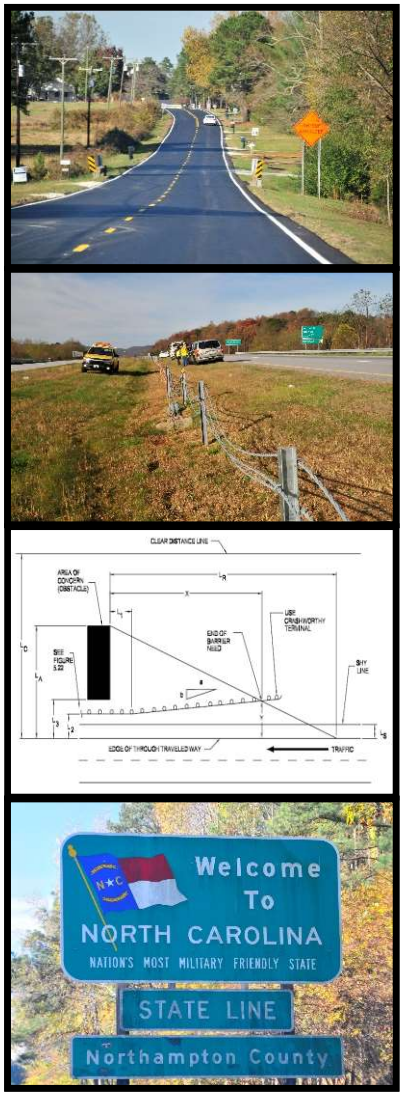


North Carolina Department of Transportation

Highway Safety Barrier Installation Training

Instructor: Bill Fitzgerald, PE
KLS Engineering, LLC
(703) 973 9109

Nov. 1st and 2nd , 2023

THE UNIVERSITY OF NORTH CAROLINA HIGHWAY SAFETY RESEARCH CENTER

KLS Engineering

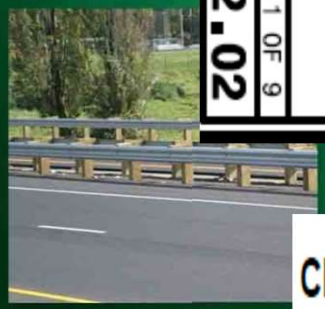
STATE OF NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

Guidance Presented

NCDOT STAND

ROADWAY STANDARD DRAW
GUARDRAIL PLACE
862.01 SHEET 1 OF 15

ROADWAY STANDARD DRAW
GUARDRAIL INSTAL
862.02 SHEET 1 OF 9



Chapter 6 Roadside Barriers

NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION
RALEIGH

STANDARD SPECIFICATIONS
FOR
ROADS AND STRUCTURES

JANUARY 2024

Roadway Design Manual

Ground Rules

- Be on time
- Participate
- Restrict sidebar conversations
- Turn off cellphones

Terminology: Page v

Three Essential Elements of Good Roadside Design

Engineering Judgment

Evaluate **Risk**

Document

Objectives of Course

At the end of this 1½ - day course you should be able to:

- Evaluate if a traffic barrier MAY be 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 significant hazards or secondary hazards.
- Recognize good installations and common errors for barriers and terminals and know how to avoid them.
- Understand when damaged barrier and/or terminal may no longer be functional.

Session 1:

