# PARTICIPANTS NOTEBOOK

## November 17, 2016

# INTRODUCTION

This one-day training session is one of the deliverables under FHWA Contract DTFH61-10-D-00021, Roadside Safety Systems Inspection, Maintenance and Designer Program. The program objective is to assist local transportation agencies by providing their personnel with the appropriate information needed to ensure optimal barrier installations. The program provides the following deliverables:

- Roadside Safety Systems Design, Inspection and Maintenance Training
- Roadside Safety Pocket Guide
- 5 – one page Technical Briefs:
    - Tech Brief 1 – Maintenance of Traffic Barrier Systems
    - Tech Brief 2 – Drive-by Inspection of Safety Hardware
    - Tech Brief 3 – Damaged Roadside Hardware; Repair or Upgrade
    - Tech Brief 4 – Roadside Safety Systems Pre-Installation Field Review Checklist
    - Tech Brief 5 – Transitioning metal beam guardrail to existing bridge rails

These deliverables were prepared by the KLS Engineering team of Karen Boodlal and Richard Powers under the direct supervision by Mr. William P Longstreet of FHWA's Office of Safety Roadway Departure Technology Transfer Team and with the assistance of the California FHWA Division office, Caltrans, LTAP Center, and county personnel for compliance to the state DOT specifications.

Personnel listed below:

| | | |
|---|---|---|
| William P. Longstreet | FHWA Office of Safety | will.longstreet@dot.gov |
| Karen L. Boodlal | KLS Engineering, LLC (Project Manager) | karen1.boodlal@kls-eng.com |
| Richard D. Powers | KLS Engineering, LLC (Technical Expert/Instructor) | richard.powers@kls-eng.com |
| Ken Kochevar | FHWA Division Office | ken.kochevar@dot.gov |
| Robert Peterson | Caltrans, Division of Local Assistance | robert.peterson@dot.ca.gov |
| Steve Castleberry | Nevada County | steven.castleberry@co.nevada.ca.us |
| Dean Lehman | LA County | dlehman@dpw.lacounty.gov |
| Rick Tippett | Trinity County | rtippett@trinitycounty.org |
| Stephanie Halloway | Placer County | shollow@placer.ca.gov |
| Tom Mattson | Humboldt County | tmattson@co.humboldt.ca.us |
| Troy Bucko | Caltrans Division of Traffic Operations | troy.bucko@dot.ca.gov |

## Target Audience

The target audience for this training includes designers, inspectors and maintenance personnel within Caltrans local government agencies having direct responsibilities for designing, installing, maintaining, or inspecting traffic barriers, including end terminals, barrier transitions, and crash cushions.

## Course Goal and Outcomes

The overall course goal is to provide personnel the information needed to design or inspect or maintain barrier as efficiently and as effectively as practical. Specifically, participants who complete this training should be able to:

- Identify possible deficiencies in a new barrier design or an existing installation.
- Inspect and repair safety hardware in accordance with existing policies and good practices.
- Avoid common errors in barrier and terminal installations to optimize crash performance and reduce liability.
- Know whether damaged hardware needs to be repaired, replaced, upgraded or removed.

## Course Contents

This one day course consists of the seven sessions listed below:

**Session 1:** Introduction and Low-cost Improvements – Provides an overview of the day's training and the course objectives, a brief description of run-off road (ROR) problem in counties in California, and discusses low cost improvements for keeping drivers on the road.

**Session 2:** Clear Zone and Barrier Warrants – Provides guidance on fixed objects and terrain features that can best be shielded by a traffic barrier

**Session 3:** Testing Requirements and Performance Characteristics of Common Barrier Systems – Outlines the crash testing guidelines, performance characteristics and maintainability of various barrier systems currently used.

**Session 4:** Testing Requirements and Performance Characteristics of Common Terminals and Crash Cushions – Outlines the crash testing guidelines, performance characteristics and maintainability of the various end terminals used in California.

**Session 5:** Guardrail Design and Site-specific Installation Considerations –Provides concise information on barrier design and on site conditions that can degrade crash performance.

**Session 6:** Guardrail/Terminal Installation and Common Errors – Outlines the basic approach to installing Guardrail and shows some common installation errors.

**Session 7:** Maintenance of Systems – Provides guidance on when to reset, repair, rebuild or remove damaged barrier and when to repair or upgrade damaged terminals.

## *Course Materials*

Materials included in this Participant Notebook are:

- PowerPoint slides used in the course,
- Note pages for participant use,
- Course Agenda and
- Course Evaluation Form.

## *Suggestion for Participants*

This training course will be more valuable if you ask questions and share your experiences. Please turn your cell phones off during the class. If you are uncomfortable with the lighting, temperature or other features of the facility please let the instructor know.

# Resources

AASHTO, Roadside Design Guide, 2011

Manual on Uniform Traffic Control Devices for Streets and Highways, 2009

AASHTO, Manual for Assessing Safety Hardware, 2009

NCHRP Report 500, Volume 7: A Guide for Reducing Collisions on Horizontal Curves

FHWA Hardware Policy and Guidance http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/

FHWA Longitudinal Barriers http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/barriers/

FHWA Resource Charts
http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/resource_charts/

AASHTO Task Force 13 website https://www.aashtotf13.org/

AASHTO Guide to Standardized Highway Barrier Hardware;

https://www.aashtotf13.org/Barrier-Hardware.php

NHTSA FARS web site: http://www-fars.nhtsa.dot.gov/Main/index.aspx

Roadside Safety Pooled Fund sites:

MwRSF: http://mwrsf-qa.unl.edu/

TTI: http://www.roadsidepooledfund.org/

NCHRP Research Projects http://www.trb.org/NCHRP/Public/NCHRPProjects.aspx

Bridge Rail Guide: http://guides.roadsafellc.com/

NCHRP Report 350: http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_350-a.pdf

Caltrans Design Information Bulletin number 79-03

Caltrans Memorandum 07/31/2015 Maintenance of Safety Devices

Caltrans Maintenance Manual Vol. II, M60010

Caltrans Manual on Uniform Traffic Control http://www.dot.ca.gov/trafficops/camutcd/

Caltrans Traffic Manual, Chapter 7 http://www.dot.ca.gov/trafficops/camutcd/traffic-manual.html

Caltrans approved products list:
http://www.dot.ca.gov/hq/esc/approved_products_list/pdf/highway_safety_features.pdf

Caltrans Standard Plans and Standard Specifications: http://www.dot.ca.gov/des/oe/construction-contract-standards.html

# Session 1: Introduction and Low-cost Improvements

FHWA Roadway Departure Technology Transfer

**Roadside Safety Systems Design, Inspection and Maintenance Training**

FHWA COTM: Will Longstreet
FHWA, Office of Safety
(202) 366 0087

Instructors: Richard Powers
KLS Engineering, LLC
(703) 858 1356

**November 17, 2016**

CALIFORNIA LTAP CENTER

## Ground Rules

- Be on time
- Ask questions
- Challenge the instructor
- Turn off/mute your cellphones

Federal Highway Administration

Session 1

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## Why are you here?

- What are you areas of responsibility?
- What safety issues are you concerned with?
- What do you want from this course?

Federal Highway Administration

Session 1

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## Real World Crashes


U.S. Department of Transportation Federal Highway Administration
Session 1
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## Need for Training

Potential consequences of poorly designed, installed, maintained, or repaired barrier systems include:

- Crash severities may be increased.
- Installer/agency may be liable for damages and injuries due to negligence.

U.S. Department of Transportation Federal Highway Administration
Session 1
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## Need for Training

Examples of improper installation of systems:


U.S. Department of Transportation Federal Highway Administration
Session 1
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## Need for Training

Examples of improper installation of systems:


Federal Highway Administration Session 1 1-7

## Need for Training

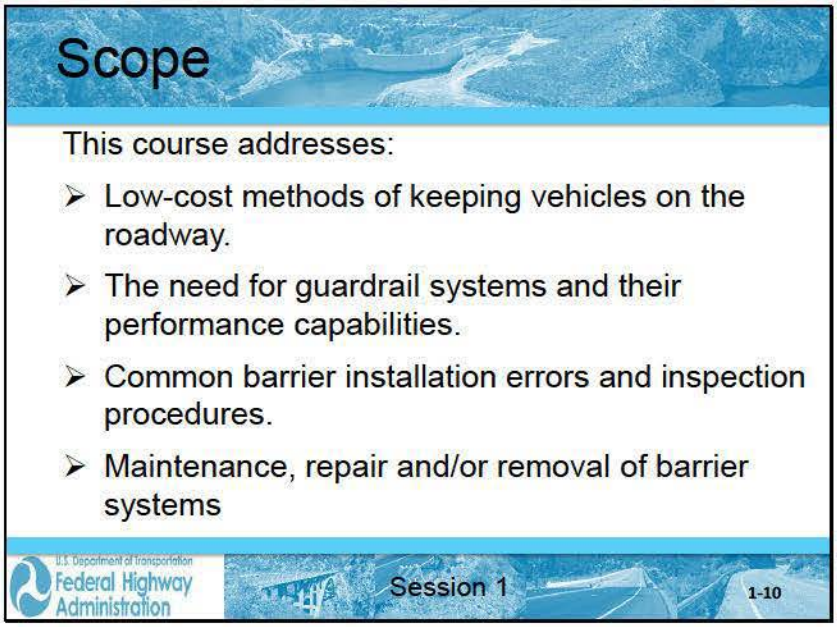
Examples of improper installation of systems:


Federal Highway Administration Session 1 1-8

## Need for Training

Examples of improper installation of systems:


Federal Highway Administration Session 1 1-9


Scope
This course addresses:
Low-cost methods of keeping vehicles on the roadway.
The need for guardrail systems and their performance capabilities.
Common barrier installation errors and inspection procedures.
Maintenance, repair and/or removal of barrier systems
U.S. Department of Transportation
Federal Highway Administration
Session 1
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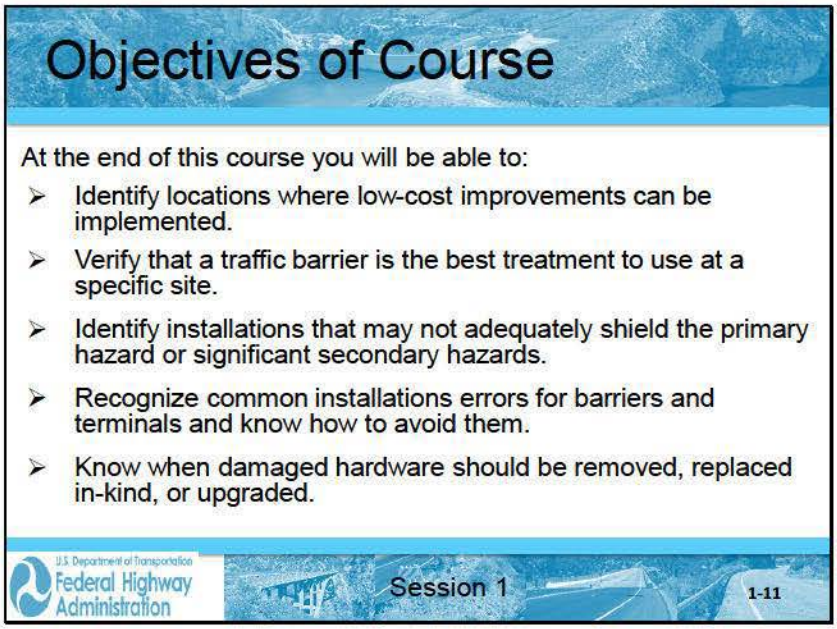
Objectives of Course
At the end of this course you will be able to:
Identify locations where low-cost improvements can be implemented.
Verify that a traffic barrier is the best treatment to use at a specific site.
Identify installations that may not adequately shield the primary hazard or significant secondary hazards.
Recognize common installations errors for barriers and terminals and know how to avoid them.
Know when damaged hardware should be removed, replaced in-kind, or upgraded.
U.S. Department of Transportation
Federal Highway Administration
Session 1
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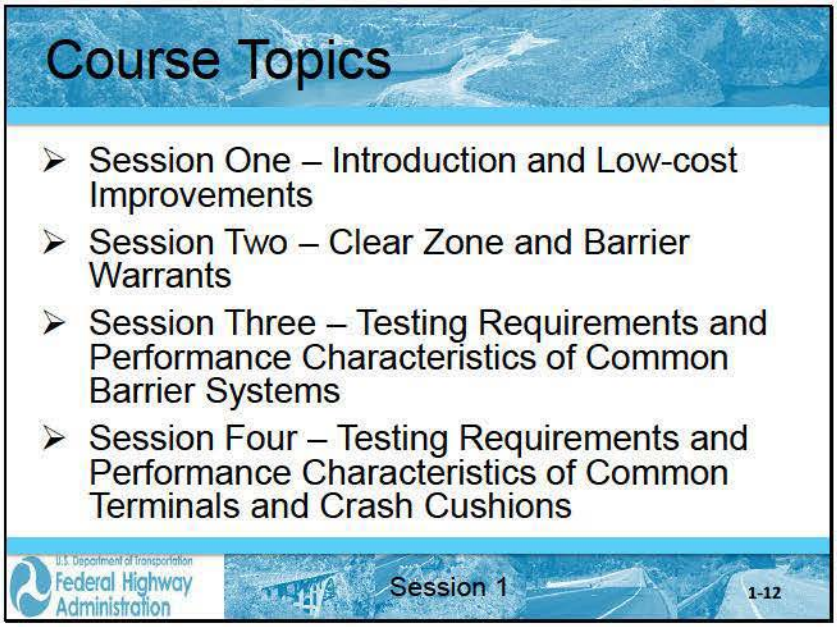
Course Topics
Session One – Introduction and Low-cost Improvements
Session Two – Clear Zone and Barrier Warrants
Session Three – Testing Requirements and Performance Characteristics of Common Barrier Systems
Session Four – Testing Requirements and Performance Characteristics of Common Terminals and Crash Cushions
U.S. Department of Transportation
Federal Highway Administration
Session 1
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Course Topics (cont'd)
Session Five – Guardrail Design and Site-specific Installation Considerations
Session Six – Guardrail/Terminal Installation and Common Errors
Session Seven – Maintenance of Systems
U.S. Department of Transportation
Federal Highway Administration
Session 1
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## Session 1 Learning Outcomes

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

- Identify the need for training
- Describe the primary Roadside Safety Concerns in California.
- Understand when something needs to be addressed and the appropriate action.
- Identify low-cost strategies for keeping vehicles on the roadway.

U.S. Department of Transportation Federal Highway Administration

Session 1

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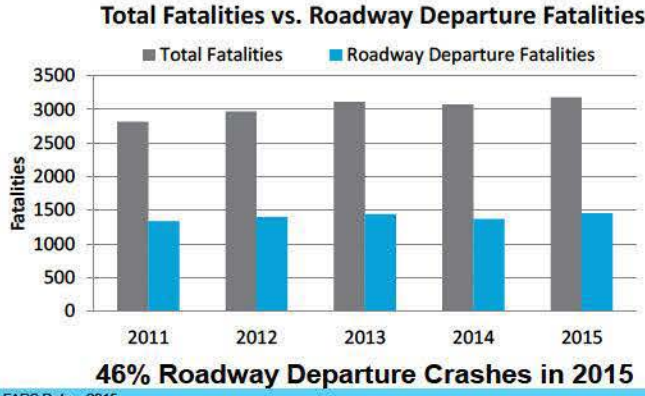
## California Crash Data Trend




**46% Roadway Departure Crashes in 2015**

Ref: FARS Data – 2015

U.S. Department of Transportation Federal Highway Administration

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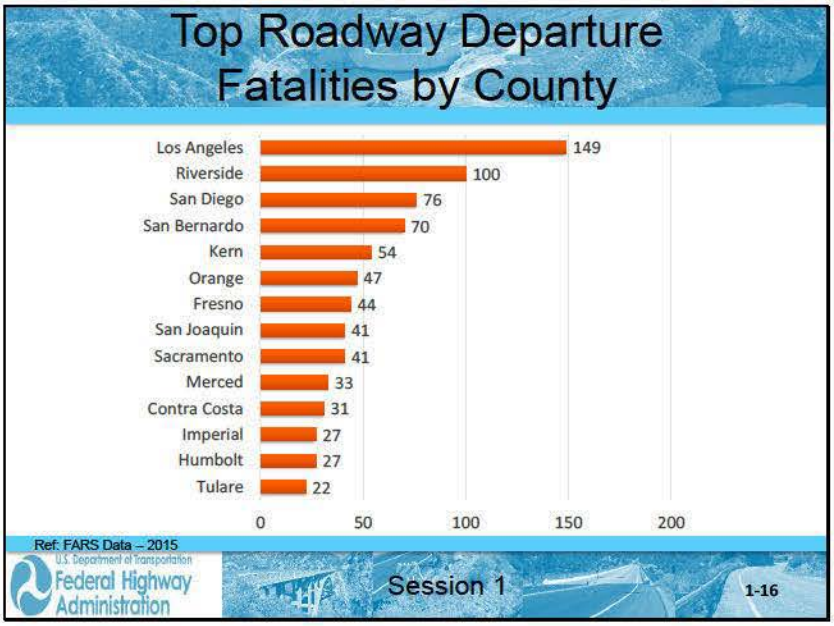
Top Roadway Departure Fatalities by County
Los Angeles 149
Riverside 100
San Diego 76
San Bernardo 70
Kern 54
Orange 47
Fresno 44
San Joaquin 41
Sacramento 41
Merced 33
Contra Costa 31
Imperial 27
Humbolt 27
Tulare 22
0 50 100 150 200
Ref: FARS Data – 2015
U.S. Department of Transportation
Federal Highway Administration
Session 1
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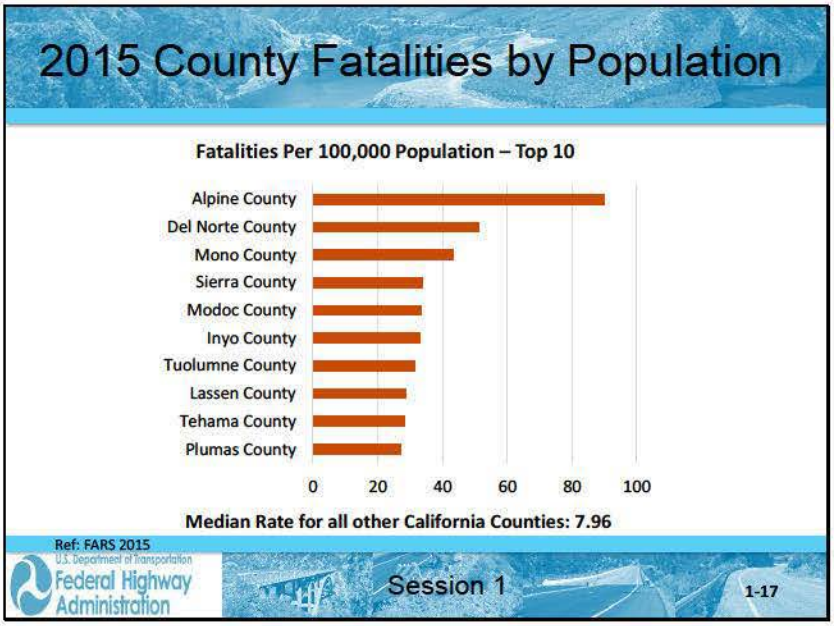
2015 County Fatalities by Population
Fatalities Per 100,000 Population – Top 10
Alpine County
Del Norte County
Mono County
Sierra County
Modoc County
Inyo County
Tuolumne County
Lassen County
Tehama County
Plumas County
0 20 40 60 80 100
Median Rate for all other California Counties: 7.96
Ref: FARS 2015
U.S. Department of Transportation
Federal Highway Administration
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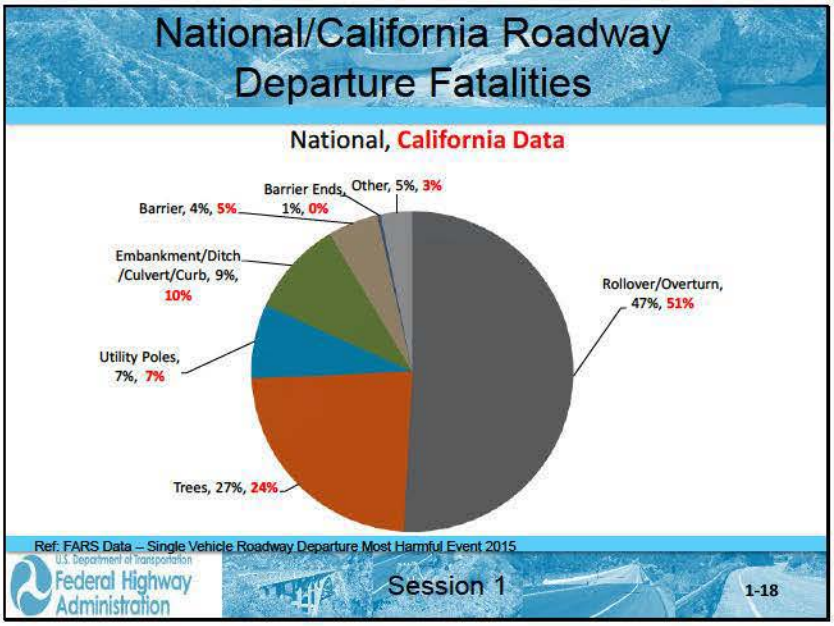
National/California Roadway Departure Fatalities
National, California Data
Barrier Ends, 1%, 0%
Other, 5%, 3%
Barrier, 4%, 5%
Embankment/Ditch /Culvert/Curb, 9%, 10%
Rollover/Overturn, 47%, 51%
Utility Poles, 7%, 7%
Trees, 27%, 24%
Ref: FARS Data – Single Vehicle Roadway Departure Most Harmful Event 2015
U.S. Department of Transportation
Federal Highway Administration
Session 1
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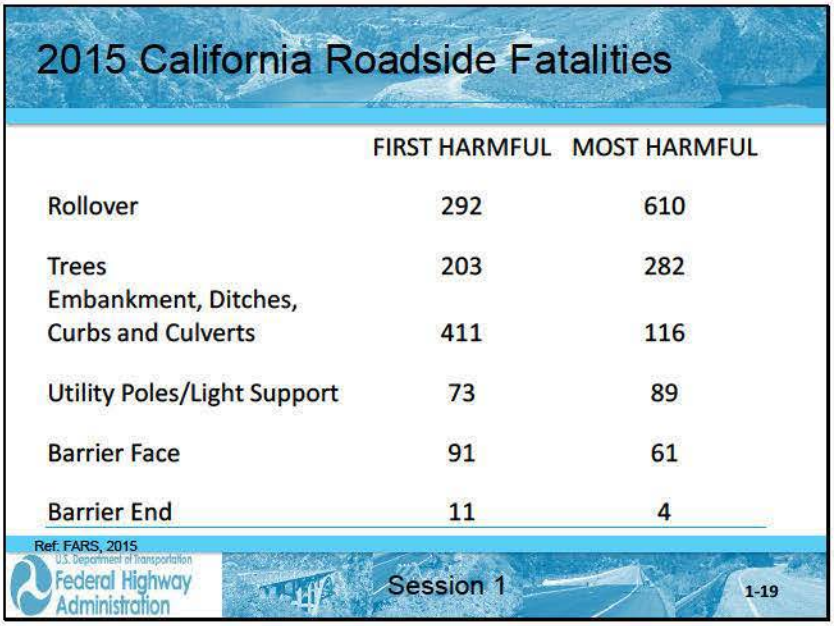
2015 California Roadside Fatalities
FIRST HARMFUL
MOST HARMFUL
Rollover 292 610
Trees 203 282
Embankment, Ditches, Curbs and Culverts 411 116
Utility Poles/Light Support 73 89
Barrier Face 91 61
Barrier End 11 4
Ref: FARS, 2015
U.S. Department of Transportation
Federal Highway Administration
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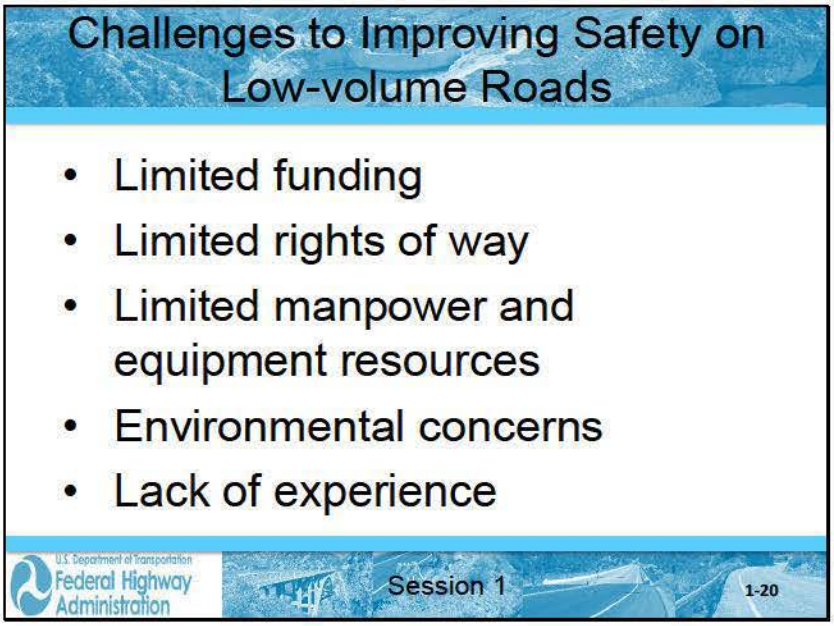
Challenges to Improving Safety on Low-volume Roads
• Limited funding
• Limited rights of way
• Limited manpower and equipment resources
• Environmental concerns
• Lack of experience
U.S. Department of Transportation
Federal Highway Administration
Session 1
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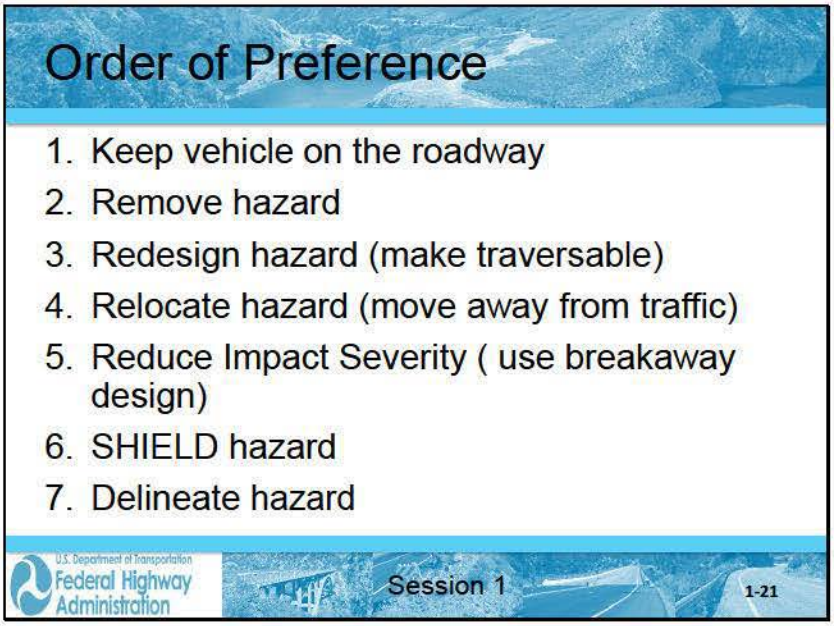
Order of Preference
1. Keep vehicle on the roadway
2. Remove hazard
3. Redesign hazard (make traversable)
4. Relocate hazard (move away from traffic)
5. Reduce Impact Severity ( use breakaway design)
6. SHIELD hazard
7. Delineate hazard
U.S. Department of Transportation
Federal Highway Administration
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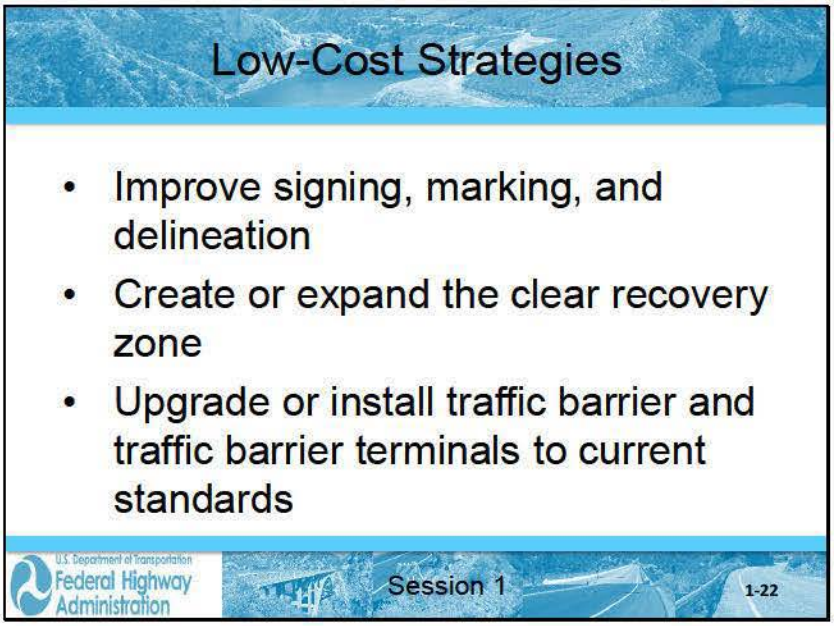
Low-Cost Strategies
• Improve signing, marking, and delineation
• Create or expand the clear recovery zone
• Upgrade or install traffic barrier and traffic barrier terminals to current standards
U.S. Department of Transportation
Federal Highway Administration
Session 1
1-22


