

Session 3: Testing Requirements and  
Performance Characteristics of Terminals and  
Crash Cushions



FAST Act Guardrail Training  
Highway Barrier Installer, Inspector and  
Maintenance Training

## Session 3: Testing Requirements and Performance Characteristics of Terminals and Crash Cushions

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## Session 3 Learning Outcomes

At the end of this session, you will be able to:

- Understand how terminals and crash cushion are tested for crashworthiness
- Identify common terminals and crash cushion
- Understand how these systems function
- Use the appropriate system for a specific site

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## Guardrail Terminals

A barrier terminal must serve two functions:

- Provide the necessary TENSION of the guardrail system for downstream impacts
- Be crashworthy when impacted end-on.

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## End Anchor – MASH

- 2 Design Tested
- Both have a strut between last 2 posts





TxDOT Design  
9'- 4 1/2" rail element  
Rail ends at last post



MwRSF Design  
12'- 6" rail  
Rail extends past last post

Eligibility Letter B-256


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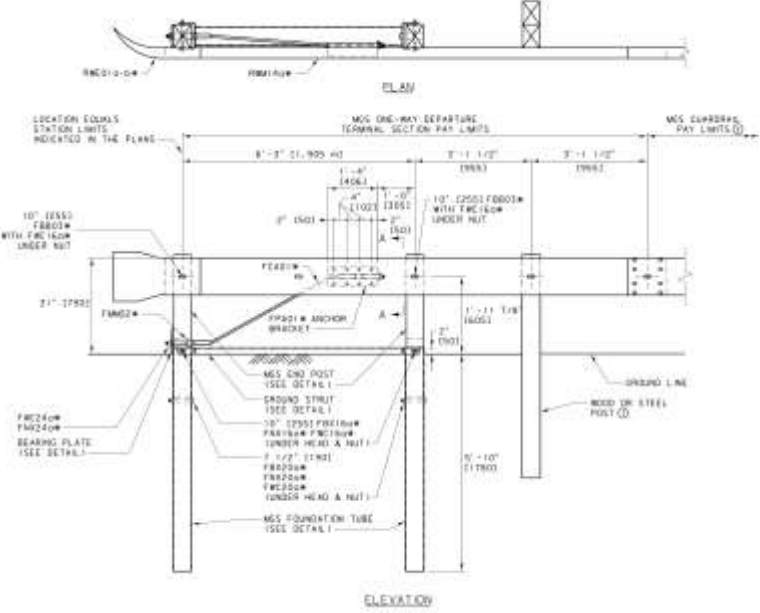
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## End Anchor – Not crashworthy



ELEVATION

DETAILED DRAWING	
REFERENCE STANDARD SPEC. SECTION 606	DWG. NO. 606-1B
ONE-WAY DEPARTURE TERMINAL SECTION (MGS)	
EFFECTIVE 1 SEPTEMBER 2014	
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### Guardrail Terminal MASH Test Matrix

