Illinois Department of Transportation
2300 South Dirksen Parkway / Springfield, Illinois / 62764

June 11, 2015

CIRCULAR LETTER 2015-10

GUARDRAIL END TERMINAL INVENTORY

COUNTY ENGINEERS / SUPERINTENDENTS OF HIGHWAYS
MUNICIPAL ENGINEERS / DIRECTORS OF PUBLIC WORKS / MAYORS
METROPOLITAN PLANNING ORGANIZATIONS - DIRECTORS
CONSULTING ENGINEERS

The Illinois Department of Transportation has undertaken an effort to inventory all of the guardrail end treatments along state highways. This inventory will be used to track quantities of the various end treatments in use for safety and performance evaluations of existing roadways, and for tracking claims, repairs, and replacements to guardrail end treatments. As part of this effort, IDOT invites and encourages the local public agencies to also take an inventory of their existing guardrail end treatments.

Acquiring an inventory of guardrail end treatments will also allow the local public agency the ability to better track quantities, claims, repairs, replacements, and perform safety evaluations. IDOT encourages the local public agencies to submit their guardrail end treatment inventories to IDOT, so a broader inventory may be acquired and utilized for the entire Illinois highway network.

The attached identification guide must be used to identify and catalog the existing guardrail end treatments for consistency. The inventory may be recorded on the attached Excel spreadsheet with GPS coordinates and photographs linked to the spreadsheet. Local public agencies may also wish to inventory and catalog the existing guardrail sections between end treatments as part of this same effort.

Questions concerning guardrail and guardrail end treatment types for the inventory may be directed to the Central Bureau of Safety Engineering at (217) 782 – 3568. Completed inventories may be submitted to IDOT through the DOT.LocalPolicy@illinois.gov electronic mailbox. Local public agencies are encouraged to complete their inventories as soon as possible and submit them to IDOT by June 1, 2016.

The Federal Highway Administration (FHWA) in their June 5, 2015 letter to the Illinois Department of Transportation further emphasizes the importance of proper selection for roadside safety hardware, proper installation and maintenance, and evaluation of the in-service condition. Attached to their letter is an FHWA publication on the “Selection, Installation and Maintenance of W-Beam Guardrail End Terminals” that may be helpful.

If you have any questions regarding this Circular Letter, please contact the Local Policy and Technology Unit at (217) 782-5048 or DOT.LocalPolicy@illinois.gov.

Sincerely,

James K. Klein

James K. Klein, P.E., S.E.
Acting Engineer of Local Roads and Streets

Attachment

TW/

cc: Priscilla A. Tobias
Greg Smothers, Illinois Association of County Engineers
Joe Schatteman, Illinois Municipal League
Bryan Smith, Township Officials of Illinois
Darrell Maxheimer, Township Highway Commissioners of Illinois

END TERMINAL INVENTORY - DISTRICT #_____

Performed by:_____

Date:_____

County	Route	Terminal Location (1)	GPS "X"	GPS "Y"	Picture # (2)	Terminal Type # (3)	Guardrail Height (in) (4)	Blockout (5)		Comments (6)
								Width (in)	Material	
										For ET-Plus, NOTE 4" OR 5" EXTRUDER RAIL

Notes:

1. Terminal location - General description of location (i.e. IL Rte 4/SB/NW quadrant)

2. Pictures (#) - Obtain a picture of the frontside, backside and roadside of the terminal and document picture(s) # that correlate

3. Terminal Type (#) - The number referenced from the pictures of the end terminal sections

4. Guardrail Height - Measure from the top of guadrail to road surface @ 1st post of terminal for SRTs / X-Tension / Breakaway Cable Types / Blunt Ends; or just beyond extrudor head of ET 2000 / ET Plus / SKTs / Fleat

5. Blockout - Measure the width and material type (i.e. 0", 6", 8", 12" and wood (w), plastic (p) or steel (s))

6. Comments: End Terminal in good/poor condition, bent or sagging, etc. ET-PLUS-4" EXTRUDER RAIL OR 5"

IDENTIFICATION GUIDE FOR IDOT GUARDRAIL TERMINALS

June 2015

Terminal #1---ET 2000

The ET 2000 is a crashworthy end. This terminal is a tangent terminal, and it should not be flared more than 12" in 50'. (Just enough to keep the extruder end from overhanging a shoulder.) It is not used with the Midwest Guardrail System (MGS)-which has the 12" blockouts. It was used with guardrail systems with a nominal height of about 27-28". It was used with guardrail systems that had only the 6" wide spacer block between the guardrail post and the back of the guardrail. It has one vertical steel spacer strap on the traffic side of the extruder head (part slipped over the end of the guardrail. The ET 2000 is close to square on the impact face. The ET 2000 may appear either with wood or steel posts.

