Reducing Roadway Departure Crashes

Day 3

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Agenda

- Part 1 – Introduction and Overview
- Part 2 – Implementation Approaches
- Part 3 – Keeping Vehicles on the Road: Signing and Delineation (continued)
- *Part 4 – Keeping Vehicles on the Road: Pavement and Geometric (continued)*
- *Part 5 – Improve the Recovery Area*
- *Part 6 – Minimize Severity of Crashes*

Part 5

Improve the Recovery Area

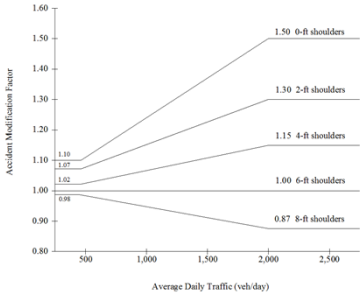
Part 5 Learning Outcome

Describe countermeasures to reduce potential for vehicles to crash if they leave the roadway.

Shoulder Widening

- Shoulders are where recovery begins
- Shoulders most critical on horizontal curves

CMF's for Shoulder Width on 2-Lane Rural Roads

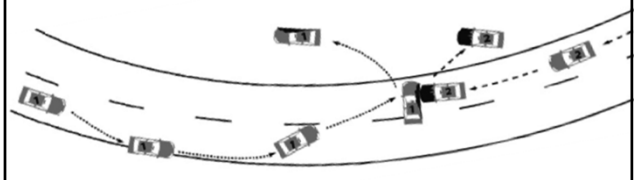


A Significant Roadside Hazard: The Edge Drop-Off

3-7

Typical Pavement Edge Drop-Off Crash

Pavement edge drop-offs:
- following resurfacing, OR
- settling, erosion, tire wear

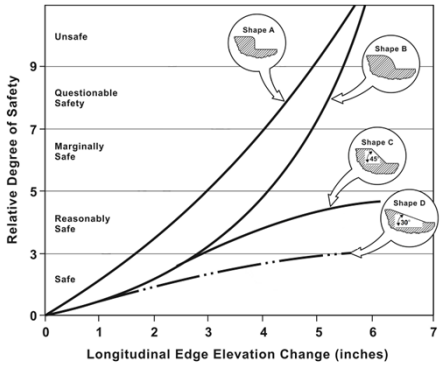


"Classic" Edge Drop-Off Crash (Fatal)

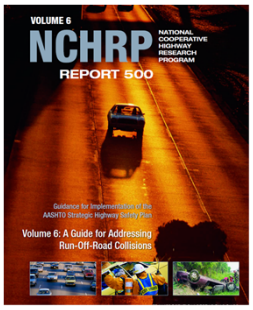
Risk Factors Associated with Pavement Edge Drop-Off Crashes

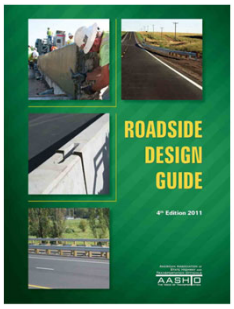
- Speed
- Driver Experience
- Vehicle/Tires
- Drop-Off Height
- **Shape of Pavement Edge**

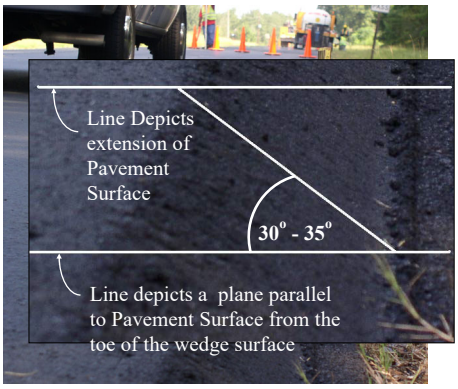
Edge Shape and Relative Risk



Safety Edge







Safety Edge Installation

"Shoe" Installed in Screed

3-15

Safety Edge Installation (cont'd)

The "Safety Edge"

