Session 3: Testing Requirements and Performance Characteristics of Common Barrier Systems

FAST Act Guardrail Training
Highway Barrier Design Training

Session 3:

Testing Requirements and Performance Characteristics of Common Barrier Systems

U.S. Department of Transportation Federal Highway Administration
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Session 3 Learning Outcomes

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

- Understand how barriers are tested for crashworthiness
- Identify common barrier systems
- Explain how these barrier systems function
- Define the key components of a transition design

U.S. Department of Transportation Federal Highway Administration
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Crash Testing Guidelines

- In 1993, crash testing and evaluation criteria were published as NCHRP Report 350
- In 2009, the Manual for Assessing Safety Hardware (MASH) was published by AASHTO. It was used by FHWA as the testing standard for all new products
- In 2016, an update to MASH was adopted and a timetable for implementation of new installations complying with this edition was signed between FHWA and AASHTO

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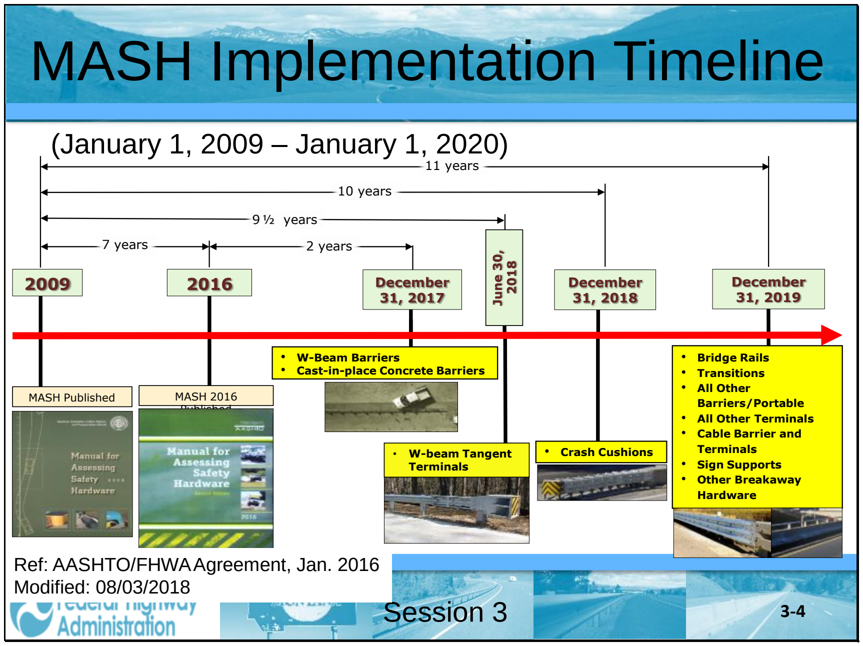
MASH Implementation Timeline
(January 1, 2009 – January 1, 2020)
11 years
10 years
9 ½ years
7 years
2 years
2009
2016
December 31, 2017
June 30, 2018
December 31, 2018
December 31, 2019
MASH Published
MASH 2016
Manual for Assessing Safety Hardware
• W-Beam Barriers
• Cast-in-place Concrete Barriers
• W-beam Tangent Terminals
• Crash Cushions
• Bridge Rails
• Transitions
• All Other Barriers/Portable
• All Other Terminals
• Cable Barrier and Terminals
• Sign Supports
• Other Breakaway Hardware
Ref: AASHTO/FHWA Agreement, Jan. 2016
Modified: 08/03/2018
Federal Highway Administration
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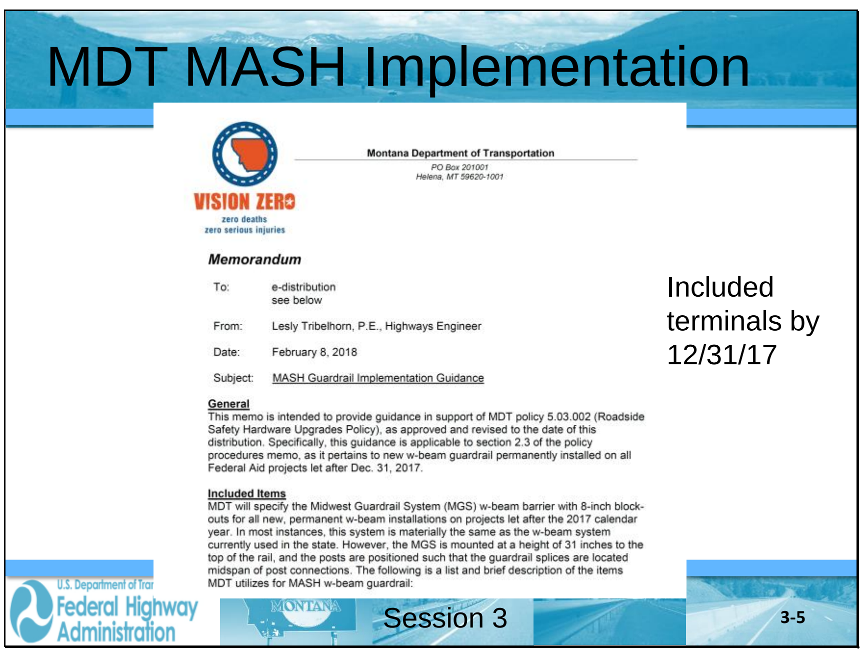
MDT MASH Implementation
Montana Department of Transportation
PO Box 201001
Helena, MT 59620-1001
VISION ZERO
zero deaths
zero serious injuries
Memorandum
To: e-distribution see below
From: Lesly Tribelhorn, P.E., Highways Engineer
Date: February 8, 2018
Subject: MASH Guardrail Implementation Guidance
General
This memo is intended to provide guidance in support of MDT policy 5.03.002 (Roadside Safety Hardware Upgrades Policy), as approved and revised to the date of this distribution. Specifically, this guidance is applicable to section 2.3 of the policy procedures memo, as it pertains to new w-beam guardrail permanently installed on all Federal Aid projects let after Dec. 31, 2017.
Included Items
MDT will specify the Midwest Guardrail System (MGS) w-beam barrier with 8-inch block-outs for all new, permanent w-beam installations on projects let after the 2017 calendar year. In most instances, this system is materially the same as the w-beam system currently used in the state. However, the MGS is mounted at a height of 31 inches to the top of the rail, and the posts are positioned such that the guardrail splices are located midspan of post connections. The following is a list and brief description of the items MDT utilizes for MASH w-beam guardrail:
Included terminals by 12/31/17
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MASH Test Conditions

Selection of a performance level is based on speed and traffic mix.

- **TL-1**, **TL-2**, and **TL-3**: crash tests with small car and pickup truck with a 25˚ impact angle at 31, 44, and 62 mph, respectively.

2,420 lbs.
1100C

5,000 lbs.
2270P

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NCHRP 350 comparison with MASH Crew Cab Truck

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MASH Test Conditions (cont'd)

- **TL- 4**: TL-3 + 15˚ impact angle, 56 mph Single-Unit Truck
- **TL- 5**: TL-3 + 15˚ impact angle, 50 mph Tractor-Van Trailer
- **TL- 6**: TL-3 + 15˚ impact angle, 50 mph Tractor-Tank Trailer

22,000 lbs.

80,000 lbs.

80,000 lbs.

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Functional Requirement of Barrier

1. Contain Vehicle
   - No Penetration
   - No Vaulting/Under-riding
2. Redirect Vehicle Smoothly (low exit angle) with no snagging/overturning, and no excessive rotation (75 degree max)
3. Tolerable Occupant Impact Forces
4. Minimum Occupant Compartment Deformation and no Debris Intrusion

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Standard Barrier Systems

- Rigid Systems
- Semi-Rigid Systems
- Flexible Systems
- Median Barrier Systems

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Barrier Systems: Rigid Barriers

Rigid Barrier Systems have little (between 0 to 1 ft.) deflection under the TL-3 pickup impact. They are generally anchored by some acceptable means.

