LTAP Transportation Technology Transfer Center

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Spokesperson Decade of Action for Road Safety 2011-2020

ROADSIDE SAFETY BARRIER ELEMENTS

Module 3

1. Remove the obstacle
2. Redesign the obstacle
3. Relocate the obstacle
4. Reduce impact severity
5. Shield the obstacle
6. Delineate the obstacle

Roadside Design Options

Expected Crash Reduction of Relocation of Fixed Objects

Increase in Obstacle Distance in meters (feet)	Mailboxes, Culverts, and Signs (%)	Guardrails (%)	Fences/Gates (%)
0.9 (3)	14	36	20
1.5 (5)	23	53	30
2.4 (8)	34	70	44
3.1 (10)	40	78	52
4.0 (13)	N.F.	N.F.	N.F.
4.6 (15)	N.F.	N.F.	N.F.

Notes:
N.F. = generally not feasible to relocate obstacles to specified distance.
The table is only appropriate for obstacle distance of 30 feet or less and only on two-lane roadways.

Source: NCHRP Report 500, Vol 6, Exhibit V-26

Purpose of Safety Barriers

- Prevent a motorist from leaving the roadway and striking an object or terrain feature that is ***more hazardous***, such as:
  1. a steep embankment,
  2. a pole or tree,
  3. a bridge or culvert end,
  4. a bridge pier,
  5. opposing traffic,
  6. **or an overhead sign support.**

Factors to Consider When Selecting a Barrier

1. Structural integrity
2. Maximum lateral deflection
3. Initial cost
4. Maintenance / replacement costs
5. Time to repair
6. Inventory cost / modular aspect
7. Installation and removal difficulty
8. Aesthetic

Barrier Types

- Roadside Barriers
- Median Barriers
- Bridge Railings

Barrier Main Objectives

1. Provide shield / prevent penetration in passenger compartment

2. Redirect vehicle

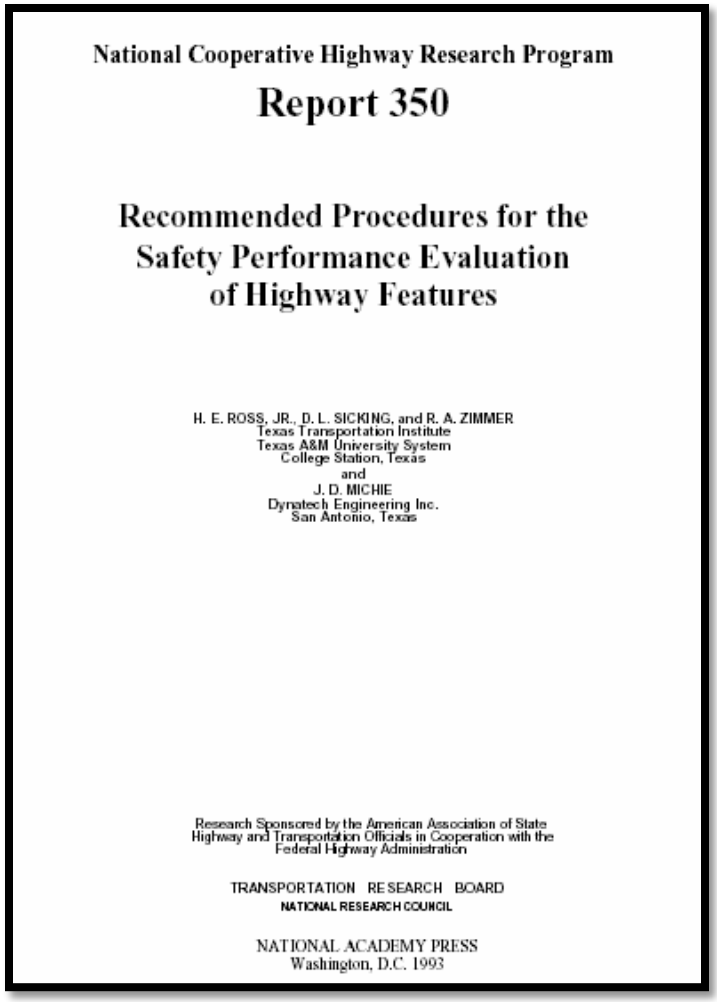
3. Reduce crash severity

Roadside Safety Selection Process

1) Performance requirements of the roadside safety device (barrier)
2) Barrier Warranting Process
    a. Embankments
    b. Roadside Obstacles
    c. Bystanders
3) Roadside Barrier Types
4) Median Barrier Types

1. National Cooperative Highway Research Program NCHRP Report 350

- Test criteria and performance specifications for road safety devices
- FHWA adopted in Federal Register
- Became effective on NHS:
  - For all Contracts LET after October 1, 1998
  - On all maintenance or force account work INSTALLED after October 1, 1998
- Existing barriers may remain if they met earlier NCHRP Report 230 criteria



National Cooperative Highway Research Program

Report 350

Recommended Procedures for the Safety Performance Evaluation of Highway Features

H. E. ROSS, JR., D. L. SICKING, and R. A. ZIMMER
Texas Transportation Institute
Texas A&M University System
College Station, Texas
and
J. D. MICHIE
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Research Sponsored by the American Association of State Highway and Transportation Officials in Cooperation with the Federal Highway Administration

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL

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Washington, D.C. 1993

Barrier Structural Adequacy

- Any test vehicle must be contained and redirected

- Controlled deflection of the barrier is acceptable

Occupant Risk

- No penetration of the passenger compartment
- Passenger compartment should not be significantly deformed
- The 820-kg and 2000-kg test vehicles must remain upright after collision

More Occupant Risks...

- Unrestrained Passenger Decelerations:
  - Under 9 m/sec preferred
  - 12 m/sec max

- Occupant deceleration over a 10 millisecond period:
  - Should not exceed 15 G's
  - 20 G's is allowable

Vehicle Trajectory

- Should not intrude into adjacent traffic lanes

- Exit angle should be less than 60% of the impact angle

NCHRP 350 Crash Tests

- Describes the vehicles to be used in testing, the test conditions, and the instrumentation that will be used in testing the hardware
- Testing criteria are hardware-specific that require multiple tests under different impact conditions
- Six levels of testing (**TL1** to **TL6**)
  - **Levels 1, 2, and 3 -** applicable for both permanent and temporary barriers used in work zones for car and pickup trucks
  - **Levels 4, 5, and 6 -** intended for permanent barriers and considers truck vehicles

1. Performance Requirements (Table 5-1b 2011 RDG)

Test level	Vehicle	Angle	Speed
TL-1	1,800lb car	20º	30 mph
TL-2	4,400lb pickup truck	25º	45 mph
TL-3			60 mph
TL-4 (mod. TL-3)	17.6kip SUT	15º	50 mph
TL-5	80kip tractor-trailer (van)	15º	50 mph
TL-6	80kip tractor-trailer (tanker)	15º	50 mph

NCHRP Report 350 Test Vehicle Test Matrix for Longitudinal Barriers (Table 5-1b RDG)

Test Level	NCHRP Report 350 Test Vehicle Designation and Type	Test Conditions		
		Vehicle Weight kg (lbs)	Speed km/h (mph)	Angle Degrees
1	820C (Passenger Car) 2,000P (Pickup Truck)	820 [1,800] 2,000 [4,400]	50 [31] 50 [31]	20 25
2	820C (Passenger Car) 2,000P (Pickup Truck)	820 [1,800] 2,000 [4,400]	70 [44] 70 [44]	20 25
3	820C (Passenger Car) 2,000P (Pickup Truck)	820 [1,800] 2,000 [4,400]	100 [62] 100 [62]	20 25
4	820C (Passenger Car) 2000P (Pickup Truck) 8,000S (Single-Unit Truck)	820 [1,800] 2,000 [4,400] 8,000 [17,600]	100 [62] 100 [62] 80 [50]	20 25 15
5	820C (Passenger Car) 2,000P (Pickup Truck) 36,000V (Tractor Trailer)	820 [1,800] 2,000 [4,400] 36,000 [80,000[1]]	100 [62] 100 [62] 80 [50]	20 25 15
6	820C (Passenger Car) 2,000P (Pickup Truck) 36,000T (Tractor–Tanker Trailer)	820 [1,800] 2,000 [4,400] 36,000 [80,000[1]]	100 [62] 100 [62] 80 [50]	20 25 15

Note 1: U.S. Customary Hard Conversion of the 36,000 kg tractor trailer is accepted as the Report 350 conversion and is used throughout for the Report 350 reference.

MASH Crash Tests

- Retains the test level conventions established in NCHRP Report 350, but
- Incorporates changes in the requirements for testing:
  - Test vehicles
  - For TL-1, 2, and 3 standard testing vehicles used:
    - a 1100 kg (2420 lb.) small car
    - A 2270 kg (5000 lb.) pickup truck
- Both NCHRP Report 350 and MASH encourage the use of in-service evaluation as a method for verifying the crashworthiness of devices.

MASH Crash Test Matrix for Longitudinal Barriers (Table 5-1a RDG)

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

NCHRP 350 Test Levels 4-6

TL-4 Vehicle

TL-5 Vehicle

TL-6 Vehicle

NCHRP 350 TL Suggested Applications

Test Level	Selection Criteria
TL-1	Work zones with low posted speed, and low volume local streets
TL-2	Work zones, and most local and collector roads with low posted speeds and a low number of heavy vehicles expected
TL-3	High speed arterials with low mixtures of heavy vehicles and with favorable site conditions
TL-4	High speed highways, freeways, expressways, and Interstate highways with a mixture of trucks and heavy vehicles
TL-5	Same locations as TL-4 where a significant percent of the ADT is made of large trucks or where there are unfavorable site conditions
TL-6	Same locations as TL-4 where a significant percent of the ADT is made of tanker trucks, and unfavorable site conditions exist

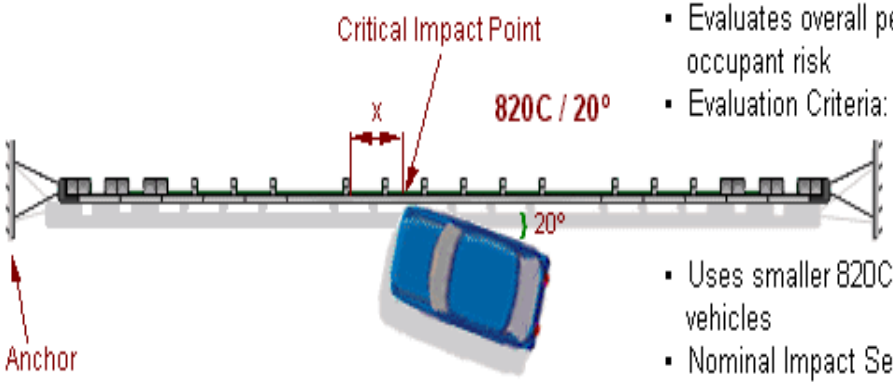
Recommended Barrier Performance

- Low-volume / low speed: lower than TL-3
- Passenger cars and light trucks for low severity impacts: TL-2
- Poor geometrics, high volume, and heavy trucks: TL-4 or better

About NCHRP 350

Longitudinal Barrier Test 10

This test involves the smaller cars impacting the barrier at a 20-degree angle at its midpoint.