Terminal #2---ET Plus

This is the ET Plus terminal. It is a crashworthy terminal. This terminal is a tangent terminal, and it should not be flared more than 12" in 50'. (Just enough to keep the extruder end from overhanging a shoulder.) This terminal's end impact head is taller than it is wide. It has one vertical strap at on the traffic side of the impact head near the far end of the impact head. In this photo, the final grading (asphalt) is not in place, but is intended to be flush with the top of the steel foundation tubes. This terminal was used with guardrail having a nominal height of 27-28", and 6" wide spacer blocks between the post and the back of the guardrail. A distinct, separate version is used with the MGS. The steel edges farming the end plate extend beyond the impact face only on the sides. The top rail of the extruder was originally 5" in width and was later modified in 2005 to 4" (see attached picture below)

ET Plus, side view

ET-Plus 4” Extruder Rail.

ET-Plus 4” Extruder Rail

Terminal #3---SKT 350

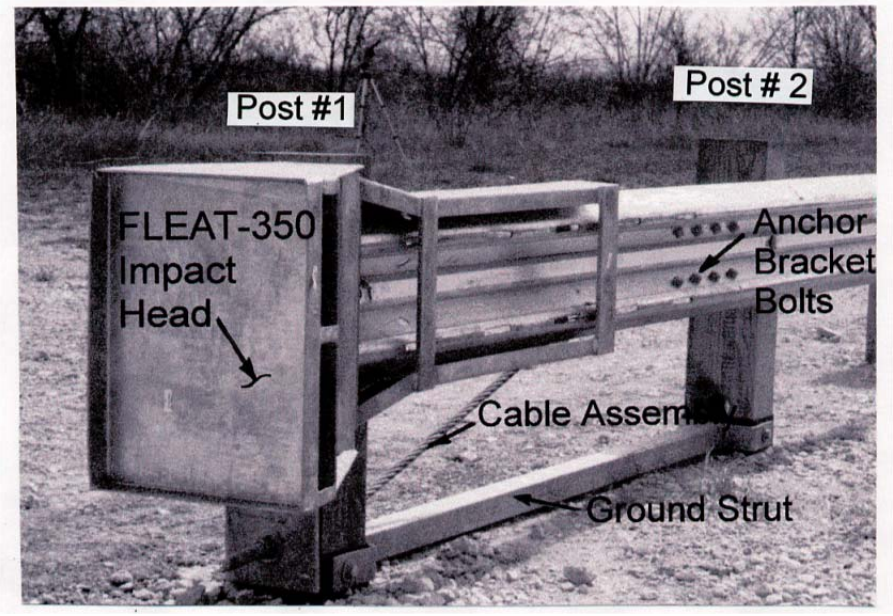
The SKT 350 is a crashworthy terminal. The SKT 350's extruder head has two vertical spacer straps on the extruder head. This terminal is a tangent terminal, and it should not be flared more than 24" in 50'. Its impact face is near square. The SKT 350 uses specially slotted guardrail panels within the limits of the extruder head (clearest view in photo below.) The SKT was used with guardrail having a top height of 27-28" and 6" wide spacer blocks between the guardrail posts and guardrail. A distinct, separate version is used with the MGS. The SKT 350 may appear with wooden or steel posts.

Terminal #4---SKT MGS

The SKT MGS is a crashworthy terminal. The above photo is from the manufacturer's website. The SKT MGS (either steel posts or wood posts) is similar to the SKT 350, except it is designed for use with the MGS.

Terminal #5---FLEAT 350

This is the FLEAT 350. The FLEAT 350 is a crashworthy terminal. Its extruder head is slightly taller than it is wide, and the steel edges framing the end plate extend beyond the end plate on all sides. The FLEAT 350 is flared 30" to 48" from the line of guardrail. The FLEAT 350 uses specially slotted rail within the limits of the extruder head. This terminal is for use with guardrail systems having a nominal height of 27-28". The extruder head has one vertical strap near the back. This system may appear with wood or steel posts.



FLEAT 350 side view. This photo is from the manufacturer's website.

Terminal #6---FLEAT MGS

This photo is from the manufacturer's website. The FLEAT MGS is a crashworthy terminal similar to the FLEAT 350. This is a terminal that will be flared from the line of guardrail by 30 to 48". It uses a specially slotted guardrail section in the area covered by the extruder head. The FLEAT MGS has one vertical steel strap at the back end of the extruder head, and this terminal may appear with wood or steel posts.