Examples include:

- New Jersey Safety Shape Concrete Barrier
- F-shape Concrete Barrier
- Single or Slope Concrete Barrier
- Vertical Wall

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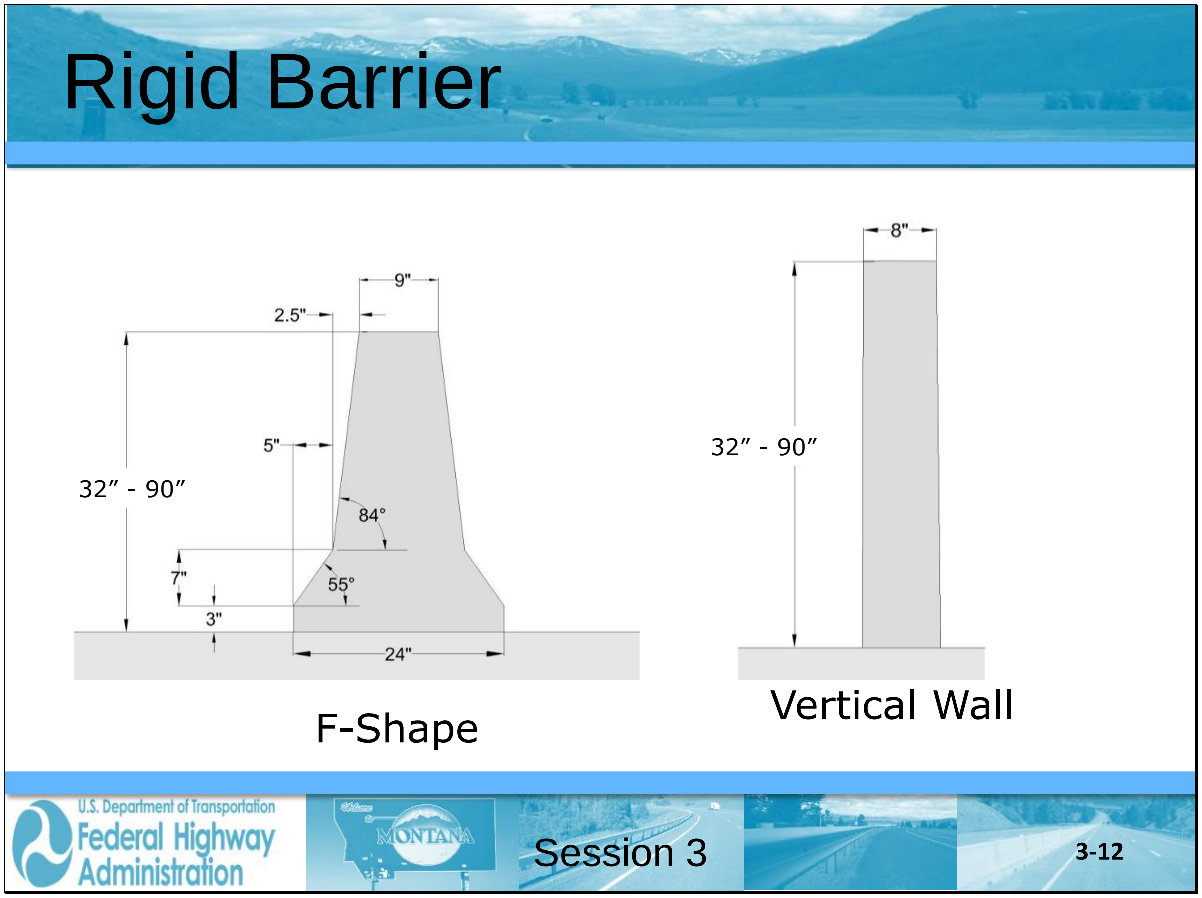
Rigid Barrier
9"
2.5"
5"
32″ - 90″
84°
7"
55°
3"
24"
F-Shape
8"
32″ - 90″
Vertical Wall
U.S. Department of Transportation
Federal Highway Administration
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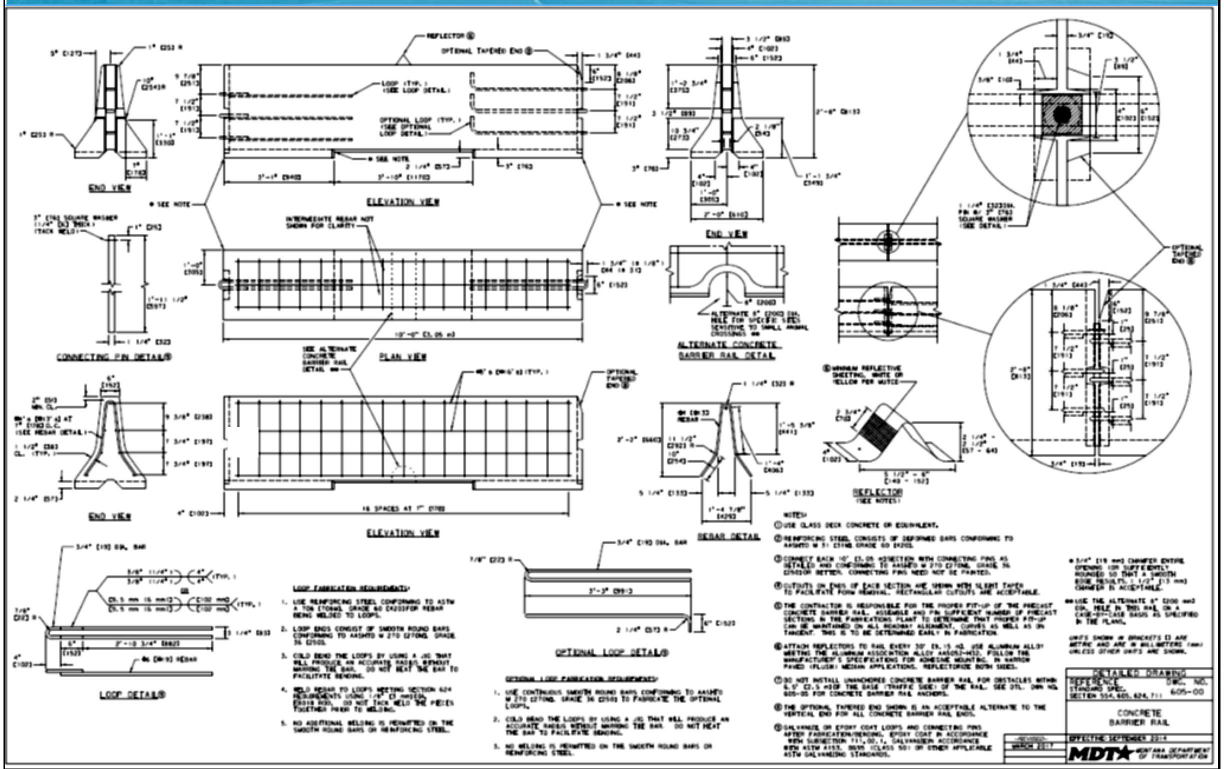
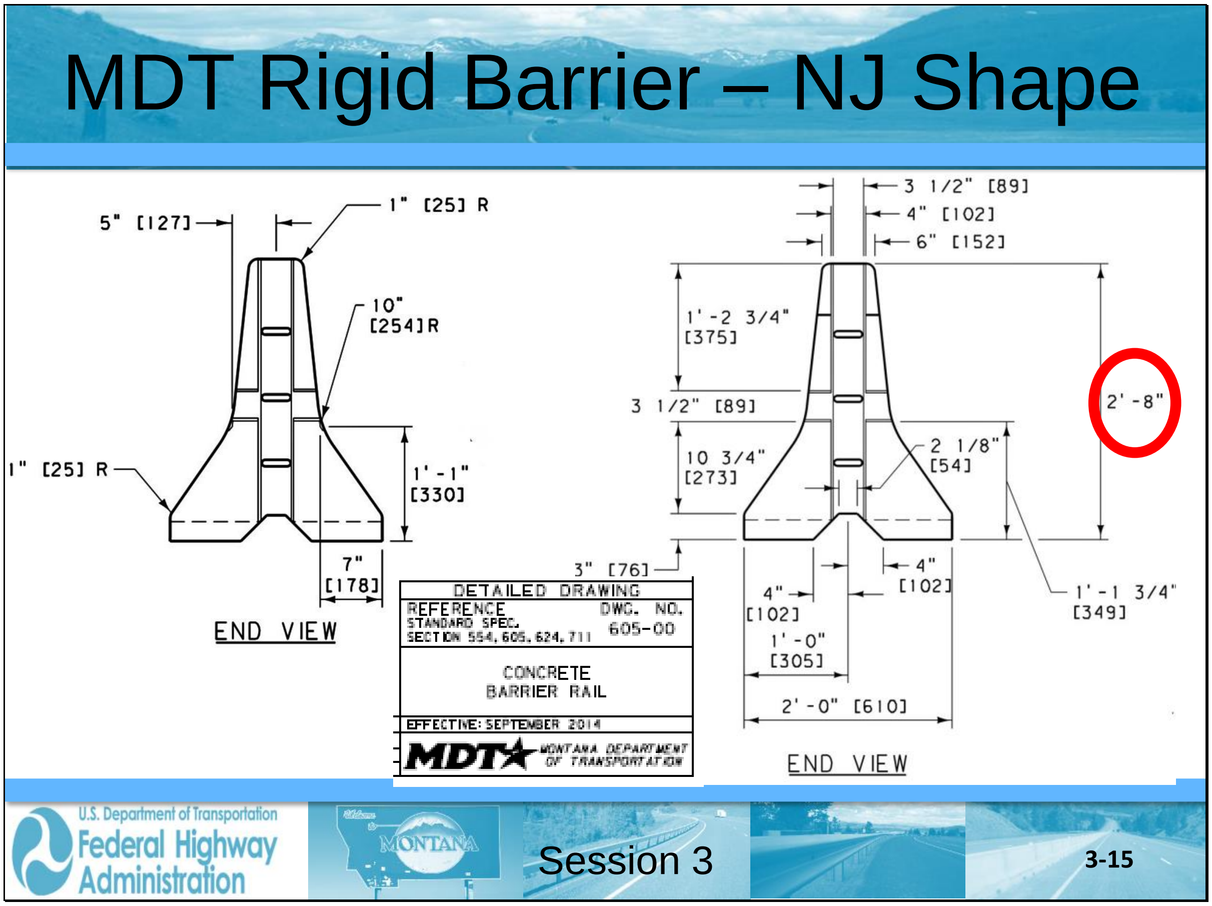
MASH Testing of 32" New Jersey Shaped Concrete Barrier
Video Clip

