—GRIT—
Guardrail Installation Training Manual

Procedures and Practices for the Installation, Replacement, and Repair of Guardrail

Revised—November 2013
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CHAPTER 1

INTRODUCTION
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A. NEED FOR BARRIER TRAINING

1. Fatalities per year/ROR fatalities – Annually, there are approximately 40,000 fatalities on our nation’s highways; nearly 12,000 of them occur as a result of run-off-the-road (ROR) crashes.

2. Guardrail fatalities - Approximately 1,200 of the ROR fatalities are caused by guardrail as the first harmful event (see Table 1).

3. In Virginia, typically about 60% of the roadway crashes are ROR crashes.

4. Virginia’s Strategic Highway Safety Plan is committed to reduce yearly fatalities and serious injuries due to crashes.

5. Requirements for the application of guardrail systems, as well as the installation instructions for numerous guardrail devices, are becoming more complex.

6. Barrier standards and specifications are constantly changing based on vehicle designs and popularity which affects the functionality of the various guardrail systems. Testing criteria changes are also made based on vehicle designs.

B. CLEAR ZONE

Clear zone definition: The total roadside border area, starting at the edge of the traveled way, available for safe use by errant vehicles.

1. There is NO “Magic” 30-foot clear zone. This distance was used in the PAST.

2. Each location has to be reviewed and the Clear Zone calculated. - Based on experience in the 1960's at the General Motors Proving Grounds using good vehicles, experienced drivers, a familiar route and flat terrain; nearly 20 percent of the vehicles leaving the traveled way (about 60 out of 300) still went beyond 30' from the edge of road.

3. Generalized “DESIGN” CZ distances - Based on design or posted speed, traffic volume and cross-section/slope (see Table 2).

4. Principle - Provide the maximum, cost-effective clear zone. Any non-removable or non-breakaway obstacle within the “design” clear zone should be considered for shielding with a barrier system. The designer should strive for consistency along any section of roadway.
Table 1: FIRST HARMFUL EVENT FIXED-OBJECT FATALITIES

BY OBJECT TYPE

<table>
<thead>
<tr>
<th>FIXED OBJECT</th>
<th>2008</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree/Shrub</td>
<td>48%</td>
<td>4182</td>
</tr>
<tr>
<td>Utility Pole</td>
<td>12%</td>
<td>1029</td>
</tr>
<tr>
<td>Guardrail/Longitudinal Barrier</td>
<td>8%</td>
<td>686</td>
</tr>
<tr>
<td>Embankment</td>
<td>6%</td>
<td>544</td>
</tr>
<tr>
<td>Highway Sign Support</td>
<td>3%</td>
<td>283</td>
</tr>
<tr>
<td>Ditch</td>
<td>3%</td>
<td>262</td>
</tr>
<tr>
<td>Culvert</td>
<td>3%</td>
<td>221</td>
</tr>
<tr>
<td>Fence</td>
<td>2%</td>
<td>179</td>
</tr>
<tr>
<td>Building</td>
<td>2%</td>
<td>173</td>
</tr>
<tr>
<td>Bridge Piers</td>
<td>2%</td>
<td>173</td>
</tr>
<tr>
<td>Wall</td>
<td>2%</td>
<td>156</td>
</tr>
<tr>
<td>Light Support</td>
<td>1%</td>
<td>125</td>
</tr>
<tr>
<td>Other</td>
<td>7%</td>
<td>610</td>
</tr>
<tr>
<td>TOTAL FATALITIES</td>
<td>100%</td>
<td>8623</td>
</tr>
</tbody>
</table>
Table 2: CLEAR ZONE DISTANCES (IN FEET FROM EDGE OF DRIVING LANE)

<table>
<thead>
<tr>
<th>Design Speed</th>
<th>Design ADT</th>
<th>FORESLOPES</th>
<th>BACKSLOPES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>6:1 or flatter</td>
<td>5:1 to 4:1</td>
</tr>
<tr>
<td>40 MPH or less</td>
<td>Under 750</td>
<td>7-10</td>
<td>7-10</td>
</tr>
<tr>
<td></td>
<td>750-1500</td>
<td>10-12</td>
<td>12-14</td>
</tr>
<tr>
<td></td>
<td>1500-6000</td>
<td>12-14</td>
<td>14-16</td>
</tr>
<tr>
<td></td>
<td>Over 6000</td>
<td>14-16</td>
<td>16-18</td>
</tr>
<tr>
<td>45-50 MPH</td>
<td>Under 750</td>
<td>10-12</td>
<td>12-14</td>
</tr>
<tr>
<td></td>
<td>750-1500</td>
<td>14-16</td>
<td>16-20</td>
</tr>
<tr>
<td></td>
<td>1500-6000</td>
<td>16-18</td>
<td>20-26</td>
</tr>
<tr>
<td></td>
<td>Over 6000</td>
<td>20-22</td>
<td>24-28</td>
</tr>
<tr>
<td>55 MPH</td>
<td>Under 750</td>
<td>12-14</td>
<td>14-18</td>
</tr>
<tr>
<td></td>
<td>750-1500</td>
<td>16-18</td>
<td>20-24</td>
</tr>
<tr>
<td></td>
<td>1500-6000</td>
<td>20-22</td>
<td>24-30</td>
</tr>
<tr>
<td>60 MPH</td>
<td>Under 750</td>
<td>16-18</td>
<td>20-24</td>
</tr>
<tr>
<td></td>
<td>1500-6000</td>
<td>26-30</td>
<td>32-40*</td>
</tr>
<tr>
<td></td>
<td>Over 6000</td>
<td>30-32*</td>
<td>36-44*</td>
</tr>
<tr>
<td>65-70 MPH</td>
<td>Under 750</td>
<td>18-20</td>
<td>20-26</td>
</tr>
<tr>
<td></td>
<td>750-1500</td>
<td>24-26</td>
<td>28-36*</td>
</tr>
<tr>
<td></td>
<td>1500-6000</td>
<td>28-32*</td>
<td>34-42*</td>
</tr>
<tr>
<td></td>
<td>Over 6000</td>
<td>30-34*</td>
<td>38-46*</td>
</tr>
</tbody>
</table>

*Where a site specific investigation indicates a high probability of continuing accidents, or such occurrences are indicated by accident history, the designer may provide clear zone distances greater than 30 feet as indicated. Clear zones may be limited to 30 feet for practicality and to provide a consistent roadway template if previous experience with similar projects or designs indicates satisfactory performance.

**Since recovery is less likely on the unshielded, traversable 3:1 slopes, fixed objects should not be present in the vicinity of the toe of these slopes. Recovery of high speed vehicles that encroach beyond the edge of shoulder may be expected to occur beyond the toe of slope. Determination of the width of the recovery area at the toe of slope should take into consideration right of way availability, environmental concerns, economic factors, safety needs, and accident histories. Also, the distance between the edge of the travel lane and the beginning of the 3:1 slope should influence the recovery area provided at the toe of slope.
C. BARRIER WARRANTS

Since guardrail itself is a hazard, it should be used only as a last resort. Consideration should first be given to alternative measures to try to avoid the need for guardrail.

1. The first priority should be to eliminate the hazardous situation. Many items such as trees, boulders and jagged rock cuts can be removed, thereby eliminating the need for guardrail.

2. Re-grade steep slopes and ditches, and modify drainage structures, to make them traversable and fill in depressions.

3. Relocate signs and signals supports, utility poles and endwalls by placing them, as a minimum, outside of the clear zone and preferably in an area where they cannot be easily struck.

4. New structures should be designed so that headwalls, piers and abutments are outside of the clear zone.

5. Make necessary features within the clear zone of a yielding or breakaway design.

Typical features that warrant consideration of barrier installation when inside the clear zone include:

1. Bridge abutments, piers and parapet ends generally require shielding.

2. Severe longitudinal and transverse ditches, such as ditches with front slopes steeper than 4:1 and back slopes of 2:1 or steeper, generally warrant guardrail.

3. Non-breakaway sign supports, luminaire supports and high mast lighting poles.

4. Permanent bodies of water more than 2’ deep.

5. Fill slopes steeper than 3:1 with a height of 7’ 6” or more (see Figure 1). (See Road Design Manual, Section A-3-Traffic Barrier Installation Criteria).

6. Innocent bystander warrants such as playgrounds, schools, etc.

7. Rough rock cuts and boulders are usually an engineering judgment decision.

8. Retaining walls, culverts, endwalls and pipe ends are an engineering judgment based on slopes and distance from the road.
9. Trees with a diameter of 4" or more at maturity if they cannot be removed.

10. Traffic signal supports and railroad warning devices in rural areas on high speed roadways.

11. Utility poles on a case-by-case basis.

Figure 1: COMPARATIVE RISK WARRANTS FOR EMBANKMENTS

- BARRIER WARRANTED
- BARRIER NOT WARRANTED FOR EMBANKMENT. HOWEVER, CHECK BARRIER NEED FOR OTHER ROADSIDE OBSTACLES.
D. FLARE RATE

Flare rate is the rate at which a barrier moves from a larger offset to a closer offset from the edge of traveled way as a vehicle moves downstream. For one-directional roadways, the downstream flare rate, as the barrier moves away from the traveled way, is not restricted. Although it is desirable to flare the barrier system as far from the traveled way and as quickly as possible, there are two criteria that must be satisfied. First, in order to keep the angle of impact with the barrier from being too severe, the flare rate is limited to the values shown in Table 3 which are based on speed and the stiffness of the barrier system. Second, the barrier should only be flared if it is on 10:1 or flatter slopes.