Signing, Marking and Delineation
Curve treatments
• Advance warning signs
• Chevron Alignment signs/Turn Arrow
• Post Mounted Delineators
• Pavement markings
• Rumble strips/Rumble stripes
U.S. Department of Transportation
Federal Highway Administration
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Advance warning signs
Curve (W1-2)
Turn (W1-1)
Winding Road (W1-15)
Ref: CA MUTCD Figure 2C-6, Page 262
U.S. Department of Transportation
Federal Highway Administration
Session 1
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SPEED LIMIT 45
YOUR SPEED
40
U.S. Department of Transportation
Federal Highway Administration
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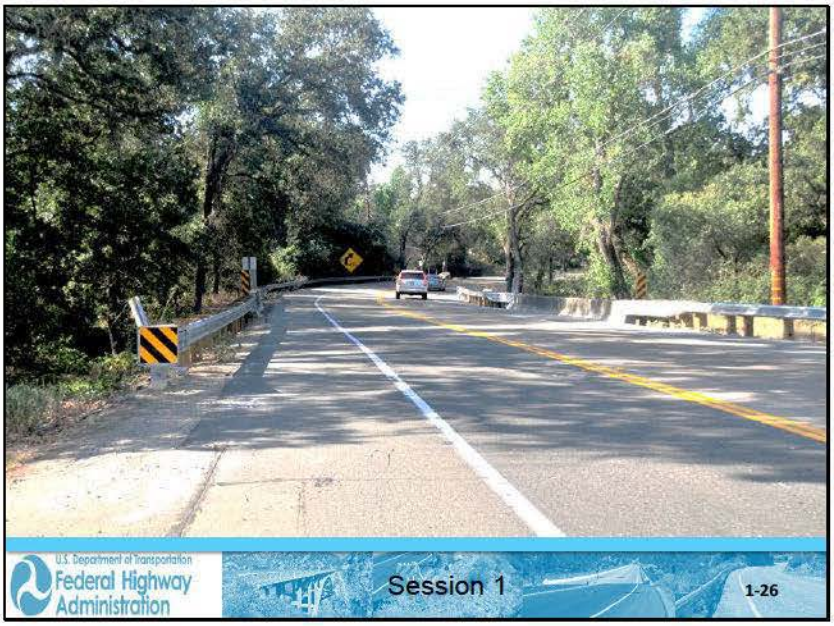
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Miners Ravine
Salmon Habitat
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Federal Highway Administration
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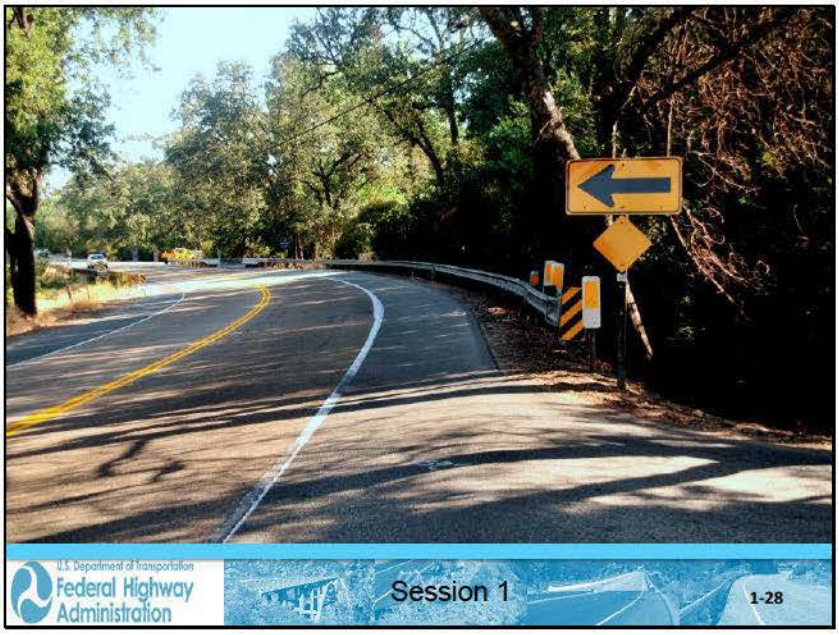
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15
MPH
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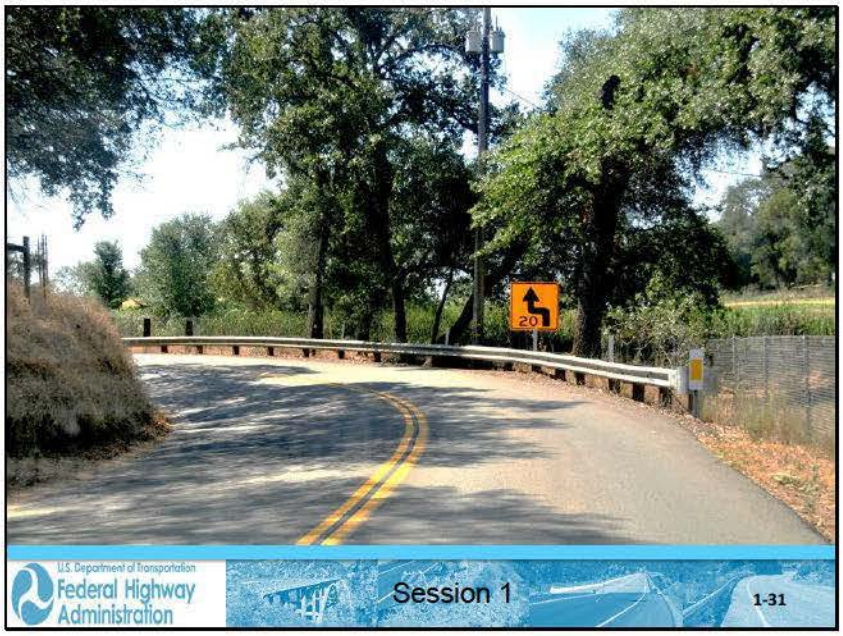
20
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Session 1
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## Chevron Alignment signs

- Provide warning throughout a curve
- Minimum of three signs required
- Set 4 ft. above edge of roadway
- Installed at PC and PT and spaced evenly in between (CA MUTCD Table 2C-6, page 262)
- Required if advisory speed is 15 mph or more below approach speed

U.S. Department of Transportation Federal Highway Administration
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U.S. Department of Transportation Federal Highway Administration
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U.S. Department of Transportation
Federal Highway Administration
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Federal Highway Administration
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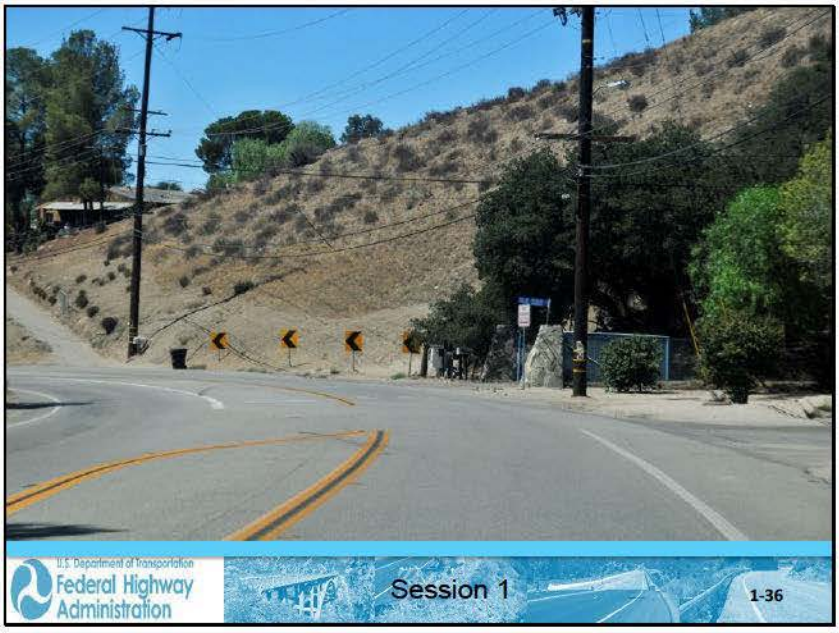
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Federal Highway Administration
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Federal Highway Administration
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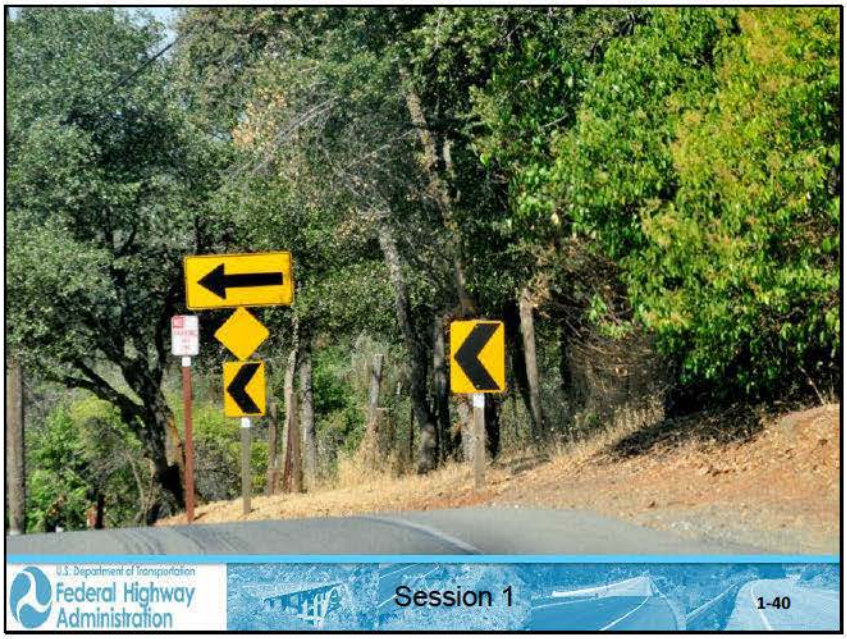
## Turn Arrow

One-Direction Large Arrow Sign (W1-6)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Federal Highway Administration
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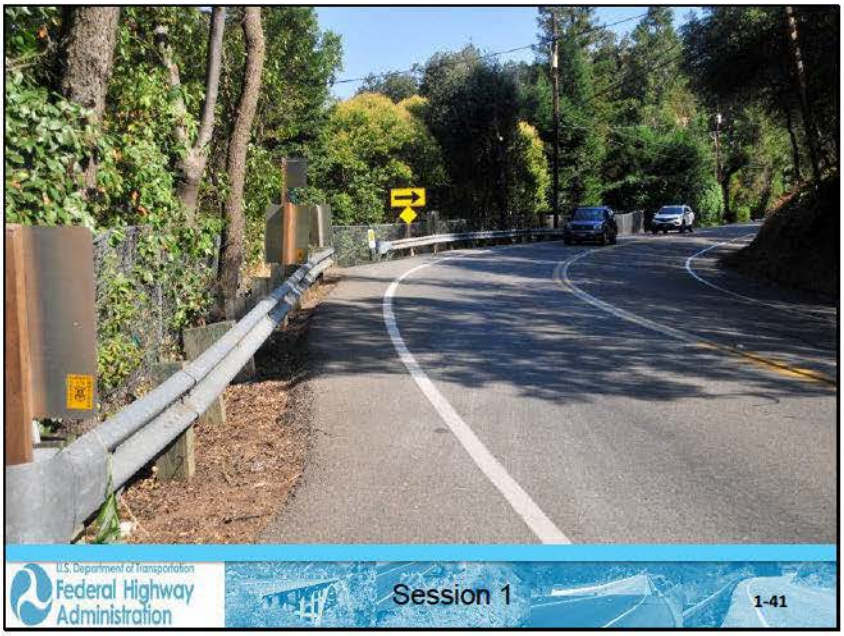
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Session 1
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## Post Mounted Delineators

- Provide guidance
- Minimum reflective surface of 3”
- Set 4 ft. above near edge of roadway
- Several visible to motorists
- Approximate spacing from MUTCD Table 3F-1


## Pavement markings

Center Line Markings

- Required on urban arterials/collectors 20 ft wide with 6000 ADT
- Recommended on rural arterials/collectors 18 ft wide with 3000 ADT
- May be used at spot locations such as horizontal curves and crest vertical curves


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## Pavement markings

Edge Line Markings

- Required on rural arterials
  20 ft wide with 6000 ADT
- Recommended on rural arterials/collectors
  20 ft or wider with 3000 ADT
- May be used without center line markings
- Wider edge line markings may be used for greater emphasis

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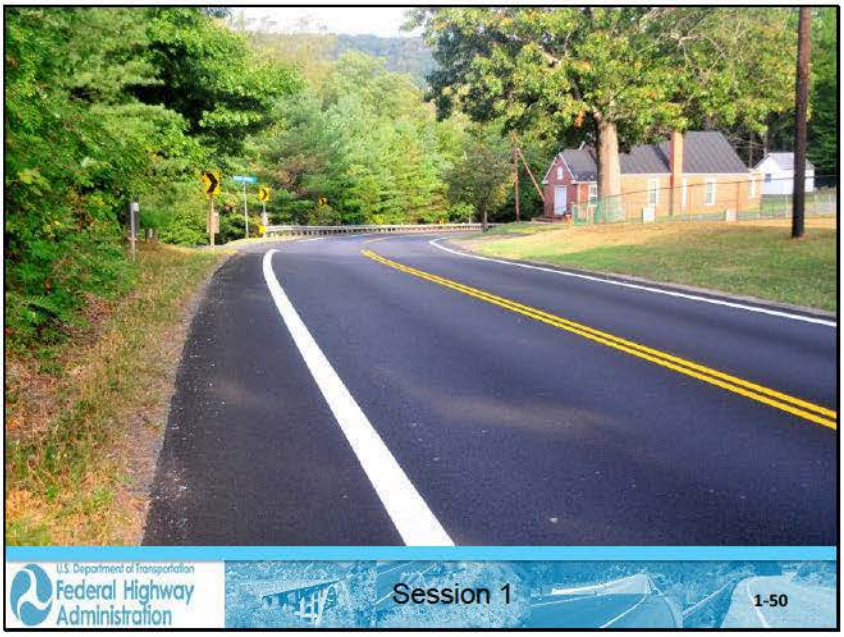
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Federal Highway Administration
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## Rumble strips/Rumble stripes

- Rumble strips where paved shoulders exist.
- Rumble stripes where center lines are used alone or in conjunction with edge lines.

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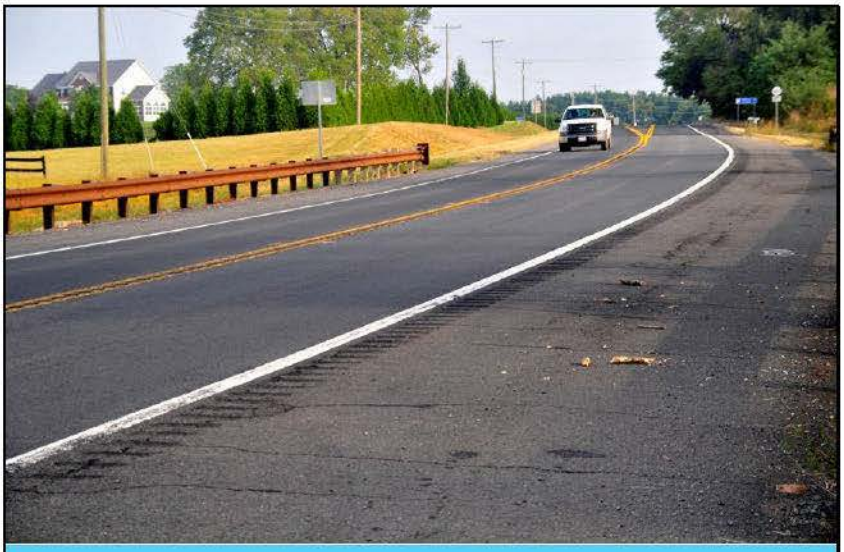

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## Rumble stripes

Rumble Stripe Advantages

- More visible on wet pavement
- May extend life of paint

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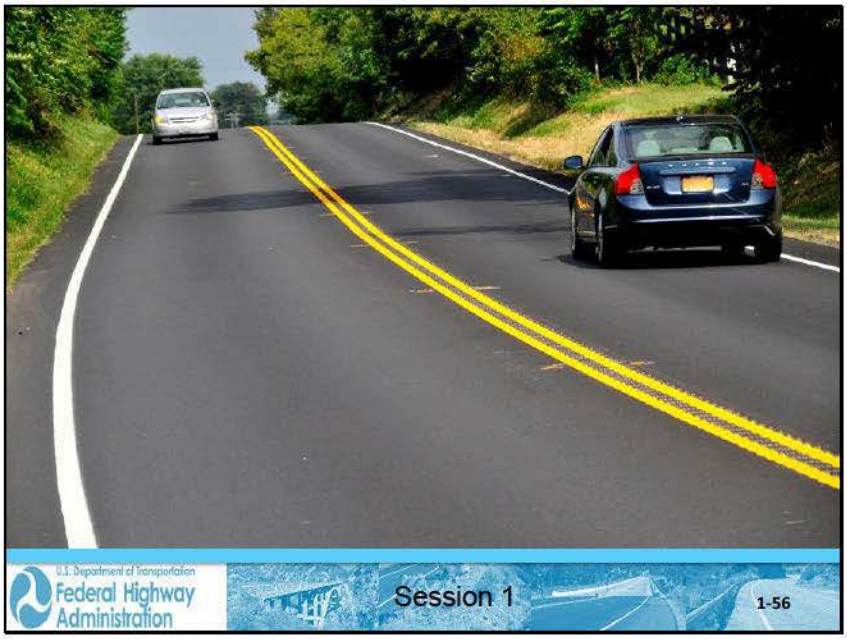
U.S. Department of Transportation
Federal Highway Administration
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U.S. Department of Transportation
Federal Highway Administration
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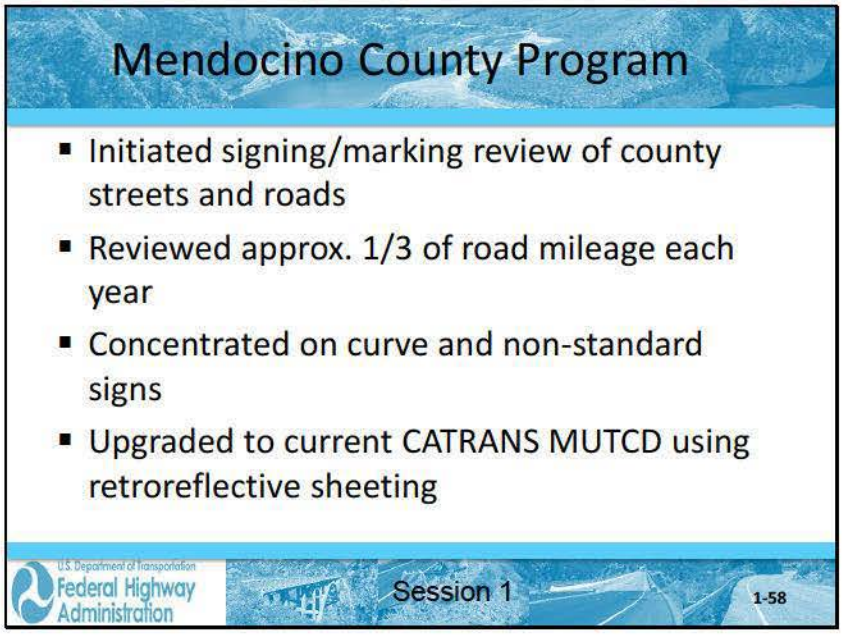
Mendocino County Program
Initiated signing/marking review of county streets and roads
Reviewed approx. 1/3 of road mileage each year
Concentrated on curve and non-standard signs
Upgraded to current CATRANS MUTCD using retroreflective sheeting
U.S. Department of Transportation
Federal Highway Administration
Session 1
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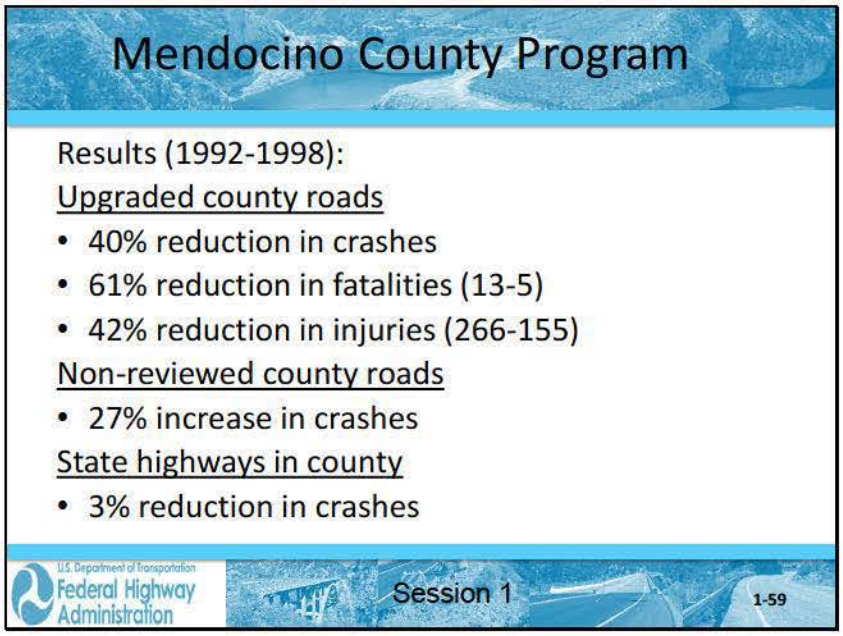
Mendocino County Program
Results (1992-1998):
Upgraded county roads
40% reduction in crashes
61% reduction in fatalities (13-5)
42% reduction in injuries (266-155)
Non-reviewed county roads
27% increase in crashes
State highways in county
3% reduction in crashes
U.S. Department of Transportation
Federal Highway Administration
Session 1
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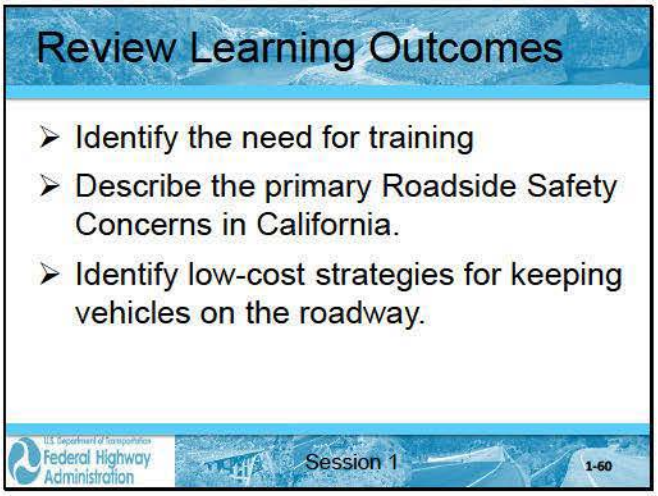
Review Learning Outcomes
Identify the need for training
Describe the primary Roadside Safety Concerns in California.
Identify low-cost strategies for keeping vehicles on the roadway.
U.S. Department of Transportation
Federal Highway Administration
Session 1
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# Session 2: Clear Zone and Barrier Warrants