- Evaluates overall performance and occupant risk
- Evaluation Criteria: A, D, F*, H, I, K, M
- Uses smaller 820C and optional 700C vehicles
- Nominal Impact Severity:

TL-1	9.3	kJ
TL-2	18.1	kJ
TL-3	37.0	kJ
TL-4	37.0	kJ
TL-5	37.0	kJ
TL-6	37.0	kJ

* Evaluation criteria "G" replaces criteria "F" for this and all following tests at Test Level 1 conditions.

0:53

3:35

7:55

8:50

17:10

BARRIER FULL-SCALE CRASH TESTS

2. Barrier Warranting Process

1. Determine the needed clear zone for the road
2. Identify and locate potential hazards
   - Review road crash history
   - Road Safety Audit
   - Survey road user experience
3. Analyze safety strategies (6 options)
4. Evaluate the need for roadside and median barriers

2. Barrier Warrants

a. Embankments
b. Roadside and median obstacles
a. Bystanders

ONLY IF IT REDUCES THE SEVERITY OF POTENTIAL CRASHES!

Barrier Warrants

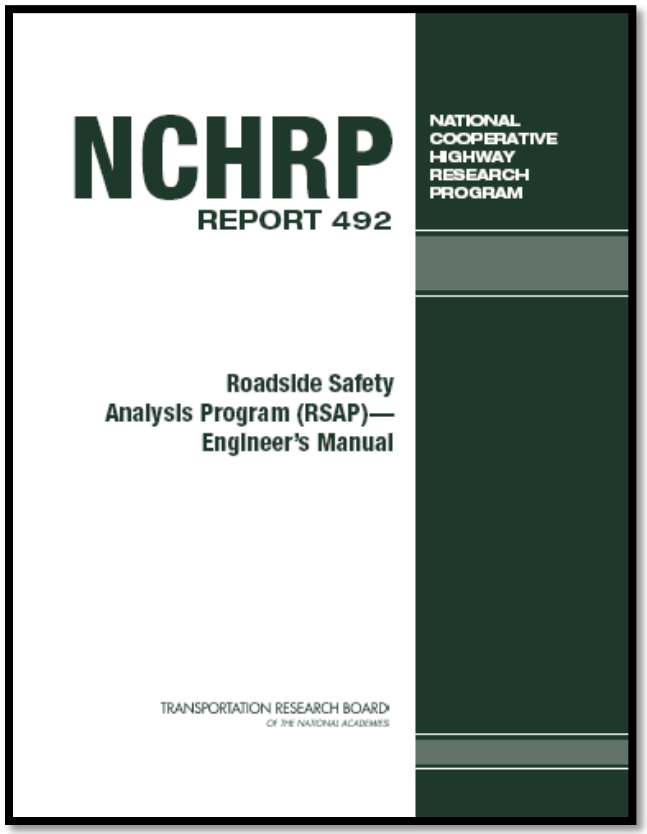
1. Benefit / cost analysis
   - Evaluate design speed and traffic volume in relation to barrier need
     - Remove or reduce area of concern so that it no longer requires shielding
     - Install an appropriate barrier
     - Leave the area of concern unshielded
2. Subjective analysis
   - When hitting a obstacle or running off the road is considered more objectionable than the barrier itself
   - Does not consider cost of installing a barrier vs. unshielded conditions

Benefit / Cost Analysis

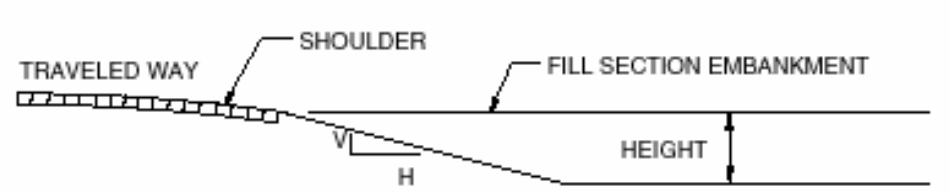
- Estimated benefits to be derived from a specific course of action are compared to the costs of implementing that action
- Benefit – annual reduction of accident costs
  - Number of crashes
  - Crash severity
- Cost – construction and annual maintenance costs

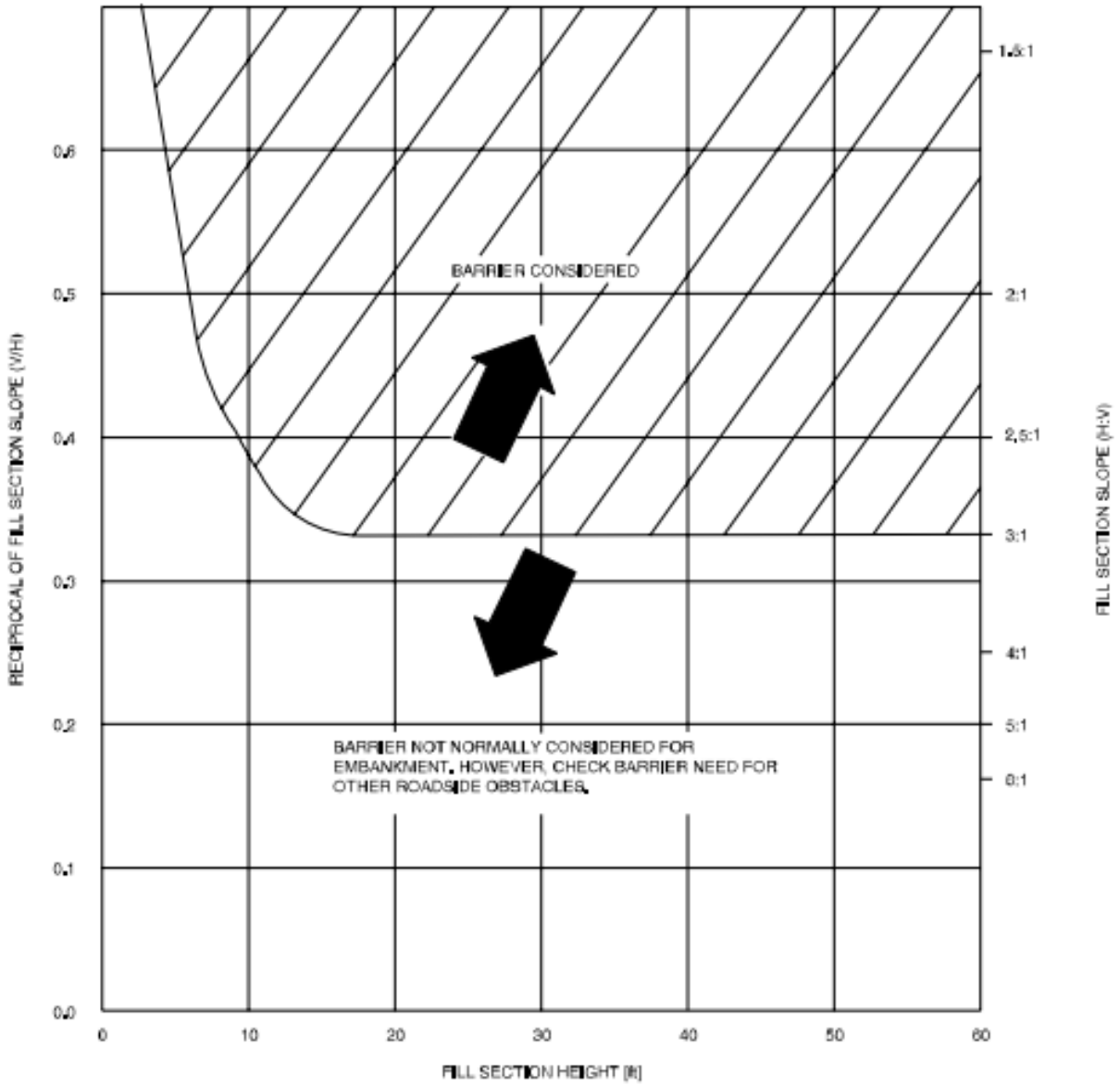
BENEFIT / COST ANALYSIS

- RSAP: Roadside Safety Analysis Program
- NCHRP Report 492



2a. Embankments





2011 RDG Figure 5-1b. Comparative Barrier Consideration for Embankments (US Customary Units)

2b. Roadside Obstacles (Table 5-2 2011 RDG)

Figure 5-2. Barrier Guidelines for Non-Traversable Terrain and Roadside Obstacles

Obstacle	Guidelines
Bridge piers, abutments, and railing ends	Shielding generally needed.
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 generally needed.
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 needed 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 needed for non-breakaway supports.
Traffic signal supports	Isolated traffic signals within clear zone on high-speed rural facilities may need shielding.
Trees	Judgment decision based on site-specific circumstance.
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.

Barrier Warrants for Low-Volume Low-Speed Roads (Federal Lands Highway)

Consideration	Barrier is more warranted if:	Barrier is less warranted if:
Speed	70 km/h (45 mph) or higher	40 km/h (25 mph) or lower
Hazard on outside of horizontal curve	350 m (1,150 ft) or smaller radius	Radius larger than 400 m (1,430 ft)
Hazard does not fit the descriptions in Tables 2.3 through 2.6	Hazard is more severe	Hazard is less severe
Size of hazard	Very large	Very small
Traffic volume	Above 1,000 vpd	Below 400 vpd
Hazard on inside of horizontal curve	350 m (1,150 ft) or smaller radius	Radius larger than 400 m (1,430 ft)
Hazard on a downgrade	5 percent or greater	Less than 3 percent
Crash history	Clear crash pattern	No crash pattern
Anticipated cost of barriers	Expected costs are low	Expected costs are high
Roadway cross section	Severe section elements	Good section elements
Multiple hazards exist at the site	Many additional hazards	
Aesthetic impacts		Serious concerns
Environmental impacts		Serious concerns

2c. Bystanders

- Particular situations that need special analysis
  - Schools
  - Business
  - Residences
  - Pedestrian
  - Bicycles
  - Motorcycles

Module 3 Review

1. Any barrier that has met Report 350 evaluation criteria may be used on the National Highway System (NHS) and can be expected to perform satisfactorily in all crashes.