3-16

Another Benefit--Increased Edge Compaction

With Safety Edge

Without Safety Edge

Benefits of A Safety Edge

- Immediate and long-term mitigation to drop-offs by helping vehicles maintain stability, particularly on roadway re-entry
- Reduce tort liability
- Cost less than 3% of material costs
- Increased pavement edged durability

Durability

Completed Safety Edge Project

8 Years After Construction

With Safety Edge

Without Safety Edge

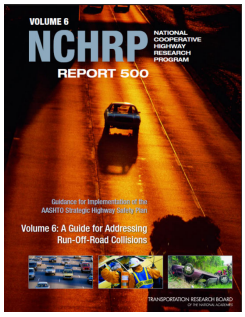
Project constructed July 2003
Photos taken June 2011

Safety Benefits of Safety Edge

- Consolidating pavement edge into 30° shape during paving to provide stability for vehicles recovering from a roadway departure
- CMF = 0.94 for total crashes
- B/C range: 4 to 63

Design Safer Slopes and Ditches to Prevent Rollovers

- 15.1 B – Minimize the likelihood of crashing into an object or overturning if the vehicle travels off the shoulder

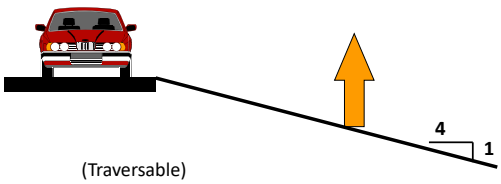


Steepness Categories of Slopes

- Recoverable - 4:1 or Flatter **
- Non-Recoverable: 3:1 to 4:1 **
- Critical: Steeper than 3:1

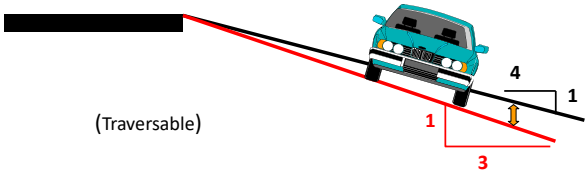
**Traversable

Recoverable



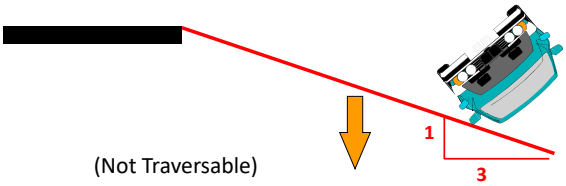
(Traversable)

Non-Recoverable



(Traversable)

Critical



(Not Traversable)

Recoverable Slope?

Effect of Flattening Slopes on Crashes

Table 13-18. Potential Crash Effects on Total Crashes of Flattening Sideslopes (15)

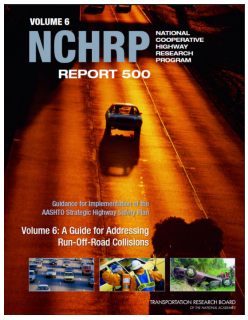
Treatment	Setting (Road Type)	Traffic Volume	Crash Type (Severity)	CMF			
				Sideslope in Before Condition	Sideslope in After Condition		
					1V:4H	1V:5H	1V:6H	1V:7H
Flatten Sideslopes	Rural (Two-lane road)	Unspecified	All types (Unspecified)	1V:2H	0.94	0.91	0.88	0.85
				1V:3H	0.95	0.92	0.89	0.85
				1V:4H		0.97	0.93	0.89
				1V:5H			0.97	0.92
				1V:6H				0.95

Base Condition: Existing sideslope in *before* condition.

NOTE: Standard error of the CMF is unknown.

Remove/Relocate Objects in Hazardous Locations

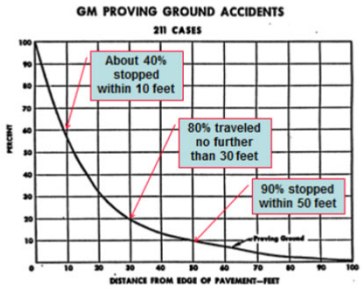
15.1 B – Minimize the likelihood of crashing into an object or overturning if the vehicle travels off the shoulder.



