Tennessee
Department of Transportation

Roadside Safety Field Guide 2014

Guidelines for the Installation and Maintenance of Roadside Safety Hardware.

U.S. Department of Transportation
Federal Highway Administration

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Contents

Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ADT	Average Daily Traffic
DOT	Department of Transportation
EMS	Emergency Medical Services
FHWA	Federal Highway Administration
L_R	Runout Length
LON	Length of Need
MUTCD	Manual on Uniform Traffic Control Devices
MASH	Manual for Assessing Safety Hardware
NCHRP	National Cooperative Highway Research Program
RDG	Roadside Design Guide
ROR	Run off Road
TCP	Traffic Control Plan
TL	Test Level
TTC	Temporary Traffic Control
TTCZ	Temporary Traffic Control Zone
WZ	Work Zone

Glossary

Adjacent Grading—Adjacent grading refers to the area on which the terminal is installed and the area immediately behind it.

Advance Grading—Advance grading refers to the area over which a vehicle may travel before any contact with a barrier terminal is made.

Anchorage—A device which anchors a flexible or semi-rigid barrier to the ground so as to develop the barrier's tensile strength during an impact. Anchorages differ from terminals in that they are not considered crashworthy.

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

Barricade—A device which provides a visual indicator of a hazardous location or the desired path a motorist should take. It is not intended 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.

Bi-directional—For the purposes of classifying crash cushions, bi-directional describes the capability of a crash cushion to safely operate the median of a divided highway or an undivided roadway, where it will be exposed to impacts from two different directions of traffic. A bi-directional crash cushion is considered. A bi-directional crash cushion is also a uni-directional crash cushion. A crash cushion is considered to be bi-directional when it has been qualified through a reverse-direction crash test.

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 a slip plane, plastic hinges, fracture elements, or a combination of these.

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

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

Clear Runout Area—The area at the toe of a non-recoverable slope available for safe use by an errant vehicle.

Clear Zone—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 desired width is dependent upon traffic volumes, speeds and roadside geometry.

Conservation of Momentum Principle—A concept of crash cushion design which involves the dissipation of the kinetic energy of an impacting vehicle by transferring the vehicles momentum to the variable masses of materials in the crash cushion, such as sand contained in sand barrels.

Cost-effective—An item or action taken that is economical in terms of tangible benefits produced for the money spent.

Crash Cushion—Device that prevents an errant vehicle from impacting a fixed object by gradually decelerating the vehicle to a safe stop or by redirecting the vehicle away from the obstacle.

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

Crashworthy—A feature that has been proven acceptable for use under specified conditions either through crash testing or in-service performance.

Design Speed—A selected speed used to determine the various geometric design features of the roadway. The assumed design speed should be a logical one with respect to the topography, anticipated operating speed, the adjacent land use, and the functional classification of the highway.

Drainage Feature—Roadside items whose primary purpose is to provide adequate roadway drainage such as curbs, culverts, ditches, and drop inlets.

End Treatment—The designed modification of the end of a roadside or median barrier.

Flare—The variable offset distance of a barrier to move it farther from the traveled way; generally in reference to the upstream end of the barrier.

Frangible—A structure quality or feature that makes the structure readily or easily broken upon impact.

Fuse Plate—The plate which provides structural reinforcement to the sign post hinge to resist wind loads but which will release or fracture upon impact of a vehicle with the post.

Glare Screen—A device used to shield a driver's eye from the headlights of an oncoming vehicle.

Hinge—The weakened section of a sign post designed to allow the post to rotate upward when impacted by a vehicle.

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

Impact Attenuator—See Crash Cushion.

Length of Need—Total length of a longitudinal barrier needed to shield an area of concern.

Length of Need (LON) Point—That point on the terminal or longitudinal barrier at which it will contain and redirected an impacting vehicle along the face of the terminal barrier.

Level of Performance—The degree to which a longitudinal barrier, including bridge railing, is designed for containment and redirection of different types of vehicles.

Longitudinal barriers—A barrier whose primary function is to prevent penetration and to safely redirect an errant vehicle away from a roadside or median obstacle.

Low Maintenance/Self Restoring Crash Cushions—Crash Cushions that either suffer very little, if any damage, upon impact and are easily pulled back into their full operating condition, or they partially rebound after an impact and may only need an inspection to ensure that no parts have been damaged, misaligned, or otherwise disabled.

Median—The portion of a divided highway separating the traveled ways for traffic in opposite directions.

Multidirectional—The capability of the fracture mechanism of a breakaway support or the plates of a split-base support to work when struck from any direction. These are also referred to as omni-directional.

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

Non-Recoverable Slope—A slope which is considered traversable but on which an errant vehicle will continue to the bottom of the slope. Embankment slopes between 3H:1V and 4H:1V may be considered traversable but non-recoverable if they are smooth and free of fixed objects.

Offset—Lateral distance from the edge of traveled way to a roadside object or feature.

Omni-directional—See Multidirectional.

Operating Speed—The highest speed at which reasonably 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 crash tests and has demonstrated satisfactory in-service performance.

Performance Level—See Level of Performance.

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

Recovery Area—Generally synonymous with clear zone.

Reusable Crash Cushions—Reusable crash cushions have some major components that may be able to survive most impacts intact and can be salvaged when the unit is being repaired.

Roadside—That area between the outside shoulder edge and the right-of-way limits. The area between roadways of a divided highway may also be considered roadside.

Roadside Barrier—A longitudinal barrier used to shield roadside obstacles or no-traversable terrain features. It may occasionally be used to protect pedestrians or "bystanders" from vehicle traffic.

Roadside Signs—Roadside signs can be divided into 3 main categories: overhead signs, large roadside signs, and small roadside signs. Large roadside signs may be defined as those greater than or equal to $50ft^2$ in area. Small roadside signs may be defined as those less than $50ft^2$ in area.

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

Rounding—The introduction of a vertical curve between two transverse slopes to minimize the abrupt slope change and to maximize vehicle stability and maneuverability.

Runout Distance Grading—Refers to the area into which a vehicle may travel after impacting a terminal ahead of its LON point.

Sacrificial Crash Cushions—Sacrificial crash cushions are crashworthy roadside safety devices designed for a single impact. These system's major comments are destroyed in impacts and must be replaced, but many of the other parts of the system can be reused.

Severity Index—A severity index (SI) is a number from zero to ten used to categorize accidents by the probability of their resulting in property damage, personal injury, or a fatality, or any combination of these possible outcomes. The resultant number can then be translated into an accident cost and the relative effectiveness of alternate safety treatments can be estimated.

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 obstacle by the typical driver to the extent that the driver will change the 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) or as a parallel or cross slope (in relation to the direction of traffic).

Staged Attenuation Device—A crash cushion that is designed to be progressively stiffer as an impacting vehicle deforms or penetrates it.

Temporary Barrier—Temporary barriers are used to prevent vehicular access into construction or maintenance work zones and to redirect an impacting vehicle so as to minimize damage to the vehicle and injury to the occupants while providing worker protection.

Terminal—A terminal is essentially a crashworthy anchorage, a device used to anchor a flexible or semi-rigid barrier to the ground. Being crashworthy, terminals are normally used at the end of a barrier that is located within the clear zone or that is likely to be impacted by errant vehicles.

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.

Transition—A section of barrier between two different barriers, or more commonly, where a roadside barrier connects to a bridge railing or to a rigid object such as a bridge pier. The transition should produce a gradual stiffening of the approach rail so vehicular pocketing, snagging, or penetration at the connection can be minimized.

Traveled Way—The portion of the roadway for the movement of vehicles, exclusive of shoulders.

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

Traversable Slope—A slope from which a motorist will be unlikely to steer back to the roadway but may be able to slow and stop safely. Slopes between 3H:1V and 4H:1V generally fall into this category.

Uni-directional—For the purposes of classifying crash cushions, uni-directional describes the capability of a crash cushion to operate in a location where it will be exposed to traffic impacts from only one direction. Such locations may include gore areas, or roadside locations on a divided highway. A crash cushion is considered to be uni-directional unless it has been qualified as bi-directional through a reverse-direction crash test.

Vehicle—A motorized unit for use in transporting passengers or freight, ranging from an 820-kg [1,800-lb] automobile to a 36000-kg [80,000-lb] van-type tractor trailer.

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

Work-Energy Principle—"A concept of crash cushion design which involves the reduction of an impacting vehicle's kinetic energy to zero, the condition of a stopped vehicle, through the conversion of kinetic energy into other forms of energy."

Working Width—The distance between the traffic face of the test article before the impact and the maximum lateral position of any major part of the system or vehicle after the impact.

Zone of Intrusion (ZOI)—The region measured above and behind the face of a barrier system where an impacting vehicle or any major part of the system may extend during an impact.

Introduction

Guardrail systems are designed and installed for one primary reason: to reduce the severity of a crash by preventing a motorist from reaching a more hazardous fixed object or terrain feature. The purpose of this document is to summarize important information contained in the TDOT Roadside Design Guide, Construction Specifications, Roadside Safety Drawings and Approved Proprietary Products that can be used in the field to ensure that all barrier installations are built and maintained to current standards and can be expected to perform acceptably when hit.

Questions We Must Ask Ourselves

When reviewing proposed and existing barrier installations in the field, we need to ask ourselves the following questions:

1. Is the guardrail system more hazardous than the condition being shielding?
2. Is an existing guardrail installation still warranted?
3. If the guardrail is installed as originally planned, is there a possibility of a motorist still reaching the hazard?
4. Can the guardrail be extended to shield a secondary obstruction?
5. Are there any vertical obstructions within the guardrail system's design deflection?
6. Is the guardrail ending within 200 feet of the start of another guardrail run that could be connected?
7. Is the guardrail terminating within 200 feet of a cut slope?
8. Does the slope need any regrading?
9. Has the guardrail height been reset after an overlay?
10. Is the best end treatment for the site being used?
11. Is guardrail considered in sensitive areas such as school playgrounds and reservoirs?
12. Is there adequate soil support behind strong post guardrail shielding a slope or are longer posts required?

This document provides the information needed to answer these and other questions pertaining to optimal design, installation, and maintenance of guardrail systems.

Part 1

Guardrail Basics

Barrier Guidelines:

- Are pre-determined situations or conditions where the use of a traffic barrier is normally considered. Refer to the Tables on pages 5 and 6 for fixed object and embankment guidelines.
- Should be considered when determining the need for a barrier, but they should not be construed as warrants.
- Are not a substitute for engineering judgment.

Establishing Barrier Guidelines

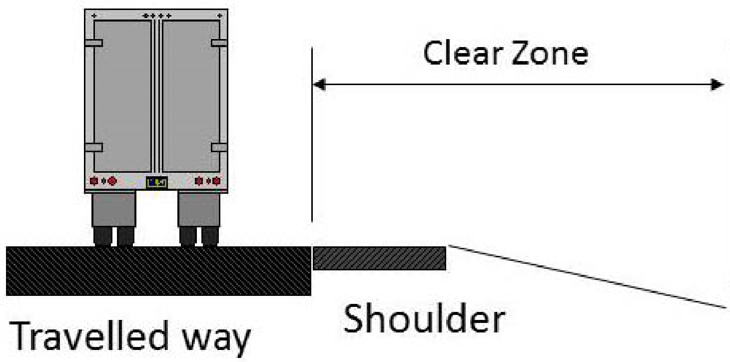
- Barrier guidelines are based on the premise that a traffic barrier should be installed only if it reduces the severity of potential crashes.
- There are instances where it is not immediately obvious whether the barrier or the unshielded condition presents the greater danger to a motorist.
- In such instances, guidelines may be established by using a benefit/cost analysis whereby factors such as design speed, roadway alignment, and traffic volumes can be evaluated in relation to the barrier need. Costs associated with the barrier (installation, maintenance, and crash-related costs) are compared to crash costs associated with the unshielded condition.
- This procedure is typically used to evaluate three options:
  1. Remove or reduce the condition so that it no longer requires shielding,
  2. Install an appropriate barrier,
  3. Leave the condition unshielded.

Considerations

- Consider eliminating short lengths of guardrail since these sections are often less effective than no barrier at all.
- Avoid short gaps between guardrail installations by making guardrail continuous where the points of need are determined to be about 200 feet apart or less.
- Consider keeping the slope clear of fixed objects when guardrail is not required due to the height of the slope.
- Consider guardrail in sensitive areas such as school playgrounds or reservoirs.

Clear Zone

The term “clear zone” is used to designate an area bordering the roadway, starting at the edge of the traveled way, which is available for safe use by errant vehicles. Safe use generally means the slope is flat enough and free of fixed object hazards so a motorist leaving the road is able to stop and return to the roadway safely.



The clear zone distances shown below represent minimum recommended distances and are based on limited data. The best answer to the question “How wide should the clear zone be ?” is “As wide as practical in each situation – but at least as wide as the distances, shown in the Table below”.

Design Clear Zone (L_c) (feet)

Design Speed (mph)	Design ADT	Foreslopes			Backslopes		
		6H:1V or flatter	5H:1V to 4H:1V	3H:1V	6H:1V or flatter	5H:1V to 4H:1V	3H:1V
≤40	UNDER 750⑦	7-10	7-10	④	7-10	7-10	7-10
	750-1500	10-12	12-14	④	12-14	12-14	12-14
	1500-6000	12-14	14-16	④	14-16	14-16	14-16
	OVER 6000	14-16	16-18	④	16-18	16-18	16-18
45-50	UNDER 750⑦	10-12	12-14	④	10-12	8-10	8-10
	750-1500	14-16	16-20	④	14-16	12-14	10-12
	1500-6000	16-18	20-26	④	16-18	14-16	12-14
	OVER 6000	20-22	24-28	④	20-22	18-20	14-16
55	UNDER 750⑦	12-14	14-18	④	10-12	10-12	8-10
	750-1500	16-18	20-24	④	16-18	14-16	10-12
	1500-6000	20-22	24-30	④	20-22	16-18	14-16
	OVER 6000	22-24	26-32③	④	22-24	20-22	16-18
60	UNDER 750⑦	16-18	⑨	⑨	14-16	12-14	10-12
	750-1500	20-24	⑨	⑨	20-22	16-18	12-14
	1500-6000	26-30	⑨	⑨	24-26	18-22	14-18
	OVER 6000	30-32③	⑨	⑨	26-28	24-26	20-22
65-70[d]	UNDER 750⑦	18-20	⑨	⑨	14-16	14-16	10-12
	750-1500	24-26	⑨	⑨	20-22	18-20	12-16
	1500-6000	28-32③	⑨	⑨	26-28	22-24	16-20
	OVER 6000	30-34③	⑨	⑨	28-30	26-30	22-24

NOTES:

③ Where a site specific investigation indicates a high probability of continuing crashes, or such occurrences are indicated by crash history, the designer may provide clear-zone distances greater than the clear zones shown in this table.

