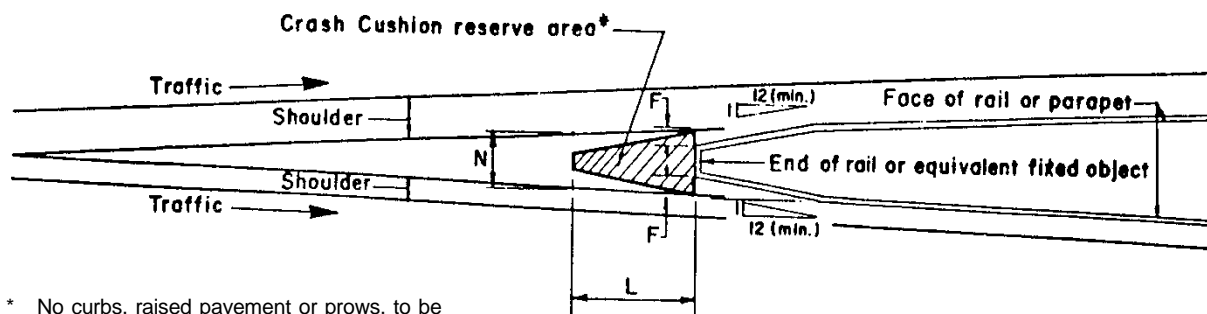
Fixed roadside hazards vary in size and shape, and in the degree of danger they present. The traffic passing by varies as well in volume, speed and density. For these reasons a selection from various types of crash cushions can be designed to meet the special requirements of a particular hazard site.

Figure I-3-3 suggests the area that should be made available for impact attenuator installation. Although it depicts a gore location, the same recommendations will generally apply to other types of fixed object hazards that require shielding. The unrestricted conditions represent the minimum dimensions for all locations except for those sites where it can be demonstrated that the increased costs for obtaining these dimensions (as opposed to those for restricted conditions) will be unreasonable. The preferred condition dimensions should be considered optimum. The space provided by these dimensions will seldom be fully used by an impact attenuator.

These dimensions are recommended so there will be additional space available should experience dictate the need for a device capable of slowing larger vehicles than originally considered or for producing lower deceleration forces. In the meantime, the unoccupied space provides valuable motorist recovery area. Site conditions may dictate the type of attenuator needed. For example, fixed objects such as barrier ends which are less than 3 feet wide should be shielded by a narrow impact attenuator. Similarly, wide hazards, e.g., those greater than 3 feet, can be effectively shielded best by a wide impact attenuator or approved sand barrier arrays.

| Design Speed<br>on Main line<br>[mph] | Dimensions for Crash Cushion, Reserve Area [feet] |    |   |                         |    |   |           |    |   |
|---------------------------------------|---|----|---|-------------------------|----|---|-----------|----|---|
|                                       | Minimum   |    |   |                         |    |   | Preferred |    |   |
|                                       | Restricted Conditions                             |    |   | Unrestricted Conditions |    |   |           |    |   |
|                                       | N   | L  | F | N                       | L  | F | N         | L  | F |
| 30                                    | 6   | 8  | 2 | 8                       | 11 | 3 | 12        | 17 | 4 |
| 50                                    | 6   | 17 | 2 | 8                       | 25 | 3 | 12        | 33 | 4 |
| 70                                    | 6   | 28 | 2 | 8                       | 45 | 3 | 12        | 55 | 4 |
| 80                                    | 6   | 35 | 2 | 8                       | 55 | 3 | 12        | 70 | 4 |

Source: The 2011 AASHTO *Roadside Design Guide*.



\* No curbs, raised pavement or prows, to be built or remain in the area surrounding or occupied by the crash cushion.

**FIGURE I-2-1**

Source: The 2011 AASHTO *Roadside Design Guide*.

## SECTION I-3 BARRIER INSTALLATION CRITERIA

### BARRIER WARRANTS

The determining warrants for Traffic Barriers on VDOT projects are (1) Embankment Heights (see below) and (2) Fixed and Hazardous Objects within the Clear Zone (see TABLE I-3-1).

| SYSTEM CLASSIFICATION             |                                  | TRAFFIC VOLUMES   | FILLS OVER 7.5' | FILLS OVER 15' | AT OBVIOUS NEEDS SUCH AS BRIDGES, LARGE END WALLS, PARALLEL WATER HAZARDS, ETC., AND FILLS WHERE RECOMMENDED DURING FIELD INSPECTION |
|-----------------------------------|----------------------------------|-------------------|-----------------|----------------|--|
| INTERSTATE - PRIMARY AND ARTERIAL | FILLS WITHOUT RECOVERABLE SLOPES | ALL               | √               |                | √  |
|                                   | FILLS WITH RECOVERABLE SLOPES    |                   |                 |                | √  |
| SECONDARY AND FRONTAGE ROADS      |                                  | ADT OVER 1000     | √               |                | √  |
|                                   |                                  | ADT 1000 - 250    |                 | *√             | √  |
|                                   |                                  | ADT LESS THAN 250 |                 |                | √  |
| URBAN                             |                                  | ALL               |                 |                | √  |

\* Exception - Bristol, Salem, and Staunton Districts. Traffic barriers are to be provided only at obvious needs such as bridges, large endwalls, parallel water hazards, etc., and fills where recommended at field inspection.

