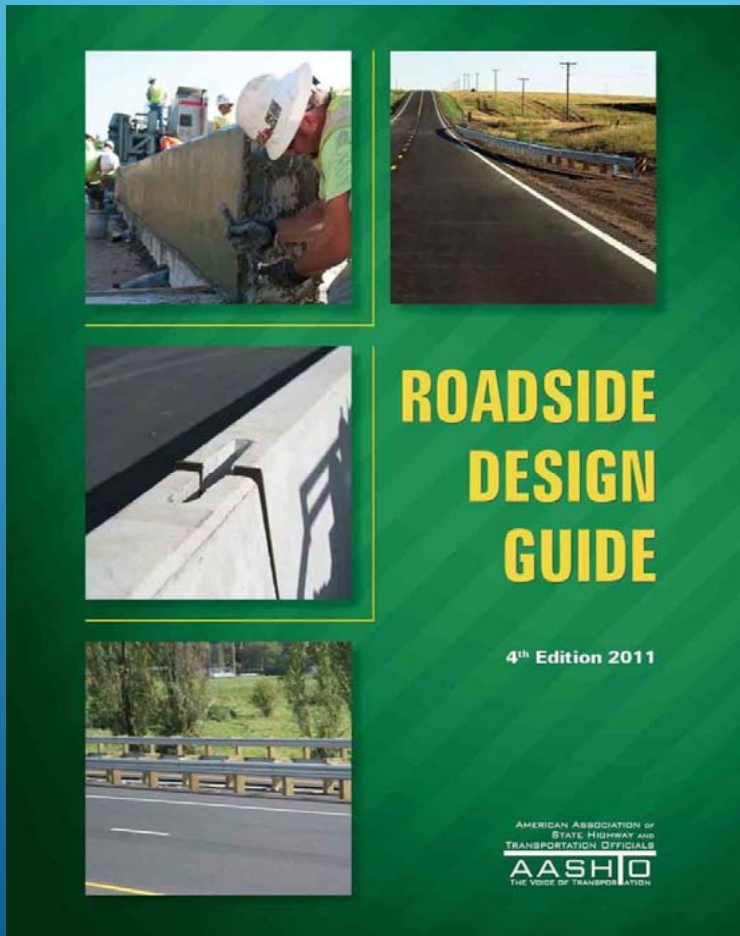


Training Day - Guardrail



Guidance Presented



Delaware Road Design Manual
Chapter Ten

OBJECTIVES OF THIS DISCUSSION

At the end of this course you will be able to:

- Verify that a traffic barrier is the best treatment to use at a specific site.
- Understand the principles of good barrier system design
- Identify installations that may not adequately shield all the warranting hazard(s) or secondary hazard(s).
- Recognize common installations errors for barriers and terminals and know how to avoid them.

Session 1: Roadside Safety Problem, Clear Zone, & Barrier Need Guidelines



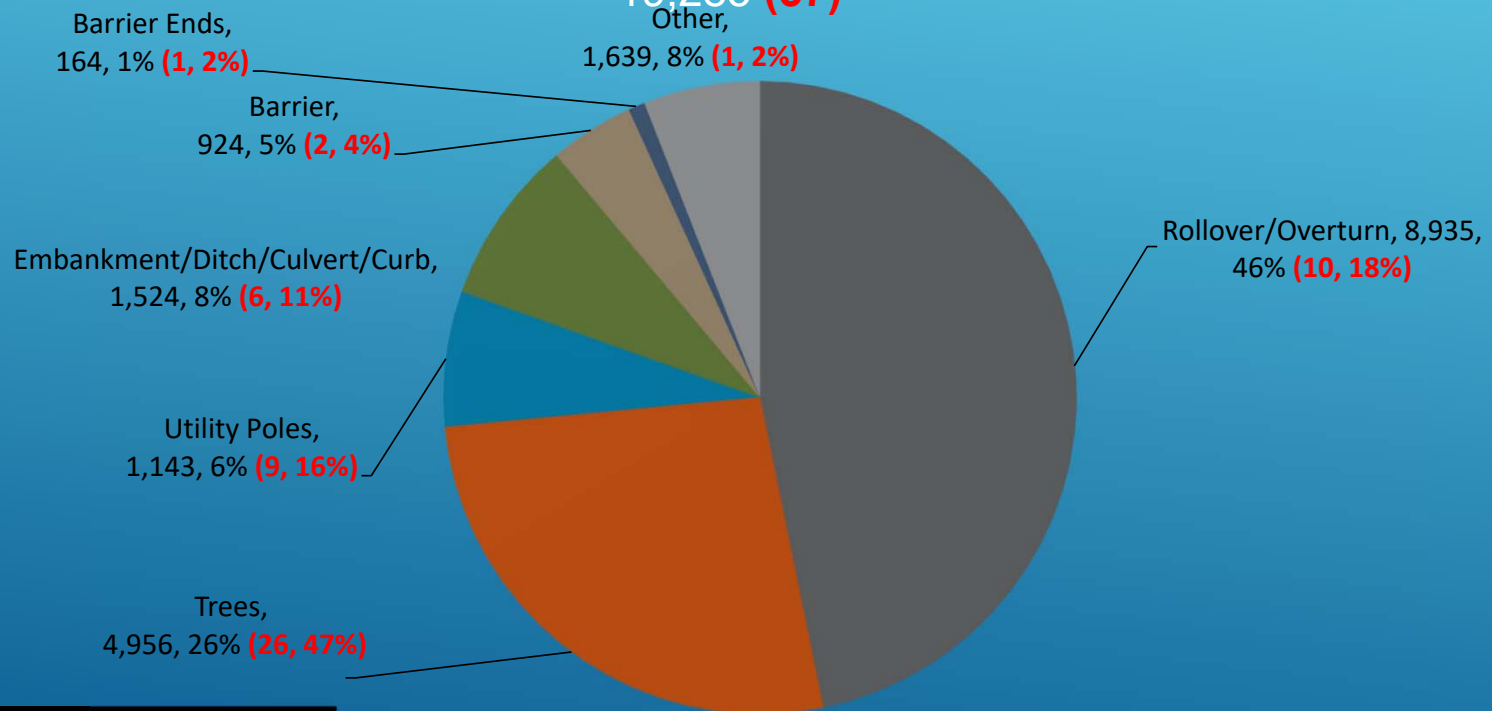
Barriers should reduce the severity of potential crashes

National Roadway Departure Fatalities

(Single Vehicle Fatal Crashes 2016)

National (**Delaware**)

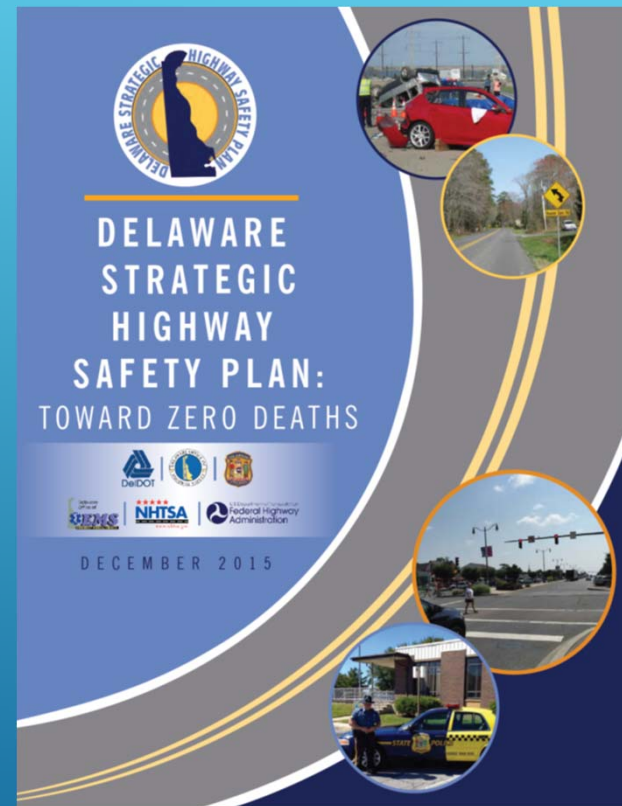
19,285 (**57**)



Ref: FARS Data – Most Harmful 2016

DELAWARE STRATEGIC HIGHWAY SAFETY PLAN

- Emphasis Area Two: Roadway Departure
In Delaware, roadway departure crashes represent the largest percentage of fatalities (40 percent) and second highest percentage of serious injuries (21 percent) based on 2007 through 2014 crash data.





NEED FOR TRAINING

Examples of improper installation of systems:



NEED FOR TRAINING

Examples of improper installation of systems:

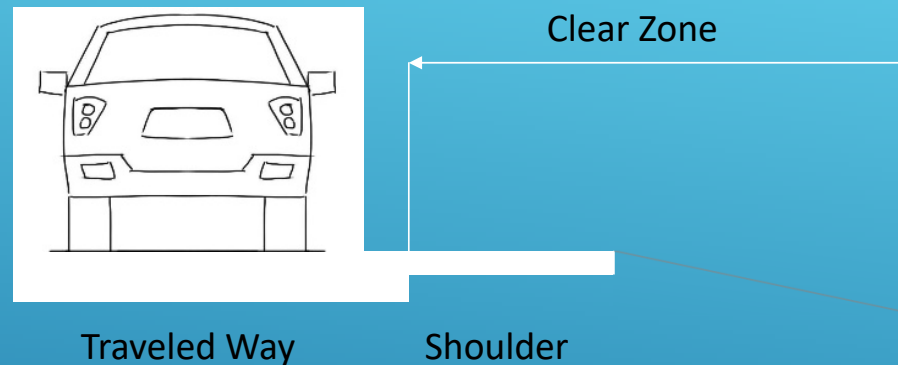


NEED FOR TRAINING

Examples of improper installation of systems:




CLEAR ZONE: A DEFINITION



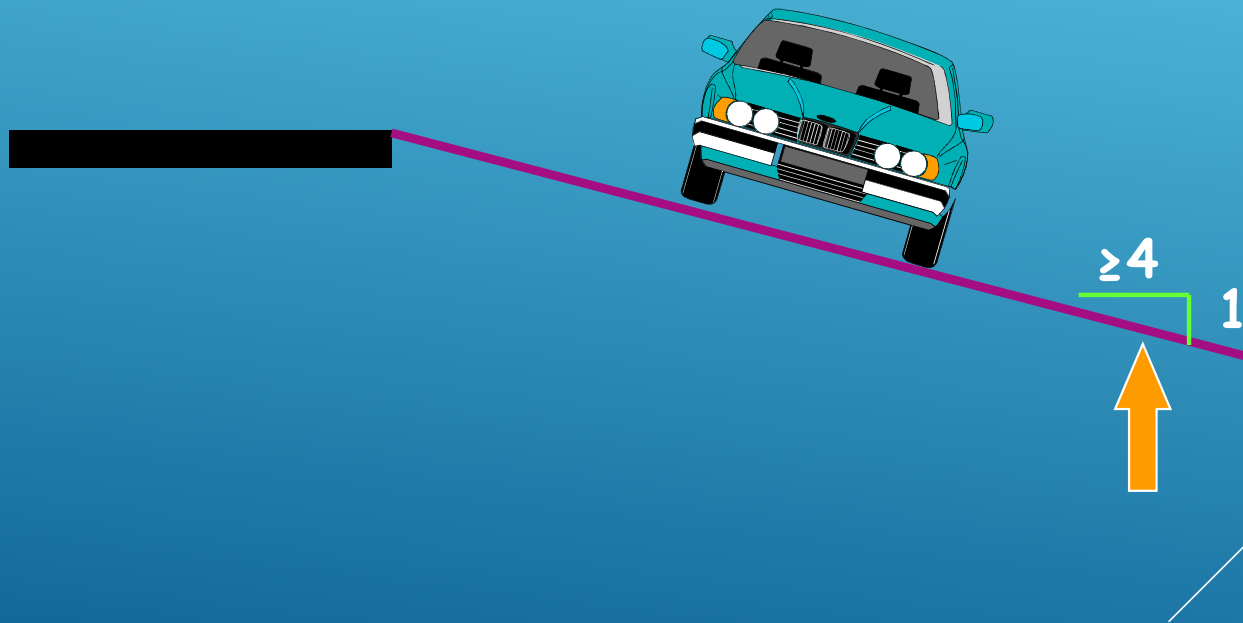
The unobstructed, traversable area provided beyond the edge of the through traveled way for the recovery of errant vehicles. The clear zone includes shoulders, bike lanes, and auxiliary lanes, except those auxiliary lanes that function like through lanes.

Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION, Glossary

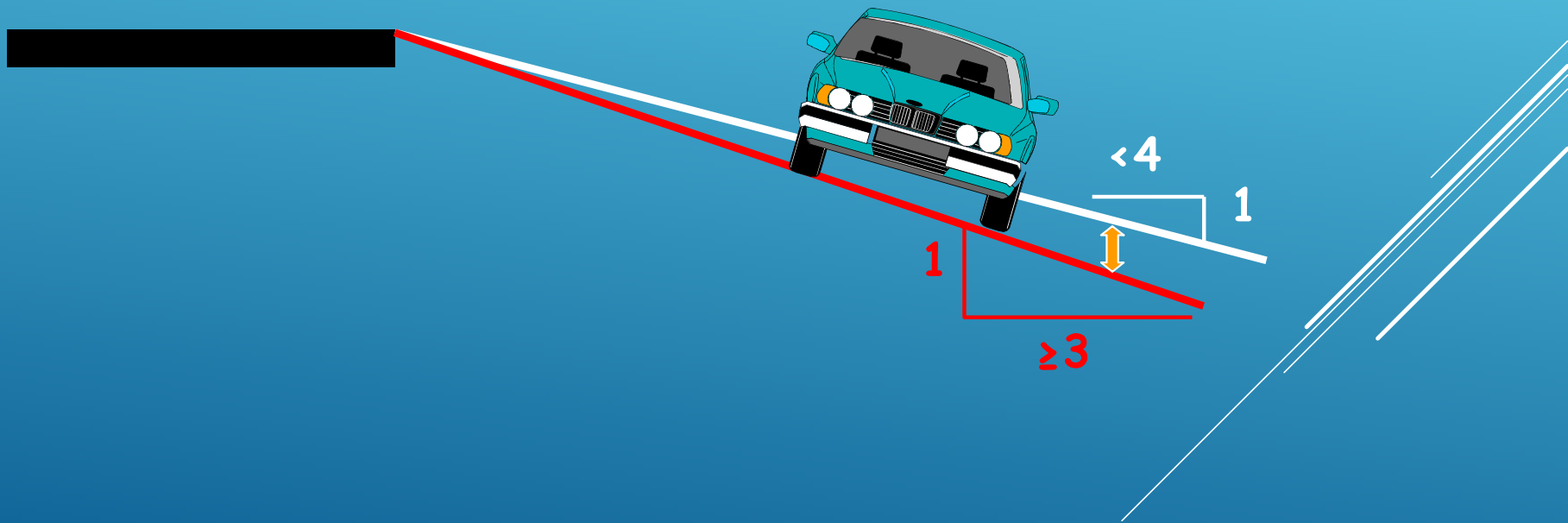
CLEAR ZONE FACTORS

- Slope Type and Steepness
 - Design Speed
 - Traffic Volume
 - Horizontal Curvature
- 
- A decorative graphic consisting of several parallel white lines of varying lengths, slanted diagonally from the bottom right towards the top right, set against the blue background.