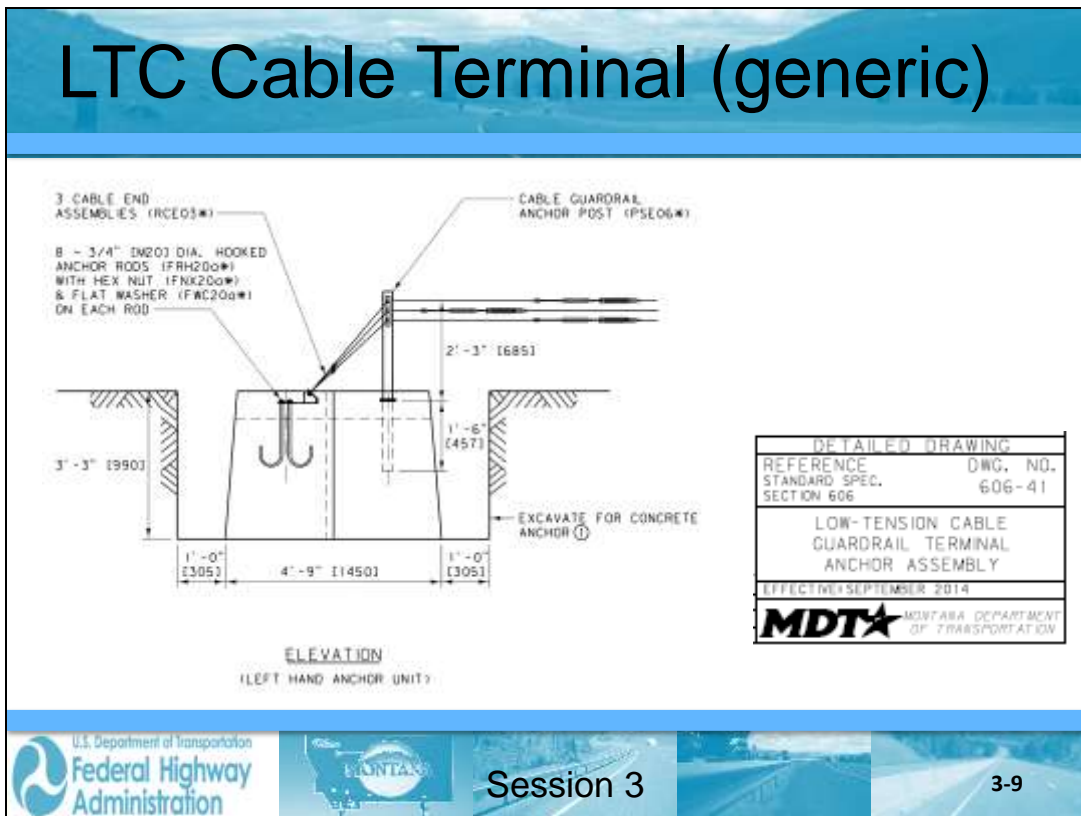
<p>Test 30</p>	<p>Test 34</p>
<p>Test 31</p>	<p>Test 35</p>
<p>Test 32</p>	<p>Test 37b</p>
<p>Test 33</p>	<p>Test 37a</p>

\* Significant Change     
 \* Small Car 1100C (2420 #)  
\* Pickup Truck 2270P (5000 #)

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## Guardrail Terminals

Types of Approved Terminals available in MDT

- W-beam *energy absorbing* terminals – terminal is parallel to the roadway or has a straight flare with a “slight” offset
- Box beam *energy absorbing* terminals – terminal is parallel to the roadway or has a straight flare with a “slight” offset

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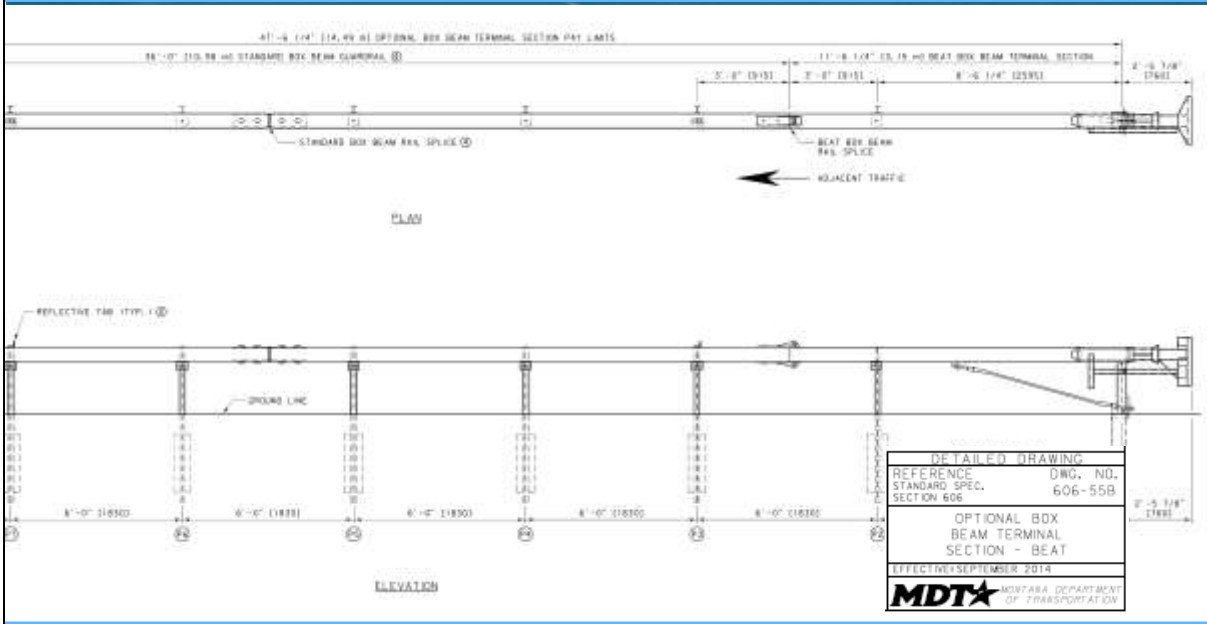
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## Box Beam Terminal – Options WYBET and BEAT