When fill slopes are 3:1 or flatter, a barrier is not required unless there are hazardous obstacles within the clear zone limits. This may include the clear runout area if the fill slope is between 3:1 and 4:1 (see Appendix A Figure A-2-4).

In some limited situations in which the embankment slopes significantly downward, a vehicle could encroach farther from the through traveled way and the clear zone might not be adequate. In these cases, guardrail should be considered.

## DETERMINING WARRANTS FOR ROADSIDE BARRIERS

| <u>Typical Fixed and Hazardous Objects Within The Clear Zone</u>  | <u>Guardrail Required</u> |    |
|---|---------------------------|----|
|   | YES                       | NO |
| 1. Sign Support (ground mounted):<br>(A) Post of breakaway design (a)   |                           | X  |
| (B) Post not meeting breakaway criteria (b)(c)(d)   | X                         |    |
| 2. Lighting/Signal Poles and Towers<br>(A) Breakaway design   |                           | X  |
| (B) Not meeting breakaway design (b)(c)(g)(h)   | X                         |    |
| 3. Bridge parapet ends; piers and abutments at underpasses  | X                         |    |
| 4. Retaining walls and culvert headwalls  | X                         |    |
| 5. Trees with a diameter of 4 inches or greater (e)   | X                         |    |
| 6. Utility Poles (f)  |                           | X  |
| 7. Above ground utilities (telephone pedestals, etc.) (i)   | X                         |    |
| 8. Rough rock cuts and large boulders   | X                         |    |
| 9. Streams or permanent bodies of water more than 2 feet deep (h)   | X                         |    |
| <p>NOTES</p> <p>(a) Multiple post installations where the spacing between posts is less than the minimum spacing required for breakaway shall be replaced or shielded by guardrail.</p> <p>(b) Every effort should be made to convert non-breakaway to breakaway.</p> <p>(c) Where these devices exist and cannot be converted to breakaway, relocated or removed, the choice of guardrail should be in accordance with the deflection shown in Table I-3-2.</p> <p>(d) Wood posts larger than 6" x 8" nominal size do not meet the breakaway requirements even if drilled.</p> <p>(e) Every effort should be made to remove the tree rather than shield it with guardrail.</p> <p>(f) Guardrail will not normally be used to shield a line of utility poles. However, where guardrails are used in front of utility poles for other reasons, the choice of guardrail should be in accordance with the deflection shown in Table I-3-2.</p> <p>(g) Pedestal poles, except for those used for power supply should be converted to breakaway standards where possible.</p> <p>(h) A field review and evaluation should be made to determine if guardrail is suitable for protecting motorists from these roadside hazards.</p> <p>(i) Consideration should be given to placing utilities underground.</p> |                           |    |

**TABLE I-3-1**



## **FIXED OBJECTS WITHIN DEFLECTION AREA**

No fixed objects, regardless of their distances from the edge-of-pavement, will be allowed within the deflection zone of the guardrail system to assure that the guardrail system will perform as designed. This will include overhead sign supports, walls, drainage structures, bridge piers, signal supports, utility poles, trees, etc. Additionally, the deflection zone must be free of breakaway signs, signals, and luminaire supports since their performance when struck by deflecting guardrail is unknown and untested. If a sign or luminaire support must remain within the deflection zone, it must be a breakaway design.

When it is impractical to locate hazards outside of the deflection zone of standard guardrail, it may be necessary to use concrete barrier.

Table I-3-2 (Typical Barrier/Guardrail Selection and Placement) specifies the minimum offset distance required from "hazardous objects" to meet deflection requirements of the different types of barrier systems.

## **PONDS OR OTHER BODIES OF WATER**

Barrier is to be constructed on all functional classifications at ponds or other bodies of water over 2 feet in depth when it is within the design clear zone.

## **SHORT GAPS**

Short gaps between barrier installations should be avoided. When the areas of concern are less than 200 feet apart, the barrier protection shall be made continuous.

## **BARRIER TYPE SELECTION**

When it has been determined that a barrier is required, a determination must be made as to the type of barrier that is to be used. System and terminal specific guidelines are provided later in this appendix that can be used in making a barrier system selection. The most desirable system is one that offers the lowest accident severity at the least cost within the given constraints.

The AASHTO *Roadside Design Guide* presents eight items which must be considered before a system selection is made.