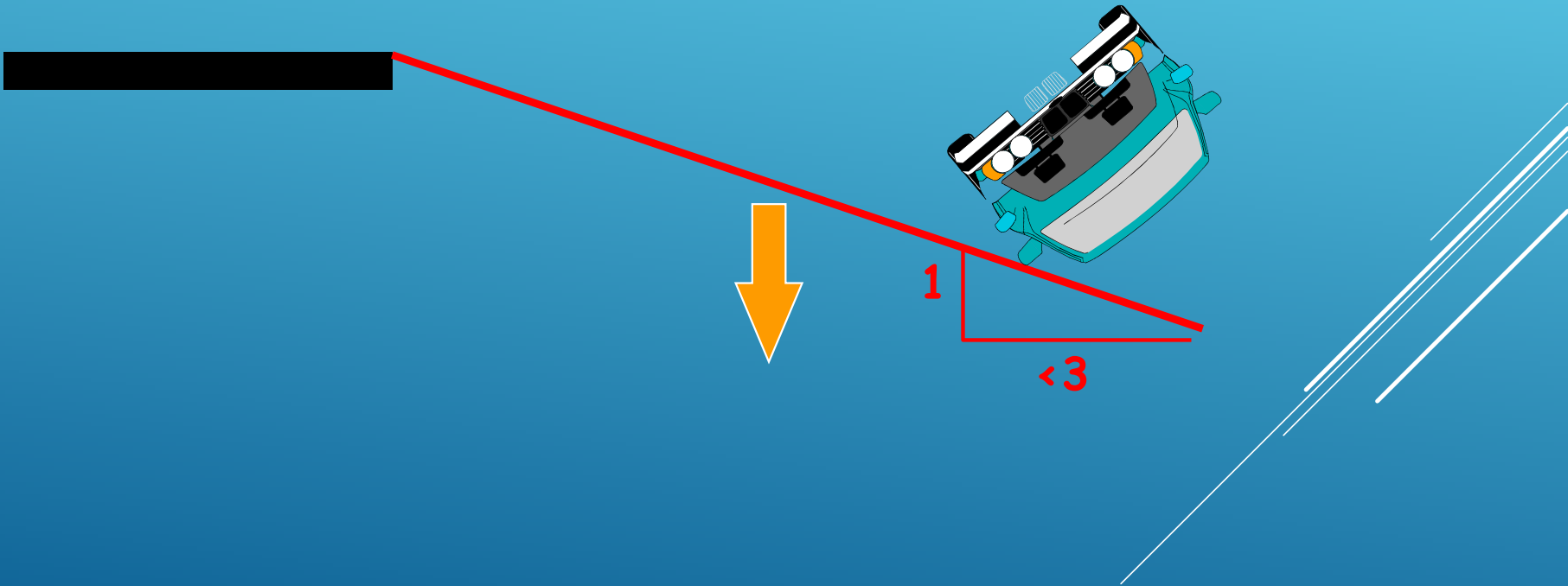
RECOVERABLE



NON-RECOVERABLE (BUT TRAVERSABLE)



Critical



Design Clear Zone Determination

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

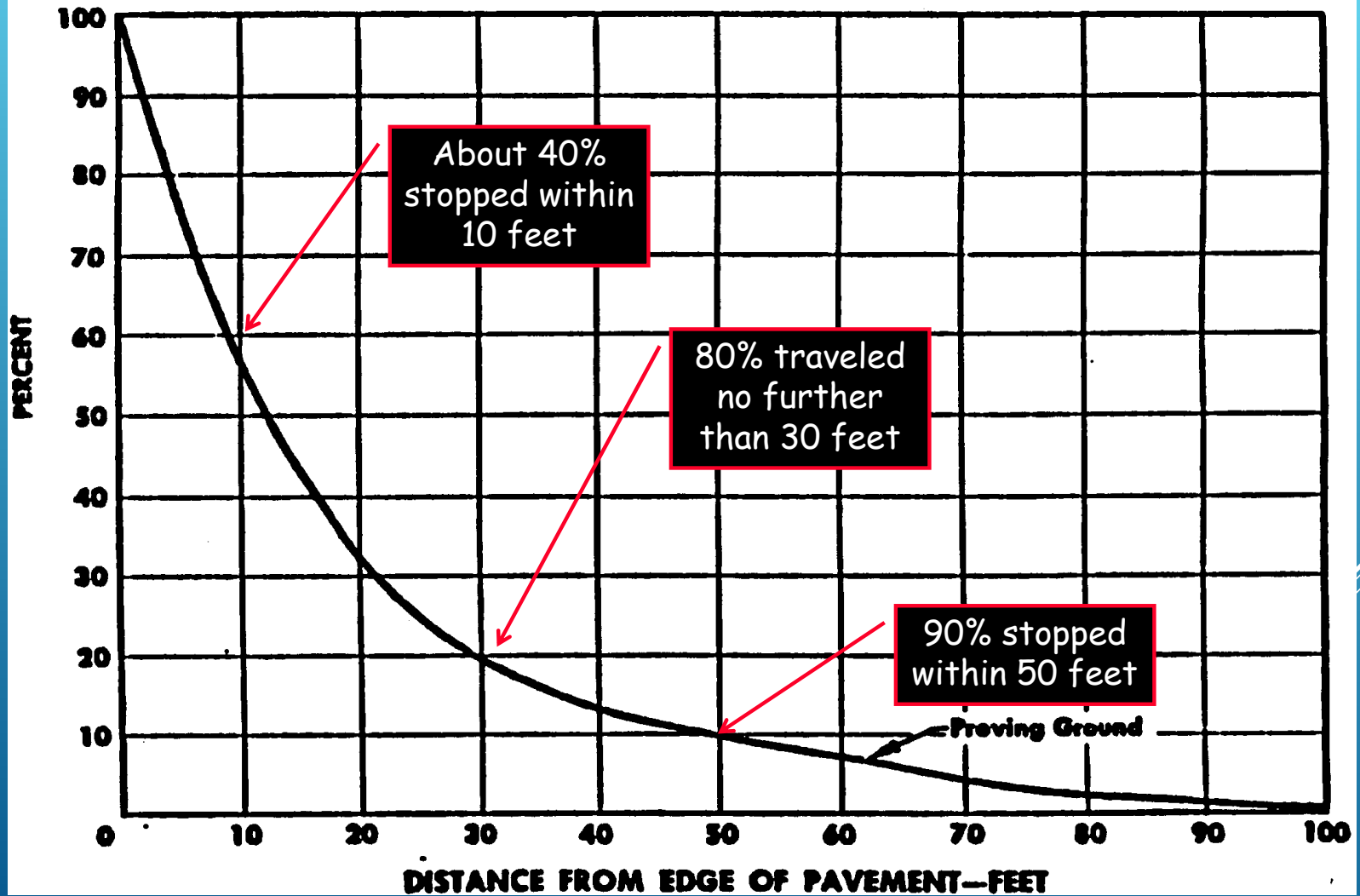
Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – TABLE 3.1, Pg. 3-3

Clear Zone

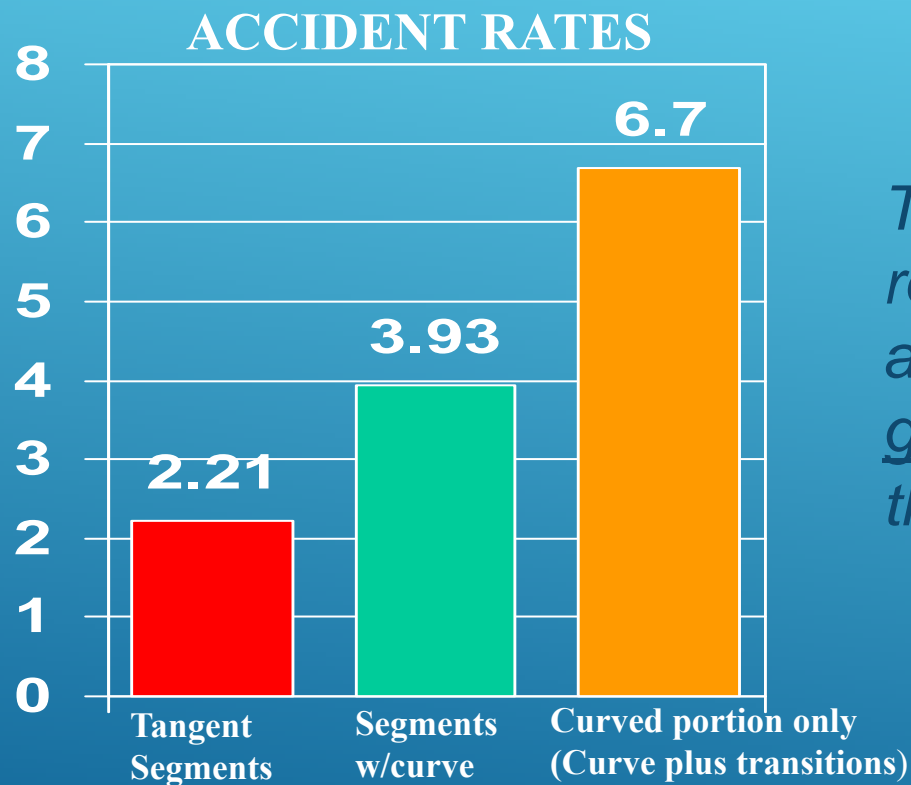
THE "MAGIC"
30 FEET

GM PROVING GROUND ACCIDENTS

211 CASES



....CURVES PRESENT PARTICULAR SAFETY PROBLEMS

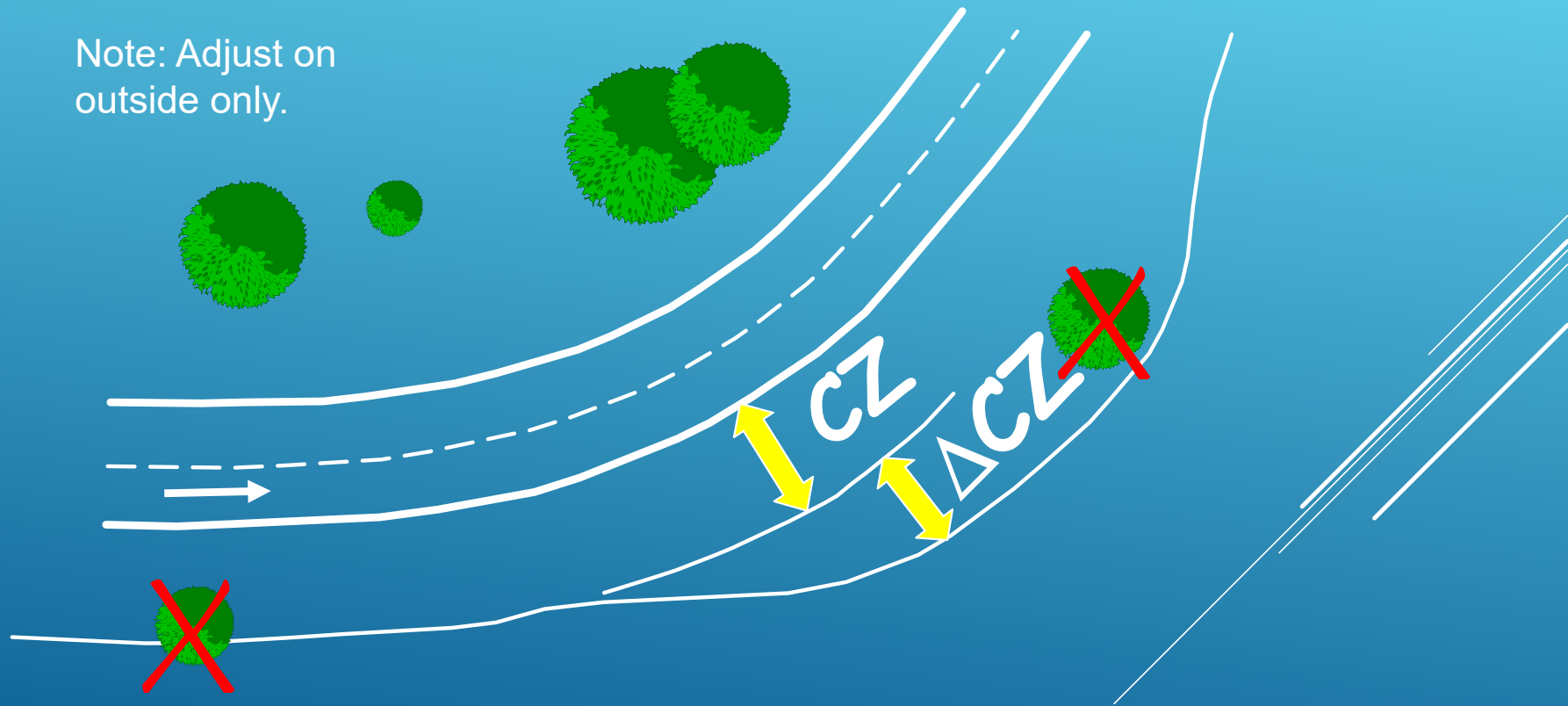


The risk of a reported crash is about three times greater on a curve than on a tangent

Source: Glennon, et al, 1985 study for FHWA

HORIZONTAL CURVES

Note: Adjust on outside only.



ORDER OF PREFERENCE

1. Remove obstacle
2. Redesign obstacle (make traversable)
3. Relocate obstacle (to point where less likely struck)
4. Reduce impact severity (use breakaway design)
5. SHIELD obstacle
6. Delineate obstacle

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












Testing Requirements and
Performance
Characteristics of
Common Barrier Systems

A decorative graphic consisting of several parallel white lines of varying lengths, slanted diagonally from the bottom right towards the top right, set against the blue background.

CRASH TESTING GUIDELINES

- Recent crash testing and evaluation criteria were published in 1993 as NCHRP Report 350
- In 2009, the Manual for Assessing Safety Hardware (MASH) was published by AASHTO. It was/is used by FHWA as the testing standard for all new products
 - FHWA Maintained the list of crashworthy products and designs.
- In 2016, AASHTO adopted an update to MASH and a timetable for implementation of new installations complying with this edition was signed between FHWA and AASHTO
 - FHWA mandated that individual states maintain a list of crashworthy products and designs.

MASH IMPLEMENTATION TIMELINE

MASH Compliance Timeline



Report 350 SUNSET



MASH SUNRISE

NCHRP 350 COMPARISON WITH MASH CREW CAB TRUCK



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 small car and pickup truck with a 25° impact angle at 31, 44, and 62 mph, respectively.



2,420 lbs.
1100C



5,000 lbs.
2270P

MASH Test Conditions (cont'd)

- **TL- 4:** TL-3 + 15° impact angle, 56 mph Single-Unit Truck
- **TL- 5:** TL-3 + 15° impact angle, 50 mph Tractor-Van Trailer
- **TL- 6:** TL-3 + 15° impact angle, 50 mph Tractor-Tank Trailer



22,000 lbs.



80,000 lbs.



80,000 lbs.

FUNCTIONAL REQUIREMENT OF BARRIER

1. Contain Vehicle


- No Penetration
- No Vaulting/Under-riding

2. Redirect Vehicle Smoothly (low exit angle) with no snagging/overturning, and no excessive rotation (75 deg max)

3. Tolerable Occupant Impact Forces

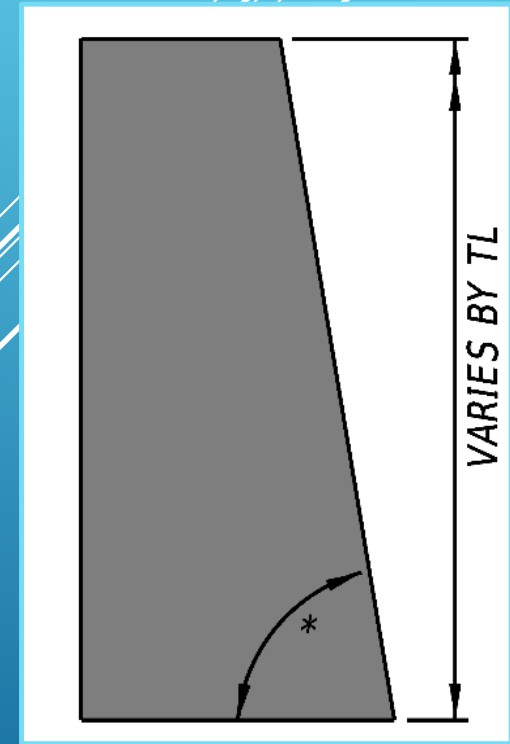
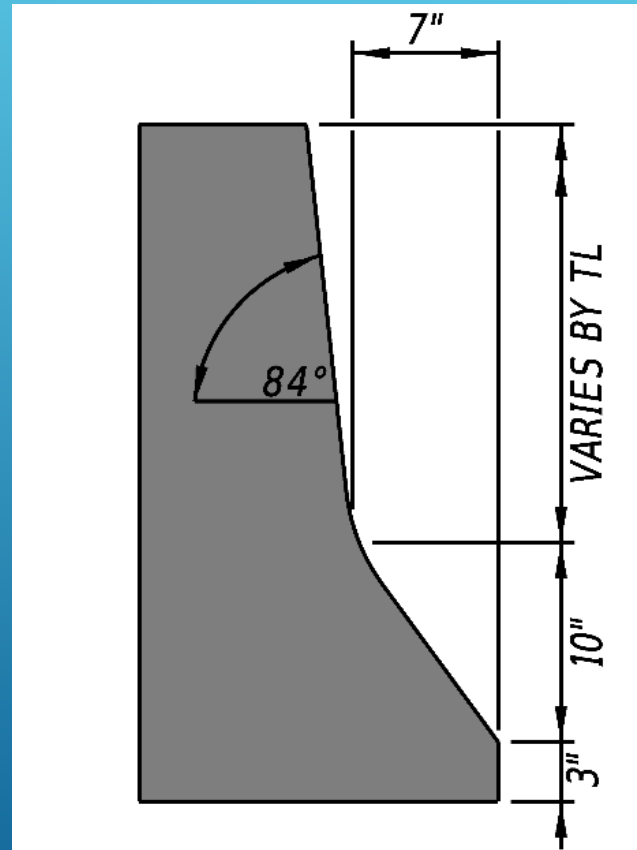
4. Minimum Occupant Compartment Deformation and no Debris Intrusion

STANDARD BARRIER SECTION

- Rigid Systems
 - Semi-Rigid Systems
 - Flexible Systems
 - Median Barrier Systems
 - Work Zone Concrete Systems
- 
- A decorative graphic consisting of several parallel white lines of varying lengths, slanted diagonally from the bottom right towards the top right, located in the lower right quadrant of the slide.

