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

Federal Highway Administration
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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

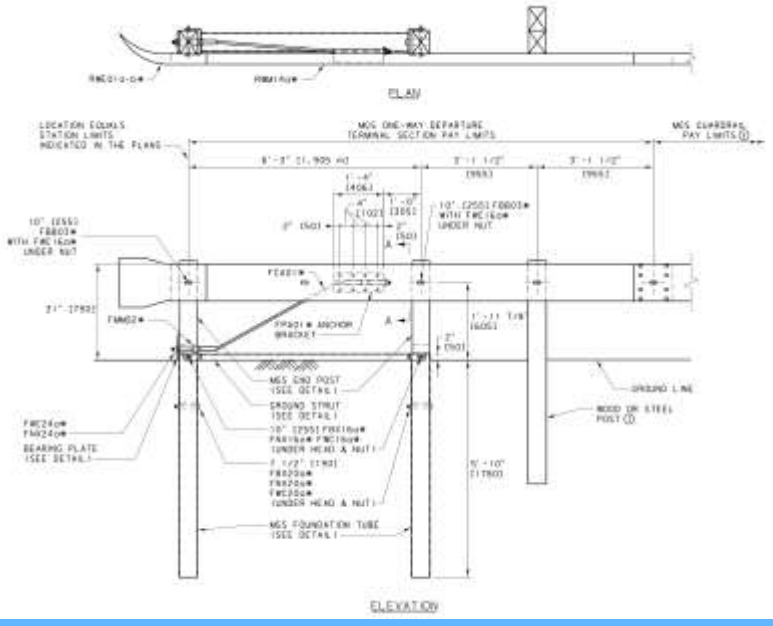
- 2 Design Tested
- Both have a strut between last 2 posts

