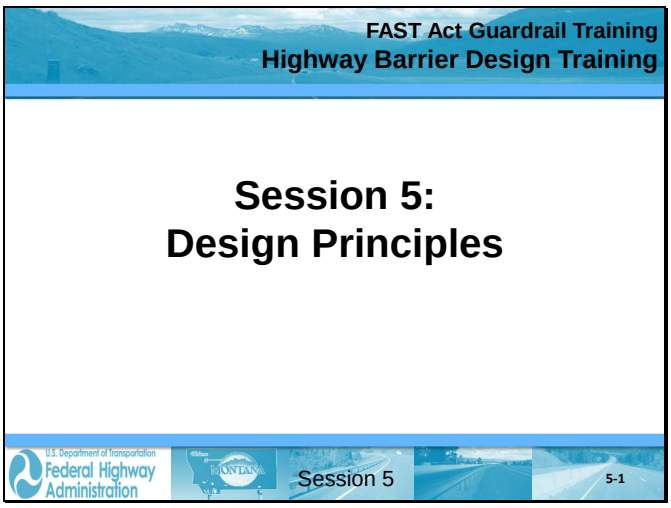
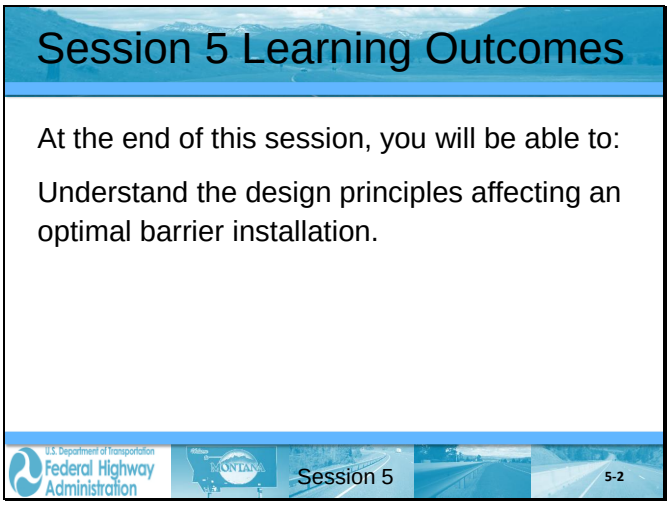
Session 5: Design Principles


FAST Act Guardrail Training
Highway Barrier Design Training
Session 5:
Design Principles
U.S. Department of Transportation
Federal Highway Administration
MONTANA
Session 5
5-1


Session 5 Learning Outcomes
At the end of this session, you will be able to:
Understand the design principles affecting an optimal barrier installation.
U.S. Department of Transportation
Federal Highway Administration
MONTANA
Session 5
5-2

MDT Range of Treatments

1. Eliminate obstacles or design proposed features free of obstacles (such as slope flattening to avoid barrier warrants, removing rock outcroppings, and removing point obstacles);
2. Relocate the obstacle;
3. Where applicable, make the obstacle breakaway (such as sign posts and luminaire supports);
4. Shield the obstacle with a roadside barrier, which is also considered an obstacle and should only be used when other alternatives cannot be achieved; or
5. Delineate the obstacle.

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Chapter 9—Roadside Safety
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MDT Road Design Manual

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Guardrail Placement

Place AS FAR AWAY as Possible

without affecting function

Barrier Design Principles

1. Deflection
2. Slope in Front of Barrier
3. Guardrail and Curb
4. Soil Backing for Fill Locations
5. Flare Rate

Principle 1: Deflection

Adequate room must be left behind the barrier to allow for lateral deflection in an impact.

- If the barrier is shielding a vertical rigid object, the distance between the barrier and the object should be sufficient to avoid the vehicle impacting or snagging on the object.
- Note that, even for rigid barriers with no lateral deflection, large vehicles may roll behind the top of the barrier even if the barrier itself does not deflect.

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Deflection Distance / Working Width

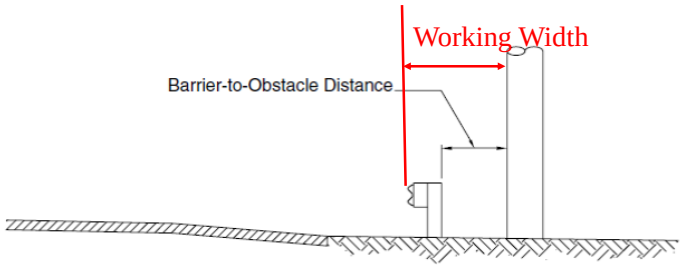

Figure 5-33. Recommended Barrier Placement for Optimum Performance

Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – Figure 5-33

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Barrier Type	Dynamic Deflection Distances (Test Level 3)	Barrier Width	Min. Dist. From Face Rail to Obstacle
"W" Beam – Wood Posts	4'	1'-7"	5.6'
"W" Beam – Steel Posts	4'	1'-7"	5.6'
Stiffened "W" Beam – Point Obstacle 3'-1 ½" Post Spacing – Single Rail	2'	1'-7"	3.6'
Stiffened "W" Beam – Line Obstacle 1'-6 ¾" Post Spacing – Double Rail	1'-1"	1'-7"	2.7'
Nested "W" Beam – 25'-0" Span	5'	1'-7"	7.3'
Metal Guardrail – 7' Posts Posts spaced at 3'-1½" with 2:1 slopes and without widening	3'	1'-7"	4.6'
Low Tension Cable Guardrail	7'-10"	4" or 5"	12.0'
Box Beam Guardrail	3'-9"	9"	4.5'
Concrete Barrier Rail	4'-6"	2'-0"	6.5'
Anchored Concrete Barrier Rail	1'-6"	2'-0"	3.5'