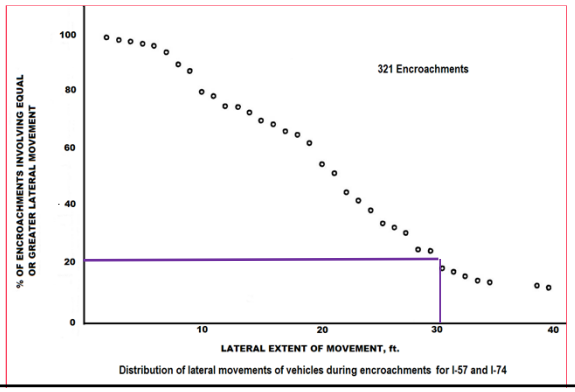
Clear Zone

The unobstructed, traversable area provided beyond the edge of the through traveled way for the recovery of errant vehicles.

Basis for Clear Zone



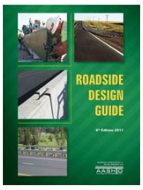
Median Study - Illinois



Distribution of lateral movements of vehicles during encroachments for I-57 and I-74

Clear Zone

- As a result, a 30-ft clear zone was adopted by AASHTO
- In the 1970's, the 30 feet was adjusted to reflect speed, side slope and ADT



Current AASHTO Clear Zone

U.S. Customary Units

Design Speed (mph)	Design ADT	Foreslopes			Backslopes		
		1V:6H or flatter	1V:5H to 1V:4H	1V:3H	1V:3H	1V:5H to 1V:4H	1V:6H or flatter
≤40	UNDER 750[c] 750–1500 1500–6000 OVER 6000	7–10 10–12 12–14 14–16	7–10 12–14 14–16 16–18	[b] [b] [b] [b]	7–10 12–14 14–16 16–18	7–10 12–14 14–16 16–18	7–10 12–14 14–16 16–18
45–50	UNDER 750[c] 750–1500 1500–6000 OVER 6000	10–12 14–16 16–18 20–22	12–14 16–20 20–26 24–28	[b] [b] [b] [b]	8–10 10–12 12–14 14–16	8–10 12–14 14–16 18–20	10–12 14–16 16–18 20–22
55	UNDER 750[c] 750–1500 1500–6000 OVER 6000	12–14 16–18 20–22 22–24	14–18 20–24 24–30 26–32[a]	[b] [b] [b] [b]	8–10 10–12 14–16 16–18	10–12 14–16 16–18 20–22	10–12 16–18 20–22 22–24
60	UNDER 750[c] 750–1500 1500–6000 OVER 6000	16–18 20–24 26–30 30–32[a]	20–24 26–32[a] 32–40[a] 36–44[a]	[b] [b] [b] [b]	10–12 12–14 14–18 20–22	12–14 16–18 18–22 24–26	14–16 20–22 24–26 26–28
65–70[d]	UNDER 750[c] 750–1500 1500–6000 OVER 6000	18–20 24–26 28–32[a] 30–34[a]	20–26 28–36[a] 34–42[a] 38–46[a]	[b] [b] [b] [b]	10–12 12–16 16–20 22–24	14–16 18–20 22–24 26–30	14–16 20–22 26–28 28–30

Remember

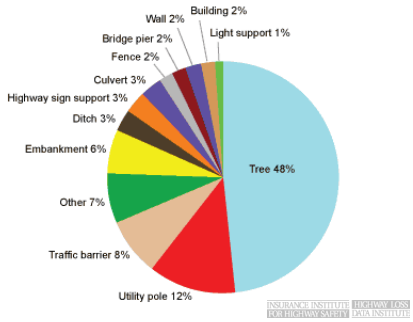
- AASHTO guidance is based on assumption that 20% of vehicles will exceed the clear zone

