

Session 4: Guardrail Design and Site-specific Installation Considerations

Session 4: Guardrail Design and Site-specific Installation Considerations

FAST Act Guardrail Training
Highway Barrier Installation, Inspection and
Maintenance Training

**Session 4:
Guardrail Design and Site-
specific Installation
Considerations**

U.S. Department of Transportation
Federal Highway
Administration

Not Quite
A Legend

Session 4

4-1

Session 4 Learning Outcomes

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

- Understand the design principles affecting an optimal barrier installation
- Apply a field procedure to check Length of Need
- Be familiar with special designs to address site-specific installation considerations

U.S. Department of Transportation
Federal Highway
Administration

Not Quite
A Legend

Session 4

4-2

Design Options in Order of Preference

1. Remove the obstruction
2. Make the obstruction traversable
3. Relocate obstruction beyond the clear zone
4. Reduce impact severity by using an appropriate breakaway system
5. SHIELD the obstruction with a longitudinal barrier or crash cushion (only if obstruction cannot be removed, relocated, or redesigned)
6. Delineate obstruction (only if all above options are not appropriate.)

Ref: NDDOT DESIGN MANUAL Section III 14.05



Session 4

4-3

Guardrail Placement

**Place AS FAR AWAY
as Possible**

without affecting function



Session 4

4-4

Barrier Design Principles

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

North Dakota
LEGENDARY

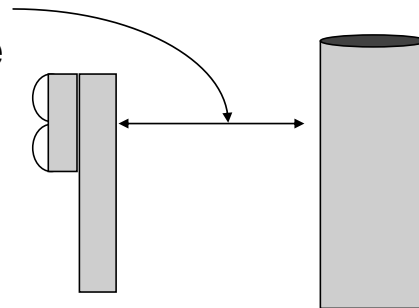
Session 4

4-5

Principle 1: Deflection Distance

The distance a barrier will deflect when impacted is a critical factor in its selection and placement.

If the barrier is shielding a rigid object, the distance between the barrier and the object should be sufficient to avoid the vehicle impacting or snagging on the object.

WELCOME TO
North Dakota
LEGENDARY

Session 4

4-6

Deflection Distance / Working Width

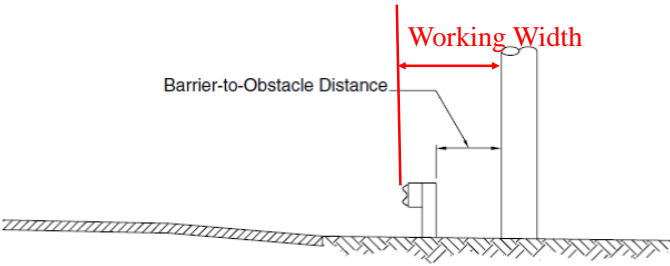


Figure 5-33. Recommended Barrier Placement for Optimum Performance

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

U.S. Department of Transportation
Federal Highway Administration

North Dakota
LEGENDARY

Session 4

4-7

NDDOT Guidance – Deflection

- Currently, for the 28" system, NDDOT guidance is 31 1/2 " clearance with standard 6' 3" post spacing.
- With half post spacing (3'-1 1/2 ") the clearance should be 24" and the reduced post spacing should extend for 25 feet in advance of the obstruction
- For three strand cable, the distance from cable to object shall be 11' or greater

NDDOT Design Manual Section III-13

U.S. Department of Transportation
Federal Highway Administration

North Dakota
LEGENDARY

Session 4

4-8



Reducing W-beam Deflection

- Reduce post spacing to 3'-1 1/2"
- Reduce post spacing again to 1'-6 3/4"
- Nest rail element
- Adding rail element to field-side of line posts
- Use larger post size and greater embedment length

Stiffening must begin gradually a sufficient distance in advance so as not to create a new hard spot

U.S. Department of Transportation
Federal Highway Administration

North Dakota
LEGENDARY

Session 4

4-10

Principle 2: Slope in Front of Barrier



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



WELCOME TO
North Dakota
LEGENDARY

Session 4

4-11

Principle 2: Slope in Front of Barrier



North Dakota
LEGENDARY

Session 4

4-12

**THERE HAS BEEN NO
HIGH SPEED, MASH
TESTING OF MGS ON
SLOPES; UNTIL
PROVEN, LIMIT SLOPE
IN FRONT TO 10:1 OR
FLATTER**

U.S. Department of Transportation
Federal Highway Administration

North Dakota
LEGENDARY

Session 4

4-13

NDDOT Guidance – Slope in Front

10:1 or flatter (A)

2' (D)

31" (C)

2" HMA

6" Aggregate Base Course

Added fill

4:1 or 6:1 (B)

Existing Foreslope

Ref: NDDOT Standard Drawing, D764-49, July 2017


U.S. Department of Transportation
Federal Highway Administration

North Dakota
LEGENDARY

Session 4

4-14

Barrier in Sloped Median



Override concern on high side of horizontal curve

ND recommends that 3-cable guardrail not be placed on inside of curves of more than 4 degrees.