DETAILED DRAWING	
REFERENCE	DWG. NO.
STANDARD SPEC. SECTION 606	606-55B
OPTIONAL BOX BEAM TERMINAL SECTION - BEAT	
EFFECTIVE SEPTEMBER 2014	
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## Buried in Backslope

- Key design considerations:
  - For slopes steeper than 10:1, keep the height of the w-beam rail constant relative to the roadway grade until the barrier crosses the ditch flow line,
  - Use a flare rate appropriate for the design speed,
  - Add a w-beam rubrail when the distance between the bottom of the w-beam rail and the ground exceeds ~19",
  - Use an anchor (concrete block or steel posts) capable of developing the full tensile strength of the w-beam rail buried 1' below ground



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**MASH**  
**Buried in Backslope End Terminal**



Video Clip

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**Buried Post End Anchor Considerations**



Video Clip

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# BIB Considerations



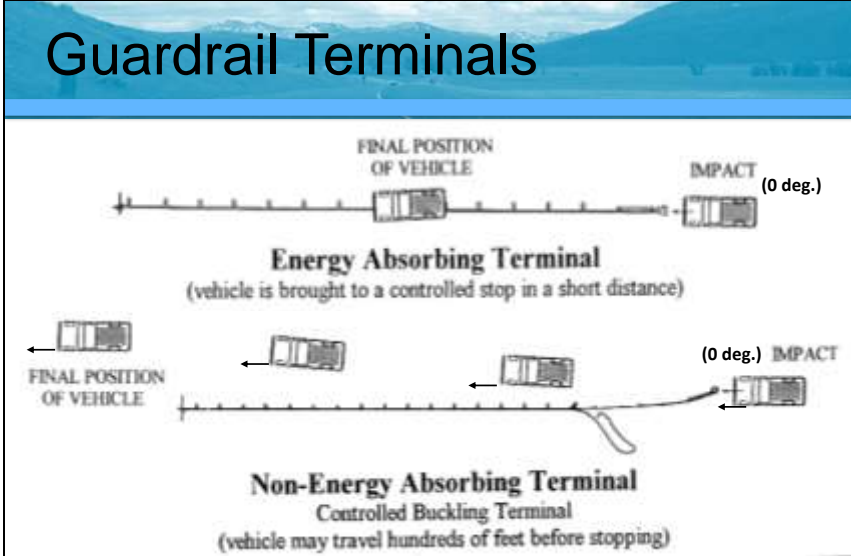
Any concerns with this installation?

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# Guardrail Terminals



**Energy Absorbing Terminal**  
(vehicle is brought to a controlled stop in a short distance)

**Non-Energy Absorbing Terminal**  
Controlled Buckling Terminal  
(vehicle may travel hundreds of feet before stopping)

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### MDT Qualified Product List – MASH Optional Terminal Sections

QPL ID #	Product/Supplier	Qualified Product Name	EF 01	Expiration	Category	Mkt #	Material No.
SS-ROADSYS-SUMP	ROAD SYSTEMS INC	MSKT	20170308	20200308	GRD	606.02.00.01	MASH W-b...
SS-TRINHWFR-PAB	TRINITY HIGHWAY PRODU...	SoftStop End Terminal	20161019	20201019	GRD	606.02.00.01	MASH W-b...