FHWA Roadway Departure Technology Transfer
Roadside Safety Systems Design, Inspectors, and Maintenance Training

## Session 2:
## Clear Zone and Barrier Warrants

U.S. Department of Transportation Federal Highway Administration
Session 2
2-1

## Course Topics

- Session 1 – Introduction and Low-cost Improvements
- Session 2 – Clear Zone and Barrier Warrants

U.S. Department of Transportation Federal Highway Administration
Session 2
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## Session 2 Learning Outcomes

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

- Understand and apply the clear zone concept
- Identify objects and features that may require shielding

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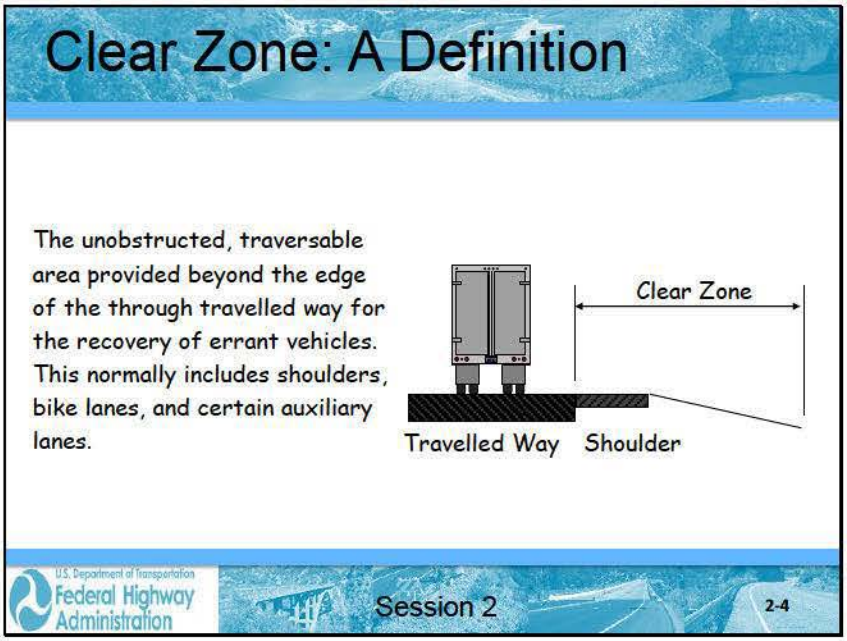
Session 2
2-3


Clear Zone: A Definition
The unobstructed, traversable area provided beyond the edge of the through travelled way for the recovery of errant vehicles. This normally includes shoulders, bike lanes, and certain auxiliary lanes.
Clear Zone
Travelled Way
Shoulder
U.S. Department of Transportation
Federal Highway Administration
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U.S. Department of Transportation
Federal Highway Administration
Session 2
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## Clear Zone Concept

- The AASHTO publication, "Highway Design and Operational Practices Related to Highway Safety", stated in its 1974 second edition (known as the "Yellow Book") that "…for adequate safety, it is desirable to provide an unencumbered roadside recovery area that is ***as wide as practical*** on a specific highway section."



## Clear Zone Concept

1977 AASHTO "Guide for Selecting, Locating, and Designing Traffic Barriers" first presented the format used today for determining clear zone distance based on traffic volume, speed, and slope direction (cut vs. fill) and steepness.

## Clear Zone Factors

- Design Speed
- Slope Type and Steepness
- Traffic Volume
- Horizontal Curvature

U.S. Department of Transportation Federal Highway Administration
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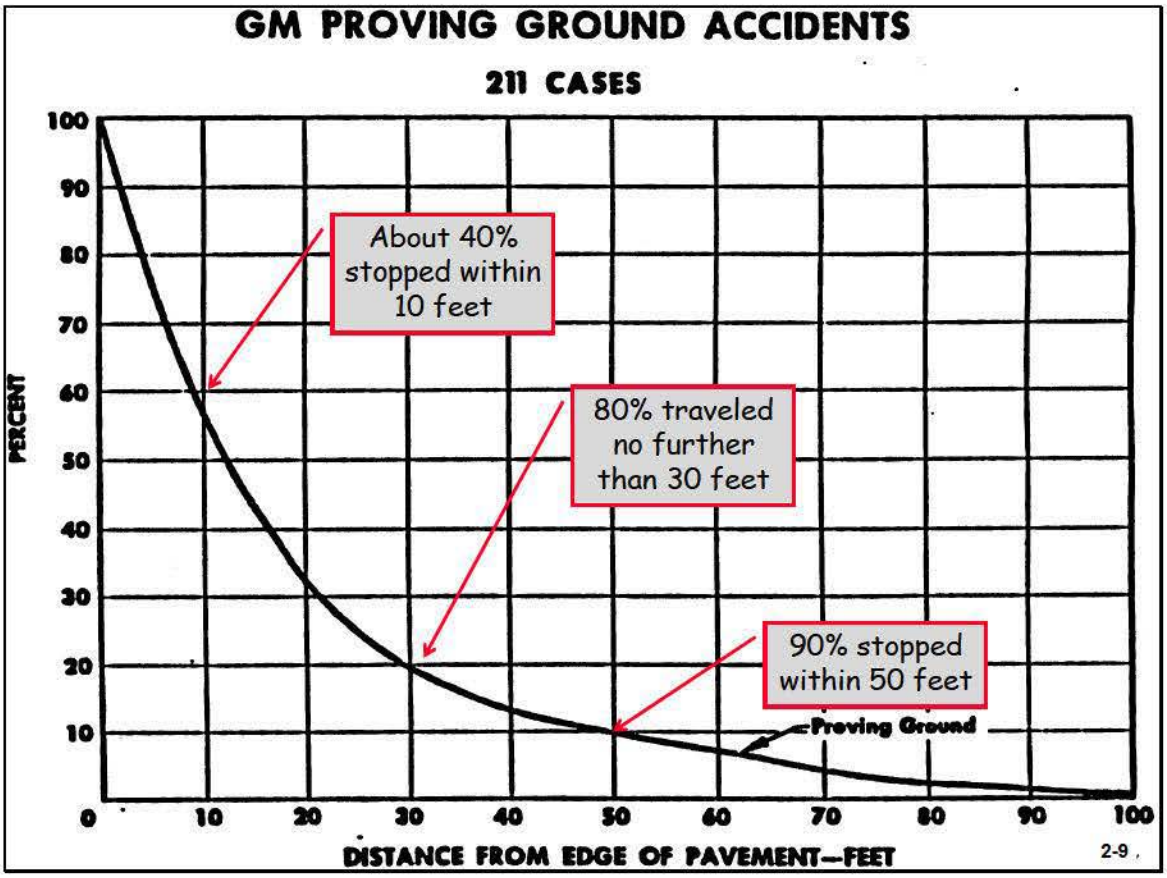

# Design Clear Zone Determination Table

| 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] | 7-10 | 7-10 | b | 7-10 | 7-10 | 7-10 |
| | 750-1500 | 10-12 | 12-14 | b | 10-12 | 10-12 | 10-12 |
| | 1500-6000 | 12-14 | 14-16 | b | 12-14 | 12-14 | 12-14 |
| | OVER 6000 | 14-16 | 16-18 | b | 14-16 | 14-16 | 14-16 |
| 45-50 | UNDER 750[c] | 10-12 | 12-14 | b | 8-10 | 8-10 | 10-12 |
| | 750-1500 | 14-16 | 16-20 | b | 10-12 | 12-14 | 14-16 |
| | 1500-6000 | 16-18 | 20-26 | b | 12-14 | 14-16 | 16-18 |
| | OVER 6000 | 20-22 | 24-28 | b | 14-16 | 18-20 | 20-22 |
| 55 | UNDER 750[c] | 12-14 | 14-18 | b | 8-10 | 10-12 | 10-12 |
| | 750-1500 | 16-18 | 20-24 | b | 10-12 | 14-16 | 16-18 |
| | 1500-6000 | 20-22 | 24-30 | b | 14-16 | 16-18 | 20-22 |
| | OVER 6000 | 22-24 | 26-32[a] | b | 16-18 | 20-22 | 22-24 |
| 60 | UNDER 750[c] | 16-18 | 20-24 | b | 10-12 | 12-14 | 14-16 |
| | 750-1500 | 20-24 | 26-32[a] | b | 12-14 | 16-18 | 20-22 |
| | 1500-6000 | 26-30 | 32-40[a] | b | 14-18 | 18-22 | 24-26 |
| | OVER 6000 | 30-32[a] | 36-44[a] | b | 20-22 | 24-26 | 26-28 |
| 65-70[d] | UNDER 750[c] | 18-20 | 20-26 | b | 10-12 | 14-16 | 14-16 |
| | 750-1500 | 24-26 | 28-36[a] | b | 12-16 | 18-20 | 20-22 |
| | 1500-6000 | 28-32[a] | 34-42[a] | b | 16-20 | 22-24 | 26-28 |
| | OVER 6000 | 30-34[a] | 38-46[a] | b | 22-24 | 26-30 | 28-30 |

Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – TABLE 3.1, Pg. 3-3

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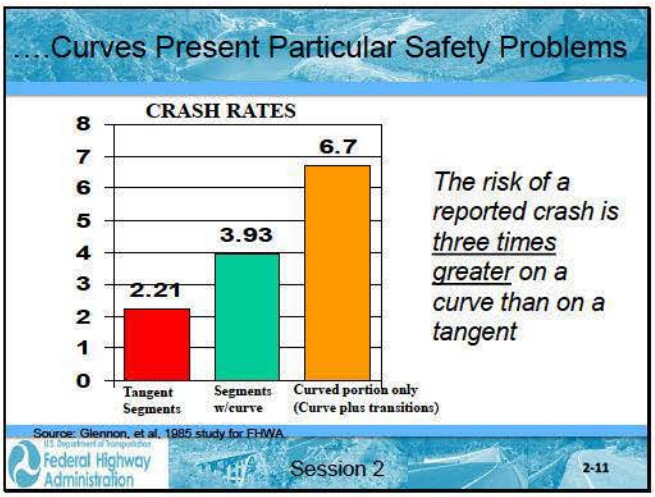

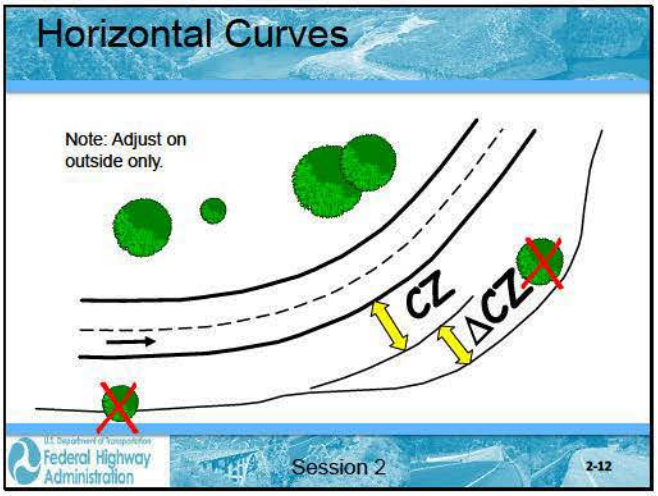


# Horizontal Curve Adjustments

## $K_{CZ}$ (Curve Correction Factor)(U.S. Customary Units)

| Radius (ft) | Design Speed (mph) | | | | | |
|---|---|---|---|---|---|---|
| | 40 | 45 | 50 | 55 | 65 | 70 |
| 2,950 | 1.1 | 1.1 | 1.1 | 1.2 | 1.2 | 1.2 |
| 2,300 | 1.1 | 1.1 | 1.2 | 1.2 | 1.2 | 1.3 |
| 1,970 | 1.1 | 1.2 | 1.2 | 1.2 | 1.3 | 1.4 |
| 1,640 | 1.1 | 1.2 | 1.2 | 1.3 | 1.3 | 1.4 |
| 1,475 | 1.2 | 1.2 | 1.3 | 1.3 | 1.4 | 1.5 |
| 1,315 | 1.2 | 1.2 | 1.3 | 1.3 | 1.4 | - |
| 1,150 | 1.2 | 1.2 | 1.3 | 1.4 | 1.5 | - |
| 985 | 1.2 | 1.3 | 1.4 | 1.5 | 1.5 | - |
| 820 | 1.3 | 1.3 | 1.4 | 1.5 | - | - |
| 660 | 1.3 | 1.4 | 1.5 | - | - | - |
| 495 | 1.4 | 1.5 | - | - | - | - |
| 330 | 1.5 | - | - | - | - | - |

Ref: AASHTO Roadside Design Guide, 4th Edition, Table 3-2.Pg. 3-4

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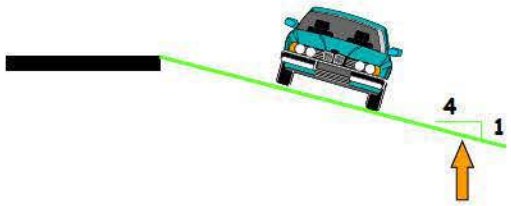
## Recoverable And Traversable



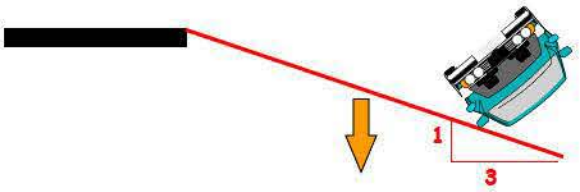



## Non-Recoverable And Traversable




## Critical

Non-Recoverable and Non-Traversable

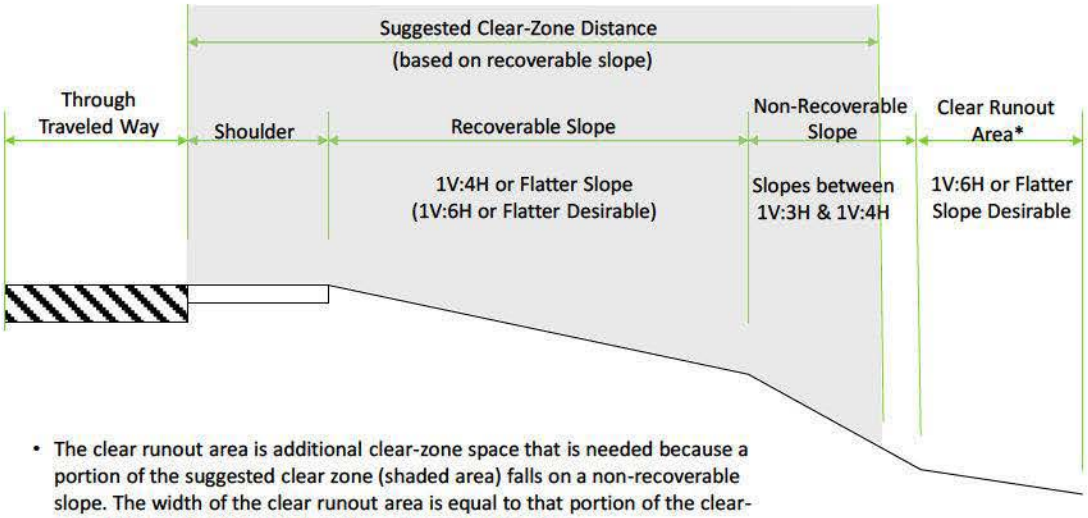


## Clear Zone & Non-recoverable Slopes

- Provide clear run out area at toe of non-recoverable, traversable slopes.
- Additional clear zone may be needed to account for portion vehicle travels on a non-recoverable slope (slopes between 3H:1V & 4H:1V).



## Clear Zone Adjustments for Non-uniform Slopes




- The clear runout area is additional clear-zone space that is needed because a portion of the suggested clear zone (shaded area) falls on a non-recoverable slope. The width of the clear runout area is equal to that portion of the clear-zone distance that is located on the non-recoverable slope.

Ref: AASHTO Roadside Design Guide, 4th Edition, Figure 3.2, Pg. 3-6/SCDOT Plan Prep. Guide Chp. 10 Pg. 10-4

## Clear Zone and Curbs

Fixed object hazards should be located as far as practical behind curbs, but no closer than 1.5 ft. from the curb face. This offset should be considered the minimum allowable horizontal clearance (or operational offset), ***but it should not be construed as an acceptable clear zone distance***. Since curbs do not have a significant redirectional capability, obstructions behind the curb should ideally be located at or beyond the minimum recommended clear zone distance.

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## Potential Hazards

- Bridge piers/abutments/railing ends
- Drainage structures/ditches
- Rigid sign and luminaire supports
- Permanent bodies of water
- Steep embankments
- Opposing traffic on divided roadways

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# AASHTO Barrier Warrants

| Obstacle | Guidelines |
|---|---|
| Bridge piers, abutments, and railing ends | Shielding generally required |
| Boulders | Judgment decision based on nature of fixed object and likelihood of impact |
| Culverts, pipes, headwalls | Judgment decision based on size, shape and location of obstacle |
| Foreslopes and backslopes (smooth) | Shielding not generally required |
| Foreslopes and backslopes (rough) | Judgment decision based on likelihood of impact |
| Ditches (parallel) | Refer to Figures 3-6 and 3-7 |
| Ditches (transverse) | Shielding generally required if likelihood of head-on impact is high |
| Embankment | Judgment decision based on fill height and slope (see Figure 5-1) |
| Retaining Walls | Judgment decision based on relative smoothness of wall and anticipated maximum angle of impact |
| Sign/Luminaire supports | Shielding generally required for non-breakaway supports |
| Traffic signal supports | Isolated traffic signals within clear zone on high-speed rural facilities may warrant shielding |
| Trees | Judgment decision based on site-specific circumstances |
| Utility poles | Shielding may be needed on a case by case basis. |
| Permanent bodies of water | Judgment decision based on location and depth of water and likelihood of encroachment. |

Ref: AASHTO Roadside Design Guide, 4th Edition Chapter 5 Table 5-2, Pg. 5-9

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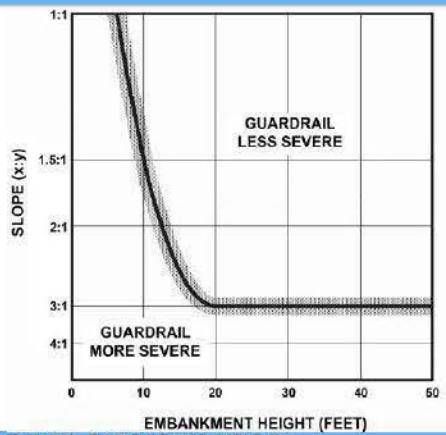
# Embankment Warrants




Barrier not warranted for embankment. However check barrier need for obstacles on slope.

Ref: Caltrans Traffic Manual – Figure 7-1: Equal Severity Curve

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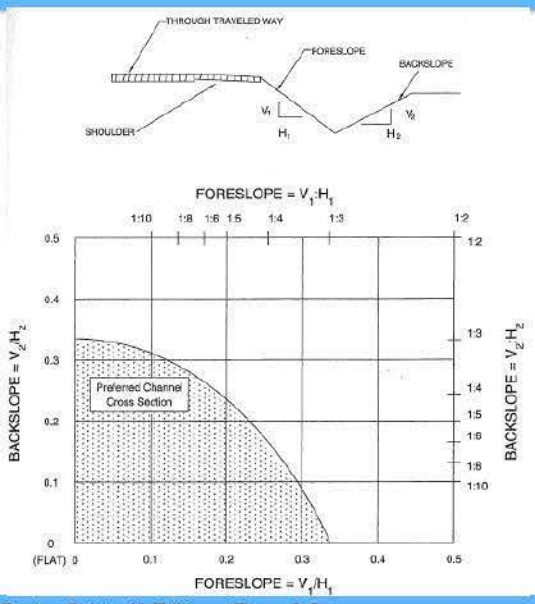
# Preferred V-Ditch Cross-sections




Ref: AASHTO Roadside Design Guide, 4th Edition – Figure 3-6



Is barrier warranted at the locations shown in the next five photos?

Do not consider effectiveness of existing barrier (if any), only the need for a barrier.


TURNOUT
1/4 MILE
U.S. Department of Transportation
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Federal Highway Administration
Session 2
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U.S. Department of Transportation
Federal Highway Administration
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## Review Learning Outcomes

- Understand and apply the clear zone concept
- Identify objects and features that may require shielding

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

FHWA Roadway Departure Technology Transfer
Roadside Safety Systems Design, Inspectors, and Maintenance Training

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

U.S. Department of Transportation Federal Highway Administration | Session 3 | 3-1

## Course Topics

- Session 2 – Clear Zone and Barrier Warrants
- Session 3 – Testing Requirements and Performance Characteristics of Common Barrier Systems.

U.S. Department of Transportation Federal Highway Administration | Session 3 | 3-2

## 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 requirements of a transition design

U.S. Department of Transportation Federal Highway Administration | Session 3 | 3-3

## Order of Preference

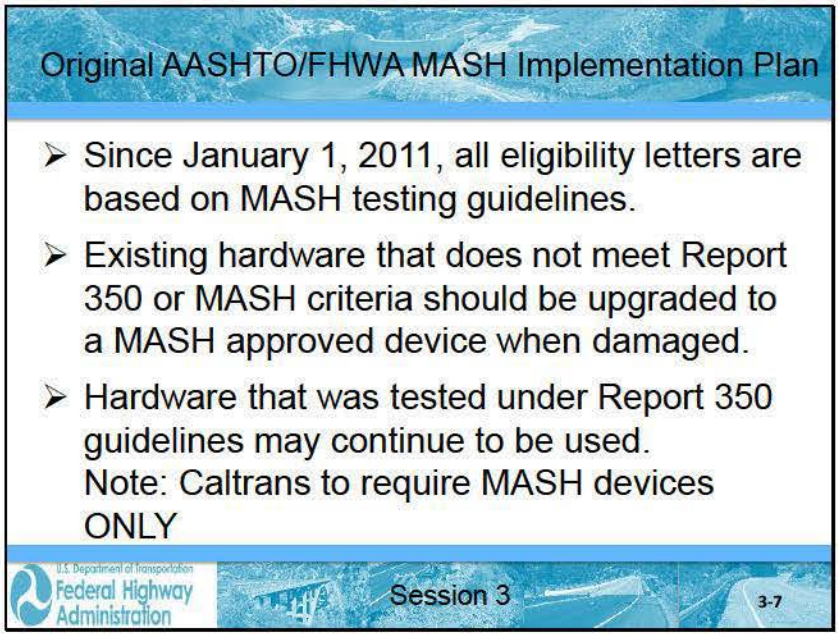
1. Keep vehicle on the roadway
2. Remove hazard
3. Redesign hazard (make traversable)
4. Relocate hazard (move away from traffic)
5. Reduce Impact Severity ( use breakaway design)
6. SHIELD hazard
7. Delineate hazard so motorist can avoid





## Crash Testing Guidelines

- Prior crash testing and evaluation standards were published in 1993 as NCHRP Report 350, "Recommended Procedures for the Safety Performance Evaluation of Highway Features."
- In 2009, the Manual for Assessing Safety Hardware (MASH) was published by AASHTO and has been adopted as the new testing standard. FHWA now requires new products to be tested to MASH.


Original AASHTO/FHWA MASH Implementation Plan
Since January 1, 2011, all eligibility letters are based on MASH testing guidelines.
Existing hardware that does not meet Report 350 or MASH criteria should be upgraded to a MASH approved device when damaged.
Hardware that was tested under Report 350 guidelines may continue to be used.
Note: Caltrans to require MASH devices ONLY
U.S. Department of Transportation
Federal Highway Administration
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New AASHTO/FHWA MASH Implementation Schedule
January 1, 2017 – W-beam in-line terminals (Caltrans schedule)
December 31, 2017 – W-beam and cast-in-place concrete barriers.
January 1, 2018 – W-beam flared terminals (Caltrans schedule)
June 30, 2018 – W-beam terminals
December 31, 2018 – Cable barrier and terminals, and crash cushions.
December 31, 2019 – Bridge rails, transitions, and all other longitudinal barrier (including portable barriers installed permanently), all other terminals, sign supports, and other breakaway hardware.
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Federal Highway Administration
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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 car and pickup truck with a 25˚ impact angle at 31, 44, and 62 mph, respectively.

2,420 lbs.

5,000 lbs.

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## MASH Test Conditions (cont'd)

- **TL- 4**: TL-3 + 15˚ impact angle, 56 mph box truck
- **TL- 5**: TL-3 + 15˚ impact angle, 50 mph tractor-trailer
- **TL- 6**: TL-3 + 15˚ impact angle, 50 mph tractor-tanker

22,000 lbs.

80,000 lbs.

80,000 lbs.