U.S. Department of Transportation
Federal Highway Administration

WELCOME TO
North Dakota
LEGENDARY

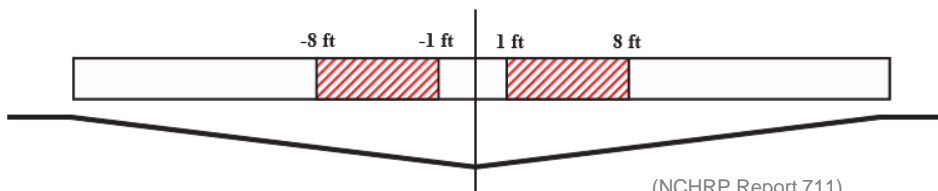
Session 4

4-15

Slope in Front of Cable Guardrail

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

* (For 3 cable Guardrail, ND specifies 10:1 slopes.)



(NCHRP Report 711)

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

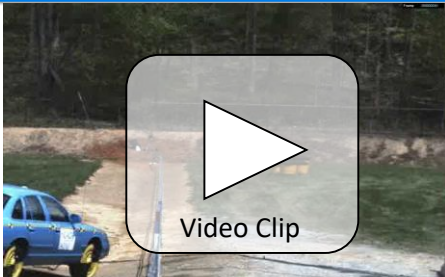
Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – 6.6.1.1, Pg. 6-18



Session 4

4-16

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



Session 4

4-17

HTCB on 4:1 Slope



Video Clip

Maximum Offset 4'


U.S. Department of Transportation
Federal Highway Administration

Next Phase
LEARNING OBJECTIVES

Session 4

4-18

Curbs should not be used along High-Speed Roadways



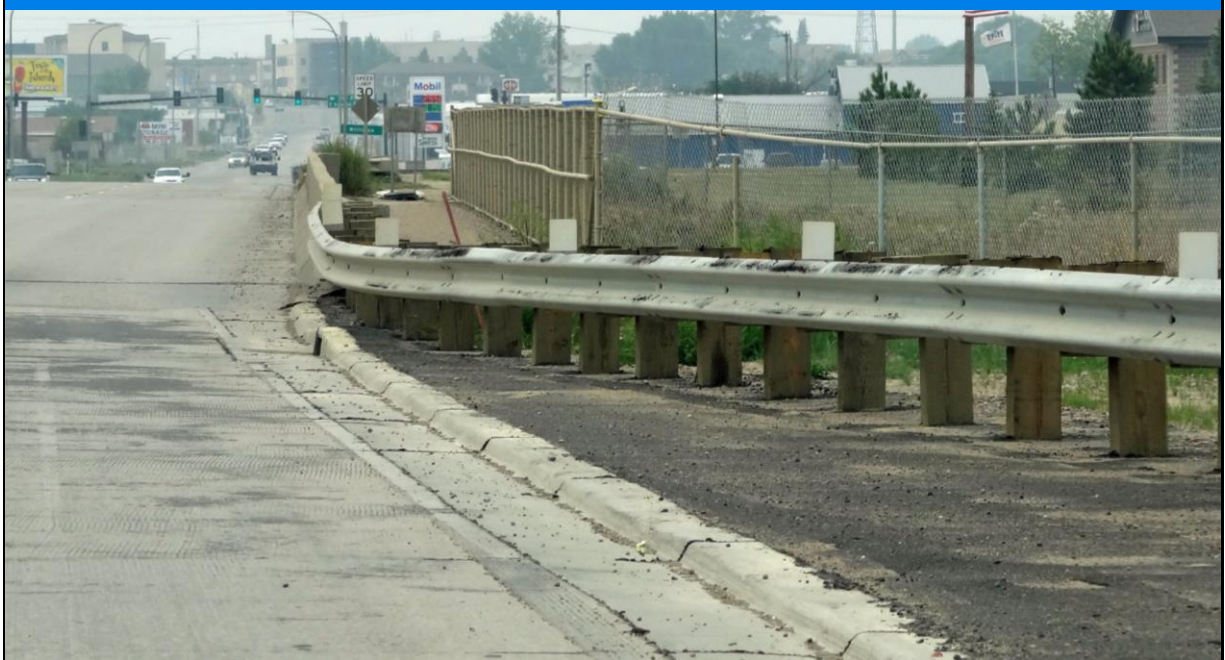
U.S. Department of Transportation
Federal Highway Administration

Next Phase
LEARNING OBJECTIVES

Session 4

4-19

Principle 3: Guardrail and Curbs



U.S. Department of Transportation
Federal Highway Administration

welcome to
North Dakota
LEGENDARY

Session 4

4-20

Guardrail and Curbs

- Curbs – 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 requires special attention.