Clear Zone Adjustment for Horizontal Curves

Radius, m [ft]	Design Speed km/h [mph]					
	60 [40]	70 [45]	80 [50]	90 [55]	100 [65]	110 [70]
900 [2,950]	1.1	1.1	1.1	1.2	1.2	1.2
700 [2,300]	1.1	1.1	1.2	1.2	1.2	1.3
600 [1,970]	1.1	1.2	1.2	1.2	1.3	1.4
500 [1,640]	1.1	1.2	1.2	1.3	1.3	1.4
450 [1,475]	1.2	1.2	1.3	1.3	1.4	1.5
400 [1,315]	1.2	1.2	1.3	1.3	1.4	—
350 [1,150]	1.2	1.2	1.3	1.4	1.5	—
300 [985]	1.2	1.3	1.4	1.5	1.5	—
250 [820]	1.3	1.3	1.4	1.5	—	—
200 [660]	1.3	1.4	1.5	—	—	—
150 [495]	1.4	1.5	—	—	—	—
100 [330]	1.5	—	—	—	—	—

Percent Distribution of Fixed Object Crash Deaths by Object Struck (2008)

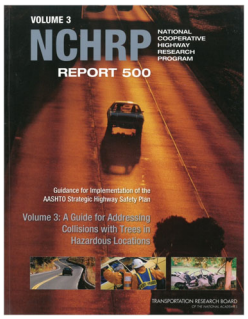
Poll



http://www.iihs.org/research/fatality_facts_2008/roadsidehazards.html

Emphasis Area 16.1 Crashes with Trees in Hazardous Locations

- 16.1A Prevent trees from growing in hazardous locations
- 16.1B Eliminate the hazardous condition and/or reduce severity of the crash



16.1A—Prevent Trees from Growing in Hazardous Locations

A1. Develop, revise and implement planting guidelines to prevent placing trees in hazardous locations.

A2. Mowing and vegetation control guidelines

16.1B—Eliminate the Hazardous Condition and/or Reduce Severity of Crash

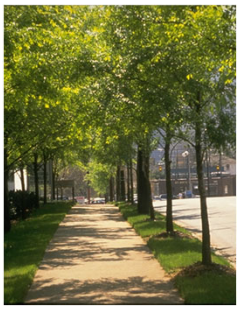
B1. Remove trees in hazardous locations

B2. Shield motorists from striking trees

B3. Modify clear zone in vicinity of trees

B4. Delineate trees in hazardous locations

Avoid Placing Trees in Hazardous Locations



Remove Trees in Hazardous Locations

Focus on trees that are:

- Close to traveled way
- Outside of curves

Don't Forget the Stumps

How Do You Address Corridors with Dense Trees That Are Close to Traveled Way?

Percent Reduction for Relocation of Roadside Hazards

- NCHRP 440 – Accident Mitigation Guide for Congested Rural Two-Lane Highways

Δ Distance	Trees	Mailbox, signs, …	Guiderail	Fences
3’	22%	14%	36%	20%
5’	34%	23%	53%	30%
8’	49%	34%	70%	44%
10’	57%			

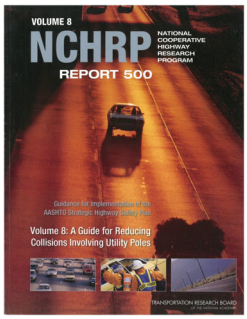
Shield Motorists from Striking Trees

Shield Motorists from Striking Trees (2)

Delineate Trees in Hazardous Locations

Emphasis Area 16.2 Collisions Involving Utility Poles

- Objectives address treating specific poles, preventing placement of poles in high-risk locations and treating poles along a corridor



Alternative Safety Treatments For Utility Poles

- Place Utility Lines Underground
- Increase Lateral Offset
- Relocate to Less Vulnerable Location
- Increase Pole Spacing
- Multiple Pole Use
- Breakaway Design

Breakaway Utility Pole

Post-Crash View of Breakaway Pole (Massachusetts)

Impacting Vehicle (Driver Walked Away)

Countermeasures for Utility Poles

- Locate poles outside of traveled way!

Countermeasures for Utility Poles

- Locate pole behind guardrail!

