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

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.
End Anchor – MASH

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

<table>
<thead>
<tr>
<th>Design</th>
<th>Rail Element</th>
<th>Post End Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>TxDOT</td>
<td>9’- 4 ½” rail</td>
<td>Ends at last post</td>
</tr>
<tr>
<td>MwRSF</td>
<td>12’- 6” rail</td>
<td>Extends past last post</td>
</tr>
</tbody>
</table>

End Anchor – Not crashworthy

[Diagram of End Anchor – Not crashworthy]
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Guardrail Terminal MASH Test Matrix

* Significant Change  * Small Car 1100C (2420 #)
* Pickup Truck 2270P (5000 #)
Historic Cable Terminal
NOT Crashworthy

LTC Cable Terminal (generic)
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
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Box Beam – BEAT

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

Buried in Backslope

- 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,
BIB Considerations

Any concerns with this installation?

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)
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

Video Clip
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

MUST HAVE MANUFACTURER’S SHOP DRAWINGS AND INSTALLATION MANUAL TO INSTALL / INSPECT ANY OF THE PROPRIETARY END TREATMENTS
Example Checklist: Installation/Inspection - SOFTSTOP

Assembly Checklist (Complete & File With Project Folder)

Performance by: ____________________________
Date: ____________________________
Location: ____________________________

1. Ensure required traffic control is in place to conduct SoftStop® system assembly.
2. Ensure only identified 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/patrol agency guidelines and
   AASHTO Standard/Transport Canada.
4. Ensure that soil around all posts is properly compacted and posts are free to rotate and
   only state/patrol agency approved base/steel material is within the base cut area.
5. Ensure SoftStop® System offset does not exceed max allowable test level and
   weight.
6. Ensure that no dead zones within the SoftStop® system are created.
7. Ensure the center of the STF hole is approximately centered at finished
grade line for Post 3 & 4.
8. Ensure the fully assembled SoftStop® Anchor Post (Post 3) has a maximum height of 4’
   [1200 mm] and a minimum height of 2.5’[760 mm] above finished grade line.
9. Ensure that the SoftStop® Anchor pad is tight to Post 3 (STF™).
10. Ensure offset bases are properly in place and not rotated.
11. Ensure the SoftStop® system that height is approximately 31”[790 mm] above the
    finished grade.
12. Verify that tails are properly tapped in the direction of traffic.
13. Ensure the SoftStop® Impact Head Connection Structure is attached to the front side of
    SoftStop® Post 1 [STF™] with required S/16” hardware.
14. Ensure SoftStop® Impact Head has no more than 0.1-0.2”[5-10 mm] of apparent hit.
15. Ensure that SoftStop® Keeper Plates and Flange Washers are properly positioned
    with required hardware.
16. Ensure the 1”[25 mm] has been fully tightened against the SoftStop® Flange Washer.
17. Ensure that both SoftStop® Anchor Angles are properly positioned.
18. Ensure the SoftStop® Angle Stud is properly attached on the rear traffic side with the
    tensioned side of the SoftStop® Angle Stud.
19. Ensure that all fasteners of the SoftStop® System are tightened to a snug position.
20. Ensure calibration is placed on SoftStop® Impact Head Strike Plate per MUTCD
    and state/patrol agency.

[Diagram of installation requirements]
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

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Stub Height Criteria

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.

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
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.

EXISTING TERMINALS
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.

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.
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.

Crash Cushion

Crash test with blunt end: 

Video Clip
Crash Cushion

Crash test with ramped end:

Video Clip

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 | 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

Crash Cushion – SCI (SMART)

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

Video Clip
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