TxDOT Design
9'- 4 ½ " rail element
Rail ends at last post

Eligibility Letter B-256

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

End Anchor – Not crashworthy

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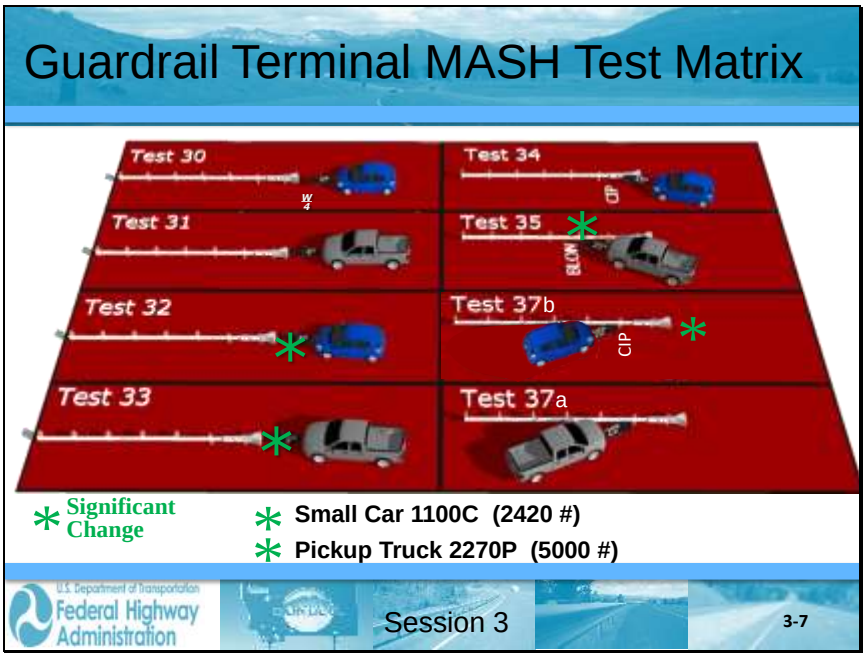
Guardrail Terminal MASH Test Matrix
Test 30
Test 31
Test 32
Test 33
Test 34
Test 35
Test 37b
Test 37a
Significant Change
Small Car 1100C (2420 #)
Pickup Truck 2270P (5000 #)
U.S. Department of Transportation
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Historic Cable Terminal
NOT Crashworthy
Federal Highway Administration
Session 3
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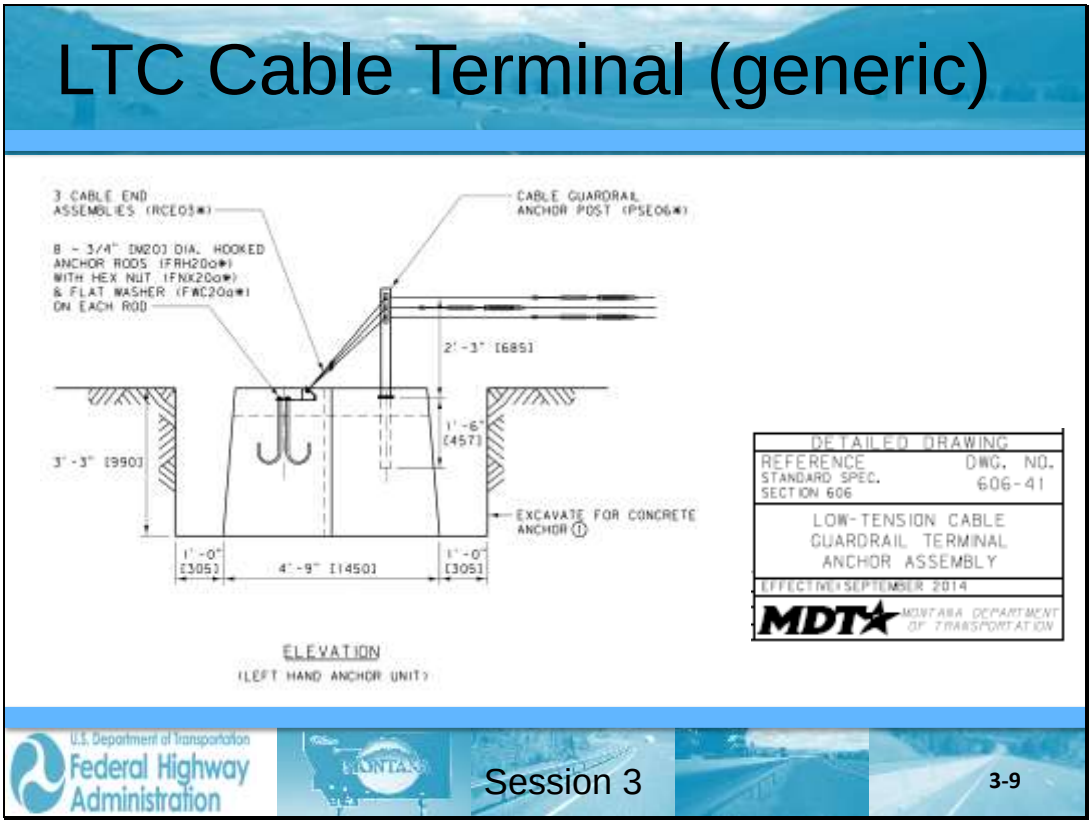