- Performance capability
- Deflection
- Site conditions
- Compatibility
- Cost
- Maintenance
- Field Experience
- Aesthetics (occasionally)

In taking all eight items into account, the deflection, strength, and safety requirements should never be compromised. Table I-3-2 groups the Standard types of guardrail by three systems: flexible, semi-rigid and rigid. The table includes barrier height, maximum dynamic deflection, minimum offset from hazardous object, post spacing, and typical terminal treatment for each Standard. The Road and Bridge Standards provide transition designs for use in various situations.

Weathering steel (COR-TEN) w-beam guardrail is no longer acceptable for use in new construction or maintenance replacement due to the potential for premature material failure from excessive rust. Guardrail terminals are no longer available with weathering steel. An acceptable “aesthetic” guardrail is powder coated galvanized rail with steel posts or treated wooden posts conforming to applicable VDOT Standards, NCHRP 350 and/or MASH requirements, and does not create undue maintenance problems and/or costs. Powder coating guardrail will have a significant impact on the cost and will require a separate pay item for powder coating. Contact the Materials Division for approved treatment methods.

Roadside safety hardware not accepted prior to the adoption of AASHTO’s Manual For Assessing Safety Hardware (MASH) must meet the requirements of MASH.

Roadside safety hardware accepted prior to the adoption of AASHTO’s Manual For Assessing Safety Hardware (MASH) must meet the requirements of The National Cooperative Highway Research Program (NCHRP) Report 350.

| BARRIER SYSTEM                          | VDOT STANDARD                              | BARRIER HEIGHT  | MINIMUM OFFSET FROM HAZARD (MAXIMUM DYNAMIC DEFLECTION) (A) | POST SPACING | DIVIDED ROADWAY OR ONE-WAY TRAFFIC |                                    | UNDIVIDED ROADWAY OR TWO-WAY TRAFFIC |                                |
|---|--|-----------------|---|--------------|------------------------------------|------------------------------------|--------------------------------------|--------------------------------|
|   |  |                 |   |              | RUN-ON TERMINAL END TREATMENT      | RUN-OFF TERMINAL END TREATMENT (B) | RUN-ON TERMINAL END TREATMENT        | RUN-OFF TERMINAL END TREATMENT |
| <b>FLEXIBLE</b><br>(WEAK POST OR CABLE) | GR-3                                       | 27" to 28"      | 11'   | 16'-0"       | GR-3                               | GR-3                               | GR-3                                 | GR-3                           |
|   | GR-8                                       | 32 1/4" (J)     | 7'  | 12'-6"       | GR-6,7,9 (F)                       | GR-8, TY. II                       | GR-6,7,9 (C) (F)                     | GR-6,7,9 (C) (F)               |
|   | GR-8A                                      | 32 1/4" (J)     | 5'  | 6'-3"        | GR-6,7,9 (F)                       | GR-8, TY. II                       | GR-6,7,9 (C) (F)                     | GR-6,7,9 (C) (F)               |
|   | GR-8B                                      | 32 1/4" (J)     | 4'  | 3'-1 1/2"    | GR-6,7,9 (F)                       | GR-8, TY. II                       | GR-6,7,9 (C) (F)                     | GR-6,7,9 (C) (F)               |
|   |  |                 |   |              |                                    |                                    |                                      |                                |
|   | MB-5 (D)                                   | 32 1/4" (J)     | 7'  | 12'-6"       | GR-9 (I)                           | GR-9 (I)                           | N/A                                  | N/A                            |
|   | MB-5A (D)                                  | 32 1/4" (J)     | 5'  | 6'-3"        | GR-9 (I)                           | GR-9 (I)                           | N/A                                  | N/A                            |
|   | MB-5B (D)                                  | 32 1/4" (J)     | 4'  | 3'-1 1/2"    | GR-9 (I)                           | GR-9 (I)                           | N/A                                  | N/A                            |
| <b>SEMI-RIGID</b><br>(STRONG POST)      | GR-2                                       | 27 3/4" (L) (K) | 3'  | 6'-3"        | GR-6,7,9 (F)                       | GR-11 (L)                          | GR-6,7,9 (F)                         | GR-6,7,9 (F)                   |
|   | GR-2A                                      | 27 3/4" (L) (K) | 2'  | 3'-1 1/2"    | GR-6,7,9 (F)                       | GR-11 (L)                          | GR-6,7,9 (F)                         | GR-6,7,9 (F)                   |
|   | MB-3 (E)                                   | 27 3/4" (L) (K) | 3'  | 6'-3"        | GR-9 (I)                           | GR-9 (I)                           | N/A                                  | N/A                            |
| <b>RIGID</b><br>(CONCRETE BARRIER)      | MB-7D, 7E<br>7F, 12A, 12B,<br>& 12C<br>(H) | 32"             | 0'  | N/A          | IMPACT ATTENUATOR (G)              | N/A                                | IMPACT ATTENUATOR (G)                | IMPACT ATTENUATOR (G)          |

TABLE I-3-2

**TYPICAL BARRIER SELECTION AND PLACEMENT**

For permanent installations only; not to be used for TMP plans.