④ Because recovery is less likely on unshielded, traversable (3:1), fill slopes, fixed objects should not be present near of the toes of these slopes. Recovery of high-speed vehicles that encroach beyond the edge of the shoulder may be expected to occur beyond the toe of slope. Determination of the recovery area at the toe of the slope should take into consideration right-of-way availability, environmental concerns, economic factors, safety needs, and crash histories. Also, the distance between the edge of the through travelled lane and the beginning of the 3:1 slope should influence the recovery area provided at the toe of the slope. See the Roadside Design Guide, AASHO 2011 for more information.

⑦ For roadways with low volumes, it may not be practical to provide full clear zones distance. In such cases provide maximum amount of clear zones that is practical.

⑨ Use only 6:1 slopes on roadways with design speeds 60 mph and above. If 6:1 is impractical, consider shielding area with barrier system.

Design Options (In order of preference)

- Remove the hazard.
- Redesign the obstruction so it can be traversed safely.
- Relocate the obstruction to a point where it is less likely to be struck.
- Reduce impact severity by using an appropriate breakaway device or crash cushion.
- Shield the obstruction with a longitudinal traffic barrier if it cannot be eliminated, relocated or redesigned.
- Delineate the obstruction if the above alternatives are not practical or cost effective.

REMEMBER: Guardrail can also be a hazard and should only be used where the results of leaving the roadway and overturning or striking a fixed object would be more severe than the consequences of striking the barrier.

Roadside Obstacles

Roadside features that are normally considered for shielding are shown in the table below. Note that many man-made hazards can be redesigned or relocated to make shielding unnecessary. Traffic volumes and speeds, roadway geometrics, and the offset distances to the hazard are factors that should be considered when deciding on barrier installation. The following conditions within the clear zone are normally considered more hazardous than a roadside barrier:

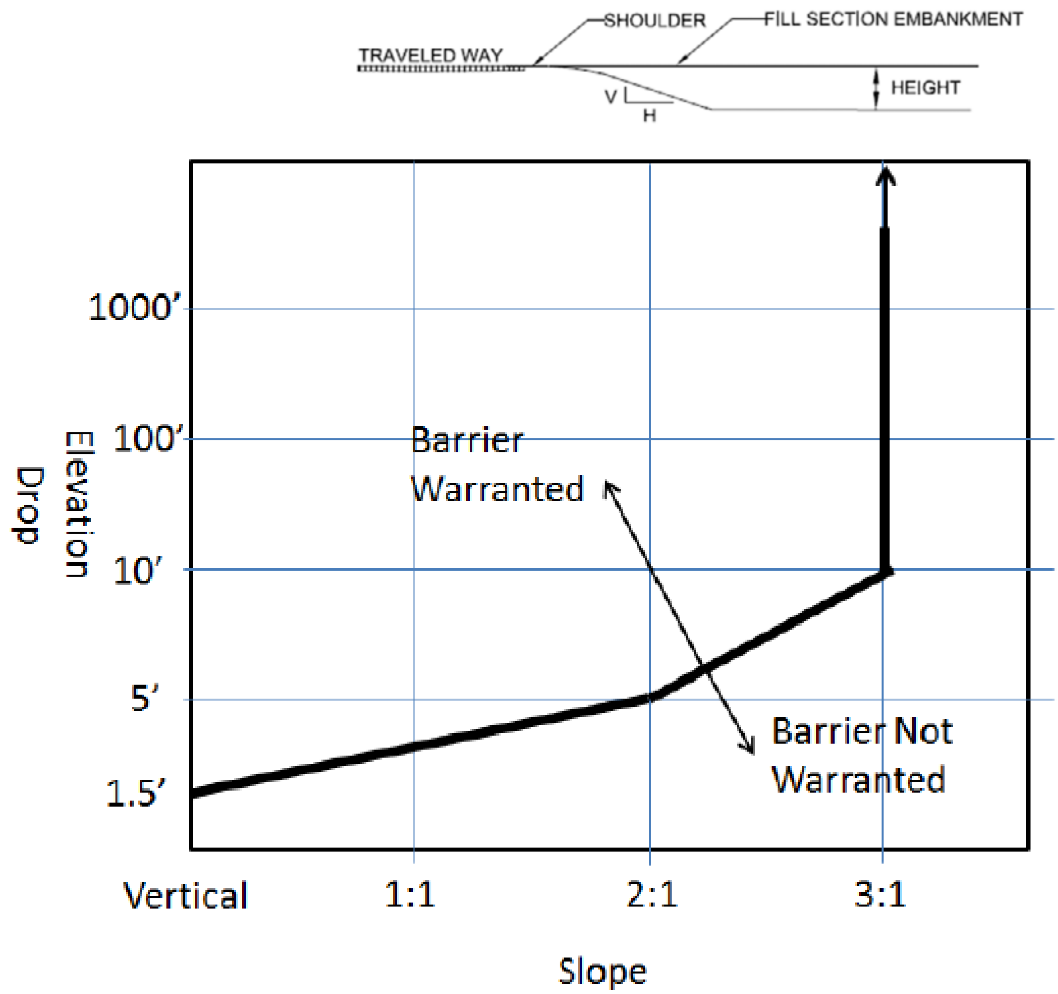
Obstacle	Guidelines
Bridge piers, abutments, and railing ends	Shielding generally required
Boulders	Judgment decision based on nature of fixed object can likelihood of impact
Culverts, pipes, headwalls	Judgment decision based in size, shape and location of obstacle
Foreslopes and backslopes (smooth)	Shielding not generally required
Foreslopes and backslopes (rough)	Judgment decision based on likelihood of impact
Ditches (parallel)	Refer to Figures 3-6 and 3-7
Ditches (transverse)	Shielding generally required if likelihood of head-on impact is high
Embankment	Judgment decision based on fill height and slope (see Figure 5-1)
Retaining Walls	Judgment decision based on relative smoothness of wall and anticipated maximum angle of impact
Sign/Luminaire supports	Shielding generally required for non-breakaway supports
Traffic signal supports	Isolated traffic signals within clear zone on high-speed rural facilities may warrant shielding
Trees	Judgment decision based on site-specific circumstances
Utility poles	Shielding may be needed on a case by case basis.
Permanent bodies of water	Judgment decision based on location and depth of water and likelihood of encroachment.

Ref: AASHTO Roadside Design Guide, 4th Edition Chapter 5, Table 5-2, Pg. 5-9.

Roadside Slopes (Embankments)

Although the AASHTO RDG graph for barrier requirements at embankments suggests that slopes steeper than 1V:3H are candidates for shielding, it does not take traffic speeds or volumes or roadway geometrics into consideration. Some transportation agencies have developed modified guidelines based on these additional factors.

Barrier Requirements for Embankment Heights



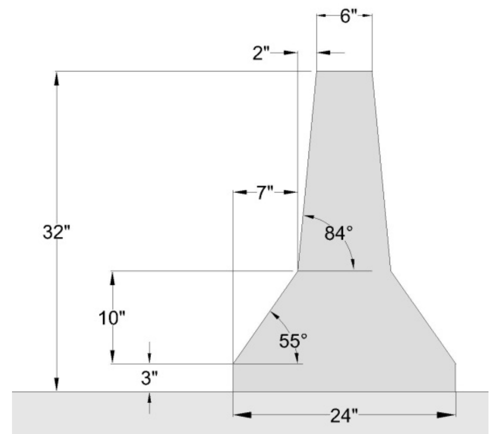
TDOT Barrier Guidelines, 4-705.12, 2013.

Barriers

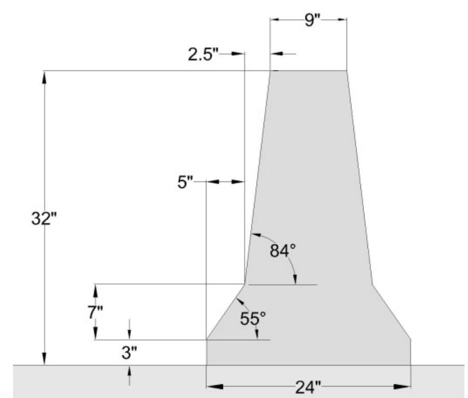
A roadside barrier is a longitudinal barrier used to shield motorists from natural and man-made obstacles located along either side of a traveled way. They are usually categorized as rigid, semi-rigid or flexible depending on their deflection characteristics when impacted.

Rigid Systems

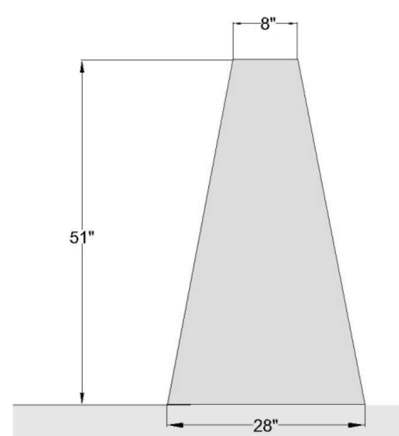
- The New Jersey Safety-Shape Barrier was the most widely used safety shape concrete barrier prior to the introduction of the F-shape. As shown, the "break-point" between the 55 deg and 84 deg slope is 13 inches above the pavement, including the 3 inch vertical reveal. The flatter lower slope is intended to redirect vehicles impacting at shallow angles with little sheet metal damage, but can cause significant instability to vehicles impacting at high speeds and angles. TL-4: 32” Tall and TL-5: 42” Tall.



- The F-Shape Barrier has the same basic geometry as the New Jersey barrier, but the "break-point" between the lower and upper slopes is 10 inches above the pavement. This modification results in less vehicle climb in severe impacts and improved post-crash trajectories. The 7.5 inch horizontal distance from the toe of the F-shape to its top corner also reduces the roll angle of impacting trucks and other vehicles with high centers-of-gravity. TL-4: 32” Tall and TL-5: 42” Tall.



- The Single Sloped Barrier, developed in Texas, has a constant 10.8 degree slope and performs comparably to the New Jersey barrier.



Semi-Rigid Systems

- Midwest Guardrail System (MGS)

  Test Level: NCHRP 350/MASH TL-3

  Post: W6 x 9 or W6 x 8.5 x 6 ft. Steel or 6” x 8” or 8” diameter wood posts.

  Height*:* 31”

  Splice: At midspan.

  Post Spacing: 6’-3”

  Block-outs: 8” timber or plastic block-outs.

- Strong-Steel or Wood Post W-Beam with wood or plastic block-outs

  Test Level: NCHRP 350/MASH TL-3

  Post: W6 x 9 or W6 x 8.5 x 6 ft. Steel or 6” x 8” or 8” diameter wood posts.

  Height: 27”

  Post Spacing: 6’-3”

  Block-outs: 6” wide x 8” x 14” routed (w/steel post) timber or plastic block-outs. Double block-outs can be used.

Flexible Systems

High Tension Cable Barriers (Propriety Systems) are installed with a significantly greater tension in the cables than generic, low-tension, three-cable systems. The deflection of these systems depends on the type of system, the post spacing and the distance between anchors. The high-tension systems also result in less damage to the barrier and usually the cables remain at the proper height after an impact which damages several posts. Note that the cable heights above ground may vary by manufacturer and by test level.

All of these systems have been tested successfully on slopes as steep as 1V:4H, but lateral placement must follow manufacturer's recommendations.

Brifen Wire Rope Safety Fence (WRSF) by Brifen USA
http://www.brifenusa.com/

Post: Z-shaped post, can be driven or socketed

Cable: 3 or 4 cable combination. Top cable is placed in a center slot at top of the post and cables 2 and 3 are weaved around post. Cables are interweaved around posts.

Typical Post Spacing: 10.5 to 21 ft.

Gibraltar
http://www.gibraltartx.com/

Post: C-channel post, can be driven or socketed

Cable: 3 or 4 cable combination. Cables are attached using a single hair pin and are placed on alternate sides of adjacent posts.

Typical Post Spacing: 10 to 30 ft.

Safence by Gregory Highway Products
http://www.gregorycorp.com/highway_safence.cfm

Post: C-Shaped post, can be driven or socketed

Cable: 3 or 4 cable combination. All cables are inserted in a slot at the center of the post and separated by plastic spacers.

Typical Post Spacing: 6.5 to 32.2 ft.

CASS by Trinity
http://www.highwayguardrail.com/products/cb.html

Post: C-Shaped and I-beam Post, can be driven or socketed
Cable: 3 or 4 cable combination. Cables are placed in a wave-shaped slot at the center of the post and separated by plastic spacers. Some versions also have cables that are supported on the flanges of the post.
Typical Post Spacing: 6.5 to 32.5 ft.

Nu-Cable by Nucor Marion Steel
http://nucorhighway.com/nu-cable.html

Post: U-Channel Post, can be driven or socketed

Cable: 3 or 4 cable combination. Cables are attached using locking hook bolts or hook bolts and a strap. 2 of 4 cables are placed on one side of post and the other two are placed on the opposite side.

Typical Post Spacing: 6.5 to 32.5 ft.

Work Zone Barriers

Use of temporary longitudinal barriers should be based on an engineering analysis. There are a number of factors, including traffic volume, traffic operating speed, offset, and duration, that affect barrier needs within work zones. These barriers are designed to shield motorists as well as roadside workers.