LTC Cable Terminal (generic)
3 CABLE END ASSEMBLIES (RCE03✱)
8 - 3/4" [M20] DIA. HOOKED ANCHOR RODS (FRH20a✱) WITH HEX NUT (FNX20a✱) & FLAT WASHER (FWC20a✱) ON EACH ROD
CABLE GUARDRAIL ANCHOR POST (PSE06✱)
2'-3" [685]
1'-6" [457]
3'-3" [990]
EXCAVATE FOR CONCRETE ANCHOR ①
1'-0" [305]
4'-9" [1450]
1'-0" [305]
ELEVATION
(LEFT HAND ANCHOR UNIT)
DETAILED DRAWING
REFERENCE STANDARD SPEC. SECTION 606
DWG. NO. 606-41
LOW-TENSION CABLE GUARDRAIL TERMINAL ANCHOR ASSEMBLY
EFFECTIVE: SEPTEMBER 2014
MDT
MONTANA DEPARTMENT OF TRANSPORTATION
U.S. Department of Transportation Federal Highway Administration
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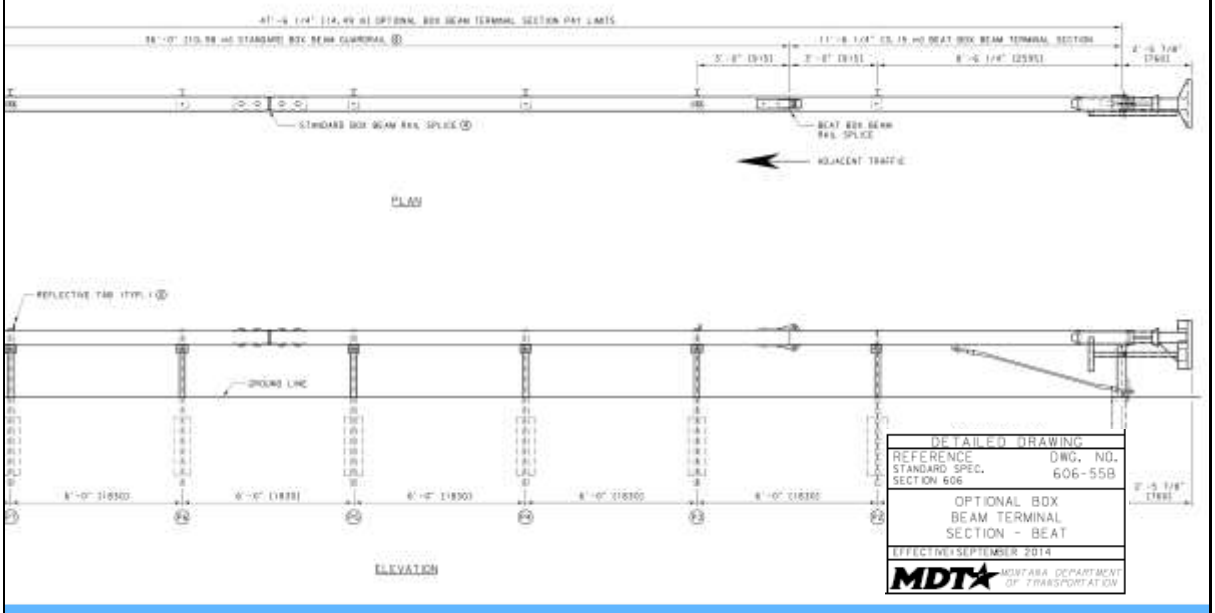
Guardrail Terminals