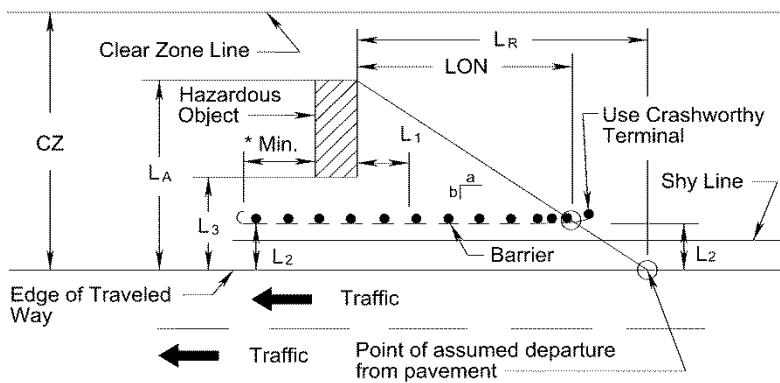
**NOTES:**

- (A) The deflection zone of all GR-2, 3 & 8 systems will be measured from the back of the post and must be totally clear of any hazards in order to assure that the system will perform as tested. MB-3 & MB-5 will be measured from the face of rail closest to hazard.
- (B) The noted terminal and treatments apply when the terminal is installed outside the clear zone of opposing traffic. If run-off terminal is installed within the clear zone of opposing traffic, see note (C).
- (C) A transition from weak post system to strong post system (terminal) must be provided in accordance with St'd. GR-INS drawings.
- (D) For use in wide, flat medians (> 30' width).
- (E) For use in narrow medians (approximately 10-30 feet width).
- (F) If more than a 200' of additional GR-2 is necessary to bury the end of the rail in the backslope (St'd. GR-6, terminal), use a St'd. GR-7 or GR-9 terminal. For St'd. GR-6 installations, St'd. GR-2 must be installed from the terminal to the beginning of the flare before introducing St'd. GR-8.
- (G) Concrete "turned down" terminals (Std. MB-9A) may be used for locations outside clear zone when operating speed is 40 mph or less.
- (H) For use in medians 0-30 feet wide.
- (I) GR-9 for MB-3. MB-5, 5A and 5B must be transitioned to MB-3 prior to terminal.
- (J) Vertical Height Tolerance for new installations, +/- 3/4".
- (K) Absolute Minimum Vertical Height for new and existing GR-2 after overlay is 27 3/4".
- (L) Vertical Height Tolerance for new installations, +1".

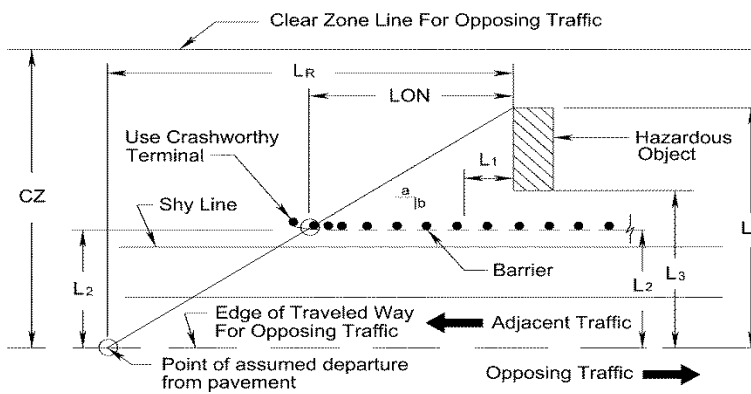
## DETERMINING LOCATION OF THE ENDS OF GUARDRAIL

Figure I-3-1 and Table I-3-3 give a method to determine the location of the end of guardrail systems. Appropriate terminals shall be placed at this point.

### Determining LON for adjacent traffic;\*



### Determining LON for opposing traffic on two-way undivided roadway;



## FIGURE I-3-1 - BARRIER LENGTH OF NEED DETERMINATION

LON = Length of Need  
 Cz = Clear Zone Width  
 LA = Distance to back of hazard, Max. = Cz  
 LR = Runout length  
 L1 = Upstream length of Guardrail prior to flare  
 L2 = Distance to Face of Guardrail  
 L3 = Distance to front of hazard  
 a:b = Flare Rate of Guardrail (if applicable)

\* For one-way traffic on undivided roadway the terminal can begin after end of hazard; 12.5' for GR-11 to terminate GR-2 & 50' for Type II run-off GR-8 terminal treatment.