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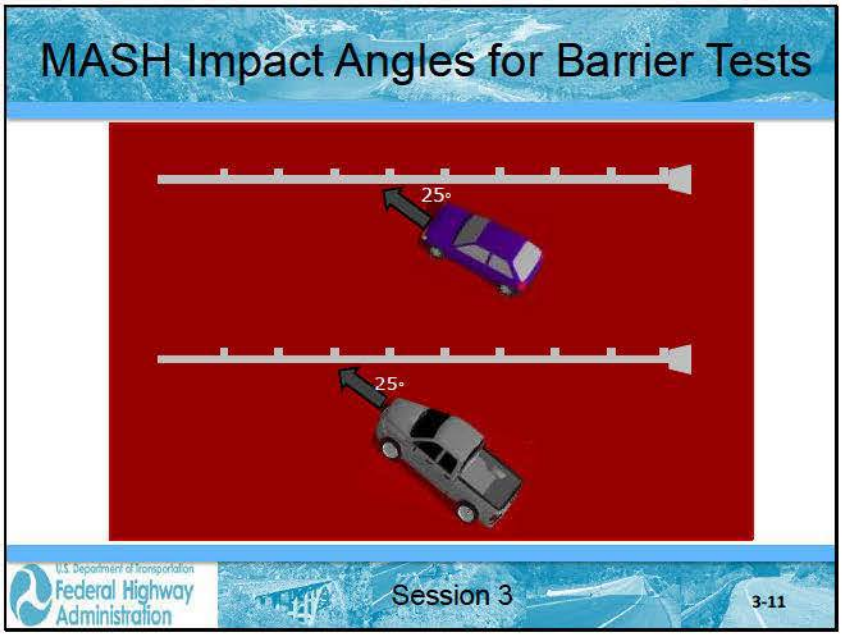
MASH Impact Angles for Barrier Tests
25°
25°
U.S. Department of Transportation
Federal Highway Administration
Session 3
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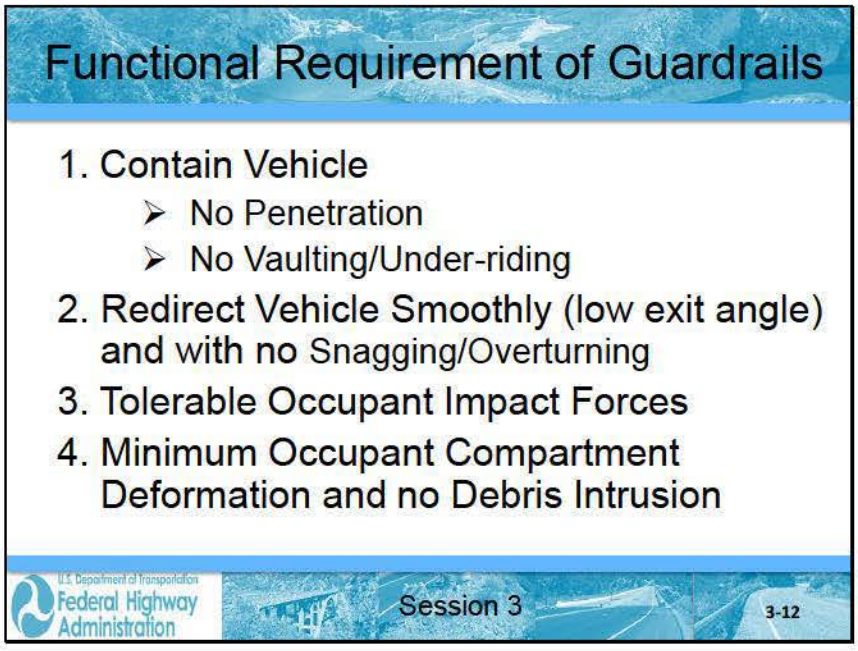
Functional Requirement of Guardrails
1. Contain Vehicle
➢ No Penetration
➢ No Vaulting/Under-riding
2. Redirect Vehicle Smoothly (low exit angle) and with no Snagging/Overturning
3. Tolerable Occupant Impact Forces
4. Minimum Occupant Compartment Deformation and no Debris Intrusion
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Federal Highway Administration
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## Standard Barrier Systems

- Rigid Systems
- Semi-Rigid Systems
- Flexible Systems
- Median Barrier Systems
- Work Zone Barriers

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## Barrier Systems: Rigid Barriers

- Rigid Barrier Systems typically have little (if any) deflection under most impact conditions.
- Some of these barriers are portable and some are permanent.
- Examples include:
  - New Jersey Safety Shape Concrete Barrier
  - F-shape Concrete Barrier
  - Single Slope Concrete Barrier
  - Vertical Wall

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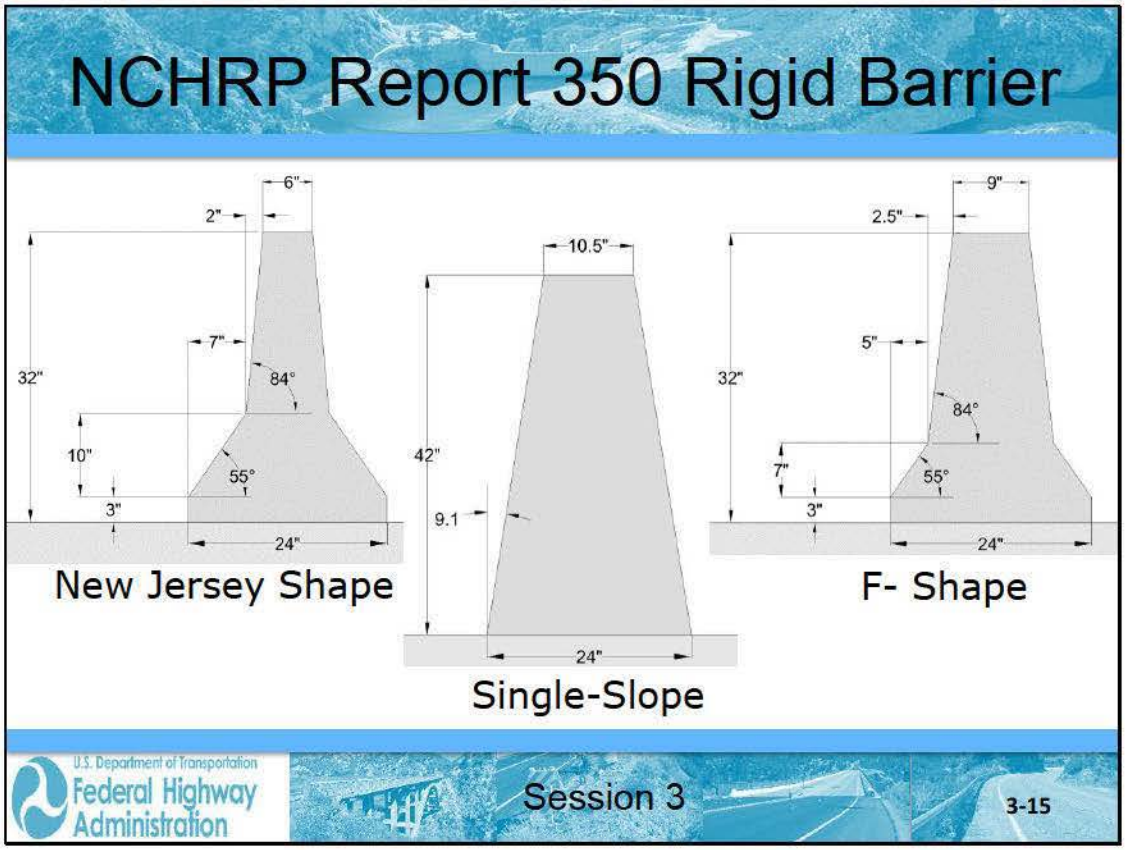
NCHRP Report 350 Rigid Barrier
6"
2"
7"
32"
84°
10"
55°
3"
24"
New Jersey Shape
10.5"
42"
9.1
24"
Single-Slope
9"
2.5"
5"
32"
84°
7"
55°
3"
24"
F- Shape
U.S. Department of Transportation
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Federal Highway Administration
Session 3
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Federal Highway Administration
Session 3
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S-8-62
SPEED LIMIT 65
Federal Highway Administration
Session 3
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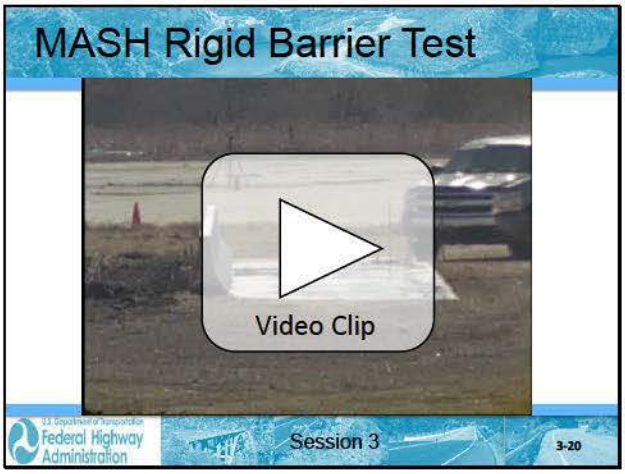
NCHRP Report 350 Rigid Barrier Tests
Video Clip
Federal Highway Administration
Session 3
3-19




## Barrier Systems: Semi-Rigid

- Semi-Rigid Barrier Systems generally have deflections of a few feet under typical impact conditions, and most consist of beam and post elements.


# Barrier Systems: Semi-Rigid

- W-Beam Guardrail
  - 12” wide W-beam rail section (12-gauge thickness).
  - Posts are spaced at 6’-3” centers, and the absolute rail height is 27 ¾ ”.
  - Two post options:
    - Steel posts, W6 x 8.5/9.0 x 6’-0” long.
    - Wood posts, 6” x 8” x 6’-0” long.
  - Block-outs: 6” x 8” wood or plastic.


MASH 27" Strong Post W-Beam Test
Video Clip
Federal Highway Administration
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MASH 27 ¾"Strong Post W-Beam Test
Video Clip
Federal Highway Administration
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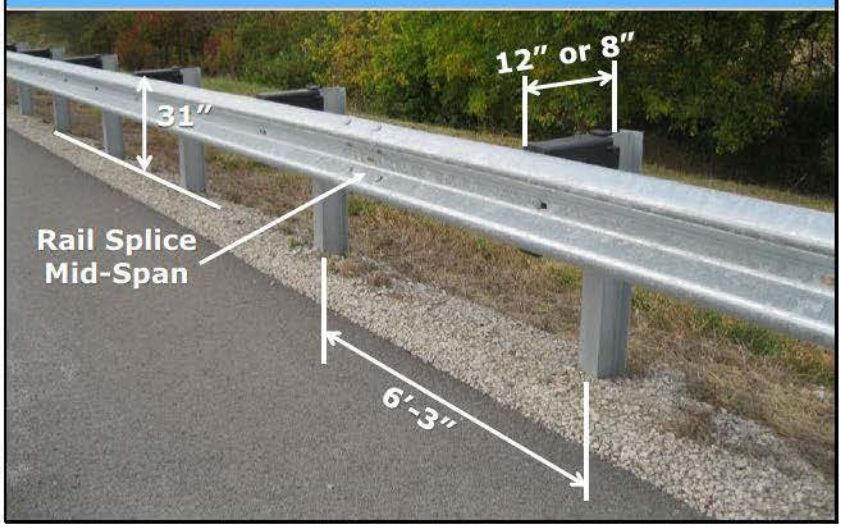
## Barrier Systems: Semi-Rigid

- Midwest Guardrail System (MGS)
  - 31" Height – Tolerance +1" – 3"
  - 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-out: 8" deep composite. 12" blocks are used only if a 6" dike is used under the rail.

NCHRP 350/MASH TL-3



## Midwest Guardrail System (MGS)



## MGS NCHRP 350 Test 3-11




## MGS MASH Test 3-11




## MGS (8" Blocks) MASH Test 3-10

# Barrier Systems: Semi-Rigid

- Thrie-Beam Guardrail
  - 20" wide Thrie-beam rail section (12-gauge thickness)
  - Posts are spaced at 6'-3" centers, and the rail height is 32"
  - Two post options:
    - Steel posts, W6 x 8.5/9.0 x 6'-6" lg.
    - Wood posts, 6" x 8" x 6'-6" lg.
  - Block-out: 6" x 8" wood or plastic

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NCHRP Report 350 Thrie-Beam Guardrail Tests


Federal Highway Administration — Session 3 — 3-32

## Barrier Systems: Flexible Barriers

- Flexible Barrier Systems typically have relatively large deflections meaning significant barrier damage when impacted. Reducing the post spacing can decrease the deflection.

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# Barrier Systems: Flexible Barriers

- Weak Post W-Beam Rail
  - 12" wide W-beam rail section (12-gauge thickness)
  - S3 x 5.7 posts
  - No block-out
  - Posts are spaced at 12'-6" centers, and the rail height is 32".
  - In order to meet NCHRP 350 and MASH, panels are now spliced mid-span between posts.

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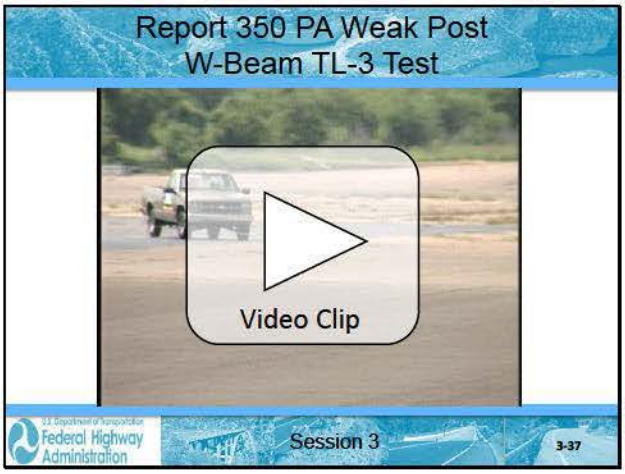
# NCHRP Report 350/MASH TL-3 Design

3-36


Report 350 PA Weak Post
W-Beam TL-3 Test
Video Clip
Federal Highway Administration
Session 3
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MASH PA Weak Post
W-Beam TL-3 Test
Video Clip
Federal Highway Administration
Session 3
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## Barrier Systems: Flexible Barriers

- High Tensioned Cable Barrier
  - Five different designs available
  - All designs are proprietary
  - Reduced deflections
  - Reduced maintenance
  - Each requires a unique proprietary terminal

***Socketed Posts often used.***

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## Barrier Systems: High Tensioned Barrier Suppliers

- Brifen
- Gibraltar
- Nucor Marion Steel
- Trinity (Cable Safety System-CASS)
- Safence

NOTE: All of the High tensioned Cable Barrier Systems tested to TL-3 & TL-4. Anchor Terminal Systems have been developed for each product. Some systems have been successfully tested on 4H:1V slopes.

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## Barrier Systems: Median Barriers

- Used to separate opposing traffic on a divided highway or to separate through traffic from local traffic.
- Many barriers approved for roadside applications are also acceptable for medians as long as the barrier is symmetrical.
- 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
Video Clip
Federal Highway Administration
Session 3
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MASH MGS Median Barrier Test
Video Clip
Federal Highway Administration
Session 3
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## Barrier Systems: Work Zone Barriers

- Types of work zone barriers include:
  - Concrete safety shape barrier
  - Portable steel barriers
- Dynamic deflection of the barrier is an important consideration in choosing a work zone barrier.



## Work Zone Barrier Performance

## NCHRP Report 350 TL-3 Test




## Barrier Systems: Work Zone Barriers

- Concrete Safety Shape Barrier



## Barrier Systems: Work Zone Barriers

- Marginal

- Unacceptable

- ?????

## Barrier Systems: Work Zone Barriers

- Portable Steel Barriers


BarrierGuard 800


ArmorGuard Barrier


ZoneGuard Barrier


Vulcan Barrier

3-50

## Transition Sections

- Used where barriers with different shapes join together, or where a semi-rigid barrier attaches to a rigid barrier, or where a flexible barrier joins a semi-rigid barrier.
- Prevents pocketing / excessive deflections
- Common features of typical transition systems:
  - Extra posts
  - Double nested rail elements
  - Snag prevention
  - Positive connection

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## Inadequate Transition


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## Inadequate Transition

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## Transition Sections

- Crash results from an inadequate transition.



Federal Highway Administration
Session 3
3-54

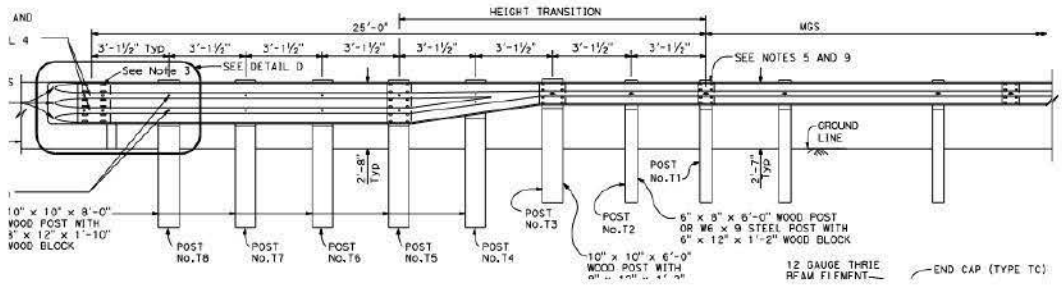
## MGS Transition Design

- 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.



## MGS Transition

# CALTRANS Transition




Ref: CALTRAN 2015 Standard Drawing, A77U4





## Review Learning Outcomes

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

Federal Highway Administration
Session 3
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# Session 4: Testing Requirements and Performance Characteristics of Common Terminals and Crash Cushions

FHWA Roadway Departure Technology Transfer
Roadside Safety Systems Design, Inspectors, and Maintenance Training

# Session 4:
# Testing Requirements and Performance Characteristics of Terminals and Crash Cushions

U.S. Department of Transportation Federal Highway Administration — Session 4 — 4-1

## Course Topics

- Session 3 – Testing Requirements and Performance Characteristics of Common Barrier Systems
- Session 4 – Testing Requirements and Performance Characteristics of Terminals and Crash Cushions

U.S. Department of Transportation Federal Highway Administration — Session 4 — 4-2

## Session 4 Learning Outcomes

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

- Understand how terminals and crash cushions are tested for crashworthiness.
- Identify common terminals and crash cushions
- Explain how these systems function
- Choose the best system for a specific site

U.S. Department of Transportation Federal Highway Administration — Session 4 — 4-3

## Guardrail Terminals

A barrier terminal must serve two functions:

- Be crashworthy when impacted end-on.
- Provide anchorage for downstream hits.

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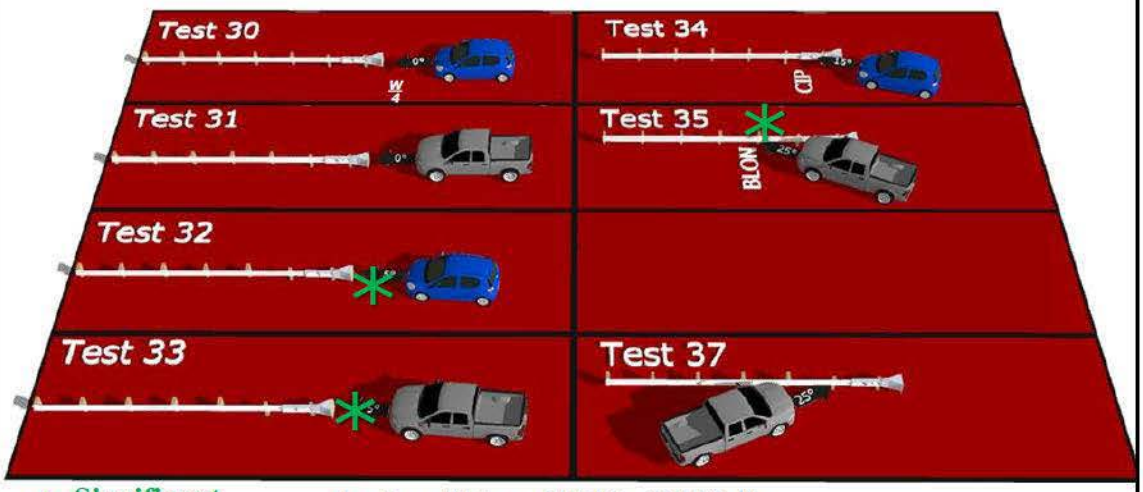
## Guardrail Terminal MASH Test Matrix




* Significant Change

* Small Car 1100C (2420 #)
* Pickup Truck 270P (5000 #)

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## Guardrail Terminals

Types of Terminals:

- Buried in Backslope
- W-beam *energy absorbing* terminals – terminal is parallel to the roadway or has a straight flare with a moderate offset
- W-beam *non-energy absorbing* terminals – terminal is generally flared away from the roadway with a specified offset



## Guardrail Terminals: Buried in Backslope Guardrail



## Guardrail Terminals: Buried in Backslope Guardrail

- Buried in Backslope Guardrail End Terminals:
  - Generic design
  - The terminal of choice when a natural non-traversable backslope is reasonably close to the point where the barrier is introduced
  - When properly designed and located, provides full shielding for the identified hazard, eliminates the possibility of an end-on impact with the barrier terminal and minimizes the likelihood of access behind the rail

## Guardrail Terminals: Buried in Backslope Guardrail

- Key design considerations:
  - Keep the height of the W-Beam rail constant relative to the roadway grade until the barrier crosses the ditch flow line,
  - Use a flare rate appropriate for the design speed,
  - Add a W-beam rubrail where needed, and
  - Use an anchor (concrete block or steel post) capable of developing the full tensile strength of the W-Beam rail.

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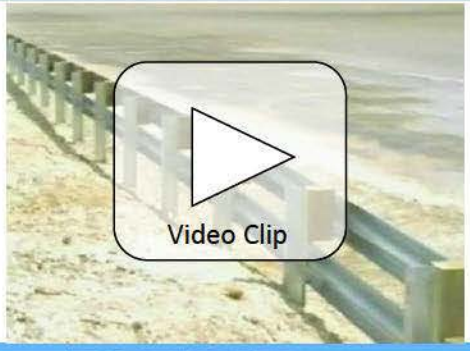
## NCHRP 350 Test 3-35 Buried in Backslope Guardrail

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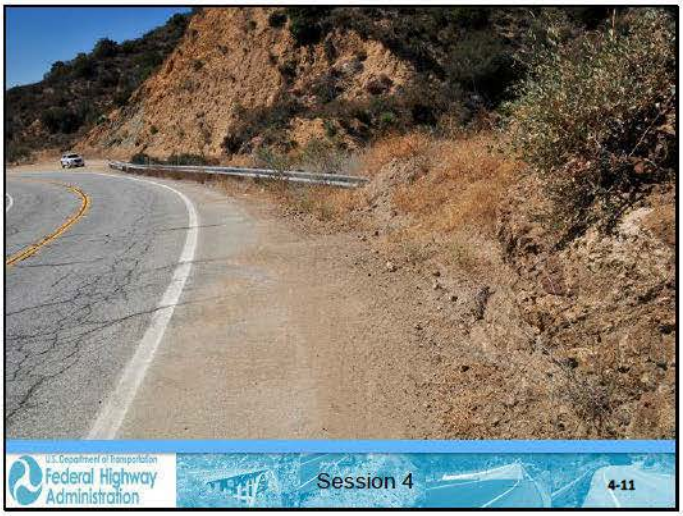
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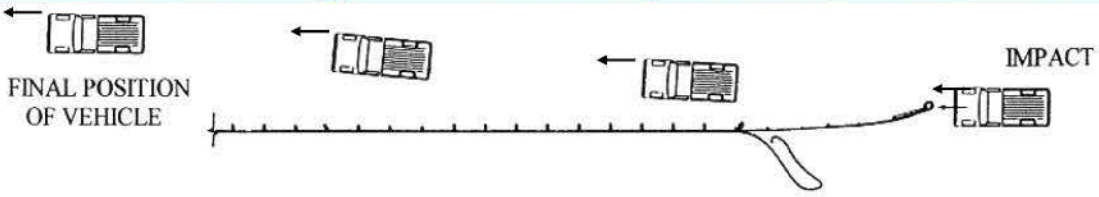
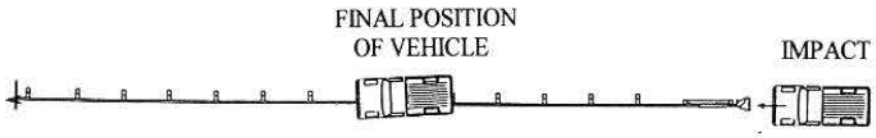
## Guardrail Terminals: Energy and Non-Energy Absorbing Designs




**Non-Energy Absorbing Terminal**
Controlled Buckling Terminal
(vehicle may travel hundreds of feet before stopping)




**Energy Absorbing Terminal**
(vehicle is brought to a controlled stop in a short distance)

## Guardrail Terminals: Energy Absorbing


- ET Plus (Guardrail Extruder Terminal)
  - Flattens and curves guardrail when hit
  - Breakaway wood or steel posts (several options available)
  - 25' long (TL-2)
  - 50' long (TL-3)
  - Recommended 1-2 ft. offset over 25 or 50 feet to reduce nuisance hits
  - Cable-anchored system

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## NCHRP 350 Test 3-31: ET Plus (Guardrail Extruder Terminal)


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## Guardrail Terminals: Energy Absorbing

- SKT 350 (Sequential Kinking Terminal)
  - Kinks and bends Guardrail when hit
  - Breakaway wood or steel posts – several options available
  - TL-2 is 25' long; TL-3 is 50' long
  - Recommended 1-2 ft. offset to reduce nuisance hits
  - Cable-anchored system

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## Guardrail Terminals: Energy Absorbing

- **MSKT** *MASH Version of SKT (Sequential Kinking Terminal)*
  - Kinks Guardrail when hit
  - Steel post system
  - TL-3 at 50' long for attachment to 31" MGS MASH Barrier
  - Cable-anchored system

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## MASH 350 Test 3-31: MSKT 350


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## Guardrail Terminals: Energy Absorbing

- FLEAT 350 (FLared Energy Absorbing Terminal)

  Straight flared (not parabolic),
  - Breakaway posts (wood or steel)
  - Energy Absorbing Variable offset 25'-0" long (TL-2) or 37'-6" long (TL-3)
  - Cable-anchored system

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## NCHRP 350 Test 3-30: FLEAT 350 (FLared Energy Absorbing Terminal)


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## Guardrail Terminals: Energy Absorbing

- X-Tension
  - Resistance is at the impact head – works in tension
  - Cables in the W-Beam are pulled thru friction plate
  - Median, Tangent, Flared from same hardware kit

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## NCHRP 350 Test 3-31: X-Tension Terminal


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## Guardrail Terminals: Energy Absorbing

- X-Lite
  - Uses a slider mechanism between post 1 and 2 that gathers and retains the rail when hit.
  - The anchor consists of posts #1 and #2 connected by tension struts and a soil plate below grade on post #2.
  - Both Tangent and Flared Layout.