RIGID BARRIER

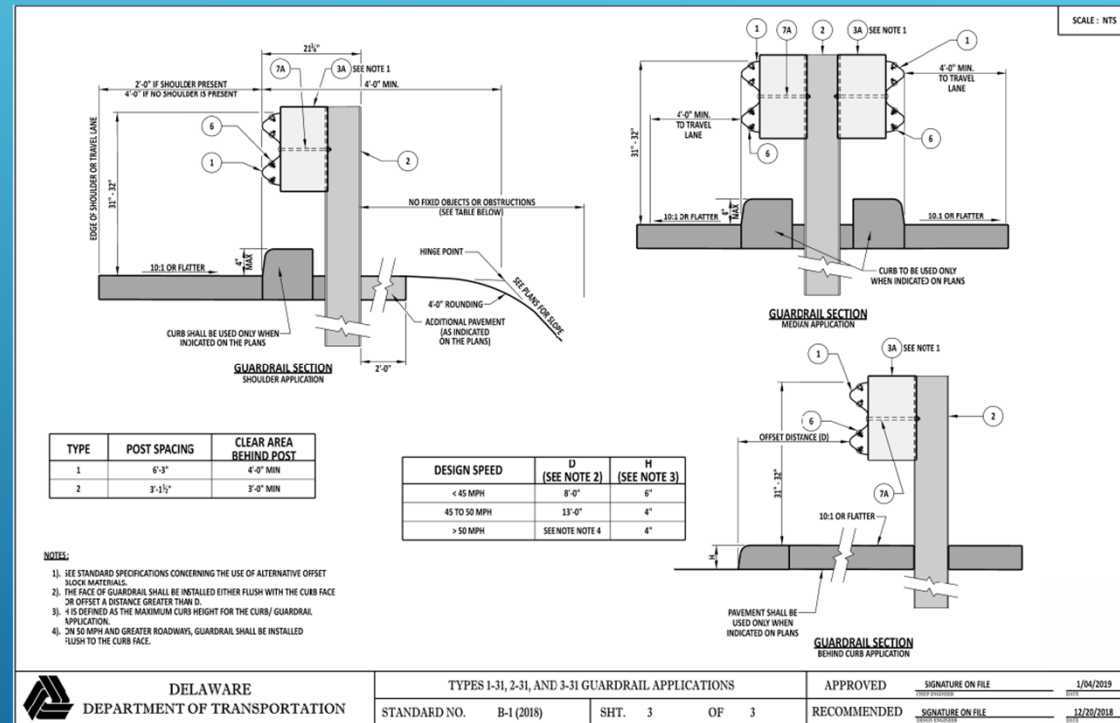
- 36" F-Shaped Barrier for TL-4
- 42" F-Shaped Barrier for TL-5
- 42" Single Slope Barrier for TL-5



BARRIER SYSTEMS: SEMI-RIGID

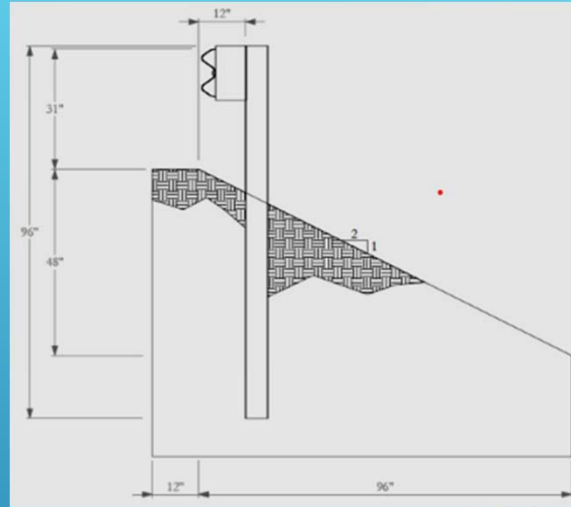
➤ Semi-Rigid Barrier Systems have deflections of a few feet (between 2 to 5 ft.) under the TL-3 pickup impact.

➤ Typically consist of beam and post elements.



STANDARD B-1 TYPES 1-31, 2-31, AND 3-31 GUARDRAIL APPLICATIONS ADDITIONS

- ▶ Adding Guardrail on 2:1 Slope
- ▶ Guardrail with a one post omission
- ▶ Note for butterfly reflectors to be placed at the guardrail splice point



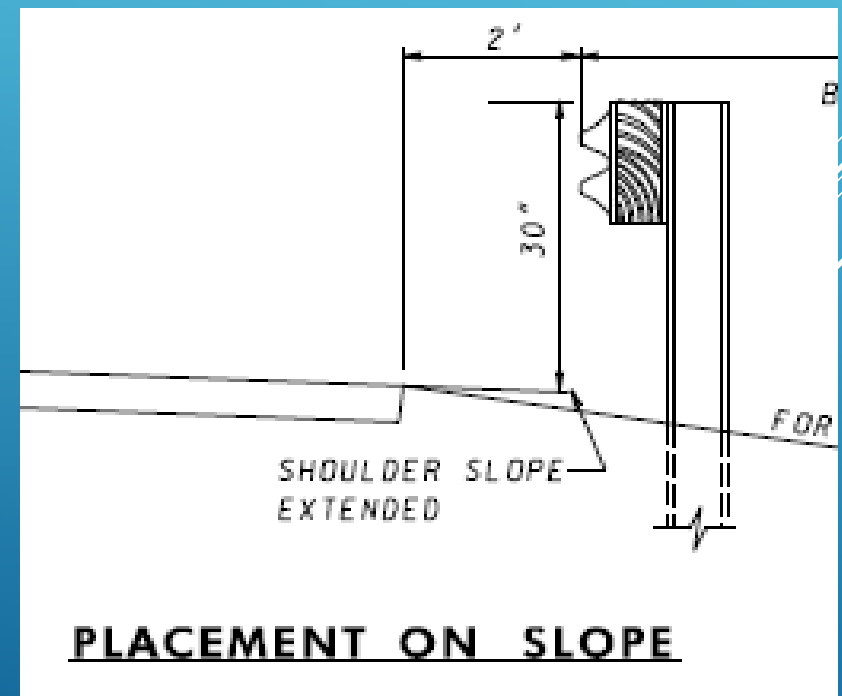
BARRIER SYSTEMS: SEMI-RIGID

- W-Beam Guardrail
 - 12" wide W-beam rail section (12-gauge thickness).
 - Posts are spaced at 6'-3" centers
 - Nominal rail height is 31"
 - Rail splice at the midpoint between the post.
 - Two post options:
 - Steel posts, W6 x 8.5/9.0 x 6'-0" long.
 - Block-outs: 6" x 8" wood or plastic.

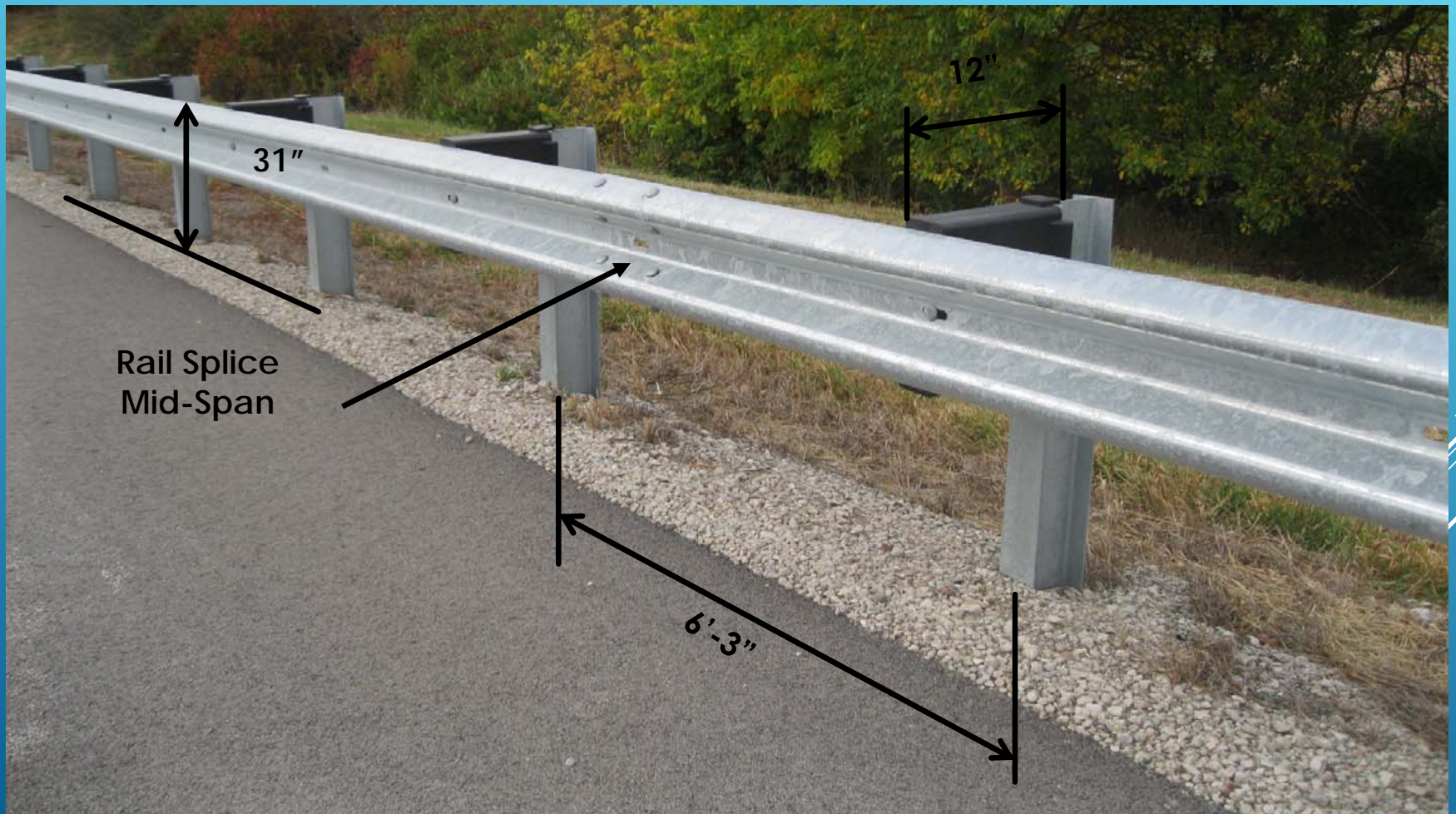


GUARDRAIL - HEIGHT MEASUREMENT

- For slopes 10:1 or flatter, the height is measured from the ground directly beneath the rail
- For slopes steeper than 10:1 but no steeper than 6:1, and within 2 feet of the breakpoint, the height is measured from the shoulder slope extended as shown
- Splice is at mid-span, between posts.



Midwest Guardrail System (MGS)



GUARDRAIL WITH WOOD POST & WOOD BLOCK-OUT

Failed Test!!!



DELDOT
STANDARD
DETAIL 1-31
GUARDRAIL

Passing Test!!!



FLEXIBLE BARRIERS SYSTEMS

Flexible Barrier Systems typically have relatively large deflections resulting in a less severe crash.

Examples include:

- ▶ Weak post W-beam
- ▶ High tension cable

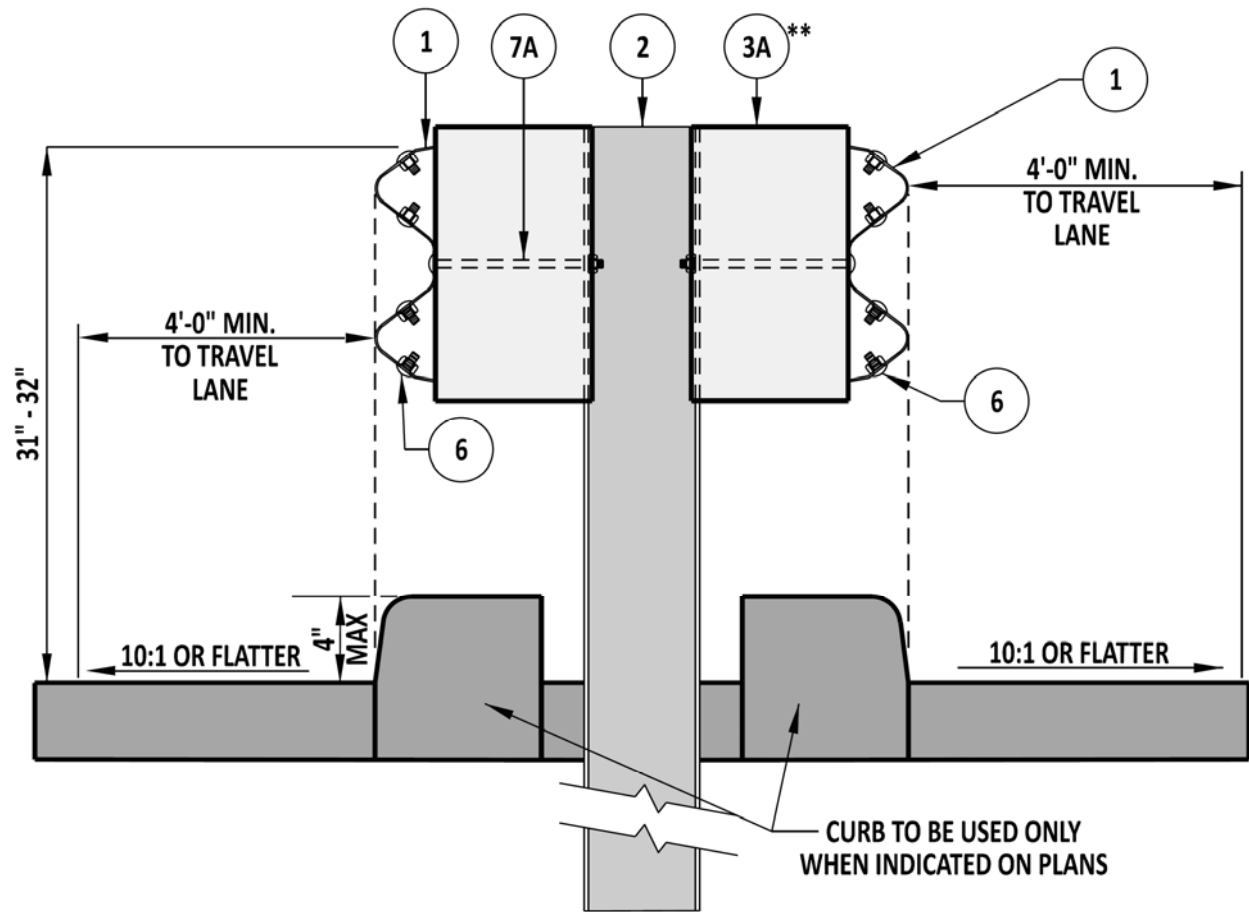
ANY alterations to the guardrail system should go through the Engineer on Record

BARRIERS IN THE MEDIAN

- Used to separate opposing traffic on a divided highway or to separate through traffic from local traffic.
- Many barriers approved for roadside applications can be modified for use in the median.
- 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.