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

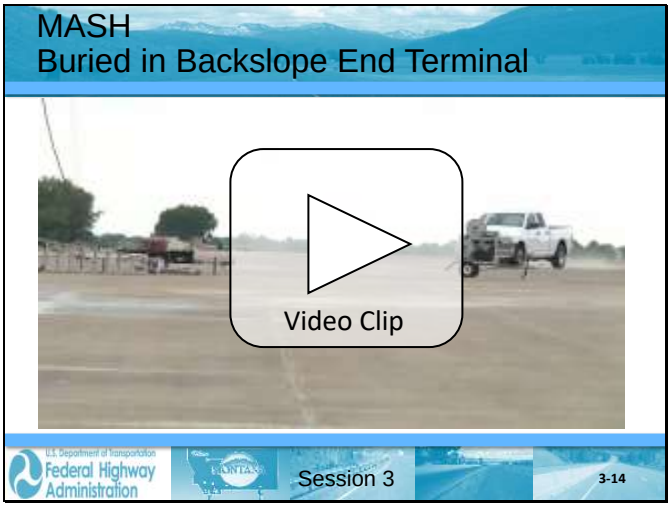
Box Beam Terminal – Options
WYBET and BEAT



Box Beam – BEAT

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


MASH
Buried in Backslope End Terminal
Video Clip
U.S. Department of Transportation
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Buried Post End Anchor Considerations
Video Clip
U.S. Department of Transportation
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BIB Considerations
Any concerns with this installation?
U.S. Department of Transportation
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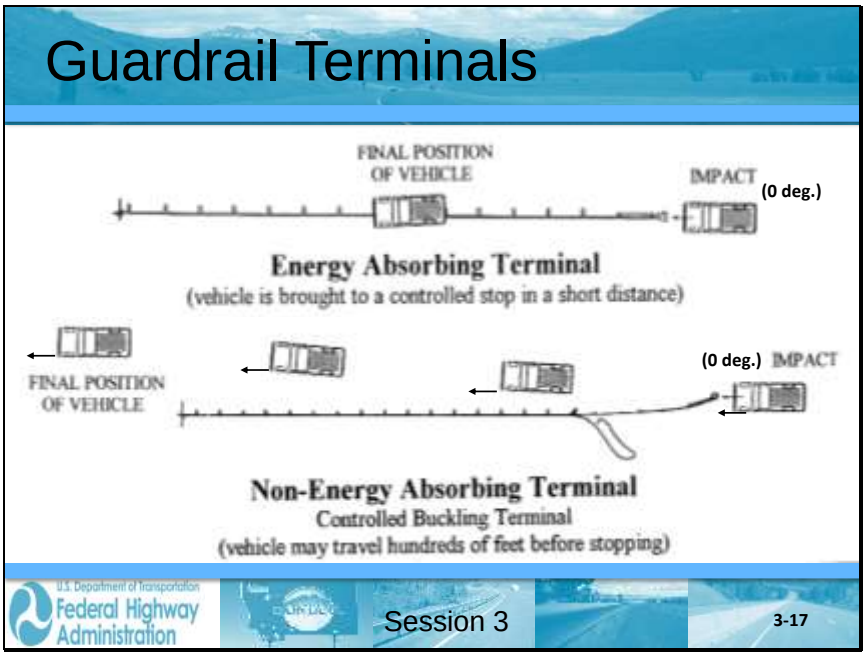
Guardrail Terminals
FINAL POSITION OF VEHICLE
IMPACT
(0 deg.)
Energy Absorbing Terminal
(vehicle is brought to a controlled stop in a short distance)
FINAL POSITION OF VEHICLE
(0 deg.)
IMPACT
Non-Energy Absorbing Terminal
Controlled Buckling Terminal
(vehicle may travel hundreds of feet before stopping)
U.S. Department of Transportation
Federal Highway Administration
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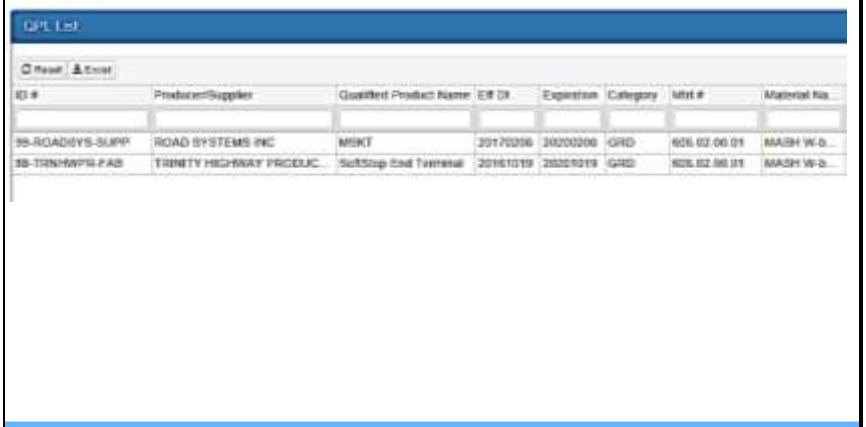
MDT Qualified Product List – MASH Optional Terminal Sections



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 3rd 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

U.S. Department of Transportation Federal Highway Administration | Session 3 | 3-21

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MSKT

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
U.S. Department of Transportation
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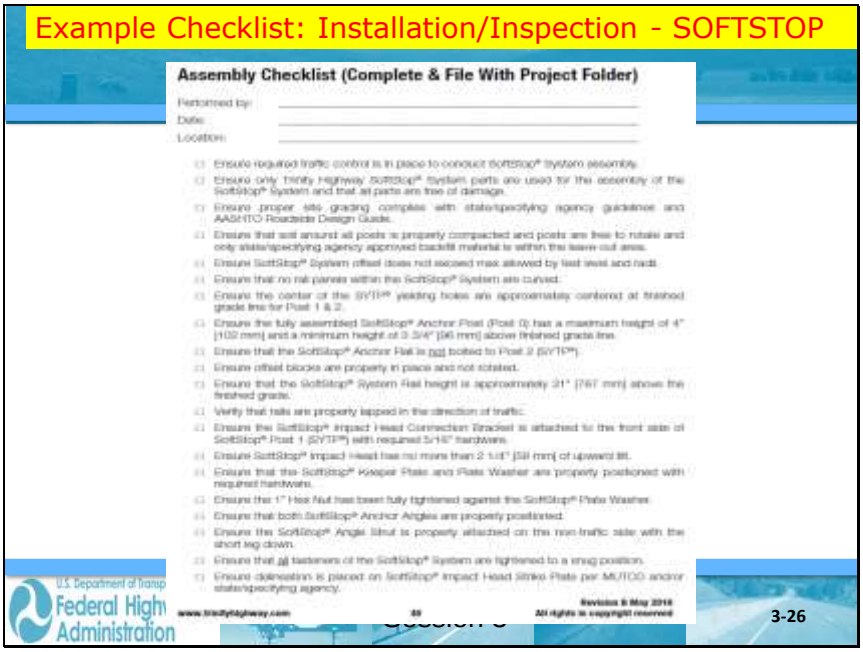
Example Checklist: Installation/Inspection - SOFTSTOP
Assembly Checklist (Complete & File With Project Folder)
Performed by:
Date:
Location:
Federal Highway Administration
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TAKE ADVANTAGE OF MANUFACTURER TRAINING FOR DETAILED INSTRUCTION ON INSTALLING ANY OF THE PROPRIETARY END TREATMENTS
Federal Highway Administration
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Guardrail Terminals: Installation