True or False?

Module 3 Review

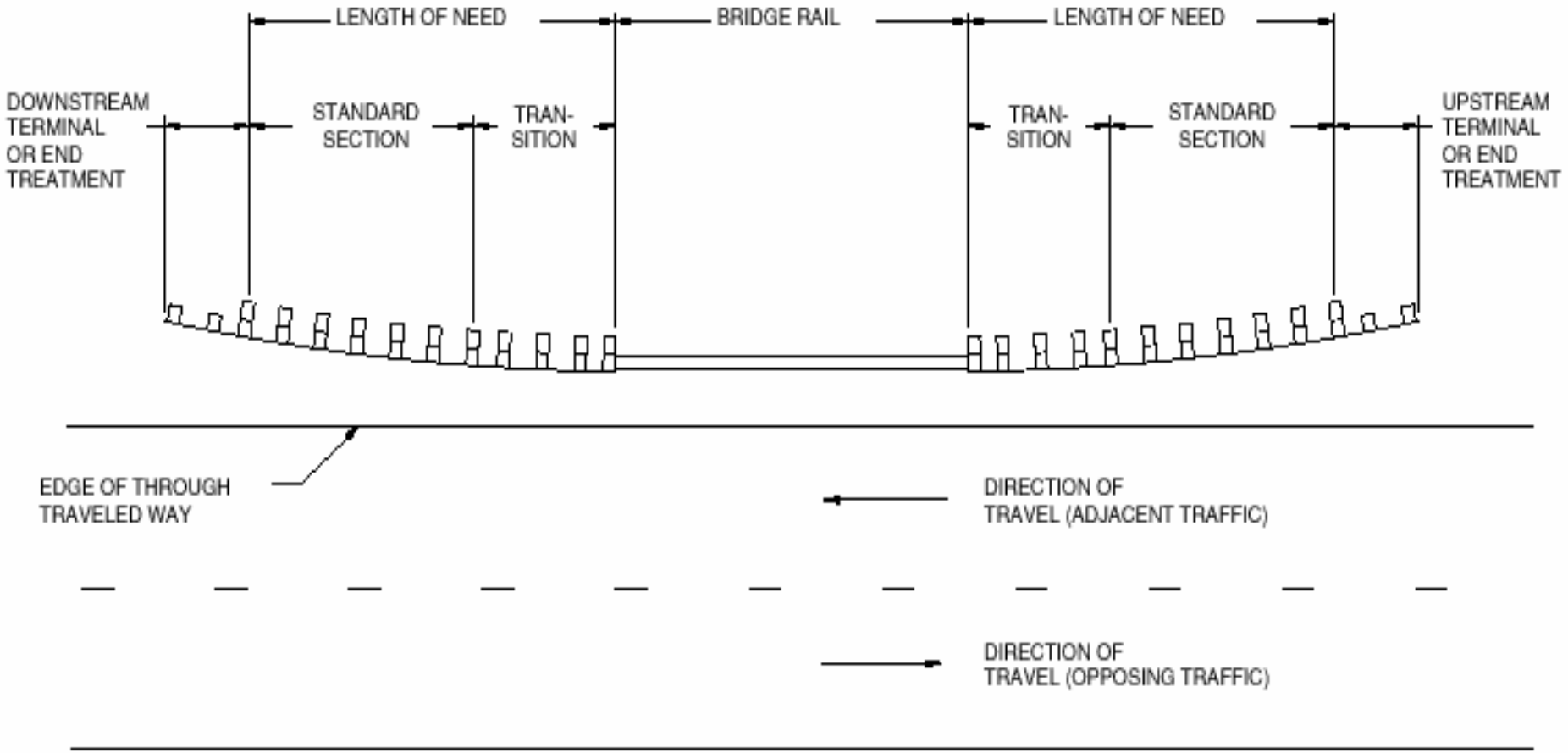
2. Where do you think a test level 5 barrier would be most appropriate:

a. In the median of an urban freeway
b. On a bridge over a river
c. On the outside shoulder of a long downgrade

Module 3 Review

3. Why is a decision to use barrier to shield an embankment oftentimes a difficult one?

a. The AASHTO embankment warrants are overly simplistic
b. It is often not obvious which would be worse: running down the slope or striking guardrail
c. Both of the above



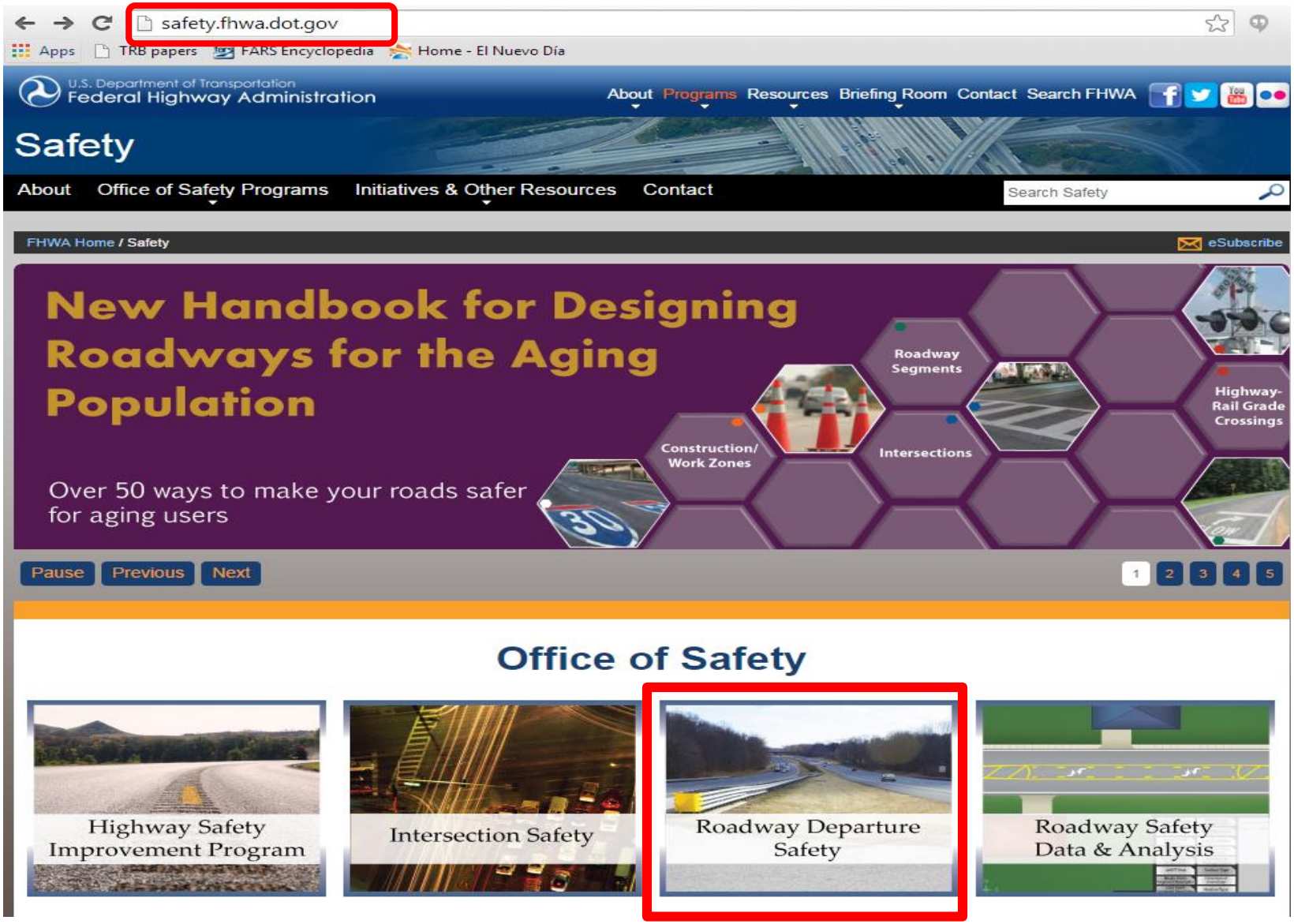
Traffic Safety Barrier System

1. Basic section
2. Terminal
3. Transition section
4. Bridge Railing

3. ROADSIDE BARRIER TYPES

a. Flexible
b. Semi-rigid
c. Rigid

How to Obtain the Information on the FHWA website:



Safety.fhwa.dot.org → Roadway Departure Safety

safety.fhwa.dot.gov/roadway_dept/

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- Policy/Guidance
- Research/Resources
- Retroreflectivity & Visibility
- Roadside Hardware

Roadway Departure Safety

The FHWA's Roadway Departure Safety Program provides important information for transportation practitioners, decision makers, and others to assist them in preventing and reducing the severity of roadway departure crashes.

Roadway departure crashes are frequently severe and account for the majority of highway fatalities. In 2011, there were 15,307 fatal roadway departure crashes resulting in 16,948 fatalities, which was 51 percent of the fatal crashes in the United States. A roadway departure crash is defined as a non-intersection crash which occurs after a vehicle crosses an edge line or a center line, or otherwise leaves the traveled way. FHWA uses the Fatal Analysis Reporting System (FARS) to compute statistics on roadway departure crashes. http://www.nhtsa.gov/FARS.

FHWA Roadway Departure Strategic Plan NEW!

The FHWA Roadway Departure Team has developed a Strategic Plan to provide a data-driven focus with a vision to "Pursue a proactive approach Towards Zero Deaths and serious injuries involving roadway departure events."

Technical Assistance/Tools

Here's where to find technical guidance and tools for practitioners.