DeIDOT Standard Detail for Median Barrier



GUARDRAIL SECTION
MEDIAN APPLICATION

TYPES 1-31, 2-31, AND 3-31 GUARDRAIL APPLICATIONS			
STANDARD NO.	B-1 (2010)	SHT.	3 OF 3

MASH 27" W-Beam Median Barrier Test




Failed Test! – Guardrail Height is critical

MASH
Median
Barrier
Test 31”
Guardrail

Passing Test!



WORK ZONE CONCRETE BARRIERS

- Portable reinforced concrete safety shape barrier
 - Dynamic deflection of the barrier is an important consideration in choosing a work zone barrier.
- 

TEMPORARY
WORK ZONE
BARRIER
PERFORMANCE



TRANSITION SECTIONS

- When a softer (more flexible) barrier precedes a stiffer barrier, a gradual stiffening must occur between the two systems.
- An effective transitions must provide the following:
 - Adequate connection (TENSION continuity)
 - Adequate length to gradually increase stiffness.



Inadequate Transition



2018

INADEQUATE TRANSITION



TRANSITION SECTIONS

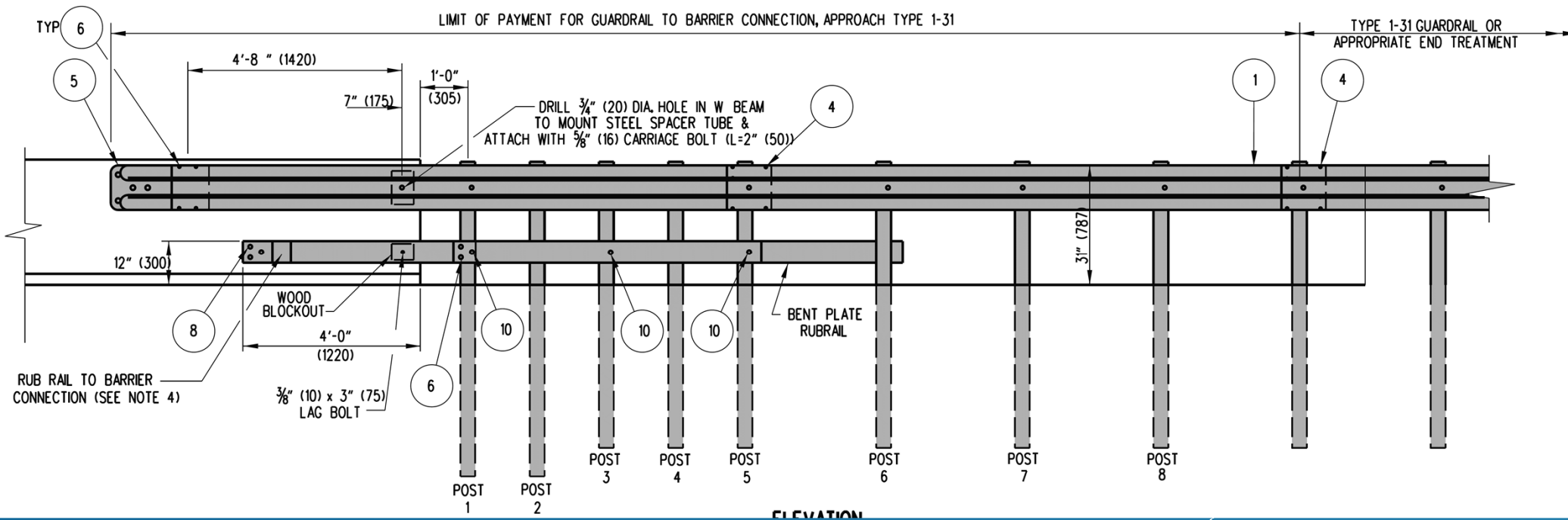
Successfully crash-tested transitions include the following essential elements (in addition to a structural connection):

- ▶ Additional and/or Larger size posts
- ▶ Nested rail (w-beam or Thrie-beam)
- ▶ Prevention of Snagging (such as Curbs {only as crash-tested transition unit}, Rub Rails, Flared Parapet Wall)

ADEQUATE TRANSITION



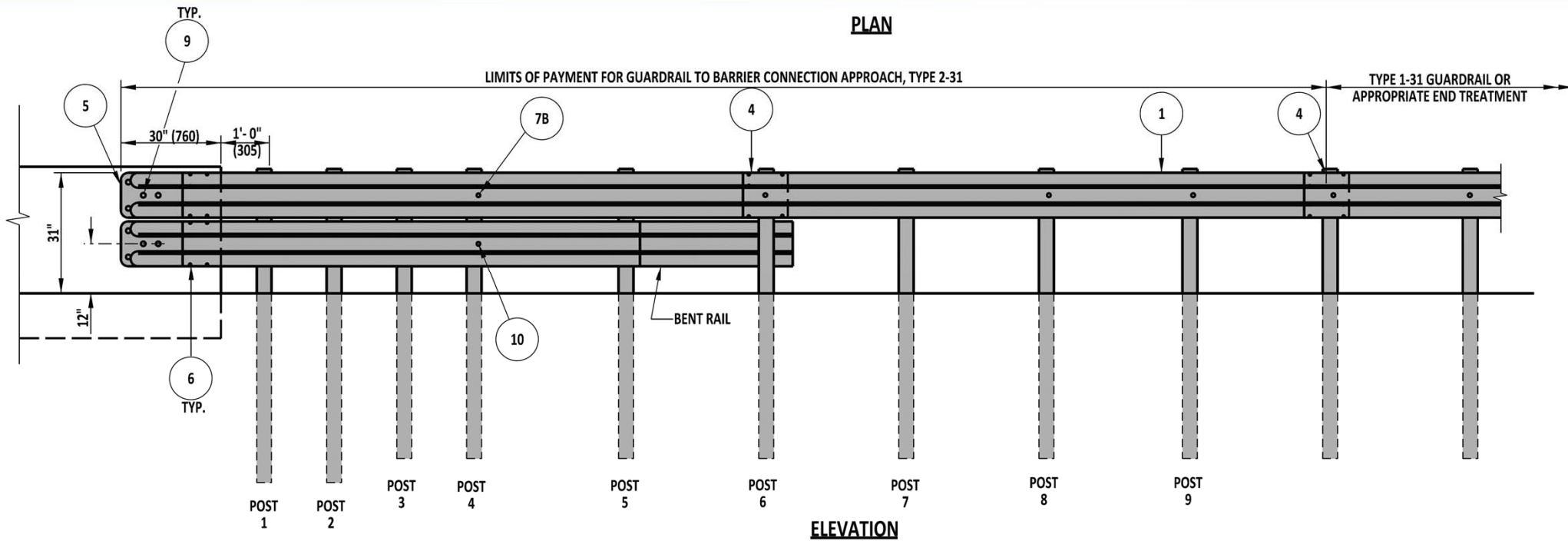
DELDOT TRANSITION – SINGLE W-BEAM



GUARDRAIL TO BARRIER CONNECTION, APPROACH TYPE 1-31			
STANDARD NO.	B-5 (2010)	SHT.	1 OF 6

DELDOT TRANSITION – STACKED W-BEAM

This Detail will be removed in the Standard Detail Updates



Ref: DeIDOT Standard Construction Details, B-5 Type 2-31

MASH 2016 Test on Stacked W-Beam



Standard B-5 Guardrail to Barrier Connection

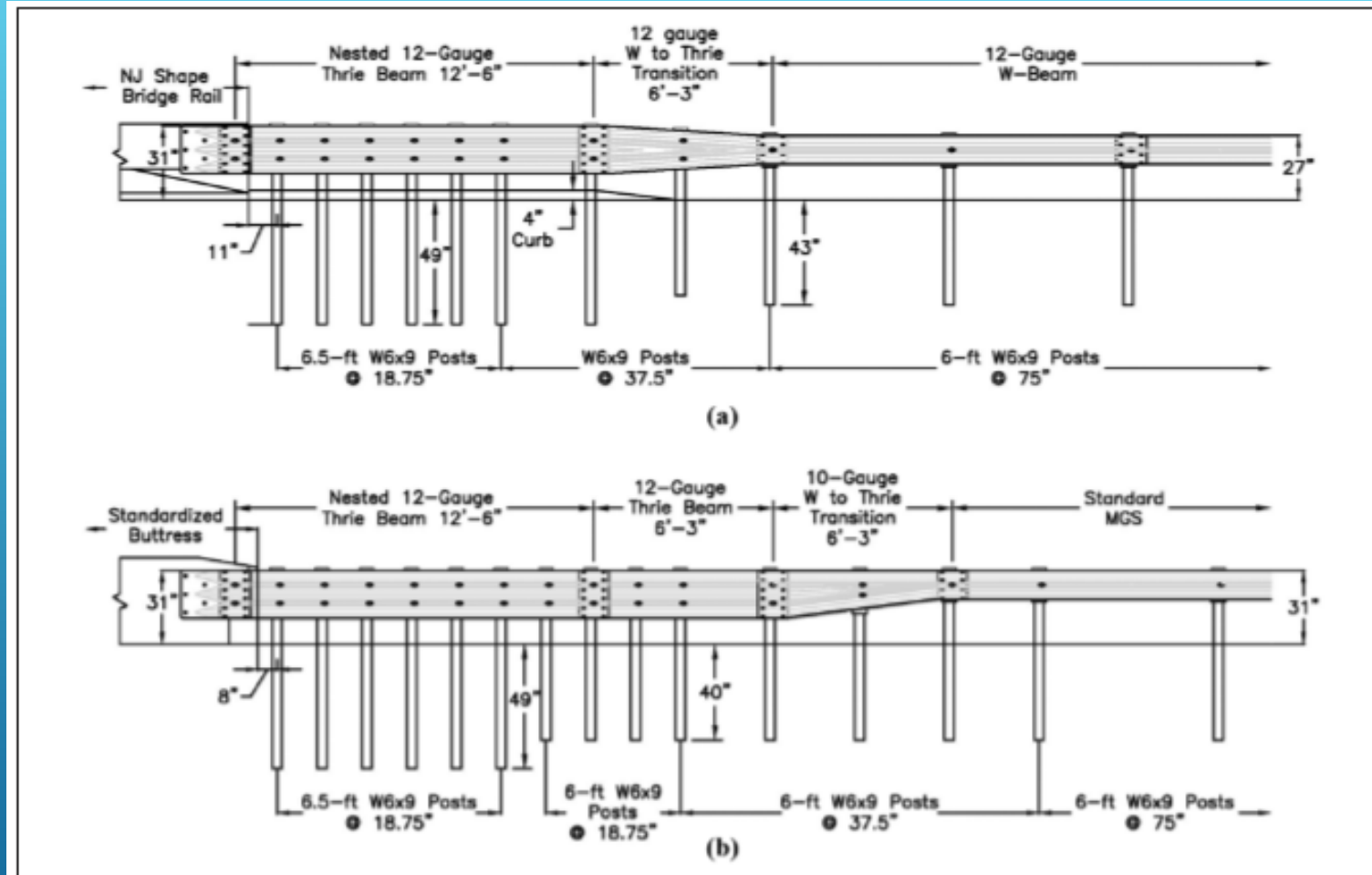
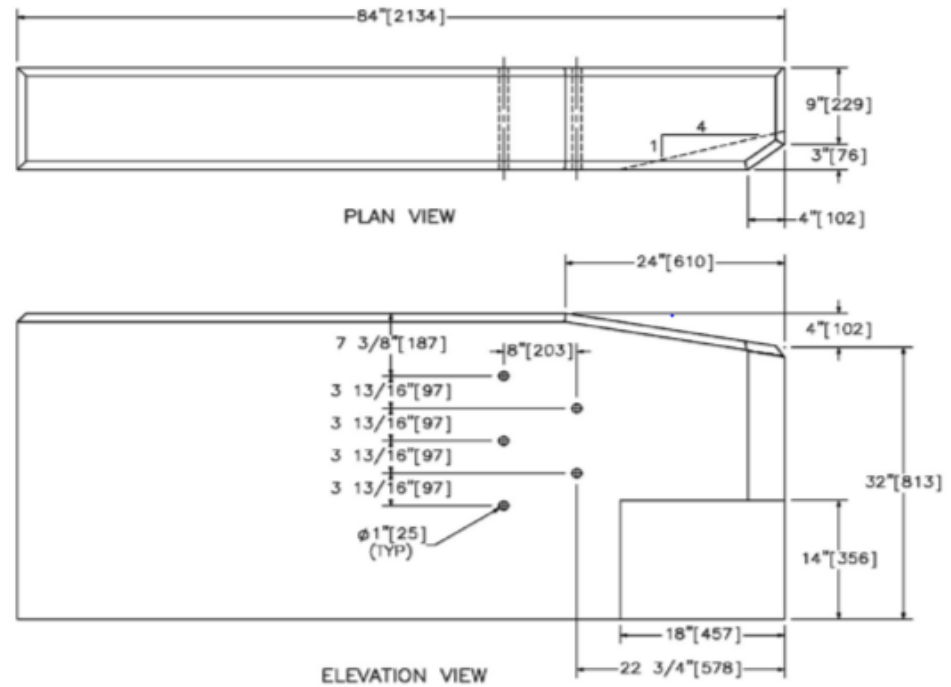
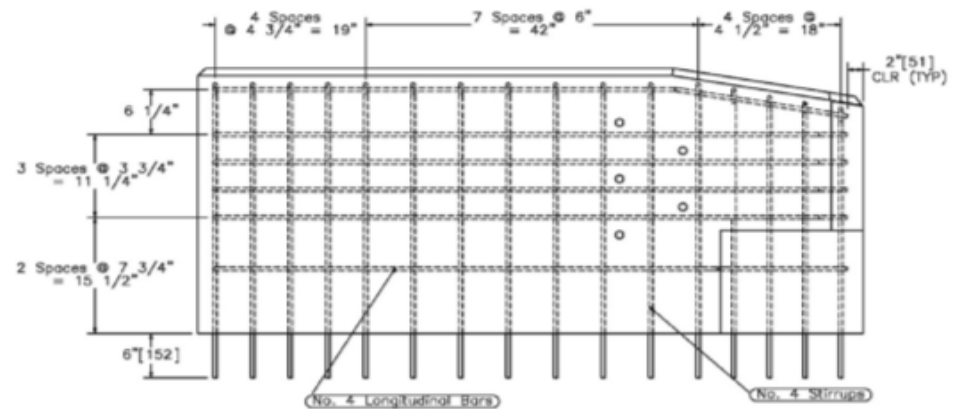


Figure 3. Selected AGT design: (a) original as-tested configuration and (b) critical configuration for evaluating the standardized buttress.


AGT: Approach Guardrail Transition



(a)



Testing Requirements and Performance Characteristics of Terminals and Crash Cushions



Why do we need a Crash Cushion?



And as we evolved...