Delineate Roadside Objects

Part 5 Learning Outcome

Describe countermeasures to reduce potential for vehicles to crash if they leave the roadway.

Exercise: Countermeasures for Roadside Hazards

- What counter-measures have you learned about today that you could apply to this location? Poll
- What crash reduction might we expect from each?

Note: The area on the right is part of the Franklin D. Roosevelt home/ Presidential Library (National Park Service) in Hyde Park, NY.

Questions??

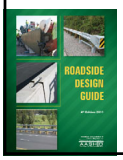
Part 6

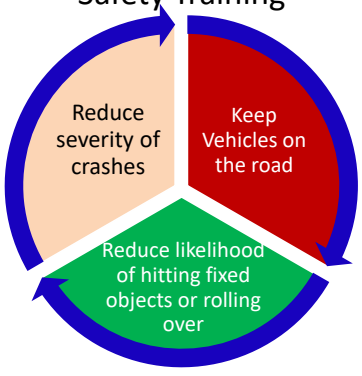
Minimize Severity of Crashes

Part 6 Learning Outcome

Describe the basics of countermeasures to minimize the severity of roadway departure crashes.

Roadway Departure Safety Training





Emphasis Area 15.1—Addressing Run-Off Road Collisions

- 15.1C Reduce the severity of the crash
  - -- C1. Improve design of roadside hardware (e.g., light poles and signs)
  - -- C2. Improve design and application of barriers and attenuation systems

Roadside Design Strategies

1. Remove the obstacle
2. Redesign the object for safe traversal
3. Relocate the obstacle further from the road
4. Reduce obstacle severity (make breakaway)
5. Shield the obstacle
6. Delineate the obstacle

Remove the Hazard

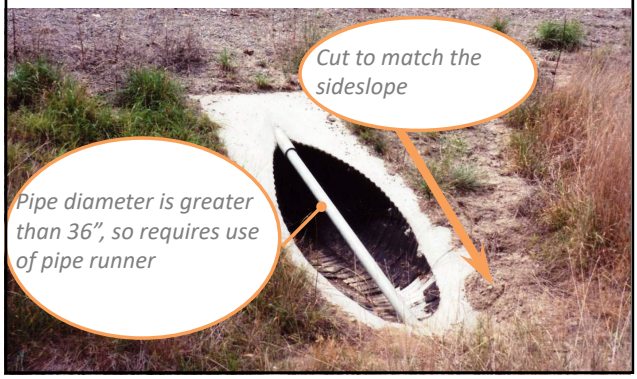
Make Traversable

Traversable?

Traversable?

- Single pipes up to 36”, cut to match the sideslope.
- 30” between pipes on sideslopes up to 3:1.

Opening Wider than 36”



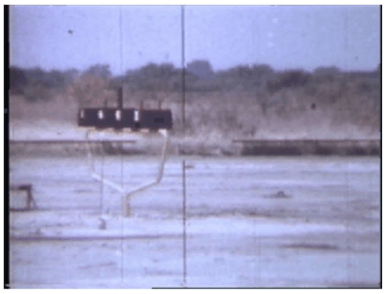
Re-Designed for Safe Traversal

Parallel Culverts

Single pipes up to 24”, cut to match the sideslope

Relocate

4. Make Crashworthy

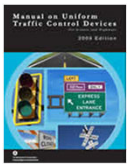


Strategy 4: Breakaway Supports

- Reduce severity by providing breakaway hardware
  - -- sign supports
  - -- luminaire supports
  - -- utility poles

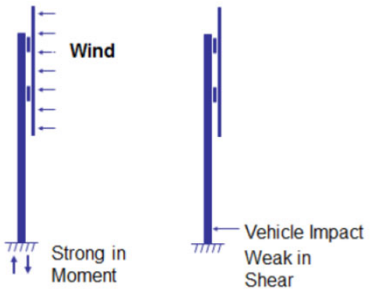
Strategy 4: Breakaway Supports

- MUTCD requires crashworthy sign supports on all public roads (Section 2A-19)



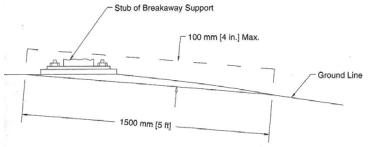
Crashworthy Support?

