

Session 5: Design Principles

Session 5: Design Principles

FAST Act Guardrail Training
Highway Barrier Design Training

**Session 5:
Design Principles**

U.S. Department of Transportation
Federal Highway Administration

North Dakota
LEGENDARY

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

North Dakota
LEGENDARY

Session 5

5-2

Design Options in Order of Preference

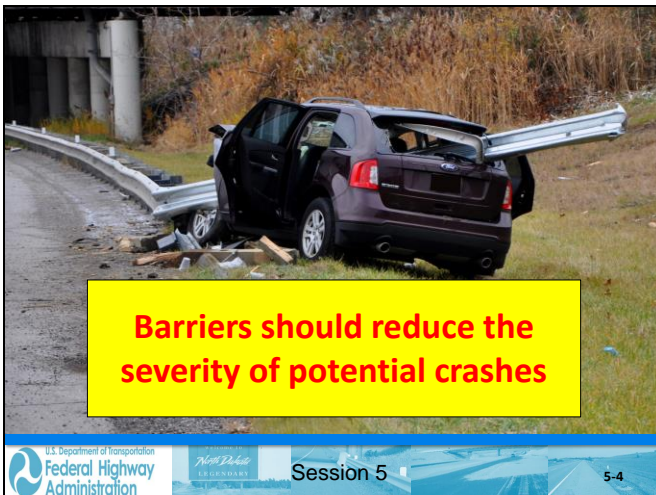
1. Remove the obstruction
2. Make the obstruction traversable
3. Relocate obstruction beyond the clear zone
4. Reduce impact severity by using an appropriate breakaway system
5. SHIELD the obstruction with a longitudinal barrier or crash cushion (only if obstruction cannot be removed, relocated, or redesigned)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

Ref: NDDOT DESIGN MANUAL, Appendix III-14-B, Revised Jan 26, 2016



Session 5

5-3



Session 5

5-4

Guardrail Placement

**Place AS FAR AWAY
as Possible**

without affecting function

U.S. Department of Transportation
Federal Highway Administration

North Dakota
LEGENDARY

Session 5

5-5

Barrier Design Principles

1. Deflection Distance
2. Slope in Front of Barrier
3. Guardrail and Curb
4. Post Support at Embankment
5. Flare Rate

U.S. Department of Transportation
Federal Highway Administration

North Dakota
LEGENDARY

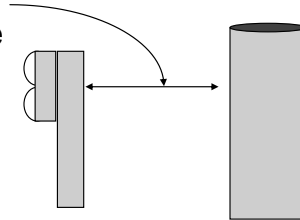
Session 5

5-6

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.



Deflection Distance / Working Width

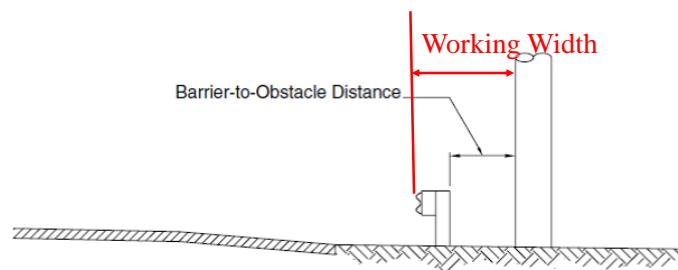


Figure 5-33. Recommended Barrier Placement for Optimum Performance

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

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



North Dakota
LEGENDARY

Session 5

5-9

Zone of Intrusion – Truck Lean-over



North Dakota
LEGENDARY

Session 5

5-10

ND Deflection Distance



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

Principle 2: Slope in Front of Barrier



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



Session 5

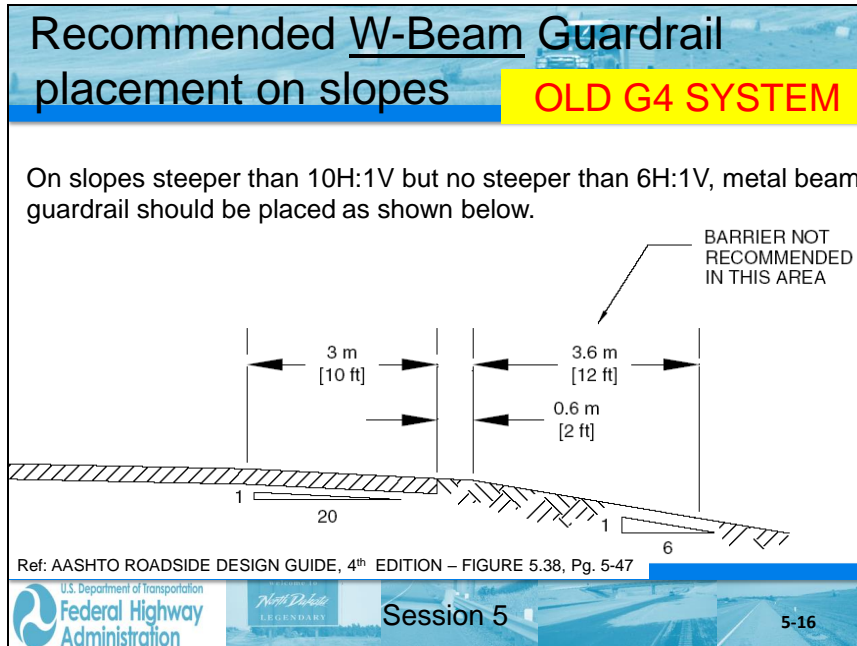
5-13

Principle 2: Slope in Front of Barrier



Session 5

5-14



**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 5

5-17

NDDOT Guidance – Slope in Front

10:1 or flatter (A)

