HIGHWAY BARRIER POCKET GUIDE

GUIDELINES FOR INSTALLATION, INSPECTION AND MAINTENANCE OF COMMONLY USED SAFETY BARRIER SYSTEMS IN NEW HAMPSHIRE

January 2024

New Hampshire DOT
Department of Transportation

GENERAL
BARRIERS
DESIGN
END TREATMENTS
TRANSITIONS
SPECIAL DESIGN
MAINTENANCE

Disclaimer

This manual provides a written account of how certain activities are performed and is designed to guide and assist staff in performing their functions. When appropriate, there may be deviations from these written procedures due to changes in personnel, policies, interpretation, law, experimentation with different systems, or simply evolution of the process itself. This manual may be changed at any time. Staffs are encouraged to review this manual periodically and suggest changes in the manual to keep the manual current and to minimize differences between the manual and actual practices.

This guide is based upon work supported by the Federal Highway Administration under Grant Agreement No. 693JJ317500085. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the Federal Highway Administration. This document does not constitute a national standard, specification, or regulation.

The purpose of this pocket guide is to present basic guidelines for guardrail installers, inspectors, and maintenance personnel. The guide presents information contained in the AASHTO Roadside Design Guide, 4th Edition, the NHDOT Standard Plans, Special Provisions and the NHDOT Highway Design Manual. Barrier installations are to be built and maintained to current NHDOT standard plans and manufacturers' recommendations.

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U.S. Department of Transportation
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Frequently Asked Questions

When reviewing proposed and existing barrier installations in the field, consider the following questions:

1. Is the obstacle being shielded significantly more severe than the barrier itself; and secondly, what is the likelihood of the obstacle being struck? (page 10, **Roadside Obstacle**)

2. Are there any vertical rigid objects within the guardrail system's design **deflection**? (page 32, **Deflection**)

3. For existing installations, does the guardrail **height** meet criteria? (page 35, **Slope in Front of Barrier—Height**)

4. Is the **slope in front** of the barrier appropriate (page 35, **Slope in Front of Barrier**)

5. If a high-speed facility, are there **curbs** in combination with guardrail? (page 36, **Guardrail in Combination with Curbs**)

6. Is there adequate soil support behind the guardrail shielding a non-recoverable fill slope or has the design been appropriately modified? (page 36, **Post Support at Embankment**)

7. Is the guardrail installation long enough to shield the obstacle? (page 39, **Length of Need**)

8. Should the guardrail be extended upstream to shield other warranting obstacle(s)? (page 43, **LON Field Check**)

9. Is an appropriate terminal being used? (page 49, **Terminal Selection Flow Chart**)

10. Is the **grading** around the terminal (approach, adjacent, and runout distance) appropriate? (page 67, **Terminal Grading Details**)

11. Does the guardrail end within 200 feet of the start of another guardrail run that could be connected? (page 45, **Gaps**)

This guide, when used in conjunction with field reviews and appropriate NHDOT manuals, practices, and policies and procedures, provides the information needed to answer these questions and ensure that personnel install and maintain appropriately performing barriers.

Review Procedure for Projects with Guardrail

The following information shall be used as a guide for the field review and design of new guardrail. (Highway Design Manual, App 11-03).

Preliminary Investigation

- Review record plans of the area using archived plans in the NHDOT Project Viewer (Engineering Tools -> GIS Interactive Map – Project Viewer) and/or in the Records Section of Highway Design for the project(s) that may have installed the guardrail to identify type and vintage.
    - Note the Design Speed used to design the guardrail should be on the front sheet of the proposed plan set. When no as-built exists, or as-built with design speed indicated, use 5 mph over the posted speed.
- Optional: Verify any information found with a satellite/street view service, such as Google Earth or Bing. This is usually a quick and easy way to check if the guardrail has been replaced, extended, or otherwise changed since the original installation.
    - If the existing guardrail is vintage/Non-MASH compliant cable, the entire run should be planned to be replaced. These areas often have less slope break than our current standards, so keep that in consideration when designing. Cable runs are often shorter than today's requirements as well, so extensions should be anticipated.
    - If the existing guardrail is beam without a turndown terminal, then the replacement will be determined by the vintage and condition of the rail, as well as the current end terminals. The Specialty Section can provide assistance if there is uncertainty about the crashworthiness of existing terminals.

- Utility Verifications – Design Services needs the location of the guardrail runs so they can perform verifications. Provide as-built plans or the plans you are creating, whichever is more accurate.
- Request Accident History if there is a suspicion of higher-than-average crashes at a particular location.
- Contact the Highway Maintenance District Office for any problems they may want to have fixed.

Field Review

- Before going out in the field be sure to review the Roadside Design Guide (Ch. 3 & 5). This book is used as a guide to design the guardrail. There will be instances when it does not make sense to fully follow the guide. Use good engineering judgment in these situations and document your assumptions, include photographs.
- When practical, take video. This video can be used to evaluate areas that you may not have taken pictures of. Consider referring back to Google, Bing or pavement van data if you need to view an area where a picture wasn't taken.
- At each replacement location a sketch should be used to identify all the key information for assessing the existing guardrail and designing new guardrail, if necessary. A field review sheet has been created and can be found at the following location: S:\Global\B34-HighwayDesign\Guardrail in the Guardrail Calculation Spreadsheet. This sheet should include all of the following information:
    - Description of Location
    - Route and direction of closest lane of traffic (ex. Route 16 NB), existing lane widths, guardrail dimensions, hazard location, type of existing terminal unit, and picture(s) taken.
    - Take a picture at each proposed end unit location using something in the picture to identify where the unit will be (measuring wheel, backpack, etc.).

- Note any potential conflicts that may need to be addressed, including their location along the rail, and distance from edge of pavement. This could include elements such as utility poles, fire hydrants, mailboxes, culverts, etc.
- Note the overall length of the existing guardrail. Separate measurements can be taken for partial replacements, if necessary.

Field Design Considerations:

New installations shall provide a clear area of 20' wide by 50' long behind the terminal. Strive for the same area at existing locations, however, ROW, wetland, or other constraints may prevent this.

- At a very minimum, be sure to not place the terminal unit in front of anything that could cause the terminal to function improperly (keep the first 12.5' free of obstructions) such as utility poles, earth berms, or non-breakaway signs.

- Evaluate and identify the hazard type and location. The location can be the distance from a fixed object such as the first post, or using the alignment stationing. Common hazards are slopes greater than 4:1, piers, abutments, overhead sign structures, drinking water sources, etc.
  - Utility poles, trees, and signs with breakaway posts are not considered warrantable for guardrail installation.
  - If no hazard is identified, it may be possible to remove the guardrail. Confirm with District to ensure there aren't other reasons the guardrail exists.
  - Where possible, flattening slopes to eliminate slope hazards is encouraged. LRS can often be used within NHDOT ROW. Coordinate with BOE if this is applicable.
- Determine the estimated Length of Need where work is being done using guidance provided by Specialty Section. Ensure the extension of guardrail and new terminal location will be appropriate for the area.

- Note existing limits of curbing or curb board. Curb board should be replaced with bituminous curb. Indicate proposed curbing in the guardrail note.

Things to remember:

- Coordination with Bridge Design should occur any time roadway guardrail attaches to a bridge. Take appropriate measurements and pictures to aid their design.
- No non-breakaway object shall be within 6' of the face of guardrail.
- Guardrail can be tapered to assist in decreasing the overall length of the guardrail run using the flare rates provided in the Roadside Design Guide.
    - The slope in front of all guardrail needs to be 10:1 or flatter. This includes all the area in front of tapered rail. A typical slope will match the slope of the roadway shoulder. It is important to consider the amount of fill that may be needed and if it is economical to bring in the fill.
- Consider E-3's when possible. E-3 units eliminate the possibility of an impact with the head of the terminal, as it is buried into the backslope. Refer to the E-3 detail posted online. It may not always be practical or economical to select an E-3, especially if the project does not include much earthwork, or if the location would require ledge work.
- Be aware of the existing drainage (closed drainage, culverts, underdrain, ditches, etc.) in the area.
    - At a minimum, 4.5 feet of cover above existing and proposed drainage must be available to consider placing a guardrail post at the same location. Ideally, greater than 5 feet should be provided to avoid the possibility of driving rocks or other objects through the drainage during installation of the post. When possible, span pipes with the standard post spacing. If longer spans are required, consult the Specialty Section.

- Terminal platforms may affect existing drainage paths and require regrading of ditch lines. Pipes can be added if needed to resolve the conflict.

- When possible, replace sluice drains with DI-DB and slope drains. Consider ROW impacts and the scope of your project to determine if this work is practical.

- Guardrail over low fill culverts or utilities can be spanned. Make note of any markers noting underground utilities during the field review. Pass the information along to Design Services.

- It is important to be on the lookout for possible wetland areas and contact the Bureau of Environment for a field review of these areas. Take pictures.

- Use curved guardrail w/CRT posts when appropriate (Ramp Noses, sideroads, etc.). Refer to the Special Detail for appropriate locations. Do not forget the clear zone needed behind the CRT posts. Keep in mind this needs a design exception memo when on the NHS.

- Guardrail on the interstate is often set at 6' from the TW on the left and 12' from the TW on the right.

  - On interstate ramps with curbing, the face of guardrail is set at 6' from the face of curb. If there is no curbing, the face of guardrail is set at the edge of pavement.

- Be aware of informal drives or access points, such as trails or pathways. District should be consulted if any of these are being considered to be closed off, as they may provide access to an undeveloped parcel or provide beach access to a landowner on the opposite side of the road.

GENERAL CHECKLIST

The following information should be used as a guide for the field review and design of barriers.

(See complete guide Highway Design Manual, App 11-03 - Review Procedure for Projects with Guardrail.)

	Review record plans of the area using archived plans in the NHDOT Project Viewer
	Review Records Section of Highway Design for the project(s)
	Check as-built for design speed, use 5 mph over posted speed when not available.
	Identify hazard type and location
	Utility poles, trees, and signs with breakaway posts are not considered warrantable for guardrail installation.
	No hazard identified, it may be possible to remove the guardrail. Confirm with District to ensure there aren't other reasons the guardrail exists.
	Where possible, flattening slopes to eliminate slope hazards is encouraged. LRS can often be used within NHDOT ROW. Coordinate with BOE if this is applicable.

Introduction

Barrier systems are designed and installed for one primary reason — to reduce the severity of a crash by preventing a motorist from reaching an area of concern, which is either an obstacle or non-traversable terrain feature. Barriers are considered when the consequences of striking the barrier are less severe than that of reaching the obstacle or area of concern.

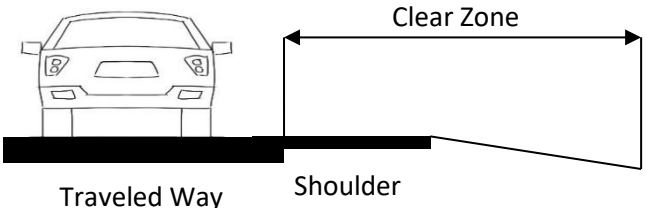
The first priority should be to remove the obstacle (or redesign it so it is no longer an area of concern). When the obstacle cannot be acceptably mitigated, then a decision is made as to whether installing a barrier is the most appropriate treatment for the situation. The following itemizes this approach:

Order of Preference (Ref. NHDOT Highway Design Manual, Chp. 11 – Clear Zone)

- Remove the obstacle.
- Redesign the obstacle so it can be traversed (e.g., flatten the slopes).
- Relocate the obstacle to a point where it is less likely to be struck.
- Reduce the impact severity by using an appropriate breakaway device.
- Consider above options before installing barrier.

Clear Zone

The clear zone is defined as the unobstructed, traversable area provided beyond the edge of the through traveled way for the recovery of errant vehicles. The clear zone includes shoulders, bike lanes, and auxiliary lanes, except those auxiliary lanes that function as through lanes. The figure below illustrates this.



There is a distinction between available clear zone and design clear zone. *Available Clear Zone* is the **existing** area for recovery. *Design Clear Zone* is a selected value used for design to provide recovery area for the majority of errant drivers.

The available clear zone should not be compromised.

Make the amount of clear zone as wide as practical.

(AASHTO *Roadside Design Guide*, 4th Edition, 2011, 3.1 The Clear-Zone Concept)

The width of the design clear zone is influenced by the traffic volume, highway design speed, and embankment slopes as discussed in the AASHTO Roadside Design Guide, Table 3-1.

Note b in essence provides for a 10-foot recovery area at the toe of a traversable but non recoverable slope.

The following table presents design clear zone values from the AASHTO Roadside Design Guide with the NHDOT criteria highlighted.

Design Speed (mph)	Design ADT	Foreslopes			Backslopes		
		1V:6H or flatter	1V:5H to 1V:4H	1V:3H	1V:3H	1V:5H to 1V:4H	1V:6H or flatter
≤40	UNDER 750[c]	7-10	7-10	b	7-10	7-10	7-10
	750-1500	10-12	12-14	b	10-12	10-12	10-12
	1500-6000	12-14	14-16	b	12-14	12-14	12-14
	OVER 6000	14-16	16-18	b	14-16	14-16	14-16
45-50	UNDER 750[c]	10-12	12-14	b	8-10	8-10	10-12
	750-1500	14-16	16-20	b	10-12	12-14	14-16
	1500-6000	16-18	20-26	b	12-14	14-16	16-18
	OVER 6000	20-22	24-28	b	14-16	18-20	20-22
55	UNDER 750[c]	12-14	14-18	b	8-10	10-12	10-12
	750-1500	16-18	20-24	b	10-12	14-16	16-18
	1500-6000	20-22	24-30	b	14-16	16-18	20-22
	OVER 6000	22-24	26-32[a]	b	16-18	20-22	22-24
60	UNDER 750[c]	16-18	20-24	b	10-12	12-14	14-16
	750-1500	20-24	26-32[a]	b	12-14	16-18	20-22
	1500-6000	26-30	32-40[a]	b	14-18	18-22	24-26
	OVER 6000	30-32[a]	36-44[a]	b	20-22	24-26	26-28
65-70[d]	UNDER 750[c]	18-20	20-26	b	10-12	14-16	14-16
	750-1500	24-26	28-36[a]	b	12-16	18-20	20-22
	1500-6000	28-32[a]	34-42[a]	b	16-20	22-24	26-28
	OVER 6000	30-34[a]	38-46[a]	b	22-24	26-30	28-30

NOTES: b. Because recovery is less likely on unshielded, traversable 1V:3H fill slopes, fixed objects should not be present in the vicinity of the toe of these slopes.----- **A 10-ft recovery area at the toe of the slope should be provided for all traversable, non-recoverable fill slopes.**

See AASHTO Roadside Design Guide, 4th Edition 2011, Chapter 3, Table 3-13.

These values are based on the concept of addressing 80 percent of the vehicle departures. Since it is anticipated that 20 percent of the errant vehicles will exceed these distances, consideration should be given to the type obstacles to be encountered beyond and the consequences in order to create a forgiving roadside environment.

Roadside Obstacles

Obstacle	Guidelines
Bridge piers, abutments, and railing ends	Shielding generally required
Boulders	Judgment decision based on nature of fixed object and likelihood of impact
Culverts, pipes, headwalls	Judgment decision based on 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.

*NHDOT – this is not a general practice, nor would guardrail be extended to protect utility poles.

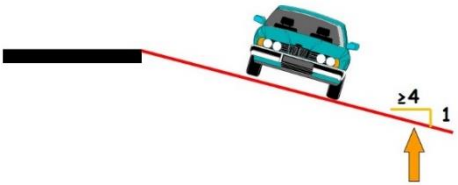
Ref: AASHTO Roadside Design Guide, 4th Edition Chapter 5 Table 5-2, Pg. 5-9

Roadside Slopes/Embankments

In general, parallel slopes should be as flat as practical.