Sign Supports



Sign Support Design

- Breakaway mechanism (base-bending, fracture or slip base)
- Hinge
- Stub height



Replace/Relocate Non-Crashworthy Sign Supports

- Sign supports are required to be crashworthy
- Acceptable sign supports for small signs from ITE *Traffic Control Devices Handbook*

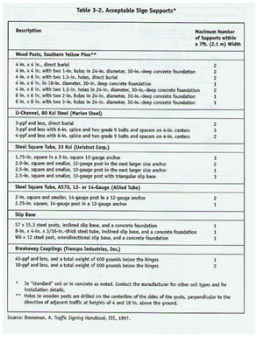


Table 3-2. Acceptable Sign Supports*

Description	Maximum Number of Supports within a 7ft. (2.1 m) Width
Wood Posts, Southern Yellow Pine**	
4 in. x 4 in., direct burial	2
4 in. x 4 in. with two 1-in. holes in 24-in. diameter, 30-in.-deep concrete foundation	2
4 in. x 6 in. with two 1.5-in. holes, direct burial	2
4 in. x 6 in. in 18-in. diameter, 30-in. deep concrete foundation	1
4 in. x 6 in. with two 1.5-in. holes in 24-in. diameter, 30-in.-deep concrete foundation	2
6 in. x 6 in. with two 2-in. holes in 24-in. diameter, 30-in.-deep concrete foundation	1
6 in. x 8 in. with two 3-in. holes in 24-in. diameter, 30-in.-deep concrete foundation	1
U-Channel, 80 Kzl Steel (Marion Steel)	
3-psf and less, direct burial	2
3-psf and less with 4-in. splice and two grade 5 bolts and spacers on 4-in. centers	3
4-psf and less with 4-in. splice and two grade 5 bolts and spacers on 4-in. centers	2
Steel Square Tube, 33 Ksi (Unistrut Corp.)	
1.75-in. square in a 2-in. square 12-gauge anchor	3
2.0-in. square and smaller, 12-gauge post in the next larger size anchor	2
2.5-in. square and smaller, 10-gauge post in the next larger size anchor	1
2.5-in. square and smaller, 10-gauge post with triangular slip base	3
Steel Square Tube, A570, 12- or 14-Gauge (Allied Tube)	
2-in. square and smaller, 14-gauge post in a 12-gauge anchor	2
2.25-in. square, 10-gauge post in a 12-gauge anchor	1
Slip Base	
3" x 10.3 steel posts, inclined slip base, and a concrete foundation	1
8-in. x 4-in. x 5/16-in.-thick steel tube, inclined slip base, and a concrete foundation	1
W6 x 12 steel post, omnidirectional slip base, and a concrete foundation	1
Breakaway Couplings (Transpo Industries, Inc.)	
45-psf and less, and a total weight of 600 pounds below the hinges	1
18-psf and less, and a total weight of 600 pounds below the hinges	2

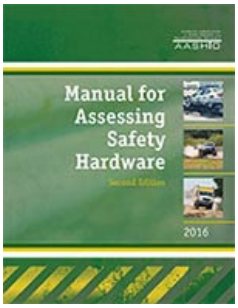
* In "standard" soil or in concrete as noted. Contact the manufacturer for other soil types and for installation details.

** Holes in wooden posts are drilled on the centerline of the sides of the posts, perpendicular to the direction of adjacent traffic at heights of 4 and 10 in. above the ground.

Source: Brenneman, A. *Traffic Signing Handbook*, ITE, 1997.