Terminal #7---SRT 350

This image is from the manufacturer's website. The SRT 350 is a crashworthy terminal. This terminal uses strategically placed slots in the guardrail panel to assure the panel breaks away rather than spearing an impacting vehicle. This is a flared terminal and may be flared 3' to 4' from the line of the guardrail. This terminal is for use with guardrail systems having a nominal 27-28" height and using the 6" spacer blocks between the posts and back of the guardrail panels.

Terminal #8---SRT 31

This terminal is a crashworthy terminal similar to the SRT, but is designed for use with the MGS. Steel posts are most often used, but wood posts may exist. This system is for use with guardrail having a nominal 31" height and with 12" spacer blocks between the guardrail posts and the back of the guardrail panels. This guardrail is distinguished from a blunt end (non-crashworthy) by the slots cut into the rail to assure the system breaks away rather than spearing an impacting vehicle.

Terminal #9---**X-Tension**

The X-Tension is a crashworthy terminal. This system may be installed in line with the attached guardrail or flared up to 4’. The distinguishing feature of this terminal is the cable anchor assembly in front of post 1. This system may be used either with the MGS or with guardrail terminals having a nominal height of 27-28”.

Terminal #10---Turned Down Guardrail End.

This is a turned down end guardrail terminal. This terminal is not crashworthy under current IDOT or FHWA requirements. Several variations may exist, but the key feature is the lowering of the guardrail panel from normal height to ground level, with a 90 degree twist.

Terminal #11---Breakaway Cable Terminal with Less than 4’ Flare

The Breakaway Cable Terminal (BCT) with less than 4’ flare is not a crashworthy terminal. At least on three occasions, this terminal has penetrated impacting vehicles and resulted in fatalities. This terminal was used with guardrail systems having a top height of 27-28” and using 6” spacer blocks between the guardrail posts and guardrail panels. Historically, this terminal may have been constructed as Traffic Barrier Terminal Type 1 by either current Highway Standard BLR 23 (with version extension) or former Highway Standard 2336 (with version extension).

Terminal #12---Breakaway Cable Terminal with 4’ flare.

The BCT with 4’ flare is <u>not</u> a crashworthy terminal. In certain crash situations it may penetrate small cars. The BCT was used with guardrail systems having a nominal height of 27-28”, and using 6” spacer blocks between the posts and back of the guardrail panels. Historically, this terminal may have been constructed as Traffic Barrier Terminal Type 1A by former Highway Standard 2336 (with version extension).

Terminal #13---Blunt End.

The blunt end is not a crashworthy terminal. Whether this terminal has a cable anchor, it has the potential to spear an impacting vehicle. If no cable anchor is present, the attached run of guardrail may experience degraded performance due to inability to develop tension on impact.

U.S. Department
of Transportation
Federal Highway Administration

Illinois Division

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Springfield, IL 62703
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www.fhwa.dot.gov/ildiv

June 5, 2015

In Reply Refer To:
HMS-IL

Mr. Randall Blankenhorn
Illinois Department of Transportation
2300 South Dirksen Parkway
Springfield, Illinois 62764

Subject: Roadside Safety Hardware

Dear Secretary Blankenhorn:

The Federal Highway Administration (FHWA) has been examining the performance of guardrail end treatments and it is recognized that there are installation and maintenance challenges with these devices. As the construction season begins, this is an appropriate time to pay particular attention to the installation and maintenance of guardrail end terminals. In the enclosed memorandum, FHWA emphasizes the need for States to have policies and procedures in place to evaluate the selection of roadside safety hardware relative to the roadway type, configuration and terrain; ensure its proper installation and maintenance; and periodically evaluate its in-service condition.

In addition, FHWA acknowledges that some obsolete, non-crashworthy guardrail end terminals still exist on the nation's highway system. As FHWA has done in previous memoranda issued over a number of years, we strongly recommend that pre-NCHRP-350 guardrail end terminals be removed or replaced.

We commend the Illinois Department of Transportation (IDOT) for initiating efforts, like the guardrail end treatment inventory, and other data collection activities to begin a process for in-service performance evaluation. To take these efforts to the next level and address the actions identified in the enclosed memorandum, we request a meeting with your staff to discuss the content of the memorandum and development of a plan of action. Our Mobility and Safety Team Leader, Alan Ho, will work with your staff to schedule the meeting.

We also request that IDOT forward this memorandum to local agencies that have the responsibility for operation and maintenance of roadways. We value the on-going efforts by IDOT to reduce highway fatalities and serious injuries.