Table 3: DESIGN PARAMETERS FOR ROADSIDE BARRIER LAYOUT

<table>
<thead>
<tr>
<th>DESIGN SPEED (MPH)</th>
<th>DESIGN TRAFFIC VOLUME (ADT)</th>
<th>FLARE RATE</th>
<th>* SHY LINE</th>
<th>BEYOND SHY LINE</th>
<th>INSIDE SHY LINE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OVER 10,000</td>
<td>5000 – 10,000</td>
<td>1,000 – 5,000</td>
<td>UNDER 1,000</td>
<td>SHY LINE</td>
</tr>
<tr>
<td></td>
<td>Lr(FT)</td>
<td>Lr(FT)</td>
<td>Lr(FT)</td>
<td>Lr(FT)</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>470</td>
<td>430</td>
<td>380</td>
<td>330</td>
<td>12</td>
</tr>
<tr>
<td>70</td>
<td>360</td>
<td>330</td>
<td>290</td>
<td>250</td>
<td>9</td>
</tr>
<tr>
<td>60</td>
<td>300</td>
<td>250</td>
<td>210</td>
<td>200</td>
<td>8</td>
</tr>
<tr>
<td>50</td>
<td>230</td>
<td>190</td>
<td>160</td>
<td>150</td>
<td>6.5</td>
</tr>
<tr>
<td>40</td>
<td>160</td>
<td>130</td>
<td>110</td>
<td>100</td>
<td>5</td>
</tr>
<tr>
<td>30</td>
<td>110</td>
<td>90</td>
<td>80</td>
<td>70</td>
<td>4</td>
</tr>
</tbody>
</table>

Flare the guardrail system away from the traveled way as far and as quickly as possible. Two criteria, however, must be met when designing the flare:

- The flare rate is limited to the values shown in the above table in order to keep the angle of impact with the guardrail from being too severe. The values are based on vehicle speed and the stiffness of the guardrail system.

- The guardrail should be flared only if it is on slopes of 10:1 or flatter.
E. LENGTH OF NEED DETERMINATION

1. Length of Need (LON) is defined as the length of barrier needed upstream of the beginning of the hazard to shield the hazard.

2. Calculation of the LON by a Designer is determined from a geometric formula using values based on speed, the distance from the traveled way to the back of the hazard, and the offset of the barrier from the traveled way (see Figure 2).

3. To check whether the LON is satisfactory on high speed roadways, use the procedure illustrated in Figure 3. The method illustrated in Figure 3 may only be used to check/verify the LON in the field.
Figure 2: DESIGN APPROACH BARRIER LAYOUT VARIABLES

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 = Offset of Guardrail from travelway
L3 = Distance to front of hazard
a:b = Flare Rate of Guardrail (if applicable)

LON = \frac{L_A + \frac{(b/a)(L_1 - L_2)}{L_3}}{L_2}

LON (No Flare) = \frac{L_A - L_2}{L_2}

LON = LON (No Flare) + \frac{(L_3/L_2)(L_1)}{L_2/L_3}
Figure 3: FIELD APPROACH BARRIER LAYOUT VARIABLES

\[ X = L_R \left( 1 - \frac{Y}{L_H} \right) \]

- **CZ** = Clear Zone Width
- **LH Max.** = CZ
- **LR** = Runout Length
- **Y** = Offset to Face of Guardrail
- **X** = Length of Need

No Less 12'-6" of CRASHWORTHY TERMINAL
F. GUARDRAIL TESTING REQUIREMENTS

All new guardrail installations installed after October 1, 1998, must meet NCHRP 350 testing criteria as noted in Instructional and Informational Memorandum LD-220. In addition to the NCHRP 350 testing criteria, all new devices after January 1, 2011, must meet the test criteria published in the Manual for Assessing Safety Hardware (MASH). The most common criteria specified by the Commonwealth is the NCHRP 350/MASH Test Level 3 (TL-3) which uses a 4400 lb/5000 lb pickup truck and a 1800 lb/2420 lb small car impacting the device at 62 mph. For standard guardrail sections there are two general types of crash tests: one is a series of strength tests, using the pickup truck at the designated speed impacting at 25°, the other series is the severity tests, using the small vehicle at the designated speed striking at 25°. Lower speed Test Levels 1 and 2 are conducted using the pickup truck and compact car at impact speeds of 31 and 43 mph respectively. For Test Levels 4 through 6 additional tests are conducted with larger trucks impacting at 50 mph at 15°.

In Virginia, Test Level 3 is the minimum test criteria for all standard guardrail applications with the following exceptions. Test Level 1 and 2 devices may be applicable on low speed local streets and in some work zones. Test Level 4 devices are typically required on bridges. Test Level 4, 5 and 6 devices may be used on roadways with a large volume of truck traffic, a specific type of truck traffic such as tankers, and/or severe/substandard geometrics.

G. DEFLECTION

No rigid, vertical object shall be placed within the deflection distance from the back of the barrier system (see Figure 4a). Although multi-directional (not bi-directional slip bases) breakaway devices within the deflection distance do not have an adverse effect on the performance of the system, they should be offset wherever possible beyond the deflection distance. This is primarily a maintenance consideration, since it should reduce damage to the supports. If the dynamic deflection distance cannot be achieved, the system must be stiffened in front of and upstream of the obstacle. Stiffening methods available include decreasing post spacing and double nesting of rail elements. Each stiffening method typically halves the deflection. The stiffening method should begin 25' in advance of the hazard and continue at least to the end of the hazard. Where the hazard is a solid obstacle and would not permit pocketing within the length of the obstacle, the stiffening may be eliminated beyond 25' downstream from the beginning of the obstacle. For two or more stiffening methods, the total stiffening should be 50' in advance of the hazard.
Figure 4: RECOMMENDED BARRIER PLACEMENT FOR OPTIMUM PERFORMANCE

MAXIMUM DYNAMIC DEFLECTION

a) DEFLECTION DISTANCE

1' TO 2'

b) PLACEMENT ON EMBANKMENTS
H. SOIL BACKING

Weak Post and Cable systems - The primary purpose of the posts is to hold the rail or cable at the proper height. Most of the redirection capability of the barrier system is developed through the tension in the rail or cable. There is, however, still some energy absorbed by the bending of the posts, therefore, some soil backing behind the posts should be provided. The standards for Std. GR-3 shows 3' from the shoulder break line for new construction.

Strong Post systems - Since there is a considerable contribution to the redirection capability of the system from the strength of the strong posts, it is necessary to develop adequate soil support for the post to prevent it from pushing backwards too easily. 1' to 2' of soil should be provided behind each post (see Figure 4b). If at least 1' of soil support cannot be provided, extra long posts, (8'), need to be used in lieu of standard 6' posts.

I. BARRIERS ON SLOPES

1. No barrier system is to be placed on slopes steeper than 6:1.

2. A cable system may be placed anywhere on slopes 6:1 or flatter.

3. In medians, a weak post system must be placed within one foot of the ditch bottom or a minimum of 8 feet up the ditch backslope.

4. W-beam systems may be placed anywhere on slopes 10:1 or flatter. On slopes between 6:1 and 10:1, but no steeper, the face of barrier needs to be within 2' of the hinge point or a minimum of 12' beyond the hinge point (see Figure 5). No w-beam system should be placed between 2 feet and 12 from the hinge point on a slope steeper than 10:1.
Figure 5: RECOMMENDED W-BEAM BARRIER LOCATION ON 6:1 SLOPE
J. Measuring the Height of Guardrail

The height of the cable or w-beam rail elements is critical for the proper performance of the guardrail system. There is one important point to consider in determining the technique or method used to measure the height of the cable/rail elements. The location of the guardrail system relative to the slope beneath the cable/w-beam will determine how the height of the guardrail is measured. The following bullet points coupled with the Figure 6 will provide the necessary guidance for measuring the height of guardrail systems during and after installation.

- **Cable systems** – The height of the cable system is measured from the finished grade below the cables (6:1 or flatter slope) to the top cable.

- **Weak and Strong Post W-beam systems** - If the face of the w-beam rail element is above the shoulder (10:1 or flatter slope), the height is measured from the shoulder to the top of the w-beam. If the finish grade is steeper than 10:1, but no steeper than 6:1, and the w-beam rail is within 2 feet of the shoulder/frontslope hinge point, the height is measured from the shoulder slope extended (See Figure 6). If the w-beam rail is 12 feet or more down the slope the height is measured from the ground directly below the w-beam rail.

**Figure 6: GUARDRAIL HEIGHT RELATIVE TO EDGE OF SHOULDER**

Hinge point: the point where the roadside cross section changes from one cross-slope to another, such as from the shoulder cross-slope to the frontslope.
K. CURB USE WITH GUARDRAIL

If curbs must be used, they shall only be used in conjunction with strong post systems (GR-2) subject to the following conditions:

1. For design or posted speeds less than or equal to 45 mph, curb height should be limited to a maximum of 4” mountable, (VDOT Standard CG-3 or CG-7). The guardrail should be constructed so that the face of rail is flush with the face of curb. If 6” curb (CG-2 or CG-6) is desired, or it is not practical to install the guardrail flush with the face of the 4” mountable curb, the guardrail should be constructed with a minimum 8’ offset from face of curb to face of rail.

2. For design or posted speeds greater than 45 mph, Curb height should be limited to a maximum of 4” mountable (VDOT Standard CG-3 or CG-7) and should be constructed so that the face of rail is flush with the face of curb. In areas where construction of the rail flush with the face of curb is not possible, a minimum 13’ offset is required for GR-2.