Hardware Testing

- NCHRP Report 350 was adopted by FHWA in 1993
- Currently use AASHTO Manual for Assessing Safety Hardware (2016)



Example of MASH Test Matrix for Traffic Barrier Systems

Test Level	Test Vehicle Designation and Type	Test Conditions		
		Vehicle Weight kg [lb]	Speed km/h [mph]	Angle Degree
1	1100C (Passenger Car) 2270P (Pickup Truck)	1,100 [2,420] 2,270 [5,000]	50 [31] 50 [31]	25 25
2	1100C (Passenger Car) 2270P (Pickup Truck)	1,100 [2,420] 2,270 [5,000]	70 [44] 70 [44]	25 25
3	1100C (Passenger Car) 2270P (Pickup Truck)	1,100 [2,420] 2,270 [5,000]	100 [62] 100 [62]	25 25
4	1100C (Passenger Car) 2270P (Pickup Truck) 10000S (Single Unit Truck)	1,100 [2,420] 2,270 [5,000] 10,000 [22,000]	100 [62] 100 [62] 90 [56]	25 25 15
5	1100C (Passenger Car) 2270P (Pickup Truck) 36000V (Tractor/Van Trailer)	1,100 [2,420] 2,270 [5,000] 36,000 [79,300]	100 [62] 100 [62] 80 [50]	25 25 15
6	1100C (Passenger Car) 2270P (Pickup Truck) 36000T (Tractor/Tanker Trailer)	1,100 [2,420] 2,270 [5,000] 36,000 [79,300]	100 [62] 100 [62] 80 [50]	25 25 15

Test Vehicle Designation

- New vehicle is a 2270P Quadcab Pickup (5000 lbs)
- Quadcab Pickup has a higher center of gravity and more closely resembles the large SUV's

Shield

MASH Testing of W-Beam Guiderail

- Standard W-Beam
- 27 5/8” height of rail
- Midwest Guardrail
- 31” height of rail

Barrier Installation Issues

Barrier Warranted Here?

Poll

Barrier Warranted Here?

Poll

Turned Down Ends

Crashworthy Terminals

- Tangent versus Flared
- Energy Absorbing vs Non-Energy Absorbing

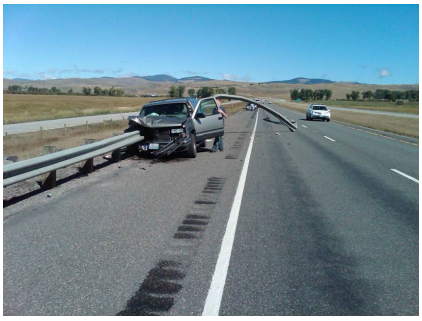


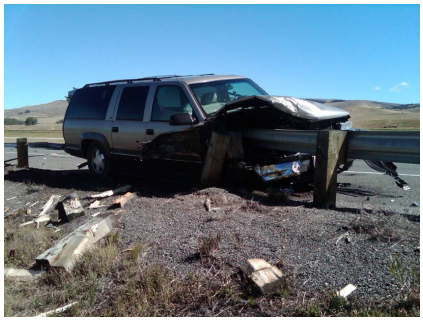

Good Terminal – Bad Installation

Shield Obstacles

- New Barrier for
  -- Slopes
  -- Fixed Objects
  -- Median Barrier
- Upgrading existing hardware

**Remember, barriers themselves are roadside obstacles





Barrier Evaluation Criteria

- Structural adequacy of the tested feature
- Occupant risk
- Vehicle trajectory after impact

Barrier Classification

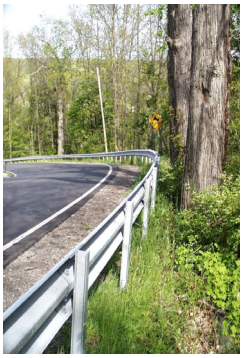
TYPE	DEFLECTION
Flexible	Over 5 Feet
Semi-Rigid	2 - 5 Feet
Rigid	0 - 1 Foot

Barrier Installation/Maintenance Issues

- Barrier-to-Hazard Distance
- Curbs
- Terminals
- Mounting Height
- Post Support
- Barrier to Barrier Transitions

Barrier-to-Hazard Distance

- What do you think?



Guardrail and Curbs
What Do You Think?