TDOT may require portable (temporary) barrier rail if the vertical drop between the traffic lane and the unfinished work is greater than 6 inches but less than 18 inches. For drop-offs greater than 18 inches, the use of portable barrier rail is mandatory. See Section 4-712.10 of the Roadway Design Guidelines for full details.

Types of work zone barriers include:

Concrete Safety Shape Barrier

- Free-standing, precast concrete segments, with built-in connecting devices.
- Requires heavy equipment for installation and removal.
- Adequate longitudinal reinforcement and positive connections provide for individual segments to act together as a smooth, continuous unit.

Portable Steel Barriers

- Free-standing, galvanized steel panels of various lengths.
- Light-weight and stackable, which allows larger quantities of barrier to be transported on a single truck.

BarrierGuard 800

http://www.highwaycareint.com/product_info/44/barrierguard800

ArmorGuard Barrier

http://www.barriersystemsinc.com/movable-workzone-barrier

ZoneGuard Barrier

http://www.hshighway.com/products/zoneguard

Vulcan Barrier

http://www.energyabsorption.com/products/products_vulcan_tl3.asp

Plastic-water filled

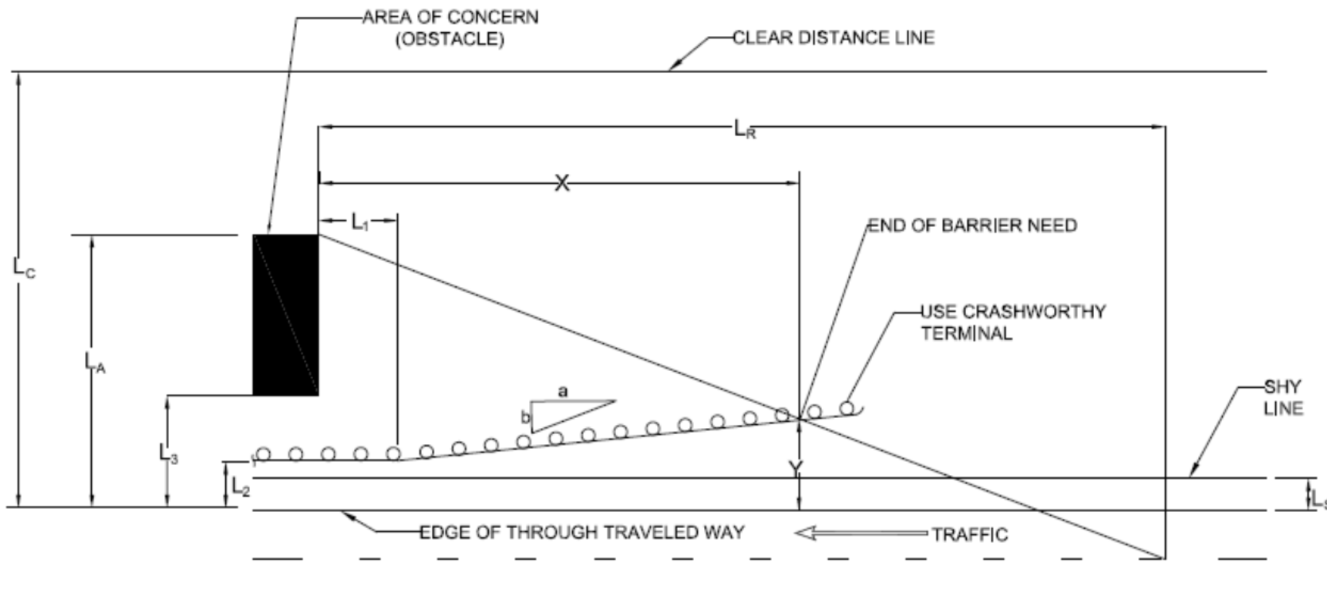
- Free-standing, polyethylene plastic shells with a steel framework.
- Steel frame can be inside the plastic or outside the plastic shell.

Internal Steel Frame

External Steel Frame

Length of Need (LON) is defined as the length of barrier needed in advance (upstream) of a fixed object hazard or a non-traversable terrain feature to prevent a vehicle that has left the roadway from reaching the shielded feature. It is determined by selecting the appropriate variables and using the formula on page 14 to calculate the LON (the “X” value) shown in the diagram below.

Approach Barrier Layout



X = Distance from the obstruction to end of barrier need.

Y = Distance from edge of through traveled way to end of barrier need.

L_A = Distance from edge of through traveled way to lateral extent of obstruction.

L_1 = Tangent length of barrier upstream from obstruction.

L_2 = Distance from edge of through traveled way to barrier.

L_3 = Distance from edge of through traveled way to obstruction.

L_C = Distance from edge of through traveled way to outside edge of the clear zone.

L_R = The theoretical Runout Length needed for a vehicle leaving the roadway to stop.

a : b = Flare Rate.

2011 AASHTO Roadside Design Guide, Figure 5-39, pg 5-49.

Length of Need Procedure:

1. Choose an appropriate L_A as it is a critical part of the design process. This distance should include all features or hazards that need to be shielded, up to the design clear zone at each site.
2. Select a Runout Length (L_R) from the table below.
3. The designer selects the tangent length, (L_1), if the barrier is flared. If the installation is parallel to the roadway, $L_1 = 0$. If a semi rigid barrier is connected to a rigid barrier, the tangent length should be at least as long as the transition section.
4. If the barrier is flared away from the roadway, the maximum recommended flare rate for median installation shown below should not be exceeded.
5. Calculate the Length of Need (X) from the following equation and round the calculated value up to the nearest 12.5-foot or 25-foot rail segment:

$$X = \frac{L_A + (b/a)(L_1) - L_2}{(b/a) + (L_A/L_R)}$$

6. For parallel installations i.e. no flare rate, the previous equation becomes:

$$X_{(AASHTO)} = \frac{L_A - L_2}{L_A / L_R} \quad \text{or}$$

$${}^{*}X_{(TDOT)} = \frac{L_A - L_2 - 0.75}{L_A / L_R}$$

*** Note:** The 0.75-ft adjustment factor is applicable when the flare on the installed terminal results in a 0.75-foot offset at post No.3, the point along the installation considered to be the beginning of the Length of Need.

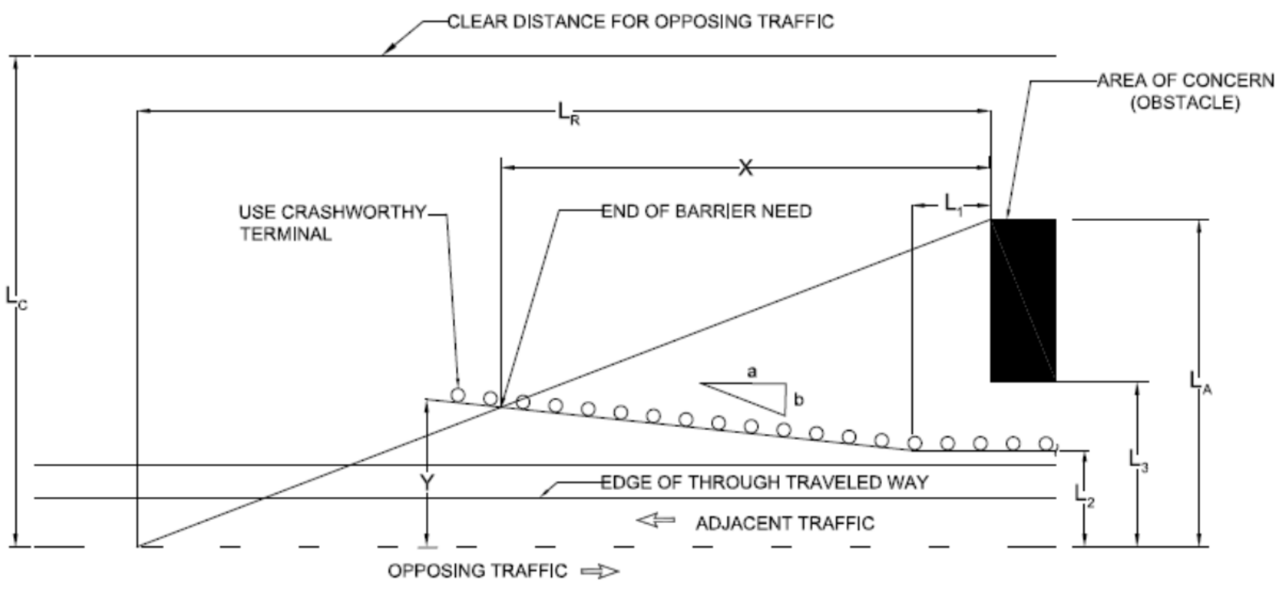
Runout Lengths

RUNOUT LENGTHS (L_R) FOR BARRIER DESIGN (FT)					MEDIAN APPLICATION	
DESIGN SPEED (MPH)	DESIGN TRAFFIC VOLUME (ADT)				FLARE RATE (a:b)	
	OVER 10,000 VPD	5,000 – 10,000 VPD	1,000 – 5,000 VPD	UNDER 1,000 VPD	Concrete Barrier	W-Beam Barrier
70	360	330	290	250	20:1	15:1
60	300	250	210	200	18:1	14:1
50	230	190	160	150	14:1	11:1
40	160	130	110	100	10:1	8:1
30	110	90	80	70	8:1	7:1

Length of Need for Opposing Traffic

- X is determined using the same equation.
- All lateral dimensions are measured from the centerline for a two-lane roadway. See the layout at the bottom of this page.
- There are three ranges of clear zone width, L_C, which deserve special attention:
  1. If the barrier is beyond the appropriate clear zone for opposite direction traffic, no additional barrier and no crashworthy end treatment is required. (NOTE: an appropriate barrier anchor remains necessary to ensure proper containment and redirection for near-side impacts).
  2. If the barrier is within the appropriate clear zone but the area of concern is beyond it, no additional barrier is required; however a crashworthy end treatment should be used.
  3. If the area of concern is within the clear zone for opposing traffic, the barrier must be extended to prevent opposite-direction hits.

Approach Barrier Layout for Opposing Traffic



2011 AASHTO Roadside Design Guide, Figure 5-42, pg 5-54.

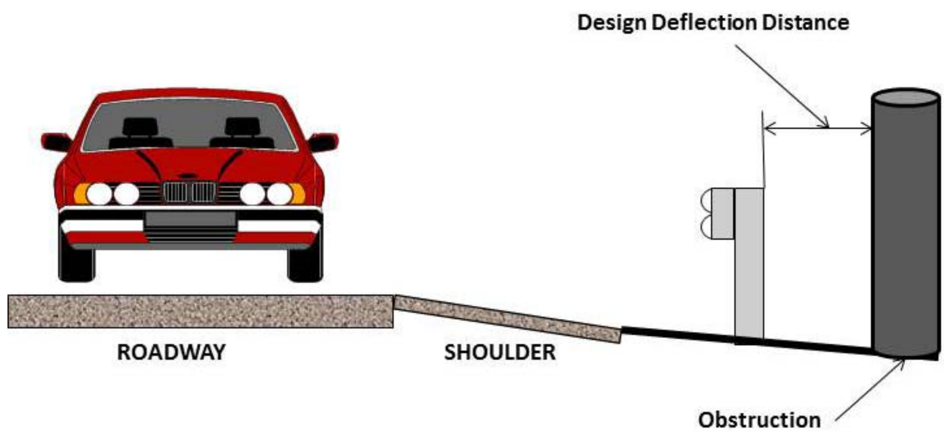
Length of Need (LON) Field Check: A straightforward method to verify correct LON in the field is to stand on the roadway edge directly opposite the shielded feature, and then pace off the appropriate runout length from the Table on page 14. At that point, turn and look at the shielded area. If the proposed (or actual) guardrail installation crosses that line of sight, then the area is adequately covered.

(NOTE: if the terrain makes it impossible for a vehicle to reach the hazard from that point, the installation may be longer than needed. On the other hand, if the intervening terrain is also hazardous or if there are other significant obstacles in the immediate vicinity, it may be desirable to extend the barrier to shield all of the dangerous conditions.)

Additional Design Considerations

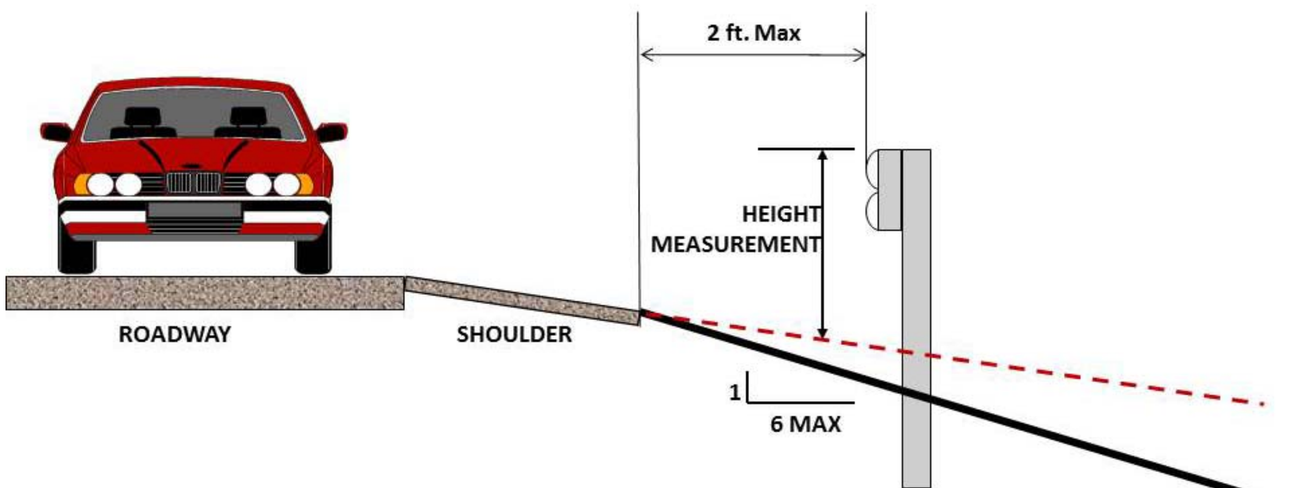
Although it is critical that the correct length of need be installed, there are several other placement considerations essential to good barrier performance. These include adequate deflection distances behind each type of barrier, barrier height, guardrail flare rates, and the location of barrier on slopes and behind curbs. These factors are discussed in the next sections.