The guardrail height, when placed flush with a curb, is measured from the roadway surface beneath the face of the w-beam rail (Flow line of curb). When offset from the curb, it is measured from the ground underneath the rail.
CHAPTER 2
STANDARD GUARDRAIL SYSTEMS
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STANDARD GUARDRAIL SYSTEMS

A. GUARDRAIL REQUIREMENTS

All guardrail installations must meet current national testing criteria. The most common criteria is Test Level 3 (TL-3). Lower speed test levels and larger vehicle test levels are also available where appropriate. Typically these devices are installed in soil. For installation in rock, refer to FHWA Memorandum HAS-10/B64-B, “W-Beam Guardrail Installations in Rock and in Mowing Strips”.

B. VDOT GUARDRAIL SYSTEMS

1. Weak Post Cable System - VDOT Standard GR-3
   a. Height of cable - The top cable must be a minimum of 27" to a maximum of 28" above the finished grade. The cables are spaced 3" apart.
   b. Posts - S3 x 5.7 by 5' 3" long steel posts with an 8" x 24" soil plate.
   c. Post spacing - The standard post spacing is 16'.
   d. Deflection - Maximum dynamic deflection is 11'.
   e. Tensioning of cable - The terminals on a cable rail system shall be fitted with turnbuckles and spring compensators to maintain and adjust desired cable tensioning for the expected ambient temperature range. After the initial tensioning, and after a period of time, the cable shall be re-tensioned due to stretching of the cable. Specifications on tensioning requirements are published in Section 505 of the Road and Bridge Specifications.

2. Weak Post W-beam System – VDOT Standard GR-8, 8A, 8B, 8C
   a. Height of rail - The height to the top of the W-beam rail element shall be 32 ¼" with a tolerance of ± ¼" (31 ½" minimum - 33" maximum). If the finished grade slope beneath the face of w-beam rail is 10:1 or flatter the height is measured from the finish grade directly below the w-beam rail. If the slope of the finished grade is steeper than 10:1, but no steeper than 6:1, and the w-beam rail is within 2' of the shoulder/frontslope hinge point, the height is measured from the shoulder slope extended (See Figure 6). If the w-beam rail is placed on a 6:1 slope at a distance of 12' or more from the shoulder/frontslope hinge point, the height of the w-beam rail is measured from finish grade directly below the w-
beam rail. Please refer to Figure 6, “Guardrail Height Relative to Edge of Shoulder” for a graphic description.

b. Posts - S3 x 5.7 by 5' 3" long steel posts with an 8" x 24" soil plate.

c. Post spacing - The Standard **GR-8 post spacing is 12' 6"**.
   - The Standard **GR-8A post spacing is 6' 3"**.
   - The Standard **GR-8B post spacing is 3' 1½"**.
   - The Standard **GR-8C post spacing is 4' 2"**.

d. Deflection - **Maximum dynamic deflection for GR-8 is 7'**.
   - **Maximum dynamic deflection for GR-8A is 5'**.
   - **Maximum dynamic deflection for GR-8B is 4'**.
   - **Maximum dynamic deflection for GR-8C is 4'-6"**.

e. Washers – 2 washers 1 ¾" square by 0.135" thick shall be used on the traffic side of each post. A single round washer and double nut connection on the opposite side of these bolts.

f. Bolts - 5/16" hex bolts and nuts are to be used for rail connection to the posts.

g. Backup Plate – a 12" long w-beam backup plate (12 gauge) shall be used at each post at a non-splice location.

h. Rail Splice – located mid-span between posts.

i. Lapping:

   (1) For one-way traffic, all W-beam panels shall be lapped in direction of traffic. The upstream/run-on panel should always overlap the downstream/run-off panel including terminal connectors at fixed object attachments and at end sections on trailing end terminals.

   (2) With two-way traffic, the laps on the right side of traffic are to be lapped in direction of the adjacent traffic. The upstream/run-on panel should always overlap the downstream/run-off panel including terminal connectors at fixed object attachments and at end sections on trailing end terminals (GR-11).
3. Strong Post, Blocked-out W-beam System (Standard GR-2, 2A)

a. Height of rail - **The top of the W-beam must be a minimum of 27 ¾" to a maximum of 28 ¾".** If the finished grade slope beneath the face of w-beam rail is 10:1 or flatter the height is measured from the finish grade directly below the w-beam rail. If the slope of the finished grade is steeper than 10:1, but no steeper than 6:1, and the w-beam rail is within 2’ of the shoulder/frontslope hinge point, the height is measured from the shoulder slope extended (See Figure 4). If the w-beam rail is placed on a 6:1 slope at a distance of 12’ or more from the shoulder/frontslope hinge point, the height of the w-beam rail is measured from finish grade directly below the w-beam rail. Please refer to Figure 6, “Guardrail Height Relative to Edge of Shoulder” for a graphic description.

b. Posts and blockouts:

(1) Wood posts - 6" x 8" x 6' long with 6" x 8" x 14" wood blockouts toenailed to posts on both sides to prevent rotation. Drive the nail 2" from the top or bottom of the blockout after the bolt is installed.

(2) Steel posts - W6 x 8.5 or 9 x.6' long with 6" x 8" x 14" long routed wood or composite blockouts to prevent rotation. Steel blockouts are not acceptable for new or relocated installations. Routed 6" x 6" x 14" long wood blockouts may be used in repair work in special situations.

c. Post spacing - The Standard GR-2 post spacing is 6' 3".
· The Standard GR-2A post spacing is 3' 1½".

d. Deflection - **Maximum dynamic deflection for GR-2 is 3'.**
· Maximum dynamic deflection for GR-2A is 2'.

e. Lapping:

(1) For one-way traffic, all W-beam panels shall be lapped in direction of traffic. The upstream/run-on panel should always overlap the downstream/run-off panel including terminal connectors at fixed object attachments and at end sections on trailing end terminals (GR-11).

(2) With two-way traffic, the laps on the right side of traffic are to be lapped in direction of the adjacent traffic. The upstream/run-on panel should always overlap the downstream/run-off panel including terminal connectors at fixed object attachments and at end sections on trailing end terminals (GR-11).
4. VDOT Standard MB-5 Weak Post and VDOT Standard MB-3 Strong Post W-beam Median Barriers

a. Standards - The height of rail, post lengths, blockouts, washer requirements, post spacing and lapping are the same as that for single rail W-beam barrier (GR-2 and GR-8).

b. Deflection - Maximum dynamic deflection is generally not a concern with median barrier, except that the offset, desirably from the edge of shoulder and absolutely from the edge of traveled way to the face of the barrier, must be greater than the expected deflection.
CHAPTER 3
GUARDRAIL TRANSITIONS
CHAPTER 3
GUARDRAIL TRANSITIONS

When a length/run of guardrail contains two or more guardrail systems, or a guardrail system is connected to a rigid object, a transition must be provided to gradually reduce the deflection distances between the different guardrail systems or the rigid object. Otherwise, a vehicle may pocket or snag as the deflection distances change. This applies to all approach traffic, whether adjacent to or from the opposing direction on divided or undivided roadways.

A. WEAK POST CABLE TO STRONG POST W-BEAM (GR-3 to GR-2)

The Standard GR-2 strong post system is to be placed such that it begins a minimum of 24' upstream of the cable anchorage deadman with a minimum offset distance of 11' behind the GR-3 weak post cable system. Refer to the GR-3 standard for the additional transition offset distances.

Figure 7: STANDARD GR-3 TO STANDARD GR-2 TRANSITION

B. WEAK POST W-BEAM TO STRONG POST W-BEAM (Standard GR-INS)

Figure 8: STANDARD GR-8 TO STANDARD GR-2 TRANSITION

Standard GR-8 weak post system post spacings must be reduced from 12' 6" to 6' 3" (GR-8A) for four spaces or 25', and then to 3' 1 ½" (GR-8B) for eight post spaces or an additional 25'. The height differential should be adjusted in the eight post spacings of the Standard GR-8B prior to the Standard GR-2.
C. W-BEAM SYSTEMS TO RIGID OBJECTS (Standard GR-FOA-1, GR-FOA-2, GR-FOA-4)

Rigid objects are defined basically as any unyielding obstacle such as bridge piers, bridge parapet ends, concrete barrier and retaining walls to which guardrail must be attached. Only a Standard GR-FOA W-beam can be tied directly into a rigid object. Two methods are used to connect W-beam systems to Standard GR-FOA devices. First, a Standard GR-8 weak post system must be transitioned to the Standard GR-2 strong post system per the GR-INS standard with an additional 25 feet of GR-2 (a minimum of four posts spaced at 6' 3") prior to beginning a fixed object attachment. Second, with restricted site conditions, Standard GR-6, GR-7 or GR-9 guardrail terminal end treatments may be connected directly to a Standard GR-FOA without the need for an additional 25 feet of GR-2.

There are many transition systems available for strong post guardrail to rigid objects. Some are dependent on the shape of the rigid object. The two predominant shapes are a vertical wall (GR-FOA-1) and a concrete safety shape (GR-FOA-2). Typically, all of these transitions incorporate features to gradually increase the stiffness to reduce the deflection distances between the systems and provide a smooth, strong connection to the rigid object. First, decrease post spacing; second, double nest two W-beam sections at the rigid object; third, provide a strong connection to the rigid object; and fourth, provide a method to prevent wheel snag at the base. In addition to these four items, GR-FOA-1 and GR-FOA-2 standards require that the two posts installed adjacent to the rigid object be larger and longer.