The AASHTO *Roadside Design Guide* (RDG) classifies slopes as:

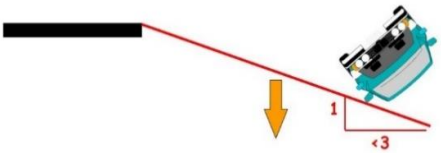
Recoverable:
1V:4H and flatter.



Traversable:
Steeper than
1V:4H but 1V:3H
or flatter.

Although considered traversable slopes, they are not considered recoverable; thus, a vehicle most likely will continue to the bottom of the embankment. A minimum 10 feet clear recovery area at the bottom of these embankments is recommended.

Critical: Steeper than 1V:3H



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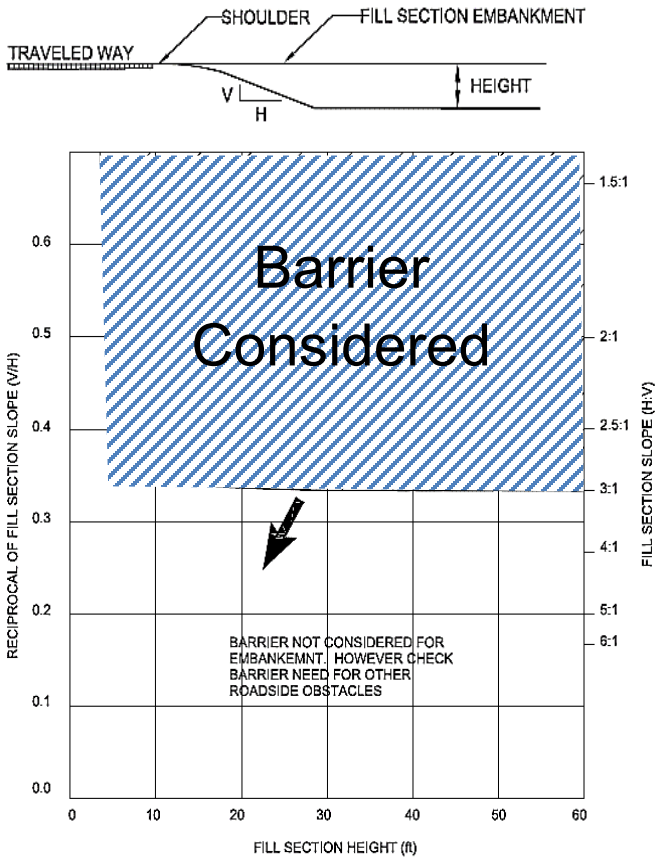
*NHDOT considers foreslope conditions steeper than 1V:4H are not part of the clear zone and have adopted a height greater than 5 feet and slope steeper than 4:1 as warranting guardrail. Although embankment heights of 5 feet or less may not

necessarily require barrier the area at the toe of the slope needs to be addressed in regard to other roadside obstacles e.g., trees or water. Also, slope flattening may still be in order.

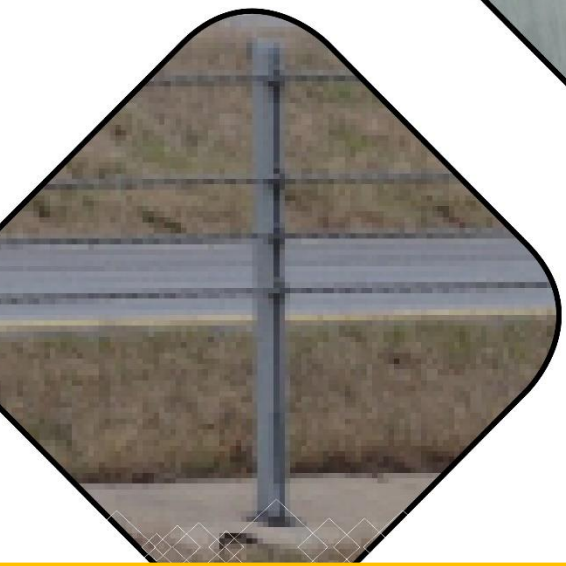


Modified Roadside Design Guide, Figure 5-1(b)

The designer may perform a cost-benefit analysis to help assess the necessity of a barrier for all hazards.

BARRIERS

A roadside barrier is a longitudinal barrier used to shield motorists from natural or man-made obstacles located along either side of a traveled way.



GENERAL CHECKLIST

The following information shall be used as a guide for the field review and design of barriers.

GENERAL - All	
	All system components are free of deterioration/rust and/or damage
	Hazard identified
	Are there additional hazards that should be shielded?
	Can hazard be removed, relocated, made breakaway?
	Obstacles are located beyond the systems deflection distance
	Length of need (LON) adequate? Field check performed
	Slope in front of barrier is 1V:10H or flatter
	Are there guardrail runs within 200 feet? Can gap be closed?
	Delineation is installed properly and located per standard

Rigid Barriers

	Barrier Safety Shape per plan (NHDOT –single slope for permanent)
	Barrier height meets MASH crash test criteria (Level of Service)
	No sections or gaps in barrier
	No imperfections in the barrier
	Joints are connected and aligned to adjacent sections
	Precast-3 loop, no missing pin
	For permanent – 3 inch embedment
	If flared, rate is within RSDG guidelines

Semi-Rigid Barriers

GENERAL	
	Obstacles are located beyond the deflection distance for system employed
	For 31” mid-splice system, on roads with speeds that are 45 mph or greater, height of curb may be 6 inches max. and located within 6 inches of Guardrail face.
	For system with splice on post, on roads with speeds that are 45 mph or greater, curbs should be limited to 4 inches with sloped face with guardrail face and curb faced aligned.
	2.5 feet of support material behind the face of the rail (1V:10H max). If not, has special design or guardrail been incorporated for post support?
	If system flared, is rate of flare within RSDG guidelines and slopes 1V:10H?
	Any transition for guardrail heights takes place over 50’.
RAIL	
	Rail is continuous
	No tears – vertical or horizontal
	No sections of rail flattened
	No non-manufactured holes
	No rail subject to cutting touch or welded elements
	Rail height within plan tolerance
	No separation of rail to post connection
SPLICE	
	Location of splices is per standard
	Laps in direction of traffic
	Eight 5/8 in bolts securely connecting rails
	No bolts torn through rail
POSTS	
	No missing post – unless by design
	No broken/damage posts
	Post spacing is per standard
	Steel post as specified in plans

	Posts are intact, plumb and firmly embedded for required depth as per plan. No cut off posts.
	No significant erosion around posts
	A minimum 7 inches clear behind post if set in structural pavement
	No washers under rail-to-post bolt head
OFFSET BLOCK	
	No missing offset blocks
	No twisted or rotated offset blocks
	Synthetic (Composite) block per plan
	Block firmly attached to post per plan

Flexible Barriers

GENERAL	
	Obstacles are located beyond the systems deflection distance (e.g. 12' for low tension cable barrier)
	Nothing in front of barrier that could cause a vehicle to vault, such as curb.
	No cable barrier installed on a curve with a centerline radius of less than 440 feet for low tension barrier.
	Max. Cable run for low tension 1,000' (compensating device on one end and turnbuckle on the other of each individual cable.)
CABLE	
	Cable is continuous
	No broken strands
	Number of cables and location per standard. (* four cables with bottom cable facing low side and remaining 3 cables staggered.)
	Cable is secured to posts in accordance with standard.
	Tensioning accord with standards
	Retention after initial set inches (*2 weeks or more)
	Proper height (*28 inches to top of top cable, 10 inches to bottom cable

	* NY 4 Cable Low Tension System
SPLICE	
	Turnbuckles have adequate threads for tensioning
	Splices in correct location – not at posts.
	Cable splices are staggered (*Provide a minimum of 20 feet between any pair. Provide a minimum of 100 feet between cable splices on the same cable.)
POSTS	
	No missing post
	No broken/damage posts
	Post spacing is per standard (*16')
	Posts are intact, plumb and firmly embedded per plan. No cut off posts
	No significant erosion around posts
	Soil plate installed away from traffic*
	J hooks up on one side down on other*
	* NY 4 Cable Low Tension System
ANCHORS	
	Non-breakaway components (such as concrete footings and stub posts) are no more than 4 inches above ground.
	Not pulling out of the ground. No significant erosion around posts and anchors.
	Grading in accordance with standard.
	Anchor footing design per standard.
	Area behind and downstream of anchor is clear of obstacle
	Anchor is placed to minimize the nuisance hits

Barriers

A roadside barrier is a longitudinal barrier used to shield motorists from natural or man-made obstacles located along either side of a traveled way. Barriers are usually categorized as rigid, semi-rigid, or flexible, depending on their deflection characteristics when struck under NCHRP 350 or MASH TL-3 impact: pickup truck strike at 62 mph and 25 degrees impact angle.

MASH Test Levels

- **TL-1:** 25 deg. impact angle at 31 mph, with small car (2,420 lb.) and pickup truck (5,000 lb.).
- **TL-2:** 25 deg. impact angle at 44 mph, with small car (2,420 lb.) and pickup truck (5,000 lb.).
- **TL-3:** 25 deg. impact angle at 62 mph, with small car (2,420 lb.) and pickup truck (5,000 lb.).
- **TL-4:** TL-3 + 15 deg. impact angle, 56 mph Single-Unit Truck (22,000 lb.)
- **TL-5:** TL-3 + 15 deg. impact angle, 50 mph Tractor-Van Trailer (80,000 lb.)
- **TL-6:** TL-3 + 15 deg. impact angle, 50 mph Tractor-Tank Trailer (80,000 lb.)

(AASHTO *Roadway Design Guide*, Chapter 5, Roadside Barriers)

Rigid Systems

Rigid Barrier Systems redirects vehicles with little (between 0 to 1 feet) deflection when impacted under the TL-3 conditions described above. These are pre-cast or anchored concrete barriers and are commonly used in narrow medians, in front of bridge piers, and in other areas requiring limited deflection or higher performance.

NHDOT – Test Levels and Performance Criteria Standards. See test level application for speed and expected barrier height.

Speed (MPH)	Test Level	Inches Height (excluding embedment)	Comments
25-40	TL-2	18”	
45-70	TL-3	27”	Standard Applications
45-70	TL-4	36”	
45-70	TL-5	42”	Median Applications
45-70	TL-6 ****	54” - 90”	Bridge Piers *** Open Road Tolling (at gantry)

*** For use with bridge piers, consult with the Bureau of Bridge Design to determine the design application

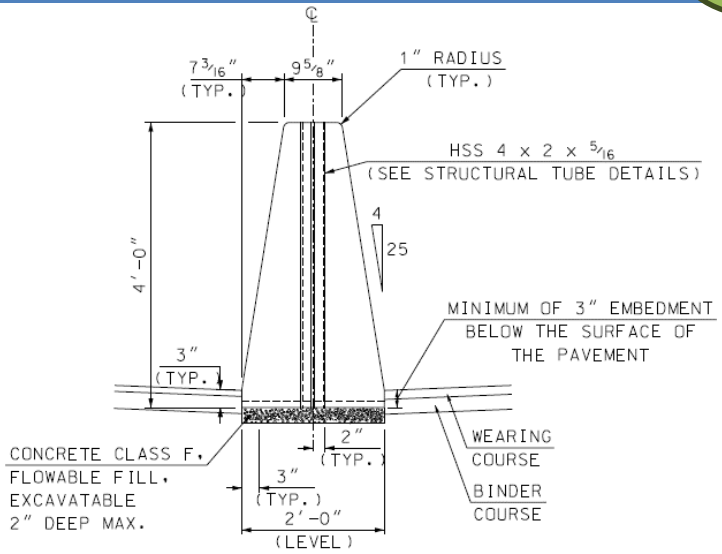
**** There has not been a MASH crash test for a 55-inch single slope barrier, so it may not pass a TL-6 loading, verify prior to use.

Under the current test criteria (MASH), the 32-inch high barrier is TL-3, 36-inch high barrier is TL-4, and 42-inch-high barrier is TL-5.

The Single Slope barriers is NHDOT current standard.

Single Slope Concrete Barrier

MASH



Details:

NHDOT Standard Plans for Road Construction GR-19.

- Typically 36 inch to 54 inch tall including 3 inch embedment
- Base 24 inch wide
- Can be constructed as a single face barrier

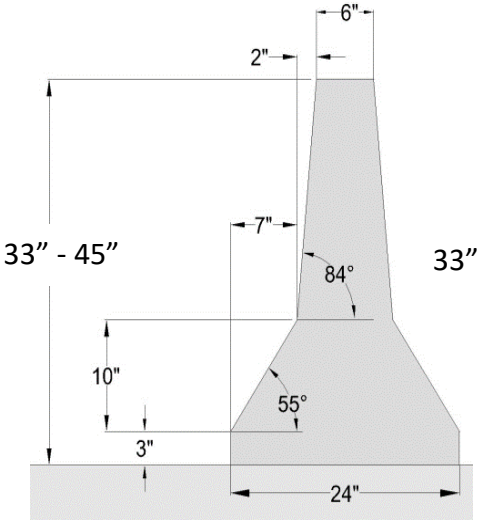
New Jersey Shape and F Shape Concrete Barriers

MASH

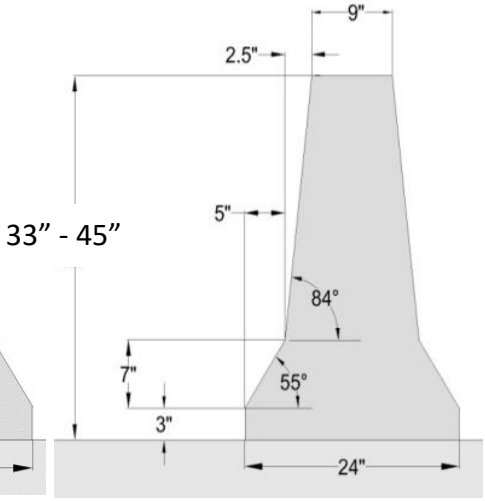
The New Jersey Shape and F shape barriers have been used within the state's roadway system.

Details

- Typically, 33" to 45" tall
- Base 24" wide
- 3" embedment



New Jersey shape



F Shape

NOTE: NHDOT discontinued use of the New Jersey barrier for permanent application, which is now the Single Slope Barrier. F Shape barrier may be used for special permanent applications. New Jersey barrier may be used for temporary applications.

Semi-Rigid System

Semi-Rigid Barrier Systems have deflections of a few feet (between 2 feet and 5 feet) under the TL-3 pickup impact conditions. Most semi-rigid systems consist of post and beam. Terminate these systems with an anchor on both ends to maintain the tension in the rail.

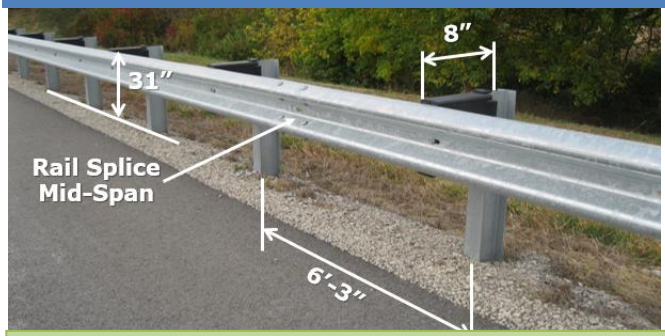
NHDOT – Test Levels and Performance Criteria Standards
See test level application for speed and expected barrier height.