$$LON = \frac{LA + (b/a)(L1 - L2)}{(b/a) + (LA/LR)}$$

$$LON \text{ (No Flare)} = \frac{LA - L2}{LA / LR}$$

| DESIGN SPEED<br>(MPH) | DESIGN TRAFFIC VOLUME                       |   |  |   | *<br>SHY LINE<br>(FT) | FLARE RATE             |                                  |                 |
|-----------------------|---|---|--|---|-----------------------|------------------------|----------------------------------|-----------------|
|                       | RUNOUT LENGTH<br>(OVER 10000 ADT)<br>Lr(FT) | RUNOUT LENGTH<br>(5000 - 10000 ADT)<br>Lr(FT) | RUNOUT LENGTH<br>(1000 - 5000 ADT)<br>Lr(FT) | RUNOUT LENGTH<br>(UNDER 1000 ADT)<br>Lr(FT) |                       | BEYOND SHY LINE        |                                  | INSIDE SHY LINE |
|                       |   |   |  |   |                       | GR-2,<br>3 & 8<br>MB-3 | MB-7D,<br>7E,7F,12A,<br>12B,&12C | ALL             |
| 80                    | 470   | 430   | 380  | 330   | 12                    | NA                     | NA                               | NA              |
| 70                    | 360   | 330   | 290  | 250   | 9                     | 15:1                   | 20:1                             | 30:1            |
| 60                    | 300   | 250   | 210  | 200   | 8                     | 14:1                   | 18:1                             | 26:1            |
| 50                    | 230   | 190   | 160  | 150   | 6.5                   | 11:1                   | 14:1                             | 21:1            |
| 40                    | 160   | 130   | 110  | 100   | 5                     | 8:1                    | 10:1                             | 16:1            |
| 30                    | 110   | 90  | 80   | 70  | 4                     | 7:1                    | 8:1                              | 13:1            |

\*Shy line is measured from the adjacent edge of pavement and is a distance beyond which a roadside object will not be perceived as a threat by a driver. In other words, a driver will not react to an object beyond the shy line offset. If possible, the roadside barrier should be placed beyond the shy line offset.

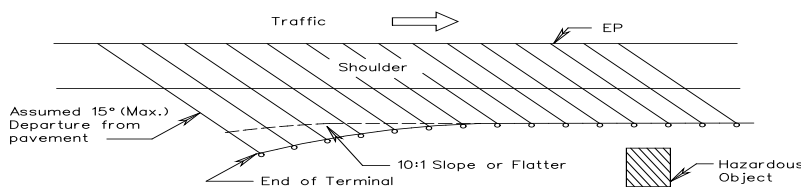
Source: The 2011 *Roadside Design Guide* Tables 5.7, 5.9 & 5.10(b)

**TABLE I-3-3**  
**DESIGN PARAMETERS FOR ROADSIDE BARRIER LAYOUT**

## SLOPES FOR BARRIERS

As a general rule, a roadside barrier should not be placed on an embankment if the slope of the embankment is steeper than 10:1; however, in special cases, such as "barn roof" ("recoverable area") slopes, it is acceptable to place semi-rigid barrier on slopes as steep as 6:1. Low tension cable can be placed anywhere on a 6:1 or flatter slope. When semi-rigid barrier is used on 6:1 slopes, a 10-foot rounding should be included between the shoulder and slope. Where it is not feasible for the entire graded median in the area of the hazard to be on a 10:1 slope, an acceptable alternative is to provide the 10:1 slope between the edge of pavement and the approach barrier (See Fig. I-3-2). A clear run-out path should also be provided behind the terminal.

When recoverable areas are less than 14 feet in width and guardrail is required, the guardrail is to be placed using at least the minimum fill shoulder width specified in the Geometric Design Standard and the recoverable area is not to be provided. Although not encouraged, guardrail is permitted on 6:1 slopes if located within 2 feet or beyond 12 feet of the shoulder hinge point.



**FIGURE I-3-2**  
**SUGGESTED SLOPES FOR APPROACH BARRIERS**

### ASPHALT PAVING UNDER GUARDRAIL

Asphalt paving shall be used under guardrail to control the growth of vegetation on projects which have asphalt concrete or portland cement concrete paved shoulders unless otherwise directed by the District Maintenance Engineer. Aggregate or soil stabilized shoulders do not require asphalt concrete paving under the guardrail. The additional paving is to begin and end without transition as detailed on “Asphalt Curb and Asphalt Paving under Guardrail” and the station limits of each segment is to be shown on the plans.

If more than one allowable type of asphalt concrete is called for on the project, the one with the lowest estimated unit cost is to be used. If the estimated unit costs are the same, the one with the smaller aggregate gradation is to be used.

For details, see Standard MC-4.