WELCOME TO
North Dakota
LEGENDARY

Session 4

4-21

Guardrail and Curbs



Video Clip



WELCOME TO
North Dakota
LEGENDARY

Session 4

4-22

W-Beam Guardrail/Curb – **G4** Recommendations – High Speed

Remove curb - Best

Limit curb height to 4" with sloping face.

Stiffen guardrail by:

- Adding rail to back of posts
- Adding a rubrail
- Reducing the post spacing



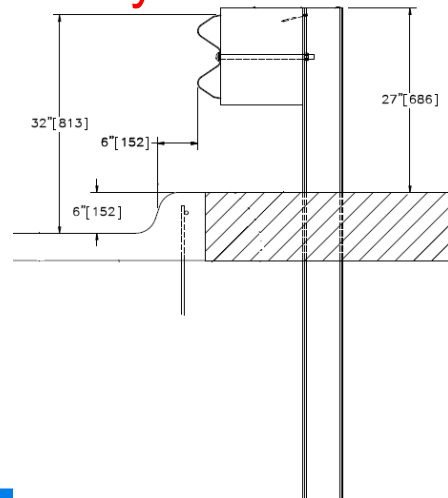
North Dakota
LEGENDARY

Session 4

4-23

MGS and Curbs

Successfully tested to MASH placed 6" behind a 6" high curb at TL-3 – **12" block only**



welcome to
North Dakota
LEGENDARY

Session 4

4-24

MASH TL-3 MGS
Placed 6" behind 6" high Curb



Video Clip

U.S. Department of Transportation
Federal Highway Administration

North Dakota
LEGENDARY

Session 4

4-25



U.S. Department of Transportation
Federal Highway Administration

welcome to
North Dakota
LEGENDARY

Session 4

4-26



MASH TL-2 MGS 6 ft. behind curb



Video Clip


U.S. Department of Transportation
Federal Highway Administration

North Dakota
LEGENDARY

Session 4

4-29

Principle 4: Post Support at Embankment



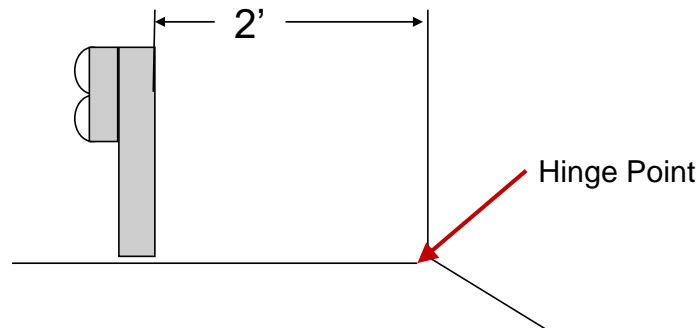
U.S. Department of Transportation
Federal Highway Administration