Deflection
U.S. Department of Transportation
Federal Highway Administration
MONTANA
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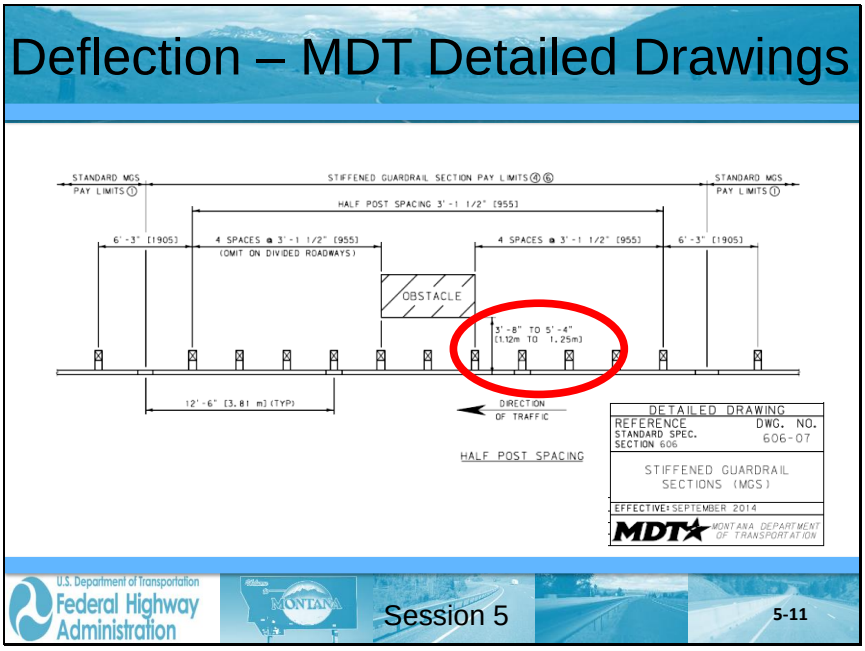
Deflection – MDT Detailed Drawings
STANDARD MGS PAY LIMITS ①
STIFFENED GUARDRAIL SECTION PAY LIMITS ④ ⑤
STANDARD MGS PAY LIMITS ①
HALF POST SPACING 3'-1 1/2" [955]
6'-3" [1905]
4 SPACES @ 3'-1 1/2" [955]
(OMIT ON DIVIDED ROADWAYS)
4 SPACES @ 3'-1 1/2" [955]
6'-3" [1905]
OBSTACLE
3'-8" TO 5'-4"
[1.12m TO 1.25m]
12'-6" [3.81 m] (TYP)
DIRECTION OF TRAFFIC
HALF POST SPACING
DETAILED DRAWING
REFERENCE STANDARD SPEC. SECTION 606
DWG. NO. 606-07
STIFFENED GUARDRAIL SECTIONS (MGS)
EFFECTIVE: SEPTEMBER 2014
MDT MONTANA DEPARTMENT OF TRANSPORTATION
U.S. Department of Transportation
Federal Highway Administration
MONTANA
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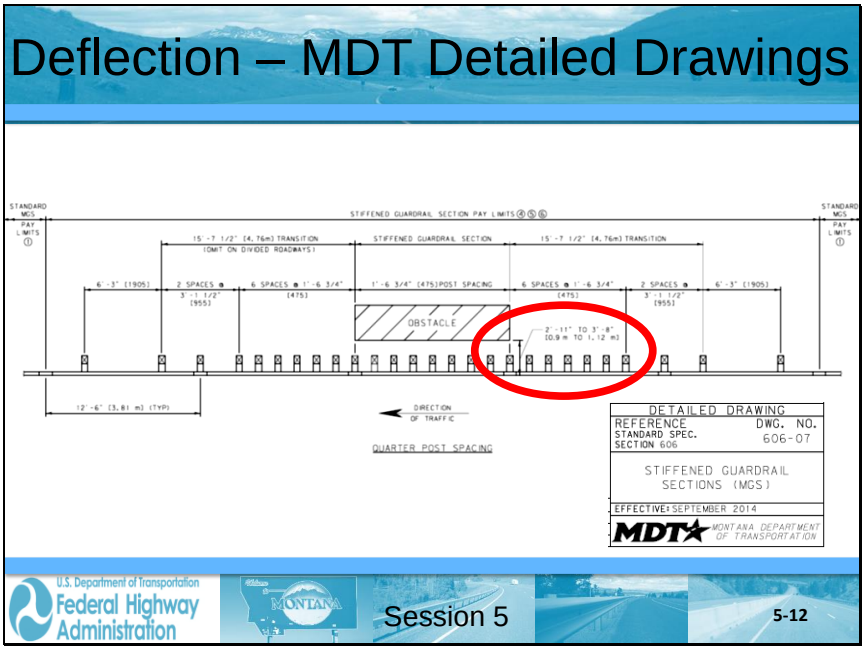
Deflection – MDT Detailed Drawings
STIFFENED GUARDRAIL SECTION PAY LIMITS
STANDARD MGS PAY LIMITS
15'-7 1/2" (4.76m) TRANSITION (OMIT ON DIVIDED ROADWAYS)
STIFFENED GUARDRAIL SECTION
6'-3" (1905)
2 SPACES @ 3'-1 1/2" (955)
6 SPACES @ 1'-6 3/4" (475)
1'-6 3/4" (475) POST SPACING
OBSTACLE
2'-11" TO 3'-8" (0.9 m TO 1.12 m)
12'-6" (3.81 m) (TYP)
DIRECTION OF TRAFFIC
QUARTER POST SPACING
DETAILED DRAWING
REFERENCE STANDARD SPEC. SECTION 606
DWG. NO. 606-07
STIFFENED GUARDRAIL SECTIONS (MGS)
EFFECTIVE: SEPTEMBER 2014
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U.S. Department of Transportation Federal Highway Administration
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Barrier Type	Dynamic Deflection Distances (Test Level 3)	Barrier Width	Min. Dist. From Face Rail to Obstacle
"W" Beam – Wood Posts	4'	1'-7"	5.6'
"W" Beam – Steel Posts	4'	1'-7"	5.6'
Stiffened "W" Beam – Point Obstacle 3'-1 ½" Post Spacing – Single Rail	2'	1'-7"	3.6'
Stiffened "W" Beam – Line Obstacle 1'-6 ¾" Post Spacing – Double Rail	1'-1"	1'-7"	2.7'
Nested "W" Beam – 25'-0" Span	5'	1'-7"	7.3'
Metal Guardrail – 7' Posts Posts spaced at 3'-1½" with 2:1 slopes and without widening	3'	1'-7"	4.6'
Low Tension Cable Guardrail	7'-10"	4" or 5"	12.0'
Box Beam Guardrail	3'-9"	9"	4.5'
Concrete Barrier Rail	4'-6"	2'-0"	6.5'
Anchored Concrete Barrier Rail	1'-6"	2'-0"	3.5'