MDT Rigid Barrier – NJ Shape




MDT Rigid Barrier – NJ Shape
5" [127]
1" [25] R
10"
[254]R
1" [25] R
1'-1"
[330]
7"
[178]
END VIEW
3 1/2" [89]
4" [102]
6" [152]
1'-2 3/4"
[375]
3 1/2" [89]
2'-8"
10 3/4"
[273]
2 1/8"
[54]
3" [76]
4"
[102]
4"
[102]
1'-0"
[305]
2'-0" [610]
1'-1 3/4"
[349]
END VIEW
DETAILED DRAWING
REFERENCE
STANDARD SPEC.
SECTION 554, 605, 624, 711
DWG. NO.
605-00
CONCRETE
BARRIER RAIL
EFFECTIVE: SEPTEMBER 2014
MDT
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U.S. Department of Transportation
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PRE-ASSESSMENT PHOTO
MUST MAINTAIN TENSION IN BARRIER SYSTEM
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Federal Highway Administration
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MUST MAINTAIN TENSION IN BARRIER SYSTEM
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Barrier Systems: Semi-Rigid

Semi-Rigid Barrier Systems have deflections of a few feet (between 2 to 5 ft.) under the TL-3 pickup impact.

Typically consist of beam and post elements.

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Barrier Systems: Semi-Rigid

- W-Beam Steel Guardrail – **“Old”, 350 Guardrail**
  - 12” wide W-beam rail section (12-gauge thickness).
  - Posts are spaced at 6’-3” centers, and the nominal rail height is 27” – 29”
  - Rail splice at the post.
  - Two post options:
    - Steel posts, W6 x 8.5/9.0 x 6’-0” long.
    - Wood posts, 6” x 8” x 6’-0” long.
  - Blocks: 6” x 8” wood or plastic.

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SPWB with Wood Post & Wood Block-Out
27 5/8" Height
Video Clip
Failed Test!!!
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SPWB with Steel Post & Wood Block-Out
27 5/8" Height
Video Clip
U.S. Department of Transportation
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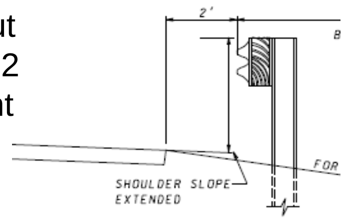
Steel Guardrail - Height Measurement ONLY "Old", 350 Guardrail

For slopes 10:1 or flatter, the height is measured from the ground directly beneath the rail

For slopes steeper than 10:1 but no steeper than 6:1, and within 2 feet of the breakpoint, the height is measured from the shoulder slope extended as shown



PLACEMENT ON SLOPE

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Barrier Systems: Semi-Rigid

- Midwest Guardrail System (MGS)
  - 31" Height – Tolerance ±1"
  - Rail Splice mid-span.
  - Post spacing 6'-3"
  - Two post options:
    - Steel posts, W6 x 8.5/9.0 x 6'
    - Wood posts, 6" x 8" x 6'
    - Block: 8" (or 12") wood or composite