![Figure 9: STANDARD GR-FOA-1](image-url)
Transitions to the concrete barriers/parapets with vertical or safety shapes are called “direct” transitions and they must have a rubrail to prevent snagging on the base of the concrete barrier or parapet which protrudes towards the roadway.

The strong connection to the rigid object is generally made by using a “Michigan Shoe” terminal connector (Standard GR-HDW, W Beam terminal connector) bolted to the concrete.
D. GUARDRAIL ATTACHMENT TO TEMPORARY CONCRETE BARRIER IN WORK ZONES (Standard GR-FOA-CZ)

Existing guardrail that is immediately upstream of temporary concrete barrier must be appropriately treated to prevent a vehicle from being directed into the end of the concrete barrier. At a point 50 feet prior to ending the guardrail, extend concrete barrier behind the end of the guardrail posts (flaring the barrier at the taper specified in the Work Area Protection Manual). Connect the standard GR-2 guardrail to the barrier with a standard fixed object attachment. Standard GR-FOA-CZ is the typical design to be used. If there are any other concerns, then other approved FOA’s may be used.

Rubrails are suggested but not required for fixed object attachments in construction zones. A construction zone is a location that requires good engineering judgment for any safety concerns that may warrant the use of a standard FOA which includes the rubrail, especially if the concrete barrier cannot be extended behind the guardrail post(s).

E. REDUCING W-BEAM GUARDRAIL DEFLECTION

Rigid objects or unyielding obstacles (hazard) such as poles, piers, etc. may be within the deflection distance of standard w-beam guardrail systems. As noted in previous sections in this chapter, a w-beam system’s deflection can be reduced using two methods. The preferred method is to reduce the standard post spacing of the w-beam system. The second method is to double nest the w-beam rail elements or mount a second w-beam rail on the back of the posts (GR-2 systems only). As illustrated in Figure 12 below and in the GR-INS standard, the stiffening of the w-beam system must begin 25 feet in advance of the hazard and continue to the opposite end of the hazard. If on an undivided roadway with two way traffic, the stiffening of the w-beam system must begin 25 feet in advance of the hazard in both directions.

Figure 12: REDUCING W-BEAM GUARDRAIL DEFLECTION (GR-INS)
CHAPTER 4
GUARDRAIL TERMINALS
CHAPTER 4
GUARDRAIL TERMINALS

The function of a terminal is twofold. It must develop the necessary tension at the end of the system to redirect a vehicle and to minimize the damage to the vehicle and its occupants if hit.

A. NCHRP 350 TERMINAL REQUIREMENTS

All guardrail terminals installed must have passed NCHRP 350 testing or MASH testing criteria. There are only three test levels for terminals. They are for speeds of 31, 43, and 62 mph. Each test level uses a 4400 lb pickup truck and a 1800 lb. small car. To pass the criteria, a terminal may have to pass up to eight individual tests including head on hits and high angle impacts.

It should be noted that all approved terminals must be installed as they were tested and approved. This includes the lapping of rail sections in the direction that they were tested. This requires that a terminal on a run-off or downstream end of a guardrail run must be lapped the same way as the system was tested regardless if it is on a one-way or two-way roadway.

B. NCHRP 350 and MASH APPROVED GUARDRAIL TERMINALS

All FHWA currently approved guardrail terminals can be found at the web site http://safety.fhwa.dot.gov/roadway_dept/road_hardware/index.htm. VDOT approved products can be found on VDOT’s web site http://www.virginiadot.org/business/locdes/nchrp350-index.asp.

1. Weak Post Cable System (Standard GR-3)

A cable terminal, similar to those in use today, has been tested and has passed the testing at TL-3. This standard shows the cables tapered down to the ground and anchored in a concrete deadman, preferably in a backslope. The location of the terminal should be determined by the LON procedure previously described. If the anchor is buried in the back slope, the full height of the barrier should be carried 75' upstream of the hazard before crossing the ditchline and tying the cables into the concrete deadman (see discussion in Chapter 3, Section A). The concrete anchor/deadman shall be constructed per the detail in the Standard GR-3.

Constant tension is maintained in the cable system with springs as part of one anchor and turnbuckles to adjust the tension based on the ambient temperature at installation as required in the specifications.
2. **Weak Post W-beam System (Standard GR-8, Type II)**

There is no NCHRP 350 approved terminal for the weak post W-beam system with run-on locations at this time. Run-on conditions must include a strong post terminal and 50 feet of Standard GR-2 and GR-INS transition to the weak post W-beam system. If the run-on locations for one-way traffic on divided roadways the GR-INS transition is not required. When the system is installed under run-off locations for one-way traffic on divided roadways, a turned-down anchorage which develops the necessary tension may be used.

3. **Strong Post W-beam Systems**

   a. **Buried in Backslope Terminal (Standard GR-6)**

   The most desirable method to terminate guardrail is to bury the end in a back slope where it cannot be hit end on. This system should be used when the front/fore slope is 4:1 or flatter. It should also be used even when the barrier system LON would normally end downstream of a cut slope if the cut slope is within 200' and there is not a large available runout area (200' x 50') beyond the terminal. The buried terminal must provide the necessary anchorage to develop the required tension forces and must be deep enough so that the end of the rail will not become exposed. Three methods of providing the anchorage are available. The first two has 6' steel posts at 6'-3" spacing with steel plates attached (either bolted or welded), to which the beam is attached with four bolts at each post. The second utilizes a concrete deadman 3' x 2' x 2' to which the rail is attached with a terminal connector to bolt anchors which are either cast in-place or drilled. Each of these anchors must have a minimum of 1' of cover (see standard) which must be compacted on the same plane as the normal ground slope with no mounds or “bubbles” being made. The third method is to anchor the w-beam rails to a rock cut slope with a 1:1 or steeper slope.

   If there is a ditch at the bottom of the 10:1 slope, the height of the rail should be measured from the 10:1 slope extended. A bottom rail should be added when the height between the groundline and the bottom of the rail exceeds 18”. The top of the top rail is held level relative to the edge of shoulder typically until it reaches the ditch bottom, then is buried and anchored. The bottom rail begins at the first post downstream of where the height between the bottom of the top rail and the ground exceeds 18”. It is bolted on the back of the post. It is then carried across the ditch bottom, buried, and anchored to a plate on the last post before the end anchor. When a bottom rail is used, the posts must be 8' long. No more than 18" can be exposed under the bottom rail. No more than this maximum is allowable even if it means lowering the top rail elevation relative to the shoulder edge.
Regardless of whether one or two rails are used, the rail must not cross the ditch bottom until it has extended a minimum of 75' upstream from the beginning of the hazard being shielded, typically the cut to fill slope transition. Two situations where the length of the rail may be shortened are: where the backslope to which the rail is to be anchored is 1:1 or steeper which would preclude a vehicle from climbing over the rail; and if the result of a vehicle climbing over the rail where it is buried would not present a significant danger. After it crosses the ditch bottom, it should end 50' upstream, offset a maximum of 8' (based on a 4:1 cut slope) back from the ditch bottom. This last 50' may be tapered down to provide the required minimum cover, and the offset may be reduced when a steep backslope would cause the cover to be greater than 1'.

Typically these devices are installed in soil. For installation in rock, refer to FHWA Memorandum HAS-10/B64-B, “W-Beam Guardrail Installations in Rock and in Mowing Strips”.

b. Flared Terminals (Standard GR-7)

A flared terminal configuration is one which flares the end of the terminal from the normal line of the barrier. Currently, only a 4' flare is accepted. The flared system is designed to allow a vehicle impacting on or near the end to pass on through the end of the terminal with minimal reduction of speed or energy.

Breakaway Cable Terminals (BCTs) and Modified Eccentric Loader Terminals (MELTs) are types of generic flared terminals that were previously used; however, they are no longer acceptable as TL-3 systems under NCHRP 350 requirements.

Types of approved flared terminals include the following:

1. Slotted Rail Terminal (SRT-350)

2. Flared Energy Absorbing Terminal (FLEAT-350)

All terminal systems are proprietary or patented and the manufacturer’s installation instructions must be precisely followed. Each utilizes a breakaway cable anchorage system, to develop the terminal tension (see FHWA, VDOT, and the manufacturer’s web sites for approved products).

The offsets for each post for the required flare of the terminal system are to be provided in accordance with the manufacturer’s specifications. If the terminal is located on either a tangent or a curve flatter than 3000' radius, the offsets are measured from a line extended from the standard run of barrier (even if it is on a flare). If the terminal is located on a curve sharper than 3000', the offsets for terminals
located on the outside of the curve are the same as above. If the terminal is on the inside of the curve, the offsets are measured from a tangential line extended from the end of the standard section of barrier. If the curve is so sharp as to make the offset less than the standard section offset, the offset will be held at the standard section offset (refer to Standard GR-7 detail).

As noted above, a vehicle hitting the end of these terminals, either head-on or at an angle, will break away the end and pass through with little absorption of energy. It is, therefore, imperative that a large runout area free of hazards be available downstream of the beginning of the terminal. This area would desirably be as long as 250' and as wide as 40', but at least the width of the design clear zone area. This amount of area will generally be provided if a LON determination has been performed. If an adequate clear area is not available, one of the GR-9 parallel terminals described below may be more appropriate since for small angle hits they have the capability to capture the vehicle and bring it to a stop within the terminal length. In all cases, there should be no obstacle in the 75' from the beginning of the terminal unless it is connected to a concrete barrier or bridge parapet.

c. Parallel Terminals (Standard GR-9)

Parallel terminals are straight systems that may be placed parallel with the roadway. These systems are designed to allow a vehicle impacting head-on to be brought to a controlled stop by absorbing its energy. For higher angle end impacts, the vehicle will pass through with little absorption of energy and reduction in speed. Some of the parallel systems utilize a large impact head at the beginning of the terminal which protrudes in front of the barrier. Offset the impact head 1' using a straight line flare for 50'.