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## Guardrail Terminals: Energy Absorbing

- Depending on Approved Product List, it is the contractor's option as to which manufacturer's system they wish to provide.
  - All are energy-absorbing.
  - Some systems may have different configurations, such as post type.
- What is **important** is to understand how the system works

# Guardrail Terminals: Energy Absorbing

- **MSKT** *MASH Version of SKT (MASH 16)*
  - Kinks Guardrail when hit head-on or at a shallow angle
  - Steel post system; BLON at 3<sup>rd</sup> Post
  - TL-3 at 47' long; attachment to 31" MGS Barrier
  - Cable-anchored system, Compression system



Needs a full panel of MGS beyond end of Terminal



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MASH  
MSKT



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## Guardrail Terminals: Energy Absorbing

- Soft Stop (MASH 16)
  - Impact head slides along panels, crushing them vertically, absorbing the energy of the vehicle in shallow angle impacts – **works in tension**
  - TL-3 at 51' long; BLON at 16'-6"; 31" only





MASH  
Soft Stop



Video Clip

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**MUST HAVE  
MANUFACTURER'S SHOP  
DRAWINGS AND  
INSTALLATION MANUAL TO  
INSTALL / INSPECT ANY OF  
THE PROPRIETARY END  
TREATMENTS**

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**Example Checklist: Installation/Inspection - SOFTSTOP**

**Assembly Checklist (Complete & File With Project Folder)**

Performed by: \_\_\_\_\_  
Date: \_\_\_\_\_  
Location: \_\_\_\_\_

- 1) Ensure required traffic control is in place to conduct SoftStop® system assembly.
- 2) Ensure only Trinity Highway SoftStop® system parts are used for the assembly of the SoftStop® system and that all parts are free of damage.
- 3) Ensure proper site grading complies with state/specifying agency guidelines and AASHTO Roadside Design Guide.
- 4) Ensure that soil around all posts is properly compacted and posts are free to rotate and only state/specifying agency approved backfill material is within the leave-out area.
- 5) Ensure SoftStop® System offset does not exceed max allowed by test west and east.
- 6) Ensure that no rail pieces within the SoftStop® System are convex.
- 7) Ensure the center of the SVP® yielding holes are approximately centered at finished grade line for Post 1 & 2.
- 8) Ensure the fully assembled SoftStop® Anchor Post (Post 0) has a maximum height of 4" (102 mm) and a minimum height of 3 3/4" (96 mm) above finished grade line.
- 9) Ensure that the SoftStop® Anchor Post is ggg bolted to Post 2 (SVP®).
- 10) Ensure offset blocks are properly in place and not rotated.
- 11) Ensure that the SoftStop® System Rail height is approximately 31" (787 mm) above the finished grade.
- 12) Verify that rails are properly lapped in the direction of traffic.
- 13) Ensure the SoftStop® Impact Head Connection Bracket is attached to the front side of SoftStop® Post 1 (SVP®) with required 5/16" hardware.
- 14) Ensure SoftStop® Impact Head has no more than 2 1/2" (64 mm) of upward lift.
- 15) Ensure that the SoftStop® Keeper Plate and Plate Washer are properly positioned with required hardware.
- 16) Ensure the 1" Hex Nut has been fully tightened against the SoftStop® Plate Washer.
- 17) Ensure that both SoftStop® Anchor Angles are properly positioned.
- 18) Ensure the SoftStop® Angle Strut is properly attached on the non-traffic side with the short leg down.
- 19) Ensure that g hardware of the SoftStop® System are tightened to a snug position.
- 20) Ensure documentation is placed on SoftStop® Impact Head Strip Plate per MUTCD and/or state/specifying agency.