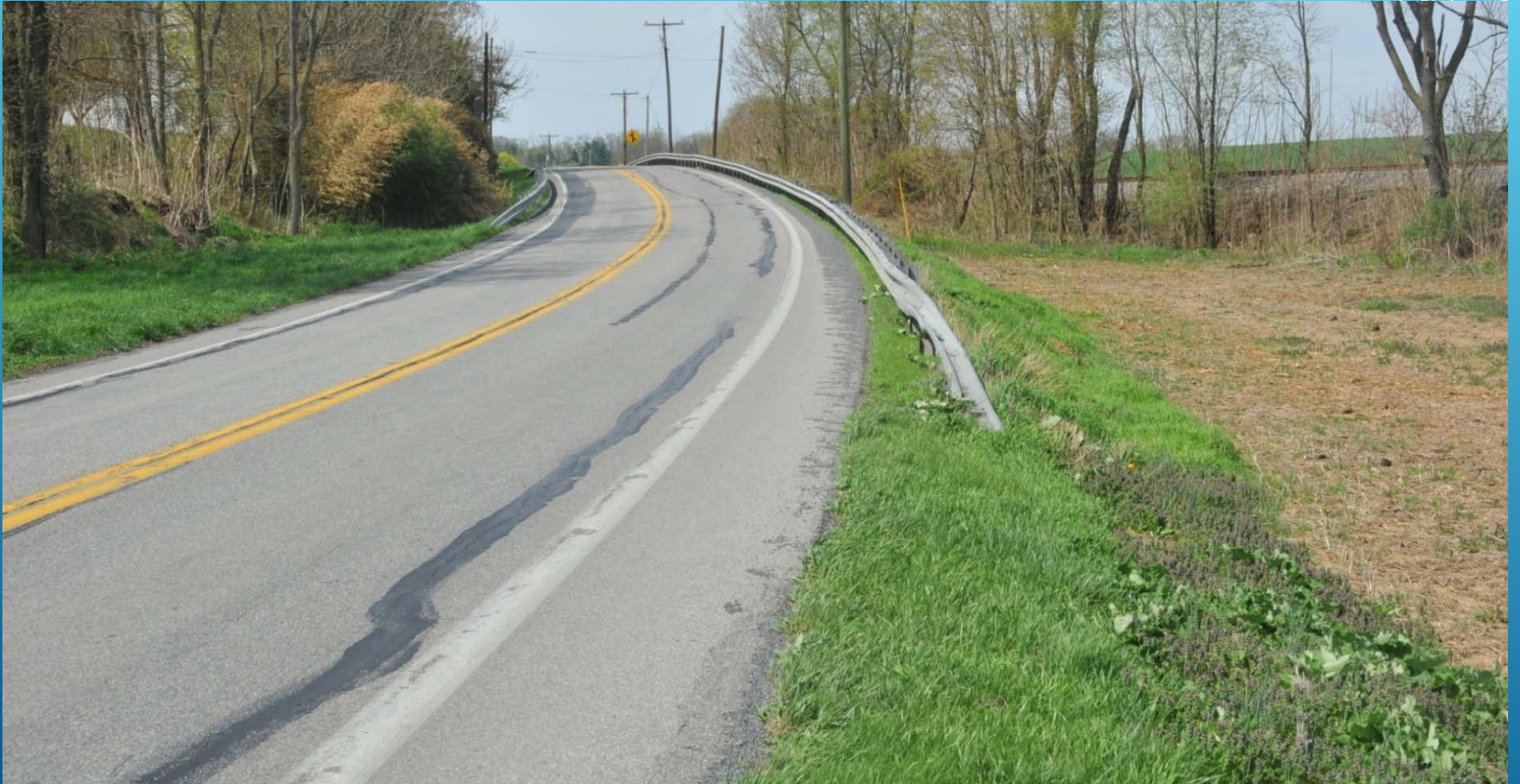


GUARDRAIL TERMINALS

The importance of this section is so you will be able to:

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

TURNED-DOWN TERMINAL



Continue to evolve...

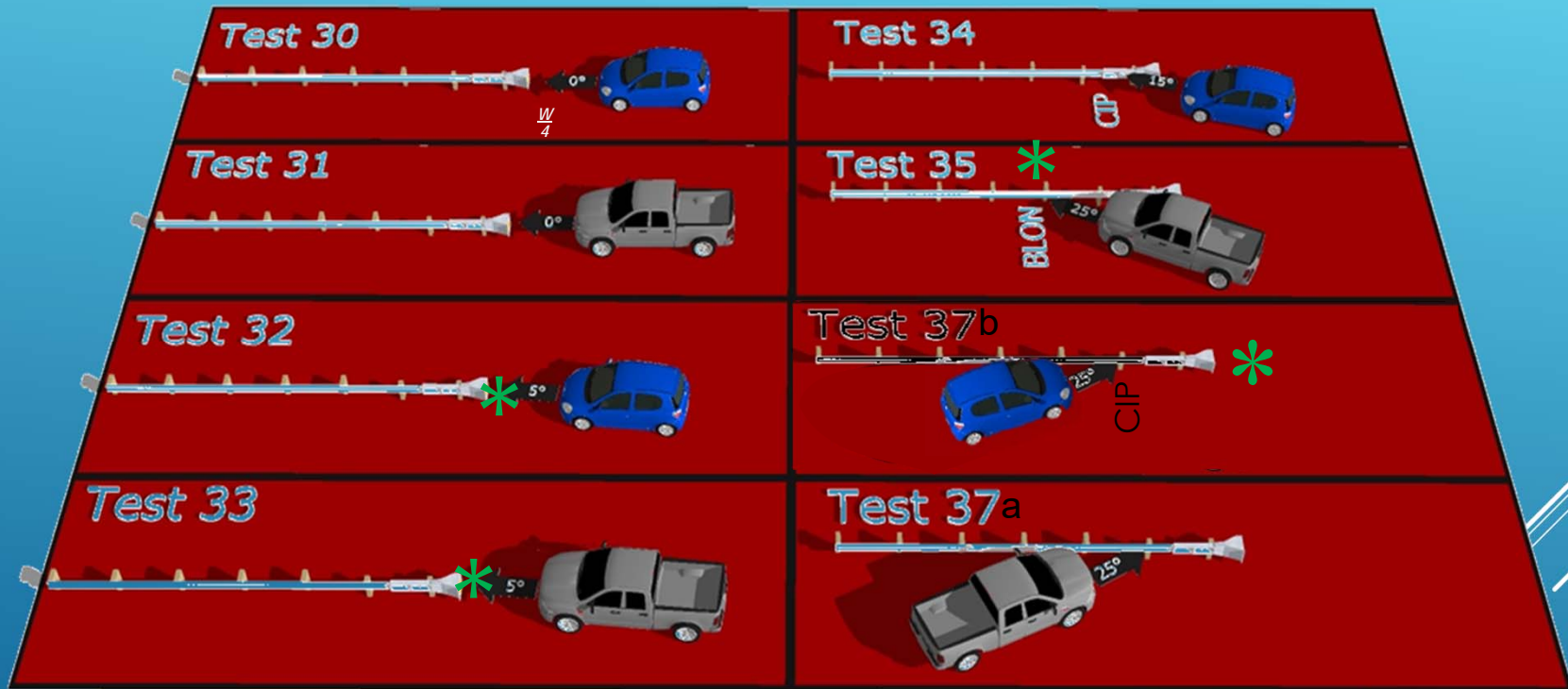


GUARDRAIL TERMINALS

A barrier terminal must serve two functions:

- Provide the necessary TENSION of the downstream guardrail system.
- Be crashworthy when impacted.

Guardrail Terminal MASH Test Matrix



* Significant Change

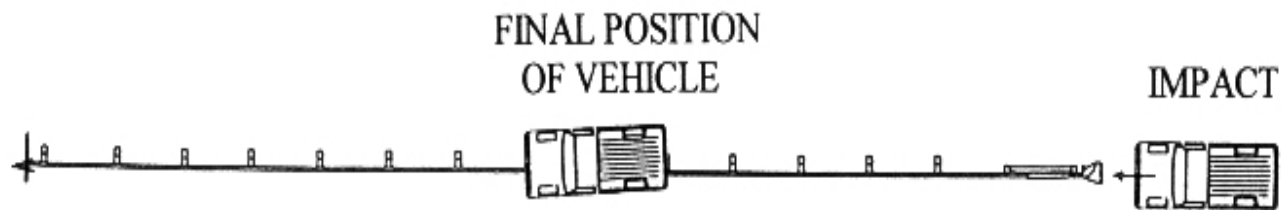
* Small Car 1100C (2420 #)

* Pickup Truck 2270P (5000 #)

GUARDRAIL TERMINALS

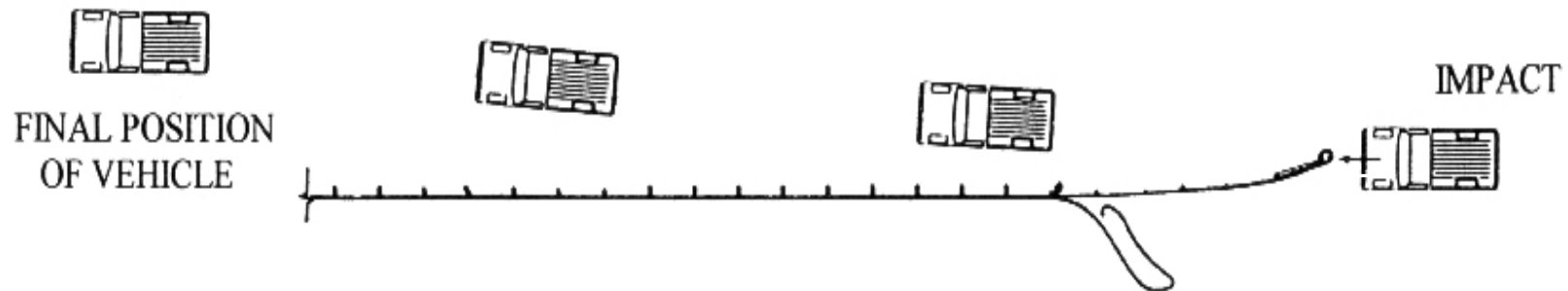
- Types of Terminals:
 - Buried End Section (Buried-in-Backslope {BIB})
 - W-beam tangent terminals (Type 1) – essentially parallel to the road (max 25:1 flare) – all are energy-absorbing
 - W-beam flared terminals (Type 2)– terminal is flared away from the road – both energy- and non-energy-absorbing
 - W-beam *median* terminals (Type 3 – Gating) – designed for ends of median barriers

Guardrail Terminals – Type 1 (Tangent) and 2 (Flared)



Energy Absorbing Terminal

(vehicle is brought to a controlled stop in a short distance)



Non-Energy Absorbing Terminal

Controlled Buckling Terminal

(vehicle may travel hundreds of feet before stopping)

DeIDOT Approved Product List for MASH 2016 Compliant Permanent Impact Attenuators

Delaware Department of Transportation Approved Products List (MASH 2016) Permanent Impact Attenuators

Standard Item		Manufacturer	Product Name	MASH Test Level	FHWA Eligibility Letter
2001 Standard Specifications	2016 Standard Specifications				
720585	724002	EASI	3-Bay QuadGuard M10 (QG M10) Narrow	TL-2	CC-121, CC-112C
720585	724002	EASI	3-Bay QuadGuard M10 (QG M10) Wide	TL-2	CC-121, CC-112C
720585	724002	EASI	QuadGuard Elite M10; 4-Bay Standard Width	TL-2	CC-112A, CC-112C
720585	724002	EASI	QuadGuard Elite M10; 4-Bay Wide Backup Width	TL-2	CC-112A, CC-112C
720585	724005	EASI	QuadGuard Elite M10; 8-Bay Standard Width	TL-3	CC-112A, CC-112C
720585	724005	EASI	QuadGuard Elite M10; 8-Bay Wide Backup Width	TL-3	CC-112A, CC-112C
720585	724005	EASI	2-Bay to 6-Bay QuadGuard M10 CZ (24", 30" and 36")	TL-3	CC-112B, CC-112C
720585	724005	Energy Absorption Systems, Inc.	6-Bay QuadGuard M10	TL-3	CC-112, CC-112C
720585	724005	Energy Absorption Systems, Inc.	6-Bay QuadGuard M10 Wide	TL-3	CC-112, CC-112C
720517	724006	Work Area Protection	SCI SmartCushion® TL-3 SCI100GM Impact Attenuator	TL-3	CC-128
720585	724002	Lindsay Transportation Solutions, Inc.	Universal TAU-M MASH Crash Cushion	TL-2	CC-146
720585	724005	Lindsay Transportation Solutions, Inc.	Universal TAU-M MASH Crash Cushion	TL-3	CC-147

DeIDOT Approved Product List

- It is the contractor's option as to which manufacturer's system they wish to provide. All are energy-absorbing. Some systems may have different configurations, such as post type.
- Developed for Delaware Specific Use with Maintenance Input.
- There is a list for Temporary Impact Attenuators as well.

Guardrail Terminals – Type 1 Tangent (Energy-absorbing)

- **MSKT** (this is a *MASH Version of SKT*)
 - Kinks guardrail when hit head-on or at a shallow angle
 - Steel (or wood) post system
 - System is 50' long; BLON at 3rd Post
 - Cable-anchored, compression system



MASH TL-3:
MSKT (Sequential Kinking Terminal)



Guardrail Terminals – Type 1 Tangent (Energy-absorbing)

- Soft Stop
 - Impact head slides along rails, vertically crushing them, absorbing the energy of the vehicle in shallow angle impacts – **works in tension**
 - System is 50'-9½" long; BLON at 16'-6"



MASH TL-3: Soft Stop Terminal



Guardrail Terminals – Type 1 Tangent (Energy-absorbing)

- MAX-Tension (MASH version of X-Tension)
 - The MAX system utilizes tensioned cables, telescoping panels, and a cutting tooth to absorb the kinetic energy and safely contain or redirect impacting vehicle – **works in tension and compression**
 - TL-3 at 50' long; BLON at 9'-4 ½"; 31" only

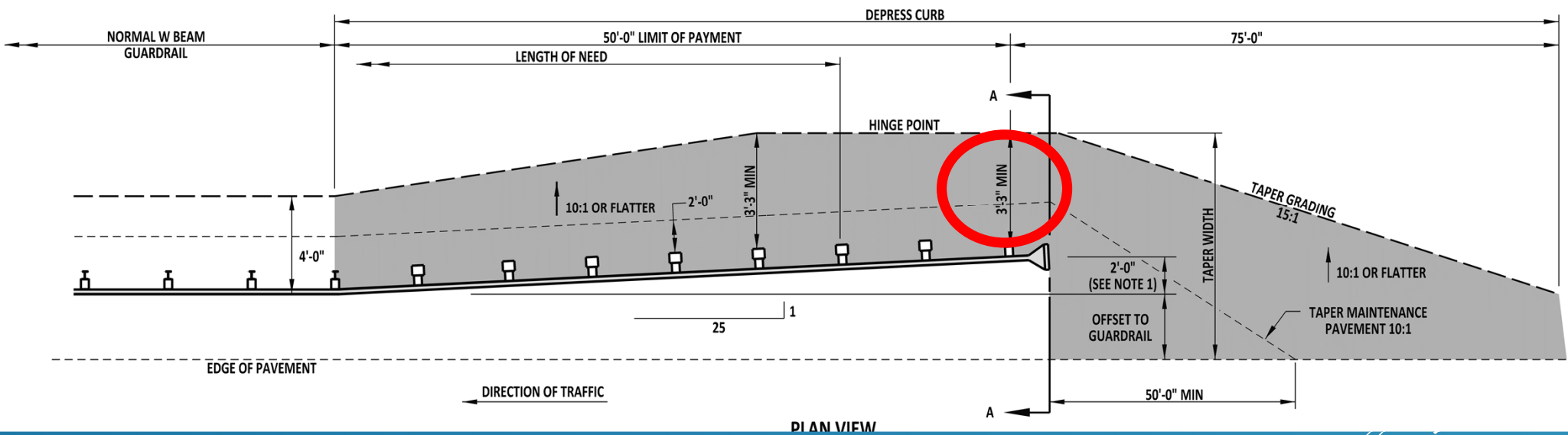


MASH TL-3: MAX-Tension

MASH Test 3-30



Type 1 Terminal Offset Tangent (Energy-absorbing)



NOTES:

- 1). FLARE THE END TREATMENT AT 25:1 BEGINNING 50'-0" FROM THE END OF THE IMPACT HEAD, UNLESS THE CONSTRUCTION PLANS OR SPECIFICATIONS SPECIFY A SMALLER FLARE.