Speed (MPH)	Test Level	Height of Rail	Comments
25-40	TL-2	31”	
45-70	TL-3	31”	Standard Applications

- New guardrail installations should be at 31”.
- Existing installations can be as low as 28 ¾”.
- No Cor-ten Guardrail. NHDOT discontinued use. Anodized rail can be used for special applications, such as historic and/or scenic areas where appearance is desired.
- Lap guardrail in the direction of travel of adjacent traffic.
- Additional considerations are required for deflection, slope placement, curbs, etc. See Section on Special Designs.

31” Mid-Splice Beam Guardrail

MASH



NHDOT Standard Plans for Road Construction GR-1.
For ALL New Construction

Details (Standard)

- **Rail Splice between posts**
- **Height:** 31 inches (Installation tolerance ±1 inches).
- **Post:** Steel: W6x9, 7 feet long
- **Post Spacing:** 6 feet, 3 inches
- **Offset Block:** 8 inch composite

Allowable Option

- **Post:** Nu-guard Steel post (proprietary) 5 lb/ft., u-channel. Used with or without an offset block (in uncurbed areas only). The intent of this item is to be able to use it in tight areas where there is limited support material behind the post. Only be considered after all other alternatives have been exhausted.

See **Special Design Section** for more applications.

Beam Guardrail

NCHRP

NHDOT Standard Plans for Road Construction GR-2.
Previous Standard

Details (Standard)

- **Rail Splice on posts**
- **Height:** 30 inches (Installation tolerance -1 inches to +2 inches).
- **Post:** Steel: W6x9, 7 feet long (GR-2)
  Wood posts: 6 inches x 8 inches x 7 feet long (GR-2A).
  Discontinued
- **Post Spacing:** 6 feet, 3 inches
- **Offset Block:** 8 inch composite.

Allowable Options

- **Nested Rail** allowed to stiffened section of rail.

- **Low speed roads (TL-2)** allowed 24-inch minimum height of rail. (Per MASH test, age and condition may be more critical at existing installations found at this height)

NOTE: For TL-3, after an overlay, Beam Guardrail less than 26½ inches high needs to be raised, reset or reconstructed.

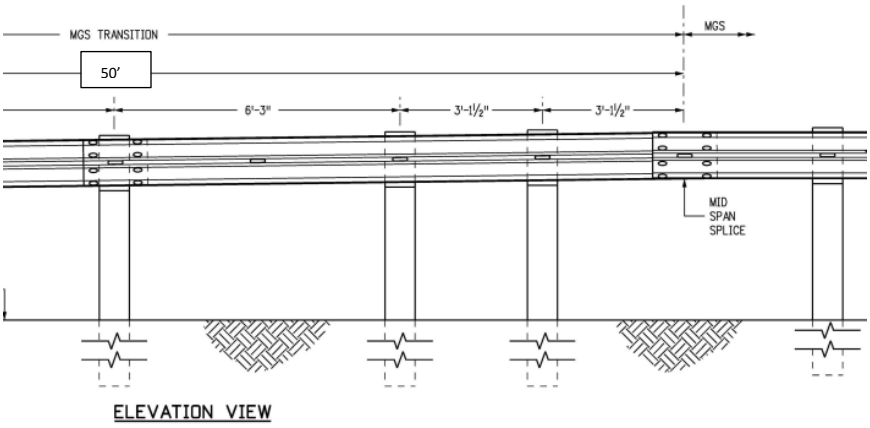
Height Guidance

Guardrail Transitions from 31-inch Rail Height to match to 27-inch High Guardrail Terminals or Bridge Approach Units

There may be situations where standard beam guardrail, set at 31 inches high, will need to be connected to guardrail terminals that have only been crash tested at 27 inches high or bridge approach units that are 27 inches high. This may reflect an existing or new installation. In those circumstances, transition the change in height over a 50 feet (minimum) length of the standard rail that is connected to the guardrail terminal or bridge approach unit (transition subsidiary to the 606 Items.)

Ref: NHDOT Highway Design Manual, Chp. 11 Appendix 11-04, Jan 2019 – Guidance for Guardrail Design Applications

Also there may be the need to transition to 31" mid span splice guardrail from lower height splice on post guardrail. An example is shown below. For NHDOT this would be over 50'.



ELEVATION VIEW

"Modified" Thrie-Beam Guardrail

MASH

NHDOT Special Provision 606, Standard GR-13

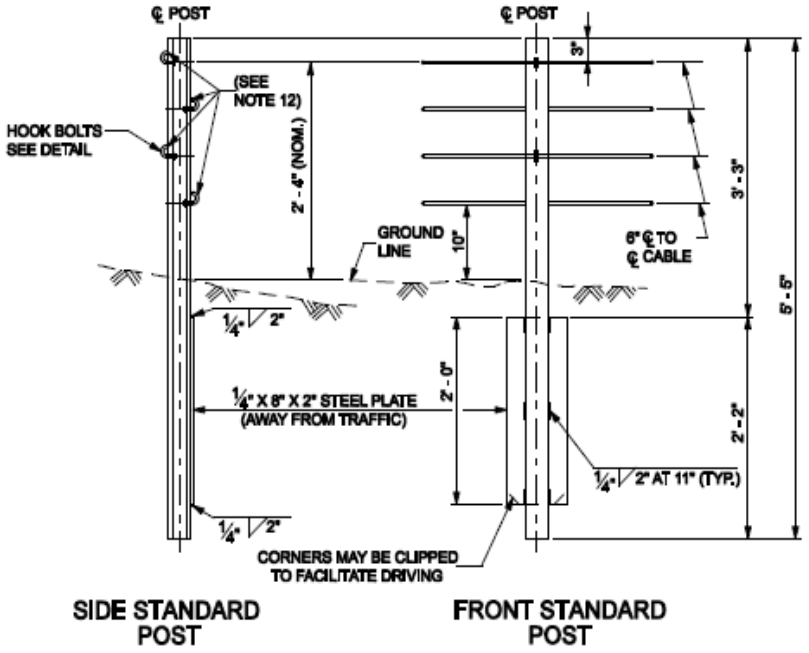
Details (Standard-with detail in special provision)

- **Rail:** 20 inches wide Thrie-beam section
- **Height:** 32 inches
- **Post:** Steel: W6x 8.5, 7 feet long
- **Post Spacing:** 6 feet, 3 inches
- **Offset Block:** Steel with cut out (per detail in special provision)
- **Median application:** Double rail and blocks with post length 6 feet – 6 inches (Standard GR-12)

Flexible Systems

Flexible barrier systems typically have relatively large deflections. Flexible systems are generally more forgiving because much of the impact energy is dissipated by the deflection of the barrier and lower impact forces are imposed upon the vehicle. Examples of Flexible Barriers include Weak-post W-beam, Low-tension cable and High-tension cable. NHDOT prefers the use of low-tension cable rail systems because of the additional advantages:

- Low initial cost
- Effective vehicle containment and redirection
- More flexible installation conditions
- Generic



Ref: Cable GR Low Tension 4-strand.dgn/Special Provision 606

Low-Tension Cable Barrier

NCHRP

Cable GR Low Tension 4-strand.dgn/Special Provision 606

Details (Standard)

- **Cables:** Four cables installed with bottom cable facing low side and remaining 3 cables staggered.
- **Height:** 28 inches to top of top cable, 10 inches to bottom cable
- **Post:** S3 x 5.7 Rolled Steel, spaced at 16 ft.
- **Length of cable run:** to 1,000 feet with compensating device on one end and turnbuckle on each run of cable.
- **Staggered Cable Splices:** Provide a minimum of 20 feet between any pair. Provide a minimum of 100 feet between cable splices on the same cable.
- **Curves:** Do not install cable barrier on a curve with a centerline radius of less than 440 feet
- **Terminal:** Consists of one steel anchor post and anchor angle set in concrete.
- **Design deflection:** approximately 12 feet

DESIGN

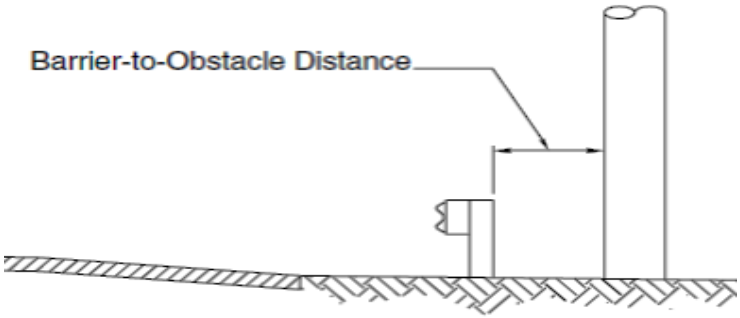
Understand the five design principles that are applied for an optimal barrier design and apply a field procedure to check Length of Need.

Barrier Design Principles

There are five principles of barrier design that should be addressed for a barrier installation to perform as designed. Some of these principles differ between the 31" mid-splice Beam Guardrail and Beam Guardrail. These differences are noted in the following guidance. Note that the 28" Beam Guardrail was tested to NCHRP 350 criteria (and successfully to MASH, as a steel post system only); the 31" mid-splice Beam Guardrail was tested to MASH with steel and wood posts.

Deflection

The needed deflection distance is based on the results of 62 mph strikes into the guardrail at a 25 degrees impact angle by a pickup truck.



Deflection – Rigid Barrier

An embedded, permanent concrete barrier when impacted (TL-3) has no observed deflection.

Unembedded temporary barrier does deflect and the risk to vehicle occupants and workers behind the barrier need to be considered.

Deflection is more critical where guardrail/barrier is used to protect vehicles from bridge piers, abutments or similar hazards (i.e., overhead sign structures). Large vehicles can overhang beyond the barrier into the region defined as the Zone of Intrusion (ZOI). In these cases, consideration of a higher test level barrier (i.e., TL-4 and/or TL-5) should be made to account for the higher center of gravity of these larger vehicles. Bridge engineers recommended that any barrier within 10 feet be 54 inches tall, and 42 inches if beyond 10 feet The *Roadside Design Guide* suggests the taller barrier begin 10 feet in advance of the obstacle preceded by a 1V:10H slope to the normal barrier height; a more recent study suggests 60 feet in advance.

Deflection – Semi-Rigid Barrier

Deflection Distance under TL-3 Performance

Beam Description	Deflection*
• Current 31" mid-splice beam Guardrail, single W-beam guardrail (splice between posts) • Previous, standard strong (steel) post W-beam guardrail (splice on post) • Single Nested Rail	44 inches
Thrie beam	29 inches
Double nested single beam rail	20 inches**

*From back of post ** With reduced post spacing

Stiffening Methods includes:

- Reduce post spacing to 3'-1 ½" - reduced deflection to 2.5' to 3'. See Stiffening detail on next page (Figure 1).
- Reduce post spacing again to 1'-6 ¾" – reduced deflection to 1.5' (actual test result from Texas A&M Transportation Institute study the deflection of 19")
- Nest rail element with ¼ post spacing – 1' to 1.5'
- Adding rail element to field-side of line posts- no data.
  These estimated values are based on data presented in Tables 5.4 and 5.6 of the Roadside Design Guide. Research regarding 31" mid-splice guardrail is in progress.

Stiffening must begin gradually a sufficient distance in advance so as not to create a new hard spot (12.5' to 25')

In NHDOT memorandum dated June 12, 2023, the following guidance was provided for stiffening, or reduced post spacing, for a utility pole or other tall hazard.

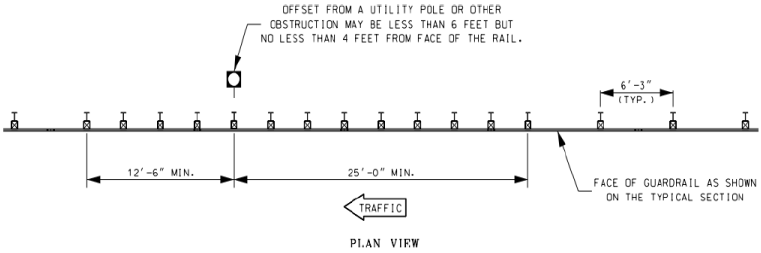


Figure 1 – Utility Pole Stiffening Detail

This detail shows 8 posts spaced at 3'-1½" on the approach, and 4 posts spaced at 3'-1½" on the departure (if outside clear zone of opposite direction). The object should be no less than 4 feet from the face of the rail. Note: May be revised based on ongoing research.

Deflection – Flexible Barrier

Low-Tension cable systems have a deflection distance of up to 12 feet.

Slope in front of Barrier

Barrier, regardless of type, performs best when the striking vehicle is stable as contact is first made. A vehicle running off the road at high speed and crossing a slope breakpoint may become airborne and strike the barrier too high, resulting in override.

The slope in front of all guardrails needs to be 10:1 or flatter. This includes all the area in front of tapered rail. A typical slope will match the slope of the roadway shoulder.

In addition, under NCHRP 350, cable guardrail could be placed on a 1V:6H slope, but its location on the slope is critical when near a swale. Avoid the area from 1 feet to 8 feet from the ditch.

Guardrail in Combination with Curb

Using curb in combination with guardrail on high-speed facilities is generally not recommended. When necessary, at high-speed locations (45 mph or greater), use a 4 inches or shorter sloping-face curb with the curb face flush with face of rail.

Placement of 31" mid-splice in conjunction with curb—up to 6 inches high and up to 6 inches behind the face of curb—was recently successfully crash tested to MASH TL-3. However, the test was not successful when a post was omitted. It was also successfully tested at lower speed (MASH TL-2) in combination with a 6 inches curb when the face of barrier was 6 feet (most critical offset) behind the curb.

Post Support at Embankment

If guardrail is shielding a steep embankment, there should be sufficient soil support behind the post to provide for the post's strength.

NHDOT typical guardrail installation consists of a 7-foot-long post with 2.5 feet of support material behind the face of the rail to embankment breakpoint. In instances where guardrail may not fit the standard installation application shown in the Standard Plans for Road Construction (12) other acceptable alternatives could be considered.

For applications where there is less than 2.5 feet of support material behind the face of the rail, a longer post could be considered (see Washington State Design Manual Section 1610,

https://www.wsdot.wa.gov/publications/manuals/fulltext/M22-01/1610.pdf, under Beam Guardrail Placement (Appendix 11-12) or consider a longitudinal barrier that allows for no block out (e.g. slightly modified 31" mid-splice, Nu-Cor, etc.).

Flare Rate

Flared barriers can provide several advantages as listed below. Flared barriers can only be placed on 1V:10H or flatter slopes and within the allowable flare rates based on speed.

The advantages of the flare are:

- Locate terminals and barrier farther from the roadway.
- Lessen driver reaction to a roadside obstacle.
- Reduce total length of rail needed.
- Reduce nuisance hits.
- Increase available recovery area.

The tradeoffs and restrictions of flared barriers are:

- Flare increases the angle at which the barrier can be hit.
- Flare may increase the angle of redirection after an impact.