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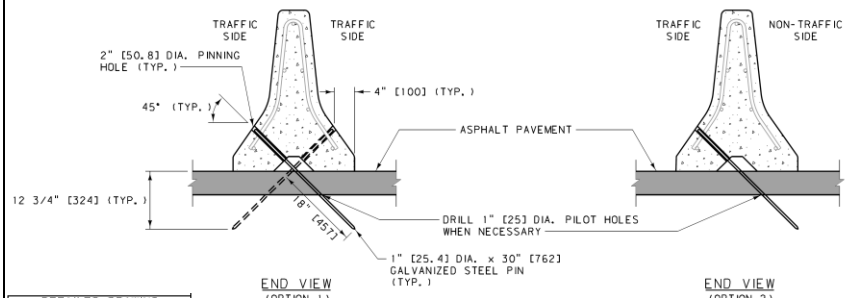
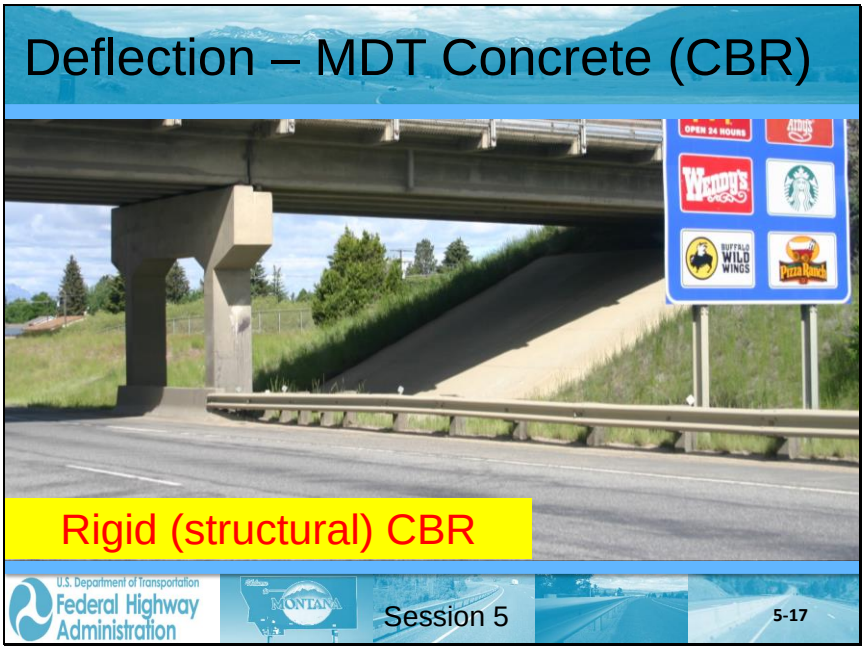
Deflection – MDT Concrete (CBR)



Deflection – MDT Concrete (CBR)


Deflection – MDT Concrete (CBR)
Rigid (structural) CBR
U.S. Department of Transportation
Federal Highway Administration
MONTANA
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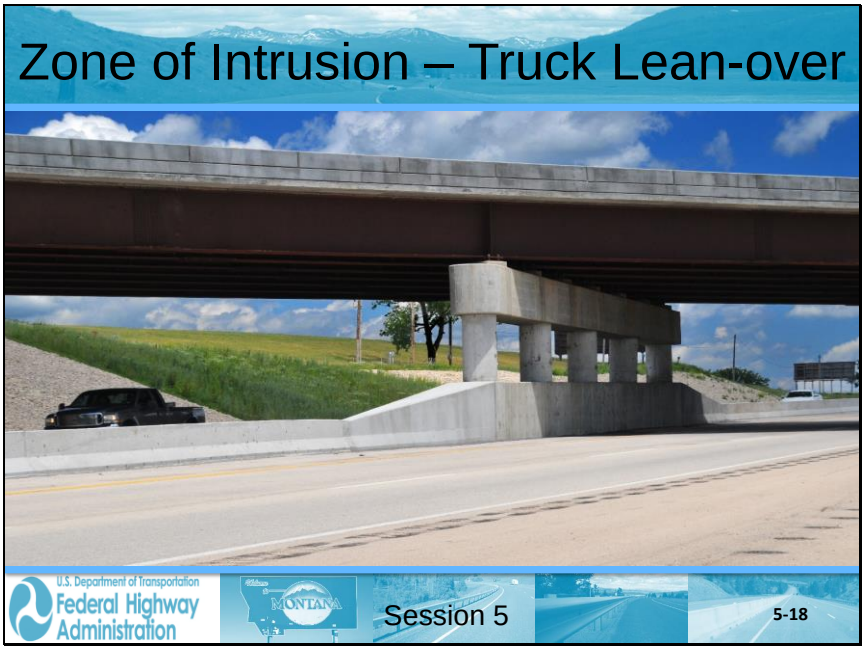
5-17


Zone of Intrusion – Truck Lean-over
U.S. Department of Transportation
Federal Highway Administration
MONTANA
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Zone of Intrusion (almost)

2. Barrier-Mounted Obstacles. If trucks or buses impact the CBR, their high center of gravity may result in a vehicular roll angle which possibly will allow the truck or bus to impact obstacles on top of the CBR (e.g., luminaire supports). If practical, move these devices to the outside and make them breakaway, or provide additional distance between the barrier and obstacle by using a flared/divided median barrier.

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Principle 2: Slope in Front of Barrier

Any barrier may be placed anywhere on a 10H:1V or flatter slope.

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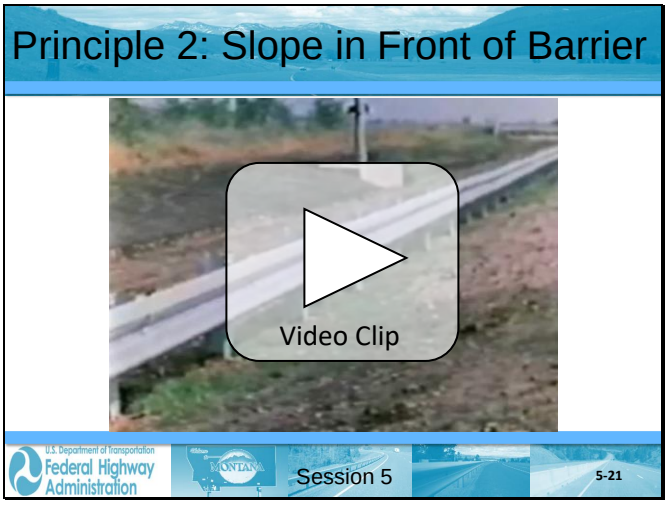
Principle 2: Slope in Front of Barrier
Video Clip
U.S. Department of Transportation
Federal Highway Administration
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NCHRP 350 TL-3 MGS on 8:1 Slope
5-ft
8:1
Video Clip
Vehicle is contained and redirected but shows some instability
U.S. Department of Transportation
Federal Highway Administration
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Slope in Front of Barrier

9.4.3.7 Placement on Slopes

Slopes in front of a barrier should be 10:1 or flatter. This also applies to the areas in front of the flared section of guardrail and to the area approaching the terminal ends. See the MDT Detailed Drawings.