North Dakota
LEGENDARY

Session 4

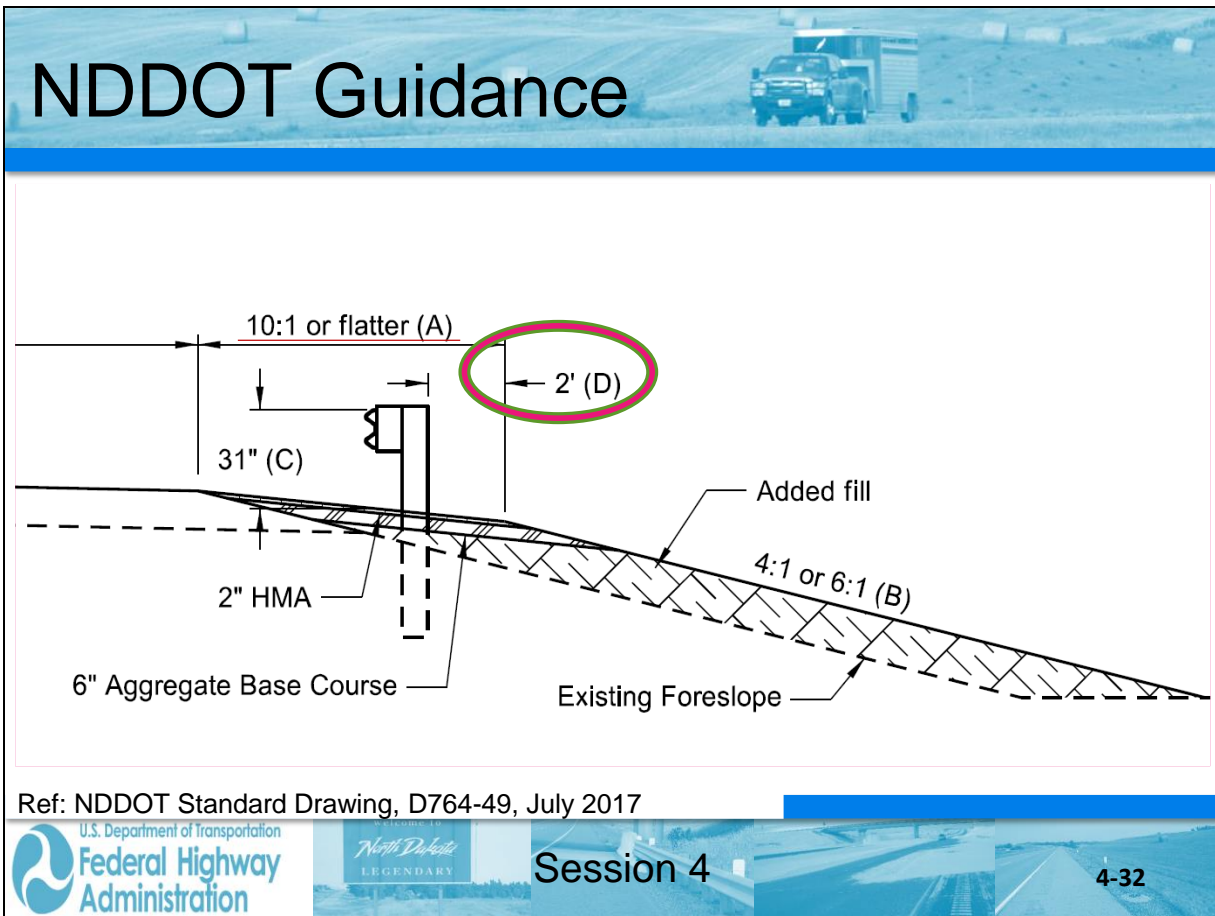
4-30

Soil Backing Recommendation



- 1 A 2 ft. offset to the embankment hinge point is desirable for adequate post support but may vary depending on the embankment slope, soil type and expected impact conditions.
2. Increase embedment length of post if less than 2-ft

Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – FIGURE 5.33, Pg. 5-41



MGS shielding a 2:1 Slope – at Hinge

➤ Adjacent to 2H:1V slope

- Standard steel posts.
- Standard 6'-3" post spacing.



Break-line of 2H:1V Slope

MGS shielding a 2:1 Slope – at Hinge



MGS With Posts on a 2:1 Slope

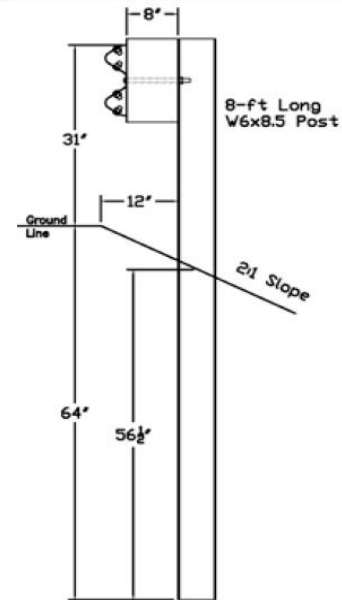
MGS with face of POST ONE foot down from slope break point of 2:1 slope

Posts

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

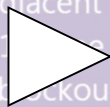
Blocks

- 8" block tested; 12" block accepted



MGS With Posts on a 2:1 Slope

MASH Testing of
MGS adjacent to a
2:1 slope
8" blockout
8' long post at
6'-3" spacing



Video Clip

Eligibility Letter B-211



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)

The slide has a blue header with the title 'Flare Rate' and a blue footer with logos for the U.S. Department of Transportation Federal Highway Administration, North Dakota LEGENDARY, and Session 4, along with the slide number 4-38.

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.



Session 4

4-39

NDDOT Flared Guardrail

NDDOT provides that W-beam guardrail may be flared away from the roadway at the flare rate indicated, dependent on the design speed.