RSDG Flare Rates

Design Speed (mph)	*Flare Rate for Barrier at or Beyond Shy Line	
	Rigid Barrier	Semi-Rigid Barrier
70	20:1	15:1
60	18:1	14:1
55	16:1	12:1
50	14:1	11:1
45	12:1	10:1
40	10:1	8:1
30	8:1	7:1

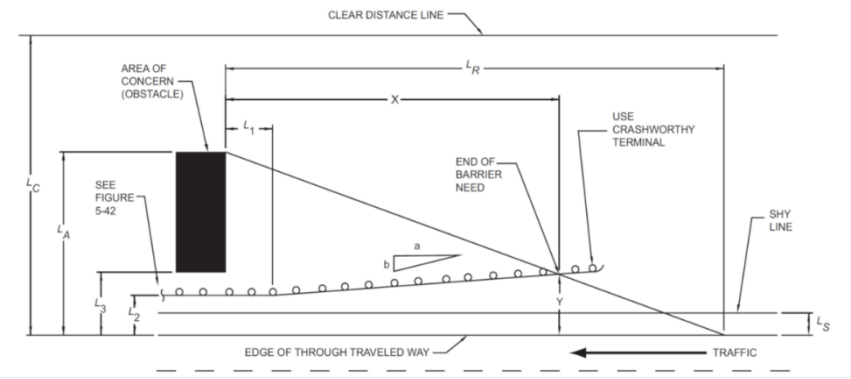
Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – Table 5-9

It is important to note that NHDOT specified Energy-Absorbing Guardrail Terminals (EAGRTs), aside from special use MFLEAT, are tangential and cannot be placed any steeper than a 25:1 taper, regardless of the flare rate of the longitudinal rail.

Length of Need (LON)

Length of need (*X*) is defined as the length of fully effective barrier needed in ADVANCE (upstream) of the obstacle to prevent a vehicle that has left the roadway from reaching the shielded obstacle. It is determined by the designer selecting the appropriate variables, as shown below key of which are L_R – Runout Length, L_H – Lateral Extent of Obstacle (which may be limited to Clear Zone L_C), and the guardrail offset and flare.

On any project where guardrail or barrier is being proposed, the length of need calculation is required. Chapter 5 in AASHTO's "Roadside Design Guide - 2011" contains information and details on length of need calculations.



L_A = Back of Obstacle
L_c = Clear Zone Distance
b/a = Flare rate (see Table 5-9)
L_1 = Beginning of Flare
L_2 = Barrier Offset
L_3 = Distance to Obstacle
L_R = Runout Length (see Table 5-10)
L_s = Shy Line Distance
X = Length of Need
Y = Lateral Offset

Length of Need Calculation - X

For flared guardrail installations:

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

For parallel guardrail installations:

$$X = \frac{L_A - L_2}{L_A / L_R}$$

RUNOUT LENGTHS-L_R

Design Speed (mph)	Runout Length (L_R) Given Traffic Volume (ADT) (ft)			
	Over 10,000	5,000 to 10,000	1,000 to 5,000	Under 1,000
80	470	430	380	330
70	360	330	290	250
60	300	250	210	200
50	230	190	160	150
40	160	130	110	100
30	110	90	80	70

Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – TABLE 5.10

These values for L_R can also be used in the field for a quick check to verify if the length of barrier is adequate as described below.

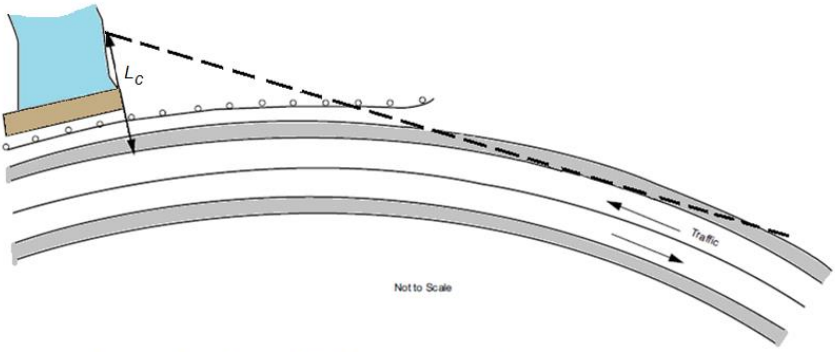
For two-way roadways, an identified obstacle must sometimes be shielded for opposite-direction traffic. The LON procedure is exactly the same; except all lateral measurements are now from the roadway centerline. On two-way two-lane roadways guardrail is typically used to shield opposing traffic at bridge rails.

Note that a portion of the terminal contributes to the length of need. In the past the LON began at the 3rd post (12.5 feet) for

almost all the terminals. With the new MASH terminals this will vary depending on where the length of need begins for that particular terminal. (Essentially 12.5' for MSKT & Softstop)

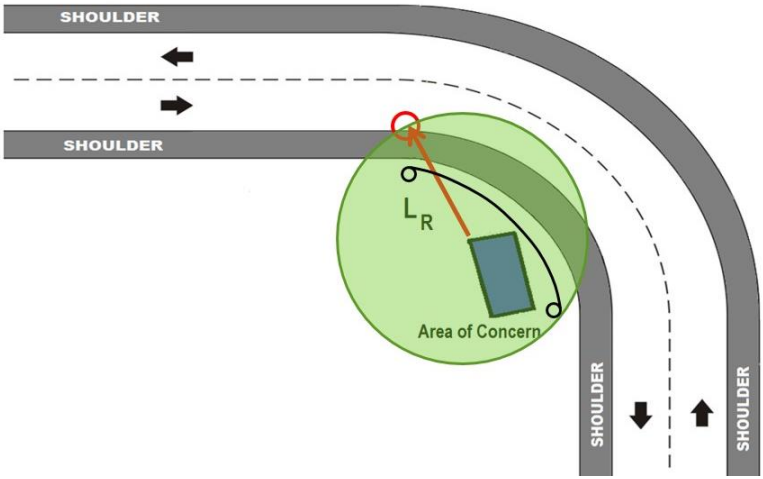
After determining the total amount of barrier needed for the obstacle (in advance of obstacle—length of obstacle—downstream of obstacle), and after considering other barrier contributing to the amount of barrier needed that is paid for under another bid item (such as effective portion of end terminal, bridge rail, transition, Type 3 guardrail etc.), use 12.5 feet or 25 feet panel lengths and convert to *LF* for bid purposes. The guardrail design worksheet helps with this rounding.

On curves (generally greater than 2 degrees) the runout path is plotted tangent to the outside edge of the driving lane so that it intersects the obstacle at the adjusted lateral extent of the obstacle. (Figure 5-48 of the AASHTO Roadside Design Guide).



Example of Barrier Design for Fixed Object on Horizontal Curve

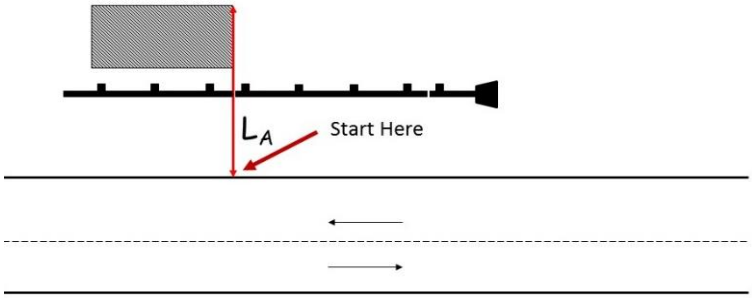
For the inside of curves, the following graphic method may be used.



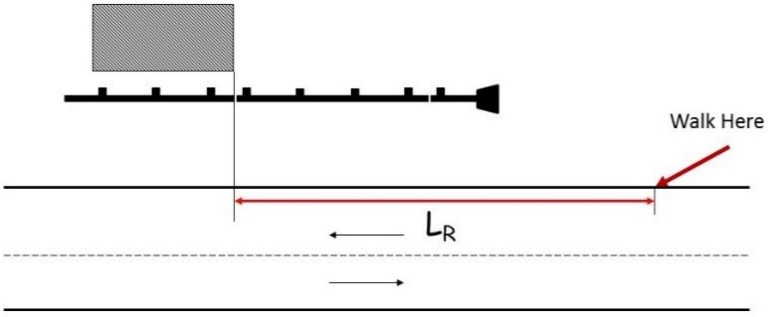
LON Field Check

The following is a guide for performing a check in the field to verify that adequate length of barrier is provided:

Stand on the edgeline directly opposite the upstream end of the obstacle.



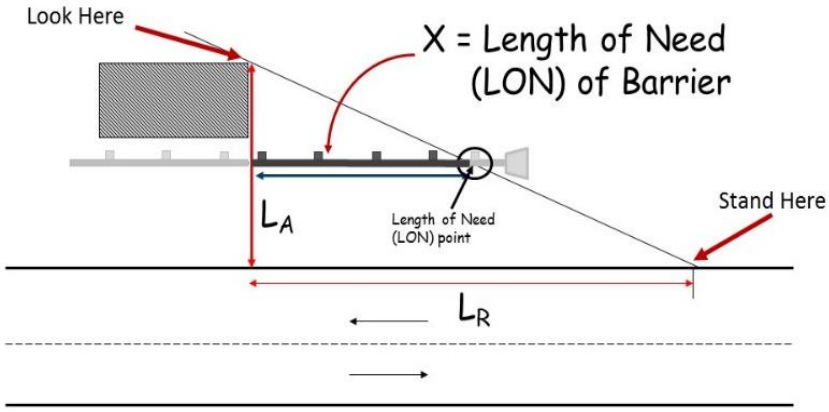
Stand at Upstream End of Obstacle



Pace the Runout Length

Pace off upstream the appropriate runout length from table.

From that point, turn and look at the back of the obstacle. (If the obstacle has no clear far side, such as a river or embankment, this distance may be limited to the design clear zone.)



Line of Sight to Back of Obstacle

If the proposed (or actual) guardrail installation crosses (or is close to) that line of sight, then the area is adequately covered.

On a two-way roadway there is a need to check LON for the opposing direction of traffic. This time the pacing would be from the downstream end of the obstacle and would be along the centerline. Start by standing on the centerline directly opposite the downstream end of the obstacle and pacing downstream precede in the same manner as above.

Be observant of any other obstacles in the immediate vicinity that would warrant shielding. Consider these when determining adequate length of barrier.

Gaps

Avoid short gaps between runs of barrier resulting in installing multiple terminal units. In general, it is suggested that gaps of less than 200 feet between barrier termini be connected into a single run but this is not a fixed value. Short gaps are acceptable when the barrier is terminated in a cut slope. Also, access issues must be considered when determining whether or not to connect barriers.

END TREATMENTS

Terminals and Impact Attenuators used in New Hampshire. System Description, Characteristics, Requirements and Links to Manufacturers Website.

End Treatments

The purpose of an end treatment is to:

- To provide anchorage for the guardrail to allow development of the full tensile strength of the W-beam rail for all impacts within the terminal length of need (LON).
- To minimize injury to vehicle occupants in the event of a crash near or at the approach end of the terminal.

Types of End Treatments:

- End Anchors
- Terminals – Roadside and Median
- Impact Attenuators

End Anchors

The NHDOT Type G-2 end terminals are essentially anchors that are used on the departure end of guardrail of One-Way or Divided Roads only.

End Anchors are used where the only concern is to develop the tension in the guardrail for impacts along the face of the barrier. NOT to be used where approach traffic can impact the end.

31” Downstream Anchor Terminal – G-2

Non-Proprietary System

NHDOT Standard Plans for Road Construction GR-10.

Distinguishing Characteristics:

- No impact head. Curled end section.
- Posts 1 and 2. Breakaway anchor posts consist of BCT timber posts set into steel foundation tube.
- Ground strut assembly between Posts 1 and 2.
- No offset blocks on Posts 1 and 2.
- Cable anchor attaches to back of rail with anchor bracket and 8 bolts between Post 1 and 2.
- Post spacing is 6 feet 3 inches
- Rail Element is 9 feet 4 ½ inches
- Attaches to 31” mid-splice Beam Guardrail.

Downstream Anchor Terminal – G-2

Non-Proprietary System

Existing Terminal (Previous Standard)

Distinguishing Characteristics:

Same as 31” End Anchor except:

- Attaches to 30” Beam Guardrail splice on post.
- Rail Element is 12 feet 6 inches
- No Ground strut.

Terminal

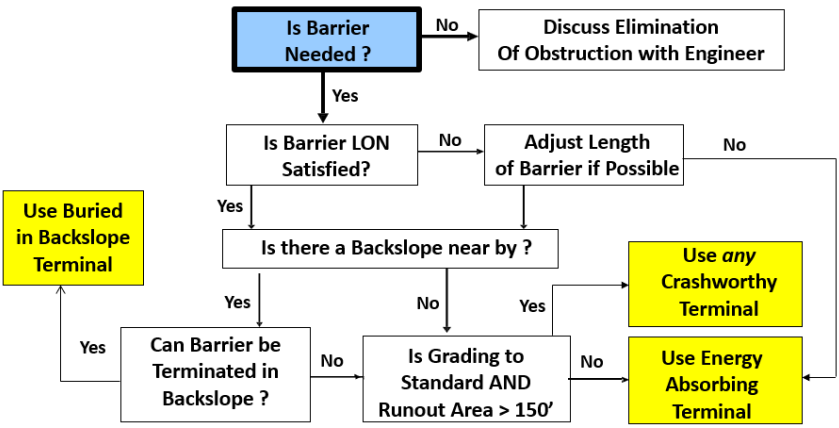
A guardrail anchor is required at the end of a run of guardrail to develop tensile strength throughout its length. In addition, when the end of the guardrail is subject to head-on strikes, a crash-tested guardrail terminal is required.

The three types of crashworthy terminals are: Buried in Backslope, non-energy-absorbing, and energy-absorbing systems. **NHDOT currently does not** use terminals that are non-energy-absorbing.

Terminal Types and Selection

The flow chart below may be used by the designer in selecting the appropriate terminal type. Field personnel may wish to confirm that the appropriate type of terminal has been identified for new installations or for leaving in place existing systems.

Type of Terminals Selection



Buried-in-Backslope – E-3

MASH

NCHRP 350 E-2

Non-Proprietary System

NHDOT Standard Plans for Road Construction GR-5.

Distinguishing Characteristics for MASH TL-3 System:

- Uses standard 12-gauge W-beam guardrail.
- Upstream end of guardrail not exposed.
- Rail height held constant above pavement (31”), but not greater than 47”, until it crosses ditch line.
- Add a w-beam rub rail when the distance between the bottom of the w-beam rail and the ground exceeds 18”.
- Splices mid-span between the posts.
- The Beginning of Length of Need (BLON) is the location where effective barrier begins and occurs where the face of the rail crosses the toe of the backslope.
- Rail is flared back 13:1 (8:1 beyond ditch line) into the ideal backslope of 1V:2H or greater.
- End of the anchor is buried a minimum of 1 feet under the natural groundline at a maximum offset of 8 feet. No (artificial) mounds are to be constructed in order to bury the end of rail.
- 8-feet long posts are used as soon as rub rails are used. There are no offset blocks on the bottom (rub) rail.

How it works: The Buried-In-Backslope (BIB) is a generic system, where a w-beam guardrail can be terminated by burying the end of the rail element into a natural backslope. This type of anchor eliminates the possibility of an end-on impact with the barrier end and, when properly designed and constructed, minimizes the likelihood of a vehicle intruding behind the barrier and reaching the area of concern. Therefore, it should be the terminal of choice at locations where it can be appropriately applied. The system, using rub rail, has been successfully tested under TL-3 impacts to be used with the 31" mid-splice guardrail system (Texas A&M Transportation Institute {TTI}, Report No. 608431-01-1&2, October 2018). These tests were on a 4:1 foreslope and it is considered acceptable for flatter foreslopes. A technical determination has been made (by TTI) that a single rail BIB over a 10:1 or flatter foreslope is also MASH compliant (as it is simply standard guardrail). NHDOT only utilizes the rub rail design.