Types of approved parallel terminals include the following:

1. Extruder Terminal (ET-2000)

2. Sequentially Kinking Terminal (SKT-350)

Note: A Beam Eating Steel Terminal (BEST) has also passed NCHRP 350 TL-3, but it essentially is being replaced with the SKT-350.

3. Crash-cushion Attenuating Terminal (CAT-350)

4. Brakemaster 350

The anchorage for these systems shall be in accordance with the manufacturer’s specifications.
All of these terminal systems are proprietary or patented and the manufacturer’s installation instructions must be followed (see FHWA, VDOT and Manufacturer’s web site for approved products).

Since the last two terminals have additional capabilities, they can be used as median or two sided end terminals and in gores. They are usually more costly, therefore, they are not competitive with terminals 1 and 2 for one side rail barriers, even though they are totally acceptable. The other flared and parallel systems must not have a backrail within 50' of their beginning. The Brakemaster may have some advantage in rock areas since it only requires two ground holes for its anchorage. The remaining supports are on skids and slide along a firmly compacted surface. The Brakemaster and CAT must not be used on the end of roadside barriers with one rail if there is any likelihood that there could be an opposite direction hit on the back side, since they would create a possible spearing or snagging condition.

The first three systems above utilize the breakaway cable anchorage. All the hardware remaining after a post breaks away must not exceed 4" projection in a 5' cord. Although the terminals, as noted above, are designed to absorb all the energy of the impacting vehicle in head-on and low angle hits, higher angle impacts will probably result with the vehicle passing through with minimal reduction in energy. It is, therefore, necessary to have a clear runout area available downstream of the beginning of the terminal. Again, this area will generally be provided if a LON determination has been performed. However, there are many cases where it will not be practical to have the guardrail end at the desired location. For those situations, the parallel terminals provide some additional capability over the flared terminals since they will probably capture the vehicle in the small angle impacts. Since the anchorage for the Brakemaster does not breakaway, it may be more able to capture a medium angle impacting vehicle. In all cases, there should be no obstacle in the first 75' from the beginning of the terminal unless it is connected to Fixed Object Attachment, concrete barrier or bridge rail.

4. Median Barrier Terminals

When a median barrier is likely to be hit from either side, only the CAT and the Brakemaster terminals as described above may be used for a W-beam median barrier system. If the barrier is unlikely to be hit on the back side due to being at least 40' away from traffic, single face barrier terminals may be used if called for on the plans. For the cable barrier system, the current standard terminal will be used. When a terminal is subject to being hit often, or is very close to traffic, a higher type, more sophisticated terminal/crash cushion is generally preferred. This course does not address crash cushions. When a crash cushion is used to terminate a W-beam barrier, the barrier system still must have its tension requirement provided.
5. Terminals for Curbed Sections

There are currently no terminals approved for use in conjunction with curbs. The best advice for high speed roadways is:

1. Widen the outside travel lane by 4’ and install the terminal in front of the curb per detail in IIM-LD-220

2. Drop the curb to 2" height for approximately 50' in advance of the end of the terminal so the vehicle is at the appropriate height when contact is made. For a parallel terminal, the 2" height should be carried an additional 12' beyond the upstream end of the terminal, and the end of the terminal should be offset 1' to keep the impact head behind the face of curb. For a flared terminals, the 2" height should be carried 37' beyond the upstream end of the terminal. A request for a detail of this design may be submitted to Location & Design Division’s Standards/Special Design section.

3. Taper the rail back from the face of curb on a 25:1 taper for 50', raising the height an amount equal to the height of curb, and use a crashworthy terminal based on this line of the 25:1 extended

6. Trailing End Terminals

The trailing end or downstream end of a barrier system that is not likely to be hit by opposing traffic only needs to develop the necessary tension of the barrier system. This can be done in several ways.

The best way is to use the trailing end anchorage, Standard GR-11, which uses the principle of an anchorage cable which is restrained by the steel bearing plate against a wooden post in a steel foundation tube, similar to approach end terminals. The second post and strut are unnecessary in this installation. The soil plate is placed on the upstream side of the tube. This last post is generally located approximately two spaces beyond the end of the hazard. Due to the large dynamic deflection of the weak post system, this terminal should only be used with a length of GR-2 and a transition from GR-8 to the GR-2 as described in Chapter 3 and the Standard GR-INS detail.

Turned-down terminals that develop the necessary tension may also be used. Again, the full capability of the barrier system must be available at the end of the hazard. This system may be desirable for use to terminate a barrier that is considerably outside the clear zone for the opposing traffic where there is still some likelihood of an opposing traffic hit. The weak post turned-down terminal (Std. GR-8, Type II), with full anchorage, is acceptable for the trailing end of the weak post barrier.
7. **Bullnose Terminal**

The current design for the Bullnose Terminal is a special design insertable sheet available upon request from the Location & Design Division’s Standards/Special Design section. This Thrie Beam Terminal design is NCHRP 350 approved, but it is recommend that all other options be addressed before its use.

C. **GAPS BETWEEN BARRIER RUNS**

When the end of one barrier run terminates within 200' of the beginning of the next downstream barrier run of the same type of barrier, and there is no obvious reason for the gap, the terminals should generally be eliminated and the runs connected together.

D. **SITE GRADING**

With the exception of the buried in backslope terminal which was tested on a 4:1 max. frontslope, crash testing is generally done on flat terrain. It is, therefore, desirable to reproduce this feature as close as practical for field installations. For barrier terminal installations that occur at the top of frontslopes, the following principles should be followed. If the barrier installation is offset far from the edge of the traveled way in accordance with the criteria described under guardrail on slopes above, the terminals may be placed on that cross-slope. Details are illustrated in the respective GR-7 and GR-9 standard sheets.

1. Grading in front of the terminal - The ground between the roadway and the terminal must be graded to a 10:1 or flatter cross-slope for the length of the terminal. There are no exceptions.

2. Grading in advance of the terminal - A grading platform should be developed upstream of the end of the terminal so the approaching vehicle will be stable when it strikes the end of the terminal. A triangular wedge of embankment must be provided from the edge of the normal shoulder grading back to the end of the grading at the end of the terminal on a 10:1 cross-slope. The taper on this wedge for new construction and reconstruction should be 15:1. For 3R work, using only the Standard GR-9, the taper should be at least 10:1 (see Figure 8). The slope beyond the 10:1 platform should be gentle so as not to introduce a discontinuity in the parallel side slope.

3. Grading behind the end post - The 10:1 grading in front of a terminal should extend behind the terminal so that a vehicle impacting the end of the terminal head-on will be relatively level. For new and reconstruction, the platform should extend a minimum of 5'-0" behind the end post. For 3R work, using only the Standard GR-9, the grading should be as close as possible to new construction but must extend a
minimum of 2'-0" behind the blocked out terminal posts for the length of the terminal from a point 10'-0" prior to the impact head (see Figure 9).

4. Grading behind the terminal downstream of the end post - The grading should be safely traversable for a vehicle passing through the end post. Because the vehicle may be somewhat unstable after impacting the terminal end, this area should be as flat as possible and extend some distance downstream. Desirably, the slope should be no steeper than 4:1 except in restricted 3R situations.

5. Protrusion of stub above finished grade – If a steel tube is used the top of the steel tube is not to protrude more than 4" above the ground. This is the same requirement as that for breakaway devices to allow a small vehicle to safely pass over the remaining stub of a breakaway device (see Figure 10). If the steel soil plate on a foundation tube is exposed, adequate grading has not been provided. Also, the height of the steel strut, as described under Breakaway Cable Anchorage, is a good telltale sign of adequate site grading. There shall not be more than 2" between the ground and the bottom of the strut, and preferably, the bottom of the strut should be flush with the ground.

6. Payment for grading - For new construction and reconstruction, grading to provide the required site preparation should be incidental to general earthwork. For 3R work, a separate pay item will generally be needed for placement, compaction and seeding of borrow material. The material must be adequately stabilized to prevent erosion.
Figure 13: SUGGESTED ROADSIDE SLOPES FOR APPROACH BARRIERS

1:10 SLOPE OR FLATTER

15:1 MAX (10:1 MIN)

END OF NEED

AREA OF CONCERN

SHOULDER

EDGE OF THROUGH TRAVELED WAY

DIRECTION OF TRAFFIC
E. BREAKAWAY CABLE ANCHORAGE INFORMATION

Terminals with exposed ends have many common features necessary to assure proper field performance. The tests on these systems were conducted on level ground and under precise installation conditions. All systems utilize an anchored cable to develop required tension for downstream hits. For end-on hits, the vertical end of the terminal is broken away, allowing the vehicle to continue downstream.

With exception of the Brakemaster system, the exposed end is a wooden post with a hole and steel sleeve in the post near ground level through which the anchor cable passes. This is called a “breakaway cable anchorage”. The cable is restrained with a bearing plate on the upstream side of the post and steel tube, and is attached to the rail element with a cable anchor bracket just in advance of the second post. The bearing plate must be restrained from rotating by using a restraining device. Some systems provide for a nail through the bearing plate to prevent rotation. For those that don’t, a nylon tie strap is utilized to restrain the bearing plate.