1. In no case should the slope in front of the W-beam guardrail be greater than a 10:1 slope.
2. A minimum length of 25 feet of tangent railing shall be installed in advance of an obstruction.
3. In all cases, a curved section will transition the straight section to the flared section.
4. When conditions will not allow the W-beam guardrail to be flared at the taper rates given, the guardrail should be installed either straight along the shoulder, parallel with the traveled lane, or wherever possible, should be flared at a rate flatter than the standard taper rates. A 50:1 taper rate has been used for unusual conditions.

Ref. NDDOT Design Manual III-13.06 Guardrail Location



Session 4

4-40

NDDOT Flared Guardrail

NDDOT taper rates:

Up to 45 mph - 10:1

50 mph - 11:1

55 mph - 12:1

60 mph - 14:1

65 to 70 mph - 15:1

75 mph - 16:1

Based on NDDOT Design Manual III-13.09



North Dakota
LEGENDARY

Session 4

4-41

Length of Need (LON) Definition

The length of effective barrier needed **IN ADVANCE OF** the area of concern to intercept and redirect an encroaching vehicle.

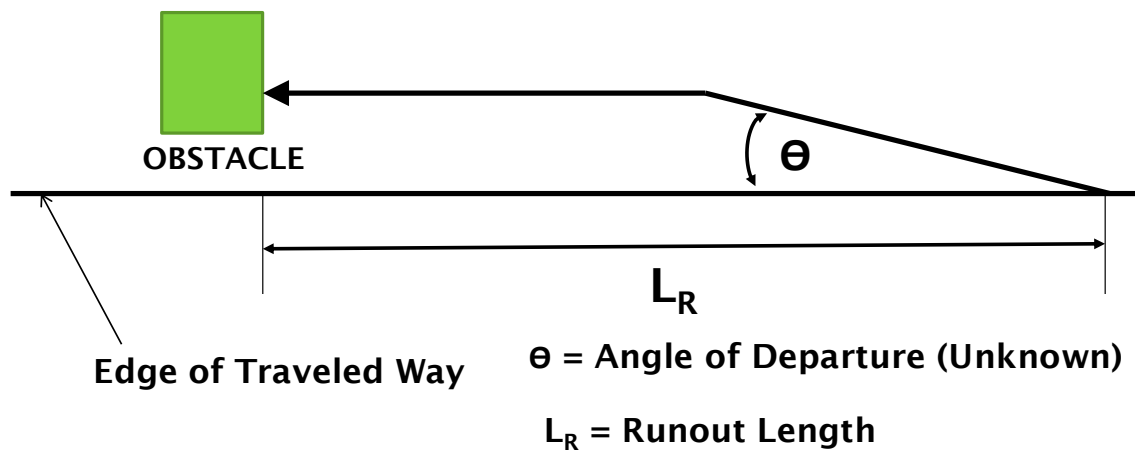


North Dakota
LEGENDARY

Session 4

4-42

Length of Need (LON) Theory



Runout Lengths - NDDOT

Design Speed (mph)	Runout Length (L_R) Given Traffic Volume (ADT) (ft)			
	Over 6,000	2,000 to 6,000	800 to 2,000	Under 800
75	520	485	430	395
70	475	445	395	360
65	450	425	370	345
60	425	400	345	330
55	360	345	315	280
50	330	300	260	245
45	260	245	215	200
40	230	200	180	165
30	165	165	150	140

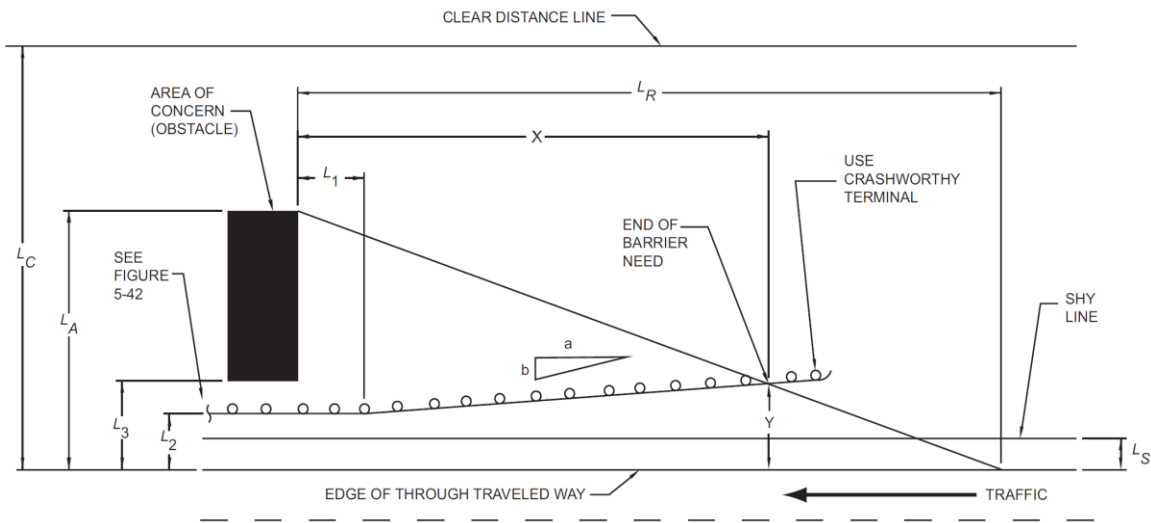
Ref: NDDOT Design Manual, Section III-13, Pg 188, October 2007