Sincerely,

Catherine Batey
Division Administrator

Enclosure

ecc: Ms. Sarah Kurmann, Office of the Secretary, IDOT
Ms. Christine Reed, Office of the Secretary, IDOT
Mr. Omer Osman, Division of Highways, IDOT
Mr. Aaron Weatherholt, Division of Highways, IDOT
Mr. Justan Mann, Division of Highways, IDOT
Mr. James Klein, Bureau of Local Roads and Streets, IDOT
Ms. Priscilla Tobias, Bureau of Safety Engineering, IDOT
Mr. Jeff South Office of Planning and Programming, IDOT
Mr. Jeff Heck, Division of Traffic Safety, IDOT

U.S. Department of Transportation
Federal Highway Administration

Memorandum

Subject: **ACTION:** Roadside Safety Hardware

Date: MAY 26 2015

From: Tony Furst
Associate Administrator

In Reply Refer To:
HSST

To: Division Administrators
Federal Lands Division Engineers
Safety Field

Purpose

The purpose of this memorandum is to bring to your attention two primary issues related to guardrail end terminals that will require you to take action. As you are aware, we have been closely examining the performance of guardrail end terminals. It's recognized that there are installation and maintenance challenges with these devices. As the construction season starts, and after the heavy winter, this is the appropriate time to pay particular attention to installation and maintenance issues. In this memo, FHWA emphasizes the need to have in place policies and procedures to evaluate the selection of roadside safety hardware relative to the roadway type, configuration and terrain; ensure its proper installation and maintenance; and periodically evaluate its in-service condition. In addition, we are aware there are some obsolete, non-crashworthy guardrail end terminals that still exist on the nation's highway system. We have raised awareness regarding these terminals through previous memoranda issued over a number of years. We strongly recommend that you encourage the removal of pre-NCHRP-350 guardrail end terminals.

Background

It is FHWA policy that roadside safety hardware installed on the National Highway System (NHS) should be in compliance with the crash testing and evaluation criteria contained in the Manual for Assessing Safety Hardware (MASH) or its predecessor the National Cooperative Highway Research Program (NCHRP) Report 350. Devices that are compliant with either of these two sets of criteria are currently considered crashworthy devices.

It is critical that devices be installed and maintained properly so they are in the best position to perform as designed and tested. Attached is a technical brief titled "Selection, Installation, and Maintenance of W-beam Guardrail End Terminals" which highlights general guidelines regarding the selection, installation, and maintenance of W-beam

guardrail end terminals. In addition, common issues of concern are identified with generally accepted practices to address these concerns.

Even when a successfully crash tested device is properly selected, installed, and maintained, individual crashes in the field are unique events and may result in performance that was not observed during crash testing. For this reason, a crash tested device should be monitored for its in-service performance, as indicated in both NCHRP 350 and MASH.

It is known that roadside safety hardware installed prior to the implementation of NCHRP 350 in 1993 remains on the NHS or other roadways across the nation. However, as indicated in the FHWA action memorandum, "Traffic Barrier Safety Policy and Guidance," dated 9/29/1994, non-crashworthy hardware should be removed and replaced with crashworthy roadside hardware at the earliest possible opportunity in concert with the maintenance of the roadway. It has been more than twenty years since that memo was issued and devices listed in that memo are still in service. We strongly recommend that pre-NCHRP 350 guardrail end terminals be removed and replaced.

Action

Please share this memorandum and its enclosure with your State DOT and any city, county or municipality in your State with responsibility for the operation and maintenance of their roadways.

Please ask them to review and, if necessary, update their policies, procedures, standards, and guidelines relative to the selection, installation, maintenance, and in-service evaluations of crashworthy roadside safety hardware on their roadways, specifically:

1. Relative to installation and maintenance of crashworthy roadside safety hardware, it is strongly recommended that they put in place the necessary protocols to ensure that any entity installing or maintaining roadside safety hardware, including contractors or State or local personnel, are capable (e.g., trained, credentialed or authorized by the roadside hardware manufacturer for the installation and maintenance of their hardware) of doing this work.
2. Review standard plans and specifications to ensure that only crashworthy devices are used on the National Highway System (NHS).

Finally, strongly encourage the highway agencies to increase their efforts to systematically upgrade pre-NCHRP 350 guardrail end terminals, particularly those that are on the NHS.

Resources

FHWA's Office of Safety and the Safety and Design Team in FHWA's Resource Center can provide training and technical assistance that focus on the proper selection, installation, and maintenance of guardrail end terminals to State Departments of Transportation (DOTs). Many states have taken advantage of this resource.

FHWA's Office of Safety will offer assistance to help set up pooled fund arrangements to conduct in-service performance evaluations.

For more information, accessing the above resources, or if you have questions or comments, please contact Will Longstreet at (202)366-0087 or Nick Artimovich at (202)366-1331.

References

• The September 29, 1994, FHWA memorandum, "Traffic Barrier Safety Policy and Guidance", called for replacement of "blunt ends" and discontinued the use of turned down ends and Breakaway Cable Terminals. The memorandum also suggested a policy to upgrade these terminals.