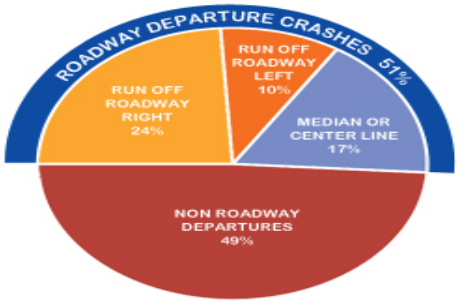
- **Pavement Safety**
  - Pavement Friction
  - Safety Edge
  - Rumble Strips and Stripes
  - High Friction Surfaces
- **Nighttime Visibility**
- **Horizontal Curve Safety**
- Clear Zones
- Strategic Approach to Roadway Departure
- The Principles of a Safe Roadside Design

Eligibility Letters

Federal-Aid Reimbursement Eligibility Process

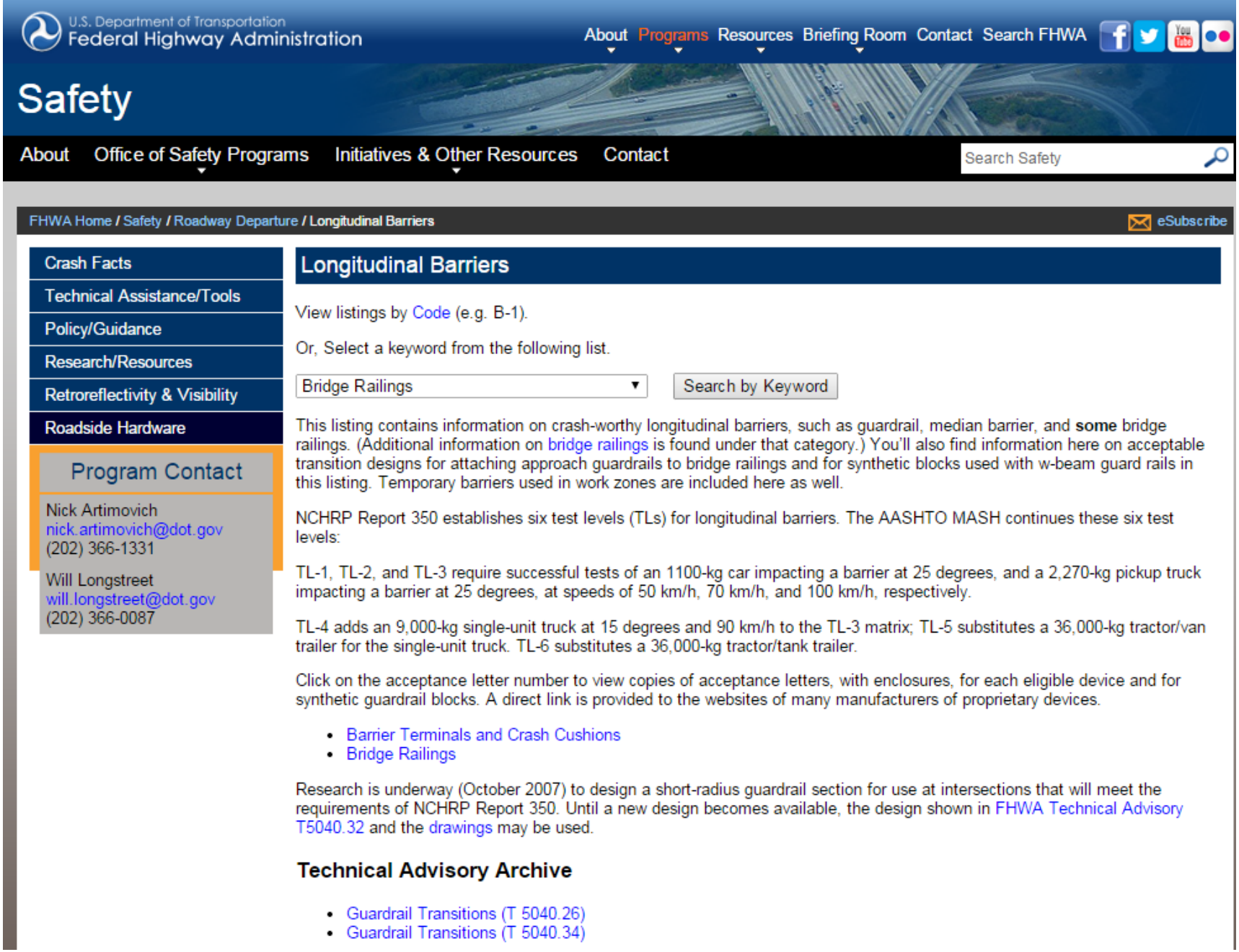
- Barriers/Guardrails
- Breakaway Signs/Lighting Supports
- Work Zone Devices

Roadway Departure Crashes Account for 51 Percent of Fatal Crashes



A roadway departure crash is defined as

Safety.fhwa.dot.org → Roadside Hardware



Safety.fhwa.dot.org → Longitudinal Barriers

Deflection Characteristics

a. Flexible systems

Table 5-3. Roadside Barriers and NCHRP Report 350 Approved Test Levels

System	Test Level	FHWA Acceptance Letter	System Designation	Reference Section
FLEXIBLE SYSTEMS				
W-Beam (Weak Post)	2	B-64	SGR02	5.4.1.3
Three-Strand Cable (Weak Post)	3	B-64	SGR01a and b	5.4.1.1
High-Tension Cable Barriers	3 and 4	Various	Various	5.4.1.2
Modified W-Beam (Weak Post)	3	B-64	SGR02	5.4.1.3
Ironwood Aesthetic Barrier	3	B-56, 56-A, and 56-B		5.4.1.4

The Acceptance Letters can be found under the fhwa website:

Keyword: Aesthetic Barriers

Keyword: Aesthetic Barriers

Code	Date	350/Mash	Manufacturer	Device Description	View PDF
B-56B	9/5/2003		Structures of Ironwood	Design alternative: rectangular timber rail	(51 Kb)
B-56A	5/11/2000		Structures Of Ironwood, L.L.C.	IRONWOOD Guidrail	(113 kb)
B-56	6/18/1999		David Hubbell	IRONWOOD Guardrail-aesthetic timber/steel rail	(3960 kb)

Deflection Characteristics

b. Semi-rigid systems

Table 5-3. Roadside Barriers and NCHRP Report 350 Approved Test Levels

System	Test Level	FHWA Acceptance Letter	System Designation	Reference Section
SEMI-RIGID SYSTEMS				
Steel Post with Steel Blockout	2	B-64	SGR04a	5.4.1.6
Box Beam (Weak Post)	3	B-64	SGR03	5.4.1.5
Steel or Wood Post with Wood or Plastic Blockout	3	B-64	SGR04a and b	5.4.1.6
NU-GUARD by Nucor Marion	3	B-162		5.4.1.8
Trinity T-31 and Trinity Guardrail System	3	B-140		5.4.1.8
Gregory (GMS)	3	B-150		5.4.1.8
Midwest Guardrail System (MGS)	3	B-133		5.4.1.7
Blocked-out Thrie-Beam (Strong Post)	3	B-64	SGR09c SGR09a	5.4.1.9.1
Merritt Parkway Aesthetic Guardrail	3	B-38		5.4.1.10
Steel-Backed Timber Guardrail	2 and 3	B-64-D		5.4.1.11
Modified Thrie-Beam (Strong Post)	4	B-64	SGR09b	5.4.1.9.2
Trinity T-39 Non-Blocked-Out Thrie Beam	4	B-148		5.4.1.9.3

Keyword: Boxbeam Guardrail Terminal

Code	Date	350/Mash	Manufacturer	Device Description	View PDF
B-148	6/2/2006		Trinity	T-39 Thrie-beam guardrail @ TL-4	(1.99 MB)

Note the “keywords” are only meant to help the user sort out products that may suit the terrain, traffic volumes, travel speeds, highway geometry, etc. They are NOT intended as a formal classification system and should not be used as such. When considering any crash cushion or barrier terminal, the user is responsible for reading the FHWA letter and attachments and understanding any limitations noted, and for reviewing the manufacturer’s literature to ensure proper selection, installation, and maintenance.

Deflection Characteristics

c. Rigid systems

Table 5-3. Roadside Barriers and NCHRP Report 350 Approved Test Levels

System	Test Level	FHWA Acceptance Letter	System Designation	Reference Section
RIGID SYSTEMS (Concrete and Masonry)				
Stone Masonry Wall/Precast Masonry Wall	3	B-64-D		5.4.1.14
New Jersey Safety-Shape Barrier				5.4.1.12
• 810 mm [32 in.] tall • 1070 mm [42 in.] tall	4	B-64	SGM11a	5.4.1.12
	5	B-64	SGM11b	5.4.1.12
F–Shape Barrier				5.4.1.12
• 810 mm [32 in.] • 1070 mm [42 in.]	4	B-64	SGM10a	5.4.1.12
	5	B-64	SGM10b	5.4.1.12
Vertical Concrete Barrier				5.4.1.12
• 810 mm [32 in.] • 1070 mm [42 in.]	4	B-64		5.4.1.12
	5	B-64		5.4.1.12
Single Slope Barrier				5.4.1.12
• 810 mm [32 in.] • 1070 mm [42 in.]	4	B-17, B-45		5.4.1.12
	5	Note 1		5.4.1.12
Ontario Tall Wall Median Barrier	5	B-19	SGM12	5.4.1.12

Keyword: Permanent Concrete Barriers

B-64	2/14/2000	FHWA Memo to Resource Centers, etc.	Nonproprietary Guardrails and Median Barriers	(97 kb)
B-45	2/4/1998	California DOT	Single slope roadside/median barrier-9.1 degrees	(287 kb)
B-19	5/13/1992	Nat. Ready Mix Concrete Assn.	Ontario "Tall Wall" Concrete Median Barrier	(72 KB)
B-17	2/11/1992	(Minute Memo to Regions)	Constant Slope Concrete Median Barrier.	(6 MB)