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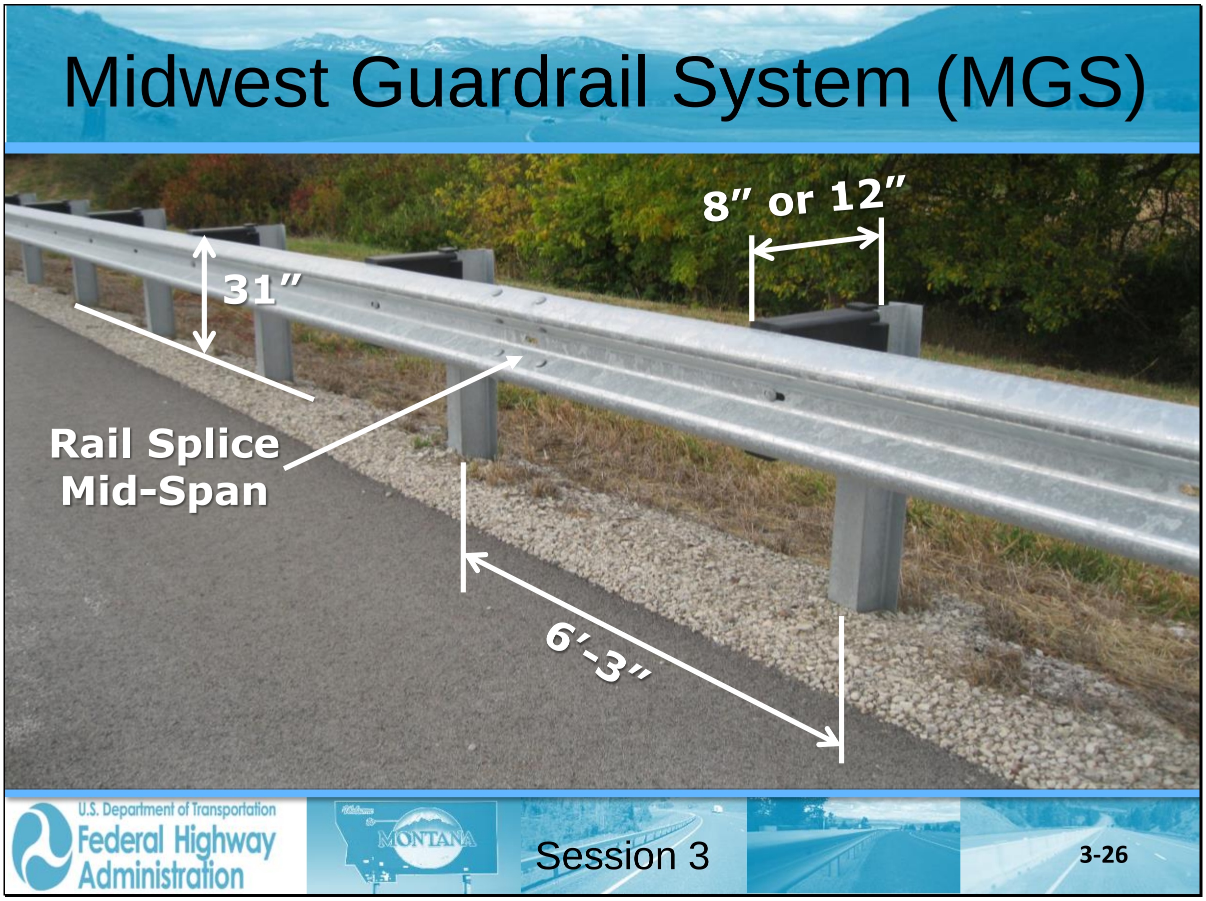
Midwest Guardrail System (MGS)
8″ or 12″
31″
Rail Splice
Mid-Span
6′-3″
U.S. Department of Transportation
Federal Highway Administration
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MGS MASH Test 3-11
Video Clip
U.S. Department of Transportation
Federal Highway Administration
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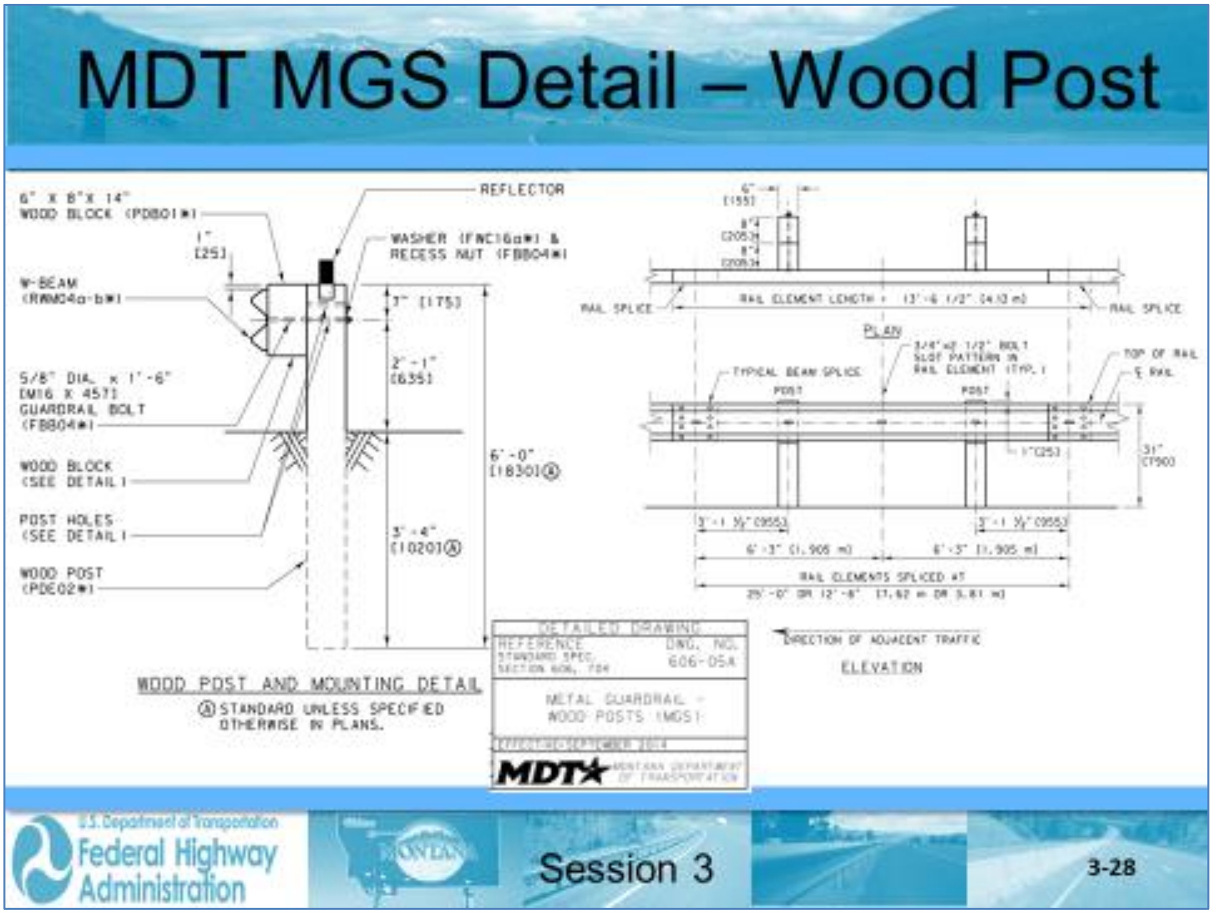
MDT MGS Detail – Wood Post
REFLECTOR
6" X 8" X 14" WOOD BLOCK (PDB01*)
WASHER (FWC16a*) & RECESS NUT (FBB04*)
W-BEAM (RWM04a-b*)
5/8" DIA. x 1'-6" [M16 X 457] GUARDRAIL BOLT (FBB04*)
WOOD BLOCK (SEE DETAIL)
POST HOLES (SEE DETAIL)
WOOD POST (PDE02*)
WOOD POST AND MOUNTING DETAIL
Ⓐ STANDARD UNLESS SPECIFIED OTHERWISE IN PLANS.
RAIL SPLICE
PLAN
TYPICAL BEAM SPLICE
TOP OF RAIL
ELEVATION
DIRECTION OF ADJACENT TRAFFIC
DETAILED DRAWING
METAL GUARDRAIL - WOOD POSTS (MGS)
MDT
U.S. Department of Transportation
Federal Highway Administration
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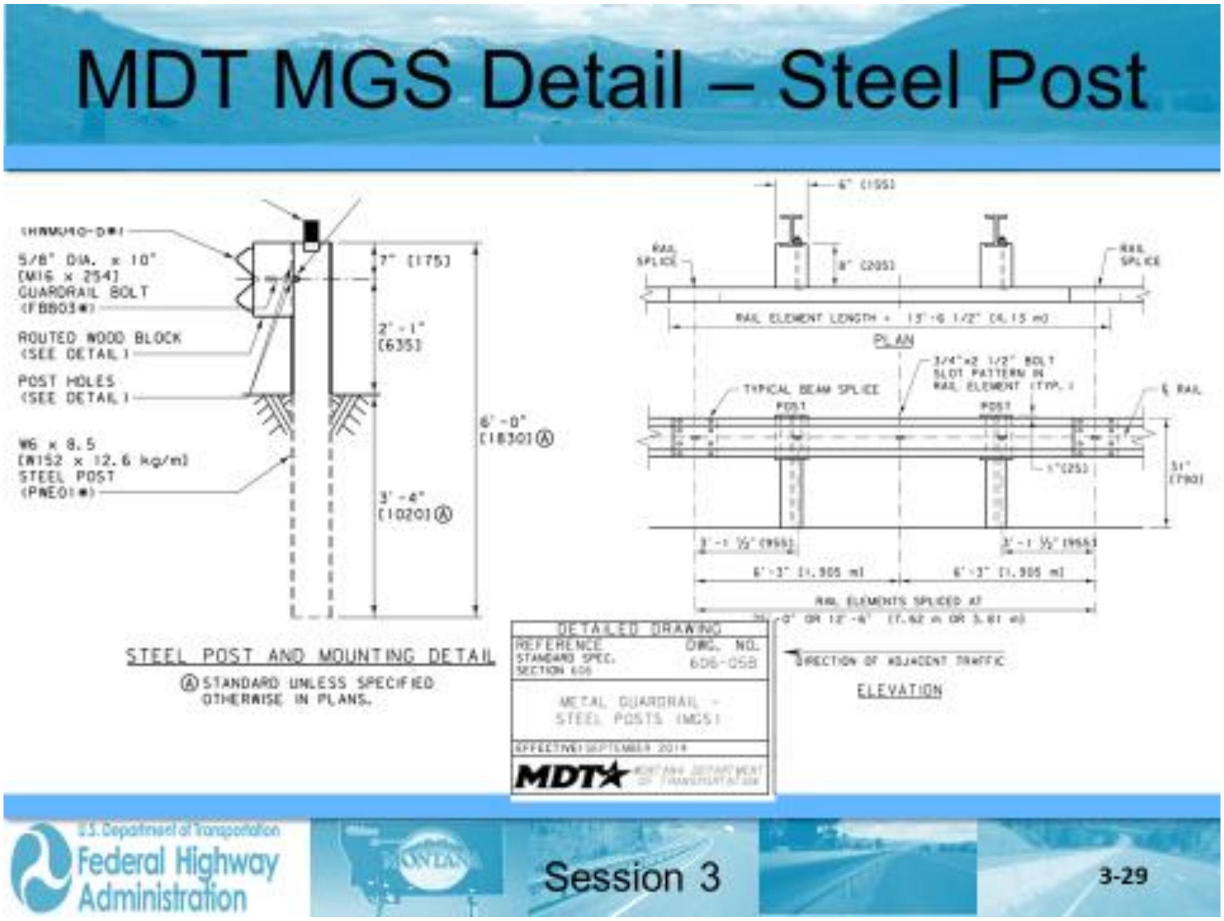
MDT MGS Detail – Steel Post
5/8" DIA. x 10"
[M16 x 254]
GUARDRAIL BOLT
(FBB03★)
ROUTED WOOD BLOCK
(SEE DETAIL)
POST HOLES
(SEE DETAIL)
W6 x 8.5
[W152 x 12.6 kg/m]
STEEL POST
(PWE01★)
7" [175]
2'-1"
[635]
6'-0"
[1830] Ⓐ
3'-4"
[1020] Ⓐ
STEEL POST AND MOUNTING DETAIL
Ⓐ STANDARD UNLESS SPECIFIED OTHERWISE IN PLANS.
6" (155)
8" (205)
RAIL SPLICE
RAIL SPLICE
PLAN
TYPICAL BEAM SPLICE
POST
POST
1" (25)
31"
[790]
6'-3" [1.905 m]
6'-3" [1.905 m]
RAIL ELEMENTS SPLICED AT
DIRECTION OF ADJACENT TRAFFIC
ELEVATION
DETAILED DRAWING
REFERENCE
STANDARD SPEC.