Design Deflection Distance is based on the results of 62-mph impacts into the barrier at a 25-degree impact angle by the NCHRP Report 350 or MASH pickup truck. In the field, actual deflections can be much greater (or less) depending on actual impact conditions. Note that the AASHTO RDG measures the distance from the back of the posts.



Height Measurement

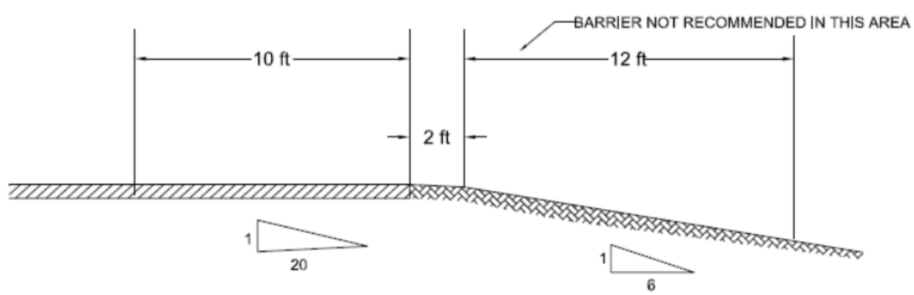
The minimum height of Strong-Steel Post W-Beam Guardrail is 27” and MGS is 31”, measured as shown below or from the gutter line when set above a curb. If set behind a sidewalk barrier height should be set from the sidewalk elevation.



Barrier Placement on Slopes

Barrier, regardless of type, performs best when an impacting vehicle is stable when contact is first made. Since vehicles running off the road at high speeds tend to become airborne and are likely to override barrier placed on a slope, the following guidelines apply:

- Do not place W-beam guardrail on slopes steeper than 1V:6H.
- W-beam systems can be placed anywhere on 1V:10H or flatter slopes.
- MGS barrier can be installed on 1V:8H slopes but 1V:10H is preferred.
- When the slopes are between 1V:10H and 1V:6H, the face of the barrier must not be between 2 to 12 feet beyond the grade hinge point.
- Strong post systems need 2 feet of soil support behind the rail for support. When 2 feet is not obtainable, strong posts that are a minimum of 1 foot longer shall be provided.
- Cable barrier can be placed anywhere on a 1V:6H or flatter roadside slope, but that are some placement restrictions when used in a median application. Most proprietary systems can be placed on 1V:4H slopes, but manufacturers' recommendations must be followed.



See AASHTO Roadside Design Guide, 4th Edition, Figure 5-38, pg 5-47.

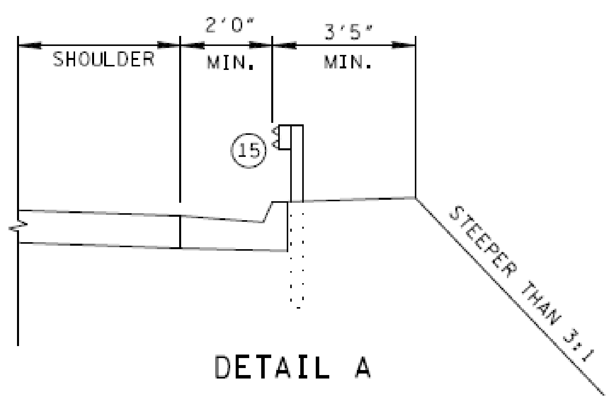
Guardrail and Curb

Curbs do not have a significant redirection capability and can have the same type effect on vehicle trajectory as slopes, i.e., wheel impact with a curb can cause a vehicle to vault over a barrier placed above or beyond it. The following guidelines apply:

- Guardrail should not be used with curb installation on high speed (Design Speed of 50 mph and higher), rural roads.
- When guardrail/curb combinations are unavoidable, the curb type and barrier placement should follow the recommendations shown in the details below. Any curb in front of a guardrail terminal should be limited to a 2 inch height.

If the curb exceeds 4 inches, follow these guidelines:

1. Strong post W-beam or Thrie-beam guardrail should be used.
2. Stiffen the guardrail
   - Add a rubrail or
   - Double nest the rail or
   - Bolt a W-beam to back of the posts
3. Curb must be flush with, or slightly behind, the face of the guardrail.
4. The guardrail height is measured from the edge of travel lane to the top of rail when the guardrail is placed in front of or at the face of the curb.
5. When guardrail is placed behind the face of curb see figure below.



DETAIL A

GUARDRAIL PLACEMENT ON
CURB AND GUTTER SECTION

Ref: TDOT, Design Standards for Local Roads and Streets, RD01-TS-1, 2002

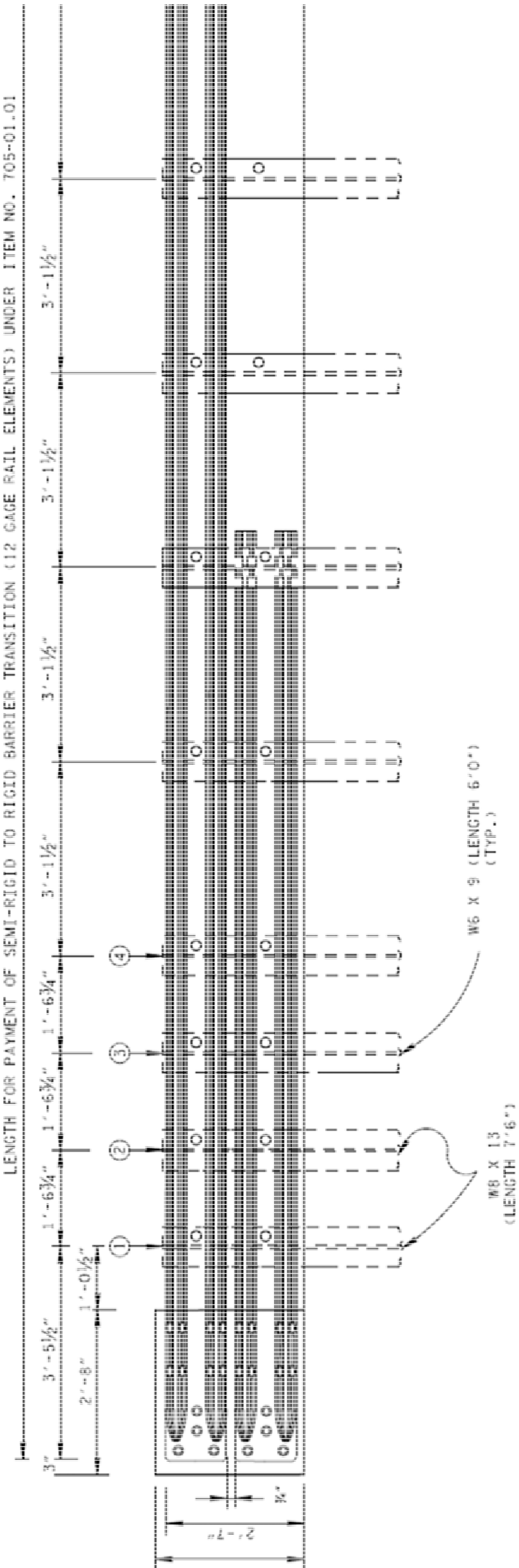
Guardrail and Trees

- Generally guardrail is not used to shield utility poles or trees. However, individual trees and poles that are in vulnerable locations and cannot be removed or relocated are sometimes shielded.
- Where guardrail is used in front of poles or trees due to other obstructions barrier deflection must be considered.
- Consider removing trees where they are an obstruction and in locations where they are likely to be hit.
- Use crash history at similar sites, scars indicating previous crashes or field reviews to determine removable trees.
- Tree removal is usually a preferred option but an assessment regarding its expense and effectiveness should be considered.
- Roadways through wooded areas with heavy nighttime traffic volumes, frequent fog, and narrow lanes should be well delineated.
- Pavement markings and post mounted delineators are among the most effective and least costly improvements that can be made to a roadway.

Connections to Bridge Barriers

Since there are numerous bridge barrier designs currently in place on Tennessee highways, the attachment details shown in the latest Design Standards for new construction will not always be directly applicable for every project. However, crashworthy designs can be developed if three concerns are met: an adequate transition between the bridge end and the approach guardrail, an adequate attachment to the bridge barrier itself, and the elimination of any potential snag points at the bridge end.

- A transition is simply a gradual stiffening of the approach guardrail at the bridge end so the rail cannot deflect enough to result in a vehicle “pocketing” when it reaches the rigid bridge barrier.
- A structurally adequate attachment of the guardrail to the bridge barrier is shown on the transition details as well. This detail is needed to prevent the approach railing from pulling free from the bridge barrier. Some existing bridge railings may not be structurally adequate to support such a connection. In such situations extending the guardrail across the structure eliminates the need for a structural connection at the bridge end and may increase the capacity of the bridge barrier itself.
- Finally, if the bridge barrier is significantly higher then the approach railing, a truck or SUV impacting the approach railing could lean over the railing far enough to snag on the end of the bridge barrier, or if no rubrail or concrete curb is used, a vehicle’s tire could fold under the guardrail and snag on the bottom edge of the bridge parapet.

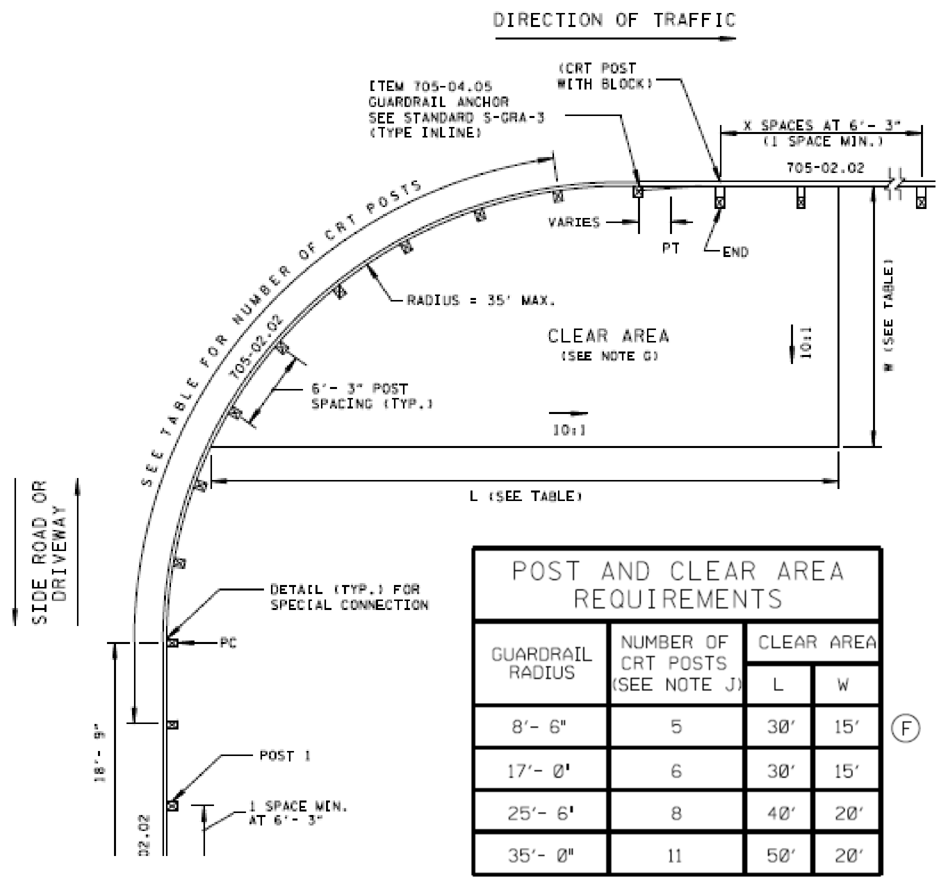


TDOT, Roadside Safety Drawings, S-GRC-1, 2013

Guardrail at Intersections and Driveways

When secondary roads or driveways intersect a main road so close to a bridge or other hazard that a full run of barrier cannot be installed, a strong post W-beam guardrail can be curved around the radius where the two roads meet. While the site conditions can vary greatly, there are two major concerns that should be addressed.

1. If the hazard is a bridge end or pier, a crashworthy transition design is required. A crash cushion can be used if the space is too limited to use a standard transition. The section of barrier along the primary road must be long enough to react in tension to redirect impacting vehicles away from the shielded rigid object.
2. Oftentimes the feature traversed by a structure or another hazardous feature between the intersecting road and the structure can be shielded using a curved rail design. By using a curved rail design, high angle impacts into the curved section are likely. To reduce the risk of a vehicle going through or over the W-beam, modifications can be made to the posts, the W-beam-to-post connections, and the end treatment along the intersecting road or driveway. TDOT 's typical treatment at such locations is shown here.



POST AND CLEAR AREA REQUIREMENTS			
GUARDRAIL RADIUS	NUMBER OF CRT POSTS (SEE NOTE J)	CLEAR AREA	
		L	W
8'- 6"	5	30'	15'
17'- 0"	6	30'	15'
25'- 6"	8	40'	20'
35'- 0"	11	50'	20'

Ref: TDOT, Roadside Safety Systems, S-PL-2, 2013

Part 2

Terminals and Crash Cushions

Terminals

Crashworthy terminals anchor a barrier installation and are designed to eliminate spearing or vaulting when hit head-on, or redirect a vehicle away from the shielded object or terrain feature when the barrier is struck on the traffic face near the terminal. Typical Tennessee installations require a TL-3 end terminal.