### ASPHALT CURBS

Standard MC-3B Asphalt curb is to be used, where necessary, in conjunction with paving under Standard GR-2 or 2A guardrail on high fills to provide a means of erosion control to preserve the slopes. Asphalt curb is not permitted in conjunction with paving under Standard GR-8 (weak post) guardrail. The need for the asphalt curb should be determined during the project Field Inspection. The necessity for asphalt curb may affect the type of guardrail specified.

A minimum 5' (1.5 m) length of asphalt curb is to be constructed past the end of an inlet and transitioned to grade level.

Payment for Asphalt Concrete Curb and Asphalt Concrete Curb back-up material 11' before and 5' Min. past the inlet must be set up for separate payment.

For details, see Standard MC-3B.

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\* Rev. 7/16

## GUARDRAIL INSTALLATION ADJACENT TO CURB

Guardrail is not recommended where curb, or curb and gutter is used. Whenever it is necessary to provide guardrail along a curbed section (no sidewalk or sidewalk space) Standard GR-2 or GR-2A Strong Post Guardrail shall be used in conjunction with Standard CG-3 or CG-7 (4" mountable curb) and the face of the rail shall be aligned with the face of curb. For design speeds 45 mph or less, use Standard GR-2. For design speeds greater than 45 mph, use Standard GR-2A. This decreases the possibility of an errant vehicle striking the curb and vaulting the guardrail. Standard GR-8 Weak Post Guardrail shall not be used adjacent to any curb.

If the guardrail cannot be aligned with the face of the CG-3 or CG-7 curb, the guardrail shall be offset behind the face of curb in accordance with the following:

- For roadways with design speeds less than 45 mph and using CG-2 or CG-6 (6" curb) the guardrail shall be offset a minimum of 8' behind the face of curb.
- For roadways with design speeds 45 to 50 mph, the guardrail shall be offset a minimum of 13' behind the face of curb.
- For roadways with design speeds over 50 mph, guardrail shall be aligned with the face of curb and stiffened as noted previously.

For new construction or upgrading, where guardrail is aligned with the face of curb, use the typical curb layout as shown below or as approved by the engineer at the terminal location. The designer should adjust the typical cross section as necessary to account for the curb layout. When existing curb cannot be removed or relocated, contact the Central Office Standards and Special Design Section.