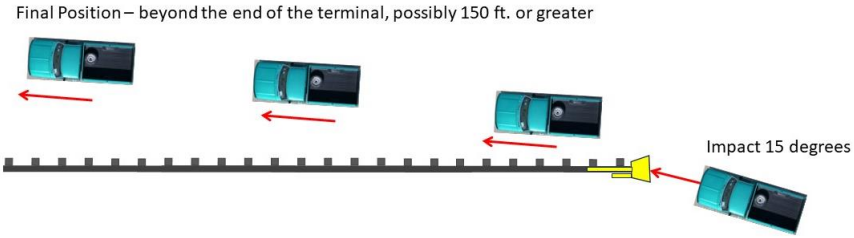
Energy-absorbing Guardrail Terminals (EAGRT)

In locations where the Buried-in-backslope (Type E-3) terminal is not appropriately applied, an energy-absorbing guardrail terminal (EAGRT) should be used.

The EAGRT is based on crash testing demonstrating that a pickup truck impacting head-on (**0 degrees**), travelling at 62 mph for TL-3 or 44 mph for TL-2 systems, will come to a controlled stop within the system, as shown below. A non-energy-absorbing guardrail terminal (NEAGRT), will come to a controlled stop 150 feet or more behind the guardrail system.

Energy Absorbing Terminal
Vehicle is brought to a controlled stop in a short distance

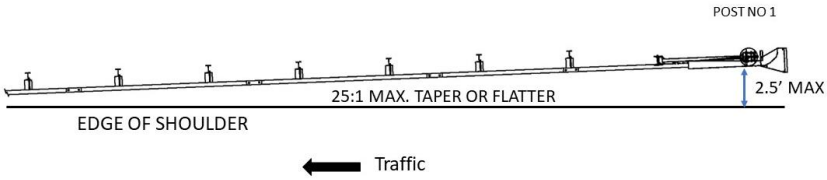
Note that a vehicle impacting at a high degree such as 15 degrees on the end will pass through the system and will typically travel 150 feet or more behind the guardrail system. This is referred to as **Gating**, as shown below. For side impacts these systems will have redirectional capabilities, typically beginning at the BLON, generally at the 3rd Post.



NHDOT Terminal Types

NHDOT currently allows EAGRT Tangent Terminals as its standard specification, with Flared Terminals in a special case.

Tangent terminal – is a terminal that can be placed parallel to the roadway or on a straight flare, with up to 2.5 feet offset at Post 1 (max. 25:1 taper).



Flared terminal – is terminal that must be placed on a flare relative to the edge of the pavement. The offsets from the roadway variers with different products but is typically between 2.5 feet and 4 feet NHDOT currently uses Flared (MFLEAT) for special use. (NHS, constrained site).

The following are NHDOT current and existing:

- EAGRT Tangent Systems
- EAGRT Flared Systems
- NEAGRT Flared Systems
- Median Terminals

EAGRT Tangent Terminals Systems

SoftStop®

MASH

Proprietary System

NHDOT Special Provision 606_125X EAGRT Units MASH

TL-3 at 50'-9½" long (46-2 ½" from head), TL-2 at 38'-3½" long

For current details of this system, visit Manufacturer's Installation/Assembly Manual at website:
https://www.valtir.com/product/softstop-system/

Distinguishing Characteristics for MASH TL-3 System:

- Rectangular impact head and chute.
- Post 0 is an Anchor post in front of the impact head.
- Post 1 is 4 feet, 9½ inches SYTP (Steel Yielding Terminal Post).
- Post 2 is 6 feet SYTP.
- Posts 3 to 8 are 6 feet long steel posts.
- BLON at Post 3 (16 feet 6 inches from Post 0 or 11 feet 11 inches from Post 1 (head)).
- 31" high, mid-splice span begin at 8 feet -9 ½ inches from Post 1 or 13 ft-4 ½ inches from Post 0.

How it works: The energy of the impacting vehicle is absorbed by vertically compressing the rail elements as the impact head is pushed down the rails, typically containing the compressed rail on the ground just below. The front anchorage is designed to allow the rail panels to remain anchored during end-on impacts.

MASH Sequential Kinking Terminal (MSKT®)

MASH

NCHRP 350

Proprietary System

NHDOT Special Provision 606_125X EAGRT Units MASH

TL-3 at 50'. (46'-10 ½") long, TL-2-at 25' long.

For current details of this system, see Manufacturer's Installation/ Assembly Manual at: http://www.roadsystems.com/mash-mskt/

Distinguishing Characteristics for MASH TL-3 System:

- Square impact head.
- Enclosed feeder chute (SKT engraved).
- Post 1 is a square Tube top section, W6" x 15# bottom section.
- Post 2 is a steel - hinged post.
- Posts 3–8 are 6 feet long steel posts.
- BLON at Post 3 (12 feet 6 inches from Post 1).
- Rail must be straight, no bends, kinks or creases.
- 31" high, mid-splice span begin at 21 feet 10 ½ inches from Post 1.

NOTE: MASH head can be used on the NCHRP 350 SKT but the head alone does not make it a MASH system.

How it works: The energy of a vehicle in a head-on strike is absorbed by the impact head being forced down the rail elements deforming them in short kinks.

MAX-Tension ™

MASH

Proprietary System

NHDOT Special Provision 606_125X EAGRT Units MASH

Only used in a TL-2 – 25' Application*

*Meant for creating short gaps of access within runs.

For current details of this system, see Manufacturer's Installation/Assembly Manual at website:

https://www.lindsay.com/usca/en/infrastructure/brands/barrier-systems/solutions/end-treatments/max-tension/

Distinguishing Characteristics for MASH TL-2 System:

- Rectangular impact head.
- Post 0 is a Soil Anchor post in front of the impact head.
- Post 1 is 6 feet long, I-Beam, W6" x 9#.
- Ground strut is connected between Post 1 and Post 0.
- Two cables are anchored at Post 0.
- Posts 2 to 6 are 6 feet long steel posts.
- Uses a slider mechanism between Post 3 and 4 that gathers and retains the rails when hit head-on.
- **BLON at Post 1 (9 feet 4 ½ inches from Post 0).** (TL-3 version BLON at post 3)
- 31" high, mid-splice span begin at 12 feet-6 inches from Post 1 or 17 feet-9 ¾ inches from Post 0.

How it works: The MAX Tension system uses tension cables, telescoping panels, and a cutting tooth to absorb the kinetic energy and safely contain or redirect the striking vehicle.

ET 2000 (Guardrail Extruder Terminal)

NCHRP 350

Proprietary System

Acceptable In Place Existing Terminal – Refer to NHDOT Highway Design Manual – Appendix 11-13

Product no longer available.

Distinguishing Characteristics for the TL-3 NCHRP 350 system:

- Square impact head.
- Flattens the rail element as it passes thru head when hit head-on or at a shallow angle.
- Weakened wood or steel posts options.
- 50 feet long, straight.
- Cable and strut-anchored system.
- BLON at Post 3 (12 feet 6 inches from Post 1).

ET Plus (Guardrail Extruder Terminal)

NCHRP 350

Proprietary System

For Replacement Refer to NHDOT HDM – Appendix 11-13

Product no longer available.

Distinguishing Characteristics for the TL-3 NCHRP 350 system are same as the ET 2000 except: Rectangular impact head.

X-Tension

NCHRP 350

Proprietary System

Acceptable In Place Existing Terminal – Refer to NHDOT Highway Design Manual – Appendix 11-13

Product no longer available.

Distinguishing Characteristics for the TL-3 NCHRP 350 system:

- 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.
- BLON at head (non-gating, both TL-2 & TL-3, as well as the X_MAS-median)

EAGRT Flared Terminals Systems

MASH Flared Energy-Absorbing Terminal (MFLEAT®)

MASH

NCHRP 350

Proprietary System

NHDOT Special Provision 606_1253 MFLEAT

TL-3 at 39’-7” long

For current details of this system, see Manufacturer’s Installation/Assembly Manual at:
http://www.roadsystems.com/mash-mfleat/

Distinguishing Characteristics for the TL-3 MASH system:

- Square impact head.
- Enclosed feeder chute (FLEAT engraved).
- 3 feet offset.
- Posts 1 to 3 are steel-hinged post.
- BLON at Post 4 (16 feet 8 inches from Post 1). (not the same as tangent terminals)
- 31” high, mid-splice span begin at 22 feet-11 inches from Post 1.
- Posts 4 thru 8 are standard posts.

Cable anchored compression system - The energy of a vehicle in a head-on impact is absorbed by the impact head being forced down the rails sequentially kinking them and exiting on the traffic side of the guardrail.

NEAGRT Flared Terminals Systems

Modified Eccentric Loader Terminal (MELT)

NCHRP 350

Non- Proprietary System

Acceptable In Place Existing Terminal - TL-2– Refer to NHDOT Highway Design Manual – Appendix 11-13

Distinguishing Characteristics for the TL-2 NCHRP 350 system:

- Flared terminal – installed on a parabolic curve with a 4’ offset.
- No impact head.
- Uses standard w-beam rail elements.
- Strut between the steel tube foundation for the two end posts to 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.

Eccentric Loader Terminal (ELT)

NCHRP 350

Non-Proprietary System

Acceptable In Place Existing Terminal – Refer to NHDOT Highway Design Manual – Appendix 11-13

Distinguishing Characteristics for the TL-3 NCHRP 350 system:

- Flared terminal – installed on a parabolic curve with a 4 feet offset.
- Impact head made from corrugated steel pipe with fabricated structural steel lever inside.
- Strut between the first post and a front anchor post.
- Only wood post options available.
- Should be installed at locations where sufficient runout area exists behind and downstream of the terminal.

NON-NCHRP 350 Terminals

For all projects with speed limit 55mph the NON-NCHRP 350 obsolete terminals are to be replaced. Refer to NHDOT Highway Design Manual – Appendix 11-13 for all replacement recommendations.

Breakaway Cable Terminal (BCT)

OBSOLETE

Non-Proprietary System

Distinguishing Characteristics for the TL-3 NCHRP 350 system:

- Flared terminal – installed on a parabolic curve with a 4-foot offset. However, some older installations are incorrectly installed.
- No impact head or ground strut between the two end posts.
- Only two weakened posts.

Blunt end

OBSOLETE

Non-Proprietary System

Distinguishing Characteristics

- No impact head or ground strut between the two end posts.
- Ends abruptly with no anchoring element – Blunt Ends.

Turndown – Terminal F

OBSOLETE

Non-Proprietary System

Distinguishing Characteristics

- Eliminated spearing but introduced vaulting and overturn.

Damaged terminals requiring repair

The **NHDOT Highway Design Manual – Appendix 11-13** provides the following guidance:

For existing guardrail terminals that require repair due to damage, the following maintenance action shall be implemented:

a. All Tier Roadways and Speed Limits: Damaged ET-Plus, X-Lite, or non-NCHRP-350 terminals shall be replaced with a MASH terminal.

Median Terminal Systems

MAX-Tension Median

MASH

NHDOT Special Provision 606_XX
TL-3 at 50 ft. 9½ inches long

Installation/Assembly Manual at website:
https://www.lindsay.com/usca/en/infrastructure/brands/barrier-systems/solutions/end-treatments/max-tension/

Distinguishing Characteristics for TL-3 MASH System:

- Rectangular impact head.
- Post 0 is a Soil Anchor post in front of the impact head.
- Post 1 is 6 feet long, I-Beam, W6 x 9.
- Ground strut is connected between Post 1 and Post 0.
- Two cables are anchored in front of Post 0 to the impact head.
- Posts 2 to 6 are 6 feet long steel posts.
- Uses a slider mechanism between Post 5 and 6 that gathers and retains the rails when hit head-on.
- BLON at Post 3 (14 feet 8 ¼ inches from Post 0).

How it works: The MAX tension system utilizes tensioned cables, telescoping panels and a cutting tooth to absorb the energy of an impacting vehicle by friction on the cables passing through the deflector plates in the non-extruding impact head and by the couplers/cutting tooth located between posts 5 and 6.

MATT ™ Median Attenuating TREND

MASH

Proprietary System

NHDOT Special Provision 606_XX

TL-3 at 34 ft. 4 ½ in

For current details of this system, visit Manufacturer's Installation/Assembly Manual at website: https://www.valtir.com/product/matt-median-attenuating-trend-terminal/.

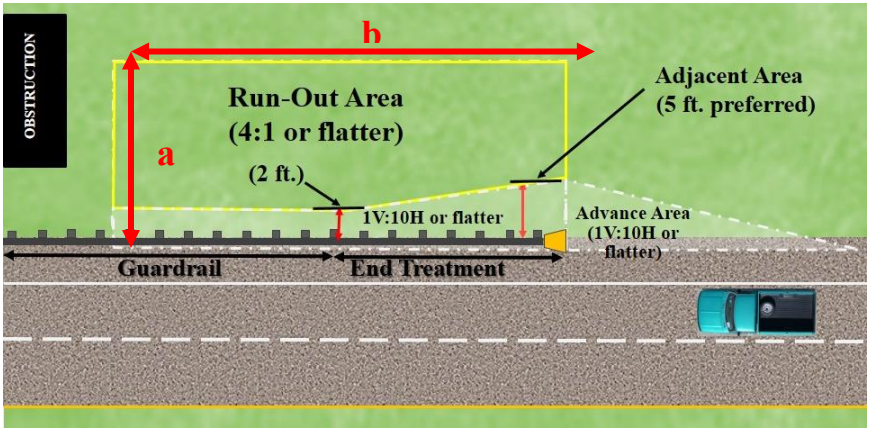
Distinguishing Characteristics for TL-3 MASH System:

- Square impact head.
- Cable release post at Post 1.
- Posts 2 to 5 are W6x8.5# Steel Yielding Terminal Post (SYTP).
- Posts 1 to 6 have soil plates.
- Post 7 and beyond – standard line post with 8 inch Offset blocks.
- Slotted rail panels.
- BLON at Post 3 (12.5 feet from Post 1).

How it works: Cable-anchored, compression system. During head on impacts the system telescopes rearward, utilizing special HS bolts to tear tabs between multiple slots in 6 feet-3 inches rail panels to decelerate the vehicle.

Terminal Grading Details

A terminal is most likely to perform best when a vehicle is stable at the moment of impact. There are three grading areas around guardrail terminals to help achieve the desired performance: advance, adjacent, and run-out distance; these are highlighted on figure below.



a. Extend out to clear zone when practical; if not, it should be at least as wide as area upstream of the terminal.

b. Length of Need (LON) Required; when LON cannot be provided due to site conditions, a minimum of 75 feet from post 1 may be acceptable.

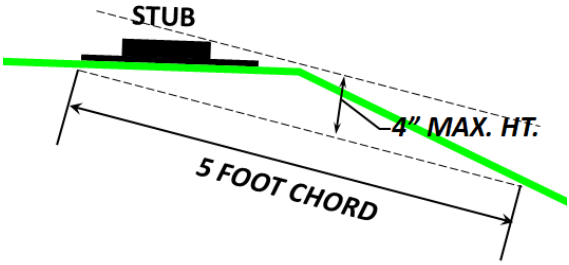
Special grading requirements for guardrail terminals:

a. Flat terrain (1V:10H or flatter) is required *in* **ADVANCE** *of all terminals* so that vehicles are relatively stable on approach.

b. Flat grading must extend *behind* post 1 (**ADJACENT**) so vehicle is stable at impact **and** no stub height criteria is violated.

Stub Height

A second consideration for terminal grading is the stub height criteria, shown in figure below. Any hardware remaining after the vehicle impact should not exceed this stub height criteria.