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www.trinityhighway.com

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**TAKE ADVANTAGE OF  
MANUFACTURER  
TRAINING FOR DETAILED  
INSTRUCTION ON  
INSTALLING ANY OF THE  
PROPRIETARY END  
TREATMENTS**

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Guardrail Terminals: Installation

**DO NOT MIX  
DIFFERENT  
SYSTEMS PARTS**

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# Terminal Grading

- Special grading requirements for guardrail terminals:
  - Flat terrain (10:1 or flatter) is required *in ADVANCE of all terminals* so that vehicles are relatively stable on approach
  - Flat grading must extend *behind* post 1 (**ADJACENT**) so vehicle is stable at impact and stub height criteria is satisfied

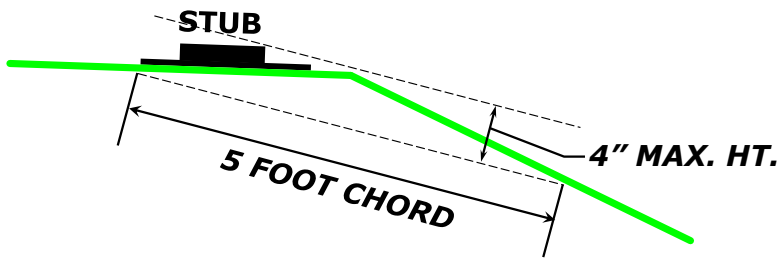
Ref: FHWA Memorandum, Roadside Safety Hardware, May 26, 2015 with attachment and Ref: AASHTO Roadside Design Guide, 4<sup>th</sup> Edition, Section 8.3.3.

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## Stub Height Criteria



The diagram illustrates the stub height criteria. It shows a cross-section of a road surface with a dashed line representing the original grade. A solid line shows the new grade after a stub is installed. The stub is a rectangular block on the road surface. A dimension line indicates a 5-foot chord length for the new grade. Another dimension line indicates a maximum height of 4 inches for the stub.

**RDG Figure 4.1**

Ref: AASHTO Roadside Design Guide, 4<sup>th</sup> Edition – Figure 4.1

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## Terminal Grading Requirements

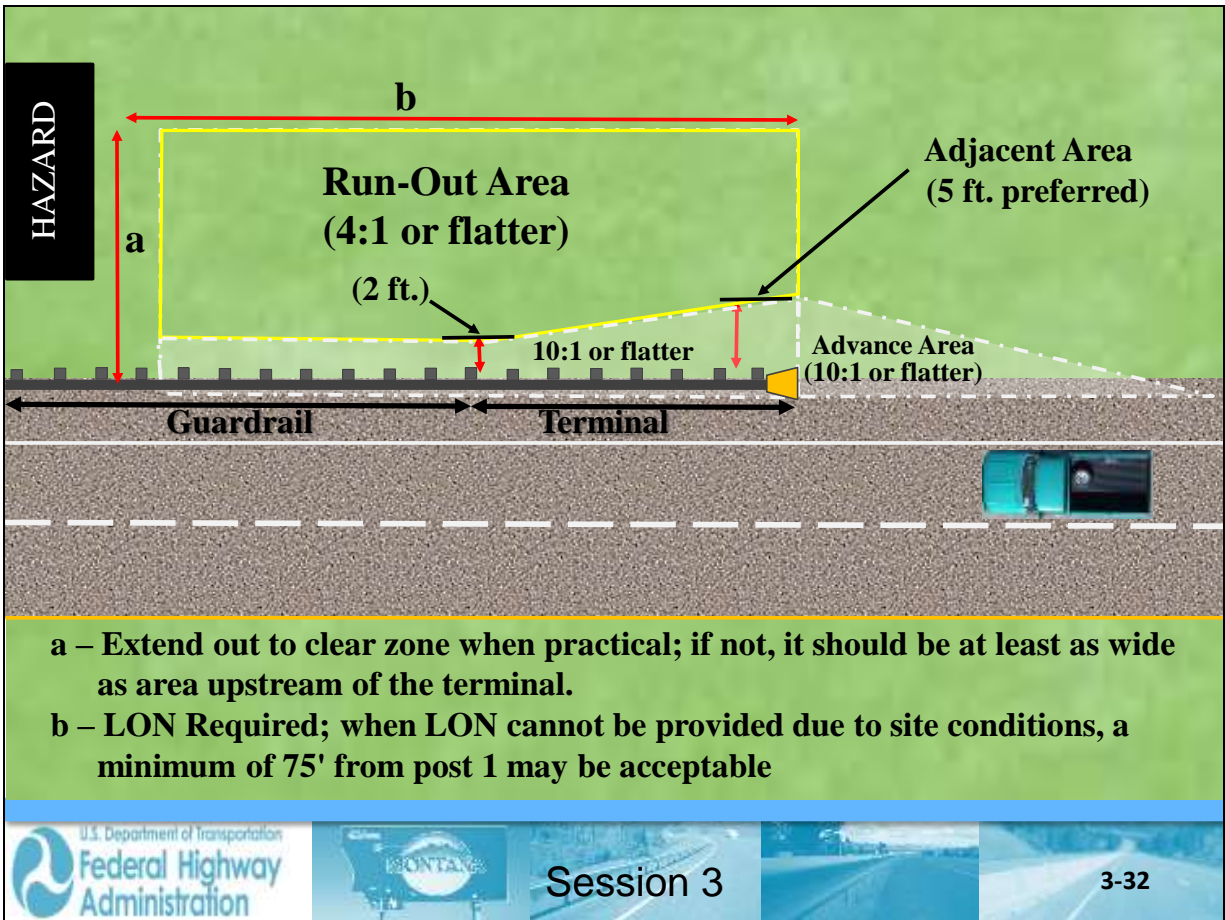
- **Runout Distance** - grading refers to the area into which a vehicle may travel after impacting a terminal ahead of its length-of-need point.
  - The lateral runout distance directly behind a terminal ideally should be at least as wide as the roadside clear distance immediately upstream of terminal.
  - The minimum recovery obstacle-free area behind and beyond a terminal should be approximately 75 ft. long.