SECTION 606
DWG. NO.
606-05B
METAL GUARDRAIL - STEEL POSTS (MGS)
EFFECTIVE: SEPTEMBER 2014
MDT
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Existing Guardrail Height
Must be ≥ 27 ¾” to remain in place
U.S. Department of Transportation
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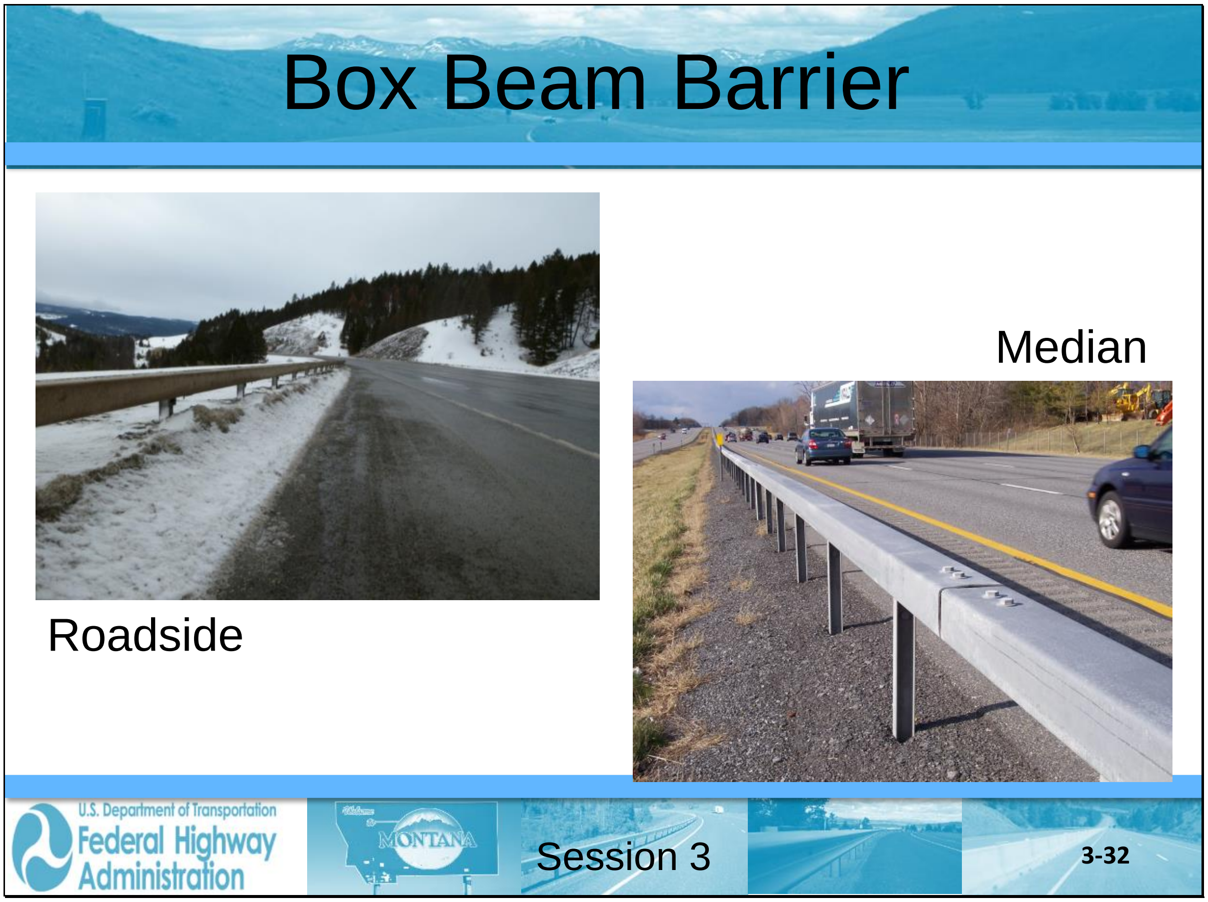
Box Beam Barrier
Median
Roadside
U.S. Department of Transportation
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Box Beam Barrier MASH Test 3-31
Video Clip
U.S. Department of Transportation
Federal Highway Administration
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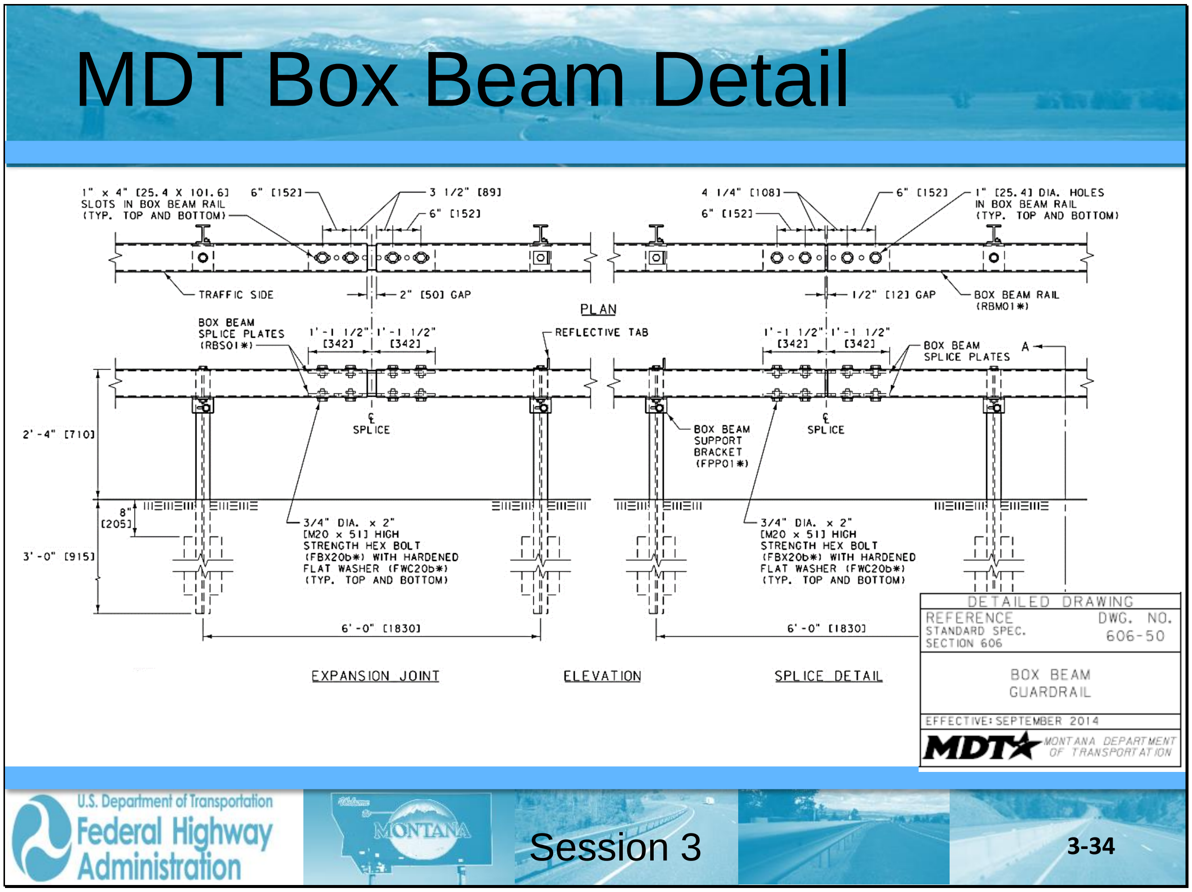
MDT Box Beam Detail
1" x 4" [25.4 X 101.6] SLOTS IN BOX BEAM RAIL (TYP. TOP AND BOTTOM)
6" [152]
3 1/2" [89]
6" [152]
4 1/4" [108]
6" [152]
6" [152]
1" [25.4] DIA. HOLES IN BOX BEAM RAIL (TYP. TOP AND BOTTOM)
TRAFFIC SIDE
2" [50] GAP
PLAN
1/2" [12] GAP
BOX BEAM RAIL (RBM01*)
BOX BEAM SPLICE PLATES (RBS01*)
1'-1 1/2" 1'-1 1/2" [342] [342]
REFLECTIVE TAB
1'-1 1/2" 1'-1 1/2" [342] [342]
BOX BEAM SPLICE PLATES
A
2'-4" [710]
SPLICE
BOX BEAM SUPPORT BRACKET (FPP01*)
SPLICE
8" [205]
3'-0" [915]
3/4" DIA. x 2" [M20 x 51] HIGH STRENGTH HEX BOLT (FBX20b*) WITH HARDENED FLAT WASHER (FWC20b*) (TYP. TOP AND BOTTOM)
3/4" DIA. x 2" [M20 x 51] HIGH STRENGTH HEX BOLT (FBX20b*) WITH HARDENED FLAT WASHER (FWC20b*) (TYP. TOP AND BOTTOM)
6'-0" [1830]
6'-0" [1830]
EXPANSION JOINT
ELEVATION
SPLICE DETAIL
DETAILED DRAWING
REFERENCE STANDARD SPEC. SECTION 606
DWG. NO. 606-50
BOX BEAM GUARDRAIL
EFFECTIVE: SEPTEMBER 2014
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MDT Box Beam Guidance