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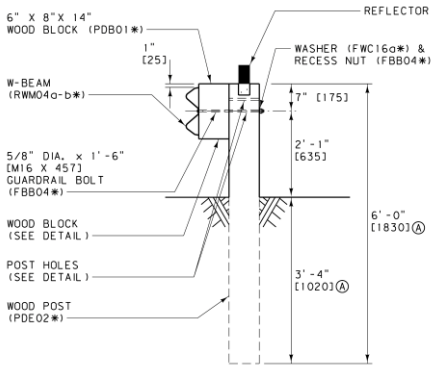
MDT Road Design Manual

Slope in Front of Barrier



WOOD POST AND MOUNTING DETAIL

Ⓐ STANDARD UNLESS SPECIFIED OTHERWISE IN PLANS.

Only shows **FLAT**

DETAILED DRAWING
REFERENCE STANDARD SPEC. SECTION 606, 704
DWG. NO. 606-05A
METAL GUARDRAIL - WOOD POSTS (MGS)
EFFECTIVE: SEPTEMBER 2014
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Barrier in Sloped Median

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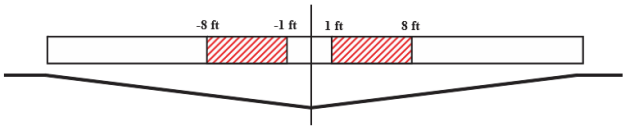
Slope in Front of Cable Barrier

- Cable barrier may be placed anywhere on a 10:1 or flatter slope.
- Cable barrier may be placed on slopes of 6:1, but not in the area from 1 ft. to 8 ft. from the ditch bottom.



(a) Medians shallower than 6H:1V slope (NCHRP Report 711)

Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – 6.6.1.1, Pg. 6-18

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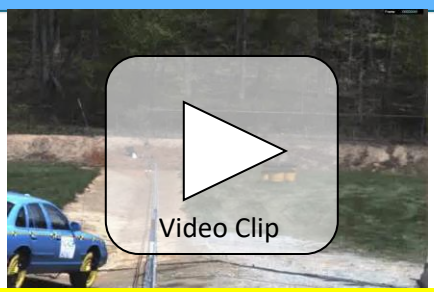
Location of Cable in Swales

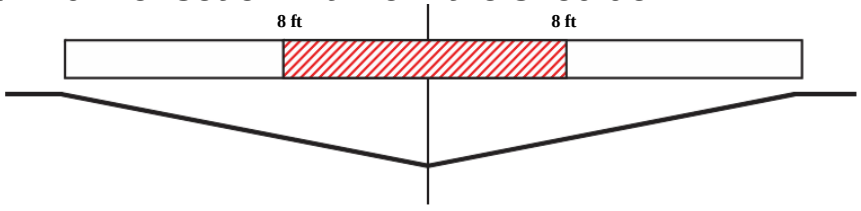


CABLE SHOULD NOT BE PLACED BETWEEN 1' AND 8' BEYOND THE BOTTOM OF A DITCH

Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – 6.6.1.1, Pg. 6-18

Slope in Front of Cable Barrier

- Cable barrier may be placed on ***4:1*** slopes with a maximum offset of 4 ft. from the shoulder.



(b) Medians steeper than 6H:1V slope

Figure 6.1. Underride criteria for V-shaped medians. (NCHRP Report 711)

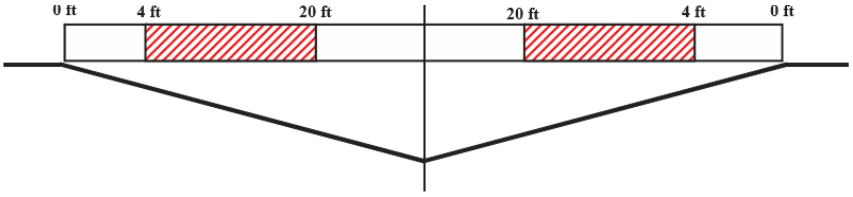
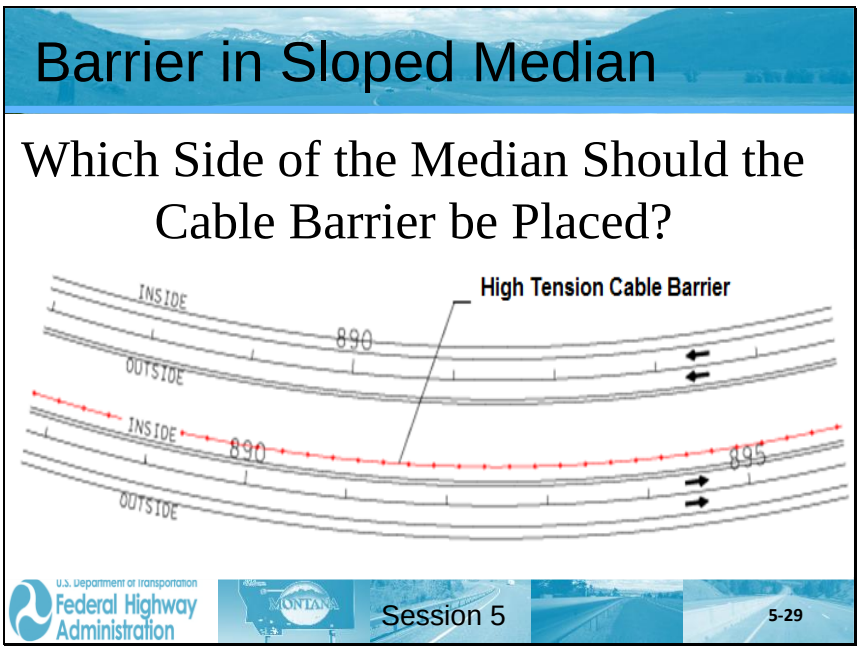


Figure 6.2. Override criteria for V-shaped medians steeper than 6H:1V slope. (NCHRP Report 711)

Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – 6.6.1.1, Pg. 6-18


Barrier in Sloped Median
Which Side of the Median Should the Cable Barrier be Placed?
High Tension Cable Barrier
INSIDE
OUTSIDE
890
INSIDE
890
OUTSIDE
895
U.S. Department of Transportation
Federal Highway Administration
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Principle 3: Guardrail and Curbs
U.S. Department of Transportation
Federal Highway Administration
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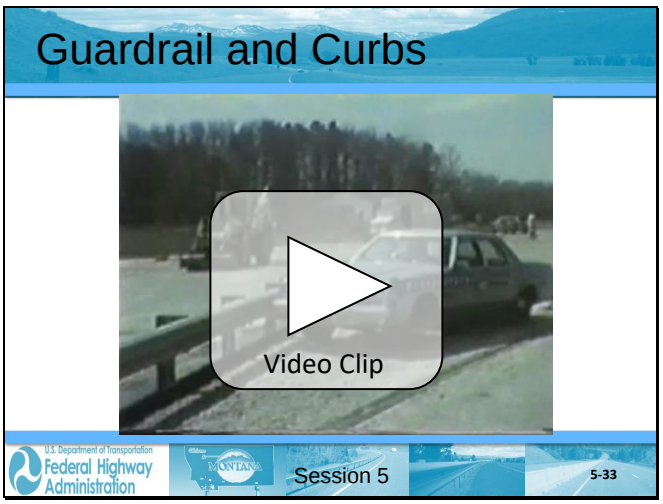
Guardrail and Curbs

- Curbs may function to channelize traffic, to control drainage, improve delineation, control access, and reduce erosion.
- Curbs are not adequate to prevent a vehicle from leaving the roadway; they are not a barrier.
- Use of any guardrail/curb combination where high-speed, high-angle impacts are likely should be discouraged.