The anchorage cable should be taut which means that the cable can not easily be lifted more than 1”. When tightening the nut to make the cable taut, the cable must be restrained from twisting. This can be accomplished by clamping the cable with pliers or vice grips while the nut is being turned.

In order to spread the tension developed in the cable anchor to more than the first foundation tube, a steel strut and yoke is used to connect the first two foundation tubes. The strut can be used as an indication of proper installation with respect to site grading. There shall not be more than 2” between the ground and the bottom of the strut and preferably, it should be flush with the ground.

Most of the proprietary systems were tested with either different length steel foundation tubes, wood CRT posts, and steel yielding or hinged breakaway posts. Therefore, follow the manufacturer’s installation instructions for the particular unit to be installed. For utility conflicts involving soil plates on steel foundation tubes, the installer must demonstrate, normally by exposing the conflict, to the project engineer’s satisfaction that the installation will not cause damage to the underground structure.

For all posts that are part of the systems that do not sit in steel foundation tubes, weakened wood CRT posts or steel yielding/hinged breakaway posts are used. These weakened posts allow vehicles to pass through the end posts without being severely decelerated while providing adequate strength for redirection on downstream hits. The weakening for wood CRT posts is achieved by drilling two 3 ½” holes: one 16" below ground and the other centered at ground level. These holes are oriented parallel to the roadway centerline. For the steel yielding/hinged breakaway posts a proprietary and/or patented system is used to allow
vehicles to pass through the end posts without being severely decelerated while providing adequate strength for redirection on downstream hits.

Whenever a wood blockout is called for on a wooden post, the blockout must be toe nailed to the post within 2" of the top or the bottom of the blockout to prevent rotation, regardless whether it is a CRT post or a shortened wood post in a foundation tube. If steel posts are utilized routed wood or composite blockouts shall be used.

Normally, installation of the posts or steel foundation tubes is into soil. If rock is encountered, refer to the installation instructions or contact the manufacturer for instructions on an allowable method for installing the device in rock.
Figure 14: SPECIAL TRAFFIC BARRIER W-BEAM END TREATMENT GRADING ADJUSTMENT

(Application for 3R Replacement Only for Use with Std. GR-9 Terminals)
Figure 15: BREAKAWAY SUPPORT OR SOIL TUBE STUB HEIGHT MEASUREMENT

STUB OF BREAKAWAY SUPPORT

GROUND LINE

5' CHORD

4" MAXIMUM
CHAPTER 5
SPECIAL GUARDRAIL TREATMENTS
CHAPTER 5
SPECIAL GUARDRIAL TREATMENTS

A. GUARDRAIL AT LOW FILL CULVERTS (Standard GR-10)

When it is not possible to drive a full length post due to some obstruction such as a drop inlet, shallow culvert or electrical pull box, it is permissible to leave out one, two or three posts and modify the rail element by adding a second rail section nested inside the normal rail. The nested beams must be installed as per Standard GR-10. The splice on the back rail must align with that on the front rail.

B. EXTRA BLOCKOUTS (Standard GR-INS)

When a post cannot be driven in its normal location, additional blockouts may be added to provide more offset, allowing the post to be placed farther back. For one post only, and only in unusual circumstances, a total of three blockouts may be used. Two blockouts may be used for special situations for a series of posts.

C. SPECIAL DESIGNS

Virginia has a special design for guardrail installations where it is not possible to drive standard posts and the above treatments are not practical due to the length of the box culvert or other obstruction. The design uses short steel posts with steel plates welded on the bottom which can be bolted to the top of the box culvert slab. An example of this is Standard BGR-01 (Texas T-6) for speeds less than or equal to 45 mph.

Another common situation is the occurrence of driveways, turnouts or side roads along what would otherwise be a continuous run of barrier (Standard GR-INS). In the past the most common treatment for this situation was to use shop-bent radial W-beam panels around the radius, with either standard post spacing or halving the post spacing to create additional stiffness. Specific crash data indicates that this treatment does not prevent spearing and is unlikely to provide any redirection. It may also cause vaulting or excessive decelerations. **The required method is the use of a Standard GR-9 Terminal. Never use the radial end treatment method to terminate a regular run of rail.**

D. HIGH-TENSION CABLE SYSTEMS

Virginia has installed high-tension cable guardrail systems on roadways in the commonwealth. All high-tension cable guardrail systems are proprietary and/or patented. All high-tension cable guardrail systems meet NCHRP 350 TL-3 standards with some systems meeting TL-4 and the new MASH criteria. The installed system must meet the VDOT’s specifications for the project’s application. Also, the systems manufacturer’s installation instructions must be precisely followed.
Figure 15: NESTING OF W-BEAM RAIL FOR LEFT OUT POST

See Standard GR-10 for Type I, II, and III (Type I illustrated below)
CHAPTER 6
DELINEATION
CHAPTER 6
BARRIER DELINEATION

Note: Delineation shall be installed on all new, repaired and relocated guardrail and terminals.

A. LONGITUDINAL RUNS

1. Delineators shall be made of plastic and be flexible in order to recover from impact. They shall have a minimum reflective area of 7 sq in, project no more than 5" above the post or blockout, and utilize prismatic lens sheeting.

2. The delineator should be mounted on the web on top of guardrail blockout and if no blockout is used, on the web on top of the post. If wood blockouts are used, they should be installed on top of the blockout using adhesive, or either stainless or galvanized screws.

3. Install delineators at the spacing specified, typically, a maximum of 80' on centers. On curves the spacing should be reduced to comply with the spacings specified for interstate road edge delineators. When installed as part of a guardrail repair, at least one delineator should be placed upstream and one downstream of the repair.

4. The color of the delineator should match that of the roadway edgelines.

B. TERMINALS

1. Install a minimum 8" x 36" yellow reflective sheeting when a buffered end section is used.

2. When terminals are used that employ an impact head, yellow reflective sheeting with black diagonal stripes should be installed covering the full area inside the end of the impact head. The black diagonal stripes point down towards the roadway.

A special situation exists in snow country for terminals that have impact heads that protrude in front of the normal run of guardrail. Experience has shown that many of these terminals are damaged by snow plowing. In order to better mark the inside head of the terminal, a delineator tube which extends well above the top of terminal may be attached directly to the side of the head closest to the roadway. Delineator posts should not be placed in front of the terminals.
CHAPTER 7
GUARDRAIL INSTALLATION
REFERENCES
CHAPTER 7
GUARDRAIL INSTALLATION REFERENCES

In addition to the guardrail installation information in the Road and Bridge Standards covered in this manual, there are several other documents that govern the application and installation of guardrail devices. Designers, Inspectors and Installers should refer to these documents to ensure the appropriate guardrail installation specifications and guidance is followed. For all proprietary and/or patented guardrail systems and devices, the manufacturer’s installation instructions shall be followed. All guardrail systems and devices shall be installed as tested per NCHRP 350 and/or MASH criteria.

For installation procedures and inspection on installation, Section 505 of the Road and Bridge Specifications should be utilized with the standard and special design guardrail systems. Specific information on setting the tension on GR-3 cables and the reuse of guardrail systems as well as other requirements are covered in Section 505 of the Road and Bridge Specifications. In addition to the applicable standards and specifications, project specific special provisions such as requirements for high-tension cable systems, may also be utilized.

The department has published memorandums providing guidance on the application, current condition, and repair and upgrading of guardrail systems. Designers and engineers should refer to Instructional and Informational Memorandum (IIM)-LD-220 for guidance on the application of various guardrail standards and guardrail systems. Traffic Engineering (TE) Memorandum 366 and related form should be utilized to rate the condition of existing guardrail systems and devices for the completion of an engineering study. TE Memorandum 367 and related form should be utilized for the repair of damage to existing guardrail systems and safety upgrades for existing guardrail systems in the completion of an engineering study. IIM-LD-222 contains test requirement for various guardrail systems and devices as well as a listing of approved products for use in Virginia.
APPENDIX 1
Noted Problems/Acronyms and Glossary
NOTED PROBLEMS

A. STANDARD SECTIONS:

1. Too short to provide adequate LON
2. Insufficient deflection offset
3. Rail too low on overlay projects
4. Rail installed too high
5. Rotated blockouts due to lack of toe nailing
6. Improper use in conjunction with curbing
7. Improper transitions to stronger sections
8. No offset in front of the slope break for strong post soil backing
9. Poor alignment of rail and plumbness of posts
10. Hardware and fasteners left off
11. Fasteners not tight
12. Rectangular washers installed where not required
13. Rectangular washers not installed on last 50' of trailing stand-up end of strong post W-beam guardrail
14. Wood blockouts with dimensions of 6" x 6" instead of 6" x 8" as required by standard plans
15. W-beam rail and terminal connectors lapping in wrong direction

B. TERMINALS:

1. Poor site preparation with steel foundation tubes protruding, strut too high or soil plates exposed
2. Anchorage cable not taut
3. Impact heads not parallel to top of rail
4. Exposed ends of W-beam on buried in back slope terminals
5. Improper flare or improper offset on flared terminals
6. End of terminal too high
7. Improperly drilled breakaway hole height
8. Two abutting terminals side-by-side in gore and median areas
9. Inadequate length of buried terminal in cut slope
10. Height of buried terminal not consistent across ditchline
11. Buried terminals not graded and seeded properly
12. Terminal located too close to curb
13. No terminal anchorage installed on run-off end of weak post W-beam trailing end
14. W-beam guardrail not bottomed out in impact head