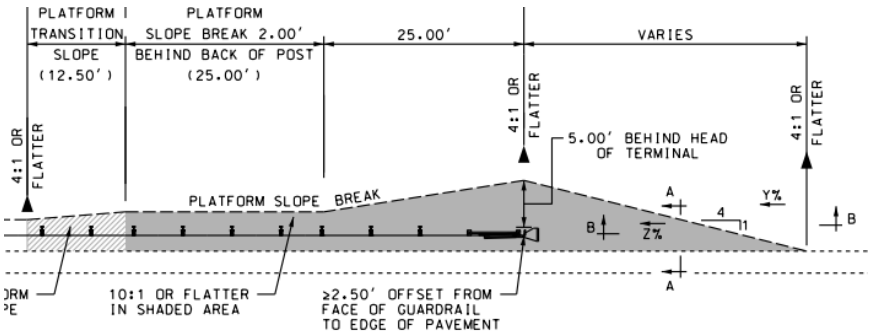


NHDOT Platform

The platform is an integral component of the performance of the guardrail terminal unit. Proper grading for each guardrail platform is necessary; these are typically included as contract bid items and are shown in the Standard Plans for Road Construction (12). The earthwork required for the platform is a unit pay item quantified separately from the earthwork calculations. The platforms should be drawn as a dashed line style on the cross sections. This differentiates the platform from the earthwork items ensuring the quantity is not double counted. See the Highway Design Manual Volume II for a sample.

Ref: NHDOT Highway Design Manual, Chp. 11 – Platforms

NHDOT preferred platform for parallel EAGRT- TL-3



Ref: NHDOT Special Detail ITEM 203.5561

Refer to the special details for TL-2 platform and alternate platform details.

Terminal Installation

Review the following items for a proper installation:

- Grading should be appropriate.
- Stub height should satisfy criteria.
- All parts should be for the specific model being installed.
- For breakaway cable anchorages:
  - Top of post 1 must be able to separate from its base for end-on strikes—to release the cable.
  - Properly orient and restrain the bearing plate on the cable at post 1 so that it remains in that position. The bearing plate should not be buried.
- For energy-absorbing, with impact heads:
  - Firmly seat rail panel into the head.
  - System should be on a straight line for its full length.

- Proper cable anchor bracket attachment to the rail must allow for the release of the anchor bracket when hit by the impact head.
- No bolt through the rail at post 1.
- Use rail to post bolts only when called for and attach on the correct side of the post.
- Securely attach impact head to post 1 (again, no post to rail connection).
- Ensure top of impact head is parallel with the top of the rail.
- Tighten anchor cable appropriately.

It is a challenge to remember all the intricacies of properly installing the multitude of systems and models within each system. It is impossible to overemphasize the importance of having and following the **MANUFACTURER'S INSTALLATION MANUAL AND SHOP DRAWINGS** onsite for every installation.

AMENDMENT TO SECTION 606

Terminal Units. Terminal sections shall be installed at each end of every installation of beam guardrail unless otherwise specified. Before installation, the Contractor shall provide the Engineer with copies of the manufacturer's documents indicating satisfactory testing in accordance with MASH 2016 and/or its subsequent revisions and of the approval by the FHWA for use of the terminal unit as intended. The Contractor shall also provide the Engineer with copies of the following:

- Manufacturer's detail sheets and installation guide detailing all requirements and system dimensions prior to installation.

- Proof of Training for the Trained Installer from the manufacturer of the specific terminal unit to be installed.
- Manufacturer's Installation Checklist completed and signed off by the Trained Installer who observed and inspected the installation of the terminal unit.
- Manufacturer's list of component parts which will be forwarded to the appropriate maintenance office, if not included in the installation guide.
- The Trained Installer shall have documented proof of training from the manufacturer to install the specific terminal unit. The Trained Installer shall be prepared to show documentation/proof of training prior to any terminal unit installation.
- The Trained Installer must be present during the installation of the terminal unit.

For median terminals the following is added:

- Manufacturer's detail sheets and installation guide detailing all requirements and system dimensions prior to installation. This documentation shall include technical data including the overall length, width, connection details, the point at which redirection is provided, where length of need is established on the device and the test level tested.

Impact Attenuator

Impact attenuators or crash cushions are generally used to shield a point obstacle or where space is limited.

They can be used for both temporary and permanent installations. MASH standards took effect January 1, 2019.

Impact Attenuators can be classified by the following:

- **Sacrificial.** Designed for a single impact and provide no redirectional capabilities.
- **Reusable.** Some components need to be replaced, but some major components are salvageable.
- **Low-maintenance and/or self-restoring crash cushions.** Suffer very little damage and are readily restored or self-restoring.

Reusable and Low Maintenance systems function as non-gating systems.

To be considered non-gating these three conditions must be satified:

1. Head-on (0 degrees) hit with pick-up – Captured.
2. 15 degrees End-on hit with pick-up – Captured.
3. Redirection begins “very near” to upstream end.

Sacrificial Systems – Sand Barrels

Sand barrels are relatively inexpensive and designed for single impacts. NHDOT allows sand barrels for Temporary applications ONLY.

CrashGard

MASH

NCHRP 350

Proprietary System

CrashGard® | Sand Barrel Crash Cushion | PSS (pss-innovations.com)

Big Sandy

MASH

NCHRP 350

Proprietary System

Big Sandy Sand Barrel | TrafFix Devices

Energite® III

MASH

NCHRP 350

Proprietary System

ENERGITE® III - Valtir

Temporary Impact Attenuation Devices

NHDOT Qualified Product List. Item 606.9523 – TL-3

Individual barrel designs vary in shape by manufacturer, but they all function in the same manner: Sand-filled plastic barrels decelerate a striking vehicle by transferring the vehicle's momentum to the variable masses of sand in the barrels it hits.

Arrays of sand barrels may be designed to shield any shape obstruction and obstacles of varying widths.

Striking vehicles will not be redirected. With no redirective capability, the corner of the obstruction must be reasonably shielded. The rear corner barrel should offset the shielded object by at least 30 inches.

Barrels from different systems are interchangeable for the equivalent weights as long as they are in the correct location.

The sand barrels are arranged by weight (200, 400, 700, 1,400, and 2,100 lbs.) with the orientation of the layout with the expected angle of impact (10 degrees desirable).

If the system is to function properly in all anticipated climate conditions, it is important that the moisture content and any anti-freezing treatment follow the specification.

A pad, with marked barrel locations, is desirable.

Sand barrel arrays and water filled arrays will not be allowed for use November 1st to April 15th, unless they are at least ten (10) feet away from the travelway (measured to the face) or specifically approved in writing by the Engineer. If approved by the Engineer for winter use, the sand or water shall be treated to prevent freezing. (NHDOT Standard Specification 606.2.10.4)

Reusable Systems

TAU-M (MASH) and TAU IIR Systems

MASH

NCHRP 350

Proprietary System

Temporary Impact Attenuation Devices (Redirective)

NHDOT Qualified Product List:

Item 606.9513 – TL-3, Item 9512 – TL-2

For current details of this system, visit Manufacturer's Installation/Assembly Manual at website:
http://www.barriersystemsinc.com/tau-ii-crash-cushion

- Designed to attach to a median barrier.
- Common set of parts for 36 inches–102 inches widths in 6 inches increments – NCHRP 350 only.
- TAU-M, width 30 inches
- TL-3 length 22 feet – 9 inches TL-2 length 14 feet – 2 inches
- Energy-absorbing elliptical cartridges crush (and are reusable for the II-R) upon impact. Thrie-beam panels slide back when struck end-on and along with two cables at the bottom, redirect vehicles when struck on the side.
- Anchored at front and rear only.
- Pad requirement—6 inches reinforced concrete pad. Also Asphalt pad design. See manufacture's installation manual.
- Upgrade kit available.

Delta ™

MASH

Proprietary System

Temporary Impact Attenuation Devices (Redirective)

NHDOT Qualified Product List: Item 606.9513 – TL-3

For current details of this system, visit Manufacturer's Installation/Assembly Manual at website: https://www.traffixdevices.com/products/attenuators/delta

- Designed to attach to a median barrier.
- Fully enclosed metallic front attenuation module.
- Side rails are thrie-beam slider type.
- 5 Pairs of thrie-beam fender panels are bolted to 4 or 9 internal steel diaphragms.
- System does not include any energy absorbing cushions or cartridges.
- Track weldment base is bolted to pavement, concrete or asphalt, and includes stationary rear diaphragm.
- Front and internal diaphragms slot onto and slide along 2 track rails.
- Fender mounting bolts tear through weakened materials in the valley of the thrie-beam panels as the fender panels telescope rearward on impact.
- 30 inches width, 21 feet long.
- In head on crash, everything but the base needs replacing.

QuardGuard M10/QuadGuard

MASH

NCHRP 350

Proprietary System

Temporary Impact Attenuation Devices (Redirective)

NHDOT Qualified Product List:

Item 606.9513 – TL-3, Item 9512 – TL-2

For current details of this system, visit Manufacturer's Installation/Assembly Manual at website:
https://www.valtir.com/product/quadguard-ii/

- Can be attached directly to a W-beam or Thrie-beam median barrier, as well as to a concrete safety shape.
- Slides back on a single track when struck head-on and uses specially fabricated side panels having four corrugations that redirect the vehicle in side impacts.
- Hex-foam cartridges crush upon impact, absorbing the energy of the striking vehicle for end-on hits and need to be replaced if damaged.
- Pad requirement—see manufacture's installation manual.
- Available in widths from 24–36 inches with parallel sides and 69 or 96 inches with flared sides. (M10 currently only available in 24 inches or 69 inches)
- TL-3 length of M10 is 26 feet 2 inches.

Low Maintenance – Self Restoring Systems

QuadGuard Elite M10

MASH

NCHRP 350

Proprietary System

Temporary Impact Attenuation Devices (Redirective)

NHDOT Qualified Product List:

Item 606.9513 – TL-3, Item 9512 – TL-2

For current details of this system, visit Manufacturer's Installation/Assembly Manual at website:
https://www.valtir.com/product/quadguard-elite/

- Similar operation, except that QuardGuard Elite M10 (MASH) uses high-density polyethylene plastic (HDPE) cylinders that essentially self-restore to absorb energy.
- Essentially for use in locations where a high number of hits are anticipated. The cylinders likely need replacement after impact.
- QuadGuard Elite M10 - TL-3 – 26 feet – 2 inches Long, 24 inches wide
- Pad requirement—Asphalt or concrete - see manufacture's installation manual.

REACT M

MASH

NCHRP 350

Proprietary System

Temporary Impact Attenuation Devices (Redirective)

NHDOT Qualified Product List: Item 606.9513 – TL-3

For current details of this system, visit Manufacturer's Installation/Assembly Manual at website:
https://www.valtir.com/product/react-m/

- High density Polyethylene cylinders HMW/HDPE.
- Essentially self-restoring after design impact.
- Self-contained back-up.
- Side redirection by side cables anchored to foundation
- Single cylinder width with cable guides 38 ¾ inches.
- TL-3 Length- 22 feet - 2 ¾ inches Long.
- Pad requirement— concrete - see manufacture's installation manual.

SCI Smart Cushion

MASH

NCHRP 350

Proprietary System

Temporary Impact Attenuation Devices (Redirective)

NHDOT Qualified Product List: Item 606.9513 – TL-3

For current details of this system, visit Manufacturer's Installation/Assembly Manual at website: https://hillandsmith.com/product/smart-cushion-crash-attenuator/

- Variable Reaction Force.
- Internal cables and a hydraulic cylinder provide resistance to stop a vehicle.
- Steel panels redirect side impacts.
- Minimal component replacement. General repair parts consist of replacing shear pins.
- Highly reusable design but must be reset after an end-on hit.
- Width 37 ½" inches, TL-3 21 feet – 6 inches length; TL-2 13 feet – 6 inches length.
- Pad requirement— Asphalt or concrete - see manufacture's installation manual.

Consult the *Roadside Design Guide* (9) before recommending the type of cushion for a particular location. The actual selection of the type of attenuator as a bid item should be carefully considered and reviewed for approval. Since most impact attenuators are proprietary, a "performance specification" is usually written by the Bureau's Specifications Section that identifies the criteria that must be achieved for the product to be acceptable. This practice promotes competitive bidding while satisfying the safety requirements of the design. For additional information on Special Provisions, Specifications, and Proprietary Items, see Chapter 13, "Plans, Specifications and Estimate".

Ref: NHDOT Chapter 11

TRANSITIONS

When two systems are connected with different deflection properties a gradual stiffening transition typically occurs between the two systems.

Transitions

W-beam to Rigid Barrier/Bridge Rail

When a softer (more flexible) barrier precedes a stiffer barrier, gradual stiffening must occur between the two systems. An effective transition must provide an adequate connection (TENSION continuity) and an adequate length to gradually increase stiffness.

NHDOT Standard Detail – GR-18

Regardless of the system (Mid-splice or splice on post), transition details include the following four essential elements which the figure illustrates:

1. Strong structural connection of steel beam to the concrete (to provide for tension continuity).
2. Additional, and typically, larger posts.
3. Nested W-beam or Thrie-beam.
4. Some design to reduce snagging of the wheel on the rigid barrier (typically a curb or rubrail or flared back bridge parapet). Note that any curb is part of the transition design (and does not violate any guidance for curbs with standard runs of guardrail).

Although the Standard Plans may not be applicable to all situations encountered in the field, including the four essential elements might provide an acceptable transition; coordinate with the appropriate design or traffic safety staff.

The NHDOT Standard Transition incorporates:

- 10 gauge Transition element - w-beam to thrie beam
- Reduced post spacing 3 feet - 1 ½ inches and 1 feet - 6 ¾ inches
- Nested 12 gauge Thrie beam
- Curb section
- Structural connection- Thrie beam terminal connector with 5 high strength 7/8 inch bolts through the concrete

NOTE: A strong structural connection employs bolts that extend through the barrier wall. The NHDOT Standard Drawing provides five high strength 7/8 inch diameter bolts that extend thru the concrete barrier in cored drilled holes with nut and washer.

NOTE: Special case of rehab with constrained length due to side road or driveway is covered in a memo dated June 12, 2023. Also, a separate June 6, 2023 memo aids in connection of transition to existing bridges/structures.

Transitions—Cable to W-beam

There also needs to be a transition from cable to W-beam. A generic transition is an overlap of the systems with a spatial separation of systems of at least 8 feet so as not to redirect a striking vehicle into the terminal as well as sufficient length to prevent a vehicle from passing through the overlap.

SPECIAL DESIGNS

Designs for when certain situations are encountered.

Special Designs

Omitted Post

The **31" mid-splice beam guardrail** has been successfully tested where a single post was omitted without any modifications to the typical system (i.e., no weakened posts, no nested rail elements, and no special posts). As with any special design, only omit a post in special circumstances; and only within a standard run of guardrail with the engineer's approval.

The following also must be considered:

1. The omitted post cannot be used within transitions**,** terminals, or special designs.
2. There are no curbs.
3. 8 inch or 12 inch offset blocks are allowable.
4. If a 2:1 slope is present, can only use if the standard 2.5 feet platform is available from the face of the breakpoint.
5. There is a minimum length of 12.5 feet from the end of the EAGRT.

Long-span Guardrail System

The long-span guardrail design is an alternate treatment that has been successfully tested to span low-fill culverts (or other impediments to driving posts) in lieu of attaching posts to the top of these structures with a maximum of 3 posts omitted. As with the Omitted Post design, only use the long-span system in a standard run of guardrail (not in the transition section, terminal, etc.). Where using the long-span design, it is important that the headwall extend no more than 2 inches above the ground and the deflection can 8 feet for the 31" mid-splice beam guardrail design. Also the minimum spacing requirements, as identified under the omitted post above, apply.

The **31" mid-splice beam guardrail** long-span design uses three CRT posts with 12" blockouts on each side of the opening, but NO nesting of rail.

A similar design was available for the splice on post system with up to 100 feet of nested rail with 3 posts omitted and double blocks with the CRT posts. NOT FOR NEW INSTALLATIONS.