MDT Guidance – Guardrail and Curbs

9.4.3.6 Placement in Conjunction With Curbs

For rural (outside the boundaries of urban areas) roadways and urban roadways where the design speed is greater than 45 miles per hour, do not place curbs in front of roadside barriers. Where curbs are used in conjunction with roadside barriers on low-speed facilities, the face of the barrier should be in line with the face of the curb (i.e., at the gutter line). Do not use curbs higher than 4 inches with a barrier on new construction facilities. Existing curb installations higher than 4 inches may remain if the installation otherwise meets MDT criteria.

Measure the height of the barrier from the pavement surface (e.g., where curbs are on bridges). A weak post system, such as cable or box-beam guardrail, cannot be used in conjunction with curbing.

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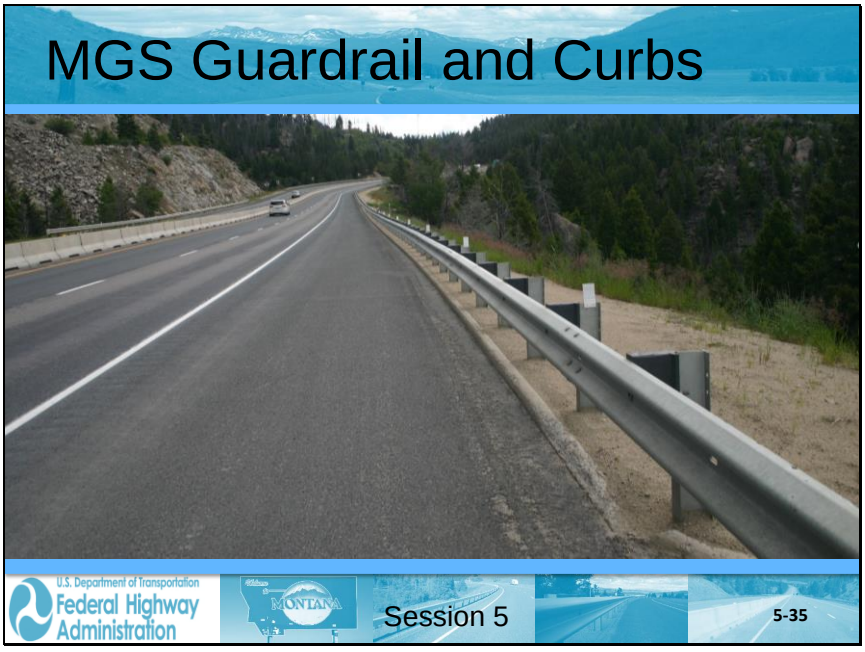
MGS Guardrail and Curbs
U.S. Department of Transportation
Federal Highway Administration
MONTANA
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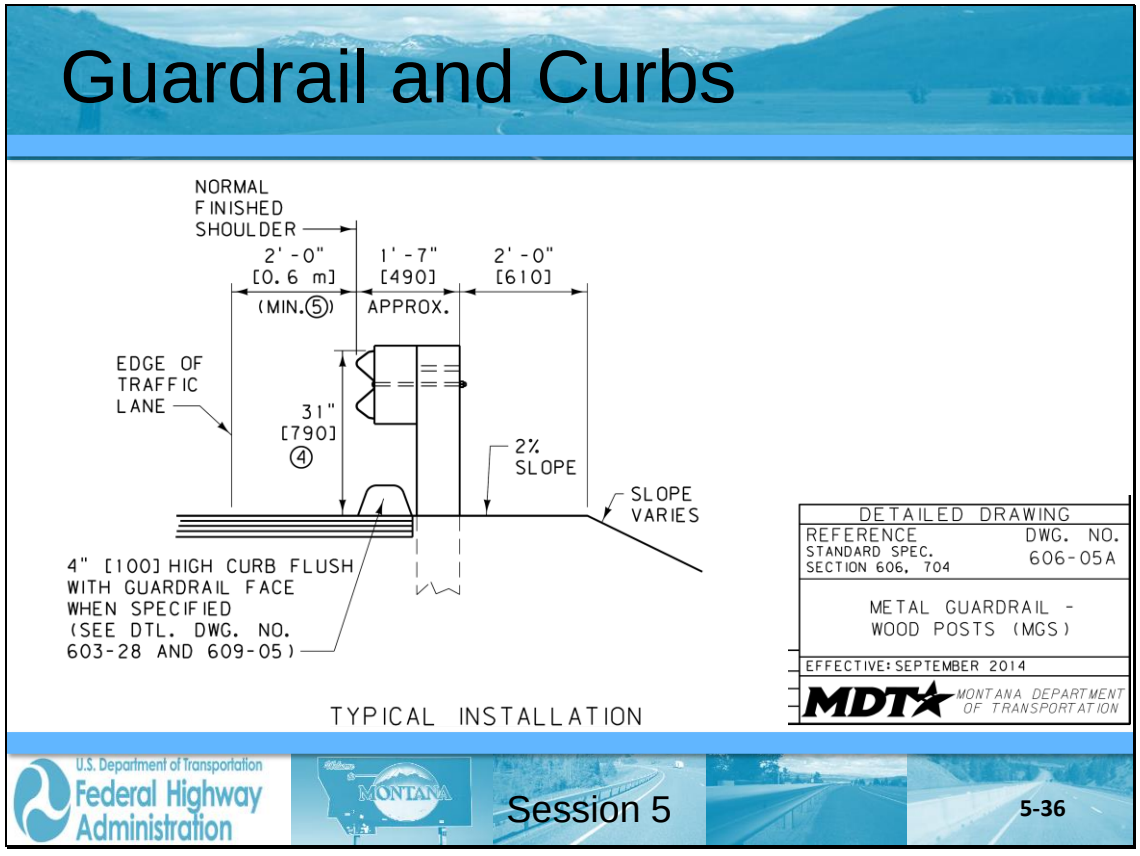
Guardrail and Curbs
NORMAL FINISHED SHOULDER
2'-0" [0.6 m] (MIN.⑤)
1'-7" [490] APPROX.
2'-0" [610]
EDGE OF TRAFFIC LANE
31" [790] ④
2% SLOPE
SLOPE VARIES
4" [100] HIGH CURB FLUSH WITH GUARDRAIL FACE WHEN SPECIFIED (SEE DTL. DWG. NO. 603-28 AND 609-05)
TYPICAL INSTALLATION
DETAILED DRAWING
REFERENCE STANDARD SPEC. SECTION 606, 704
DWG. NO. 606-05A
METAL GUARDRAIL - WOOD POSTS (MGS)