Flexible Barriers

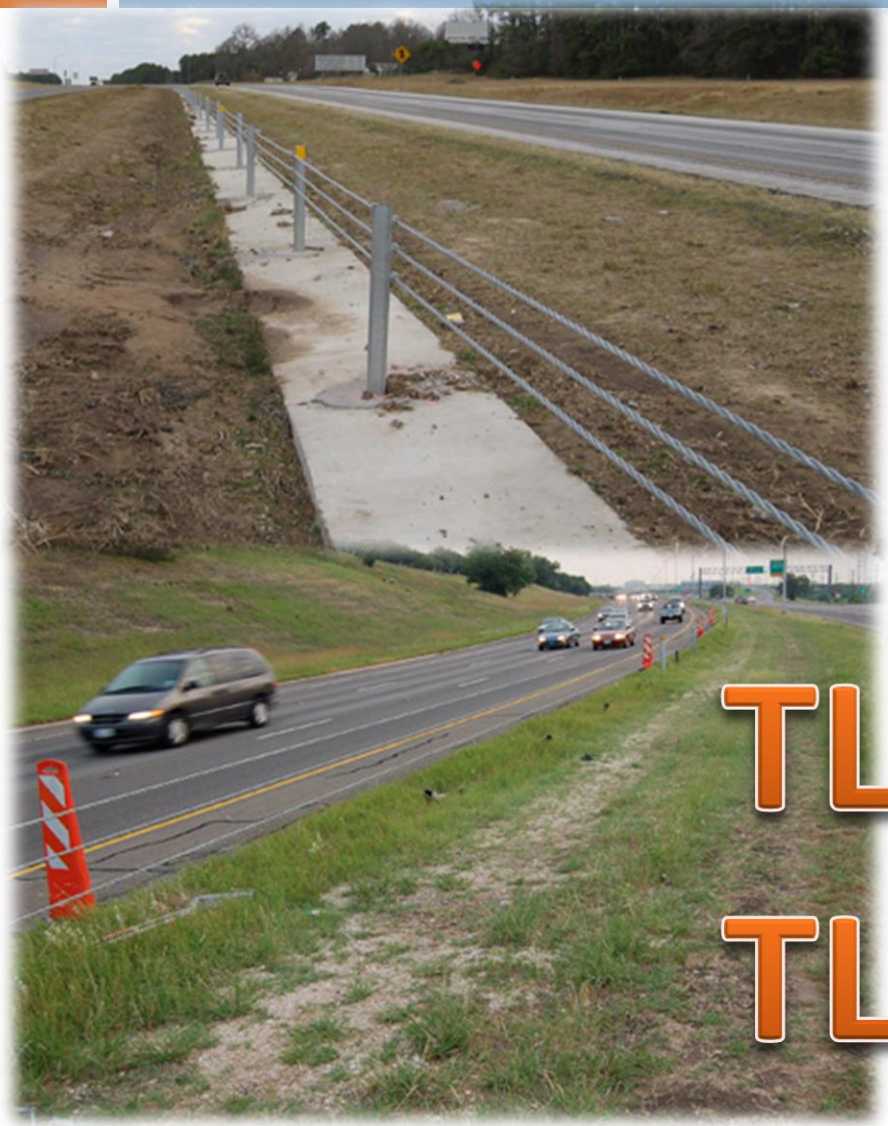
High impact deflections!
7 to 17 feet

Cable Barrier

- High tension steel cables (3 and 4) mounted on weak posts
- Redirects vehicle after tension is developed in the cable
- Advantages
  - Low initial cost
  - Low deceleration forces
  - Minimized sight distance problems
- Disadvantages
  - Periodic monitoring of cable tension required
  - More barrier damage in a typical accident
  - Needs more clear area behind the barrier

Deflection	Post Spacing
9'3"	30.FT
9'	28.FT
8'	20.FT
7'	12.FT

Cable Barriers



TL-3

TL-4

W-Beam (Weak Post)

- Behave like cable system, but with less deflection
- Posts serve primarily to hold the rail at the proper elevation
- Modified system w/ back-up plates tested at TL3
- Advantages
  - Low initial cost
  - Low deceleration forces
- Disadvantages
  - More barrier damage after a typical accident
  - Vulnerable to vaulting
  - Lateral deflection is 2.225 m

W-beam (Flexible)

NAME	ILLUSTRATION	TEST LEVEL		POST
		NCHRP 350	MASH	
W-beam (weak post) https://www.aashtotf13.org/Files/Drawings/sgr02a.pdf Generic		TL-2		S3 x 5.7 post 5 ft. 3 in. long with soil plate Post spacing 12 ft. 6 in.
Modified W-beam (weak post) https://www.aashtotf13.org/guide_display.php Generic		TL-3	TL-3	S3 x 5.7 post 5 ft. 5 in. long with soil plate Post spacing 12 ft. 6 in.

http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/resource_charts/roadsidepost.pdf

Semi-Rigid Barriers

Box Beam (Weak Post)

- Achieves resistance through combined flexural and tensile resistance of box beam
- Posts break away and distribute force to adjacent posts
- Disadvantages
  - Sensitive to mounting height and soil irregularities
  - Numerous parts and bolts may become a maintenance problem
  - Relatively expensive weak-post barrier

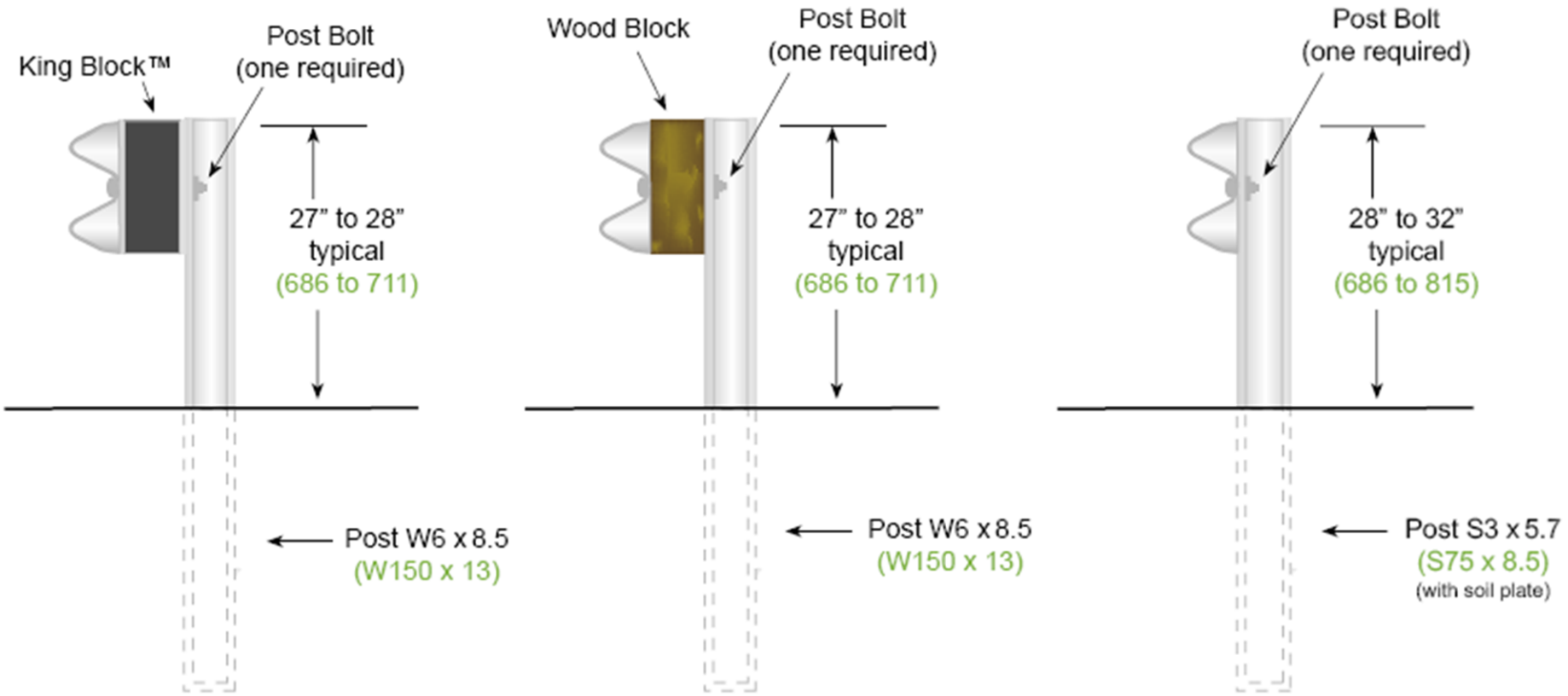
TL-3

Semi-rigid

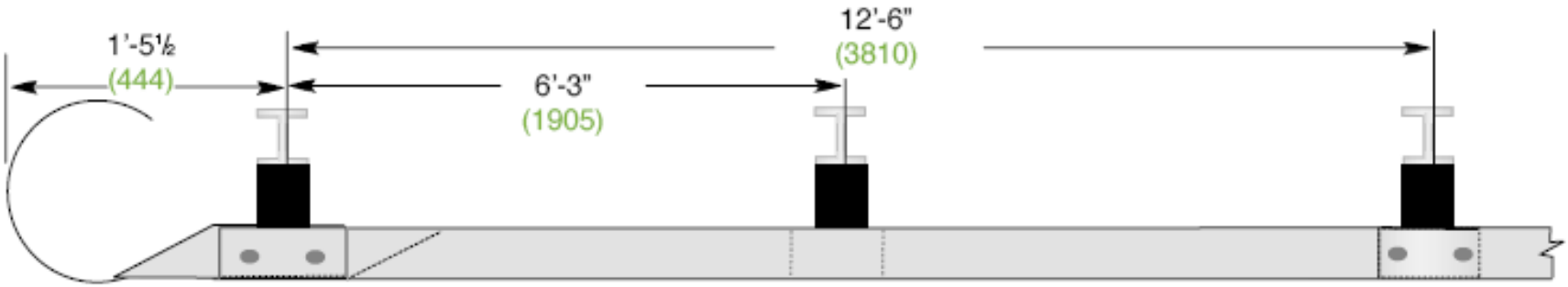
NAME	ILLUSTRATION	TEST LEVEL		POST
		NCHRP 350	MASH	
Box Beam weak Post https://www.aashtotf13.org/Files/Drawings/sgr03.pdf Generic		TL-3	TL-3	S3 x 5.7 post 5 ft. 3 in. long with soil plate Post spacing 6 ft.

http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/resource_charts/roadsidepost.pdf

W-Beam Post



STRONG POST WITH KING BLOCK™ | STRONG POST WITH WOOD BLOCK | WEAK POST



PLAN

Rail Deflection Characteristics, RDG Table 5-6

Run Number	Post Spacing		Beam Description	Impact Angle	Maximum Deflection[a]			
					Simulation		Field Test[b]	
	mm	[in.]			mm	[in.]	mm	[in.]
1	1905	[75]	Single W-Beam	15°	589	[23.2]	NA	NA
2	1905	[75]	Single W-Beam	25°	907	[35.7]	754	[29.7]
3	952	[38]	Single W-Beam	15°	389	[15.3]	NA	NA
4	952	[38]	Single W-Beam	25°	541	[21.3]	597	[23.5]
**	1905	[75]	MSG Single W-Beam	25°	NA	NA	1094	[43.1]
**	953	[38]	MSG Single W-Beam	25°	578[d]	[22.8][d]	NA	NA
**	476	[19]	MGS Single W-Beam	25°	NA	NA	447	[17.6]
*	1905	[75]	Double W-Beam	25°	NA	NA	902[c]	[35.5]
5	952	[38]	Double W-Beam	15°	358	[14.1]	NA	NA
6	952	[38]	Double W-Beam	25°	437	[17.2]	498	[19.6]
7	476	[19]	Double W-Beam	15°	NA	NA	NA	NA
8	476	[19]	Double W-Beam	25°	320	[12.3]	NA	NA
9	1905	[75]	Single Thrie-Beam	15°	488	[19.2]	NA	NA
10	1905	[75]	Single Thrie Beam	25°	716	[28.2]	NA	NA
11	952	[38]	Single Thrie-Beam	15°	386	[15.2]	NA	NA
12	952	[38]	Single Thrie-Beam	25°	480	[18.9]	NA	NA
13	952	[38]	Double Thrie-Beam	15°	333	[13.1]	NA	NA
14	952	[38]	Double Thrie Beam	25°	414	[16.3]	NA	NA
15	476	[19]	Single Thrie-Beam	15°	NA	NA	NA	NA
16	476	[19]	Single Thrie-Beam	25°	353	[13.9]	NA	NA
17	476	[19]	Double Thrie-Beam	15°	NA	NA	NA	NA
18	476	[19]	Double Thrie-Beam	25°	307	[12.1]	NA	NA