Definitions:

Energy Absorbing Terminals can stop vehicles in relatively short distances in direct end-on impacts (usually 50 feet or less depending on type of terminal).

Non-Energy Absorbing Systems will allow an unbraked vehicle to travel 150 feet or more behind and parallel to guardrail installations or along the top of the barrier when struck head-on at high speeds.

Flared Terminals: have up to 4-foot offset at the approach end, but require a larger platform for installation.

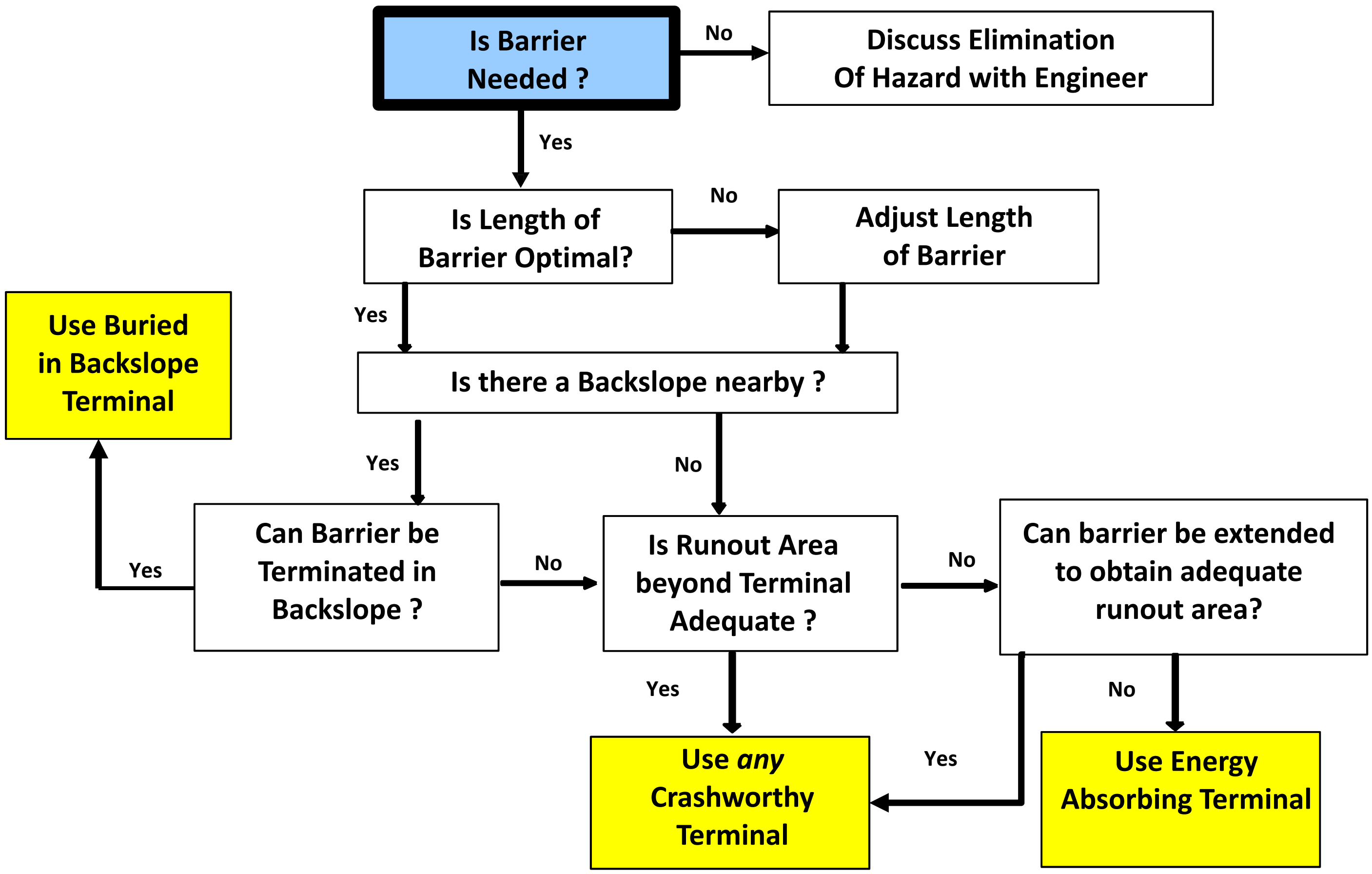
Tangent Terminals: are installed parallel to the roadway but may have a 2-foot offset over the first 50 feet of length.

NOTE:

- At the trailing end of guardrail, a distance of 50 feet beyond the end treatment is to be kept clear of all roadside obstructions (hazards) or the rail may be extended to shield such secondary hazards.
- This "downstream clear zone" is intended to minimize the likelihood that a vehicle may be forced into an obstruction by the barrier.
- On two lane highways with two way traffic, provide end treatments on both the approach and trailing ends of the guardrail.
- On four-lane divided highways, use crashworthy end treatments on the approach ends. If the departure rail is within the clear zone for opposing traffic, provide end treatments on both the approach and trailing ends. Note that oftentimes no rail is needed on the departure ends of bridges on divided roadways unless site specific circumstances require additional barrier.

Terminal Selection

The flowchart below can be used by a designer to select the most appropriate type based on site conditions.



Types of Terminals

The following terminals include those often used in Tennessee.

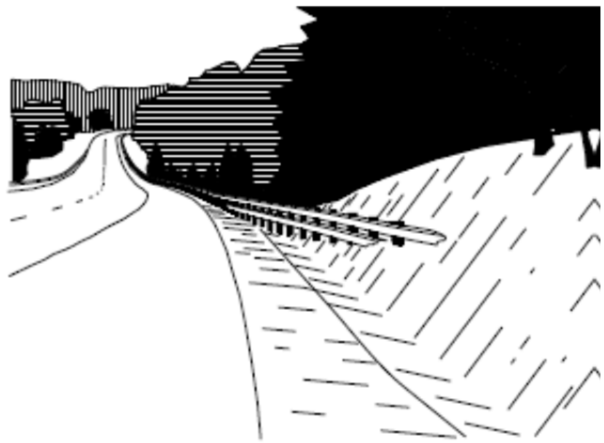
For additional terminals go to the FHWA website at
http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/barriers/index.cfm

- Buried in Backslope (Type 12)
- TL-2 Terminals (Not to be used on NHS Projects)
- Energy Absorbing Terminals (Type 38)
- Non-Energy Absorbing Terminals (Type 21)

Buried in Backslope (Type 12)

Test Level: NCHRP 350: TL-3

Characteristics:



- Used when the natural backslope (2H:1V or steeper) is reasonably close to the point where the barrier is introduced.
- Keep the height of the w-beam rail constant relative to the roadway grade until the barrier crosses the ditch flow line.
- Use a flare rate appropriate for the design speed.
- Add a w-beam rubrail where needed, and
- Use an anchor (concrete block or steel post) capable of developing the full tensile strength of the w-beam rail.

TL-2 Terminals (Not to be used on NHS Projects)

Modified Eccentric Loader Terminal (MELT)

Test Level: NCHRP 350: TL-2

Characteristics:

- Flared terminal – installed on a parabolic curve with a 4’ offset.
- No impact head.
- Uses standard w-beam rail elements.
- Rail is not bolted to posts 2 through 8.
- Strut between the steel tube foundation for the two end posts act together to resist cable loads.
- Comprised of wooden posts only.
- Should be installed at locations where sufficient runout area exists behind and downstream of the terminal.

NOTE: The non-crashworthy BCT has no ground strut and only two weakened posts.

Energy Absorbing Terminals (Type 38)

- Used for single runs of strong post guardrail
- Redirection begins beyond the third post

Extruder Terminal ET-2000 Plus

Test Level: NCHRP 350: TL-3

Characteristics:

- Tangent terminal.
- Rectangular impact front face (Extruder head).
- Rectangular holes in 1st rail support the tabs of the cable anchor bracket.
- Steel HBA and SYTP and wood post options are available.
- SYTP Retrofit in tube sleeve option available.
- End of W-beam rail with offset of 0' to 2'-0".

http://www.highwayguardrail.com/products/etplus.html

Sequential Kinking Terminal (SKT-350)

Test Level: NCHRP 350: TL-3

Characteristics:

- Tangent terminal.
- Square impact front face.
- Has a feeder chute (channel section that surrounds the rail) which gets wider at the downstream end.
- Breakaway steel end posts #1 and #2 and standard steel guardrail posts #3 and beyond.
- Rail has 3 (1/2" x 4" long) slots in the valley of the rail.
- There may be 5 additional slots (1/2" x 4" long) on both the top and bottom corrugations of the w-beam section, which makes it interchangeable with the FLEAT system.
- Cable anchor bracket is fully seated on the shoulder portion of the cable anchor bolts.
- All hinge steel post, plug weld steel posts, or wood posts available.
- End of W-beam rail with offset of 0' to 2'-0".

http://roadsystems.com/skt.html

Flared Energy Absorbing Terminal Median (FLEAT-MT)

http://roadsystems.com/fleat-mt.html

Test Level: NCHRP 350: TL-3

Characteristics:

- Flared terminal.
- Rectangular impact front face, with steel tube on top.
- Rail has 5 slots (1/2" x 4" long) on both the top and bottom corrugations of the w-beam section.
- There may be 3 additional (1/2"x4" long) slots in the valley of the rail which makes it interchangeable with the SKT system.
- Breakaway steel end posts #1 and #2, standard steel guardrail posts #3 and beyond.
- Cable anchor bracket is fully seated on the shoulder portion of the cable anchor bolts.
- All hinge steel post, plug weld steel posts, or wood posts available.
- End of W-beam rail with offset of 2'-6" to 4'-0".

X-Tension Median Attenuator System (X-MAS)

http://www.barriersystemsinc.com/xmas-impact-attenuator

Test Level: NCHRP 350: TL-3

Characteristics:

- Impact head with locking bar to lock cables into place.
- Strut between the first post and a front anchor post.
- Steel and wood post options available.
- Two cables attached to soil anchor extend the entire length of the terminal.

TREND 350 Terminals

Test Level: NCHRP 350: TL-3

Characteristics:

- Rectangular Impact Face.
- All steel driven posts.
- Breakaway steel posts at #1 and #2, standard steel guardrail posts #3 and beyond.
- Steel Strut between posts #1 and #2.
- During head on impacts the system telescopes rearward, using friction between the guardrail panels and deformation of the rail sections to decelerate the vehicle.

http://www.highwayguardrail.com/products/et.html

SoftStop

Test Level: MASH TL-3

Characteristics:

- Rectangular Impact Face.
- All steel driven posts.
- Breakaway steel posts at #1 and #2, standard steel guardrail posts #3 and beyond.
- Impact head flattens and extrudes w-beam guardrail upon end-on impact.

http://www.highwayguardrail.com/products/SoftStop.html

X-Lite

Test Level: NCHRP 350: TL-3

Characteristics:

- Rectangular Impact Face.
- All steel driven posts.
- Uses a slider mechanism between post 1 and 2 that gathers and retains the rail when hit.
- The anchor consists of posts #1 and #2 connected by tension struts and a soil plate below grade on post #2.
- Both Tangent and Flared Layout.

http://www.barriersystemsinc.com/xlite-end-terminal

Non-Energy Absorbing Terminals (Type 21)

- Used for single runs of strong post w-beam guardrail.
- Redirection begins beyond the third post.

Slotted Rail Terminal (SRT-350)

Test Level: NCHRP 350: TL-3

Characteristics:

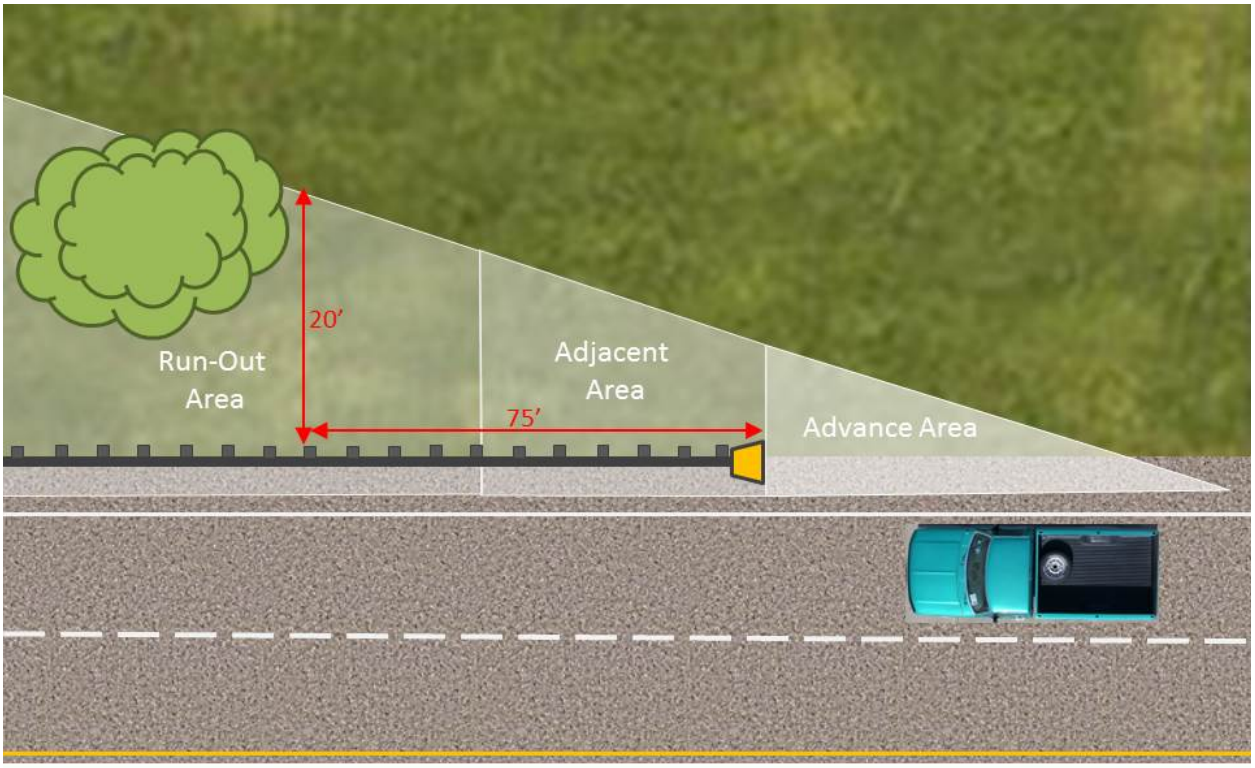
http://www.highwayguardrail.com/products/et-srt350.html

- Flared terminal.
- No impact head.
- Longitudinal slots on w-beam rail element.
- Strut and cable anchor bracket between posts #1 and #2 act together to resist the cable loads.
- Slot Guards on downstream end of slots.
- Steel and wood post options available.
- Parabolic flare on wood post option.
- Straight line flare on all SYTP steel post and HBA steel/wood post options.
- Should be installed at locations where sufficient runout area exists behind and downstream of the terminal.
- End of w-beam rail with offset of 4’-0”
- Wood post option has 3’-0” to 4’-0” offsets.