31" (C)

2" (D)

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 5

5-18

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.



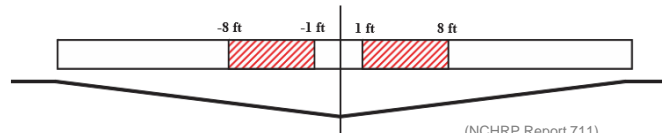
North Dakota
LEGENDARY

Session 5

5-19

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.)



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

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

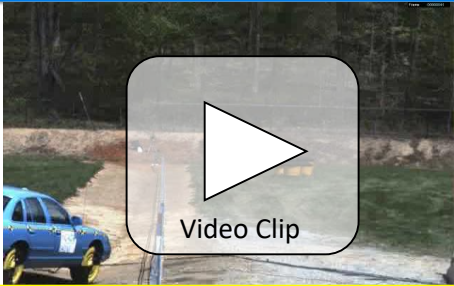


North Dakota
LEGENDARY

Session 5

5-20

Location of Cable in Swales



Video Clip

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

U.S. Department of Transportation
Federal Highway Administration

North Dakota
LEGISLATIVE

Session 5

5-21

HTCB on 4:1 Slope



Video Clip

Maximum Offset 4'


U.S. Department of Transportation
Federal Highway Administration

North Dakota
LEGISLATIVE

Session 5

5-22

Curbs should not be used along High-Speed Roadways

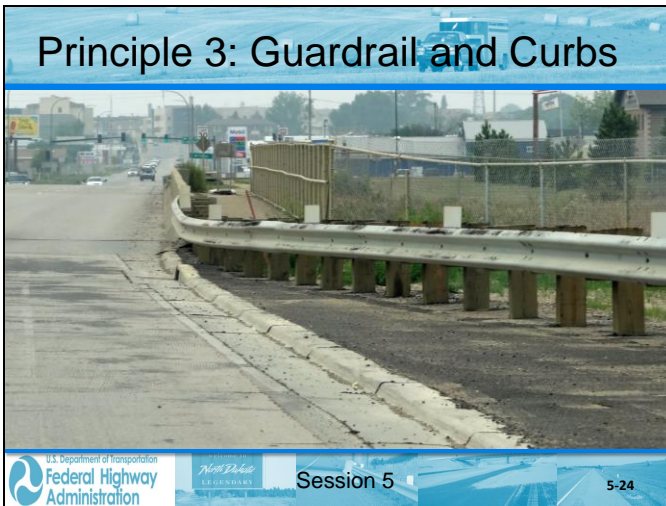


U.S. Department of Transportation
Federal Highway Administration

North Dakota
LEGISLATIVE

Session 5

5-23



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.