Notes:
a) Simulation of 2000-kg [4,400-lb] sedan at 97 km/h [60 mph].
b) Kansas Department of Transportation field test results with 2000-kg [4400-lb] sedan at 97 km/h [60mph].
c) Test conducted during wet soil conditions.
d) BARRIER VII Analysis results calibrated from crash tests of standard and $^1/_4$ post spacing.
NA = Not Available
*Field test only
** Crash Test of 2000P pickup truck at NCHRP Report 350 TL-3

Blocked Out W-beam (Strong Post)

- Minimizes vehicle snagging
- Reduces vaulting over barrier
- Achieves resistance through combined flexural and tensile stiffness of rail and shear strength of posts
- Tend to remain functional after moderate collisions

Blocked Out W-beam (Strong Post)

- Moderate installation cost
- Moderate occupant forces
- Many options for local strengthening
- Moderate dynamic deflection
- Numerous propietary and non-propietary terminal and transitions


TL-2

W-beam Guardrail w/ steel blocks

3:40

Rubber Block-out

- Lightweight (8 pounds)

TL-3

T-31 W-Beam Guardrail

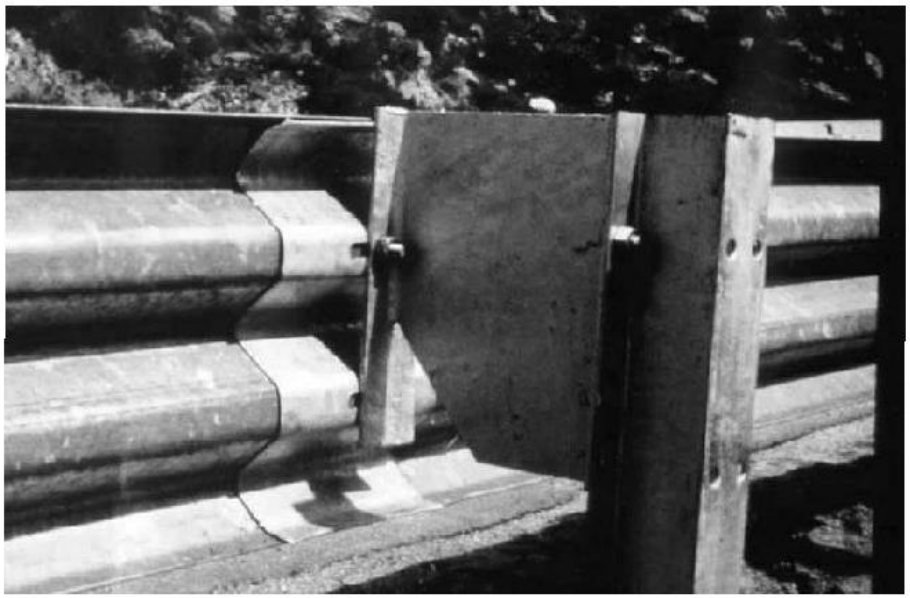
- Proprietary, strong post w-beam
- W-beam attaches directly to Steel Yielding Line Posts (SYLP) eliminating need for offset blocks
- System height = 31”

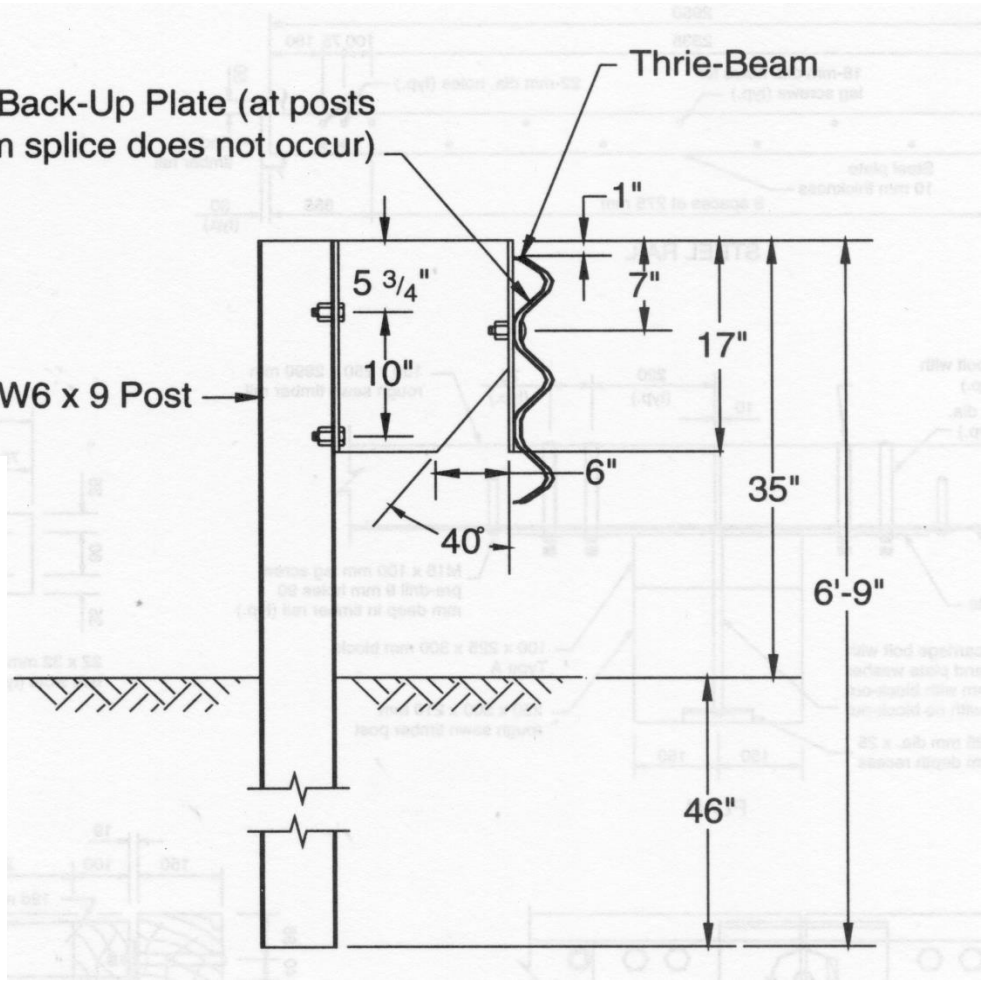
TL-3

Blocked Out & Modified Thrie-beam

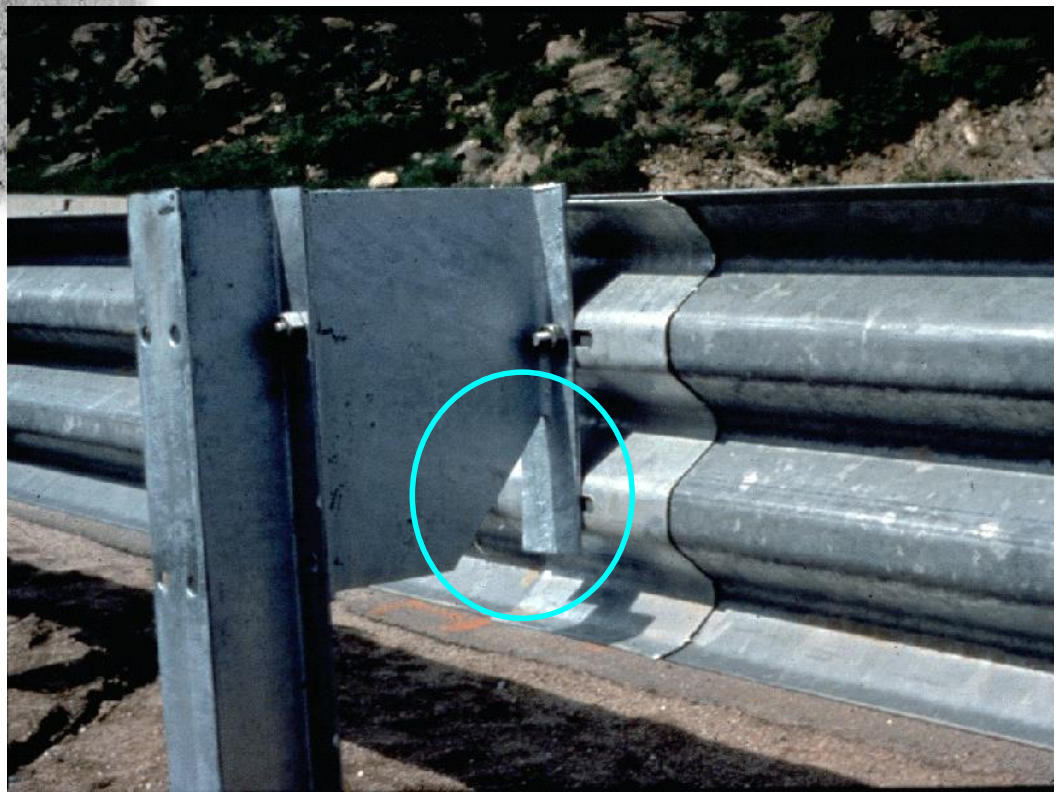
- Similar to W-beam, but with deeper, stiffer, and additional corrugation rail
- Allows higher rail mounting, making it better able to contain larger vehicles
- Modified Thrie beam – reduces likelihood that a vehicle roll over barrier
  - Effective with large pick-up truck and school buses