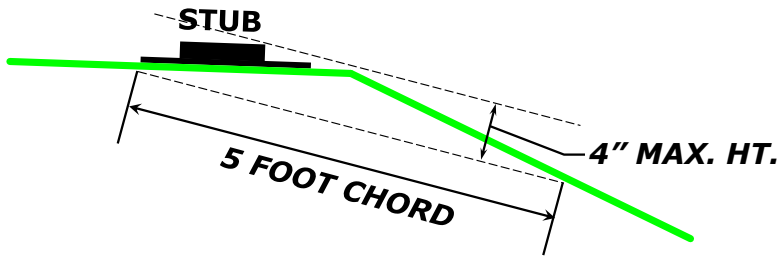
DO NOT MIX DIFFERENT SYSTEMS PARTS

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, 4th Edition, Section 8.3.3.

Stub Height Criteria



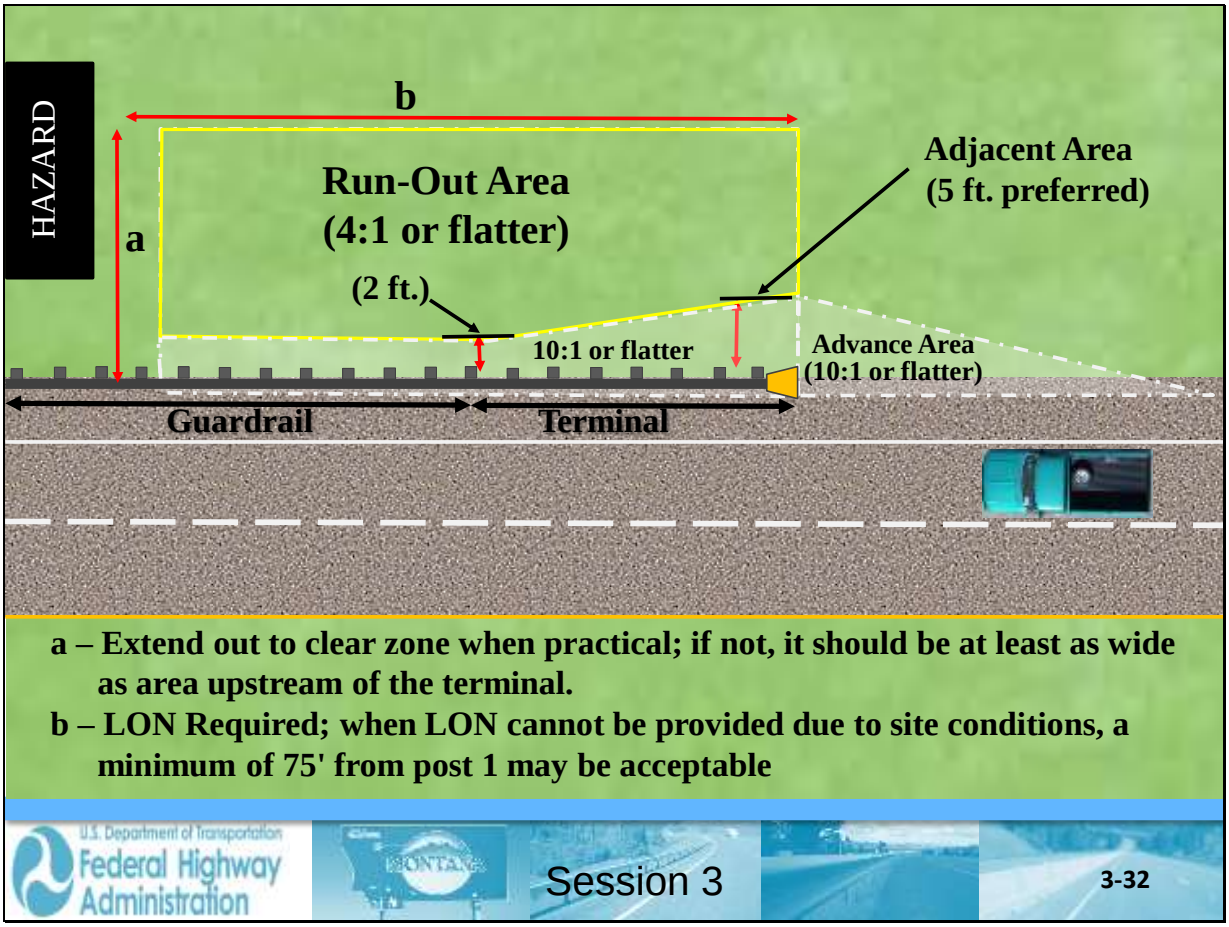
RDG Figure 4.1

Ref: AASHTO Roadside Design Guide, 4th Edition – Figure 4.1

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, 4th Edition, Section 8.3.3.


HAZARD
b
a
Run-Out Area
(4:1 or flatter)
(2 ft.)
Adjacent Area
(5 ft. preferred)