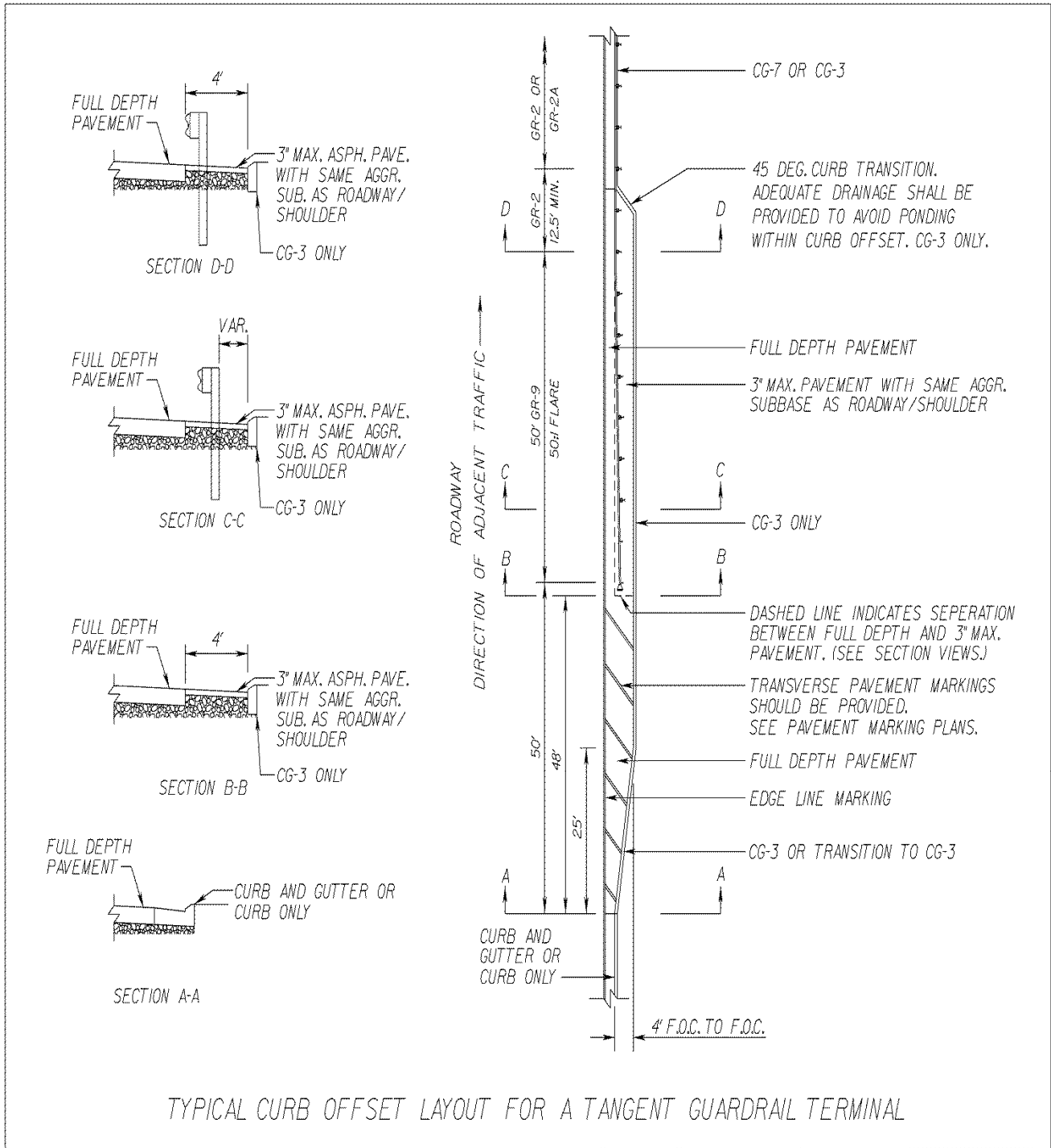


FIGURE I-3-3

TYPICAL CURB OFFSET LAYOUT FOR A TANGENT GUARDRAIL TERMINAL\*

\* Rev. 7/16



It is usually impractical to install guardrail between the roadway and a pedestrian route. When necessary to provide guardrail along a pedestrian route (at ponds, steep embankments, etc.) the guardrail shall be placed 1' behind the sidewalk (or sidewalk space) provided that minimum offset requirements from the face of curb are met. In these situations, sound engineering judgment should be used in determining guardrail locations and evaluating needs when hazards exist outside the clear zone.

When a sidewalk or shared-use path transitions from the roadway onto a bridge, guardrail is required if the travel way and the sidewalk or shared-use path are separated by a barrier on the bridge. See detail in RDM, [Appendix A\(1\)](#)<sup>\*</sup>, [Section A\(1\)-1](#) for shared-use paths and [IIM-LD-55](#) for sidewalks.

## **PAVEMENT DROP-OFFS WITH GUARDRAIL**

Whenever the pavement drop-off is within 2'-0" in front of the face of rail and in order to ensure that a pavement drop-off does not become a factor in guardrail performance, the guardrail and blockout shall be removed during the paving operation to allow the pavement to be placed as close as possible to the post. This will place the drop-off to at least the face of guardrail or behind the face of guardrail. No more than 2" drop-off allowed. Any drop-offs at the edge of pavement will have to be feathered down across a paved shoulder to the guardrail. It is critical that the guardrail height measured from the top of the overlay to the top of the guardrail be within the guardrail height tolerance limits.

Whenever it is not practical to have the pavement drop-off at or behind the face of guardrail, the drop-off shall not be located any closer than 2'-0" in front of the face of guardrail. The drop-off shall be limited to a range of 1½" to 2" in height with a 3:1 or flatter wedge to minimize the effect of the drop-off on a vehicle. Any drop-off that should happen to fall within 2'-0" of the face of guardrail and/or have a height greater than 2" shall be reviewed on a per project basis. Any drop-off that should happen to fall within 2'-0" of the face of guardrail and/or have a height greater than 2" on the NHS shall be jointly reviewed by VDOT and FHWA.

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\* Rev. 7/18

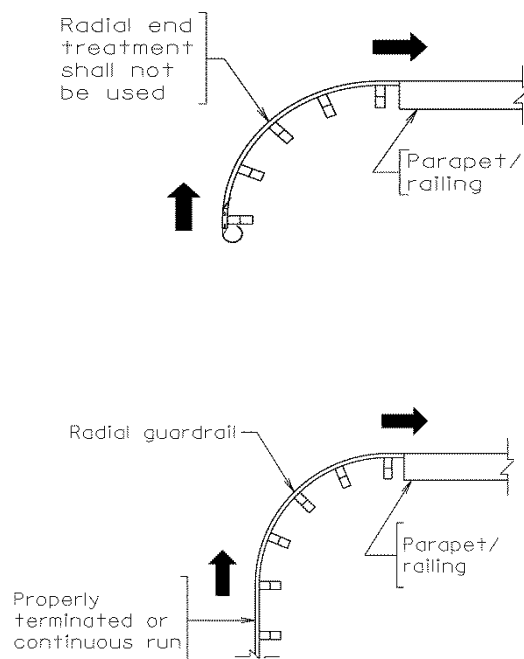
## Radial Guardrail

Radial guardrail is w-beam railing that is shop curved when the radius is 150 feet or less.

### Radial end treatments verses radial guardrail:

Radial end treatments shall not be used as they do not reduce the severity of a crash (e.g., between a bridge parapet or guardrail end at a private entrance). A crash tested terminal shall be installed.