Ref: AASHTO Roadside Design Guide, 4<sup>th</sup> Edition, Section 8.3.3.

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# Typical Grading near Post 1

12'-6" (3.81 m)  
OPTIONAL TERMINAL SECTION WIDENING

7'-0" (2.134)  
APPROX. (3)

10:1 OR FLATTER

15" MAX.

3:1 OR FLATTER

EDGE OF SHOULDER OR FACE OF GUARDRAIL

12'-6" (3.81 m)  
POST #1 LOCATION

ENGT POST

COMPACT SLOPES PER SECTION 203.

DETAILED DRAWING	
REFERENCE STANDARD SPEC. SECTION 606. 203	DWG. NO. 606-13
MASH OPTIONAL TERMINAL SECTIONS	
EFFECTIVE JANUARY 2018	
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**Need special bid item for 3R projects**

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## Good thought, but not adequate

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# Tangent Terminal – Special consideration

The diagram illustrates a tangent terminal design with the following specifications:


- Overall length: 34'-4 1/2" (10.48 m)
- Optional terminal section widening transition: 34'-4 1/2" (10.48 m)
- Optional terminal section widening: 12'-6" (3.81 m)
- Optional terminal section flare rate: 50:1 (circled in red)
- Optional terminal section pay limits: 12'-6" (3.81 m)
- Length of need post location: 12'-6" (3.81 m)
- 10:1 OR FLATTER
- 3'-0" (APPROX.)
- 3'-1" (3.03 m) widening
- 10:1 OR FLATTER
- 3'-4 1/2" (2.86 m)
- 12'-6" (3.81 m)
- 34'-4 1/2" (10.48 m)
- LENGTH OF NEED POST LOCATION

DETAILED DRAWING	
REFERENCE STANDARD SPEC. SECTION 606, 203	DWG. NO. 606-13
MASH OPTIONAL TERMINAL SECTIONS	
EFFECTIVE JANUARY 2018	
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**Terminal to be offset at a 50:1 flare from normal line of rail; terminal proper must be on a straight line**




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## EXISTING TERMINALS



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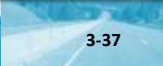


## Guardrail Terminals Tangent, Energy-Absorbing

- SKT 350 (Sequential Kinking Terminal)(NCHRP 350)
  - Kinks panels when hit head-on or at a shallow angle
  - Wood or Steel post system (many options)
  - TL-3 at 50' long; BLON at 3<sup>rd</sup> Post
  - Cable-anchored, Compression system





Ref: FHWA Eligibility Letter CC-88 dated 3/8/05




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## Guardrail Terminals Tangent, Energy-Absorbing

- ET Plus (Guardrail Extruder Terminal)(NCHRP 350)
  - Flattens the rail element when hit head-on
  - Weakened wood or steel posts (several options available)
  - 50' long; attaches to either height w-beam system
  - BLON at 3<sup>rd</sup> Post
  - Cable-anchored, compression system




Ref: FHWA Eligibility Letter CC-12Q dated 3/15/10

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### Non-crashworthy Terminal BCT Terminal

- Breakaway Cable Terminal (BCT) NCHRP 230
  - W-Beam rail with a parabolic curve and 4-ft offset.
  - No impact head or ground strut between the two end posts.
  - Only two breakaway posts.
  - Rail bolted to all posts.