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## NCHRP 350 Test 3-31: X-Lite Terminal


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## Guardrail Terminals: Energy Absorbing

- Softstop
  - Impact head flattens the w-beam guardrail vertically upon end-on impact.
  - Anchored upstream from impact head.
  - Breakaway steel posts at #1 and #2, standard posts and beyond.

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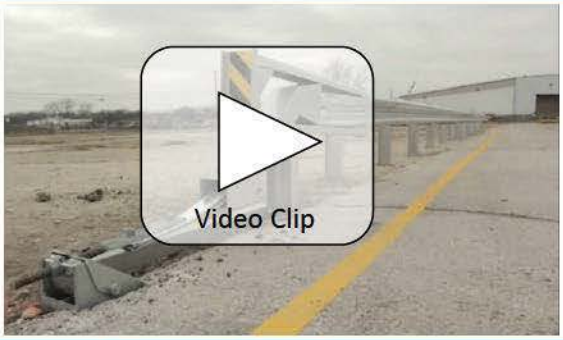
## MASH Test 3-31: Softstop Terminal

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## Impacted Softstop Terminal

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## Guardrail Terminals: Non-energy Absorbing

- SRT 350 (Slotted Rail Terminal)
  - W-Beam rails with a parabolic curve and horizontal slots in rail
  - Variable parabolic offset 3'-4'
  - 37'-6" long with 8 posts
  - Cable-anchored system



## Guardrail Terminals: Non-energy Absorbing

- SRT M10 (Slotted Rail Terminal)
  - Modified w-beam panels containing horizontal slots installed in a straight line flare.
  - CRP at post 1.
  - SYTPs at posts 2 to 10.
  - System is 37'-6" long and connects to 31" high guardrail.

## MASH Test 3-31: SRT M10




## Guardrail Terminals: Non-Compliant

- Turned-down Terminal
- Breakaway Cable Terminal (BCT)
- Modified Eccentric Loader Terminal – (MELT)



## Turned-down Terminal


Video Clip
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Breakaway Cable Terminal (BCT)
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SBCT


## Guardrail Terminals: Non-Energy Absorbing

- MELT – Modified Eccentric Loader Terminal (TL-2)
  - W-Beam rail with a parabolic curve and 4-ft offset
  - Strut between the steel tube foundation between two end posts.
  - 37'-6" long with 8 breakaway posts.
  - No rail-to-post bolts except at posts 1 and 8 and beyond,


NCHRP 350 Test 2-31
MELT
Video Clip
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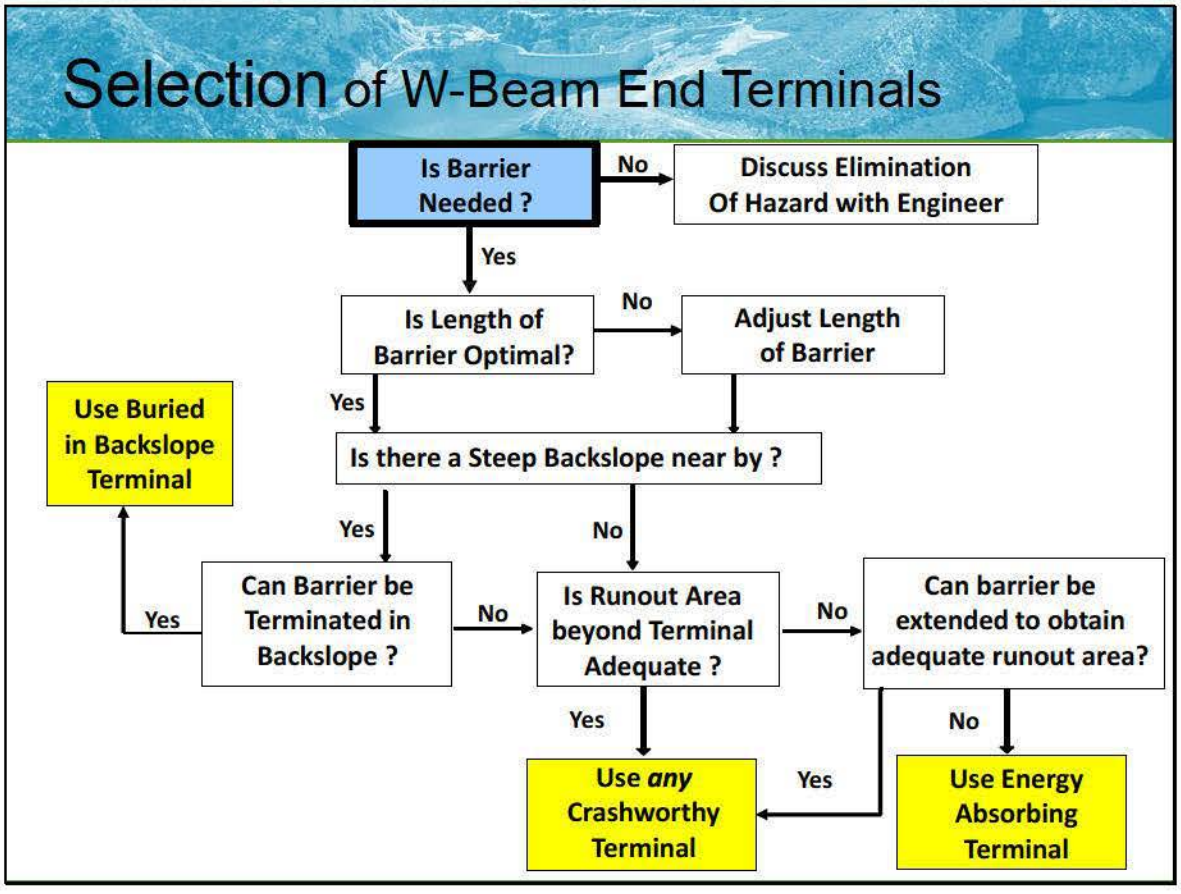
Selection of W-Beam End Terminals
Is Barrier Needed ?
No
Discuss Elimination Of Hazard with Engineer
Yes
Is Length of Barrier Optimal?
No
Adjust Length of Barrier
Yes
Use Buried in Backslope Terminal
Is there a Steep Backslope near by ?
Yes
No
Yes
Can Barrier be Terminated in Backslope ?
No
Is Runout Area beyond Terminal Adequate ?
No
Can barrier be extended to obtain adequate runout area?
Yes
Yes
No
Use any Crashworthy Terminal
Yes
Use Energy Absorbing Terminal


Crash Cushions
Crash test with blunt end:
Video Clip
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Crash Cushions
Crash test with ramped end:
Video Clip
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## Crash Cushions

- CAT (Crash Cushion Attenuating Terminal) (NCHRP 350)
  - Slotted rail tears tabs between slots
  - Best suited to terminate a double-faced strong-post median W-Beam barrier
  - Can be attached directly to a W-Beam median barrier, or to a Thrie-Beam median barrier using the standard W-Beam to Thrie-Beam transition section
  - Cable-anchored system

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## Crash Cushions

- Quest (NCHRP 350)
  - Approved for TL-2 & TL-3 systems.
  - Designed to attach to a concrete median barrier.
  - Consists of a series of W-beam fender panels supported by diaphragms with a trigger mechanism at the nose that releases the front assembly for end on hits.

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## Crash Cushions

- TRACC (TRinity Attenuating Crash Cushion) (NCHRP 350)
  - Permanent or Construction Zone
  - TL-3 TRACC / TL-2 Short TRACC / FASTRACC / WIDETRACC
  - Designed to attach to a concrete median barrier.
  - Consists of an impact "sled," energy absorbing tracks, intermediate steel frames, and double tiered 10 gauge W-Beam side panels; shipped to the field assembled.

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## Crash Cushions

- QuadGuard (MASH)
  - Can be attached directly to a W-beam or Thrie-beam median barrier as well as to a concrete safety shape.

  - Slides back on a single track when struck head-on and uses specially fabricated side panels having four corrugations.
  - Energy-absorbing cartridges in each bay need to be replaced after a crash.
  - Available in widths from 2 to 3 feet.
  - Adjustable in length from 1 to 12 bays for various speeds including 70 mph.

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## Crash Cushions

- QuadGuard Variations:
  - **QuadGuard LMC** (Low Maintenance) – narrow parallel sided version that uses elastomeric cylinders; essentially self-restoring after most impacts and best suited for use in locations where a high number of hits are anticipated.
  - **QuadGuard 69/90 LMC** – wide tapered version of the QuadGuard LMC (widths from 5'-9" to 7'-6").
  - **QuadGuard Elite** – uses High Density Polyethylene cylinders; essentially self- restoring after most impacts.



## Crash Cushions

- TAU II and TAU IIR Systems (NCHRP 350)
  - Approved for TL-2 & TL-3 systems.
  - Designed to attach to a concrete median barrier.
  - Common set of parts for 36" to 102" widths in 6" increments.
  - Consists of Thrie-beam panels, expendable energy absorbing cartridges, steel diaphragms and two cables at the bottom to provide redirection. Anchored at front and rear only.

## Crash Cushions

- SCI Smart Cushion (MASH)
  - Variable Reaction Force
  - Re-usable without Component Replacement



## Crash Cushions: Non-Redirective and Gating

- Sand Barrels (NCHRP 350)
  - Four types of sand barrels:

    **CrashGard /Energite / Fitch/Big Sandy**.
  - Individual barrel designs vary in shape by manufacturer, but they all function the same. For the same barrel weights, they are interchangeable within a given array.
  - Arrays of sand barrels may be designed to shield any shape hazard.
  - Susceptible to damage from nuisance hits; best used in areas where hits are infrequent.
  - No appreciable re-directive capability, so the corner of the hazard must be reasonably shielded. The rear corner barrel should overlap the shielded object by at least 30".

## Crash Cushions:

- Sand Barrels:

Energite

TrafFix Big Sandy

Fitch

CrashGard



## Review Learning Outcomes

- Understand how terminals and crash cushions are tested for crashworthiness.
- Identify common terminals and crash cushions
- Explain how these systems function
- Choose the best system for a specific site

# Session 5: Guardrail Design and Site-specific Installation Considerations

FHWA Roadway Departure Technology Transfer
Roadside Safety Systems Design, Inspectors, and Maintenance Training

# Session 5: Guardrail Design and Site-specific Installation Considerations

U.S. Department of Transportation Federal Highway Administration — Session 5 — 5-1

## Course Topics

- Session 4 – Testing Requirements and Performance Characteristics of Common Terminals and Crash Cushions
- Session 5 – Guardrail Design and Site-specific Installation Considerations

U.S. Department of Transportation Federal Highway Administration — Session 5 — 5-2

## Session 5 Learning Outcomes

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

- Define barrier Length of Need (LON) and explain its basis
- Evaluate field installations
- Apply a field procedure to check Length of Need
- Describe the basic principles of an optimal barrier installation under different scenarios.

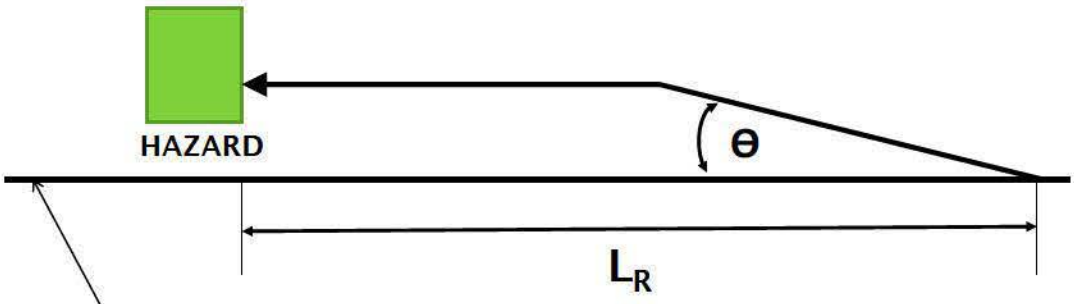
U.S. Department of Transportation Federal Highway Administration — Session 5 — 5-3

## Length of Need (LON) Definition

The length of barrier needed in advance of the primary hazard to intercept and redirect the path of an encroaching vehicle.



## Length of Need (LON) Theory



## Runout Lengths - AASHTO

Table 5-10(b). Suggested Runout Lengths for Barrier Design (U.S. Customary Units)

| Design Speed (mph) | Runout Length ($L_R$) Given Traffic Volume (ADT) (ft) | | | |
|---|---|---|---|---|
| | Over 10,000 | 5,000 to 10,000 | 1,000 to 5,000 | Under 1,000 |
| 80 | 470 | 430 | 380 | 330 |
| 70 | 360 | 330 | 290 | 250 |
| 60 | 300 | 250 | 210 | 200 |
| 50 | 230 | 190 | 160 | 150 |
| 40 | 160 | 130 | 110 | 100 |
| 30 | 110 | 90 | 80 | 70 |

Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – TABLE 5.10, Pg. 5-50



## Length of Need - AASHTO

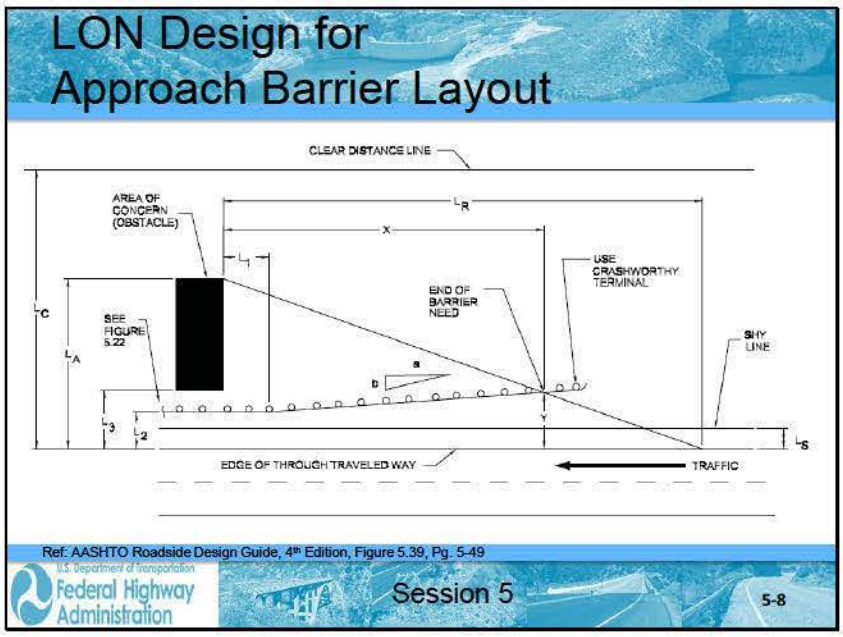
- Calculating the length of need (X) for straight or nearly straight sections of roadway:
  - For flared guardrail installations:

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

  - For parallel guardrail installations:

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

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


LON Design for Approach Barrier Layout
CLEAR DISTANCE LINE
AREA OF CONCERN (OBSTACLE)
$L_R$
X
$L_1$
USE CRASHWORTHY TERMINAL
END OF BARRIER NEED
SEE FIGURE 5.22
$L_C$
$L_A$
a
b
SHY LINE
$L_3$
$L_2$
$L_S$
EDGE OF THROUGH TRAVELED WAY
TRAFFIC
Ref: AASHTO Roadside Design Guide, 4th Edition, Figure 5.39, Pg. 5-49
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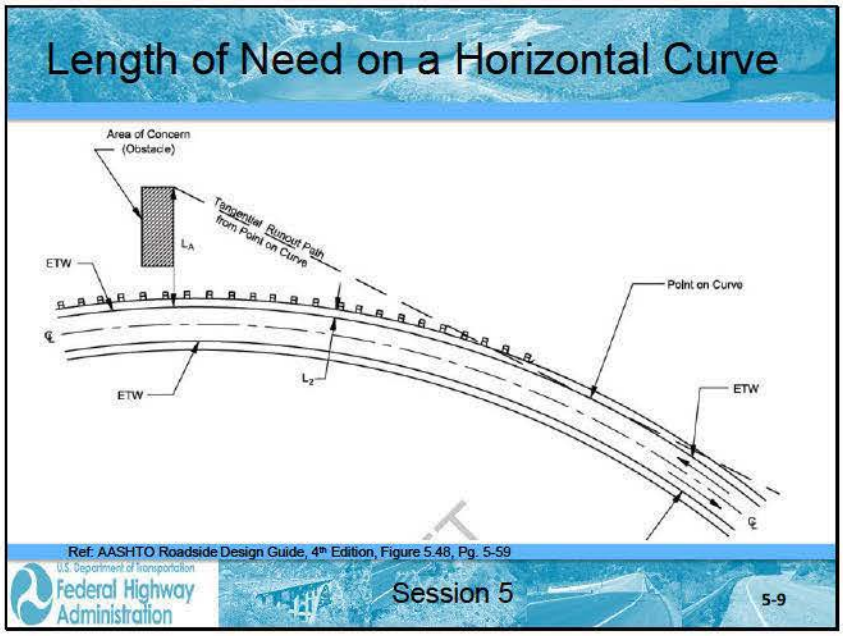
Length of Need on a Horizontal Curve
Area of Concern (Obstacle)
Tangential Runout Path from Point on Curve
$L_A$
ETW
Point on Curve
℄
ETW
$L_2$
ETW
℄
Ref: AASHTO Roadside Design Guide, 4th Edition, Figure 5.48, Pg. 5-59
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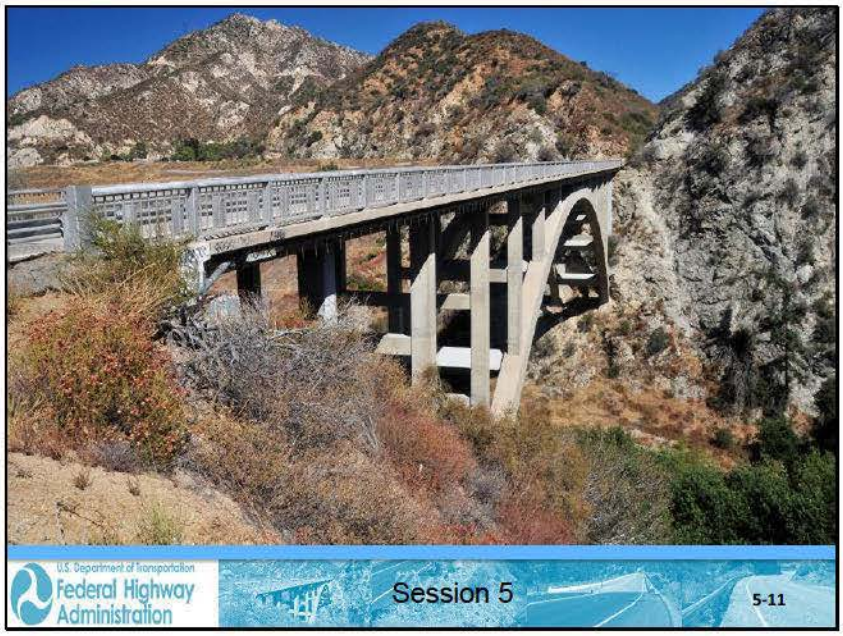
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SPEED LIMIT 45
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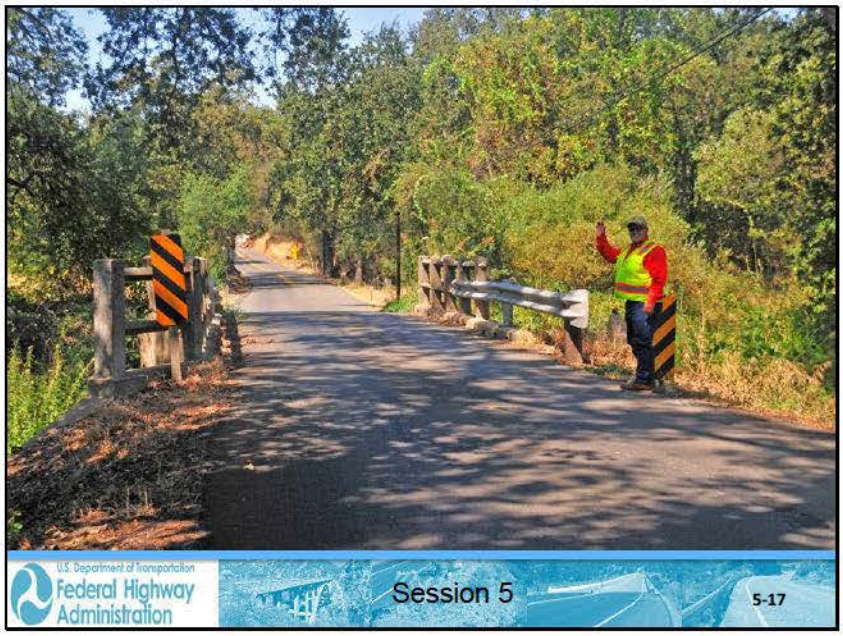
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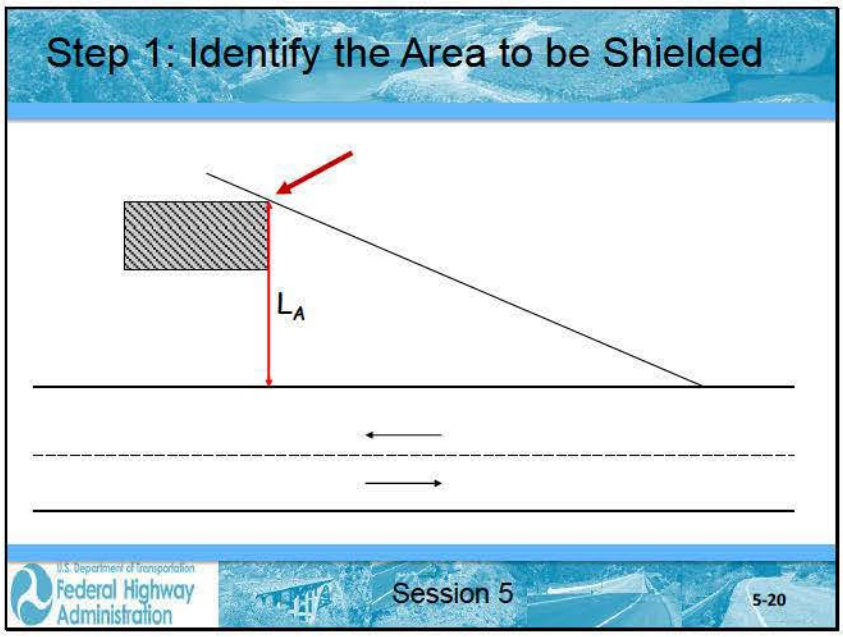
Step 1: Identify the Area to be Shielded
$L_A$
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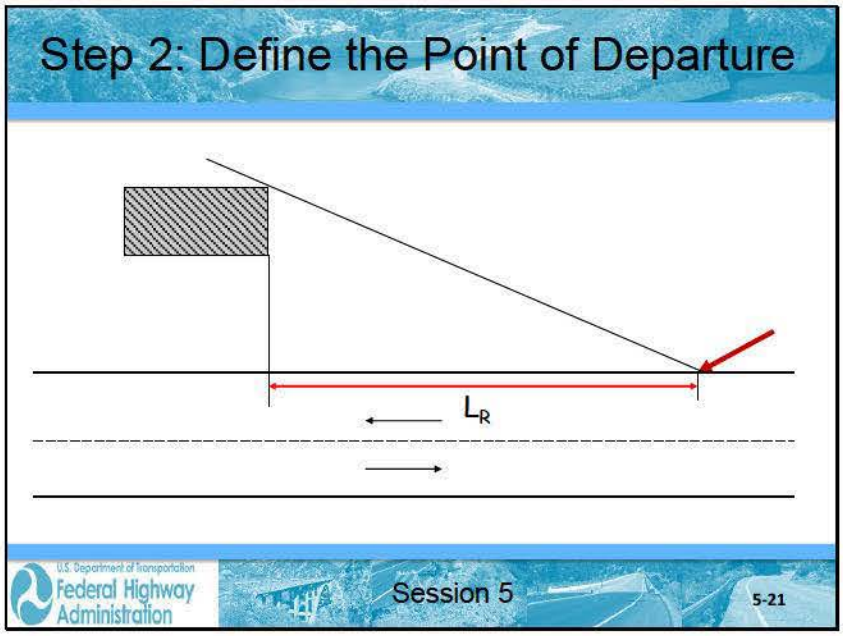
Step 2: Define the Point of Departure
$L_R$
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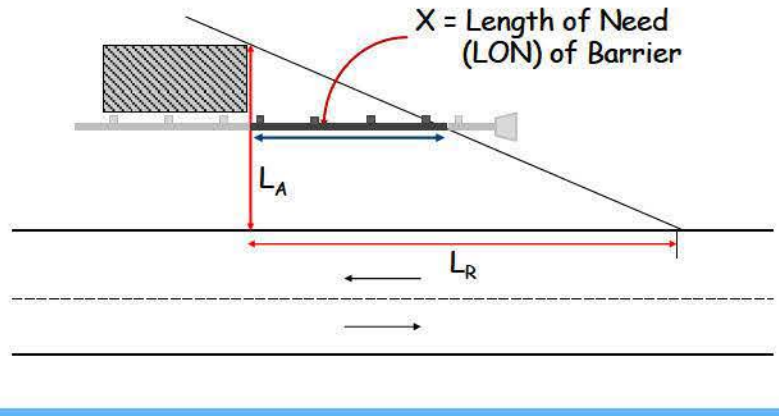
## Step 3: Intersect the Hypotenuse

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## Quick Field Check of LON

1. Stand on roadway edgeline opposite the upstream edge of the hazard.
2. Pace upstream along edgeline appropriate runout length (based on speed of roadway and traffic volume).
3. Turn and look at far lateral edge of hazard.
4. If planned (or existing) guardrail run intercepts this line of sight, it satisfies basic design length of need.
5. Check for "secondary" hazards that could be economically shielded by extending barrier.
6. Check for better terminal location by extending barrier a short distance.