EFFECTIVE: SEPTEMBER 2014
MDT MONTANA DEPARTMENT OF TRANSPORTATION
U.S. Department of Transportation
Federal Highway Administration
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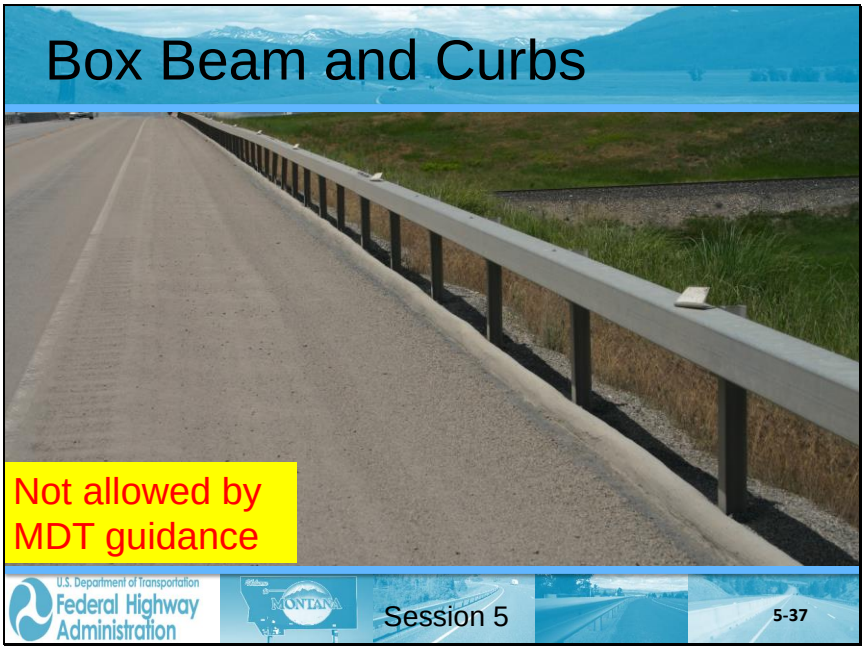
Box Beam and Curbs
Not allowed by MDT guidance
U.S. Department of Transportation Federal Highway Administration
MONTANA
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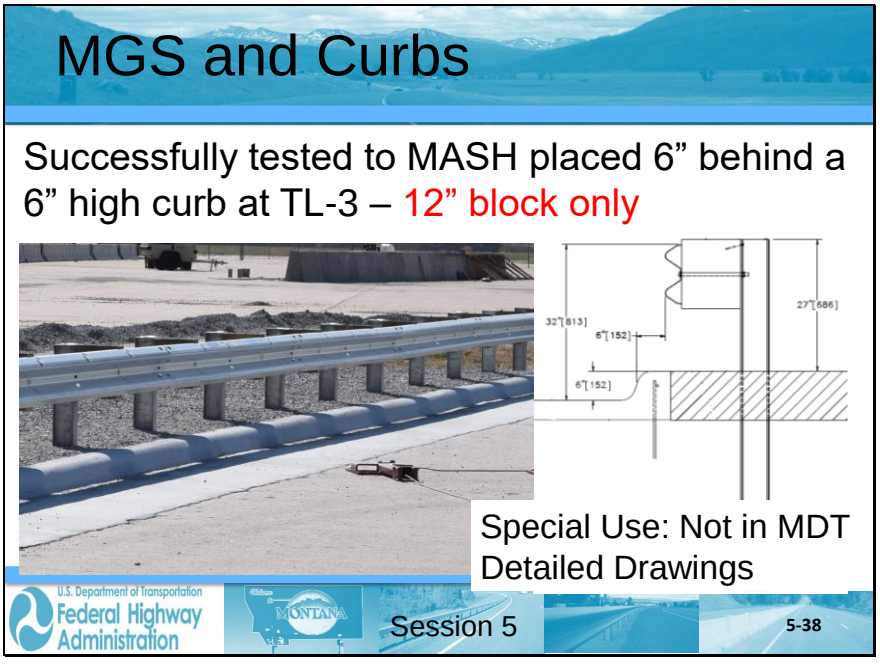
MGS and Curbs
Successfully tested to MASH placed 6” behind a 6” high curb at TL-3 – 12” block only
32[813]
6[152]
6[152]
27[686]
Special Use: Not in MDT Detailed Drawings
U.S. Department of Transportation Federal Highway Administration
MONTANA
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Terminals and Curbs
CURRENTLY UNDER STUDY –
DO NOT BURY BEARING PLATE
2” maximum height recommended
U.S. Department of Transportation
Federal Highway Administration
MONTANA
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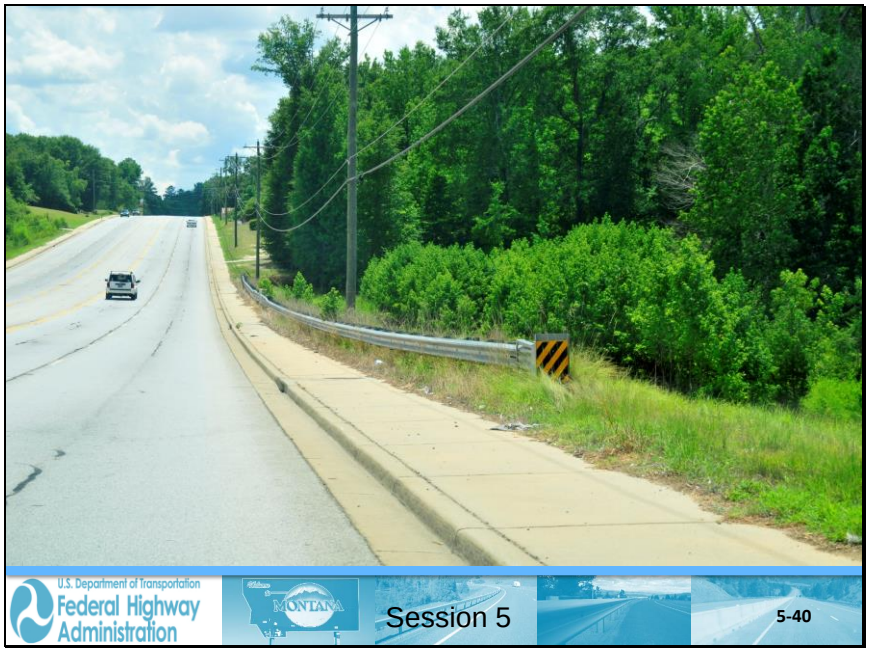
U.S. Department of Transportation
Federal Highway Administration
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MASH TL-2 MGS 6 ft. behind curb
Video Clip
U.S. Department of Transportation
Federal Highway Administration
MONTANA
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Principle 4: Soil Backing For Fill Locations
U.S. Department of Transportation
Federal Highway Administration
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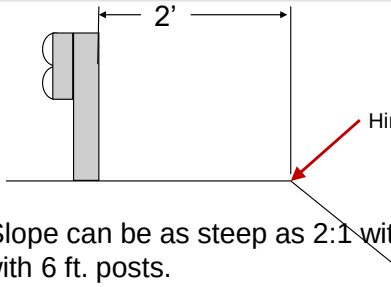
Soil Backing Recommendation