10:1 or flatter
Advance Area
(10:1 or flatter)
Guardrail
Terminal
a – Extend out to clear zone when practical; if not, it should be at least as wide as area upstream of the terminal.
b – LON Required; when LON cannot be provided due to site conditions, a minimum of 75' from post 1 may be acceptable
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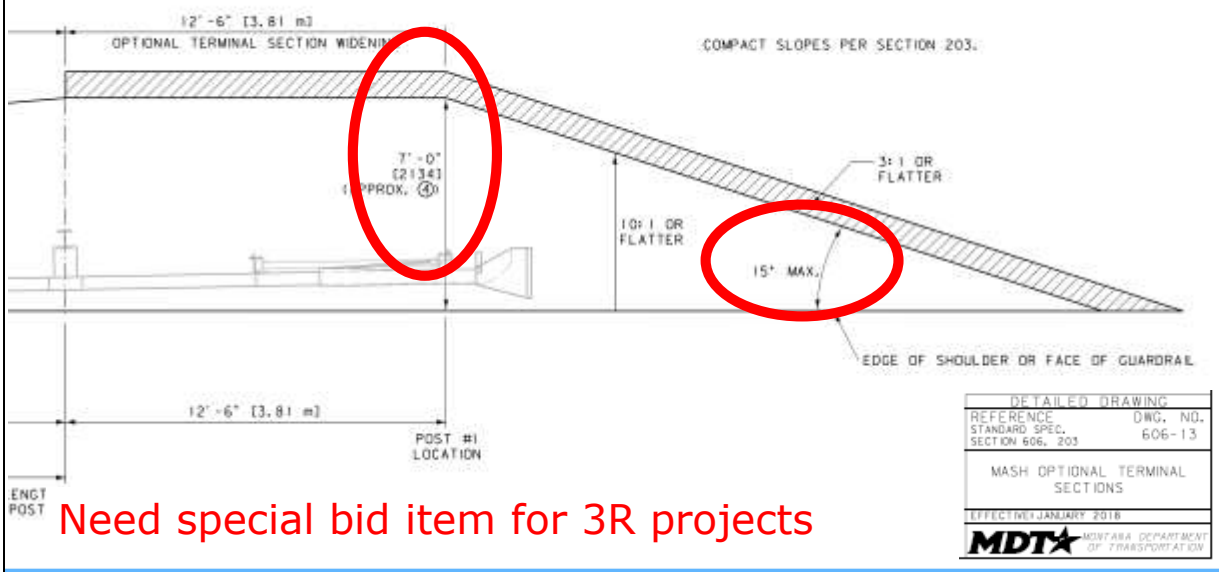
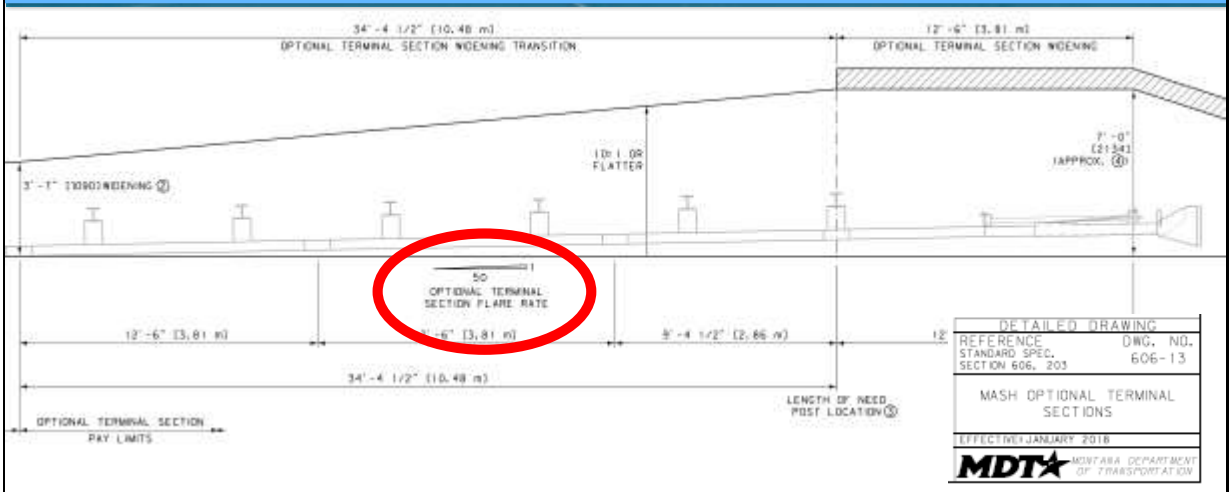
Typical Grading near Post 1