• The August 18, 1998, FHWA memorandum, "National Cooperative Highway Research Program (NCHRP) Report 350 Hardware Compliance Dates," announced the FHWA-AASHTO Implementation Plan for NCHRP Report 350 hardware. This plan required the upgrade of terminals not meeting NCHRP Report 350 as part of 3R projects on the NHS.

• The October 26, 2004, FHWA memorandum, "Guidelines for the Selection of W-Beam Barrier Terminals" identified several characteristics of W-beam terminals that need to be understood in order to select the appropriate system including site grading, type of terminal, and terminal layout.

• The November 17, 2005, FHWA memorandum, "In-service Performance Evaluation and Continuous Monitoring of Roadside Safety Features," identified the need to routinely conduct in-service performance evaluations of crash tested roadside safety hardware.

• The June 26, 2012, FHWA memorandum, "AASHTO Roadside Design Guide 4th Edition," encourages State DOTs to have a written roadside policy that aligns with the AASHTO Roadside Design Guide, 4th edition.

Attachment

• Technical brief titled "Selection, Installation, and Maintenance of W-Beam Guardrail End Terminals.

Selection, Installation and Maintenance of W-Beam Guardrail End Terminals

This brief provides general guidelines regarding the selection, installation, and maintenance of W-beam guardrail terminals. In addition, common issues of concern are identified for these elements with generally accepted practices to address these issues. The American Association of State Highway and Transportation Officials (AASHTO) Roadside Design Guide 4th Edition Chapter 8.3 provides additional guidance on terminal design concepts.

Terminal Selection:

There are three primary W-beam guardrail end terminal designs in use at present: buried-in-backslope, non-energy-absorbing, and energy-absorbing. Figure 1 shows the relative trajectories of a vehicle impacting non-energy-absorbing and energy-absorbing terminals head-on and at high speed (62 mph). The decision to use either an energy-absorbing terminal or a non-energy-absorbing terminal should be based on the likelihood of a near end-on impact and the nature of the recovery area immediately behind and beyond the terminal.

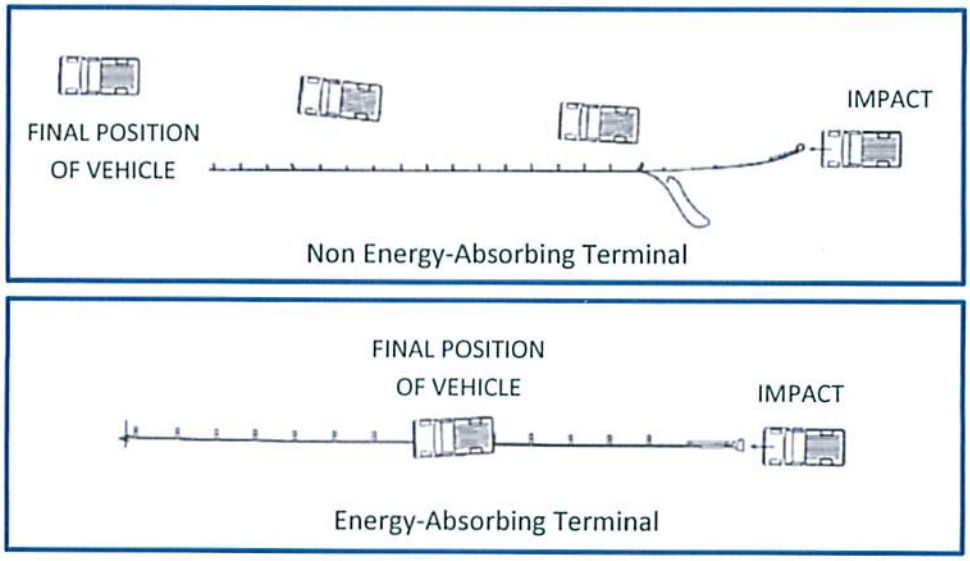


Figure 1: Vehicle Trajectories by Terminal Type

Characteristics of the Different Terminal Types:

I. Non Energy-absorbing – A terminal that does not dissipate a significant amount of kinetic energy in a head-on crash and is a gating system that allows the vehicle to traverse the area behind and parallel to the guardrail. Some key characteristics include:

- Does not significantly reduce vehicle speed in a near head-on hit
- Run out distance can exceed 150 feet
- Best specified when there is a long, clear, traversable area behind and parallel to the guardrail installation, such as often found in a flat freeway median

II. Energy-absorbing – A terminal that dissipates a significant amount of kinetic energy in a head on crash. Some key characteristics include:

- Barrier installations less than 150 feet in advance of any shielded object must be energy absorbing
- Energy-absorbing terminals have been shown to stop an impacting pick-up truck in about 50 feet when struck head-on
- Best suited to locations where traversable area behind barrier is limited; or, contains fixed object hazards.