Lack of Proper Post Support

Guardrail Maintenance

- Check hardware periodically
  - Bolt torque and cable tension
  - Crash damage
  - Corrosion or rot
  - Obsolete rail
- Check height

Barrier-to-Barrier Transitions


Gradually Increase Stiffness

TL-2 W-Beam Transition

- NCHRP 350
- W6X9 posts
- Additional posts are added at half the spacing
- Nested W-Beam

TL-3 MGS Thrie-Beam Transition

- Additional posts are added at half the spacing
- Larger and longer posts
- Thrie-beam rail is nested
- Non-Symmetrical Thrie-Beam to W-Beam

Update/Replace Roadside Hardware

Update/Replace Roadside Hardware

Update/Replace Roadside Hardware

Update/Replace Roadside Hardware

Roadside Cable Barrier

Roadside Cable Barrier

Delineate

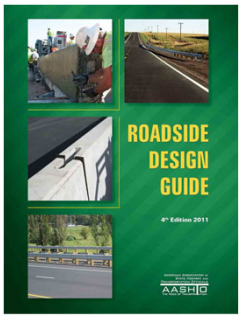
Delineate

Examples of Barrier Delineation

Examples of Barrier Delineation (cont'd)

Mailboxes—Chapter 11, RDG

- Sensitive issue since postal patrons may view their mailboxes as an extension of themselves and part of their domain.



What Do You Think?

What Do You Think?

What Do You Think?

Mailboxes (cont'd)

- Mailboxes supported by structures such as masonry columns, railroad ties, tractor wheels, plow blades and the like can turn a single mailbox installation into a roadside hazard.

General Guidelines and Principles

- Typical light-weight sheet metal mailboxes mounted on 4"x 4" wood post or 1½" dia. light-gage pipe is not a serious threat to motorists.
- Improvements to strengthen typical post-to-box mounting details would further reduce threat
- Agencies should adopt regulations for design and placement of mailboxes within public ROW

Part 6 Learning Outcome

Describe the basics of countermeasures to minimize the severity of roadway departure crashes.

Exercise 1--Urban 2-Lane Road

- Speed limit: 35 mph
- ADT: 4,500 vpd
- No shoulder
- One streetlight
- Vertical drop to the I&M Canal is 9 feet
- Normal cross slope for outside lane

Collision Information

- 6 Run-Off-The-Road Crashes in 3 years –

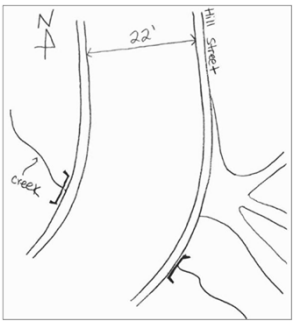
  -- 1 daytime
  -- 5 night
  -- 2 involved vehicles in the canal

What Are Your Ideas to Improve Safety on This Section of Road?

Exercise 2: Rural Two-Lane Road Exercise

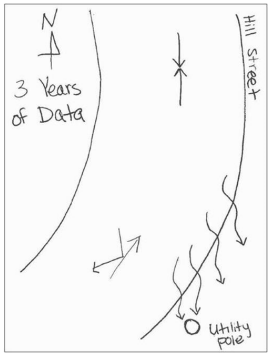
- Analyze available information
- Define problem or contributing factors
- Identify appropriate countermeasures

Condition Diagram



- Posted Speed Limit = 35 mph
- Turf Shoulders of Variable Width
- 6 % Superelevation
- Radius = 110'

Collision Diagram



3 Years Crash Data

- 4 Run-off-road
  - 1 overturned
  - 1 went into creek
  - 2 struck utility pole
- 1 Sideswipe Opposite
- 1 Head-on

Site Photographs

Southbound View From Upstream Of Curve

Site Photographs

Southbound View Of Curve

5-133

Site Photographs

Northbound View Of Curve

5-134

Site Photographs

Evidence of Vehicles Running Off Road on Outside of Curve

5-135

Your Task

- Identify any crash patterns
- If there are patterns, what are the underlying causes/contributing factors
- Identify appropriate countermeasures to address any problems

Questions??