U.S. Department of Transportation
Federal Highway Administration

North Dakota
LEGENDARY

Session 5

5-25

Guardrail and Curbs



Video Clip

U.S. Department of Transportation
Federal Highway Administration

North Dakota
LEGENDARY

Session 5

5-26

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

U.S. Department of Transportation
Federal Highway Administration

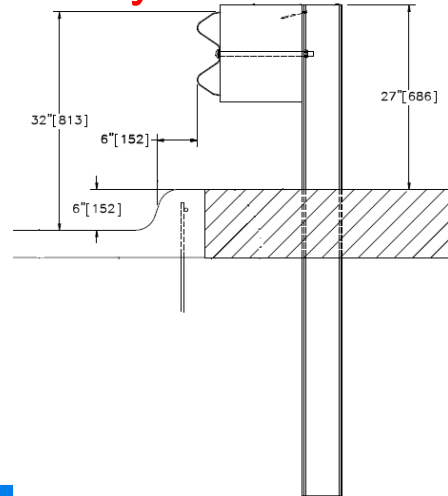
welcome to
North Dakota
LEGENDARY

Session 5

5-27

MGS and Curbs

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



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



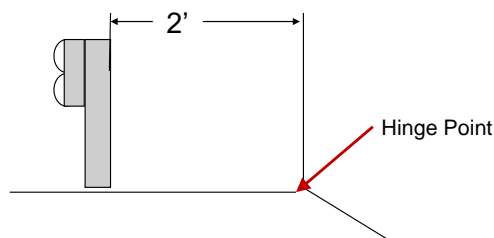




Principle 4: Post Support at Embankment



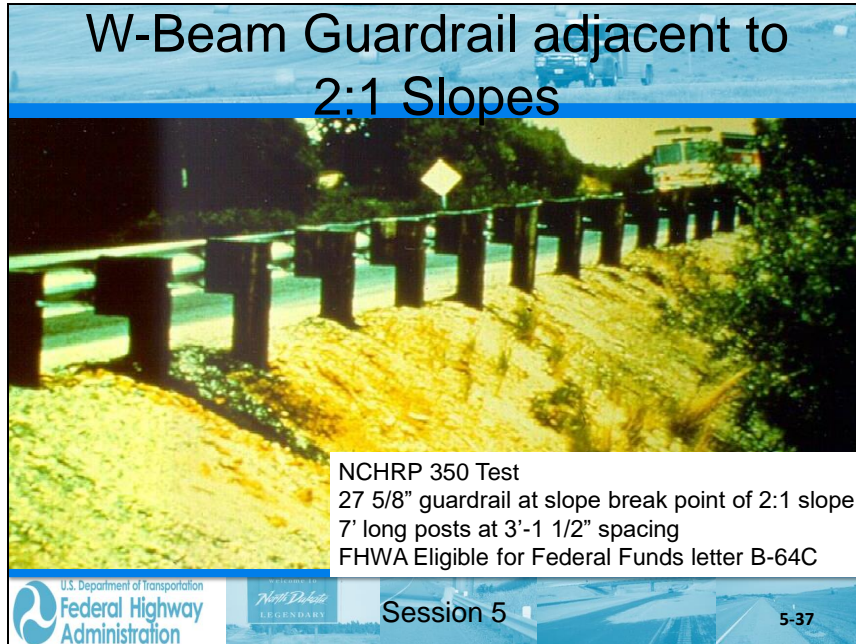
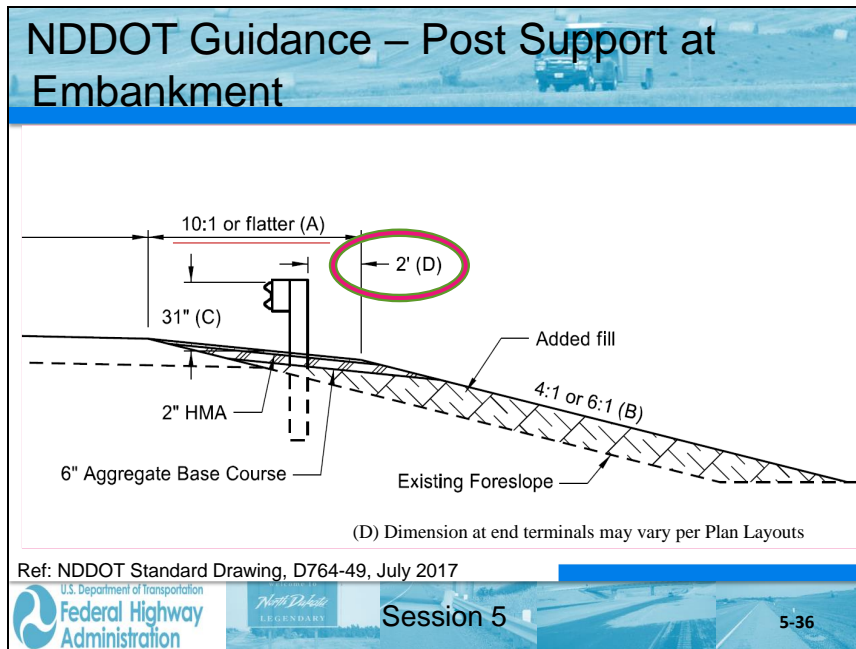
Soil Backing Recommendation



- 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

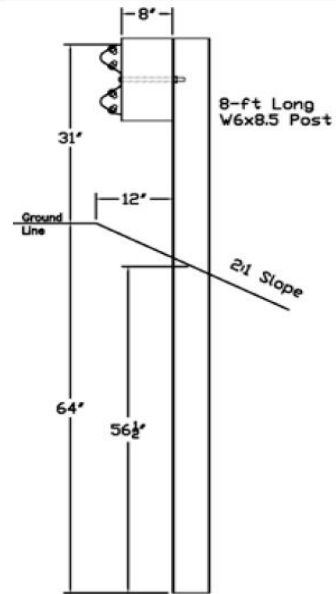
MGS with face of POST ONE foot down from slope break point of 2:1 slope

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
8" breakout
8' long
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 5, with the number 5-43.

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 5

5-44

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 5

5-45

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 5

5-46

Suggested Flare Rates

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]		Rigid Barrier	Semi-Rigid Barrier
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.

Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – Table 5-9



North Dakota
LEGENDARY

Session 5

5-47

Flared W-Beam Guardrail Example



Review Learning Outcomes

Understand the design principles affecting an optimal barrier installation