9.4.1.3 Box Beam Guardrail

Box beam guardrail (weak post) is a semi-rigid system with a dynamic deflection of 3 feet, 9 inches. Resistance in this system is achieved through the combined flexure and tensile stiffness of the rail. Posts near the impact are designed to break or tear away, thereby distributing the impact force to adjacent posts.

Box beam guardrail is generally used in snow drift areas and areas that require substantial snow plowing where cable guardrail is not acceptable (such as on the inside of curves, where the 12-foot deflection distance required for cable guardrail is not available). Box beam guardrail used on curves with radii less than 715 feet should be shop-bent (Note: NOT WITHIN THE TERMINAL).

MDT Road Design Manual — Page 9-23, Chapter 9— Roadside Safety

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Barrier Systems: Flexible Barriers

Flexible Barrier Systems typically have relatively <u>large deflections</u>

Examples of Flexible Barriers include:

- Weak post W-beam Not presented
- Low tension cable
- High tension cable

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Barrier Systems: Flexible Barriers

Advantages of cable systems include:

- Low initial cost
- Lower deceleration forces
- Effective vehicle containment and redirection
- Installation conditions (cable)
- SNOW

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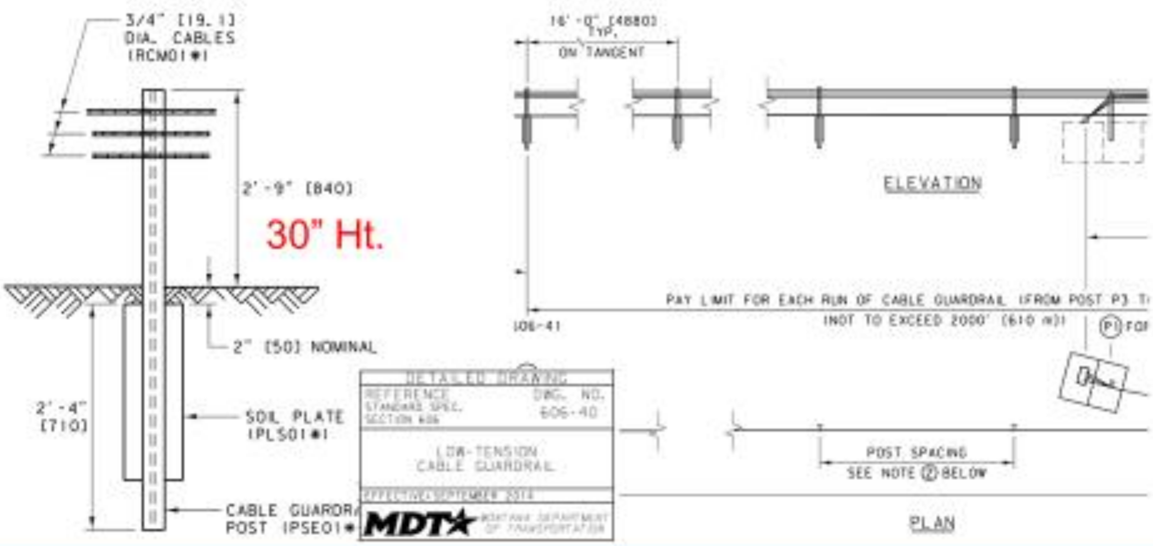
Barrier Systems: Flexible Barriers

- Low Tensioned Cable Barrier



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Barrier Systems: Flexible Barriers

- High Tensioned Cable Barrier
  - Five different proprietary designs available
  - Each requires a unique proprietary terminal
  - Somewhat reduced deflections
  - Generally easier maintenance
  - Can retain effectiveness after most impacts

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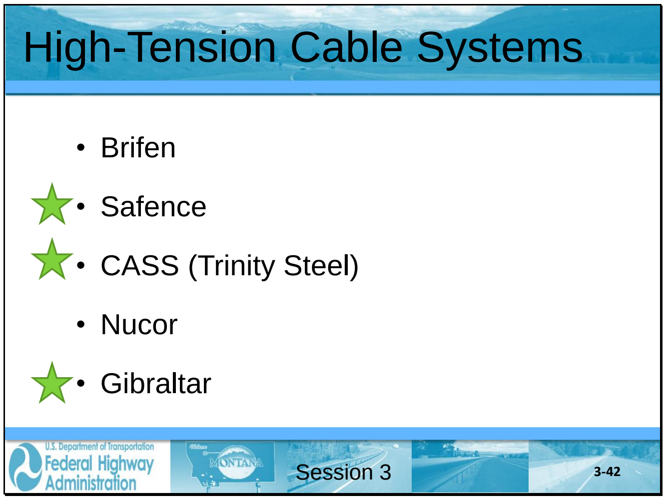
High-Tension Cable Systems
• Brifen
• Safence
• CASS (Trinity Steel)
• Nucor
• Gibraltar
U.S. Department of Transportation
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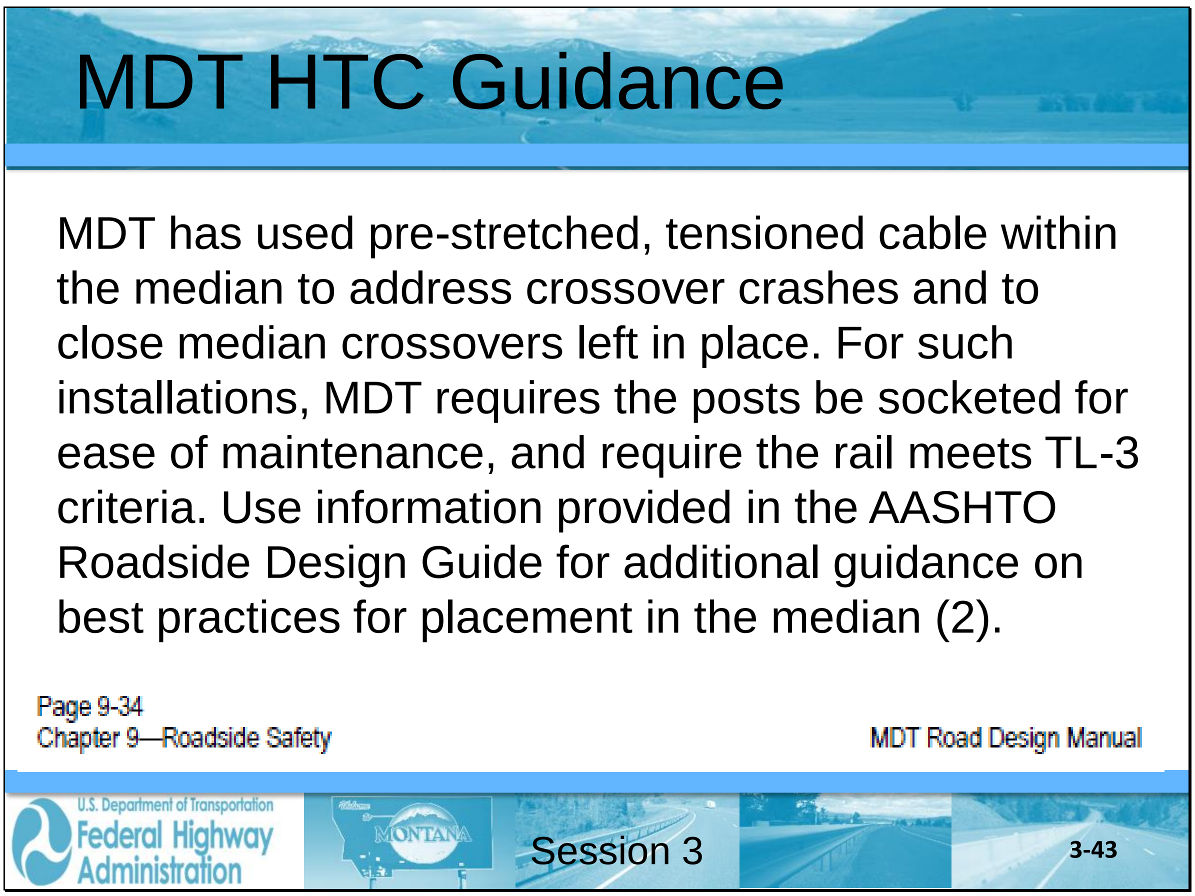
MDT HTC Guidance
MDT has used pre-stretched, tensioned cable within the median to address crossover crashes and to close median crossovers left in place. For such installations, MDT requires the posts be socketed for ease of maintenance, and require the rail meets TL-3 criteria. Use information provided in the AASHTO Roadside Design Guide for additional guidance on best practices for placement in the median (2).
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Chapter 9—Roadside Safety
MDT Road Design Manual
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Four Cable System
Video Clip
U.S. Department of Transportation
Federal Highway Administration
MONTANA
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Post Foundation and Typical Terminal