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## Guardrail Placement ($L_2$)

Place as far from outside edge of traffic lane as practical (without affecting performance)

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## Principle 1: Deflection Distance

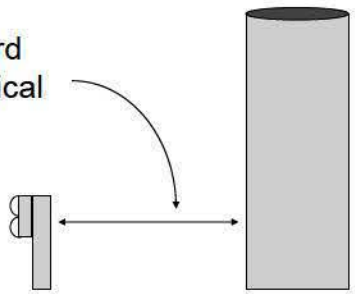
Adequate room must be left behind the barrier to allow for lateral deflection in an impact.

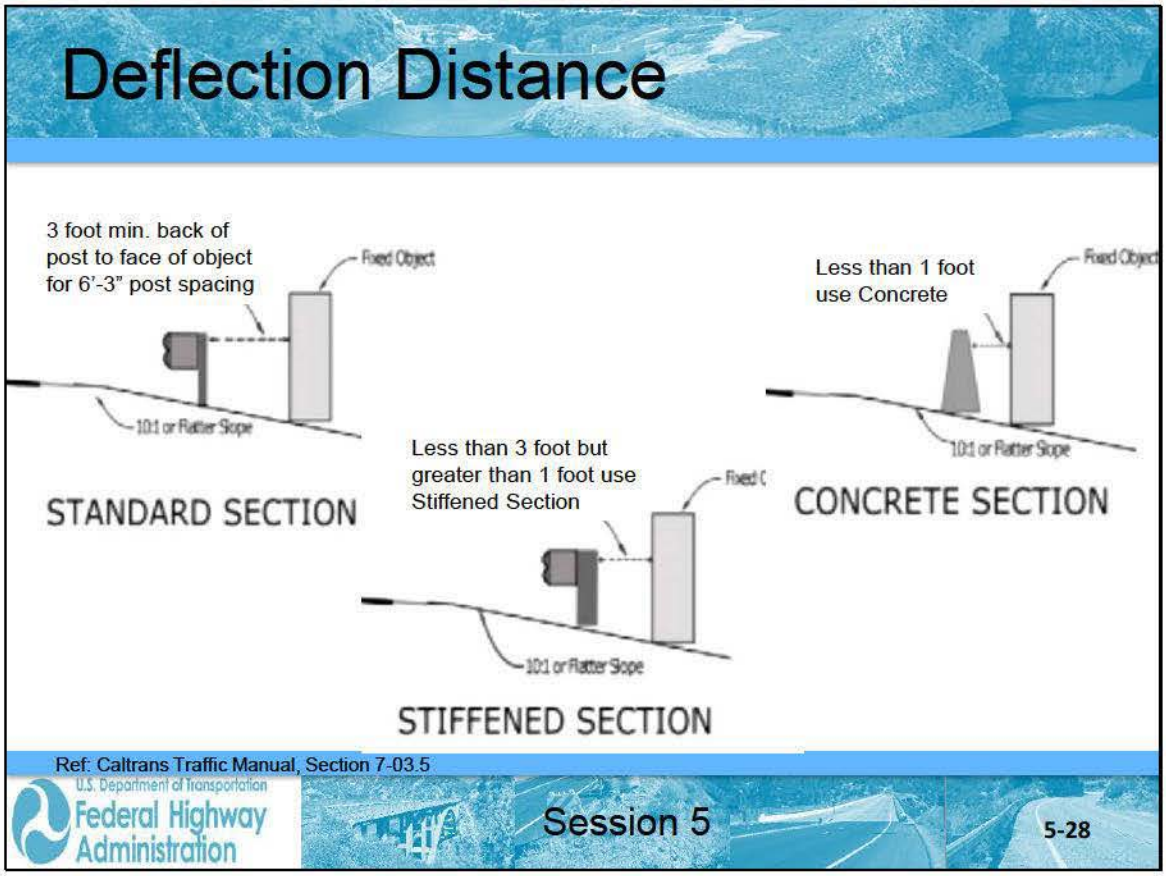
- If the barrier is shielding a fixed object, the distance between the barrier and the object should be sufficient to avoid the vehicle impacting or snagging on the object.
- Note that large trucks may roll or tip and need more room for lateral deflection.



## Deflection Distance

Barrier to Hazard Distance Is Critical Element




Deflection Distance
3 foot min. back of post to face of object for 6'-3" post spacing
Fixed Object
10:1 or Flatter Slope
STANDARD SECTION
Less than 3 foot but greater than 1 foot use Stiffened Section
10:1 or Flatter Slope
STIFFENED SECTION
Less than 1 foot use Concrete
10:1 or Flatter Slope
CONCRETE SECTION
Ref: Caltrans Traffic Manual, Section 7-03.5
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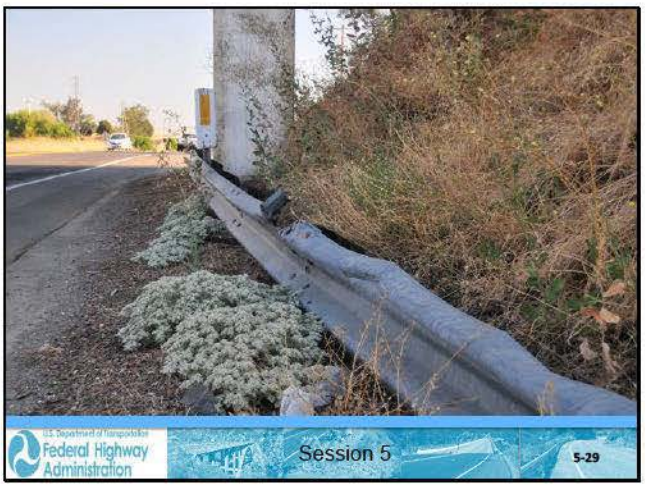
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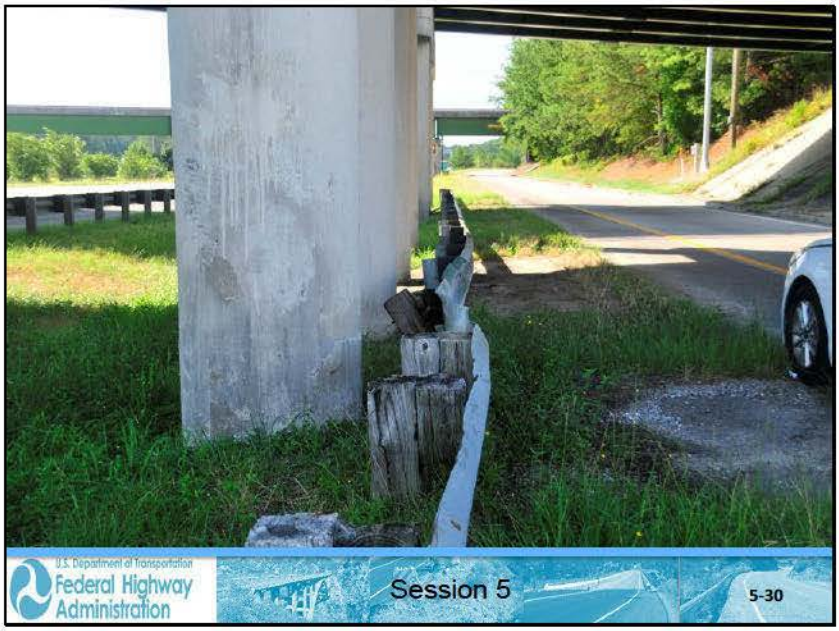
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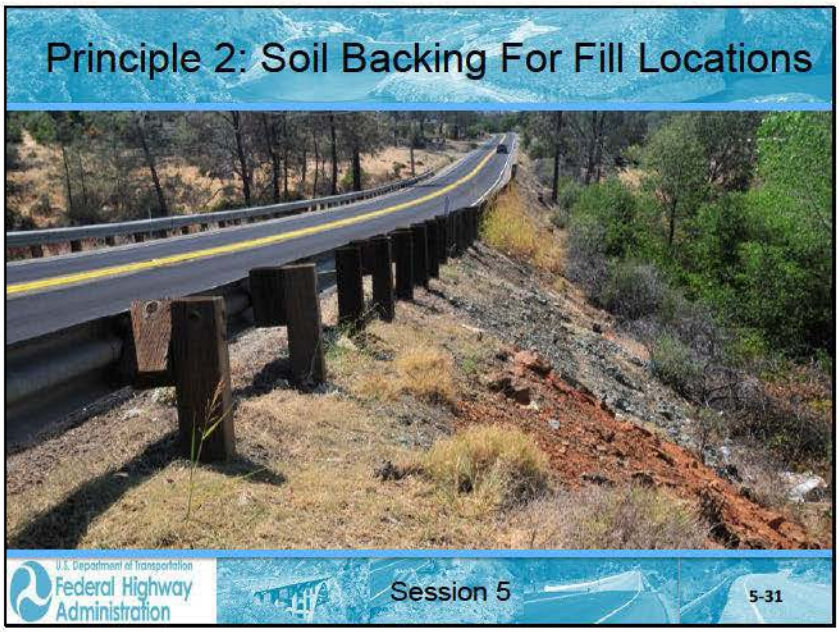
Principle 2: Soil Backing For Fill Locations
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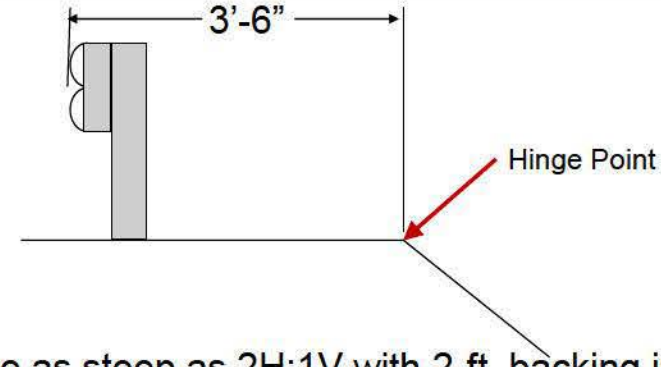
## Soil Backing Recommendation




1. Slope can be as steep as 2H:1V with 2-ft. backing in strong soil with 6 ft. posts.
2. Backing can be less than 2 ft. with 2H:1V slope in strong soil with 7 ft. posts.

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

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## Principle 3: Flare Rate

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## 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.
- Transition from barrier to an obstacle nearer the roadway (bridge parapet or railing).
- Reduce total length of rail needed.
- Reduce nuisance hits.

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## Flare Rate

Disadvantages of flared barriers:

- Flare *increases the maximum angle* at which the barrier can be hit.
- Flare *increases the probability* that a vehicle will be redirected into or across the roadway after an impact.
- Flared barriers *require more grading* to provide a flat area between the traveled way and the barrier.

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# Flare Rate Table

Table 5.7 Suggested flare rates for Barrier Design (U.S. Customary Units)

| Design Speed (mph) | Flare Rate for Barrier inside Shy Line | Flare Rate for Barrier beyond Shy Line | |
|---|---|---|---|
| | | Rigid Barrier | Semi-Rigid Barrier |
| 70 | 30:1 | 20:1 | 15:1 |
| 60 | 26:1 | 18:1 | 14:1 |
| 55 | 24:1 | 16:1 | 12:1 |
| 50 | 21:1 | 14:1 | 11:1 |
| 45 | 18:1 | 12:1 | 10:1 |
| 40 | 16:1 | 10:1 | 8:1 |
| 30 | 13:1 | 8:1 | 7:1 |

Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – TABLE 5.9, Pg. 5-48



# Flared W-Beam Guardrail Example


Principle 4: Slope in Front of Guardrail
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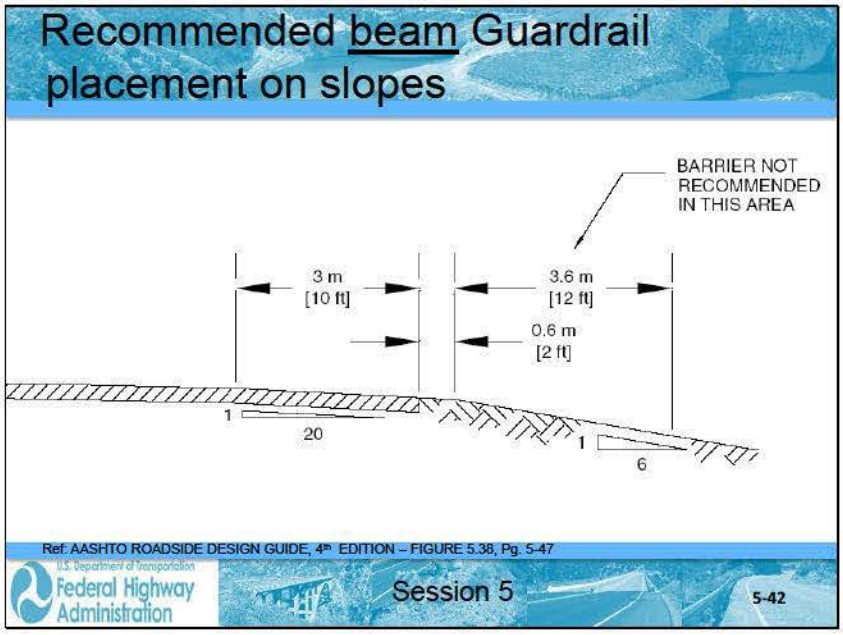
## Slope in Front of Guardrail

- Any barrier may be placed anywhere on a 10H:1V or flatter slope.
- Cable Guardrail may be placed on slopes of 6H:1V or 4H:1V, but its location on these slopes is critical for minimizing penetrations.
- On slopes steeper than 10H:1V but no steeper than 6H:1V, metal beam guardrail should be placed in compliance with Figure 5-38 (AASHTO RDG).


Recommended beam Guardrail placement on slopes
BARRIER NOT RECOMMENDED IN THIS AREA
3 m [10 ft]
3.6 m [12 ft]
0.6 m [2 ft]
1
20
1
6
Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – FIGURE 5.38, Pg. 5-47
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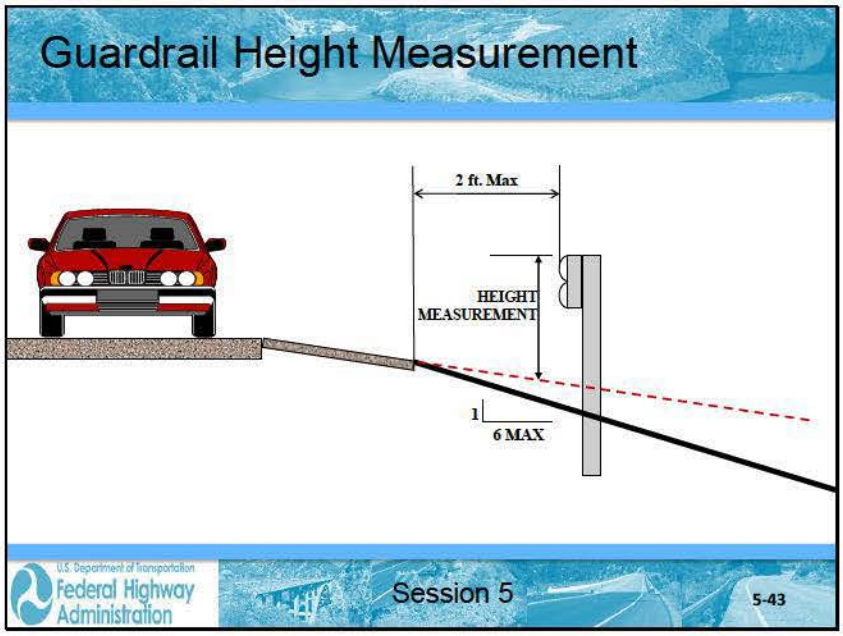
Guardrail Height Measurement
2 ft. Max
HEIGHT MEASUREMENT
1
6 MAX
U.S. Department of Transportation Federal Highway Administration
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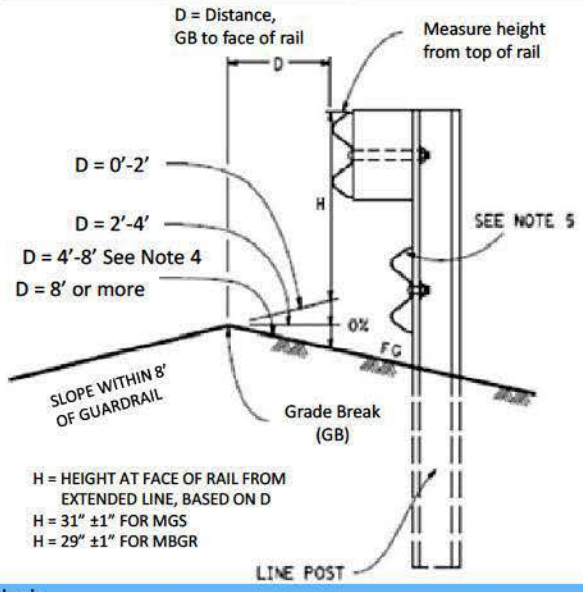
## Guardrail Height Measurement




Ref: CALTRANS Standards

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## Guardrail on Slopes


U.S. Department of Transportation Federal Highway Administration

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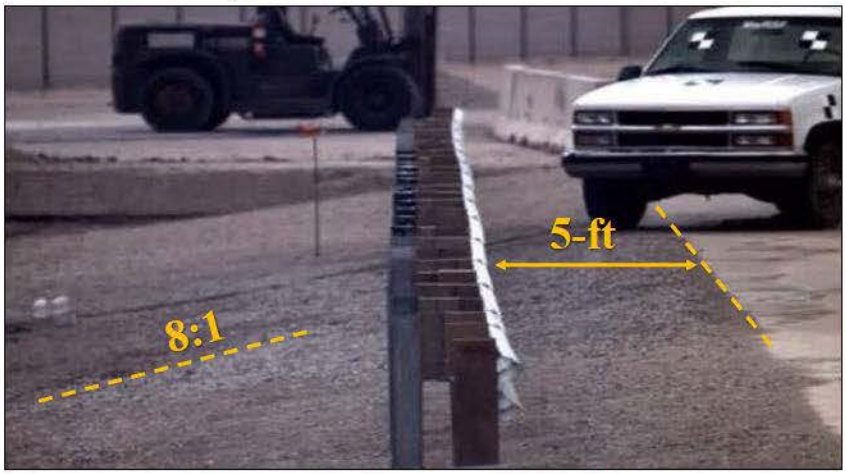
## Slope in Front of Guardrail

- **MGS on 8H:1V slope**




**5-ft from Shoulder on 8H:1V Slope**



## Location of Cable in Swales

## Terminal Grading

- Special grading requirements for Guardrail terminals:
  - Avoid installing terminals on or too near steep slopes.
  - Relatively flat terrain is required *in front of terminals* so that vehicles do not vault into the air or dive into the ground.
  - Modest slopes are used *behind terminals* to allow sufficient recovery areas for vehicles gating through the end treatment.
  - FHWA has guideline requirements for both tangent and flared terminals.

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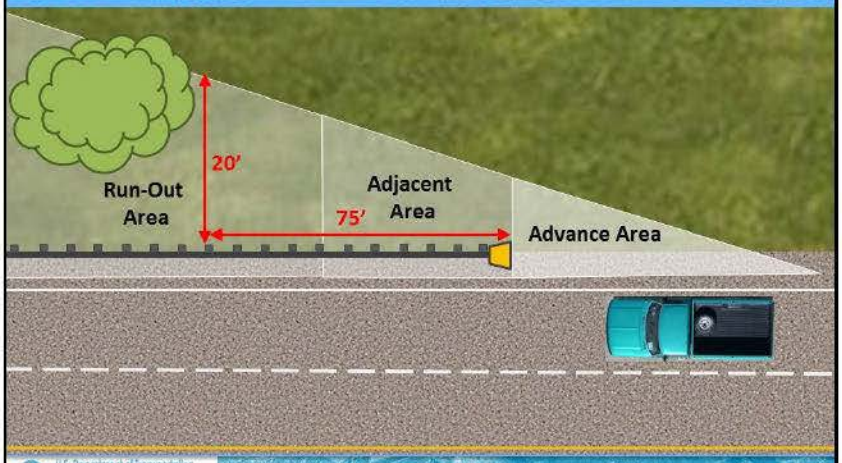
## Terminal Grading

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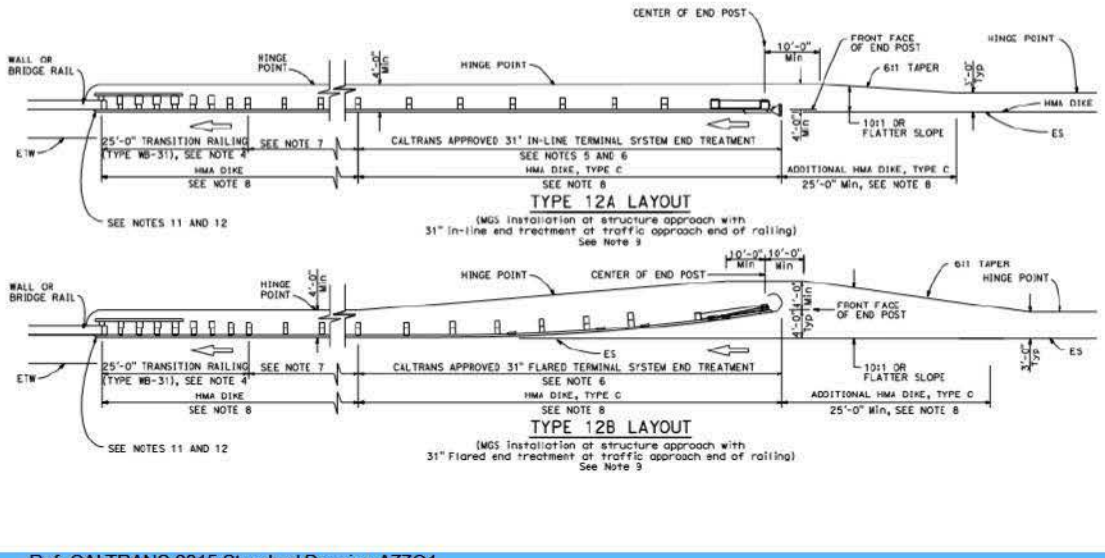
# Terminal Grading




Ref: CALTRANS 2015 Standard Drawing A77Q1

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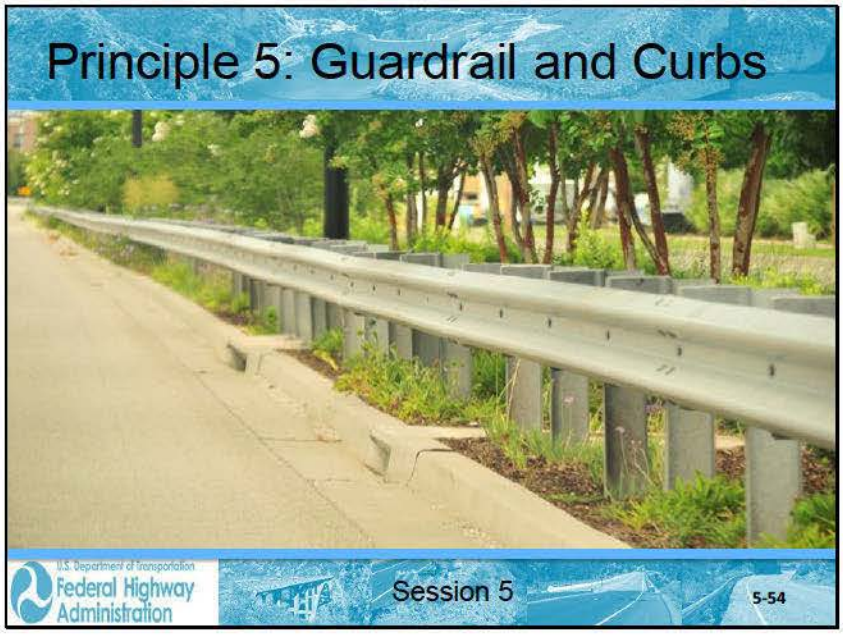
Principle 5: Guardrail and Curbs
U.S. Department of Transportation
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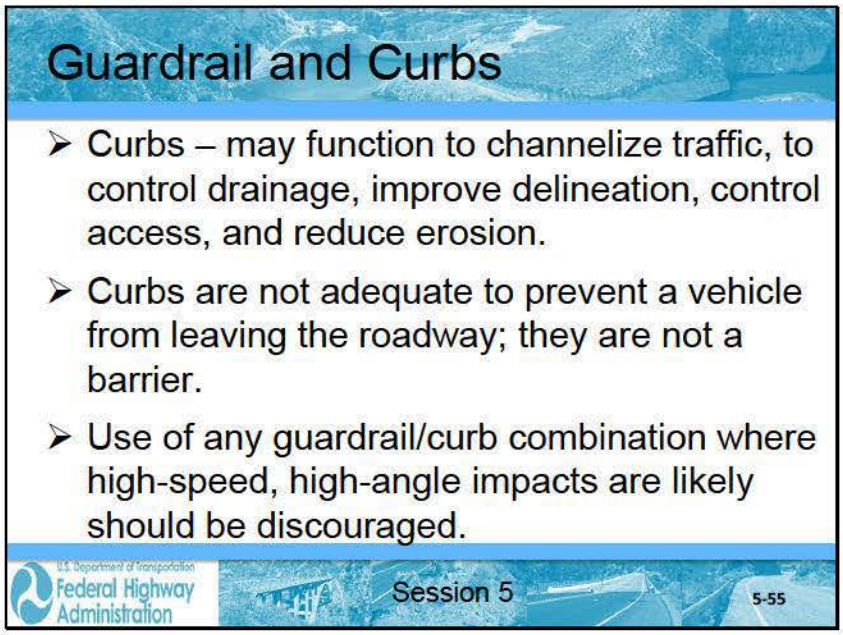
Guardrail and Curbs
Curbs – may function to channelize traffic, to control drainage, improve delineation, control access, and reduce erosion.
Curbs are not adequate to prevent a vehicle from leaving the roadway; they are not a barrier.
Use of any guardrail/curb combination where high-speed, high-angle impacts are likely should be discouraged.
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Guardrail and Curbs
Video Clip
U.S. Department of Transportation
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W-Beam behind 4" Asphalt Curb
Video Clip
U.S. Department of Transportation
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NCHRP 350 TL-3 MGS behind 6" Asphalt Curb
Video Clip
Federal Highway Administration
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MASH TL-2 MGS 6 ft. behind curb
Video Clip
Federal Highway Administration
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## MGS with Curbs

- Can be up to 7" behind the face of vertical curbs:
  - For a 6" high vertical curb use a 12" blockout or
  - For a 4" high vertical curb with 8" blockouts
- Flush with a vertical or sloped curb no higher than 6".
- 6 ft. beyond the curb

  (TL-2 only)

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## Guardrail/Curb Recommendations

Best: Remove curb

May also: Limit curb height to 4" or stiffen guardrail by:

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

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## Curbs should not be used along High-Speed Roadways


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## Guardrail Placement at Intersections

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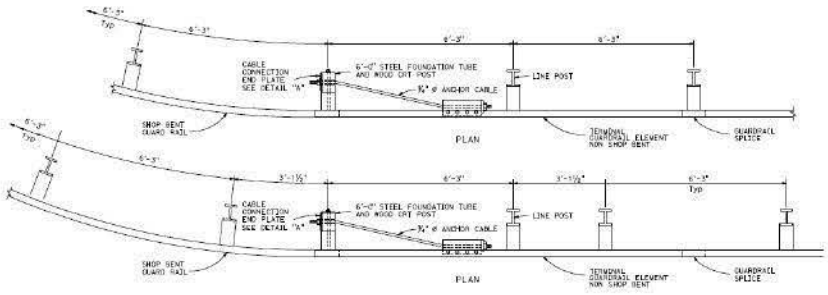
## Guardrail Placement at Intersections

A non-breakaway anchor should be used to add intermediate anchorage when there is an abrupt change in the alignment of the guardrail, such as when the guardrail is continued down an intersecting road or if there is an area of concern on the side slope that would cause a more severe collision than impacting the guardrail. If there is no area of concern on the side slope, then a breakaway anchor with drilled posts set in foundation should be used for intermediate anchorage.