Session 4

4-44

LON Design for Approach Barrier Layout



Ref: AASHTO Roadside Design Guide, 4th Edition, Figure 5.39, Pg. 5-49



Session 4

4-45

Length of Need

- Calculating the length of need (X) for straight or nearly straight sections of roadway:

- For flared guardrail installations:

$$X = \frac{L_A + (b/a) (L_1) - L_2}{(b/a) + (L_A/L_R)}$$

- For parallel guardrail installations:

$$X = \frac{L_A - L_2}{L_A/L_R}$$

Ref: AASHTO Roadside Design Guide, 4th Edition, Equation 5-1 and 5-2, Pg 5-51



North Dakota
LEGENDARY

Session 4

4-46

Length of Need

On a two way roadway the procedure is the same except the edge of travelway is the centerline from which the lateral measurements are made.



North Dakota
LEGENDARY

Session 4

4-47

Length of Need (LON) Field Check

- Identify upstream face of obstruction
- Identify back of obstacle –(if the obstruction extends a significant distance away from the travel way – such as a river – limit the back of obstruction to the clear zone)
- Beginning at the upstream face of obstruction, pace upstream along edgeline appropriate runout length
- From this position, sight to the upstream, back edge of obstruction (or clear zone)
- If the proposed (or actual) guardrail installation crosses that line of sight to the back of the obstruction (or clear zone), then the area is adequately covered.



Session 4

4-48

Session 4: Guardrail Design and Site-specific Installation Considerations



Session 4: Guardrail Design and Site-specific Installation Considerations



Guardrail Placement in Special Situations

- Short Radius at Intersecting roadways
- Long Span Guardrail
- Omitted Posts
- Extra Blockouts
- Post in Rock
- Leaveout in Mowing Pads
- Height Transition – G4 to MGS

Guardrail Placement at Intersections





Guardrail Placement at Intersections

- Some designers eliminate this non-crashworthy aspect by using an offset energy-absorbing terminal (if there is room) along the main highway with a run of barrier upstream of the access point based on the LON. Although crashworthy, there is still some risk of a vehicle gating through or passing behind it to enter the area of concern.



Session 4

4-56

Guardrail Placement at Intersections

- Wherever possible, approaches should be relocated rather than providing breaks in the guardrail installation.
- On low-volume, low-speed roadways a curved rail may be placed as shown on Standard Drawing D-764-13. The speeds on the main roadway shall be 55 mph or less and the 750 ADT or less.
- Some alternate designs are illustrated in the following slides.

Ref. Design Manual III- 13.09.01.