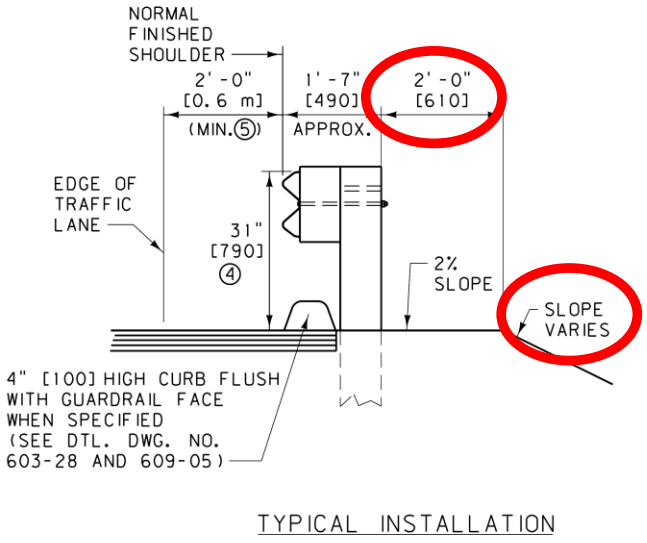


Historical Guidance

1. Slope can be as steep as 2:1 with 2-ft. backing in strong soil with 6 ft. posts.
2. Backing can be less than 2 ft. with 2:1 slope in strong soil with 7 ft. posts. NCHRP 350 requires half post spacing – ONLY applies to "Old" system

Ref: AASHTO Roadside Design Guide, 4th Edition – Figure 5.33, Pg. 5-41

Soil Backing – MDT



TYPICAL INSTALLATION

DETAILED DRAWING
REFERENCE STANDARD SPEC. SECTION 606, 704
DWG. NO. 606-05A
METAL GUARDRAIL - WOOD POSTS (MGS)
EFFECTIVE: SEPTEMBER 2014
MDT MONTANA DEPARTMENT OF TRANSPORTATION


Soil Backing – Good
If posts are in structural pavement, it's a problem
U.S. Department of Transportation
Federal Highway Administration
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Soil Backing – ????
U.S. Department of Transportation
Federal Highway Administration
MONTANA
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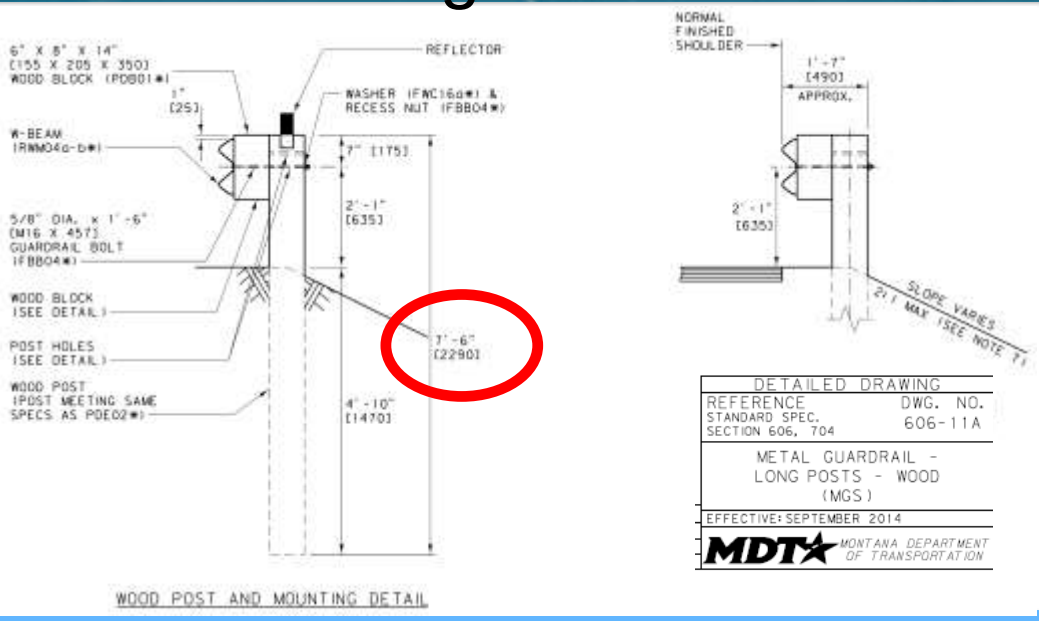
Soil Backing – MDT – Long Wood Post



MGS shielding a 2H:1V Slope – at Hinge

- **On 2H:1V slope**
  - Standard steel posts.
  - Standard 6’-3” post spacing.