Ref: CALTRANS Traffic Manual pg. 7-23



## Guardrail Placement at Intersections




Ref: CALTRANS Construction Detail – Intermediate Assembly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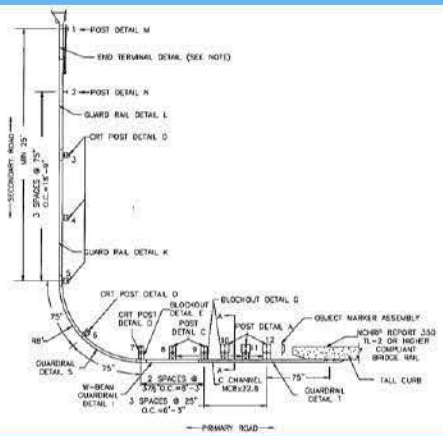
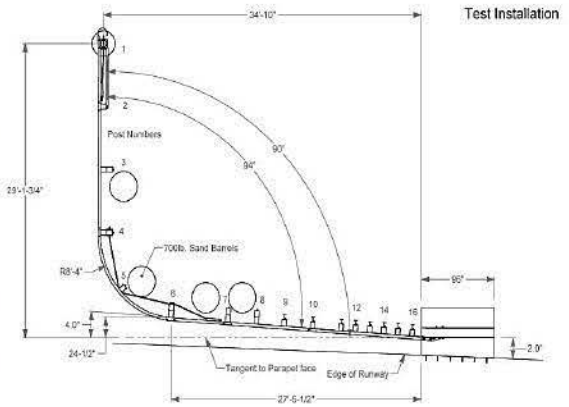
## Transportation Pooled Fund Program


Accepted at NCHRP Report 350 at TL-2

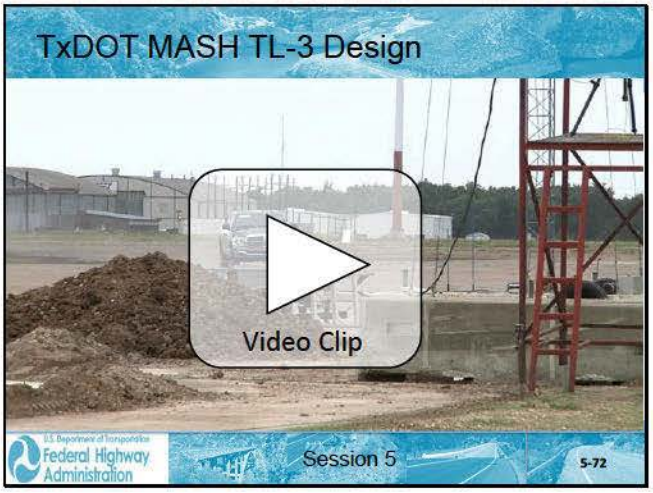


# TxDOT MASH TL-3 Design


## Short Radius at Intersecting roadways



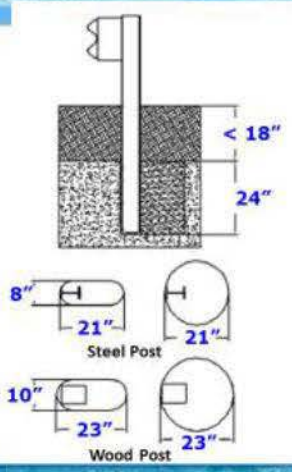


## Guardrail Placement in Rock

If solid rock is encountered within 0" to 18" of the finished grade.

Drill a 21" dia. hole for steel post or 23" dia. hole for wood post, 24" into the rock.

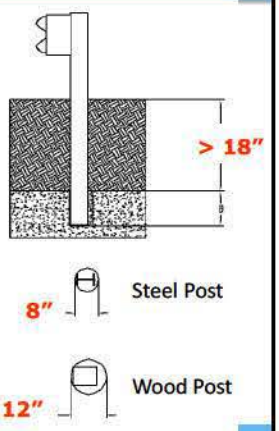





## Guardrail Placement in Rock

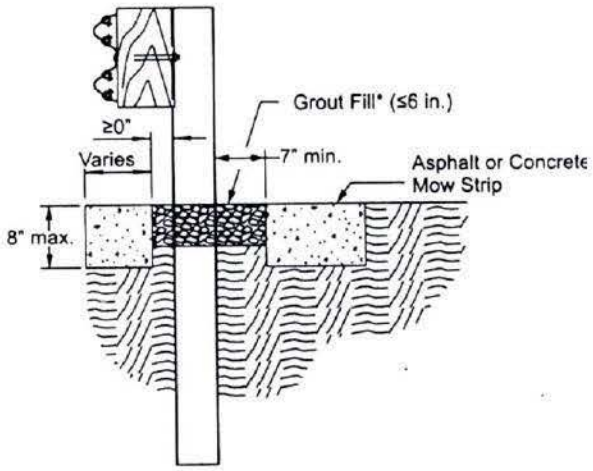
If solid rock is encountered below 18".

Drill a 8" dia. hole for steel post or 12" dia. hole for wood post, for 12" into the rock or to the desired standard embedment depth minus the depth of soil whichever is less.



## Guardrail Placement in Paved Areas

- Any excess post length, after meeting these depths, may be field cut to ensure proper guardrail mounting height.
- Backfill with a cohesionless material.

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## Review Learning Outcomes

- Define barrier Length of Need (LON) and explain its basis
- Evaluate field installations
- Apply a field procedure to check Length of Need
- Describe the basic principles of an optimal barrier installation under different scenarios.

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# Session 6: Guardrail/Terminal Installation and Common Errors

FHWA Roadway Departure Technology Transfer
Roadside Safety Systems Design, Inspectors, and Maintenance Training

# Session 6: Guardrail/Terminal Installation and Common Errors



## Course Topics

- Session 5 – Guardrail Design and Site-specific Installation Considerations
- Session 6 – Guardrail/Terminal Installation and Common Errors



## Session 6 Learning Outcomes

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

- Describe basic layout and installation techniques for common traffic barriers and terminals
- Identify common installation errors
- Inspect completed installations

## Session 6 Outline

- Guardrail Installation
- Terminal Installation
- Common Installation Errors
- Inspection



## Common Installation Errors: Corrugated Systems

- Incorrect height of the system.
  - Check the State standard sheets to make sure that the top of the post and the top of the rail are at the correct height.
  - Consider final pavement thickness when measuring height of rail if installing the barrier before the roadway surface is completed.

## Common Installation Errors: Corrugated Systems

**Rail too high**

**Rail too low**



## Common Installation Errors: Corrugated Systems

- Lapping
  - For one-way traffic, all guardrail panels should be lapped in the direction of traffic with the upstream panel lapping the downstream panel including terminal elements and end sections. (Some exceptions i.e. CAT)
  - For two-way traffic always mount guardrail going with traffic, meaning rail laps will be opposite on each side of the road.

## Common Installation Errors: Corrugated Systems

- Lapping Rail in Terminals
  - Lap all rail in the terminal in the direction of traffic.

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## Common Installation Errors: Corrugated Systems

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## Common Installation Errors: Corrugated Systems

- Splice bolts missing



## Common Installation Errors: Corrugated Systems

- Incorrect post spacing.
  - Post spacing must be accurate on all systems.
  - Post spacing may need to be adjusted when going up-hill, downhill and around curves. Always fit radius rail to suit field conditions.
  - Post spacing is critical when connecting w-beam to a stiffer system and when inadequate deflection distance is available.

## Other Considerations

Missing Posts

| Metal Beam Guardrail | MGS |
|---|---|
| No more than two may be omitted | No more than three may be omitted |
| Nested rail across span to 2nd post on both sides | Does not require nested rail |
| Breakaway posts on both sides of clear span | |

Ref: AASHTO Roadside Design Guide, 2011



## Other Considerations

Additional Blockouts (MBGR only)

- One additional blockout for any number of posts.
- Two additional blockouts for up to two consecutive posts.

Additional Blockouts (MGS only)

- Two 12 inch blockouts
- Three 8 inch blockouts

Ref: AASHTO Roadside Design Guide, 2011

## Other Considerations

- Barrier Delineation
  - Final Alignment
    - All lines to be pleasing to sight and correct height.
    - Any necessary adjustments need to be made with post driver.

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## Common Installation Errors: Improper Application

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Common Installation Errors:
Improper Application
Does Not Allow for Deflection
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Common Installation Errors:
Improper Application
EXIT
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Common Installation Errors:
Improper Application
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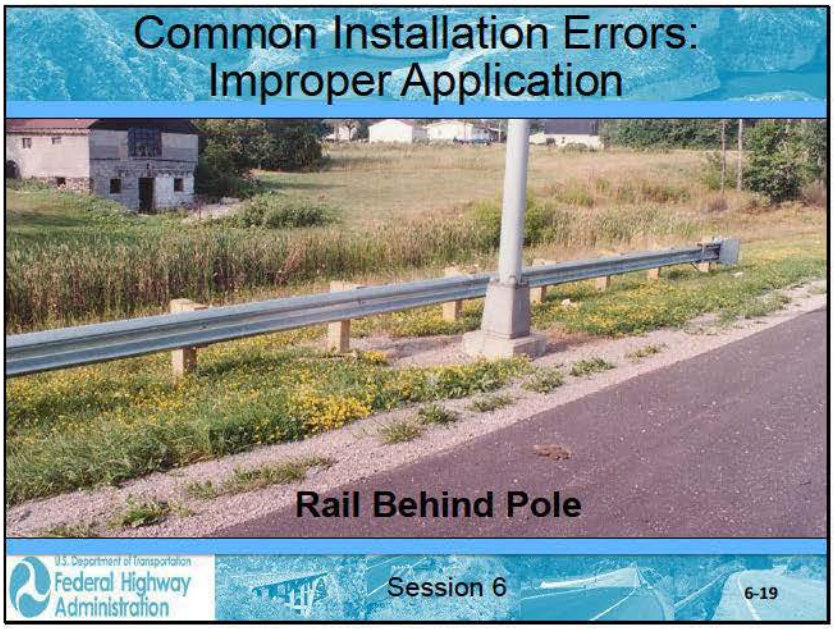
Common Installation Errors:
Improper Application
Rail Behind Pole
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Federal Highway Administration
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## Terminal Installation

- See manufacturer's installation instructions and State standards.

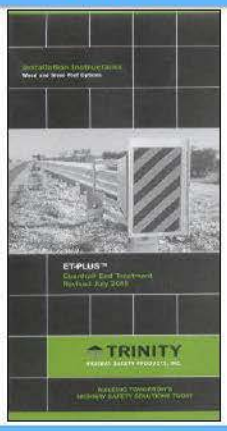
**Crashworthy**
approach end terminal

**Non-crashworthy**
trailing end



## Terminal Installation Manuals

**Tangent Terminals ET-Plus and SKT/FLEAT**




## Terminal Installation: Example

- Terminals can be wood post or steel post systems.
- Steel posts may be hinged. Some may be driven.

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## Terminal Installation: Example

- Be sure the correct end panel has been used.

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## Terminal Installation: Example

- **Install ground strut if one is used.**
- **Install anchor cable.**
  - Place cable anchor bracket on back side of guardrail.
  - Place cable assembly through the bracket and through post 1.
  - Place bearing plate at the base of post 1 (Note 5" side up & 3" side down). Secure to prevent rotation.
  - Secure both ends of cable assembly holding the cable to prevent twisting.

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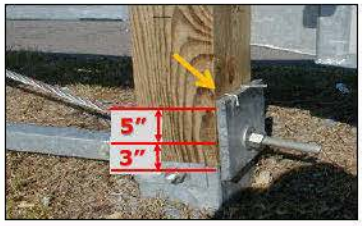
## Terminal Installation: Example

- **Secure Bearing Plate.**
  - Wood Post – Toe nail.
  - Steel Post – Use retainer tie or bearing plate with bent tabs.

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## Terminal Installation: Example

- Install impact head bolted to post #1, not guardrail.
  - Wood Post – Lag Screw
  - Steel Post – Hex Bolt

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## Terminal Installation: Example

- Delineate the impact head – install reflectorization on the front face as per CA MUTCD requirements.

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Common Installation Errors: Terminals
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Common Installation Errors: Terminals
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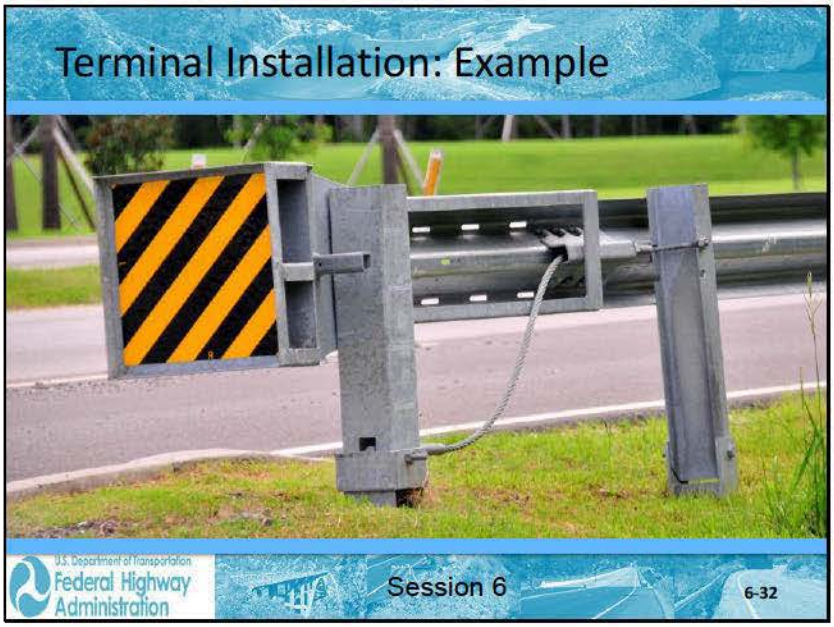
Terminal Installation: Example
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Federal Highway Administration
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U.S. Department of Transportation
Federal Highway Administration
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## Common Installation Errors: Terminals

A common error with all terminal types is:

*Improper Grading*

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## Common Installation Errors: Terminals

- Poor location for an impact head.
- Excessive flare on a tangent terminal.

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## Common Installation Errors: Terminals

- Terminal is placed too close to the hazard.
- Check to see which posts are bolted to the rail. Some terminals use posts that are backup posts and should not be bolted to the rail.

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## Common Installation Errors: Terminals

- Terminals with an impact head: the impact head should be attached to post #1 and parallel to the rail.
- Steel foundation tubes, stubs for hinged/breakaway posts, ground struts should not be more than 4" above the ground line to avoid snagging and/or instability in the vehicle.

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## Common Installation Errors: Terminals

- Terminals with an impact head: the end of the first W-beam rail section should be pushed against the throat area of the impact head so the end of the rail cannot be seen.

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## Common Installation Errors: Terminals

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## Common Installation Errors: Terminals

- Be sure impact head is facing the proper direction.
- Check the type and combination of breakaway posts against the State standards and the manufacturer's instructions.
- Not all posts in all terminals use a block-out.
- Check to see that the correct cable anchor bracket is used and it is properly attached to the rail.


Federal Highway Administration Session 6 6-40

U.S. Department of Transportation Federal Highway Administration Session 6 6-41

## Common Installation Errors: Terminals

- The cable assembly should be taut and correctly installed.
- Many terminals will not function as designed if washers are used on the traffic side. Check the manufacturer's instructions to see if and when washers are to be used.
- Check to see that bearing plate is properly oriented.


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## Common Installation Errors: Terminals

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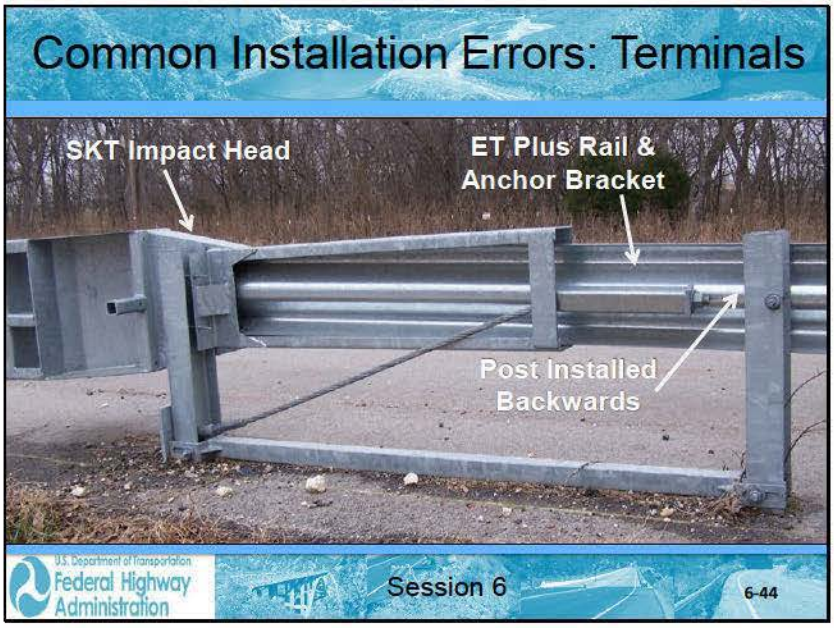
Common Installation Errors: Terminals
SKT Impact Head
ET Plus Rail & Anchor Bracket
Post Installed Backwards
U.S. Department of Transportation
Federal Highway Administration
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Common Installation Errors: Terminals
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Common Installation Errors: Terminals
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Common Installation Errors: Terminals
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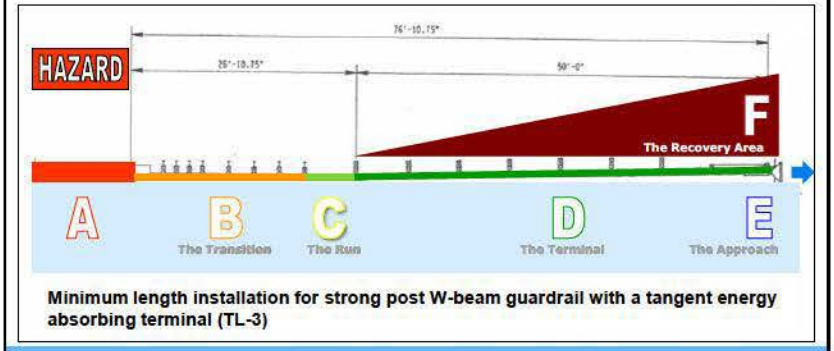
## Installation Inspection

- Where To Begin: Breaking Down The Task




**Minimum length installation for strong post W-beam guardrail with a tangent energy absorbing terminal (TL-3)**



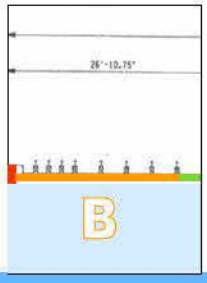
## Installation Inspection

- The Fixed Object / Hazard


- If Rigid Bridge Railing Exists
  - Make sure semi-rigid barrier is properly connected to the end of the rigid barrier.
- If No Bridge Railing
  - Ensure that guardrail adequately shields the downstream end of the hazard and is adequately anchored.

## Installation Inspection

- The Transition
  - Keep eye out for post/concrete interference.
  - Watch out for special oversize posts and variable post spacing.

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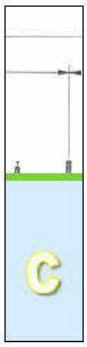
## Installation Inspection

- The Run
  - Can be 1 section of rail or 100+.
  - Each post set at proper height.
  - Each block set correctly on the post.
  - Each bolt is tightened snugly.




- Each rail/cable section
  - Check protective coating
    - Thickness & continuity
    - White rust
    - Existing damage
  - Proper overlapping
- Delineation
  - Local standards (CA MUTCD)

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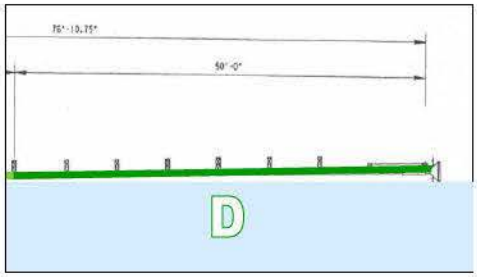
## Installation Inspection

- The Terminal
  - RULE #1: FOLLOW MANUFACTURER INSTRUCTIONS
- Watch out for:
  - Impact Head Connections
  - Cable Tautness
  - 4" Ground Exposure Limit

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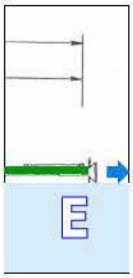
## Installation Inspection

- The Approach
  - Terrain must be smooth, traversable and unobstructed and blend with existing slopes.
  - No Rocks, Trees, Breakaway Utility Poles, Uneven Terrain, Sidewalks/Curbs, or anything that may upset the vehicle prior to impact.

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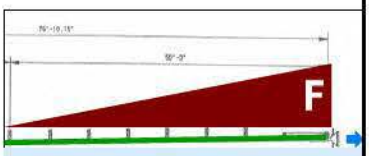
## Installation Inspection

- The Impact Zone / Recovery Area
  - In impact, vehicle needs traversable surface for safe deceleration
  - Drivers that miss terminal have area in front of hazard to regain control.
  - Typical slopes:
    - 10:1 to 4 ft. behind terminal






## Terrible Results



## Review Learning Outcomes

- Describe basic layout and installation techniques for common traffic barriers and terminals
- Identify common installation errors
- Inspect completed installations.

# Session 7: Maintenance of Systems

FHWA Roadway Departure Technology Transfer
Roadside Safety Systems Design, Inspectors, and Maintenance Training

# Session 7: Maintenance of Systems



## Course Topics

- Session 6 – Guardrail/Terminal Installation and Common Errors
- Session 7 - Maintenance of Systems



## Session 7 Learning Outcomes

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

- Explain when damaged barrier needs to be reset, repaired, rebuilt, or removed.
- Describe when a damaged barrier terminal is no longer functional, and know whether to repair, replace in-kind, or upgrade to a newer design.
- Perform repairs in a safe, cost-effective manner.