GRADING FOR GUARDRAIL END TREATMENT ATTENUATOR, TYPE 1				
STANDARD NO.	B-2 (2013)	SHT.	1	OF 3

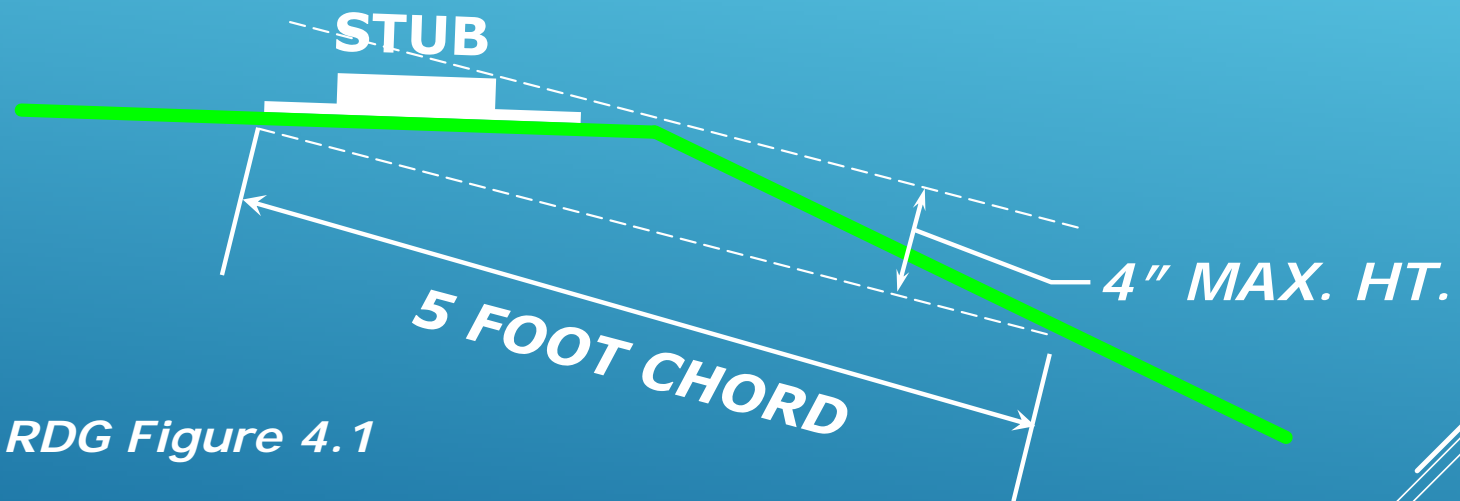
TERMINAL GRADING

Special grading requirements for guardrail terminals:

- Flat terrain (10:1 or flatter) is required *in ADVANCE of all terminals* so that vehicles are relatively stable on approach
- Flat grading must extend *behind* post 1 (or anchor) (**ADJACENT**) so vehicle is stable at impact **and** no stub height criteria is violated.

Ref: FHWA Memorandum, Roadside Safety Hardware, May 26, 2015 with attachment and
Ref: AASHTO Roadside Design Guide, 4th Edition, Section 8.3.3.

STUB HEIGHT CRITERIA



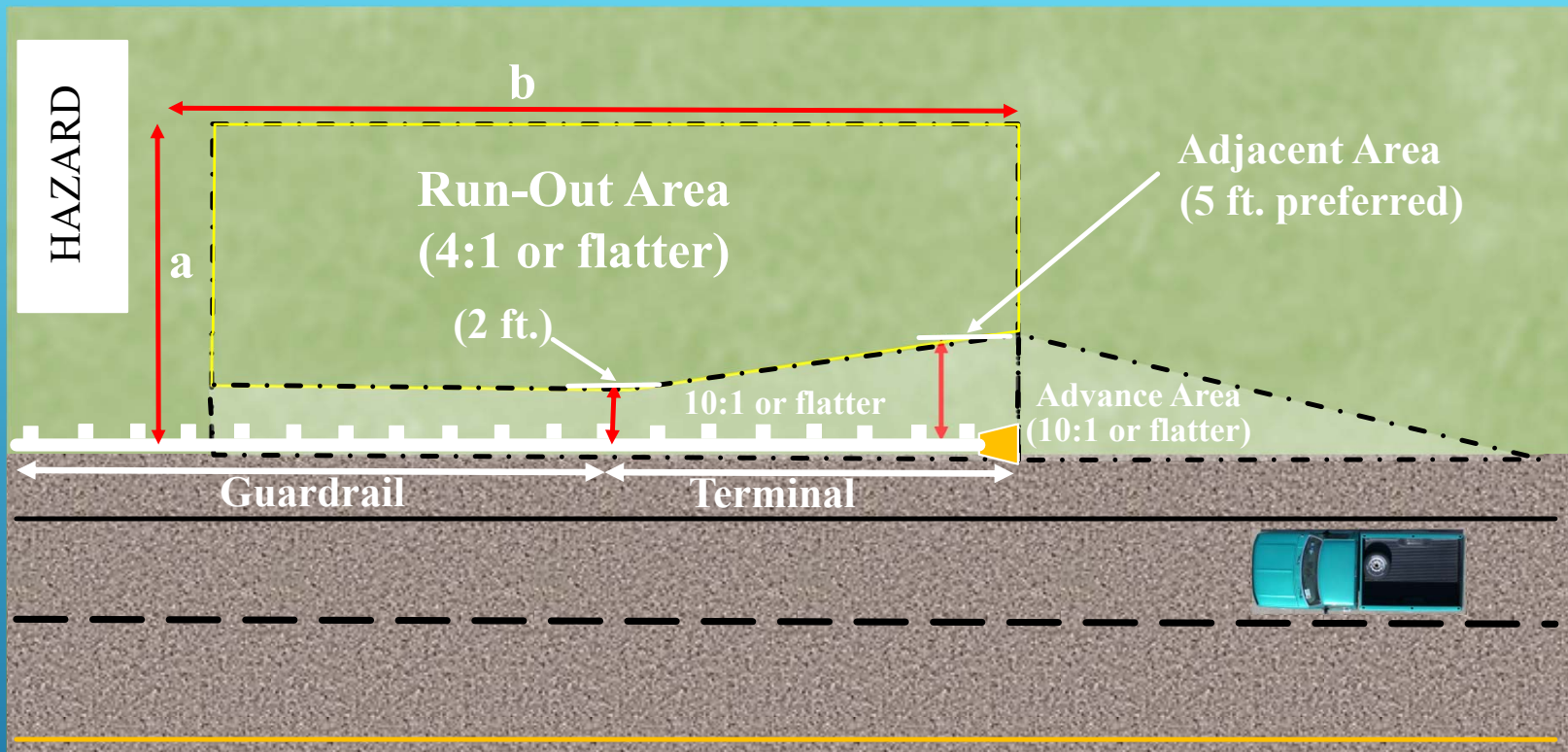
RDG Figure 4.1

Ref: AASHTO Roadside Design Guide, 4th Edition – Figure 4.1

TERMINAL GRADING REQUIREMENTS

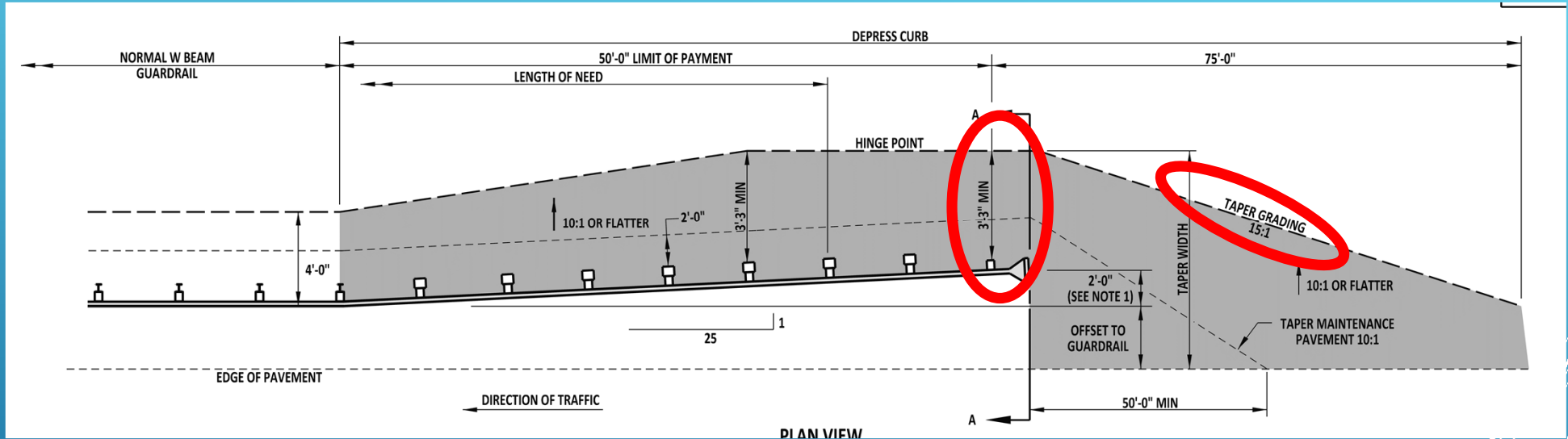
- ▶ **Runout Distance** - grading refers to the area into which a vehicle may travel after impacting a terminal ahead of its length-of-need point. The lateral runout distance directly behind a terminal ideally should be at least as wide as the roadside clear distance immediately upstream of terminal. The recovery obstacle-free area behind and beyond a terminal should be determined by the LON calculation; however it should be a minimum of 75 ft.

Ref: AASHTO Roadside Design Guide, 4th Edition, Section 8.3.3.

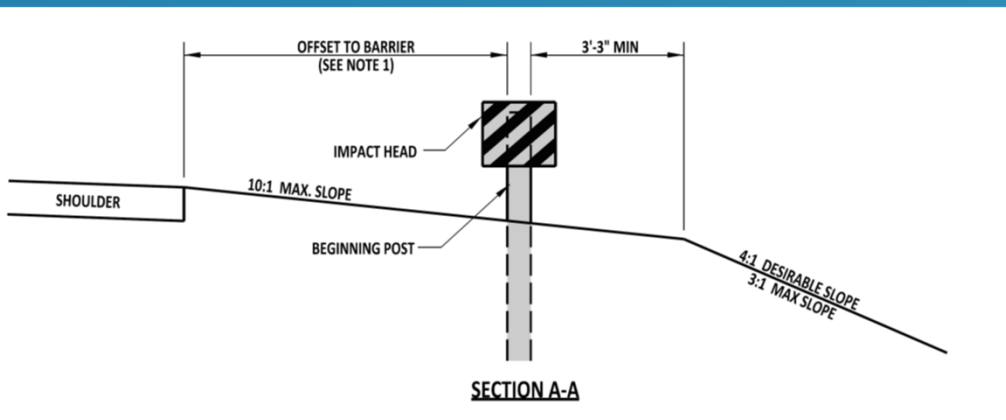


- a – Extend out to clear zone when practical; if not, it should be at least as wide as area upstream of the terminal.
- b – LON Required; when LON cannot be provided due to site conditions, a minimum of 75' from post 1 may be acceptable

Type 1 Terminal Grading Tangent (Energy-absorbing)



PLAN VIEW



SECTION A-A

GRADING FOR GUARDRAIL END TREATMENT ATTENUATOR, TYPE 1

STANDARD NO.

B-2 (2013)

SHT.

1

OF

3

Crash Cushions – Sand Barrels Non-Redirective

➤ Sand Barrels

- Three types of sand barrels:

CrashGuard / Energite / Traffix Devices.

- Individual barrel designs vary in shape by manufacturer, but they all function the same.
- Arrays of sand barrels may be designed to shield any shape hazard and for any speed – orient for expected impact angle
- Susceptible to damage from nuisance hits; best used in areas where nuisance 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”.

Guardrail Terminals – Type VI Gating Non-Redirective

➤ Sand Barrels:



Energite



TrafFix Big Sandy



CrashGard

Guardrail Terminals – Type VI Gating Non-Redirective



Crash Cushions Gating Non-Redirective

➤ Water Filled Crash Cushions:



Absorb 350 (TL-3)

Not on DELDOT APL



Sled (MASH)



ACZ-350

Water
Filled



Crash Cushions (Impact Attenuator Type 5)

➤ QuadGuard (NCHRP 350/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; damaged cartridges need to be replaced after a crash.
- MASH available only in 24" width; wider hazards will require flaring the barrier beyond the crash cushion



Crash Cushions (Impact Attenuator Type 5 & 6)

- SCI Smart Cushion (NCHRP 350/MASH)
 - Variable Reaction Force
 - Re-usable with minimal component replacement
 - Needs repair before next hit



Example Guardrail Terminal – Type 5 & 6



Example Impact Attenuator - Self Restoring Crash Cushion



Crash Cushions (Impact Attenuator Type 5 & 6)

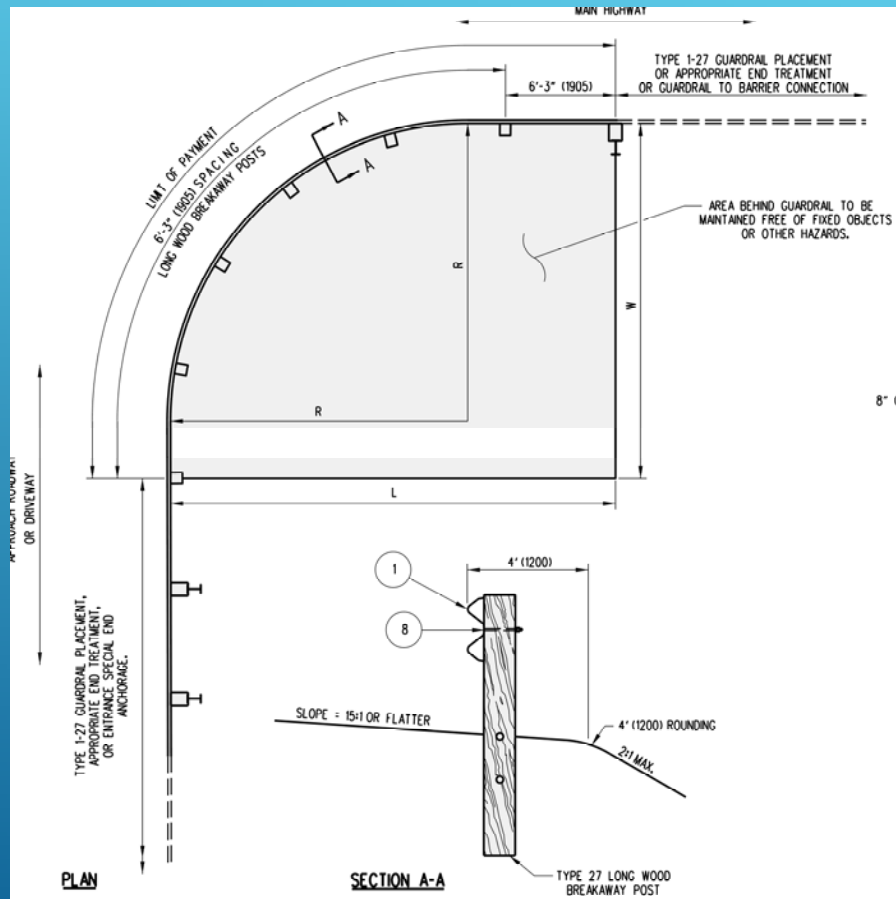
- TAU II and TAU IIR Systems (NCHRP 350)
 - Can be attached directly to a W-beam or Thrie-beam median barrier as well as to a concrete safety shape.
 - Designed to attach to a median barrier.
 - Common set of parts for 36" to 102" widths in 6" increments.
 - Consists of Thrie-beam panels, expendable or **self-restoring (R)** absorbing cartridges, steel diaphragms and two cables at the bottom to provide redirection.



Treatment at Intersections and Driveways

Special treatment is required where side entrances interrupt the installation of guardrail. Additional flares and end treatments may be required, or it may be more economical to eliminate the need for guardrail.

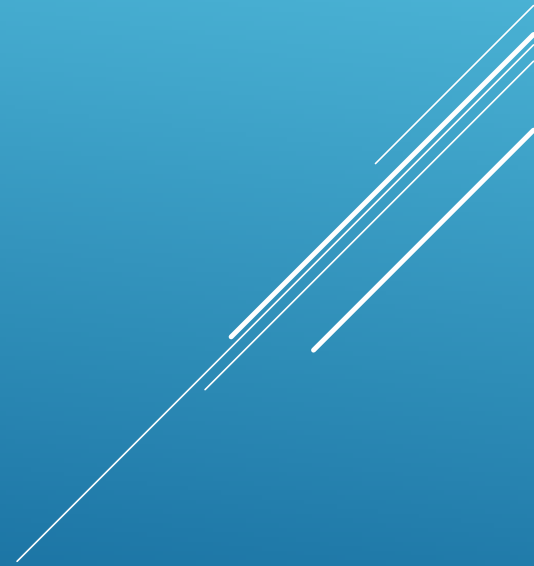
Treatment at Intersections and Driveways




RADIUS	MIN. REQUIRED AREA FREE OF FIXED OBJECTS
	L x W
8'-6" (2600)	25' x 15' (7600 x 4500)
17'-0" (5200)	30' x 15' (9144 x 4500)
25'-6" (7800)	40' x 20' (1200 x 6000)
35'-0" (10700)	50' x 20' (15200 x 6000)

CURVED GUARDRAIL SECTION			
STANDARD NO.	B-18 (2010)	SHT.	1 OF 1

Guardrail Design and Site-specific Installation Considerations



BARRIER DESIGN PRINCIPLES

1. Deflection Distance
 2. Slope in Front of Barrier
 3. Guardrail and Curb
 4. Soil Backing for Fill Locations
 5. Flare Rate
- 
- A decorative graphic consisting of several parallel white lines of varying lengths, slanted diagonally from the bottom right towards the top right, located in the lower right quadrant of the slide.