For Identification Only

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### Guardrail Terminals: Non-energy Absorbing – For Identification Only

- MELT – Modified Eccentric Loader Terminal
  - W-Beam rail with an accentuated parabolic curve and 4-ft offset.
  - Strut between the steel tubes foundation of the two end posts
  - 37'-6" long with 8 breakaway posts; BLON at Post #3.
  - No rail-to-post bolts except at posts 1 and 8 and beyond.



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# Guardrail Terminals: W-Beam Median

- CAT (Crash Cushion Attenuating Terminal) (NCHRP 350)
  - Special HS bolts tear tabs between multiple slots in rail upon head-on impact.
  - Typically used to terminate a double-faced strong-post median W-Beam barrier
  - Can be attached directly to a double-sided concrete median barrier with appropriate transition section.
  - Cable-anchored, compression system
  - Length of needs begins at post 4.






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## Crash Cushion

Crash test with blunt end:



Video Clip



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### Crash Cushion

Crash test with ramped end:



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## Crash Cushion: Redirective and Non-Gating - MDT

IMPACT ATTENUATOR - QUADGUARD .....	606-30A
IMPACT ATTENUATOR - TRACC .....	606-30B
IMPACT ATTENUATOR - TRACC (METRIC) .....	606-30B
IMPACT ATTENUATOR - QUEST .....	606-30C
IMPACT ATTENUATOR - QUEST (METRIC) .....	606-30C
IMPACT ATTENUATOR - QUADGUARD II .....	606-30D

**These Detailed Drawings will soon be replaced with a QPL, and refer to manufacturers material**


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## Crash Cushion – QuadGuard's

- QuadGuard & QuadGuard II (350)
- QuadGuard M10 (MASH)
- QuadGuard Elite(350)
  - Slides back on a single track when struck head-on and uses specially fabricated side panels having four corrugations.
  - Energy-absorbing cartridges in each bay; damaged cartridges need to be replaced after a crash.
  - Available in widths from 24 to 36 inches with parallel sides and 69 to 90 inches with flared sides. (M10 only available at 24")




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## Crash Cushion – TRACC

- TRACC (TRinity Attenuating Crash Cushion) (NCHRP 350)
  - TL-3 TRACC / TL-2 Short TRACC / FASTRACC / WIDETRACC
  - Has double tiered 10 gauge W-Beam side panels; shipped to the field assembled.
  - Absorbs energy by cutting internal metal plates.



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## Crash Cushion – QUEST

- Quest (NCHRP 350)
  - Approved for TL-2 & TL-3 systems.
  - Designed to attach to a concrete or metal beam barrier.
  - Consists of a series of W-beam fender panels supported by diaphragms.
  - Absorbs energy by crushing pipes when struck end on.



REF: FHWA Eligibility Letter CC-87D dated 12/18/15

## Crash Cushion – SCI (SMART)

- SCI Smart Cushion (NCHRP 350/MASH)
  - Variable Reaction Force
  - Re-usable with minimal component replacement
  - Needs repair before next hit





Example Non-gating Crash Cushion



Video Clip

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Very Appropriate Use



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# Crash Cushions – Self-Restoring (one of several)

- QuadGuard Elite (NCHRP 350/MASH)
  - Uses High Density Polyethylene cylinders to absorb energy
  - Essentially for use in locations where a high number of hits is anticipated.



REF: FHWA Eligibility Letter CC-57E dated 12/18/15

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### Example Self Restoring Crash Cushion

Video Clip

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## Review Learning Outcomes

- Understand how terminals and crash cushion are tested for crashworthiness
- Identify common terminals and crash cushion
- Explain how these systems function
- Use the best system for a specific site

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