U.S. Department of Transportation Federal Highway Administration

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HTC On 4:1 Slope

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Which Barrier System to Use?

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Barriers in the Median

- Used to separate opposing traffic on a divided highway or to separate through traffic from local traffic.
- Many barriers approved for roadside applications can be modified for use in the median.
- Width of the median is an important consideration.
- Also must consider the dynamic deflection of the barrier to avoid intrusion into opposing traffic.
- There are terminals designed specifically to shield the ends of median barriers.

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MASH 27" W-Beam Median Barrier Test

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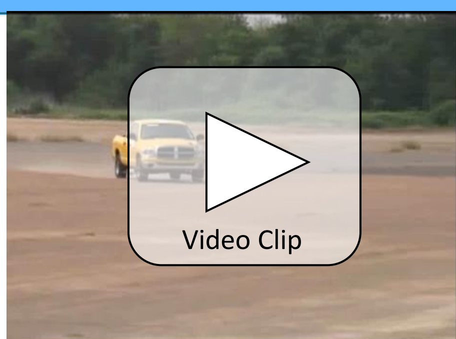
MASH MGS Median Barrier Test



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Flexible Median Barriers

Advantage of high tension cable is it may remain effective after impact.

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Flexible Median Barriers
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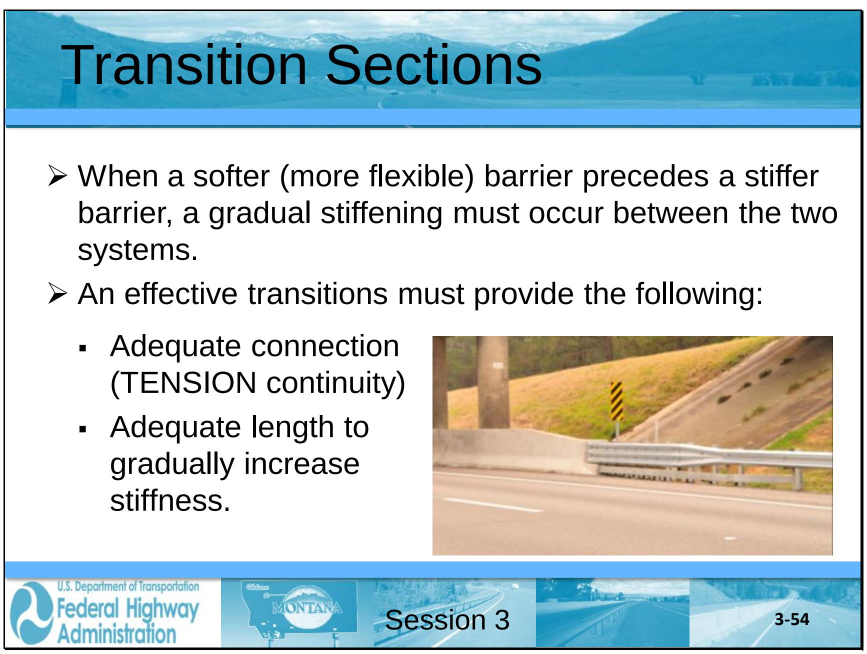
Transition Sections
➢ When a softer (more flexible) barrier precedes a stiffer barrier, a gradual stiffening must occur between the two systems.
➢ An effective transitions must provide the following:
▪ Adequate connection (TENSION continuity)
▪ Adequate length to gradually increase stiffness.
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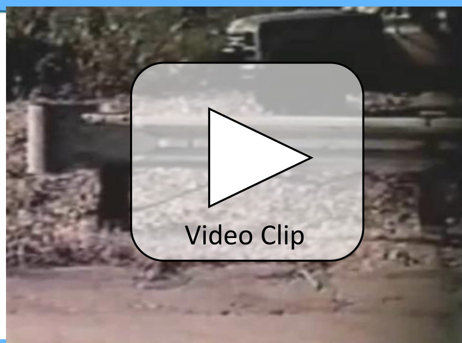
Inadequate Transition



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Transition Sections

Successfully crash-tested transitions include the following essential elements (in addition to a structural connection):

- Additional and/or Larger Posts
- Nested rail (w-beam or Thrie-beam)
- Curbs (only as crash-tested transition unit), Rub Rails, and/or Flared Parapet Wall to Prevent Snagging

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MGS Transition Design

- Compatible with most existing Thrie-beam to bridge railing transition designs
- Uses a non-symmetrical w-beam to thrie-beam transition piece.
- Posts can either be steel or wood.

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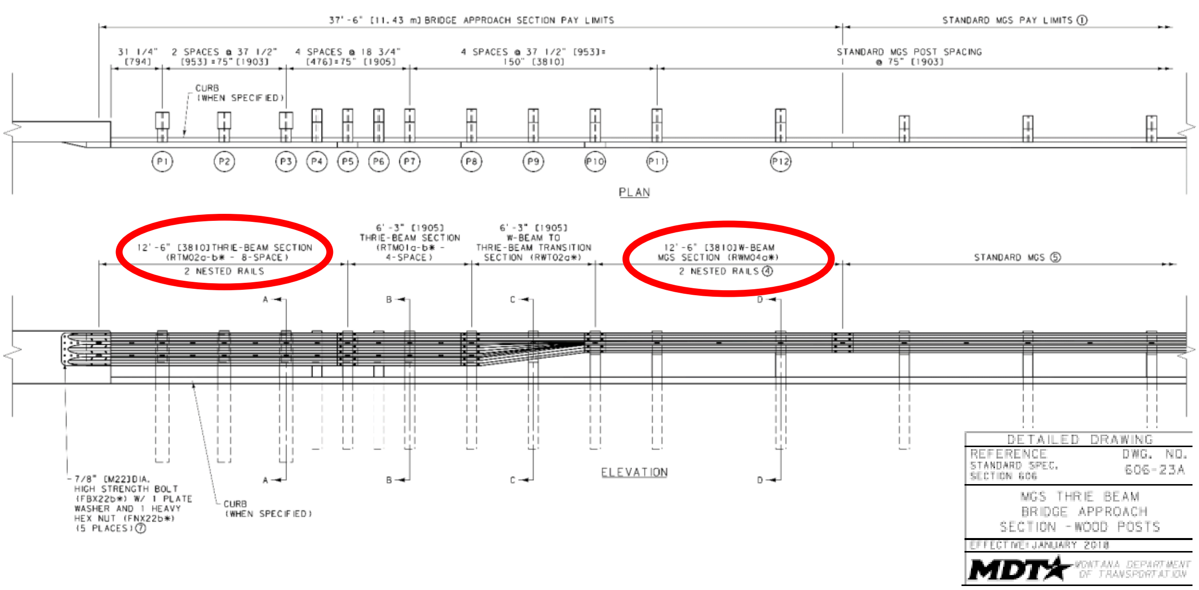
MDT Transition – MGS