Session 4

4-57



Long-Span Guardrail – MGS



Video Clip

Ref: FHWA Eligibility Letter B-189

U.S. Department of Transportation
Federal Highway Administration

North Dakota
LEGENDARY

Session 4

4-60


Long-Span Guardrail

For 27 ¾" Guardrail

- 3 weakened posts on each side of span
- Double blockouts
- Nested rail

For 31" (MGS) Guardrail

- Nested rail not necessary



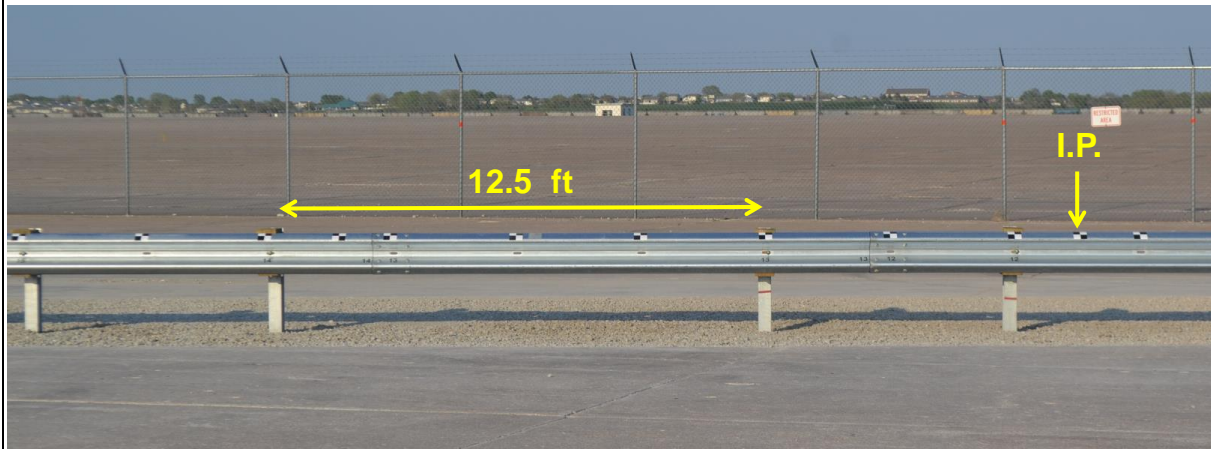
U.S. Department of Transportation
Federal Highway Administration

North Dakota
LEGENDARY

Session 4

4-61

Omitting 1 post – MGS



Removed one post – nothing else done

MASH TL-3 Omitting 1 post – MGS



Condition: Interfering Post Placement



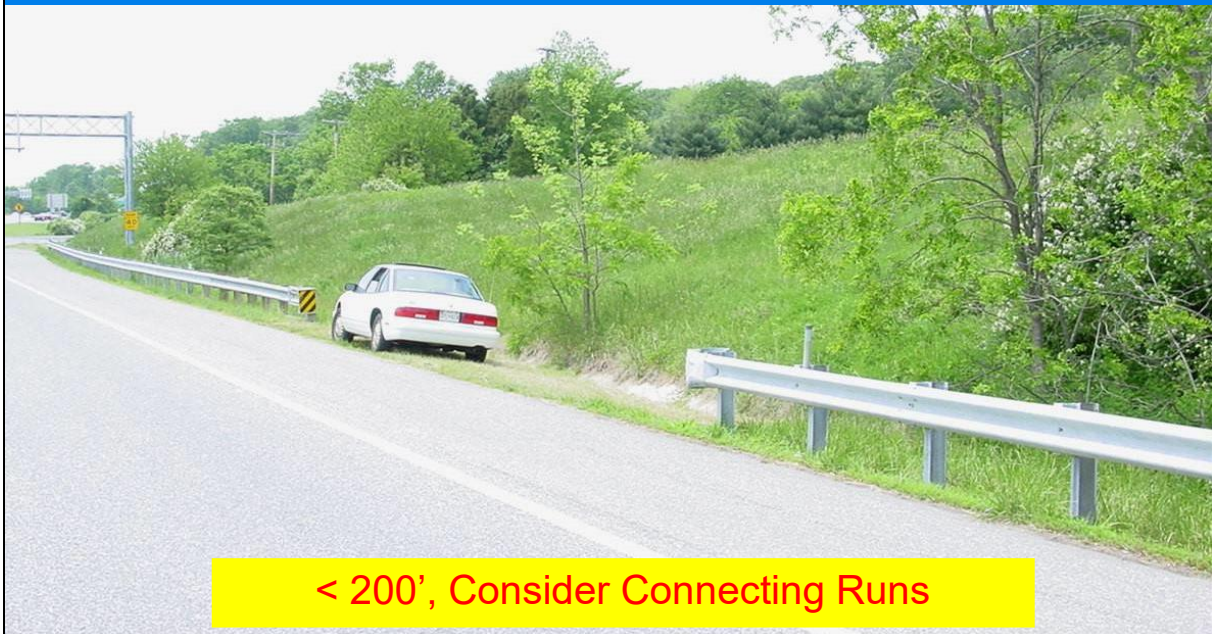
Extra Block-outs (Strong-post W-beam)

- Two block-outs (up to 16" deep) may be used at any time, for any number of posts.
- Three block-outs may be used at one or two posts in a section of guardrail.