Need special bid item for 3R projects

Good thought, but not adequate

Tangent Terminal – Special consideration



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 3rd Post
  - Cable-anchored, Compression system

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

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 3rd Post
  - Cable-anchored, compression system

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

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.

For Identification Only

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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:

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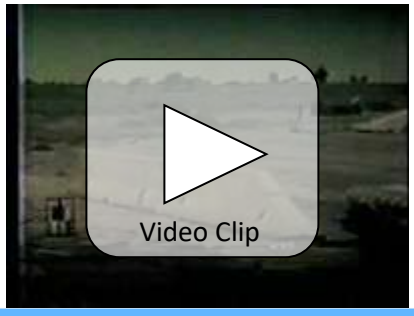
Crash Cushion

Crash test with ramped end:



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

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")

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.

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

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Crash Cushion – SCI (SMART)

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

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Example Non-gating Crash Cushion
Video Clip
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Very Appropriate Use
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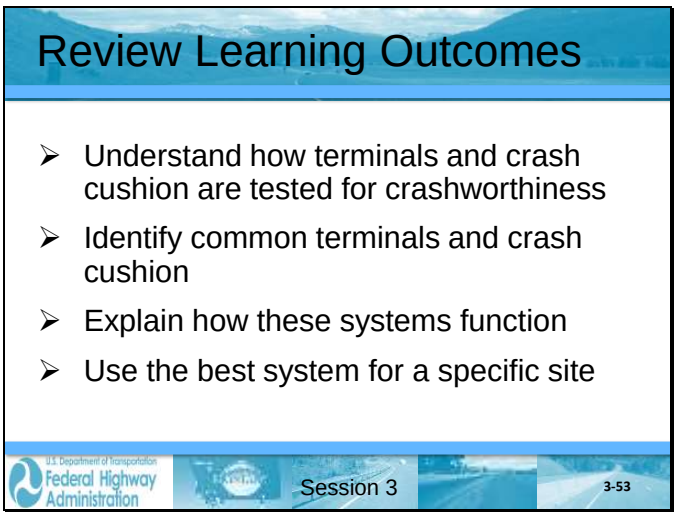
Crash Cushions – Self-Restoring
(one of several)

- 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

Example Self Restoring Crash Cushion


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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