III. Buried-in-Backslope – A terminal that terminates a W-beam guardrail installation by burying the end in the backslope. Grading is critical for a buried-in-backslope terminal because the terrain leading up to the buried-in-backslope must be traversable and contain no fixed object hazards. If the backslope is relatively flat, a vehicle can ride up the slope and bypass the terminal. When this condition exists at a site, the designer must ensure that the hazard remains shielded by assessing the available clear run out distance behind the rail and the barrier length-of-need. Also, there are other "grading" design considerations to follow:

- The backslope itself must be sufficiently steep to prevent a vehicle from climbing over the rail
- The barrier flare rate must be appropriate for the roadway design speed and traffic volume
- The height of the rail must remain constant in relation to the roadway edge at least until the guardrail crosses the ditch flow-line
- W-beam rub rail must be added if the distance from the bottom of the primary rail and the ground exceeds about 17 inches.

Figure 2 is a suggested flowchart that can be used by a designer to select the most appropriate terminal for a specific location. It's important to note that the starting point is to verify that a barrier is actually needed. If so, then the correct length of need should be confirmed. If a total length of barrier is less than about 150 feet, an energy-absorbing terminal should be selected for the reason previously stated. When an appropriate backslope exists near the end of the barrier, the buried-in-backslope terminal should be considered. When no suitable backslope exists, either a non-energy-absorbing or energy-absorbing may be appropriate.

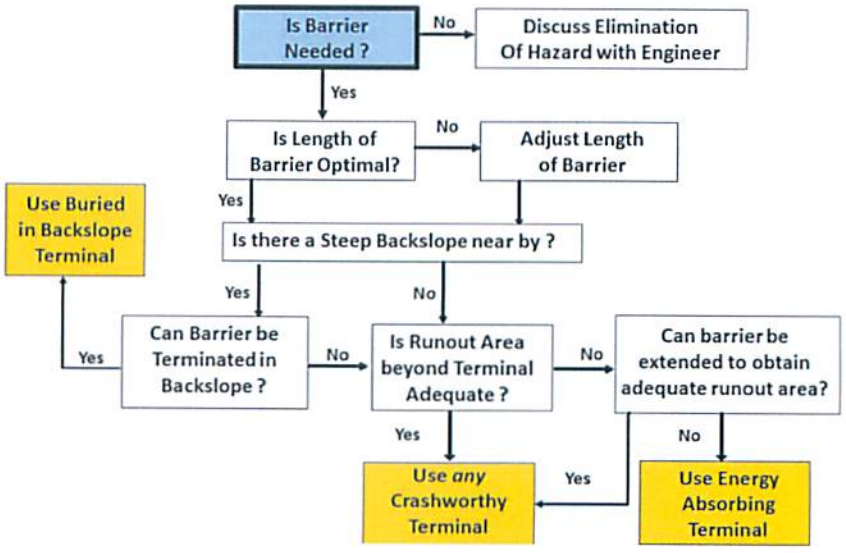


Figure 2: Terminal Selection Flowchart

Terminal Selection: Common Issues of Concern and Current Generally Accepted Practices.

Common Issue of Concern	Current Generally Accepted Practice
Side-by-side Terminals: If the ends of two barriers are within seven feet of each other, they should be combined and terminated as a median barrier or a bullnose design should be considered. This should reduce the potential for the vehicle to reach the hazard or obstruction.	Bullnose Guardrail System for Median Applications

Common Issue of Concern	Current Generally Accepted Practice
Curbs The presence of a curb can introduce instability as the vehicle hits the terminal and should be avoided or minimized if possible. In addition, added rub rails or other items not part of the original design might affect the performance of the terminal and should not be added.	Curb–Guardrail Combinations Refer to NCHRP Report 537 Recommended Guidelines for Curb and Curb–Barrier Installations. There are tested curb and guardrail and curb and end terminal combinations covered.

Common Issue of Concern	Current Generally Accepted Practice
Inadequate Length of Need (LON). Guardrail insufficient length to shield the hazard.	Extending the barrier or a buried-in-backslope to appropriately shield the hazard.

Common Issue of Concern	Current Generally Accepted Practice
Terminal flare rate can be excessive on a flared terminal.	A gating terminal may be considered here because of existing run out area.

Terminal Installation:

When installing the terminal, the manufacturer's installation manual should be followed closely. Additionally, grading in the area of the terminal is important because terminals are tested for crashworthiness on flat and unobstructed terrain. As shown in Figure 3, there are three grading locations of concern around barrier terminals:

a. Advance area
b. Adjacent area
c. Run-out area

All of these areas should be carefully considered during the design phase of a project. Engineered earthwork and specification of a platform* should also be considered to achieve successful terminal performance. In addition, necessary earthwork should be completed prior to the installation of the safety feature.