No crash tests to date

Ref: AASHTO Roadside Design Guide – 3rd Edition, Section 5.4.1.6

Openings in Barriers



< 200', Consider Connecting Runs

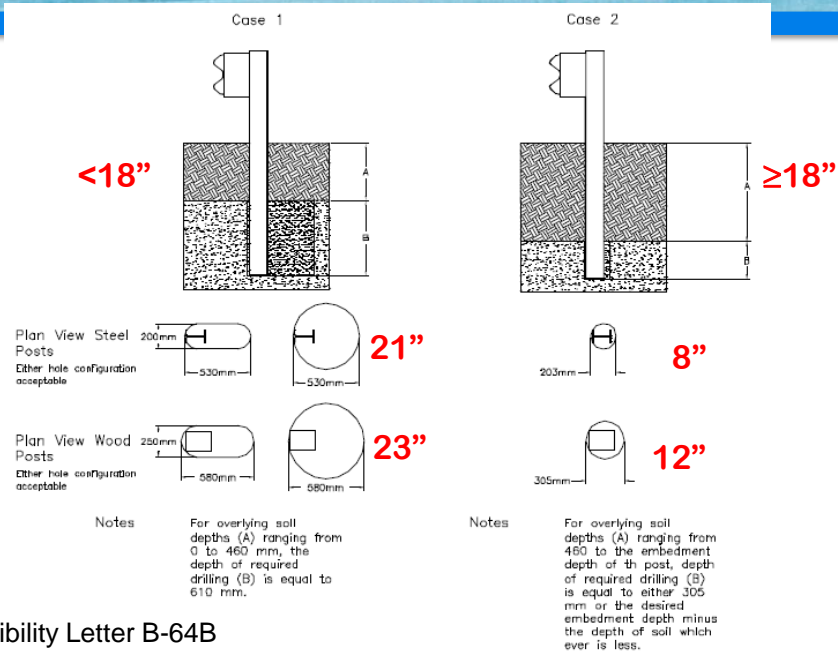
U.S. Department of Transportation
Federal Highway Administration

welcome to
North Dakota
LEGENDARY

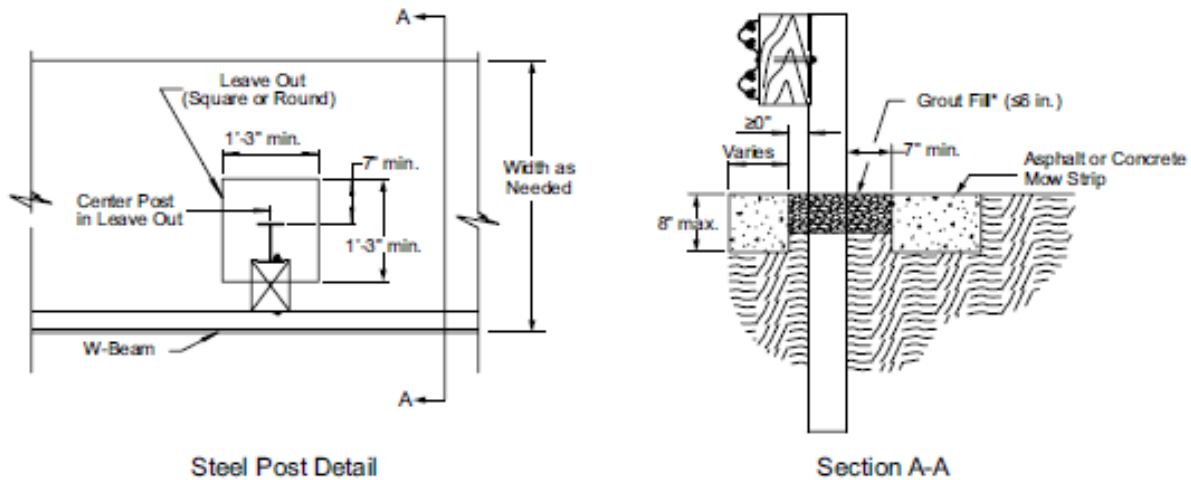
Session 4

4-66

Guardrail Posts in Rock



Leaveouts in Structural Pavement



Ref: AASHTO Roadside Design Guide – 4th Edition, Figure 5-52

Leaveouts in Structural Pavement



Height Transition – G4 to MGS

FHWA recommendation:

You should transition from a 27-3/4 inch tall barrier or terminal to a 31-inch tall barrier over the span of two 12-foot, 6-inch pieces of w-beam rail. When replacing or repairing long portions of a damaged rail the new rail should be installed at the proper design height, transitioning down to the existing rail over the length of two 12 foot, six inch, pieces of rail at either end.



Session 4

4-70

Review Learning Outcomes

- Understand the design principles affecting an optimal barrier installation
- Apply a field procedure to check Length of Need
- Be familiar with special designs to address site-specific installation considerations



Session 4

4-71