Modified Thrie-beam





Modified Thrie-beam



TL-3

& TL-4

T-39 Thrie Beam Guardrail

- Strong post Thrie-beam
- Thrie-beam attaches directly to Steel Yielding Line Posts (SYLP) eliminating the need for off-set blocks
- System height = 39 in

TL-4

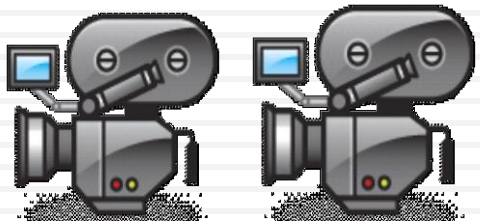
Thrie, Mod Thrie, T-39 Beams

NAME	ILLUSTRATION	TEST LEVEL		POST
		NCHRP 350	MASH	
Thrie-Beam https://www.aashtotf13.org/guide_display.php Generic		TL-3		Wood or steel strong post W6 x 9 or W6 x 8.5 x 6 ft. 6 in. Steel post Post spacing 6 ft. 3 in.
Modified Thrie-beam https://www.aashtotf13.org/guide_display.php Generic		TL-3 and TL-4		W6 x 9 or W6 x 8.5 x 6 ft. 9 in. Steel post. Post spaced at 6 ft. 3 in.
Trinity T-39 (Thrie-beam) http://highwayguardrail.com/products/grT39.html Trinity Highway Products		TL-4	TL-3	W6 x 9 or W6 x 8.5 x 6 ft. Steel post. 6 ft. long Steel Yielding Line Posts (SYLP) Each post has four 13/16-in. diameter holes in the flanges at ground line Post spacing 6 ft. 3 in.

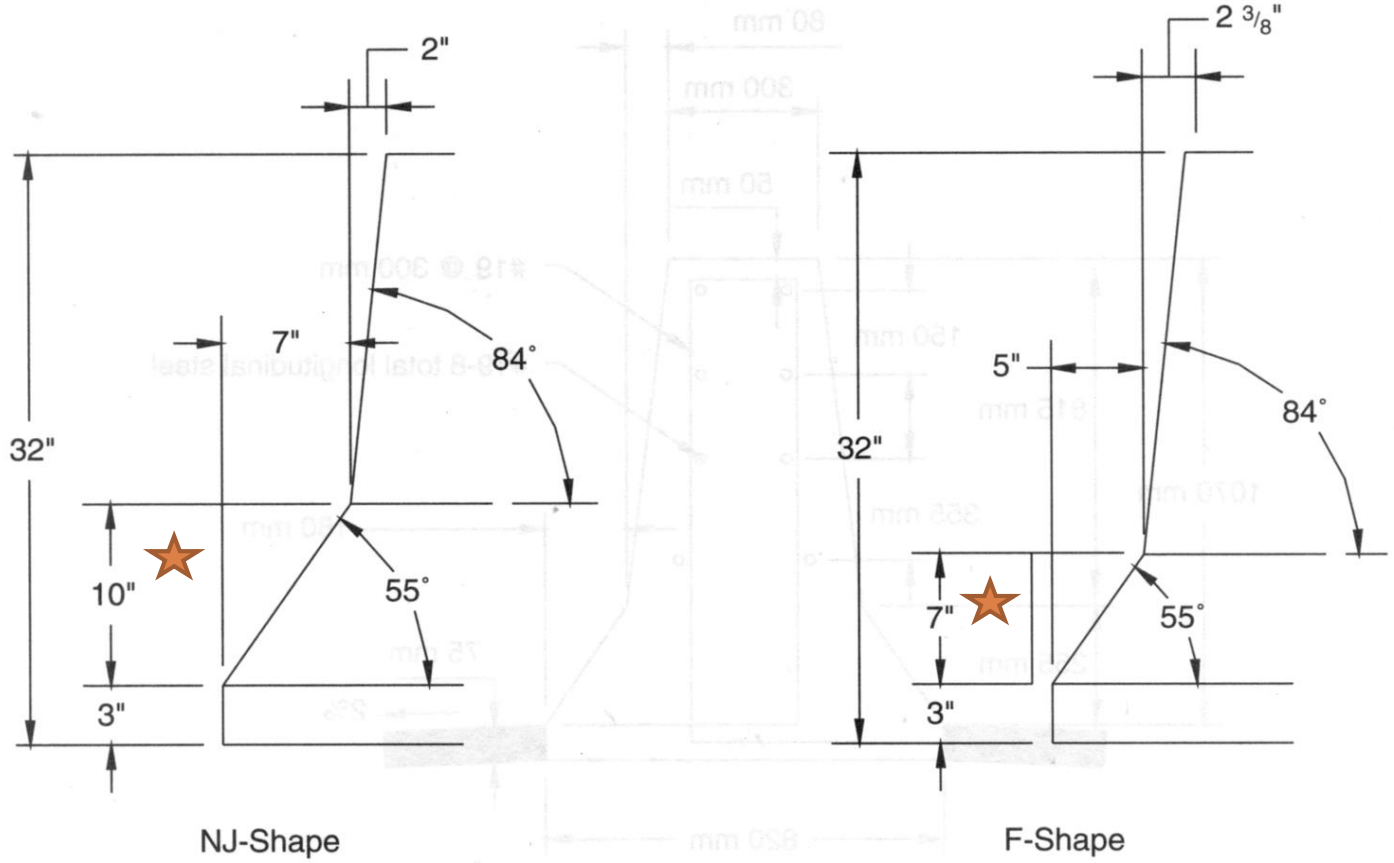
Rigid Barriers

Lateral deflection practically 0’

Source: FHWA



F-shape and New Jersey Concrete Barriers



TL-4 (32”) & TL-5 (42”)


Church's


SunCom
"MEJOR CONEXIÓN DE VOZ EN PUERTO RICO."
Tapia
C. Degetau
C. Providencia

Single Slope Barrier

Tall Barrier

- Height: 42” vs. 32” (traditional)
- Applications
  - Highways with high percentage of heavy trucks (> 8%)
  - Mountainous terrain with significantly steep longitudinal grades (> 6%)

Truck Trailer / Tanker Rigid Barrier 90”

Roadside Barriers Selection Criteria

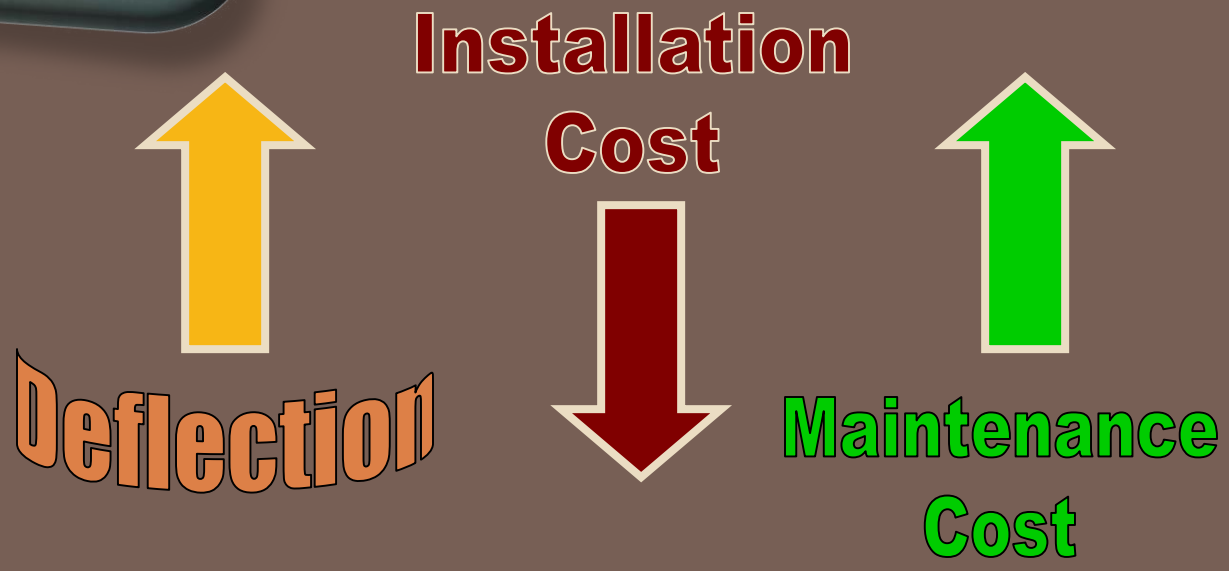
Table 5-5. Selection Criteria for Roadside Barriers

Criteria	Comments
1. Performance Capability	Barrier should be structurally able to contain and redirect the design vehicle for the appropriate test level.
2. Deflection	Expected deflection of barrier should not exceed available deflection distance. ZOI should be considered.
3. Site conditions	Slope approaching the barrier and distance from traveled way may preclude use of some barrier types.
4. Compatibility	Barrier should be compatible with planned terminal or anchorage and capable of transitioning to other barrier systems (such as bridge railing).
5. Cost	Standard barrier systems are relatively consistent in cost, but high-performance railings can cost significantly more.