C. TERMINAL REPAIRS:

1. Substandard terminal replaced in kind

D. FIXED OBJECT ATTACHMENTS:

1. Improper post spacing
2. Plates not installed behind parapet walls
3. Use of threaded rods for connection projecting in front of rail
4. No FOA’s or improper FOA’s at guardrail approaches to temporary barriers in work zones

E. DELINEATION:

1. Delineators missing on guardrail runs
2. Missing delineation on flared terminals
### List Of Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>3R</td>
<td>Restoration, Rehabilitation and Resurfacing</td>
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<tr>
<td>AASHTO</td>
<td>American Association of State Highway and Transportation Officials</td>
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<tr>
<td>ADT</td>
<td>Average Daily Traffic</td>
</tr>
<tr>
<td>BCT</td>
<td>Breakaway Cable Terminal</td>
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<tr>
<td>BEST</td>
<td>Beam-Eating Steel Terminal</td>
</tr>
<tr>
<td>CAT</td>
<td>Crash-cushion Attenuating Terminal</td>
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<tr>
<td>CIA</td>
<td>Critical Impact Angle</td>
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<td>CIP</td>
<td>Critical Impact Point</td>
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<td>CRT</td>
<td>Controlled Releasing Terminal</td>
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<tr>
<td>CZ</td>
<td>Clear Zone</td>
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<tr>
<td>ELC</td>
<td>Eccentrically Loaded Terminal</td>
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<tr>
<td>ET</td>
<td>Extruder Terminal</td>
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<tr>
<td>FHWA</td>
<td>Federal Highway Administration</td>
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<tr>
<td>FOA</td>
<td>Fixed Object Attachment</td>
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<tr>
<td>FLEAT</td>
<td>Flared Energy Absorbing Terminal</td>
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<tr>
<td>ISRT</td>
<td>Improved Slotted Rail Terminal</td>
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<tr>
<td>LON</td>
<td>Length of Need</td>
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<tr>
<td>LR</td>
<td>Length of Runout</td>
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<tr>
<td>MASH</td>
<td>Manual for Accessing Safety Hardware</td>
</tr>
<tr>
<td>MELT</td>
<td>Modified Eccentric Loader Terminal</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>--------------</td>
<td>--------------------------------------------</td>
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<tr>
<td>NCHRP</td>
<td>National Cooperative Highway Research Program</td>
</tr>
<tr>
<td>NHS</td>
<td>National Highway System</td>
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<tr>
<td>REGENT</td>
<td>Redirecting Gating End Terminal</td>
</tr>
<tr>
<td>ROR</td>
<td>Run-off the Road</td>
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<tr>
<td>SKT</td>
<td>Sequentially Kinking Terminal</td>
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<tr>
<td>SRT</td>
<td>Slotted Rail Terminal</td>
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<tr>
<td>TL</td>
<td>Test Level</td>
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Glossary

**Average Daily Traffic (ADT):** The average 24-hour volume of traffic calculated as the total volume during a stated period divided by the number of days in that period.

**Area of Concern:** An object or roadside condition that may warrant safety treatment.

**Attenuator:** A device that lessens, weakens, or reduces the severity of an impact.

**Back Plate:** A steel plate used under the nuts of bolts through a concrete parapet or wall to keep the bolts from pulling out. (Standardized hardware nomenclature FPB02)

**Backslope:** The cross-section slope beyond the ditchline.

**Back-up Plate:** A 1' section of W-beam rail used with weak post w-beam guardrail barrier systems to prevent the guardrail from shearing on the steel post. (Standardized hardware nomenclature RWB01a-b)

**Barricade:** A device which provides a visual indicator of a hazardous location or the desired path a motorist should take. Its function is not to contain or redirect an errant vehicle.

**Barrier:** A device which provides a physical limitation through which a vehicle would not normally pass. It is intended to contain or redirect an errant vehicle.

- **Rigid Barrier** - A longitudinal barrier which does not deflect upon impact and dissipates a negligible amount of the vehicle's impact energy.

- **Semi-Rigid Barrier** - A longitudinal barrier ranging from practically rigid to quite flexible, which will dissipate some of the impact energy through yielding of the rail and post elements and in some cases, the soil.

- **Flexible Barrier** - A longitudinal barrier that deflects a considerable distance, dissipating much of the energy, and smoothly redirects a vehicle through the tension in the longitudinal element.

**Bearing Plate:** A plate used on the first post of a breakaway cable anchorage through which the cable passes to provide bearing. (Standardized hardware nomenclature FPB01)
**Breakaway**: A design feature which allows a device such as a sign, luminaire, or traffic signal support to yield or separate upon impact. The release mechanism may be slip plane, plastic hinges, fracture elements, or a combination of these.

**Breakaway Cable Anchorage**: A device designed to develop the tension in a W-beam barrier system using a cable attached to the W-beam rail and passing through a hole in a wood post near ground level and anchored with a bearing plate on the upstream side of the wood post. For downstream impacts on the barrier system, the wood post transfers the tension from the cable to the ground resistance; for end on impacts, the wood post breaks away releasing the cable, allowing the vehicle to continue moving without significant decelerations. Soil resistance is developed by steel foundation tube(s) into which the wood post is inserted.

**Bridge Pier**: Intermediate support structure for a bridge.

**Bridge Railing**: A longitudinal barrier whose primary function is to prevent an errant vehicle from going over the side of the bridge structure.

**Buffered End Section**: The curved end section used on the beginning end of breakaway cable terminal. (Standardized hardware nomenclature RWE04a)

**Cable Anchor Bracket**: A steel bracket or assembly used to attach a breakaway cable to a W-beam rail. (Standardized hardware nomenclature FPA01)

**Center of Mass (c.m.)**: Point within a test vehicle at which its total mass can be assumed to be concentrated.

**Clearance**: Lateral distance from edge of traveled way to a roadside object or feature.

**Clear Run-out Area**: The area at the toe of a non-recoverable slope available for safe use by an errant vehicle.

**Clear Zone (CZ)**: The total roadside border area, starting at the edge of the traveled way, available for safe use by errant vehicles. This area may consist of a shoulder, a recoverable slope, a non-recoverable slope and/or a clear run-out area. The “minimum design” width is dependent upon the traffic volumes and speeds, and on the roadside geometry. The desired width is the maximum, cost-effective attainable.

**Controlled Release Terminal (CRT) Post**: A drilled wood guardrail post used in breakaway terminals. (Standardized hardware nomenclature PDE09)
Cost-Effective: An item or action taken which is economical in terms of tangible benefits produced by money spent.

Crash Cushion: An impact attenuator device that prevents an errant vehicle from impacting fixed object hazards by gradually decelerating the vehicle to a safe stop or by redirecting the vehicle away from the hazard.

- Non-redirective Crash Cushion - An impact attenuator that does not control an angle impact on its side and allows pocketing or penetration of the system. The vehicle can reach the hazard.

- Redirective Crash Cushion - An impact attenuator that smoothly controls an angle impact on its side without pocketing or penetrating the system. The vehicle does not reach the hazard.

Crash Tests: Vehicular impact tests by which the structural and safety performance of roadside barriers and other highway appurtenances may be determined. Three evaluation criteria are considered, namely (1) structural adequacy, (2) impact severity, and (3) vehicular post-impact trajectory.

Crash Worthy: A device that has met the evaluation criteria when subjected to the applicable crash tests.

Critical Impact Angle (CIA): For a given test and the attendant range of vehicular impact angles, the CIA is the angle within this range judged to have the greatest potential for causing a failure when the test is assessed by the recommended evaluation criteria. For most tests, impact angles can range from 0 up to 25 degrees.

Critical Impact Point (CIP): For a given test, the CIP is the initial point(s) of vehicular contact along the longitudinal dimension of a feature judged to have the greatest potential for causing a failure when the test is assessed by the recommended evaluation criteria.

Curb Mass: Mass of test vehicle with standard equipment, maximum capacity of engine fuel, oil and coolant, and, if so equipped, air conditioning and additional optional mass engine. It does not include occupants or cargo.

Design Speed: The speed selected and used for correlation of the physical features of a highway that influence vehicle operation. It is the maximum safe speed that can be maintained over a specified section of highway when conditions are so favorable that the design features of the highway govern.

Device: Refers to a design or a specific part thereof, such as a breakaway device. Note that the terms “device” and “feature” are often synonymous.

Drainage Features: Roadside items whose primary purpose is to provide adequate roadway drainage such as curbs, culverts, culvert end treatments, ditches, and drop inlets.
**Downstream:** The leave side of a feature or trailing end relative to traffic. This term is synonymous with “run-off.”

**Dynamic Deflection Distance:** This is the distance a guardrail system deflects when crash tested by a 4400-pound pickup truck at 62 mph and 25° measured from the back of the guardrail post.

**End Section:** A short section of metal hardware used to terminal a run of guardrail. (Standardized hardware nomenclature RWE01a-b)

**End Treatment:** The designed modification of a roadside or median barrier at its end.

**Evaluation Criteria:** Criteria used to assess the results of a crash test or to assess the in-service performance of a feature.

**Experimental Barrier:** One that has performed satisfactorily in full-scale crash tests and promises, but not yet demonstrated satisfactory in-service performance.

**Feature:** Refers to a specific element of a highway. It may be a hardware item and its associated foundation, such as a sign or barrier installation, or it may be a geometric element, such as a side slope or a ditch cross section.