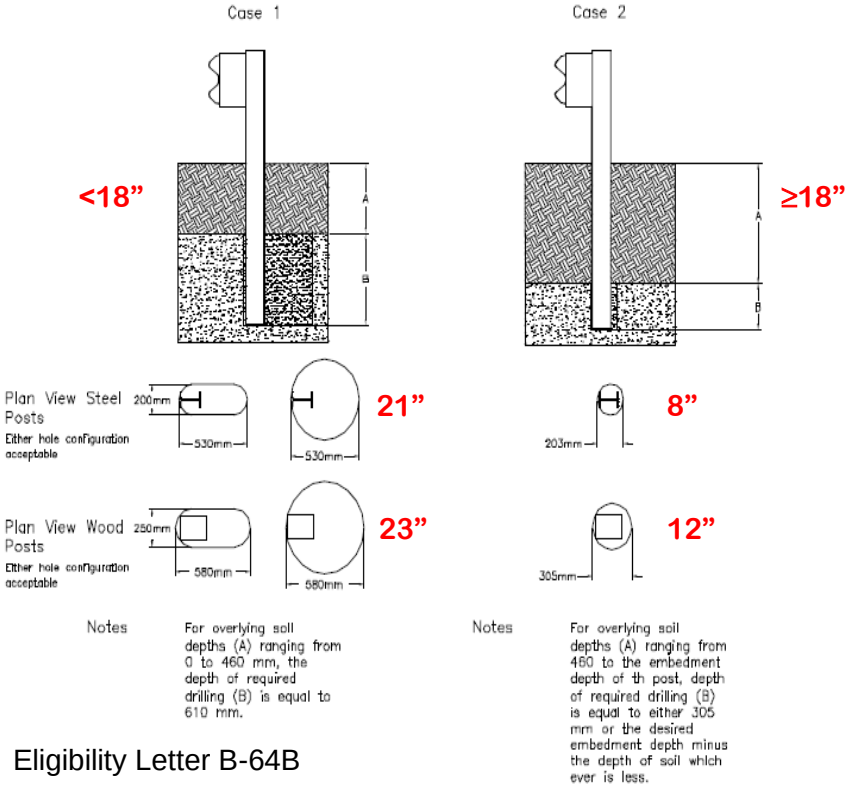
Leaveouts for Posts in Structural Pavement

In order for a post to move backward before failing (as intended), the support around the post must not be rigid; therefore, provide leaveouts in any structural pavement surrounding a post. The recommended minimum leaveout area in the mow strip or pavement will allow at least 7 inches behind post for post deflection at the ground line.

Extra Blocks

It is acceptable to use double blocks (up to 16 inches deep) to increase post offset and avoid obstacles without any limit to the number of posts. Under special circumstances, use additional blocks (up to 24 inches depth) at one or two posts.

Guardrail Posts in Rock



Eligibility Letter B-64B

Roadside Design Guide p. 5-63

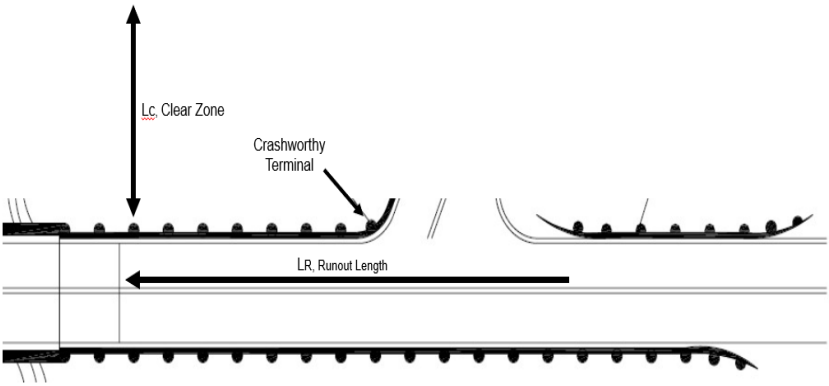
NHDOT Guidance

Nu Guard posts are utilized for locations where rock depth within the embedded post length is greater than 18 inches. Note:, 20" diameter holes for standard posts would likely require a specialty contractor at greater expense. Consider Nu-Guard for its smaller diameter drilled holes.

Turnout Conflicts (in runs of guardrail)

When encountering a side road or other interruption of the necessary guardrail length of effective barrier, in some cases the practice has been to continue the guardrail around the radius onto the side road or driveway. However, a vehicle impacting the guardrail in the radius is most likely to pass through (as there is no tension developed in the rail for this type of impact), ride over, or in the case of a small car have a severe head-on impact with the strong posts. This treatment does not meet MASH or NCHRP 350.

Ideally, relocating the side road or driveway would be desirable but not always feasible. One approach to eliminate this non-crashworthy aspect is to end the barrier with an offset energy-absorbing terminal or a crash cushion if there is adequate space and continue the barrier upstream of the access point based on the needed length of effective barrier (at a minimum, the LON for the barrier installation). Although crashworthy, there is still some risk of a vehicle gating through or passing behind the end treatment and entering the area of concern.



A special W-Beam Guardrail Radius design was developed in the 1980s which successfully sustained the direct hit—although only at 50 mph speed with sedan. The design, which can go from 8.5 feet to a 35 feet radius, used weakened wood posts (CRT) through the radius which allowed the rail to wrap around the vehicle on impact, safely decelerating it. The bolt must be omitted from the center most CRT post. The design requires a special anchor to develop adequate tension and a large clear area behind the rail (though it could have a 1V:2H slope).

This design was distributed to highway agencies as FHWA Technical Advisory T5040.32 which was incorporated into the NHDOT Design Manual as appendix 11-14

NHDOT has detailed this design in **Special Detail – Curve Guardrail with CRT Post,** for a minimum radius of 8 feet – 6 inches and for a maximum radius of 35 feet

MAINTENANCE

Keep guardrail systems in reasonable working condition so they are able to function as designed.

Maintenance

Keep guardrail systems in reasonable working condition so they are able to function as designed. Some deterioration occurs as a result of crash damage and environmental degradation. Much of this wear can be considered *cosmetic* and may not measurably affect barrier performance. However, some kinds of damage can degrade performance, such as those listed below in the Longitudinal Barrier Damage and Terminal Damage sections. Repair these types of damage in a reasonable time frame. It is important to assess, prioritize, and schedule repairs for identified damaged barrier sites.

General Guidelines

The following are General Guidelines for maintenance:

- Delineate the area of damage to warn the motorists as soon as practical after the discovery/notification of the damage. For some types of damage, such as a ruptured rail or a terminal left in a condition that renders it unable to function and/or is not crashworthy, schedule repair as soon as practical.
- **To mitigate a blunt rail end condition, it is recommended that the rail be unbolted from several posts and the leading end dropped to the ground. This will avoid exposing a blunt end condition until the installation can be repaired. Set back of the terminal head onto the blunt end of rail is also acceptable.**

- Review damaged guardrail as soon as reasonable to determine the scope of repair based on individual site conditions.
- At a minimum, consider upgrading existing or damaged barrier systems not meeting current criteria.

Cable Guardrail

Inspect and adjust cable guardrail every spring and fall to ensure proper tension of the cables.

Guardrail Maintenance

Maintain guardrail as it was constructed. Refer to the plans, department design standards, and manufacturer's installation manuals for proper installation of the various guardrails and terminals.

Promptly repair guardrail after it has been damaged. Repair work should start in a few days and work should progress continuously until repairs are completed.

Impact Attenuators

Maintain all types of impact attenuators as constructed. Refer to Manufacturers' installation and maintenance manuals.

National Guidelines for W-beam

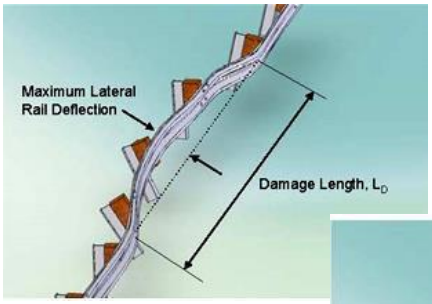
The following pages are excerpts from NCHRP Report 656, *Criteria for the Restoration of Longitudinal Barrier*. Note that the types and degree of damage to the barrier itself is prioritized as High, Medium, or Low. Use these rankings, along with the perceived likelihood of a second impact—at the crash-testing criteria of high speed, high angle—in the same location to set repair priorities**.**
Note: These evaluations were based on analysis of the splice on post beam guardrail system, not the 31" mid-splice beam guardrail. (For 31" mid-splice beam guardrail which is still functional with one post missing.)

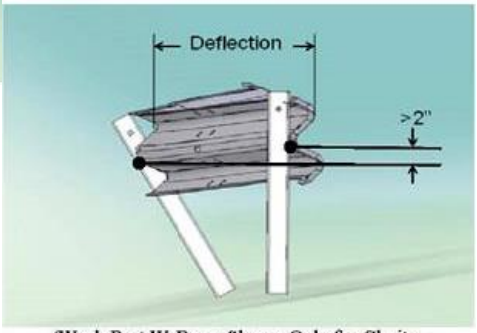
Repair priority scheme

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.

W-beam Barrier Repair Threshold

Damage Mode: Post and Rail Deflection

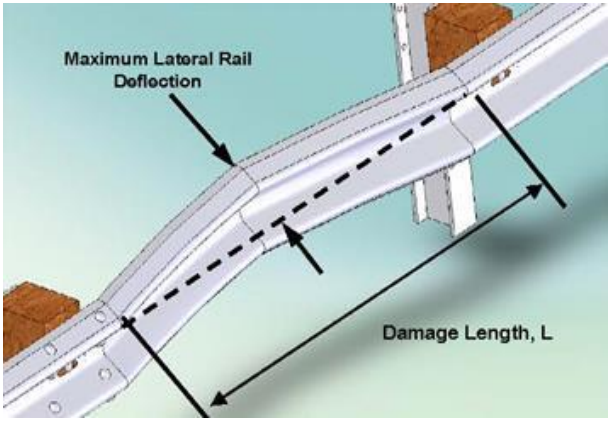




(Weak Post W-Beam Shown Only for Clarity.
Each measurement taken at rail middle fold)

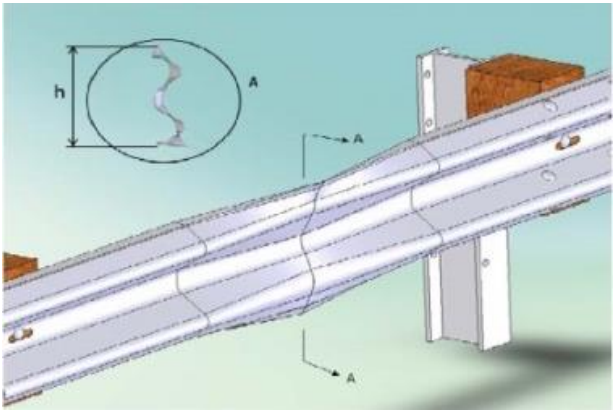
Relative Priority	Repair Threshold
High	One or more of the following thresholds: • More than 9 inches of lateral deflection anywhere over a 25 feet length of rail. • Top of rail height 2 or more inches lower than original top of rail height.
Medium	6–9 inches lateral deflection anywhere over a 25 feet length of rail.
Low	Less than 6 inches of lateral deflection over 25 feet length of rail.

W-beam Barrier Repair Threshold
Damage Mode: Rail Deflection Only



Relative Priority	Repair Threshold
Medium	6–9 inches of lateral deflection between any two adjacent posts. **Note**: Use post/rail deflection guidelines for deflection over 9 inches
Low	Less than 6 inches of lateral deflection between any two adjacent posts.

W-beam Barrier Repair Threshold
Damage Mode: Rail Flattening



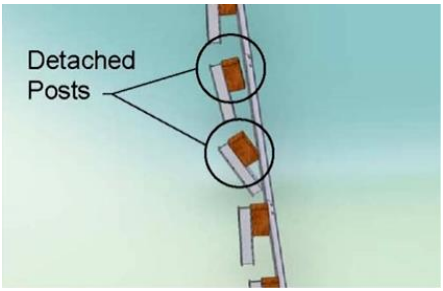
Relative Priority	Repair Threshold
Medium	One or more of the following thresholds: • Rail cross-section height, *h*, more than 17 inches (such as may occur if rail is flattened). • Rail cross-section height, *h*, less than 9 inches (such as a dent to top edge).
Low	Rail cross-section height, *h*, between 9 and 17 inches

W-beam Barrier Repair Threshold

Damage Mode: Posts Separated from Rail

Note:

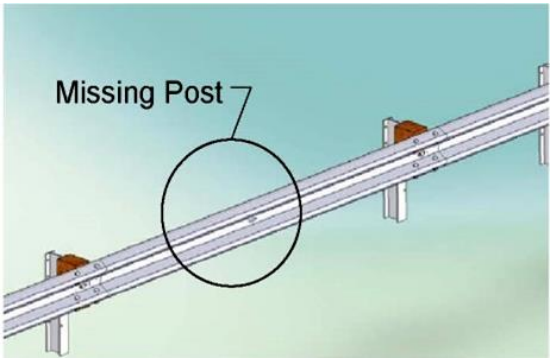
1. If the block is not firmly attached to the post, then use the missing block guidelines.
2. Evaluate damage against post/rail deflection guidelines.



Relative Priority	Repair Threshold
Medium	One or more of the following thresholds: • 2 or more posts with blocks attached with post-rail separation less than 3 inches • 1 or more post with post-rail separation exceeding 3 inches
Low	1 post with block attached with post-rail separation less than 3 inches

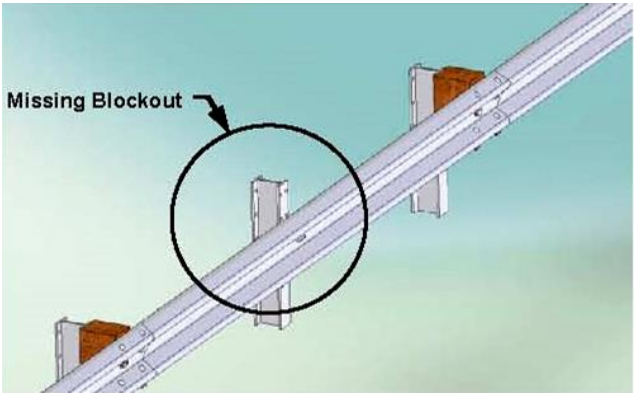
W-beam Barrier Repair Threshold

Damage Mode: Missing/Broken Posts



Relative Priority	Repair Threshold
High	1 or more posts: • Missing, • Cracked across the grain, • Broken, • Rotten, or • With metal tears.

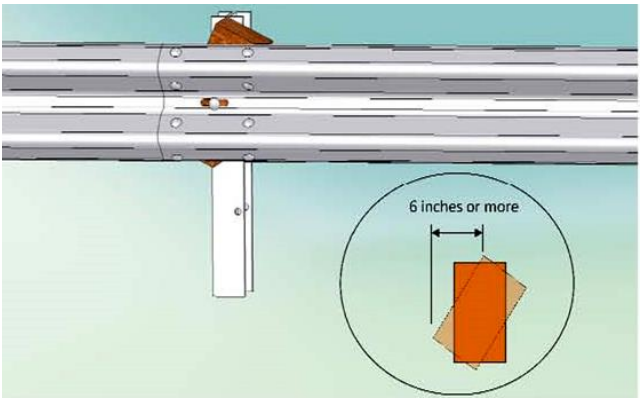
W-beam Barrier Repair Threshold
Damage Mode: Missing Block



Relative Priority	Repair Threshold
Medium	Any blocks: • Missing, • Cracked across the grain, • Cracked from top or bottom block through post bolt hole, or • Rotted.