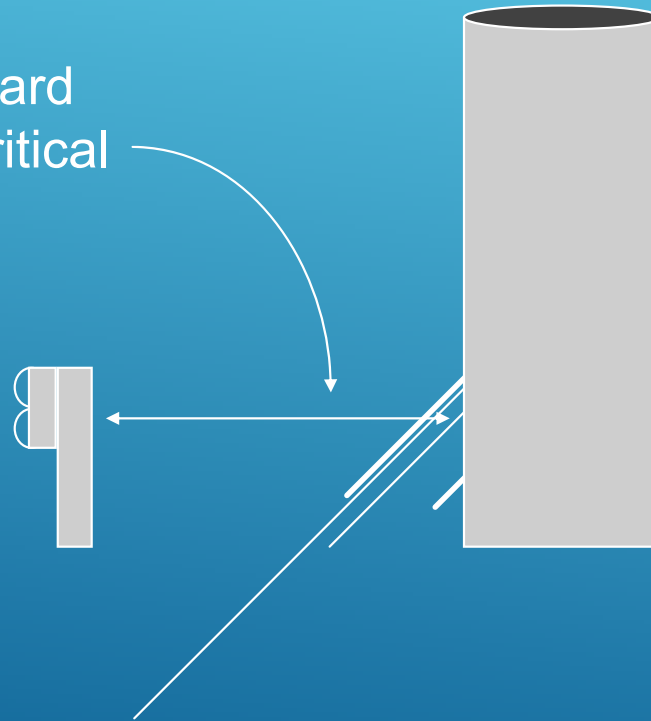
PRINCIPLE 1: DEFLECTION

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

- If the barrier is shielding a vertical rigid object, the distance between the barrier and the object should be sufficient to avoid the vehicle impacting or snagging on the object.
- Note that, even for rigid barriers, large vehicles may roll behind the top of the barrier even if the barrier itself does not deflect.

PRINCIPLE 1: DEFLECTION DISTANCE

Barrier to Hazard
Distance Is Critical
Element



TYPE 1-31 GUARDRAIL PLACEMENT
POST SPACING 6'-3"



REQUIRED CLEARANCE
3'-0" MIN FROM BACK OF POST

SEE NOTE #1 & 2

EDGE OF SHOULDER

EDGE OF TRAVEL LANE

TYPE 1-31 GUARDRAIL

TYPICAL GUARDRAIL TREATMENT WHEN THE REQUIRED
3'-0" CLEARANCE TO THE OBSTRUCTION IS AVAILABLE

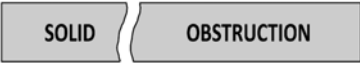
TYPE 1-31 GUARDRAIL PLACEMENT
OR APPROPRIATE END TREATMENT

TYPE 2-31 GUARDRAIL PLACEMENT
POST SPACING 3'-1 1/2"

TYPE 1-31 GUARDRAIL
OR APPROPRIATE

25'-0" MIN

25'-0" MIN



REQUIRED CLEARANCE
2'-0" MIN FROM BACK OF POST

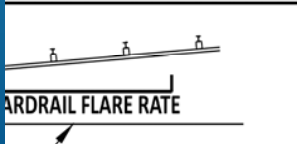
SEE NOTES 1 & 2

EDGE OF SHOULDER

EDGE OF TRAVEL LANE

TYPE 2-31 GUARDRAIL

TYPICAL GUARDRAIL TREATMENT WHEN 2'-0" TO 3'-0"
OF CLEARANCE TO OBSTRUCTION IS AVAILABLE



TYPES 1-31, 2-31, AND 3-31 GUARDRAIL APPLICATIONS			
STANDARD NO.	B-1 (2017)	SHT.	1 OF 3

Deflection Distance



Results of Inadequate Deflection Distance



Deflection – Zone of Intrusion



Guardrail on Slopes

- Any barrier may be placed anywhere on a 10H:1V or flatter slope.
- No barrier should be placed on a slope steeper than 6H:1V (exception: some high tension cable designs).
- Cable Guardrail may be placed on slopes of 6H:1V or flatter, but restriction apply when placed in a swale.
- On slopes steeper than 10H:1V but no steeper than 6H:1V, metal beam guardrail may be placed in compliance with Figure 5-38 (AASHTO RDG).

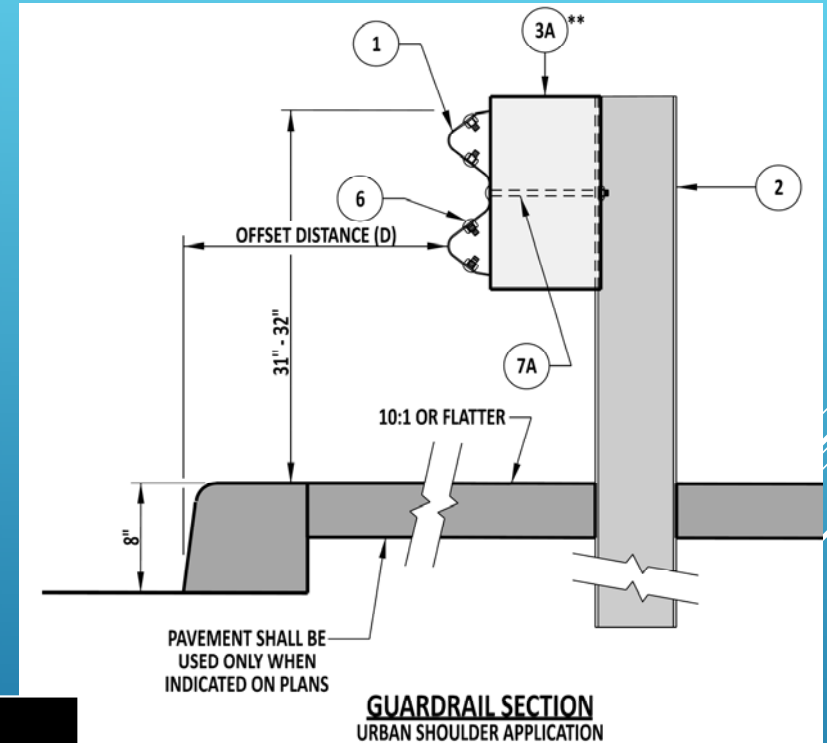
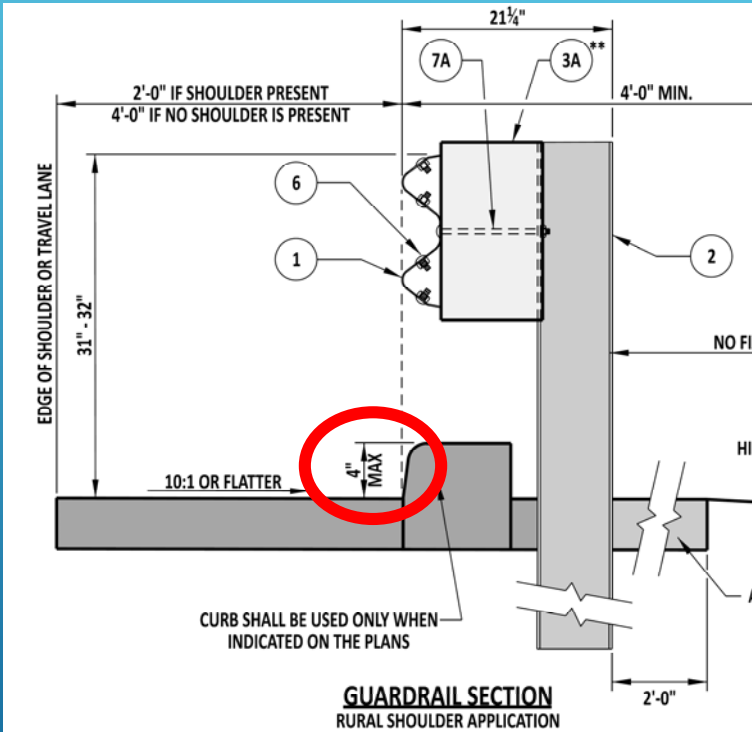
GUARDRAIL ON SLOPES



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.

Guidance – Guardrail with Curb



DESIGN SPEED	D
<50 MPH	8'-0"
≥ 50 MPH	13'-0"

TYPES 1-31, 2-31, AND 3-31 GUARDRAIL APPLICATIONS			
STANDARD NO.	B-1 (2017)	SHT.	3 OF 3

Guardrail and Curbs

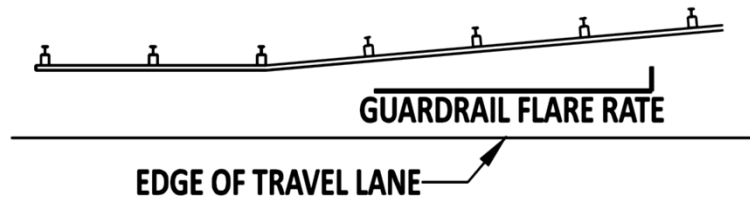


Flare Rate

Flared barriers are those that are not parallel to the edge of the traveled way. They are used to:

- Locate barrier, and terminals, farther from the roadway.
- Lessen driver reaction to a roadside obstacle.
- Reduce total length of rail needed.
- Reduce nuisance hits.

DELDOT Flare Rate Table



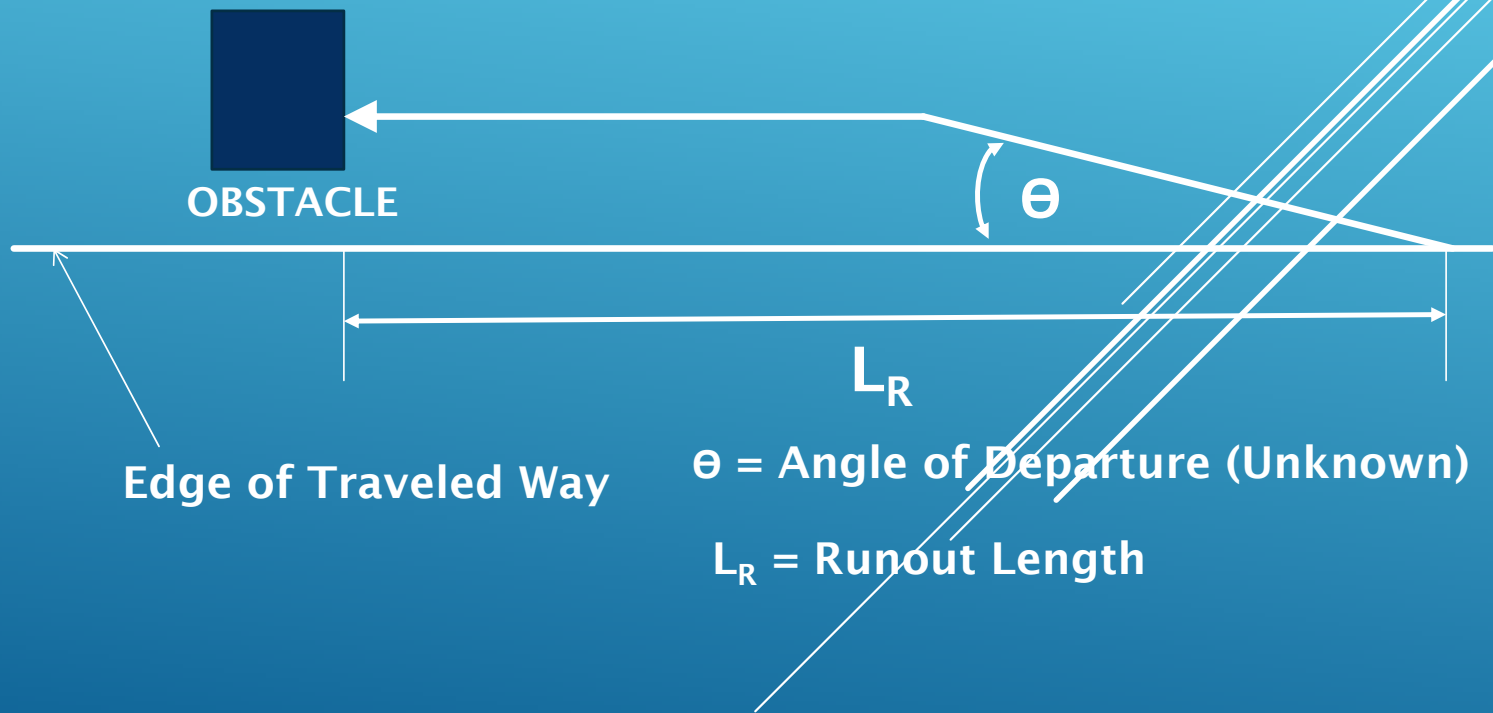
FLARE RATES	
DESIGN SPEED	FLARE RATE
70 MPH	15:1
60 MPH	14:1
55 MPH	12:1
50 MPH	11:1
45 MPH	10:1
40 MPH	9:1
30 MPH	7:1

TYPES 1-31, 2-31, AND 3-31 GUARDRAIL APPLICATIONS			
STANDARD NO.	B-1 (2017)	SHT. 1	OF 3

LENGTH OF NEED (LON) DEFINITION

- The length of effective barrier needed IN ADVANCE OF a hazard to intercept and redirect 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



Beginning of BIG hole

POOR LON

6 2:11 PM



No consideration of
secondary hazard



No consideration of all warranting hazards



Installation/Common Errors of Systems



Barrier Components

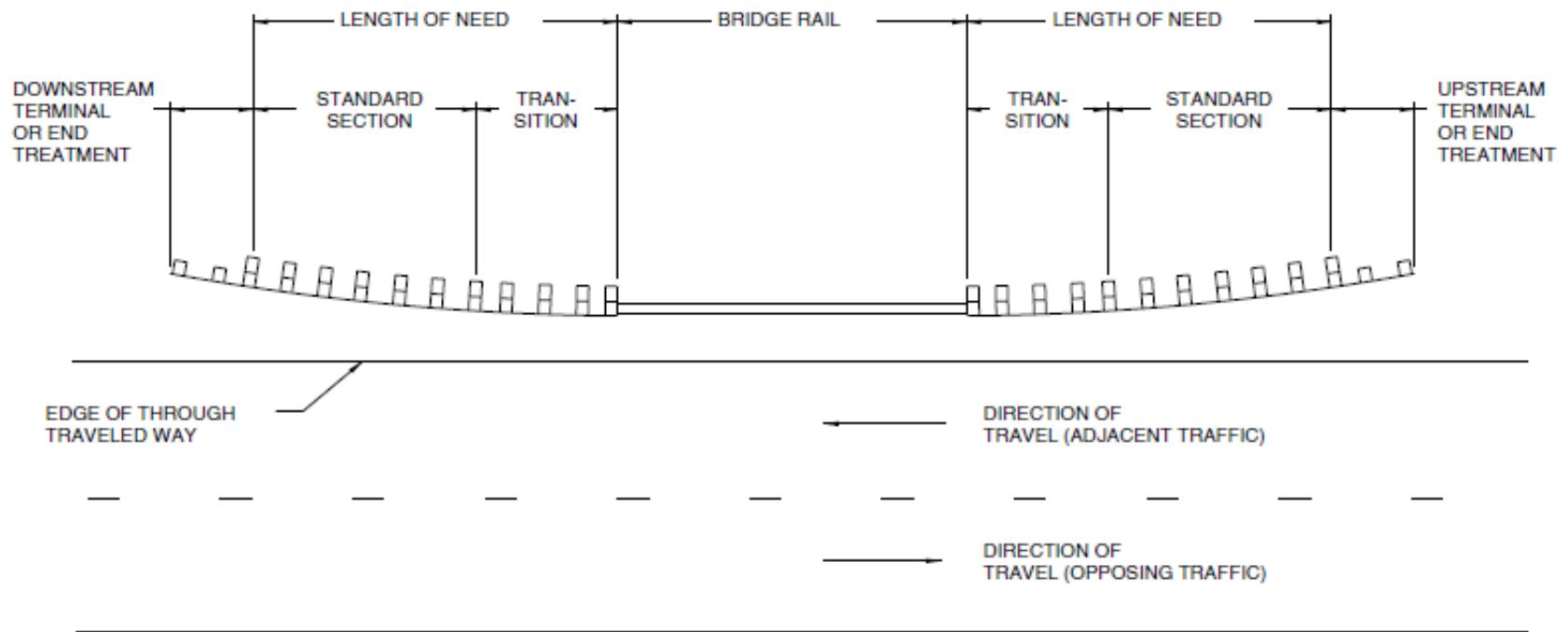




Figure 5-4. Definition of Roadside Barriers

REF: AASHTO Roadside Design Guide, 4th Edition, Figure 5-4

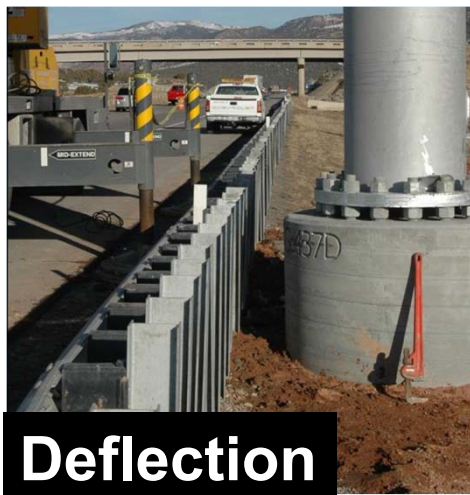
Key Components of Barrier Systems

1. Standard Run of Barrier
 2. Transition to a Stiffer System
 3. Terminal
 4. Crash Cushion
- 
- A decorative graphic consisting of several parallel white lines of varying lengths, slanted diagonally from the bottom right towards the top right, set against the blue background.