*A platform is the required grading for both adjacent & advance areas to acceptable criteria per the Roadside Design Guide.

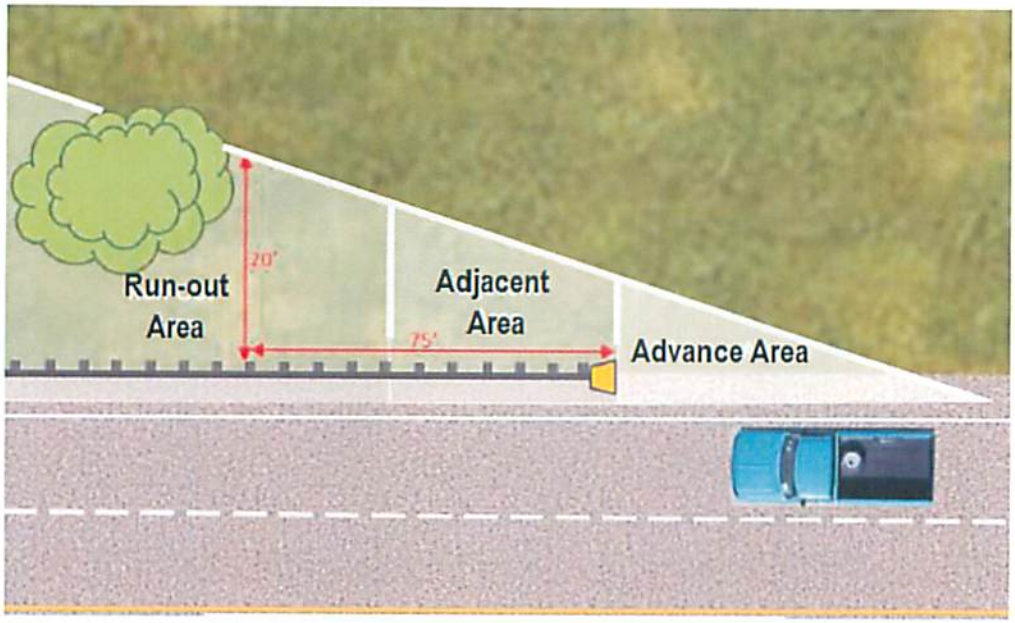


Figure 3: Terminal Grading Areas

Terminal Installation: Common Issues of Concern and Current Generally Accepted Practice

Common Issue of Concern	Current Generally Accepted Practice
Advance Area: The "advance area" consists of the space traversed by an errant motorist before the terminal is struck. If a terminal "platform" is constructed, it must be smoothly blended into the existing roadside embankment so a motorist has an opportunity to return to the roadway without striking the terminal or losing control of the vehicle by dropping off the edge of a steep platform before impact. The "grading platform" in the photo has a drop-off that creates a significantly greater hazard than previously existed.	Before selecting a grading platform, the designer should first consider the following: a. extending the barrier a short distance to a flatter location. b. specifying a non-flared end treatment.

Terminal Installation: Common Issues of Concern and Current Generally Accepted Practice (Continued)

Common Issue of Concern	Current Generally Accepted Practice
Adjacent Area: When the area immediately behind a terminal (i.e., the "adjacent area") is steep or non-traversable, a vehicle can overturn after breaking through the terminal. A minimum traversable area behind the terminal is an essential part of good barrier design. 	A field check should be made to determine if a run-out area exists. A run-out area requires the following: a. Minimum traversable area of 20-feet wide & 75-feet long. This distance is based on the final resting position typically found for a small car during crash testing. b. A heavier vehicle at a higher speed will typically travel a greater distance behind and beyond the terminal.

Common Issue of Concern	Current Generally Accepted Practice
Adjacent Area: Although the terminal shown here is an energy-absorbing design, any impact into the end will most likely end with a vehicle striking the utility pole. 	In many situations, it simply may not be practical to shield every hazard. This barrier was installed primarily to shield the slope along the curve and is effective for that purpose, but it should have been lengthened if practical, to shield the pole also. An energy-absorbing terminal can slow a vehicle in line with the rail and is preferable here rather than a non-energy-absorbing design.

Common Issue of Concern	Current Generally Accepted Practice
Advance & Adjacent Area: The adjacent grading is the area around the 1st post and is critical to help develop the anchor strength and ensure that the post stubs and strut do not stick out more than 4" above the ground. The terminal in the photo is neither crashworthy nor a good anchor. When a ground strut anchor is used, it is normally at 'ground level'. 	To achieve successful terminal performance, the designer should consider including engineered earthwork as a key component on the final construction plan for the terminal installation.