W-beam Barrier Repair Threshold

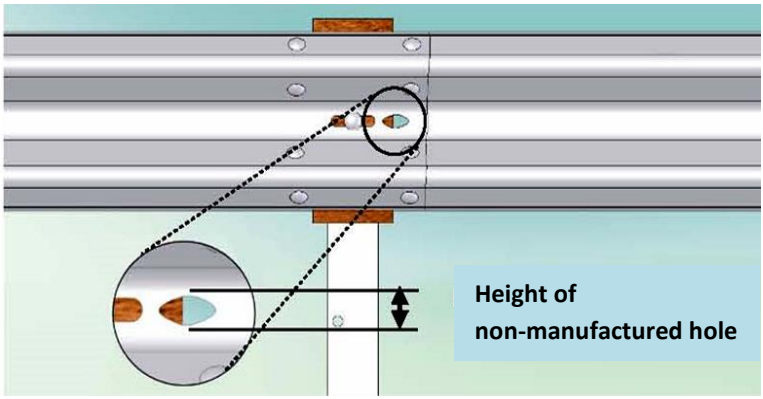
Damage Mode: Twisted Block



Relative Priority	Repair Threshold
Low	Any misaligned blocks, top edge of block 6 inches or more from bottom edge. **Note**: Repairs of twisted block are relatively quick and inexpensive.

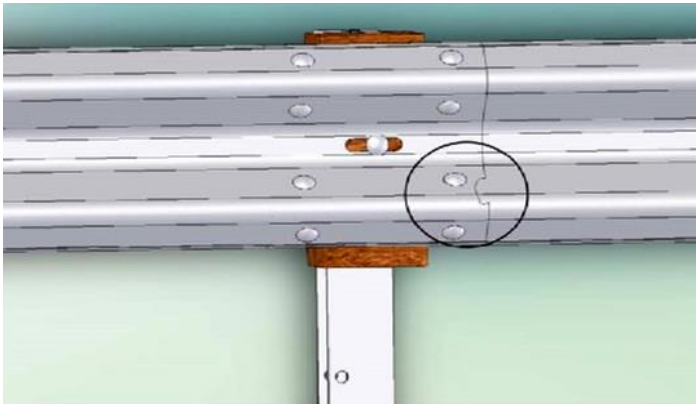
W-beam Barrier Repair Threshold

Damage Mode: Non-Manufactured Holes
(such as crash-induced holes, lug-nut damage, or holes rusted through the rail).



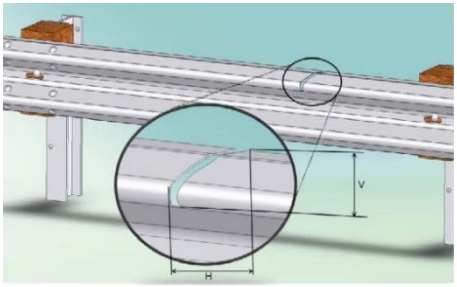
Relative Priority	Repair Threshold
High	One or more of the following thresholds: • More than 2 holes less than 1 inches in height in a 12.5 feet length of rail. • Any holes greater than 1 inches in height. • Any hole that intersects either the top or bottom edge of the rail.
Medium	• 1–2 holes less than 1 inches in height in a 12.5 feet length of rail.

W-beam Barrier Repair Threshold
Damage Mode: Damage at Rail Splice



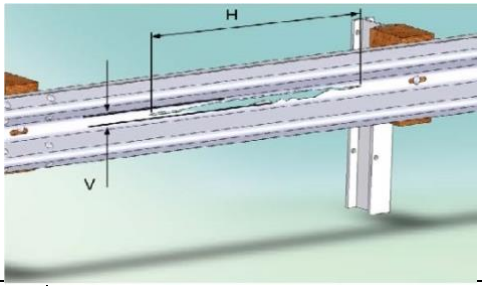
Relative Priority	Repair Threshold
High	More than 1 splice bolt: • Missing, • Damaged, • Visibly missing any underlying rail, or • Torn through rail.
Medium	1 splice bolt: • Missing, • Damaged, • Visibly missing any underlying rail, or • Torn through rail.

W-beam Barrier Repair Threshold
Damage Mode: Vertical Tear



Relative Priority	Repair Threshold
High	Any length vertical (transverse) tear.

W-beam Barrier Repair Threshold
Damage Mode: Horizontal Tear

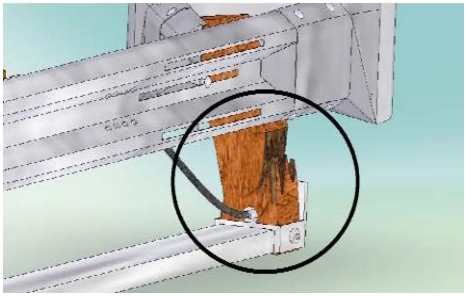


Relative Priority	Repair Threshold
Medium	Horizontal (longitudinal) tears greater than 12 inches long or greater than 0.5 inches wide.

Note: For horizontal tears less than 12 inches in length or less than 0.5 inches in height, use the non-manufactured holes guidelines.

Terminal Repair Threshold

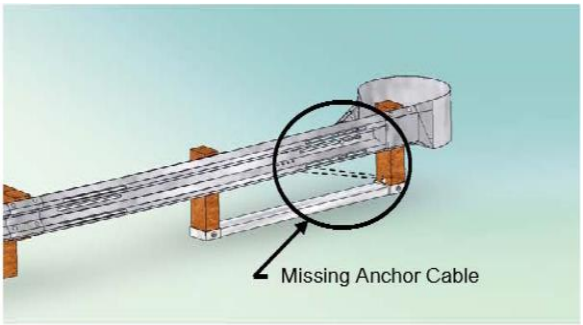
Damage Mode: Damaged End Post



Relative Priority	Repair Threshold
High	Not functional (sheared, rotted, cracked across the grain).

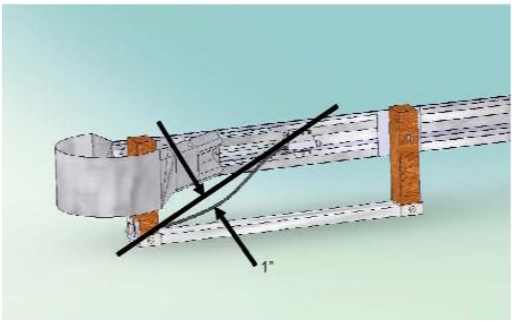
Terminal Repair Threshold

Damage Mode: Anchor Cable



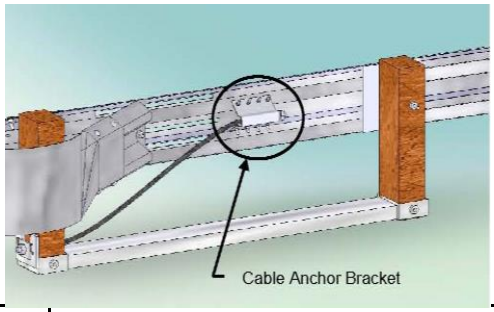
Relative Priority	Repair Threshold
High	Missing.

Terminal Repair Threshold
Damage Mode: Anchor Cable



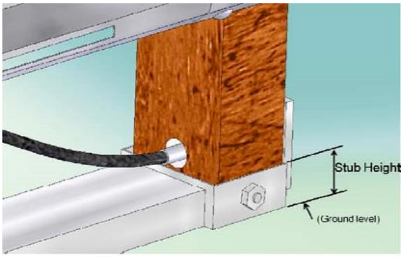
Relative Priority	Repair Threshold
Medium	More than 1 inches of movement when pushed down by hand.

Terminal Repair Threshold
Damage Mode: Cable Anchor Bracket



Relative Priority	Repair Threshold
Medium	Loose or not firmly seated in rail.

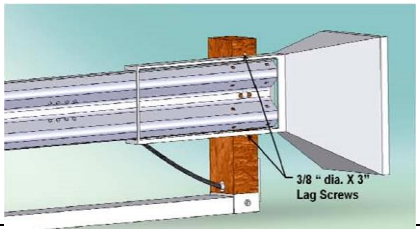
Terminal Repair Threshold
Damage Mode: Stub Height



Relative Priority	Repair Threshold
Medium	Height exceeding 4 inches

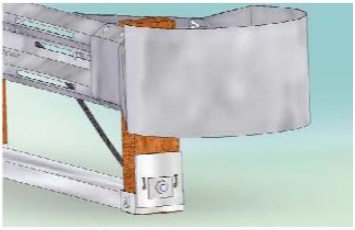
Note: Although NCHRP 656 Report rates this deficiency as medium priority, if the height is excessive, it could be potentially catastrophic.

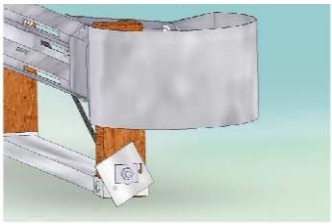
Terminal Repair Threshold
Damage Mode: Lag Screws (Energy-absorbing Only)



Relative Priority	Repair Threshold
High	Missing or failed lag screws.

Terminal Repair Threshold
Damage Mode: Bearing Plate


(Correct Bearing Plate)

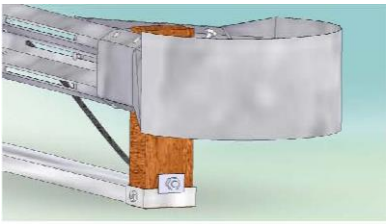

(Misaligned Bearing Plate)

Relative Priority	Repair Threshold
Medium	Loose or misaligned.

Note: Although the NCHRP 656 Report rates this as a medium priority, this can very easily be repaired in the field, thus avoiding a potentially serious crash outcome. Its significance is illustrated by it being listed on the manufacturer's inspection checklists.

Terminal Repair Threshold

Damage Mode: Bearing Plate

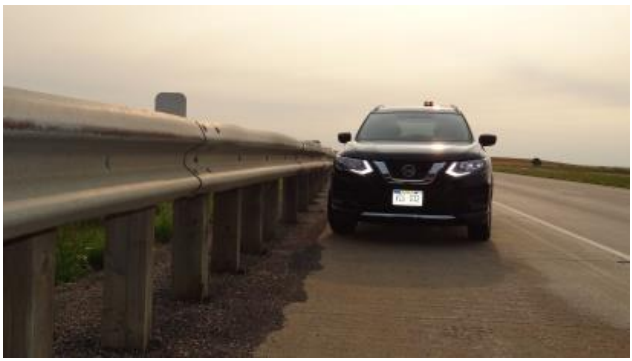


Relative Priority	Repair Threshold
High	Missing bearing plate.

Note: Although not included in the NCHRP 656 Report, improper seating of the rail in an extruder head terminal (as the Figure below shows) will not allow the terminal to function properly in a crash and could penetrate a vehicle during a strike. Once identified, correct this condition at the earliest reasonable opportunity.

Improper Seating of Rail into Head

Also, the purpose of guardrail is to contain the vehicle and not allow vaulting or underride. Therefore, consider any reduction in the system height to less than 26½ inches (splice on post /28" system) a high-priority repair. However, the mid-splice originally installed at 31 inches, has a lower tolerance of 3 inches (28 inches). Also evaluate excessively high rail. (Installation tolerance is 30 inches for splice on post and 34 inches for mid-splice).



Cable Guardrail Guidelines

Cable guardrail systems are designed to contain and redirect a striking vehicle while minimizing the forces on the vehicle and its occupants. Proper maintenance includes checking that the cables are properly tensioned and at the correct height.

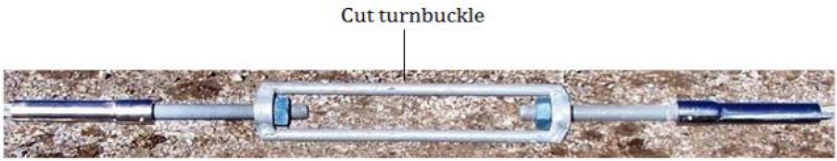
- **Routine tension check**. Perform this check even in the absence of a strike, but it is particularly important during the first few years following installation.

- **Keep the cable intact**. In the event of a crash resulting in a vehicle becoming entangled in the cable, keep the cable; only cut the cable when there is a life-or-death situation. Alternatives to cutting the cable include:

— Removing the vehicle by towing it in the opposite direction from which it struck the system.

— Loosening the cables at the turnbuckles.

— Cutting the turnbuckle is preferable to cutting the cable. Remove the adjacent posts on either side of the turnbuckle. Ensure personnel are clear of the cable; cut the center of the turnbuckle as shown below.



- Check cable height and repair to meet Standard Detail for low-tension cable or manufacturer's specifications for high-tension cable.
- Inspect cable for kinks or broken strands.
- Check for missing or damaged posts (more critical with low tension) and missing hook.

  (**Note**: Damaged posts can also present a spearing concern should a secondary impact occur; crews should remove damaged or bent-over posts to eliminate the spearing potential.)
- Check that cables are attached to the anchors, and that the anchors are flush with the ground surface.

Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ADT	Average Daily Traffic
BLON	Beginning Length of Need
CIP	Critical Impact Point
FARS	Fatal Analysis Reporting System
FAST ACT	Fixing America's Surface Transportation Act
FHWA	Federal Highway Administration
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
ROW	Right-of-Way
SHSP	Strategic Highway Safety Plan
SPWB	Strong Post W-Beam
TL	Test Level
VMT	Vehicle Miles Traveled
WZ	Work Zone

Glossary

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.

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 from going over the side of the bridge structure.

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

Clear Zone. The unobstructed, traversable area provided beyond the edge of the through traveled way for the recovery of errant vehicles. The clear zone includes shoulders, bike lanes, and auxiliary lanes, except those auxiliary lanes that function like through lanes.

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 appurtenances may be determined. Three evaluation criteria are considered, namely (1) structural adequacy, (2) occupant 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 Terminal. The designed modification of the end of a roadside or median barrier.

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

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.

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 (LON). Length of a longitudinal barrier needed to shield an area of concern.

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

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

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

Non-Energy-absorbing Systems. Systems that 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.

Non-Recoverable Slope. A slope which is considered traversable but on which an errant vehicle will continue to the bottom. 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.

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.

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.

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 50 ft^2 in area. Small roadside signs may be defined as those less than 50 ft^2 in area.

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

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 Line 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.

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).

Test Level. 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 test.

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.

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, the four classes of traffic barriers are roadside barriers, median barriers, bridge railing, 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 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 1V:3H and 1V:4H generally fall into this category.

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

Resources

New Hampshire Department of Transportation

- NHDOT Highway Design Manual – Chapter 11
  https://www.dot.nh.gov/doing-business-nhdot/engineers-consultants/highway-design-manuals
- NHDOT Standard Plans for Road Construction
  https://www.dot.nh.gov/doing-business-nhdot/contractors/standard-plans-road-construction
- NHDOT Highway Design Special Details
  https://www.dot.nh.gov/doing-business-nhdot/engineers-consultants/highway-design-special-details
- Approved Product List
  https://mm.nh.gov/files/uploads/dot/remote-docs/qpl-nhdot-qualified-products-list.pdf

  Federal Highway Administration (FHWA) https://www.fhwa.dot.gov/
- FHWA Hardware Policy and Guidance
  http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/

  American Association of State Highway and Transportation Officials (AASHTO) https://www.transportation.org/
- AASHTO, Roadside Design Guide, 2011
- AASHTO, Manual for Assessing Safety Hardware, 2016 (MASH16)

  Task Force 13 website https://www.tf13.org/
- Guide to Standardized Highway Barrier Hardware

  Roadside Safety Pooled Fund sites:
- MWRSF: http://mwrsf-qa.unl.edu/
- TTI: http://www.roadsidepooledfund.org/

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