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MGS Transition
Video Clip
U.S. Department of Transportation
Federal Highway Administration
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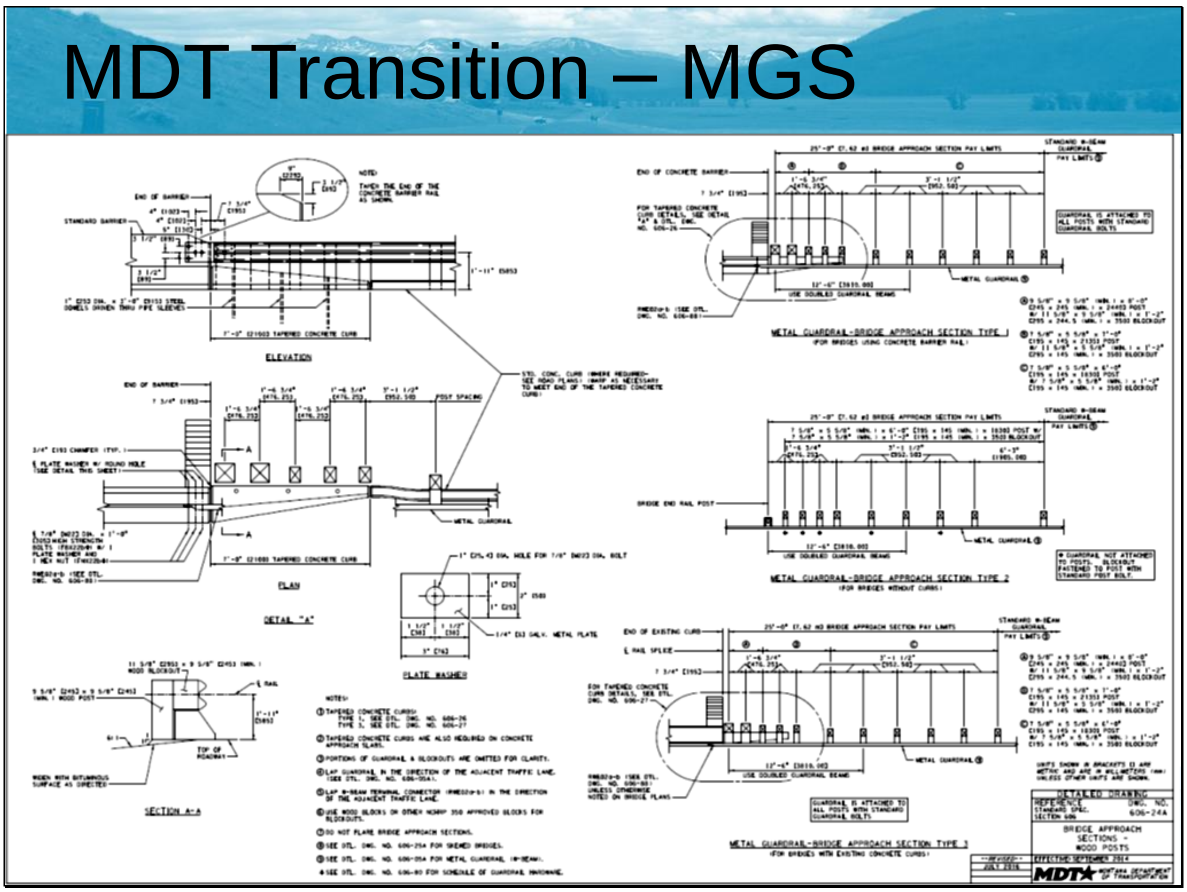
MDT Transition – MGS
ELEVATION
PLAN
METAL GUARDRAIL-BRIDGE APPROACH SECTION TYPE 1
METAL GUARDRAIL-BRIDGE APPROACH SECTION TYPE 2
METAL GUARDRAIL-BRIDGE APPROACH SECTION TYPE 3

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Connections to Low Parapets or Combination Rails

If the concrete parapet or portion of a combination rail is less than the transition height (29”, or 32” for thrie beam), a steel plate may be applicable to adjust the height.

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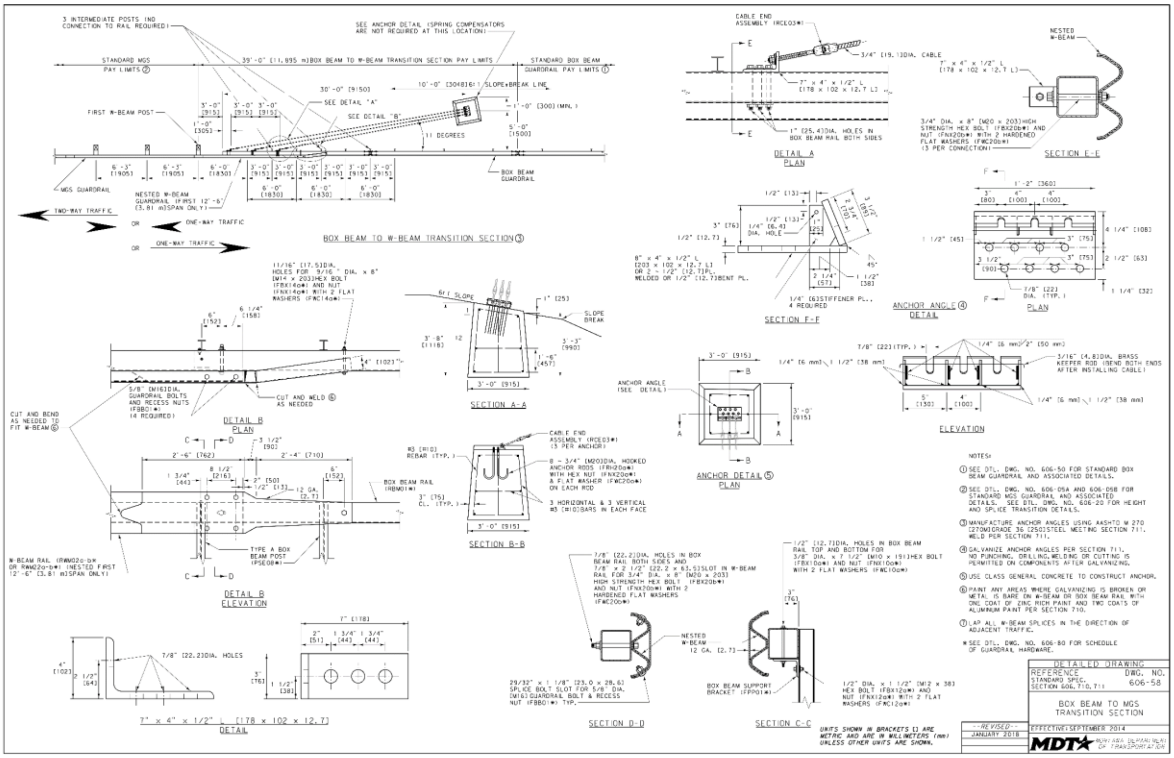
Transition: Box Beam to MGS (w-beam)




Transition: Box Beam to MGS (w-beam)
No stiffening required as relatively same stiffness; must have tension continuity
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Transition: HTC to Guardrail (Spatial)
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Federal Highway Administration
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Review Learning Outcomes

- Understand how barriers are tested for crashworthiness
- Identify common barrier systems
- Explain how these barrier systems function
- Define the key components of a transition design

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