Common Issue of Concern	Current Generally Accepted Practice
The installation shown here is an energy-absorbing design, so a vehicle impacting head-on would likely be stopped safely before reaching the concrete barrier. However, any angled hits at the end would result in significant intrusion behind the rail and into the rock outcropping. 	The guardrail should have been extended to shield the secondary hazard (i.e., the rock wall). A good field check to determine if shielding secondary hazards may be worthwhile is to note whether or not the area immediately upstream from the terminal would warrant shielding in the absence of a primary hazard (i.e., end of the bridge barrier).

Terminal Maintenance:

The Roadside Design Guide identifies maintenance factors grouped into three categories: (1) routine maintenance, (2) Crash Maintenance, and (3) material and storage requirements. Common examples of routine maintenance and material and storage requirements are listed below. Routine maintenance includes inspecting roadside devices at regular intervals to determine the condition of the device and required repair needed for the device. Proper materials and storage of them ensures routine maintenance is carried out appropriately using proper components when completing repairs.

Extruder Heads

Routine Maintenance: Care is needed when installing and repairing extruder head type terminals to ensure that the head is properly attached to the rail. This photo shows a case where the terminal of the head is not properly attached to the rail and will, therefore, not perform properly, and should be repaired immediately. This situation can also occur if the barrier is impacted upstream with sufficient force and deflection that the rail pulls out of the head.

Cable attachments

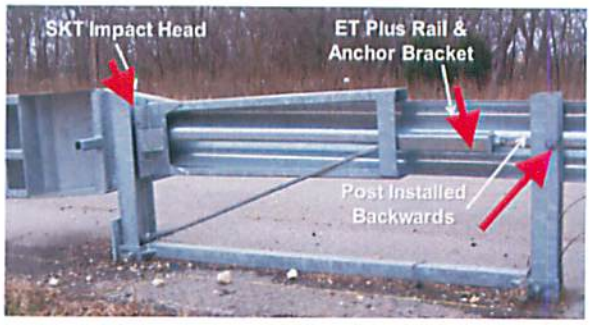
Routine Maintenance: The cable is critical in providing tensile strength in the rail. For some designs, the cable must be able to detach from the rail during an impact. The photo shows a location where the cable is not attached and where the bolts holding the cable were installed backwards.

Cable anchorage

Routine Maintenance: The photo shows a location where the shoulder bolts holding the cable were installed backwards and a metallic butterfly reflector was placed within the end treatment performance area, which may adversely affect the separation of rail from the post. Attachments to the guardrail within this performance area should not be made.

Mismatched Parts

Material and Storage Requirements: The photo shows an in-service installation using components from two different systems. This is likely due to improper maintenance decisions being made after an impact. Parts from one system to another system are not interchangeable unless specified by the manufacturer.



In efforts to effectively address the highlighted concerns, the following existing resources and noteworthy practices are provided for consideration by State Departments of Transportation and other highway agencies.

- **Inspector/Maintenance & Designer Mentoring Training**
  State and local agencies should conduct training at regular intervals for DOT personnel, consultants, and contractors to ensure the optimal barrier design and installation of new roadside safety devices, and the inspection and maintenance of existing devices. This noteworthy practice would serve to eliminate common installation and maintenance errors that adversely affect the intended performance of the roadside safety device.

- **Installer Certification**
  Installer Certification is training for the roadside safety system installers that may be offered at regular intervals to maintain a specific knowledge base of both existing and new systems. Agencies that offer this training may also make this a requirement for installation of roadside safety systems in their jurisdiction. This noteworthy practice also may serve to eliminate common installation errors that may adversely affect the intended performance of the roadside safety device.

- **Engineered earthwork design in construction plans**
  Crash testing for end treatments is performed on flat or near flat terrain. In real world applications, this type of terrain is fairly rare and some grading is likely needed. Therefore, end treatments may require individual construction details and cross sections with regard to earthwork analysis. If this information is not included in the plan, the end treatment may not fit or function as intended when installed in the field. In some cases, improperly installed end treatments can degrade the strength or performance of an entire barrier system.

- **Use of Roadside Safety Systems Pre-Installation Field Review Checklist**
  When roadside safety systems such as traffic barriers and terminals are installed exactly as shown on project plans or replaced in-kind after a crash, the end result can be an installation that may not effectively shield the primary hazard, may be too short or too long, may not shield obvious "secondary" hazards in its immediate vicinity, or may not be needed at all. A pre-installation review checklist can be used to recognize field adjustments to a design that are needed to ensure an optimal installation.