Terminal Grading Details

A barrier terminal is most likely to perform best when a vehicle is stable at the moment of impact and there is a traversable runout area immediately behind the terminal. Whenever practical, a barrier should be extended until these conditions can be met.

When a grading platform must be built it is critical that it be designed and constructed to blend with the original embankment and not cause instability in a vehicle before, during, or after a crash into the terminal. Note that the areas approaching and immediately adjacent to the terminal should be no steeper than 1V:10H. Steeper adjoining slopes should be gently transitioned to a flatter slope to minimize rollover potential. Embankment should not cause instability in a vehicle before, during, or after a crash into the terminal.



Terminal Inspection

All new guardrail, new guardrail end terminals, repair of existing guardrail, repair of existing guardrail end terminals, adjustment of guardrail, etc. shall be constructed in accordance with the appropriate section(s) of the TDOT Standard Specifications and/or Special Provisions and/or the appropriate TDOT Standard Drawing and/or approved NCHRP 350 shop drawings.

The TDOT inspector/representative shall complete the Guardrail and Guardrail Terminal Anchor Daily Field Report. The form must be signed by both the inspector and the Contractor's authorized representative. All certifications and FHWA eligibility letters for end treatments shall be attached to the inspection form. (It will only be necessary to supply one certification letter and FHWA eligibility letter for each type used.)

Installation decals shall be applied to all end terminal sections, either new installation or repair as shown below. The tag should be placed on the guardrail end terminal in an area that is least likely to be damaged on impact.

<table>
<tr><td colspan="16">TENNESSEE DEPARTMENT OF TRANSPORTATION</td></tr>
<tr><td colspan="16">TO REPORT DAMAGE CALL 615-350-4300</td></tr>
<tr><td colspan="6">INSTALLATION DATE</td><td colspan="10">CONTRACT NUMBER</td></tr>
<tr><td colspan="6">MONTH</td><td colspan="10">B C D E F</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td></tr>
<tr><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td></tr>
<tr><td colspan="6">YEAR</td><td colspan="10"></td></tr>
<tr><td>06</td><td>07</td><td>08</td><td>09</td><td colspan="2">10</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td></tr>
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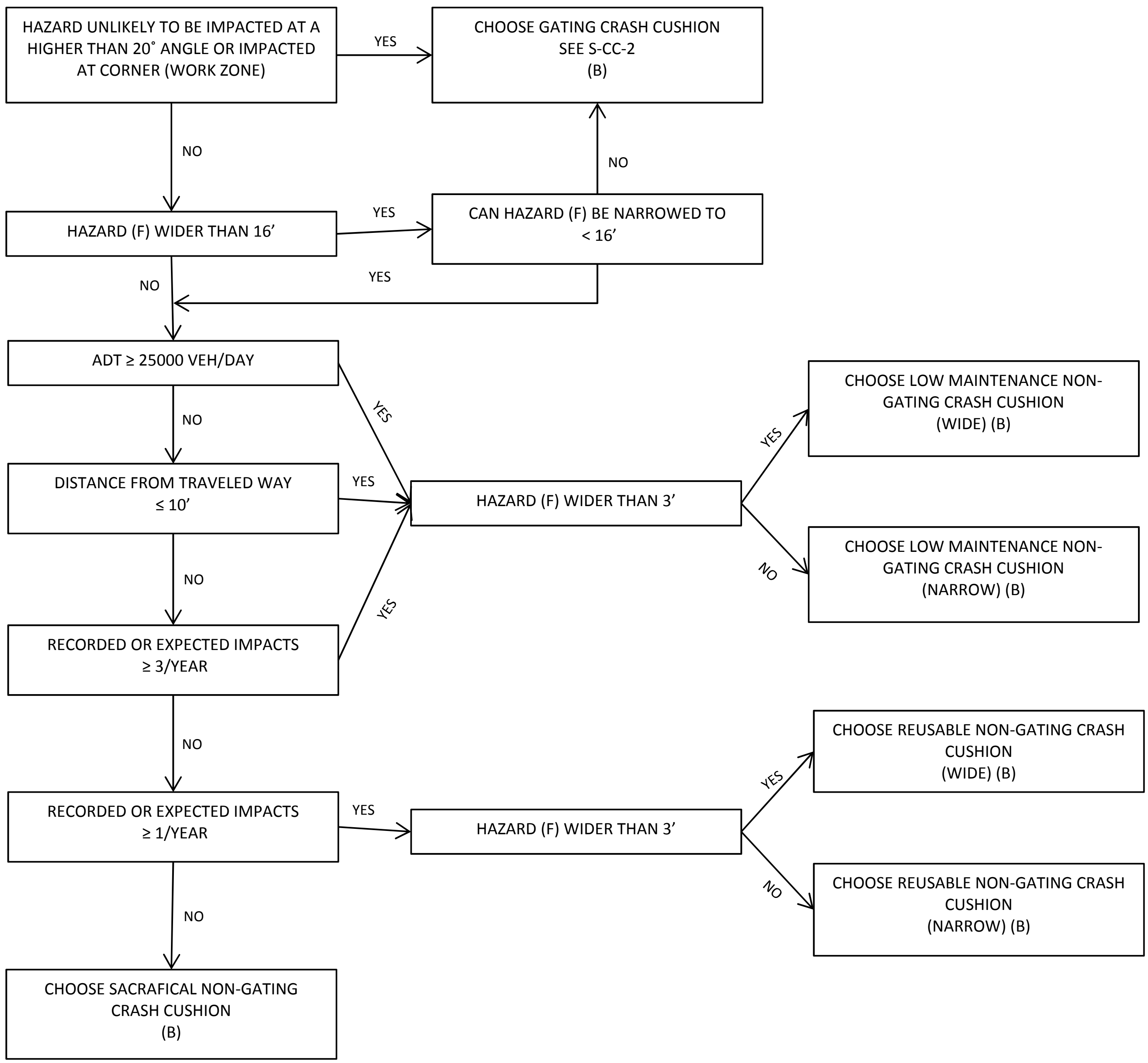
Crash Cushions

Crash cushions are generally used to shield hazards in freeway gore areas or the ends of permanent or temporary traffic barriers.

TDOT Crash Cushion Selection Process



TDOT Crash Cushions Types

Reusable Systems – Only TL-3 systems must be used for TDOT projects.

Low maintenance (self-restoring) – Only TL-3 systems must be used for TDOT projects.

Gating (Non-redirective) Systems – Only TL-3 systems shall be used on National Highway Systems

For additional commonly used attenuators throughout the U.S., go to the FHWA website at http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/barriers/index.cfm

Reusable Systems

TAU-II

Test Level: NCHRP 350/MASH TL-2 and TL-3
How it works: Energy absorbing cartridges crush upon impact. Thrie beam panels slide back when struck head-on. Anchored at the front and rear of system.
Energy absorbing cartridges in each bay may need to be replaced after each crash.
Requires a paved pad.
Locations: Median or shoulder protection.
Gore two-side protection.

http://www.barriersystemsinc.com/tau-ii-crash-cushion

X-TENuator

Test Level: NCHRP 350 TL-3
How it works: Impact head has locking bar to lock cables into place. The friction between the cables and the impact head dissipates crash energy.
Locations: Median or shoulder protection.
Gore two-side protection.

http://www.barriersystemsinc.com/xtenuator-impact-attenuator

QuadGuard Family

Test Level: NCHRP 350/MASH TL-3

How it works: Hex-foam cartridges crush upon impact. Specially fabricated side panels having four corrugations slide back on a single track when struck head-on. Energy absorbing cartridges in each bay may need to be replaced after each crash. Requires a paved pad.

Locations: Median or shoulder protection.
Gore two-side protection.

http://www.energyabsorption.com/products/products_quadguard2_crash.asp

QUEST

Test Level: NCHRP 350 TL-3

How it works: Consists of a series of W-Beam fender panels supported by diaphragms with a trigger mechanism at the nose that releases the front assembly. Requires a paved pad.

Locations: Median or shoulder protection.
Gore two-side protection.

http://www.energyabsorption.com/products/products_questimpact.asp

Trinity Attenuating Crash Cushion (TRACC)

Test Level: NCHRP 350 TL-2 and TL-3

How it works: Consists of a series of w-beam fender panels and an impact face which absorbs energy by cutting metal plates on the top sides of the guidance tracks when forced backward in an end on impact. Requires Paved Pad.

Locations: Median or shoulder protection.
Gore two-side protection.

http://www.highwayguardrail.com/products/tracc.html

Low Maintenance Systems

Hazards Narrower Than 36” Wide

TAU-IIR

Test Level: NCHRP 350 TL-3

How it works: Hyperelastic modules crush upon impact. Thrie beam panels slide back when struck head-on. Anchored at the front and rear of system. Requires a paved pad.

Locations: Median or shoulder protection. Gore Two-side protection.

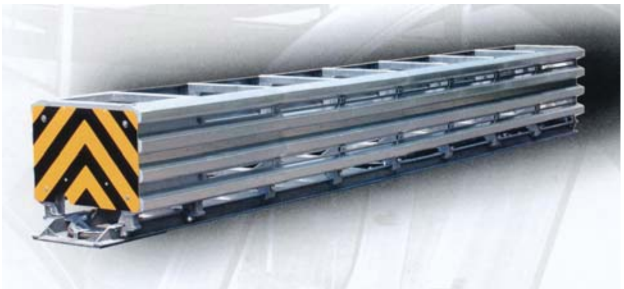
http://www.barriersystemsinc.com/tau-ii-r-crash-cushion

Smart Cushion Innovation (SCI)

Test Level: NCHRP 350 TL-3

How it works: Hydraulic cylinders in the attenuator provides resistance to stop a vehicle before it reaches the end of the cushion’s usable length. Requires a paved pad.

Locations: Median or shoulder protection.
Gore two-side protection.



http://www.workareaprotection.com/attenuator.htm

REACT 350

Test Level: NCHRP 350 TL-3

How it works: Hollow high molecular weight, high density polyethylene cylinders crush upon impact. Cables on the side are for side impacts.
Requires a paved pad.

Locations: Median or shoulder protection.
Gore two-side protection.

http://www.energyabsorption.com/products/products_react350_impact.asp

QuadGuard Elite Family

Test Level: NCHRP 350 TL-3

How it works: High Density Polyethylene cylinders and flex-belt nose collapse upon impact. Specially fabricated side panels having four corrugations slide back on a single track when struck head-on. Requires a paved pad.

Locations: Median or shoulder protection.
Gore two-side protection.

http://www.energyabsorption.com/products/products_quadguard_elite.asp

Compressor

Test Level: NCHRP 350 TL-3

How it works: Modules molded from High Density Polyethylene absorb the impact energy. Steel side panel translate during end-on impacts. The assembly is combined with Uni-Base. Requires a paved pad.

Locations: Median protection or shoulder protection.
Gore two-side protection.

http://traffixdevices.com/cgi-local/SoftCart.exe/compressor.htm?L+scstore+tsjv8007fff838f8+1360807249

Hybrid Energy Absorption Reusable Terminal (HEART)

Test Level: NCHRP 350 TL-3

How it works: High Molecular Weight / High Density Polyethylene side panels connected to steel diaphragms mounted on tubular steel tracks which compress upon impact.
Requires a paved pad.

Locations: Median or shoulder protection.
Gore two-side protection.

http://www.highwayguardrail.com/products/heart.html

Low Maintenance Systems

Hazards Wider Than 36”

REACT 350 (WIDE SYSTEM)

Test Level: NCHRP 350 TL-3
How it works: Hollow high molecular weight, high density polyethylene cylinders crush upon impact. Cables on the side are for side impacts.
Requires a paved pad.
Locations: Median or shoulder protection.
Gore two-side protection.

http://www.energyabsorption.com/products/products_react350_impact.asp

Gating (Non-redirective) Systems

Sand Barriers

Test Level: NCHRP 350 TL-2 and TL-3
How it works: Sand-filled plastic barrels dissipate the kinetic energy of an impacting vehicle by transferring the vehicle’s momentum to the variable masses of sand in the barrels that are hit.
Locations: Temporary Construction Worksites i.e. Ends of Concrete Barriers; Gore Two-sided Protection; Wide Medians; Bridge Piers.

CrashGard (TL-3)

http://plasticsafety.com/Products/Crash-Cushion/CrashGard-Sand-Barrel-System.aspx

Fitch Universal Barrel (TL-3)

http://www.energyabsorption.com/products/products_universal_barrels.asp

Energite III (TL-3)

http://www.energyabsorption.com/products/products_energite_iii.asp

Water Filled Crashed Cushions

Temporary Work Zone Applications Only

Absorb 350

Test Level: NCHRP 350 TL-3
How it works: Plastic waterfilled elements allow vehicles to be decelerated.
Locations: Any locations where it is safe for the post impact trajectories to be on the back side of the system.

http://www.barriersystemsinc.com/absorb-350-crash-cushion

ACZ – 350

Test Level: NCHRP 350 TL-3
How it works: Plastic waterfilled elements allow vehicles to be decelerated.
Locations: Any locations where it is safe for the post impact trajectories to be on the back side of the system.

http://www.energyabsorption.com/products/products_acz.asp

SLED

Test Level: NCHRP 350 TL-3

How it works: Plastic waterfilled elements allow vehicles to be decelerated.