Radial guardrail that connects two railing systems around an intersection can be used to close a gap between the two systems that is hazardous. The area within the anticipated dynamic deflection of the guardrail shall be free of fixed objects with a ground slope no steeper than 2:1. (There is a potential for greater deflections due to the possibility of high angle impacts.)



When connecting a bridge parapet to a railing system around an intersection the necessary fixed object attachment shall be installed at the parapet. The guardrail may then connect radial to the intersecting roadways guardrail and shall be terminated with a crash tested terminal. The radius used should be as flat as possible. The recommended minimum radius is 50 feet however site conditions may dictate the need for smaller radii. The absolute minimum radii for guardrail along high speed roadways shall be 30 feet and for low speed roadways shall be 20 feet. If an intersection should require the use of a radius smaller than above contact the [Standards/Special Design Section](#) for review, approval and details. Radial guardrail shall not be used on Interstate Highways or High Speed Freeways.

## **SECTION I-4 FIXED OBJECT ATTACHMENTS (FOA) AND BRIDGE GUARDRAIL ATTACHMENTS (BRGR)**

When substandard FOA's or BR-GR's exist within the limits of construction projects; both FOA's and BR-GR's shall be upgraded or replaced in accordance with the current VDOT Road and Bridge Standard or Special Design BRGR.

### **FOA**

GR-FOA's 1, 2, 3, and 4 are designed to help prevent potential vehicular snagging at the immediate upstream end of a rigid fixed object such as a vertical or safety-shaped bridge railing. These Standards use tighter post spacing and nested rail to achieve this. A rubrail is also provided to aid in the prevention of wheel snag.

A GR-FOA-3 is used as a retrofit on existing flared bridge rail terminals.

### **BRGR**

When the proposed design calls for the utilization of an existing bridge having an older type of parapet walls or rails, an appropriate detail showing the "Recommended Method for Attaching Guardrail to Bridge Rails" (BRGR) is to be obtained from the [Standards/Special Design Section](#) for inclusion in plans. Details of the existing bridge rail should accompany the request.

### **ENTRANCES OR CONNECTIONS ADJACENT TO A BRIDGE**

When entrances or connections cannot be relocated or eliminated and are located adjacent to a bridge in areas with dense entrance locations, it may be necessary to install an impact attenuator since an FOA or a BRGR with a standard guardrail terminal may not fit. Plans fitting this criteria are to be submitted to the [Standards/Special Design Section](#) for review, approval and details. Additional guardrail upstream of an entrance may provide some protection for secondary hazards such as bodies of water.

Also refer to the Section 3 which discusses the use of radial guardrail off of a bridge into a connecting roadway.

## **SECTION I-5 SAFETY/MAINTENANCE PROJECTS**

For additional guidance refer to Traffic Engineering Memos TE-366 and TE-367.

When developing details for a Safety or Maintenance project, care must be taken to ensure proper barrier installation/maintenance/replacement to upgrade any outdated locations. There may be locations on a project where the guardrail has not been hit, but the installation may not be the safest that can currently be provided if an errant vehicle impacted the guardrail. Attention should be given to the following factors in evaluating these locations:

- (1) Location of barrier:
  - relative to hazard
  - relative to pavement
  - relative to shoulder break point
  - relative to fixed objects (such as bridges); face of guardrail should be aligned with bridge rail, not closer to the roadway
- (2) Type of guardrail used (Strong Post or Weak Post):
  - no longer use Weak Post guardrail adjacent to curb
  - cable guardrail normally used only on Limited Access facility with recoverable area exceeding 14 feet
  - sufficient space for maximum deflection for type used
- (3) Terminals (need, type, proper installation, etc.):
  - end treatment needed on both ends of a run of barrier
  - terminals used with strong post guardrail
  - terminals used for run-on treatment with weak post guardrail
  - terminal treatment used as anchor for run-off end of weak post guardrail when not subject to two-way traffic
  - proper flare, anchor, post placement for terminal to effectively decrease damage caused to impacting vehicle
  - substandard terminals such as GR-5 (old turndown terminal), old standard GR-7 (those with 2' diameter concrete footings for first two posts), etc., should be replaced with approved terminals.
  - at bridges/walls, guardrail terminals should not be located closer to the roadway than the bridge rail or wall (fixed object attachment should be installed instead of separate units)
- (4) Shoulder width and site preparation:
  - provide sufficient width for site preparation
  - provide additional fill if necessary for proper flare installation
  - provide clear run-out area behind terminal installation

- (5) Fixed object attachments:
- proper attachments to fixed objects (such as bridges/walls) to reduce possibility of snagging vehicles that impact the attachment
  - align guardrail with face of bridge rail so that the end of the bridge with the fixed object attachment will not become an additional hazard
- include proper transition to gradually stiffen the overall approach