## Session 7 Outline

- Determine extent of damage
- Replacement in-kind vs. upgrade
- Upgrade existing deficient systems
- Temporary shielding/delineation of damaged hardware



## Introduction

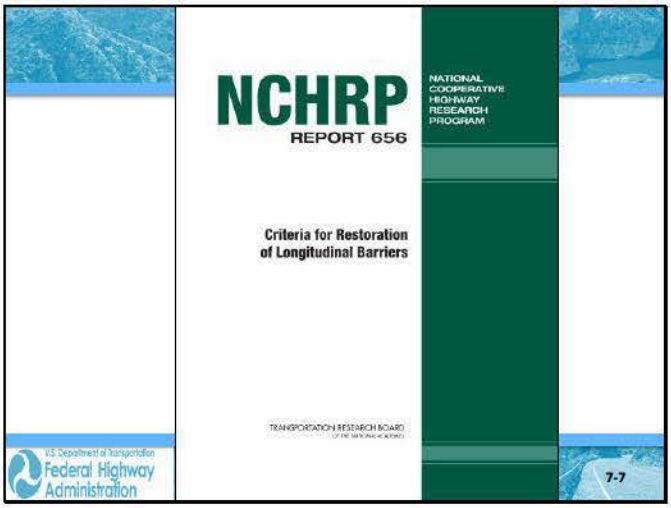
- Guardrail systems usually require repair after crashes.
- Guidelines concerning guardrail repair / replacement vary by State.



## Need To Repair

Video Clip

**VIDEO**




## Determine Extent of Damage

**NCHRP Report 656** is intended to identify methods to better determine whether minor damage to W-Beam barriers poses a crash safety risk. It is intended to enable maintenance crews to prioritize repairs.

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## Modes of Barrier Damage

**BARRIERS**
(Based on experimental testing)

- Post and rail deflection
- Rail deflection only
- Rail flattening
- Posts separated from rail
- Missing/broken posts
- Missing blockouts
- Twisted blockouts
- Non-manufactured holes
- Damage at a rail splice
- Vertical tear
- Horizontal tear

**End Treatments**
(Based on Engineering Judgment)

- Damaged end post
- Anchor cable missing
- Anchor cable loose
- Anchor cable bracket
- Stub height
- Lag screws
- Bearing plate

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Low Speed Impact Prior to Damage
Video Clip
U.S. Department of Transportation
Federal Highway Administration
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Test Level 3 After Damage
Video Clip
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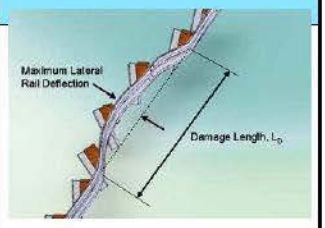
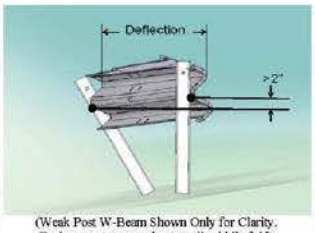
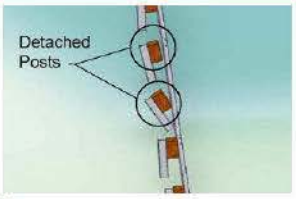
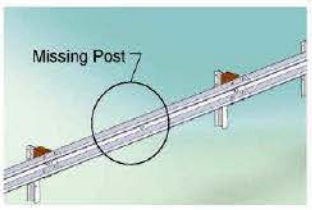
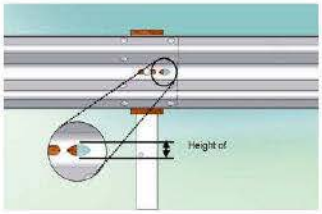
## Barriers

| Damage Mode | Repair Threshold | Relative Priority | Measurement |
|---|---|---|---|
| Post and Rail Deflection | One or more of the following thresholds:<br>• More than 9 inches of lateral deflection anywhere over a 25 ft length of rail.<br>• Top of rail height 2 or more inches lower than original top of rail height. | High |  <br>  <br>(Weak Post W-Beam Shown Only for Clarity. Each measurement taken at rail middle fold) |
| | 6-9 inches lateral deflection anywhere over a 25 ft length of rail. | Medium | |
| | Less than 6 inches of lateral deflection over 25 ft length of rail. | Low | |

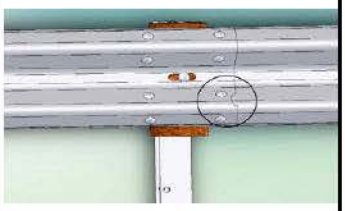
## Barriers

| Damage Mode | Repair Threshold | Relative Priority | Measurement |
|---|---|---|---|
| Posts Separated from Rail | • 2 or more posts with blockout attached with post-rail separation less than 3 inches.<br>• 1 or more post with post-rail separation which exceeds 3 inches. | Medium |  |
| | • 1 post with blockout attached with post-rail separation less than 3 inches. | Low | Note:<br>1. If the blockout is not firmly attached to the post, use the missing blockout guidelines.<br>2. Damage should also be evaluated against post/rail deflection guidelines. |
| Missing/Broken Posts | 1 or more posts<br>• Missing<br>• Cracked across the grain<br>• Broken<br>• Rotten<br>• With metal tears | High |  |

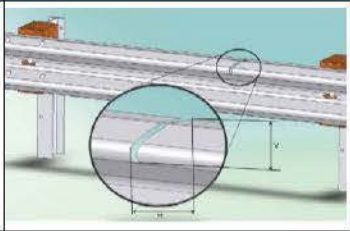
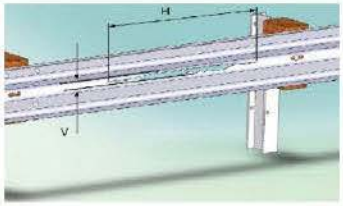
## Barriers

| Damage Mode | Repair Threshold | Relative Priority | Measurement |
|---|---|---|---|
| Non-Manufactured holes<br><br>(such as crash induced holes, lug-nut damage, or holes rusted-through the rail) | • More than 2 holes less than 1" in height in a 12.5' length of rail.<br>• Any holes greater than 1" height.<br>• Any hole which intersects either the top or bottom edge of the rail. | High |  |
| | 1-2 holes less than 1" in height in a 12.5' length of rail. | Medium | |

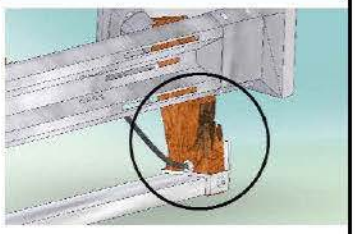
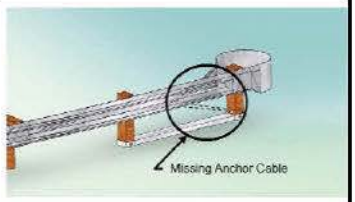
## Barriers

| Damage Mode | Repair Threshold | Relative Priority | Measurement |
|---|---|---|---|
| Damage at a rail splice | More than 1 splice bolt:<br>• Missing<br>• Damaged<br>• Visibly missing any underlying rail<br>• Torn through rail | High |  |
| | 1 splice bolt:<br>• Missing<br>• Damaged<br>• Visibly missing any underlying rail<br>• Torn through rail | Medium | |

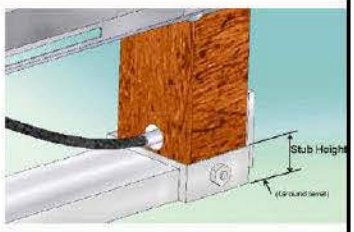
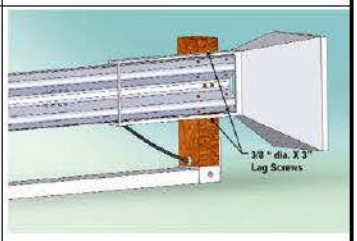
## Barriers

| Damage Mode | Repair Threshold | Relative Priority | Measurement |
|---|---|---|---|
| Vertical Tear | Any length vertical (transverse) tear | High |  |
| Horizontal Tear | Horizontal (longitudinal) tears greater than 12 inches long or greater than 0.5 inches wide.<br>Note: for horizontal tears less than 12 inches in length or less than 0.5 inches in height, use the non-manufactured holes guidelines. | Medium |  |

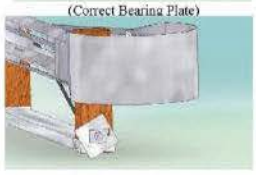
## End Treatments

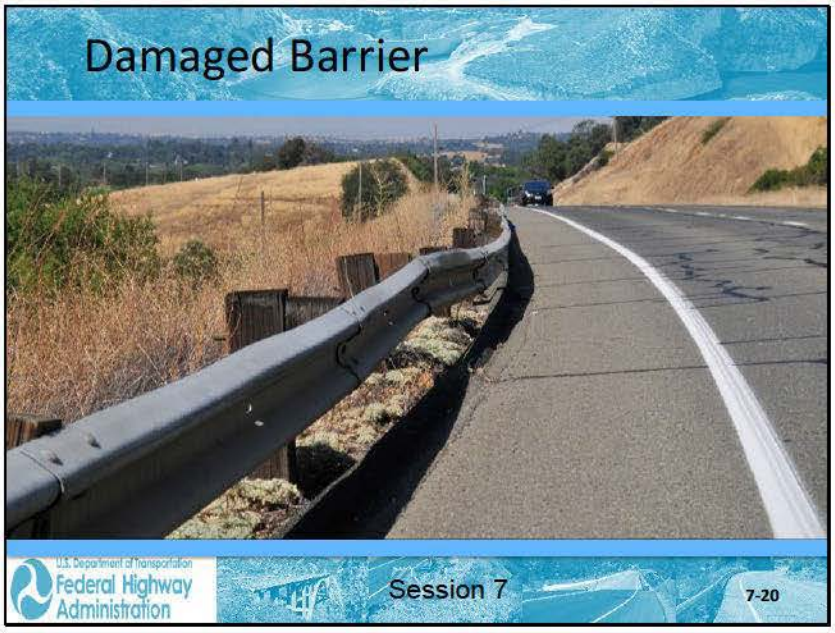
| Damage Mode | Repair Threshold | Relative Priority | Measurement |
|---|---|---|---|
| Damage End Post | Not functional (sheared, rotted, cracked across the grain) | High |  |
| Anchor Cable | Missing | High |  |

## End Treatments

| Damage Mode | Repair Threshold | Relative Priority | Measurement |
|---|---|---|---|
| Stub Height | Height which exceeds 4" | Medium |   |
| Lag Screws (Energy Absorbing Terminals Only) | Missing or failed lag Screws | High |   |

## End Treatments

| Damage Mode | Repair Threshold | Relative Priority | Measurement |
|---|---|---|---|
| Bearing Plate | Loose or Misaligned | Medium |  (Correct Bearing Plate)  (Misaligned Bearing Plate) |
| | Missing Bearing Plate | High |  (Missing Bearing Plate) |


Damaged Barrier
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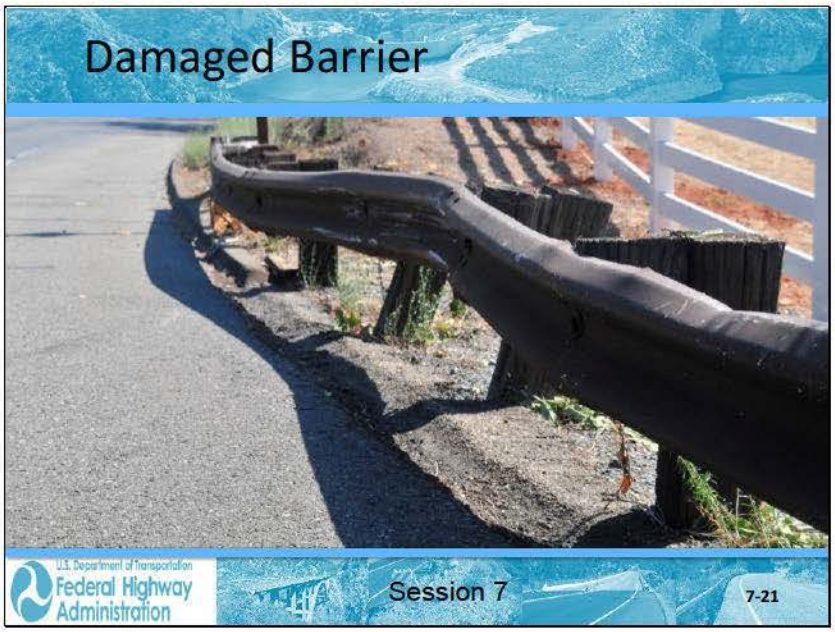
Damaged Barrier
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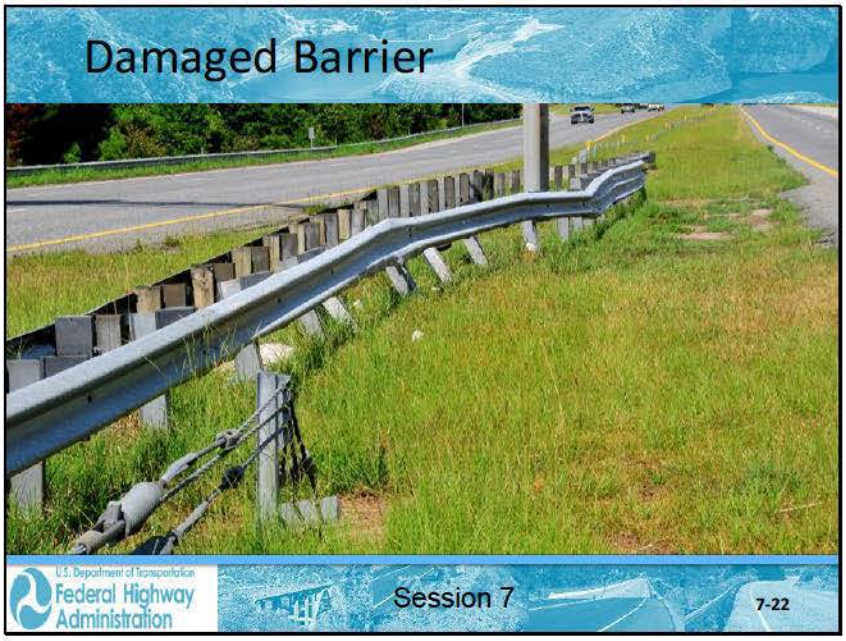
Damaged Barrier
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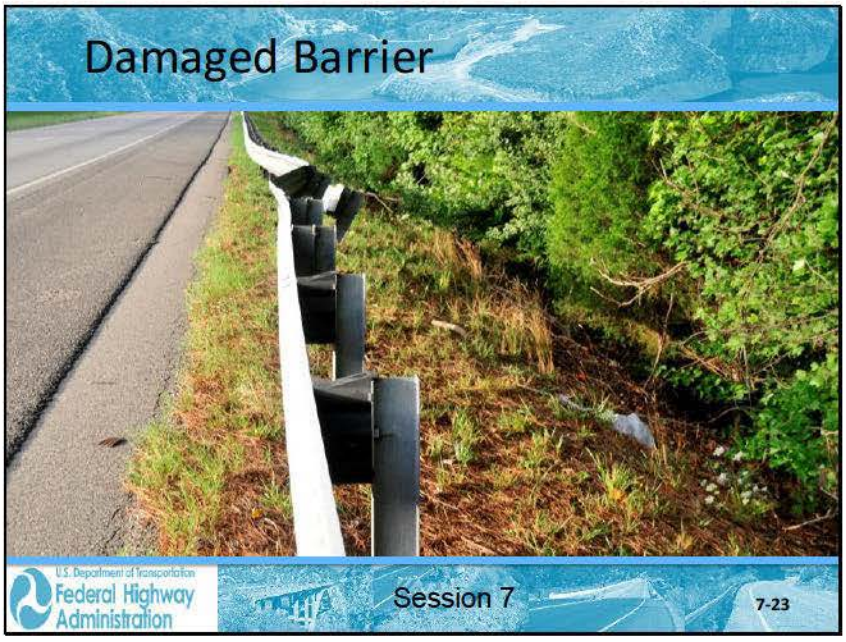
Damaged Barrier
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Damaged Barrier
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## Who Hit the Terminal?



## Damaged Terminals

- Check for nuisance hits on terminals to be sure post #1 is not damaged.
- Even with claims of "reusability" – use best judgment and closely examine all salvageable parts.
- Some items may be re-used.
- Can Impact Heads can be returned to manufacturer for repair / recertification?
  - Strut/Foundation
  - Nuts/Bolts


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Damaged Terminals
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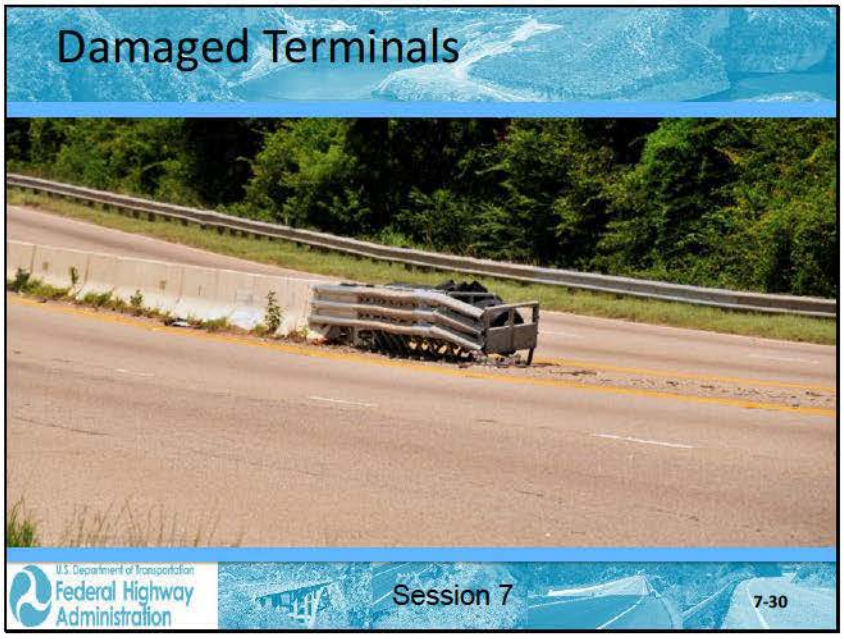
Damaged Terminals
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Damaged Terminals
EXIT
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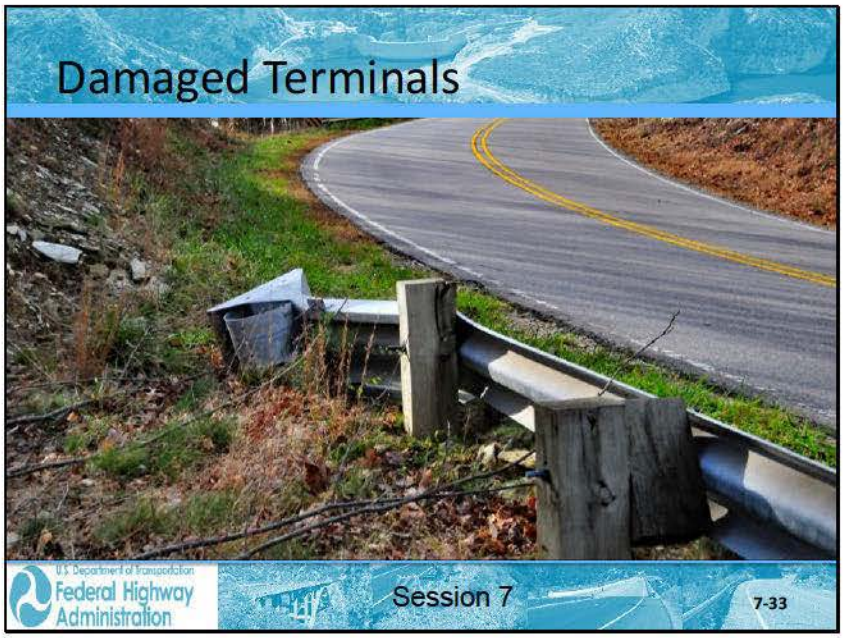
Damaged Terminals
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Other Problems?
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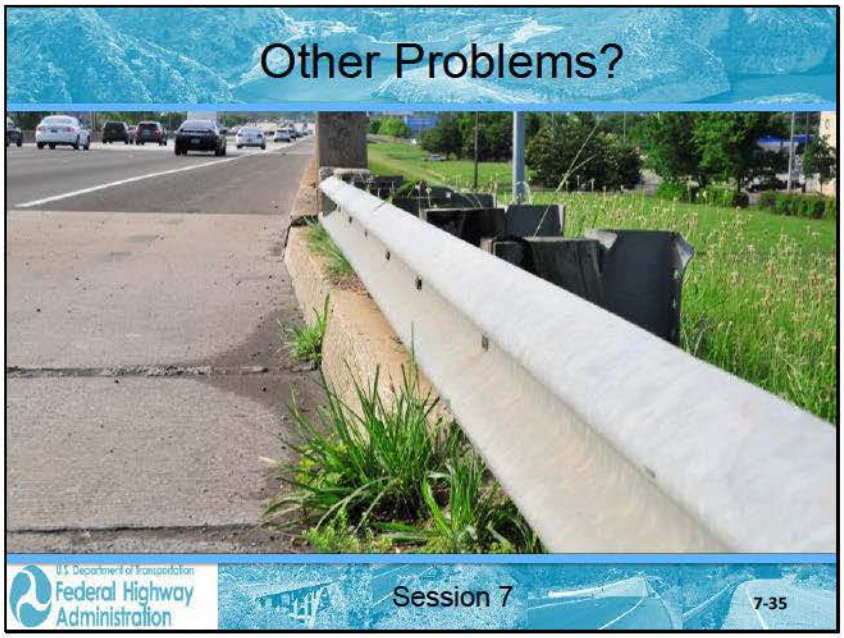
Other Problems?
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Roadway Rehabilitation Projects
Conduct Safety Screening to evaluate need for:
1. Warning signs
2. Centerlines and edgelines
3. Rumble strips (where used)
4. Roadside delineators
5. Barrier shielding
6. Barrier terminals
Ref: Caltrans Design Information Bulletin number 79-03
U.S. Department of Transportation
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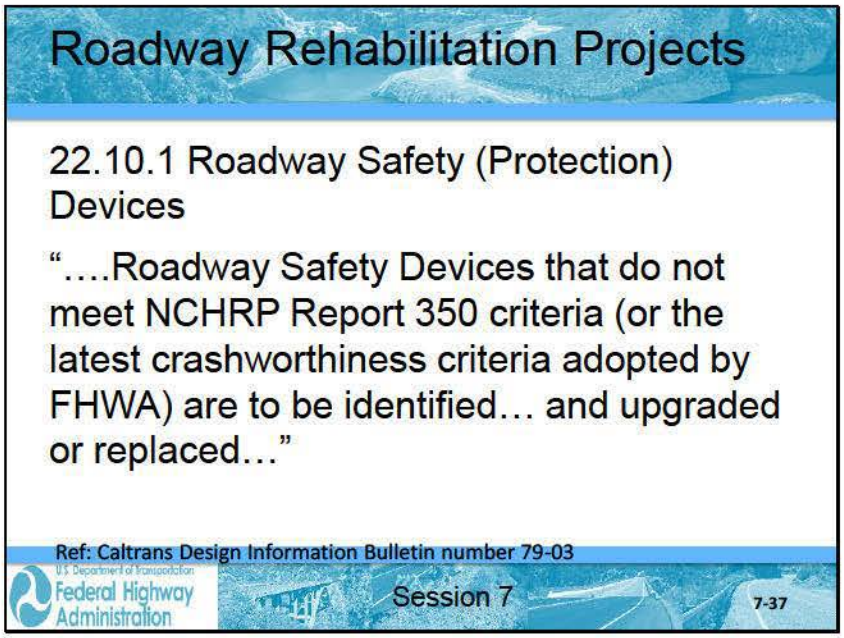
Roadway Rehabilitation Projects
22.10.1 Roadway Safety (Protection) Devices
"….Roadway Safety Devices that do not meet NCHRP Report 350 criteria (or the latest crashworthiness criteria adopted by FHWA) are to be identified… and upgraded or replaced…"
Ref: Caltrans Design Information Bulletin number 79-03
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Replacement In-Kind vs. Upgrade
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Replacement In-Kind vs. Upgrade
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Replacement In-Kind vs. Upgrade
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Replacement In-Kind vs. Upgrade
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Replacement In-Kind vs. Upgrade
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Replacement In-Kind vs. Upgrade
CHURCH
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Replacement In-Kind vs. Upgrade
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Replacement In-Kind vs. Upgrade
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Replacement In-Kind vs. Upgrade
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## Replacement In-Kind vs. Upgrade

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## Maintenance of Safety Devices

- 10 percent of inventory must be checked annually
- Separate work order for each repaired devices
- Must use manufacturers' checklist
- Repair work to be overseen by trained personnel

Ref: CT Memorandum 07/31/2015 Maintenance of Safety Devices

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## Maintenance of Safety Devices

Timing of Repairs

- Guardrails to be repaired within 1 month
- Terminals and attenuators to be repaired/replaced within 7 days
- Temporary repairs of all damaged safety devices to reduce or eliminate obvious hazards/debris to be made immediately.

Ref. CT Maintenance Manuall Vol. II, M60010



## Delineation of Damaged Barrier Systems

- Delineation of Damaged Guardrails
  - Roadways 55 mph and greater use a minimum of five delineated drums; three prior to damage and one along the damaged area every 10 ft.
  - All other roadways use a minimum of five retro reflectorized cones; three prior to the damage and one along the damaged area every 10 ft.

SCDOT Guardrail, Cable Barrier and Crash Attenuator Inspection and Repair Guidelines, Feb 1, 2015


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Damaged Terminals
COUNTY OF LA
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Temporary Protection
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## Temporary Protection




## Temporary Protection

Should these damaged rails be shielded with a temporary barrier?



## Review Learning Outcomes

- Explain when damaged barrier needs to be reset, repaired, rebuilt, or removed.
- Describe when a damaged barrier terminal is no longer functional, and know whether to repair, replace in-kind, or upgrade to a newer design.
- Perform repairs in a safe, cost-effective manner.