Locations: Any locations where it is safe for the post impact trajectories to be on the back side of the system.

http://www.traffixdevices.com/products/attenuators/sled/sled-us/

Miscellaneous

RAPTOR

Test Level: NCHRP 350 TL-1

How it works: Enclosed energy absorbing material crushes on impact.

Locations: Poles/trees located close to the road.

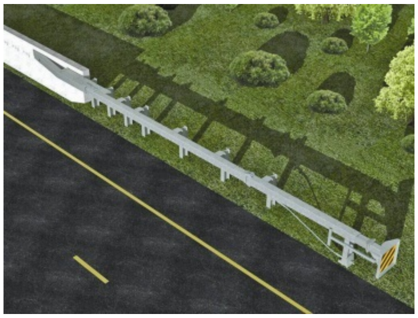
http://www.barriersystemsinc.com/pole-and-tree-attenuator

BEAT-SSCC (Single Sided Crash Cushion)

Test Level: NCHRP 350 TL-3

How it works: Mandrel section of the impact head bursts the tubing to absorb the impact energy. Attaches directly to rigid barriers, bridge rails and abutments.

Locations: Shoulder protection. Ground mounted or surface mounted post on a concrete pad.



http://www.roadsystems.com/beat-sscc.html

Part 3

Maintenance

Guardrail systems must be kept in good working condition (near "as-built condition") if they are to contain and redirect impacting vehicles. Some deterioration occurs as a result of crash damage and environmental degradation. Much of this damage can be considered "cosmetic" and may not measurably affect barrier performance. However, some kinds of damage may seriously degrade performance such as those listed below in the Longitudinal Barrier Damage and Terminal Damage sections. Repairs to these types of damage should be given priority.
While it is not practical to quantitatively define "in a timely manner", each identified damaged barrier site must be assessed, prioritized and scheduled for repairs based upon risk exposure (highway type, extent of barrier/terminal damage, potential for being restruck within the repair time window).

Longitudinal Barrier Damage

The types of guardrail damage listed below may result in inadequate structural and substandard redirective performance.

- Vertical tears in the W-beam rail that begin at the top or bottom edge. These are likely to result in rail separation in a subsequent crash.
- Similarly, holes in the rail resulting from damage or deterioration that reaches the top or bottom of a rail or one hole with a section greater than 1 inch or several holes with a dimension less than 1 inch within a 12.5-foot length of rail.
- More than 2 missing or ineffective splice bolts.
- More than 9 inches of lateral deflection over a 25-foot length of rail.
- Top rail height more than 2 inches lower than the original rail height.
- Rail flattening that increases the W-beam section width from its original 12 inches.

Terminal Damage

These types of guardrail terminal damage can result in inadequate performance if hit:

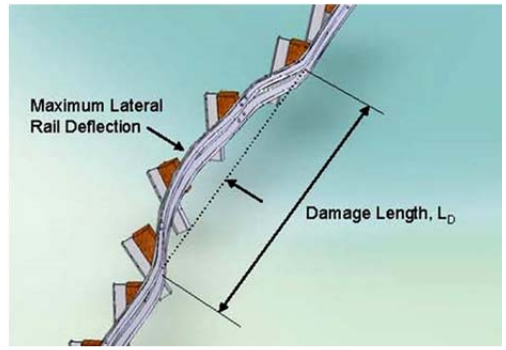
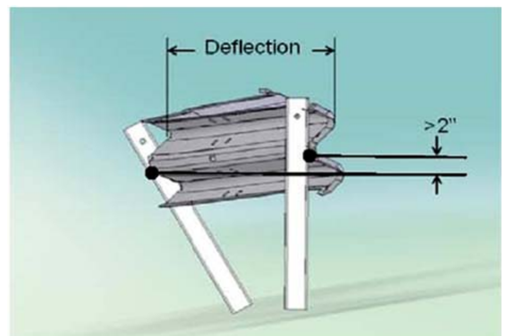
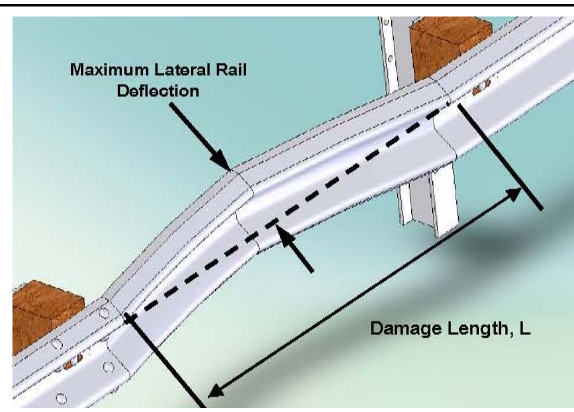
- Broken or damaged end posts.
- Missing or very slack rail-to-end post cables.
- Missing cable bearing plate at end posts.
- Impact head not properly aligned with W-beam rail elements.
- W-beam rail element not properly seated in the impact head.

The following pages consist of excerpts from **NCHRP Report 656, Criteria for the Restoration of Longitudinal Barrier**. Note that the types and degree of damage to the barrier itself and to barrier terminals is prioritized as High, Medium, or Low. These rankings, along with the perceived likelihood of a second impact in the same location can be used to set repair priorities.

Repair priority scheme

Priority Level	**Description**
High	A second impact results in unacceptable safety performance including barrier penetration and/or vehicle rollover.
Medium	A second impact results in degraded but not unacceptable safety performance.
Low	A second impact results in no discernible difference in performance from an undamaged barrier.

Summary of W-beam barrier repair thresholds

Damage Mode	Repair Threshold	Relative Priority	Measurement
Post and Rail Deflection	One or more of the following thresholds: • More than 9 inches of lateral deflection anywhere over a 25 ft length of rail. • Top of rail height 2 or more inches lower than original top of rail height.	High	  (Weak Post W-Beam Shown Only for Clarity. Each measurement taken at rail middle fold)
	6-9 inches lateral deflection anywhere over a 25 ft length of rail.	Medium	
	Less than 6 inches of lateral deflection over 25 ft length of rail.	Low	
Rail Deflection Only	6-9 inches of lateral deflection between any two adjacent posts. Note: For deflection over 9 inches, use post/rail deflection guidelines.	Medium	
	Less than 6 inches of lateral deflection between any two adjacent posts.	Low	

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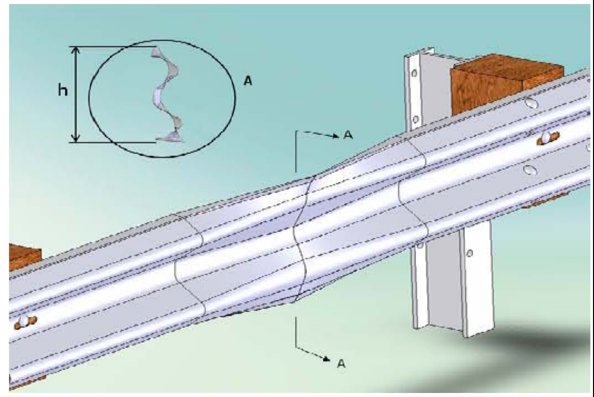
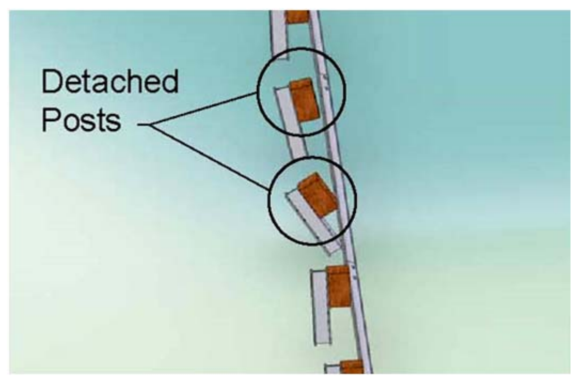
Damage Mode	Repair Threshold	Relative Priority	Measurement
Rail Flattening	One of more of the following thresholds: • Rail cross-section height, h, more than 17” (such as may occur if rail is flattened). • Rail cross-section height, h, less than 9” (such as a dent to top edge).	Medium	
	Rail cross-section height, h, between 9 and 17 inches.	Low	
Posts Separated from Rail	• 2 or more posts with block-out attached with post-rail separation less than 3 inches. • 1 or more post with post-rail separation which exceeds 3 inches.	Medium	 Note: 1. If the block-out is not firmly attached to the post, use the missing block-out guidelines. 2. Damage should also be evaluated against post/rail deflection guidelines.
	• 1 post with block-out attached with post-rail separation less than 3 inches.	Low	

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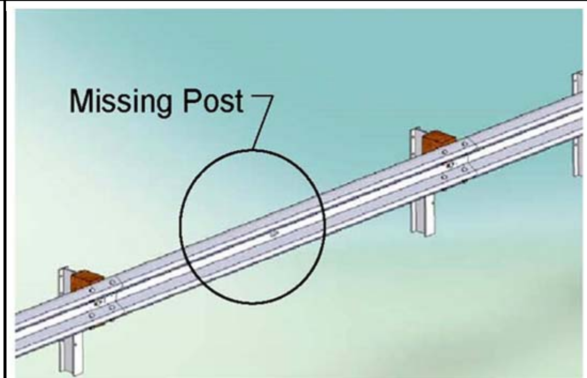
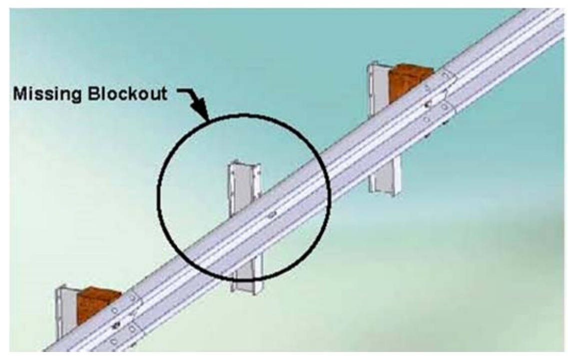
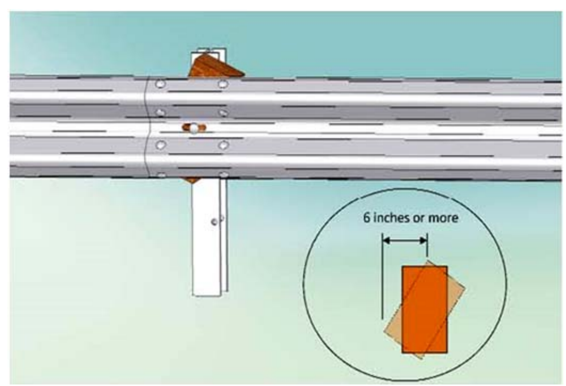
Damage Mode	Repair Threshold	Relative Priority	Measurement
Missing/Broken Posts	1 or more posts • Missing • Cracked across the grain • Broken • Rotten • With metal tears	High	
Missing Block-out	Any block-outs • Missing • Cracked across the grain • Cracked from top or bottom block-out through post bolt hole • Rotted	Medium	
Twisted Block-outs	Any misaligned block-outs, top edge of block 6 inches or more from bottom edge. Note: Repairs of twisted block-out are relatively quick and inexpensive	Low	

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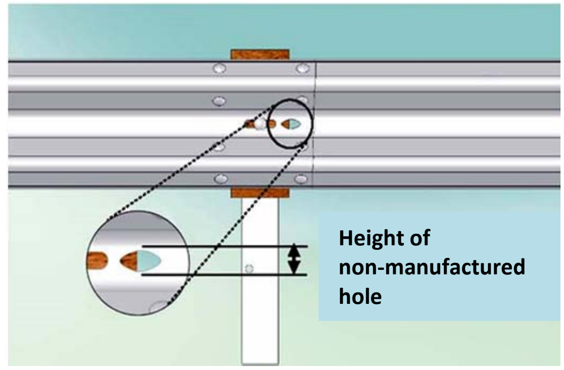
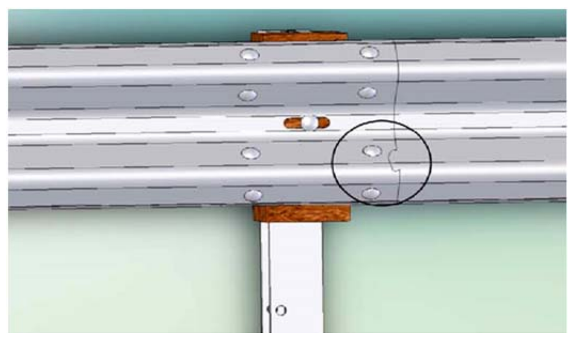
Damage Mode	Repair Threshold	Relative Priority	Measurement
Non-Manufactured holes (such as crash induced holes, lug-nut damage, or holes rusted-through the rail)	• More than 2 holes less than 1” in height in a 12.5’ length of rail. • Any holes greater than 1” height. • Any hole which intersects either the top or bottom edge of the rail.	High	
	1-2 holes less than 1” in height in a 12.5’ length of rail.	Medium	
Damage at a rail splice	More than 1 splice bolt: • Missing • Damaged • Visibly missing any underlying rail • Torn through rail	High	
	1 splice bolt: • Missing • Damaged • Visibly missing any underlying rail • Torn through rail	Medium	