**Fixed Object Attachment:** The design used to strengthen and attach a run of strong post guardrail to a immovable fixed object.

**Flare:** the variable offset distance of a barrier to move it farther from the traveled way.

**Flared Terminal:** A guardrail terminal that is flared away from the roadway.

**Flare Rate:** The ratio expressing the flare as the relation of the longitudinal length to the offset distance.

**Foundation Tube:** A metal tube installed in the soil for the installation of a breakaway wood post used in guardrail terminals. (Standardized hardware nomenclature PTE05)

**Frangible:** A structure readily or easily broken upon impact.

**Frontslope:** The slope between the shoulder break and the ditchline.

**Gating Device (Feature):** A device designed to allow penetration of a vehicle when impacted upstream of the beginning of its redirection capability point. Note: there is some distance between the end of a gating device and the beginning of its redirecting capability.
**Geometric Feature:** A roadside cross section element such as a ditch section, an embankment, a driveway or a median crossover, or a curb.

**Glare Screen:** A device used to shield a driver’s eye from the headlights of an oncoming vehicle.

**Gore:** The location where one or more lanes of the road diverge away or converge from the previous direction of travel.

**Ground Strut and Yoke Assembly:** A metal channel section installed flush with ground at the beginning of breakaway terminals between the first two posts. (Standardized hardware nomenclature PFP01)

**High Speed Roadway:** Roadway with a design speed of 45 mph or more.

**Hinge Point:** The point where the roadside cross-section changes from one cross-slope to another, such as from the shoulder cross-slope to the frontslope.

**Impact Angle:** For a longitudinal barrier, it is the angle between a tangent to the face of the barrier and a tangent to the vehicle's path at impact. For a crash cushion/terminal, it is the angle between the axis of symmetry of the crash cushion/terminal and a tangent to the vehicle's path at impact.

**Impact Attenuator:** See Crash Cushion.

**Impact Head:** The metal unit that is attached to the end of guardrail terminals which moves down the guardrail when hit dissipating energy though various methods.

**Impact Point:** The initial point on a test article contacted by the impacting test vehicle.

**Lapping:** The placement of one section of w-beam over the next downstream section so that the connection will not snag a vehicle.

**Length of Need (LON):** That length of longitudinal barrier required upstream of an area of concern necessary to appropriately shield the area, containing and redirecting an impacting vehicle.

**Length of Runout (LR):** The theoretical distance needed for a vehicle that has left the roadway to come to a stop.

**Longitudinal Barrier:** A device whose primary functions are to prevent vehicular penetration and to safely redirect an errant vehicle away from a roadside or median hazard. The three types of longitudinal barriers are roadside barriers, median barriers, and bridge rails.

**Low Speed Roadway:** Roadway with a design speed of 45 mph or less.
**Median**: The portion of a divided highway separating the traveled ways for traffic in opposite directions, measured from edge of traveled way to edge of traveled way.

**Median Barrier**: A longitudinal barrier used to prevent an errant vehicle from crossing the highway median.

**Michigan Shoe**: Standardized metal hardware transitioning from a W-beam section to a flat section used to connect W-beam rail to a rigid object. (Standardized hardware nomenclature RWE02)

**National Highway System (NHS)**: All Interstate highways and other major arterial highways nominated by the states and designated under the National Highway System Act of 1995.

**Nesting**: The doubling of W-beam guardrail to reduce deflection.

**Non-gating Device**: A device with redirectional capabilities along its entire length. Note that the end of a non-gating device is essentially the beginning of its redirecting capability.

**Non-Recoverable Slope**: A slope which is considered traversable but on which the errant vehicle will continue on to the bottom. Embankment slopes steeper than 4:1 but no steeper than 3:1 may be considered traversable but non-recoverable if they are smooth and free of fixed object hazards.

**Occupant Impact Velocity**: Velocity at which a hypothetical “point mass” occupant impacts a surface of a hypothetical occupant compartment of a vehicle.

**Offset**: Distance between the traveled way and a roadside barrier or other obstacle.

**Operating Speed**: The highest speed at which reasonable prudent drivers can be expected to operate vehicles on a section of highway under low traffic densities and good weather. This speed may be higher or lower than posted or legislated speed limits or nominal design speeds where alignment, surface, roadside development, or other features affect vehicle operations.

**Operational Barrier**: One that has performed satisfactorily in full scale tests and has demonstrated satisfactory in-service performance.
**Parallel Terminal:** A guardrail terminal that basically is parallel to the roadway with no more than a two-foot flare.

**Penetration:** Action of a vehicle passing into or through an appurtenance by overcoming its’ directive resistance.

**Pocketing:** Action of a vehicle creating excessive lateral movement of an appurtenance which can result in an abrupt redirection back into the traffic stream.

**Recoverable Slope:** A slope on which a motorist may, to a greater or lesser extent, retain or regain control of a vehicle. Slopes equal to or flatter than 4:1 are generally considered recoverable.

**Recovery Area:** Generally synonymous with clear zone.

**Ride down Acceleration:** Acceleration by a hypothetical “point mass” occupant subsequent to impact with a hypothetical occupant compartment of a vehicle.

**Roadside:** That area between the outside shoulder edge and the right-of-way limits.

**Roadside Barrier:** A longitudinal barrier used to shield roadside obstacles or non-traversable terrain features. It may occasionally be used to protect pedestrians or ”bystanders” from vehicle traffic.

**Roadway:** The portion of a highway, including shoulders, for vehicular use.

**Run-off End:** The downstream end or trailing end of a guardrail system.

**Run-off the Road Accident:** A accident that occurs beyond the edge of pavement striking and obstacle.

**Run-on End:** The upstream end or beginning end of a guardrail system.

**Shielding:** The introduction of a barrier or crash cushion, between the vehicle and an obstacle or area of concern to reduce the severity of impacts of errant vehicles.

**Shy Distance:** The distance from the edge of the traveled way beyond which a roadside object will not be perceived as an immediate hazard by the typical driver, to the extent that he will not change his vehicle’s placement or speed.

**Slip Base:** A structural element at or near the bottom of a post or pole which will allow release of the post from its base upon impact while resisting wind loads.

**Slope:** The relative steepness of the terrain expressed as a ratio or percentage. Slopes may be categorized as positive (backslopes) or negative (foreslopes), and as parallel or cross slopes in relation to the direction of traffic.
**Slope Break:** The point at which a shoulder slope and fill meet.

**Snagging:** When a portion of a test vehicle, such as a wheel, engages a vertical element in a redirective device, such as a post, snagging is said to have occurred. The degree of snagging depends on the degree of engagement. Snagging may cause large and unacceptable vehicular decelerations.

**Soil Plate:** A rectangular steel plate attached to a guardrail post or soil tube to resist horizontal movement in the ground. (Standardized hardware nomenclature PLS03)

**Taut:** This term is used when referring to a cable anchor. A taut anchor should be no more than 1" lift from its free hanging position.

**Terminal:** A device designed to treat the end of a longitudinal barrier. An upstream terminal may function by (a) decelerating a vehicle to a safe stop within a relatively short distance; (b) permitting controlled penetration of the vehicle behind the device; (c) containing and redirecting the vehicle; or (d) a combination of a., b., and c. A downstream terminal develops the tension required for the barrier system to perform properly.

**Terminal Connector:** A W-beam guardrail connector used to attach the rail to a concrete parapet, wall or deadman. (Standardized hardware nomenclature RWE02)

**Test Article (Test Feature):** All components of a system, including the foundation as relevant being evaluated in a crash test. Note that the system may be a geometric feature such as a ditch or driveway slope.

**Test Inertial Mass:** Mass of test vehicle and all items rigidly attached to vehicle's structure, including ballast and instrumentation. Mass of surrogate occupant(s), if used, is not included in test inertial mass.

**Test Level (TL):** A set of conditions, defined in terms of vehicular type and mass, vehicular impact speed, and vehicular impact angle, that quantifies the impact severity of a matrix of tests.

**Test Vehicle:** A commercially available, production model vehicle or an approved surrogate vehicle used in a crash test to evaluate the impact performance of a test article.

**Three R (3R) Projects:** Highway construction projects for restoration, rehabilitation or resurfacing.

**Traffic Barrier:** A device used to prevent a vehicle from striking a more severe obstacle or feature located on the roadside or in the median, or to prevent crossover median accidents. As defined herein, there are four classes of traffic barriers, namely, roadside barriers, median barriers, bridge railings, and crash cushions.
**Trailing End Anchorage:** An W-beam anchorage system used on the downstream end of guardrail run to provide anchorage and tension in the rail.

**Transition:** A section of barrier between two different barriers or, more commonly, where a roadside barrier is connected to a bridge railing or to a rigid object such as a bridge pier; the upstream barrier system is less stiff than the downstream system. The transition should produce a gradual stiffening of the approach rail so vehicular pocketing, snagging, or penetration at the connection can be avoided.

**Traveled Way:** The portion of the roadway for the movement of vehicles, exclusive of shoulders and auxiliary lanes.

**Traversable Slope:** A slope on which a vehicle will likely be steered back to the roadway, be able to retained control of, or continue safely to the bottom.

**Upstream:** The approach side of a feature relative to traffic. This term is synonymous with “run-on.”

**Vehicle:** A motorized unit for use in transporting passengers or freight, ranging from an 1800 lb automobile to an 80,000 lb tractor-trailer.

**Warrants:** The criteria by which the need for a safety treatment or improvement can be determined.