Not in MDT Detailed Drawings -
Use only with appropriate approval

Break-line of 2H:1V Slope

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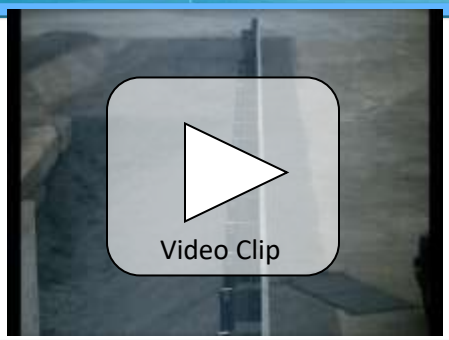
MGS shielding a 2H:1V Slope – at Hinge



U.S. Department of Transportation Federal Highway Administration | Session 5 | 5-49

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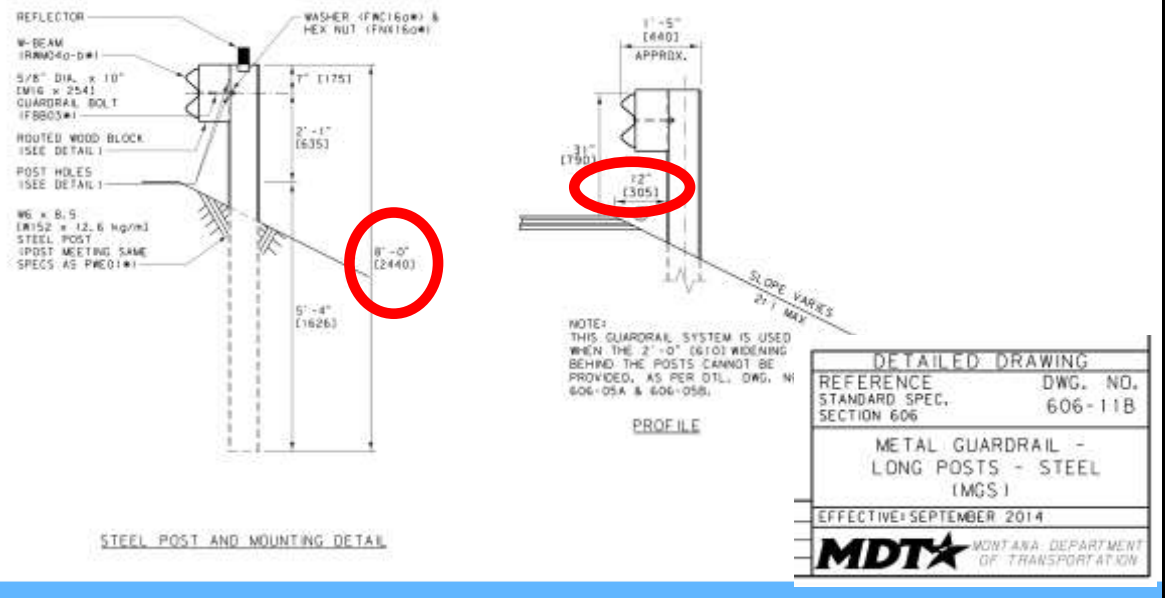
Soil Backing – MDT – Long Steel Post



MGS With Posts on a 2:1 Slope

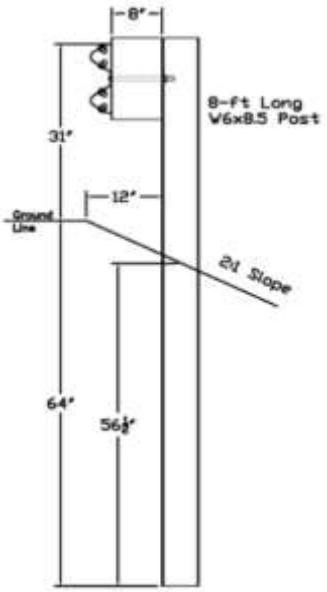
MGS with face of rail at slope break point of 2:1 slope

Posts

- 8’ long W6x9 posts tested
- Not recommended with Wood posts at this time
- 6’-3” post spacing

Blocks

- 8” block tested
- 12” block acceptable
- Not recommended without blocks at this time



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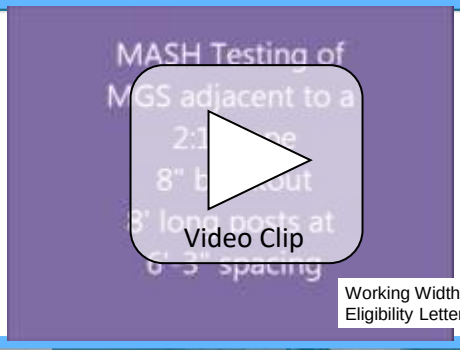
MGS With Posts on a 2:1 Slope



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Principle 5: Flare Rate

Flare Rate

Flared barriers are those that are not parallel to the edge of the traveled way. They are used to:

- Locate terminals farther from the roadway.
- Lessen driver reaction to a roadside obstacle.
- Reduce total length of rail needed.
- Reduce nuisance hits.
- When tying to a bridge rail from a farther offset (in advance of transition)

Flare Rate

Trade offs and restrictions of flared barriers:

- Flare increases the angle at which the barrier can be hit.
- Flare may increase the angle of redirection after an impact.
- Flared barriers can only be placed on 10:1 or flatter slopes.
- Maximum flare rate varies with design speed.

Flare: National Guidance

Table 5-9. Suggested Flare Rates for Barrier Design

Design Speed		Flare Rate for Barrier Inside Shy Line	Flare Rate for Barrier at or Beyond Shy Line	
km/h	[mph]		A	B
110	[70]	30:1	20:1	15:1
100	[60]	26:1	18:1	14:1
90	[55]	24:1	16:1	12:1
80	[50]	21:1	14:1	11:1
70	[45]	18:1	12:1	10:1
60	[40]	16:1	10:1	8:1
50	[30]	13:1	8:1	7:1

Notes:
A = Suggested maximum flare rate for rigid barrier system.
B = Suggested maximum flare rate for semi-rigid barrier system.
The MGS has been tested in accordance with NCHRP Report 350 TL-3 at 5:1 flare.
Flatter flare rates for the MGS installations also are acceptable. The MGS should be installed using the flare rates shown or flatter for semi-rigid barriers beyond the shy line when installed in rock formations.


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Flare at Bridge Approach Narrow Bridge Shoulder
PRE-ASSESSMENT PHOTO
Must satisfy flare rate criteria
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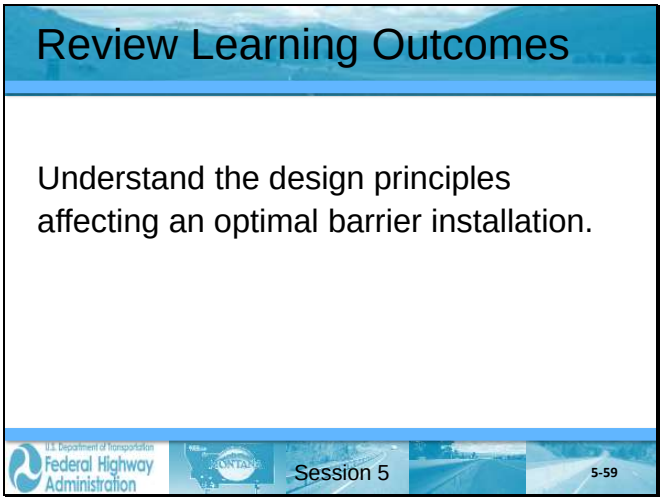
Review Learning Outcomes
Understand the design principles affecting an optimal barrier installation.
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