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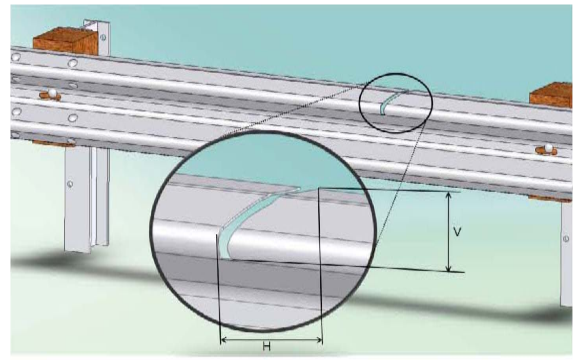
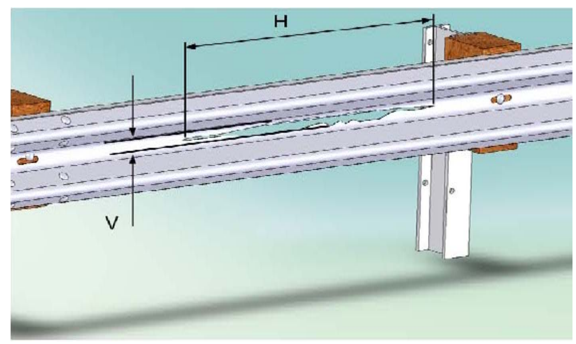
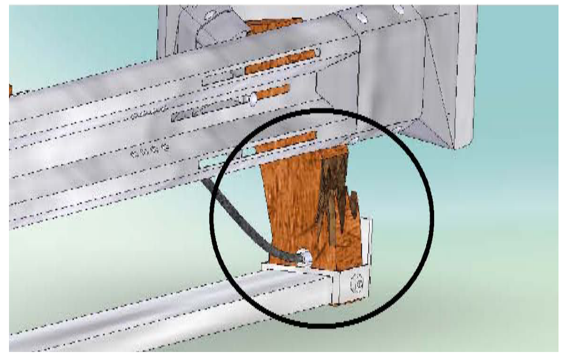
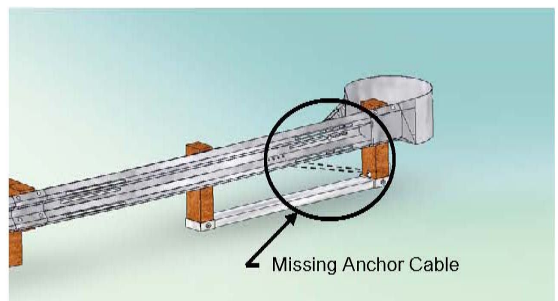
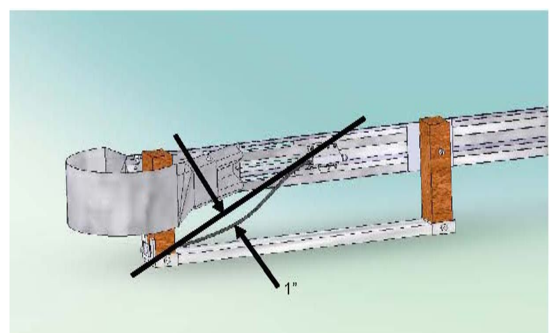
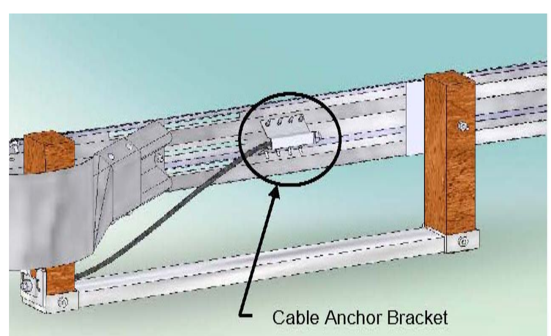
Damage Mode	Repair Threshold	Relative Priority	Measurement
Vertical Tear	Any length vertical (transverse) tear	High	
Horizontal Tear	Horizontal (longitudinal) tears greater than 12 inches long or greater than 0.5 inches wide. Note: for horizontal tears less than 12 inches in length or less than 0.5 inches in height, use the non-manufactured holes guidelines.	Medium	

Summary of generic end terminal repair thresholds

Damage Mode	Repair Threshold	Relative Priority	Measurement
Damage End Post	Not functional (sheared, rotted, cracked across the grain)	High	
Anchor Cable	Missing	High	
Anchor Cable	More than 1" of movement when pushed down by hand	Medium	
Cable Anchor Bracket	Loose or not firmly seated in rail	Medium	

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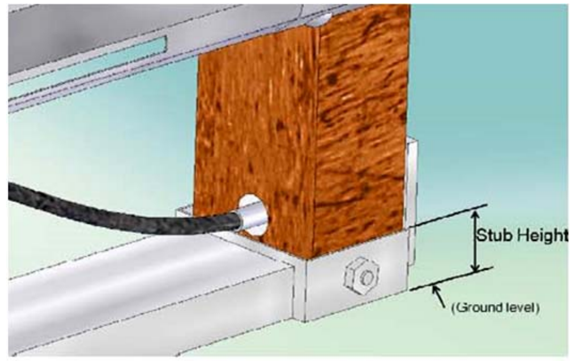
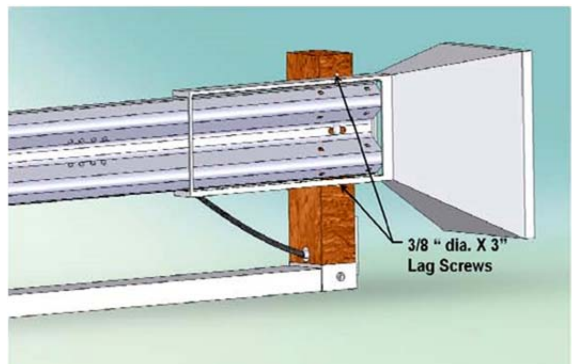
Damage Mode	Repair Threshold	Relative Priority	Measurement
Stub Height	Height which exceeds 4"	Medium	
Lag Screws (Energy Absorbing Terminals Only)	Missing or failed lag Screws	High	

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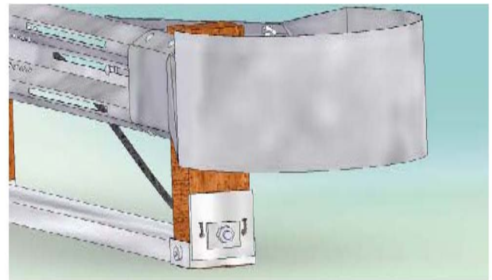
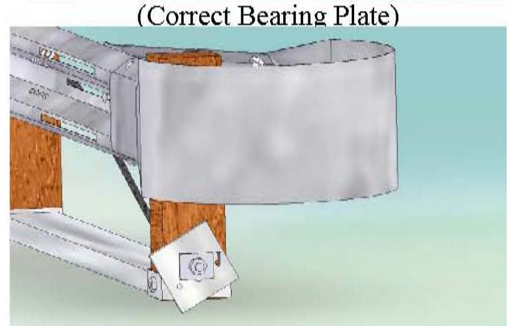
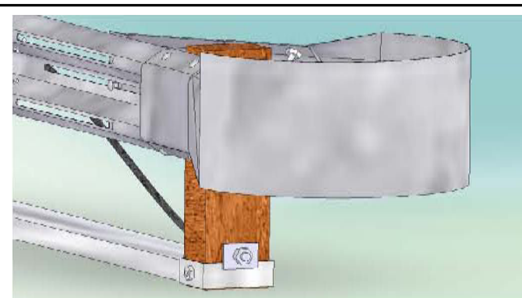
Damage Mode	Repair Threshold	Relative Priority	Measurement
Bearing Plate	Loose or Misaligned	Medium	 (Correct Bearing Plate)  (Misaligned Bearing Plate)
	Missing Bearing Plate	High	 (Missing Bearing Plate)

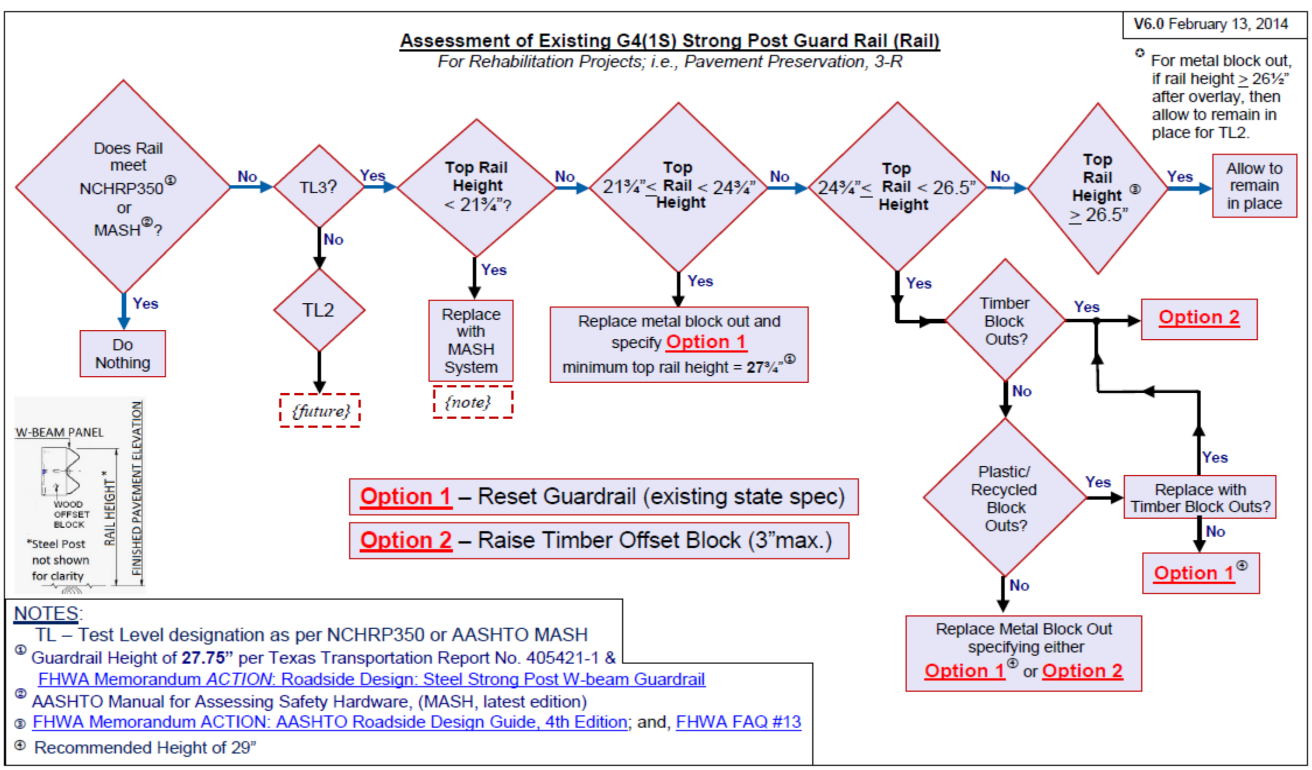
Repair/Upgrade/Remove

When a guardrail or terminal is damaged to the point where repairs are needed, several questions should be asked before the damaged hardware is simply replaced in-kind:

- Is the barrier warranted or could it be removed?
- Does the barrier meet current design standards or should it be upgraded?
- Is the terminal an acceptable crash-tested design? (NOTE: the Breakaway Cable Terminal (BCT) must be replaced; the Modified Eccentric Loader Terminal (MELT) is considered crashworthy only at speeds up to 45 mph).
- If crashworthy, is the terminal the most appropriate type for the location? (NOTE: Non-energy absorbing terminals require a significant traversable runout area behind and parallel to the rail; energy absorbing terminals require less runout distance for low-angle impacts).
- Turned-down terminals are not considered crashworthy.

Tennessee On-Call Guardrail Contract

- Entire guardrail sections may be removed and replaced to current standards if the major portion of the section is damaged beyond repair and if directed by the Engineer.
- Damaged end treatments must be replaced with NCHRP Report 350 or MASH TL-3 terminals.



TDOT On-call Guardrail Contract requires:

- Work to begin within 14 calendar days from receipt of work order, or
- Within 2 days after receipt of emergency work order.
- Once started, repair work must be continuous until completed.

Other Considerations (Maintenance only):

- Shortened Posts (27" high rail)
  - Minimum length: 64 inches
  - Minimum embedment: 36 inches
  - NO FIELD CUTTING ALLOWED

- Missing Posts
  - No more than two may be omitted.
  - Nested rail across span to 2nd post on both sides.

- Additional Blockouts
  - Only one additional blockout per post.
  - No more than 3 consecutive posts.

Resources

AASHTO, Roadside Design Guide, 2011

Manual on Uniform Traffic Control Devices for Streets and Highways, 2009

AASHTO, Manual for Assessing Safety Hardware, 2009

FHWA Hardware Policy and Guidance http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/

FHWA Longitudinal Barriers http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/barriers/

AASHTO Task Force 13 website https://www.aashtotf13.org/

AASHTO Guide to Standardized Highway Barrier Hardware;

https://www.aashtotf13.org/Barrier-Hardware.php

NHTSA FARS web site: http://www-fars.nhtsa.dot.gov/Main/index.aspx

Roadside Safety Pooled Fund sites:

MwRSF: http://mwrsf-qa.unl.edu/

TTI: http://www.roadsidepooledfund.org/

NCHRP Research Projects http://www.trb.org/NCHRP/Public/NCHRPProjects.aspx

Bridge Rail Guide: http://guides.roadsafellc.com/

NCHRP Report 350: http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_350-a.pdf

Tennessee Strategic Highway Safety Plan

TDOT QPL, List 34:
http://www.tdot.state.tn.us/materials/reseval/docs/qualprodlist.pdf

TDOT Safety Devices Standard Drawings:
http://www.tdot.state.tn.us/Chief_Engineer/engr_library/design/S.htm

TDOT Design Guidelines:
tdot.state.tn.us/Chief_Engineer/assistant_engineer_design/design/DesGuide.htm

4-705 Roadside Barriers:
http://www.tdot.state.tn.us/Chief_Engineer/assistant_engineer_design/design/DGpdf/dg-s4.pdf

NOTES