Roadside Barriers Selection Criteria

6. Maintenance	
A. Routine	Few systems require a significant amount of routine maintenance.
B. Collision	Generally, flexible or semi-rigid systems require significantly more maintenance after a collision than rigid or high performance railings.
C. Material storage	The fewer the number of systems used, the fewer inventory items/storage space required.
D. Simplicity	Simpler designs, besides costing less, are easier to maintain and more likely to be reconstructed properly by field personnel.
7. Aesthetics	Occasionally, barrier aesthetics are an important consideration in the selection of barrier design.
8. Field Experience	The performance and maintenance requirements of existing systems should be monitored to identify problems that could be lessened or eliminated by using a different barrier type.

a. Flexible
b. Semi-rigid
c. Rigid



4. MEDIAN BARRIER TYPES

Median Barriers

- Longitudinal barriers
- Separate opposing through traffic on high-volume divided highways
- Contain and redirect passenger vehicles and pick-up trucks

NCHRP 350

Recommended Procedures for the Safety Performance Evaluation of Highway Features

Crashworthy Median Barrier Systems

Barrier System	NCHRP Report 350 Test Level (TL)	FHWA Acceptance Letter	System Designation	Manufacturer	Reference Section
Weak-Post W-Beam Median Barrier	2	B-64	SGM02	Generic	6.4.1.1
Low-Tension Cable Barrier	3	B-64	SGM01	Generic	6.4.1.2
High-Tension Cable Barrier	3 4	B-82C B-119 B-167 B-88A B137	N/A	Brifen USA, Inc. Trinity Industries, Inc. Nucor Steel Marion Inc. Safence Gibraltar	6.4.1.3
Box-Beam Barrier	3	B-64	SGM03	Generic	6.4.1.4
Blocked-Out W-Beam (Strong Post) Steel or Wood Post with Wood or Plastic Block Steel Post with Steel Block	 3 2	 B-64 B-64	SGM04a-b	Generic	6.4.1.5
Blocked-Out Thrie Beam (Strong Post) Wood or Steel Post with Wood or Plastic Block	3	B-64	SGM09a-b	Generic	6.4.1.6
Modified Thrie-Beam	4	B-64	SGM09c	Generic	6.4.1.7
Concrete Barrier Vertical Wall 810 mm [32 in.] tall 1070 mm [42 in.] tall New Jersey Shape 810 mm [32 in.] tall 1070 mm [42 in.] tall Single Slope 810 mm [32 in.] tall 1070 mm [42 in.] tall F-Shape 810 mm [32 in.] tall 1070 mm [42 in.] tall	 4 5 4 5 4 5 4 5	 B-64 B-64 B-64 B-64 B-64 B-64 B-64 B-64	 N/A SGM11a-b N/A SGM10a-b	Generic	6.4.1.8
Quickchange® Movesble Barrier (Including Steel Reactive Tension System [SRTS] and Concrete Reactive Tension System [CRTS])	3	B-63, B-69	SGM22	Barrier Systems, Inc.	6.4.1.9

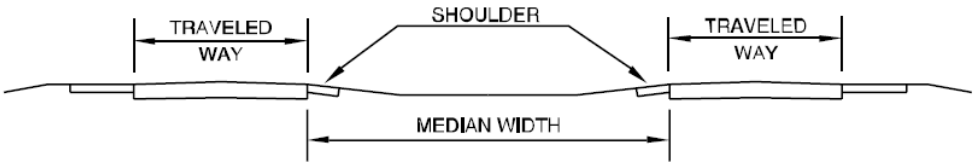
1. Performance Requirements

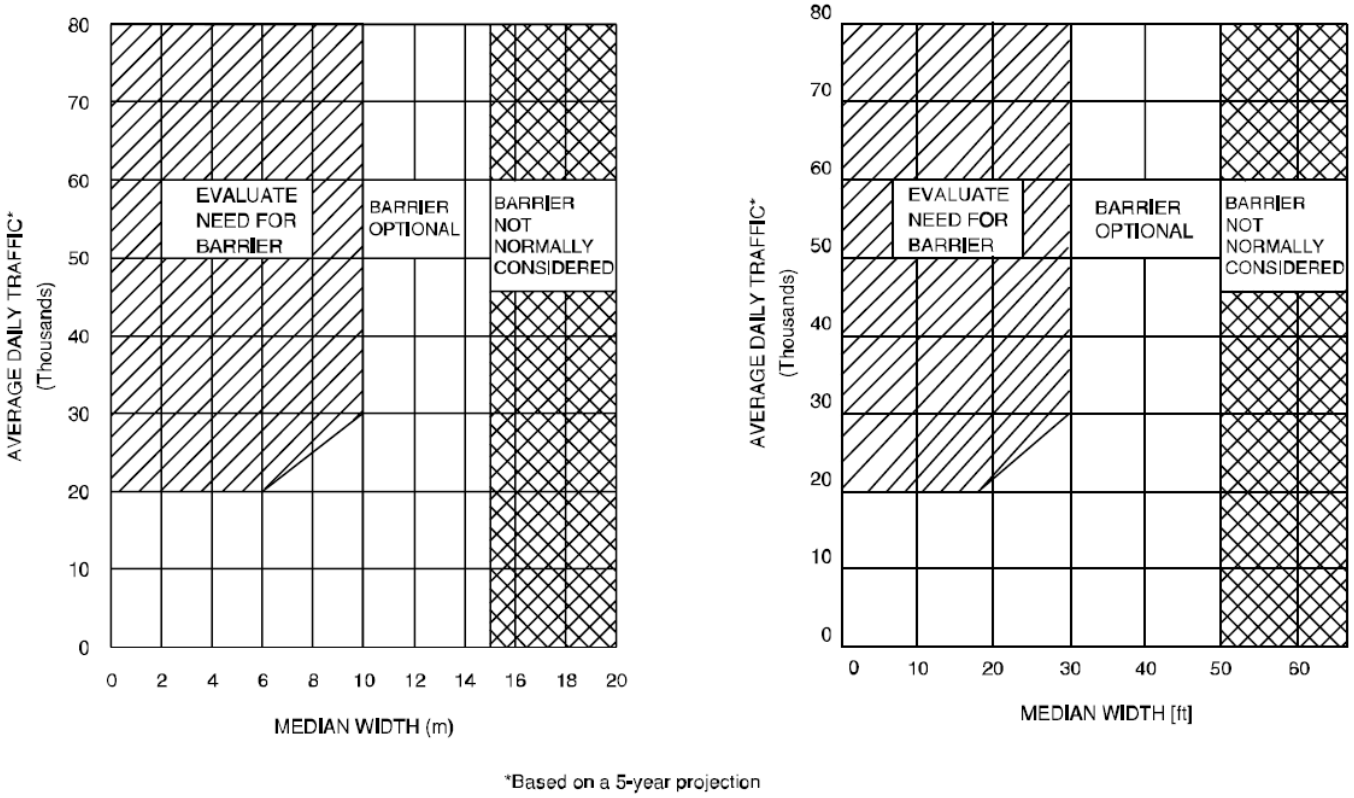
Test level	Vehicle	Angle	Speed
TL-1	1,800lb car	20º	30 mph
TL-2	4,400lb pickup truck		45 mph
TL-3		25º	60 mph
TL-4 (mod. TL-3)	17.6kip SUT	15º	50 mph
TL-5	80kip tractor-trailer (van)	15º	50 mph
TL-6	80kip tractor-trailer (tanker)	15º	50 mph

Median Barrier Selection Guidelines

- Performance: TL-3
- Deflection distance approx. half median width
  - Flexible and semi-rigid: wide and flat slopes
  - Rigid: narrow medians
- Compatibility with other median features
- Costs
- Aesthetics and Environmental
- Field experience

AASHTO Guidelines for Median Barriers on High-Speed, Fully Controlled-Access Roadways





*Based on a 5-year projection

Figure 6-1. Guidelines for Median Barriers on High-speed, Fully Controlled-Access Roadways

Deflection Characteristics

a. Flexible systems
   - Median Cable Barrier
   - W-beam (weak post)

b. Semi-rigid systems
   - Box beam
   - Blocked out W-beam and Thrie beam (strong post)
   - Modified Thrie beam

c. Rigid systems (concrete or masonry)
   - Safety shape
   - F-shape
   - Vertical
   - Single-slope

Median Cable Barrier

- Steel cables mounted on weak posts
- Redirects vehicle after tension is developed in the cable

- Mounting height of top cable is 30in and 12ft deflection distance
- Only for flat and traversable 1V:6H medians with no curb or ditches

Median Cable Barrier

W-Beam (Weak Post)

- Behave like cable system, but with less deflection
- Posts serve primarily to hold the rail at the proper elevation

- Mounting height of 33in and 7ft deflection distance
- Only for flat and traversable medians with no curb or ditches

W-Beam (Weak Post)

Box Beam (Weak Post)

- Achieves resistance through combined flexural and tensile resistance of box beam
- Posts break or tear away and distribute force to adjacent posts
- Deflection distance of 5.5 ft

Box Beam (Weak Post)

Blocked Out W-beam (Strong Post)

- Minimizes vehicle snagging
- Reduces vaulting over barrier
- Mounting height of 30 in and 2 to 4 ft deflection distance

- Rub rail is added for curb applications

Blocked Out W-beam (Strong Post)

Blocked Out & Modified Thrie-beam

- Similar to W-beam, but with deeper, stiffer, and additional corrugation rail
- Allows higher rail mounting, making it better able to contain larger vehicles
- Mounting height of 32 in and 1 to 3 ft deflection distance

Blocked Out & Modified Thrie-beam

Concrete Barriers

- Most common rigid median barrier
- High-angle and high-speed impacts
  - Airborne vehicle
  - Reach top of wall
- Fixed objects on top of wall
  - Snagging
  - Separate from barrier
- Cargo box of high center of gravity vehicles may hit fixed objects over wall

Disadvantages of Rigid Barriers

- Stability problems for some vehicles especially at extreme impact angles
- Vehicle redirection back into the roadway with little loss of speed
- High occupant forces
- Elaborate drainage structures required
- Reduction of effective height and lowering of slope breakpoint possible on pavement overlay


18 10 2005

Median Barrier Selection Criteria

Criteria	Comments
1. Performance Capability	Barrier must be structurally able to contain and redirect design vehicle.
2. Deflection	Expected deflection of barrier should not exceed available deflection distance.
3. Site conditions	Slope approaching the barrier and distance from traveled way may preclude use of some barrier types.
4. Compatibility	Barrier must be compatible with planned end anchor and capable of transitioning to other barrier systems (such as bridge railing).
5. Cost	Standard barrier systems are relatively consistent in cost, but high-performance railings can cost significantly more.
6. Maintenance	
A. Location	Low-maintenance barriers are often significantly more difficult to repair or maintain.
B. Collision	Generally, flexible or semi-rigid systems require significantly more maintenance after a collision than rigid or high-performance railings.
C. Material storage	The fewer different systems used, the fewer inventory items/storage space required.
D. Simplicity	Simpler designs, besides costing less, are more likely to be reconstructed properly by field personnel.
7. Aesthetics	Occasionally, barrier aesthetics are an important consideration in selection.
8. Field Experience	The performance and maintenance requirements of existing systems should be monitored to identify problems that could be lessened or eliminated by using a different barrier type.

Same as longitudinal barriers

State Transportation Agency Median Design and Safety Practices

- Approximately 76% of States have adopted AASHTO policy as median design barrier warrant standards
- Strong-post W-beam guardrail and concrete safety shape are the most commonly used
- Innovative strategies
  - Rumble strips on the inside paved shoulder
  - Median side slope flattening

Last Roadside Safety Design Option

QUESTIONS & REVIEW

Module 3 Review

4. Which barrier would you as a motorist prefer to hit?

a. Strong-post w-beam
b. 3-strand cable guardrail
c. New Jersey concrete barrier

Module 3 Review

5. If you are in charge of highway maintenance, what barrier would you like to see used most often?

a. Strong-post w-beam
b. 3-strand cable guardrail
c. New Jersey concrete barrier