1. Standard Run of Barrier

- a. Barrier Design Principles
 - b. Height Measurement
 - c. Tension Continuity
 - d. Additional Notes
 - e. Work Zone Barriers
- 
- A decorative graphic consisting of several parallel white lines of varying lengths, slanted diagonally from the bottom right towards the top right, set against the blue background.

A. Barrier Design Principles



Deflection



Soil Backing



Slope in Front of Barrier



Barriers and Curbs



Flare Rate

B. HEIGHT MEASUREMENT

➤ Concrete Barrier

Single Face or Median Barrier - typically 32"



B. Height Measurement



Rail too high



Rail too low

C. Tension Continuity

- Concrete Barrier
 - Continuous reinforcement and/or anchored to/in the pavement
- W-Beam
 - Splices with 8 bolts tying panels together, and some type of end anchor or structural tie to a rigid object/bridge rail (transition)

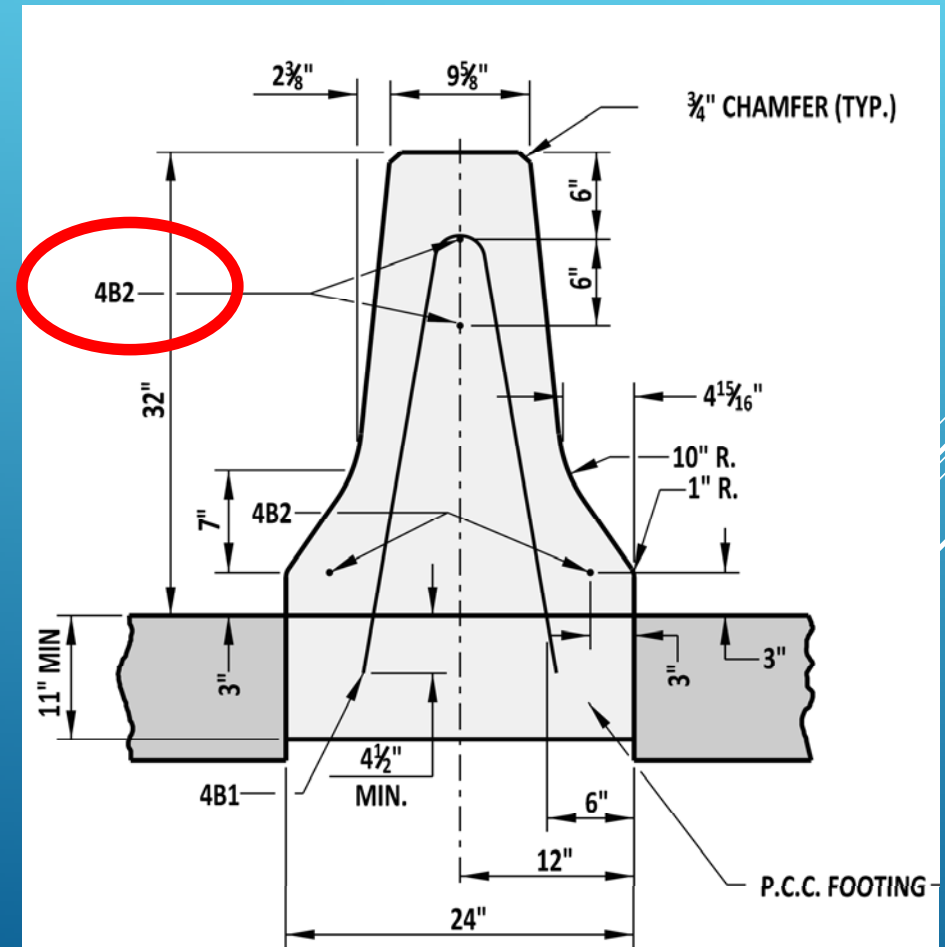
B. Tension Continuity

➤ Concrete Barrier

BAR LIST							
MARK	SIZE	NUMBER IN EACH SECTION	LENGTH	TYPE	A	B	C
4B1	4	**	5'-4"	1	7"	30½"	2"
4B2	4	4	*	STR.	N/A	N/A	N/A

* THE LENGTH OF BAR 4B2 SHALL BE 6" SHORTER IN LENGTH THAN THE NOMINAL SIZE OF THE BARRIER IN WHICH IT IS USED.
 ** SEE "BAR OFFSETS" CHART ON THIS SHEET FOR MORE INFORMATION.

32" CONCRETE SAFETY BARRIER (F SHAPE)			
STANDARD NO.	B-14 (2012)	SHT.	1 OF 4



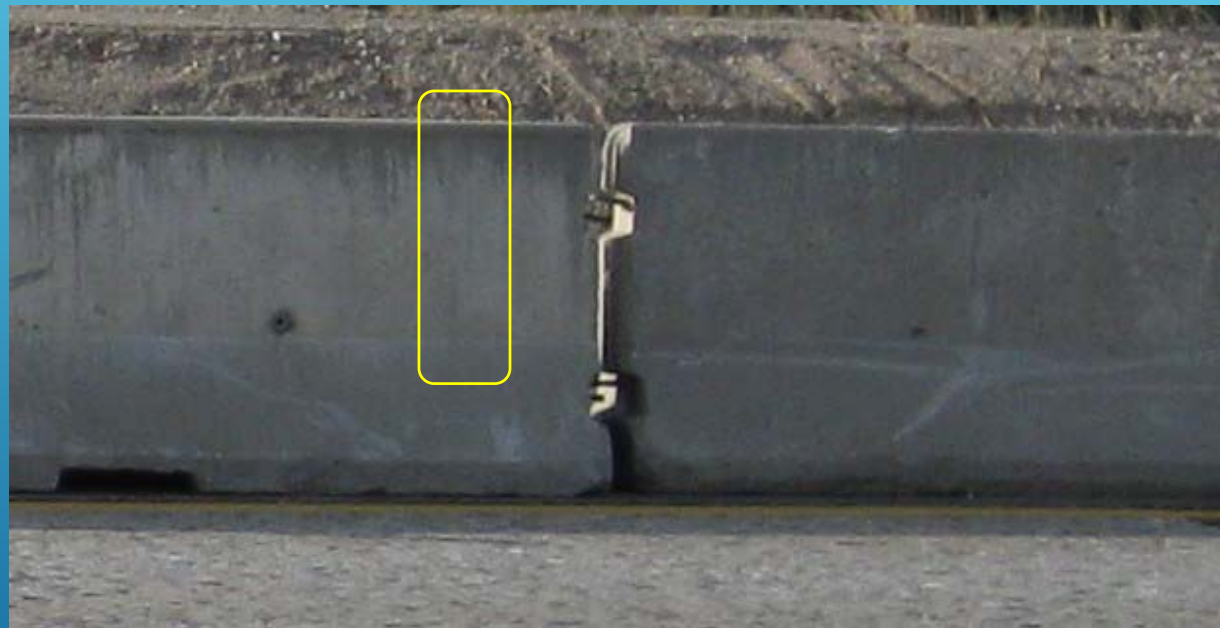
C. Tension Continuity

Cast In Place Concrete Barrier



Horizontal bars maintain continuity for cast in place barrier

Precast Concrete Barrier



Missing connection pin
NO TENSION

C. Tension Continuity

➤ W-Beam

- Left: 8 bolts tying panels together
- Right: structural connection to a rigid barrier



C. Tension Continuity



Missing bolts



No Structural connection



Additional Notes

➤ 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 adjacent traffic, meaning rail laps will be opposite on each side of the road.



Additional Notes

Drilling of holes into the rail is NOT generally recommended

**OPTION – Bolt only block to post, NOT through rail.
Probably OK for two posts, maybe even three.**



Additional Notes



Reflectors should be placed at the splice locations not the post.



Manufacturers of working head terminals generally prohibit delineators within their systems

E. Barriers in Work Zones

Barrier should be in GOOD condition



E. Barriers in Work Zones

Flare rate is too excessive here




2. Transition to a Stiffer System

- When a softer (more flexible) barrier precedes a stiffer barrier, a gradual stiffening must occur between the two systems to prevent pocketing.
- An effective transition must provide the following:
 - Adequate connection (TENSION continuity)
 - Adequate length to gradually increase stiffness.



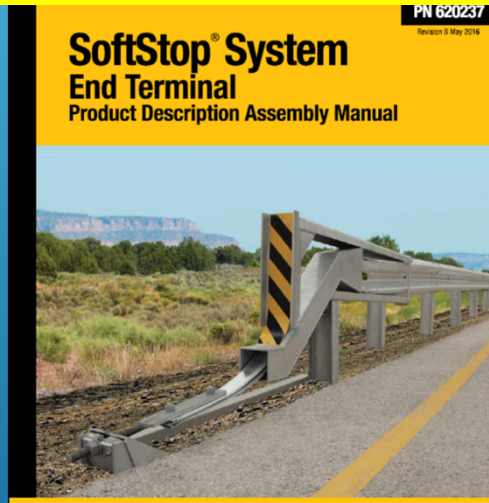
3. Terminals

- a. Manufacturers Manuals
 - b. Post types
 - c. Panel requirements
 - d. Breakaway Cable **Anchorage**
 - e. Grading
 - f. Other Considerations
 - g. Delineation
- 
- A decorative graphic consisting of several parallel white lines of varying lengths, slanted diagonally from the bottom right towards the top right, located in the lower right quadrant of the slide.

3. Terminal - Proprietary

a. Manufacturers Manuals

Must follow manufacturer's installation instructions and State standards.



These are all readily available online

Example of installation manuals

3. Terminal - Grading

Check grading compliance with Standard Drawing (or plan details). Manufacturers generally do not specify grading requirements.

Check grading material for proper density. (Material must be compacted so it won't erode.)



3. Terminal - Grading

*Improper
Grading*



A common error with all terminal types.

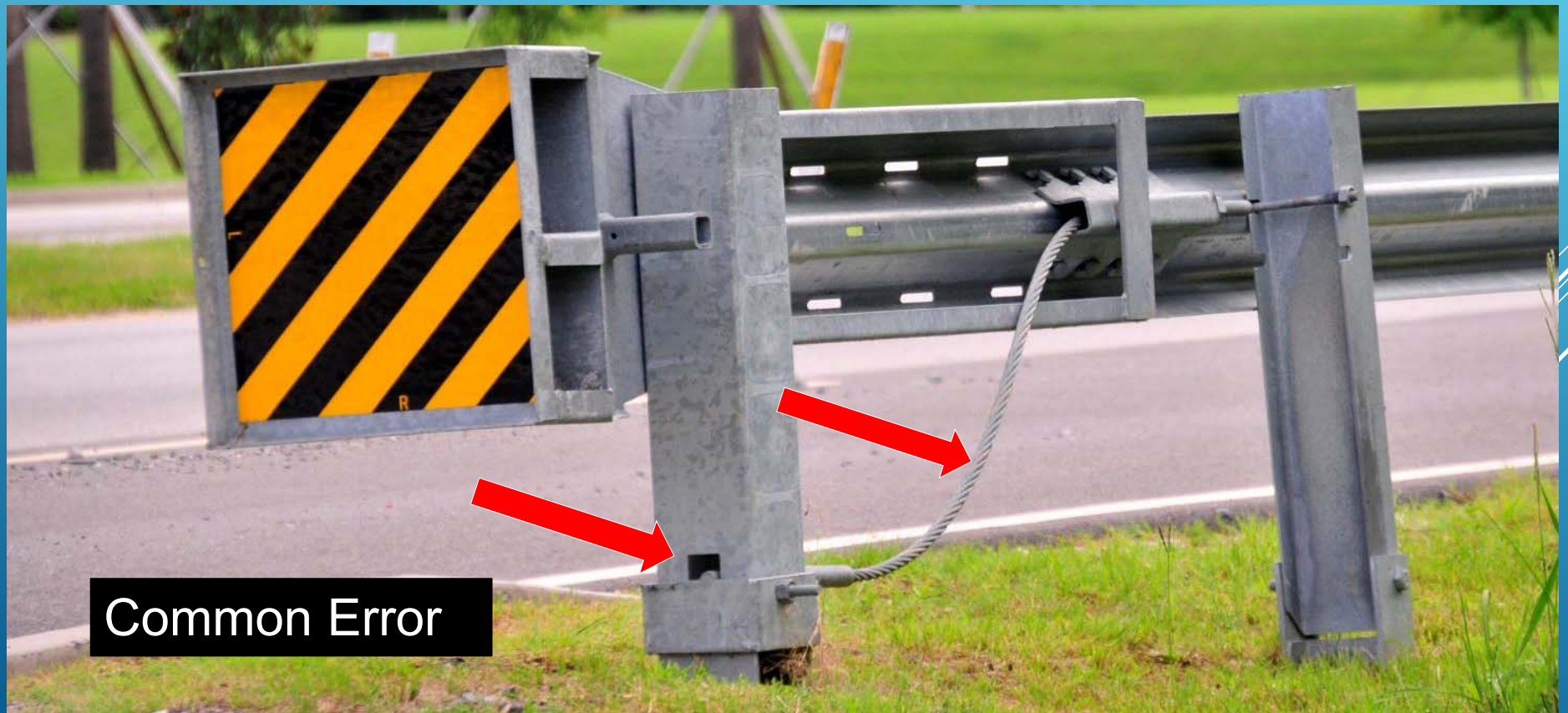
3. Terminal

e. Breakaway Cable Anchorage Assembly



3. Terminal

f. Breakaway Cable Anchorage Assembly



Common Error

3. Terminal

f. Other Common Errors



IMPROPER APPLICATION – TERMINALS SHOULD HAVE 7' SEPARATION (AND THE SIGN SHOULD BE BEYOND THE TERMINAL SYSTEM)

4. Crash Cushions

- a. Manufacturers
- Manuals
- b. Grading



4. Crash Cushions

724.03 Construction. Install the impact attenuator using personnel certified by the manufacturer to install such impact attenuators. Submit copies of personnel certification to the Engineer for approval prior to beginning installation. Assemble and install the impact attenuator as specified by the manufacturer. Grade the area between the edge of pavement and the back of the impact attenuator in accordance with the manufacturer's requirements. Provide written certification to the Engineer that the impact attenuator has been properly installed.

Standard Specifications

for

Road and Bridge Construction

AUGUST 2016

4. Crash Cushions

a. Manufacturers Manuals

- Anchorage bolts are required to secure the system to concrete/hot mix pad. Number of bolts and length of bolts vary with systems.
- Bolts are typically required to be epoxied into concrete pad.
- Bolts may have a torque value.

Full bolt depth required



Cutting bolt prohibited



Must follow manufacturer's installation instructions.

Non-crashworthy End Terminal



Failed Test! Causes spearing

Closing/Questions?

The image features a solid blue background with a gradient from light blue at the top to a darker blue at the bottom. In the center, the text "Closing/Questions?" is written in a white, sans-serif font. In the bottom right corner, there are several thin, white, parallel lines that appear to be part of a decorative graphic element, possibly representing a stylized arrow or a set of lines.