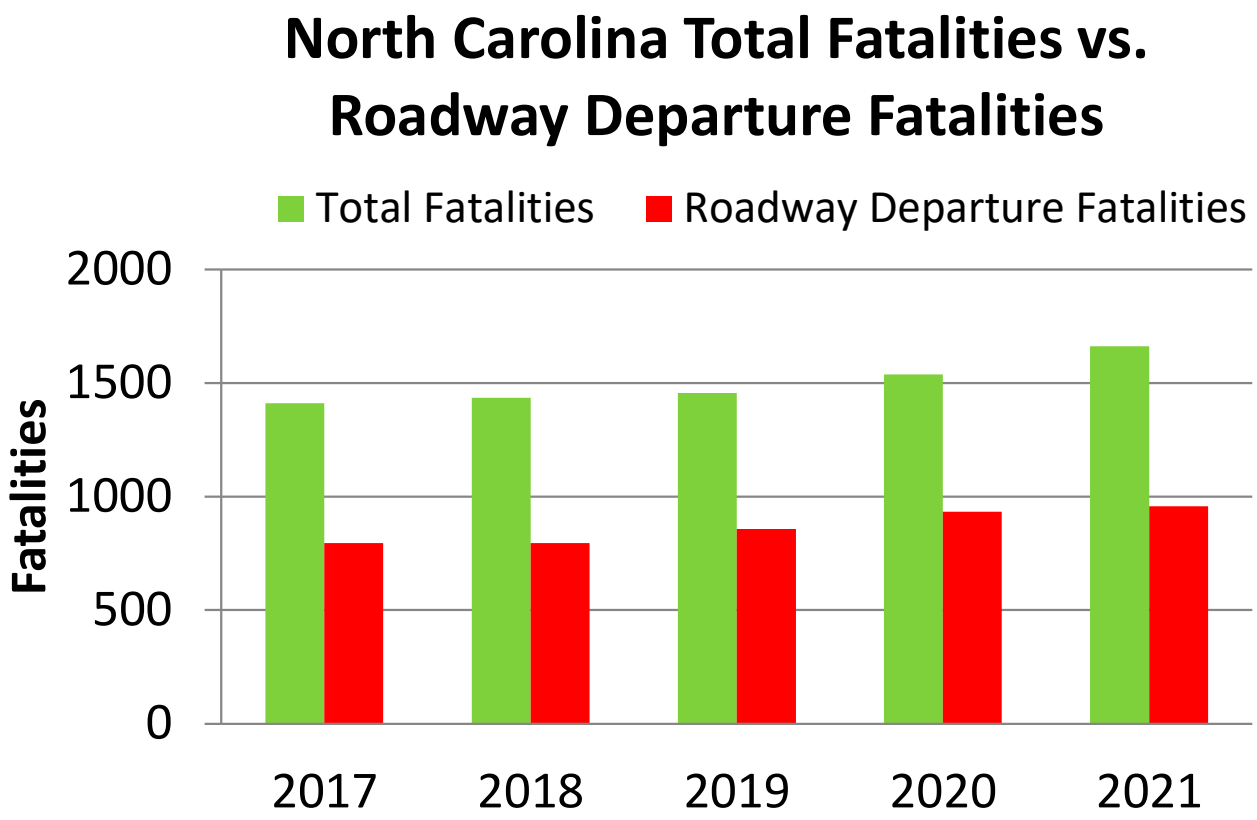
Roadside Safety Problem, Clear Zone and Warrants for Barrier

Session 1 Learning Outcomes

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

- Describe the primary Roadside Safety Concerns in North Carolina.
- Identify the need for training.
- Explain clear zone and when a barrier may be warranted.

North Carolina Crash Data Trend



Total US Highway Fatalities 2021 42,939

In 2021, 57.6 percent of all fatalities involved roadway departures

Ref: FARS Data – 2017 to 2021

North Carolina Crash Data - Fatalities

	5-Yr. Total
Culvert/Curb/Ditch	764
Trees	652
Rollover	298
Guardrail End/Face	165
Embankment	156
Utility Pole/Light Pole	125
Concrete Barrier	23
Cable Barrier	21

Ref: FARS Data – 2017 to 2021

Real World Crashes

Real World Crashes


Driving Off Roads
Prohibited

Need for Training

Potential consequences of poorly Designed/Installed barrier systems include:

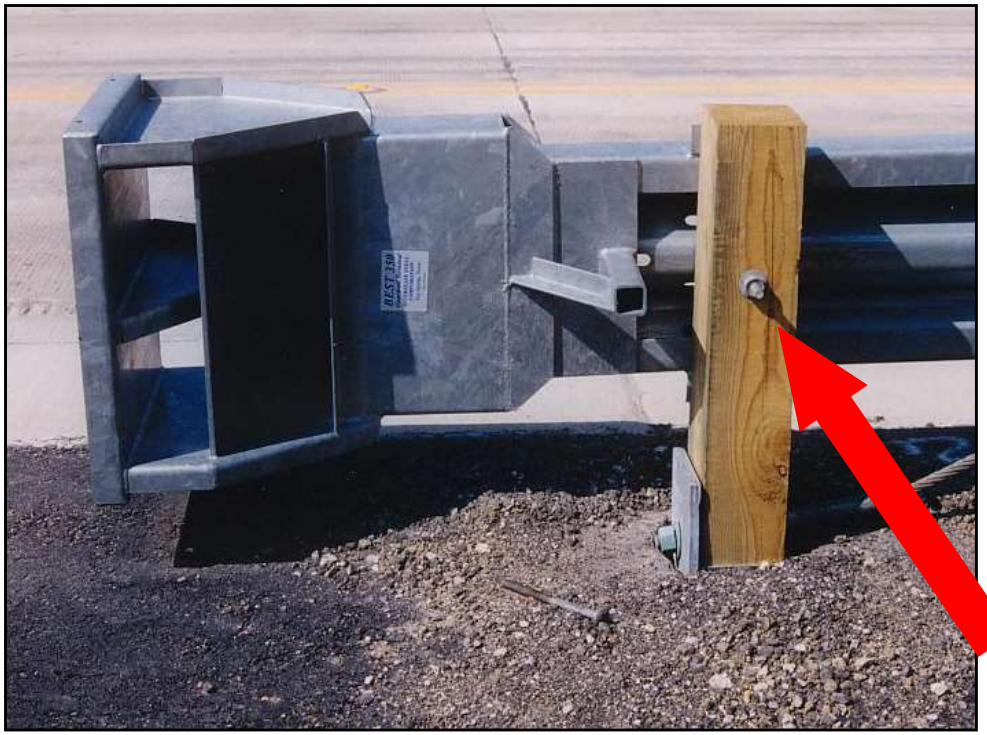
- Systems may not function as designed.
- Crash severities may be increased.

Need for Training

Must have a strong connection between systems

Need for Training

Examples of improper installation of systems:

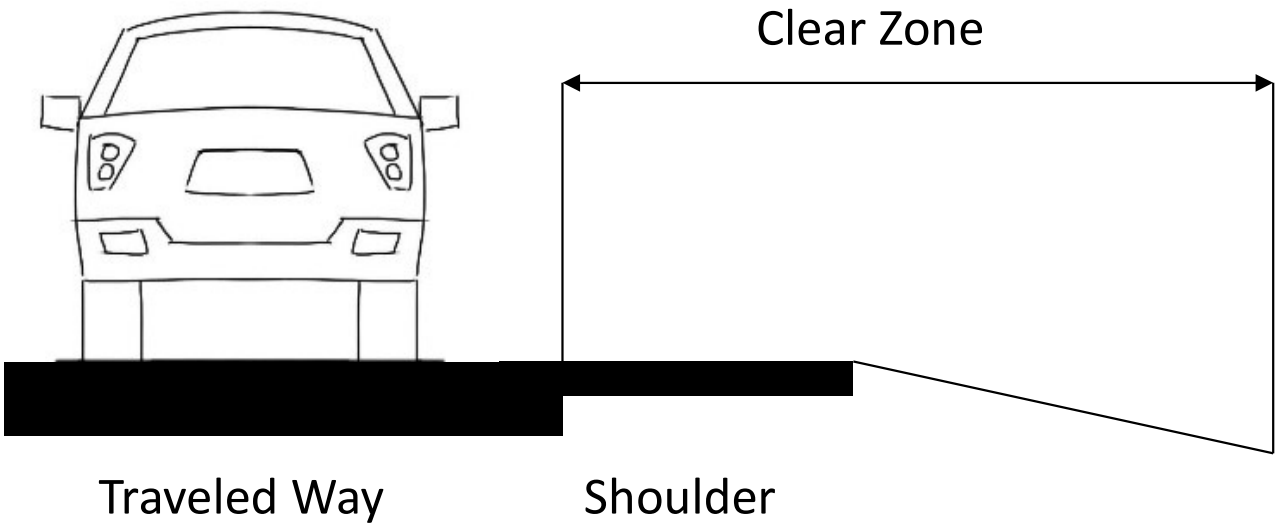


Fatal Flaw

Need for Training

Examples of improper installation of systems:

Clear Zone: Definition



4.6.1 Clear Zones

The unobstructed traversable area provided beyond the edge of the traveled way is termed the clear zone. This area is used for the recovery of errant vehicles and includes shoulders, bike lanes, and auxiliary lanes.

Clear Zone Principle

Get

MAXIMUM,

COST-EFFECTIVE

width

Important Distinction

Available Clear Zone = Area Existing for recovery

Design Clear Zone = A selected value used for design to provide recovery area for the majority of errant drivers

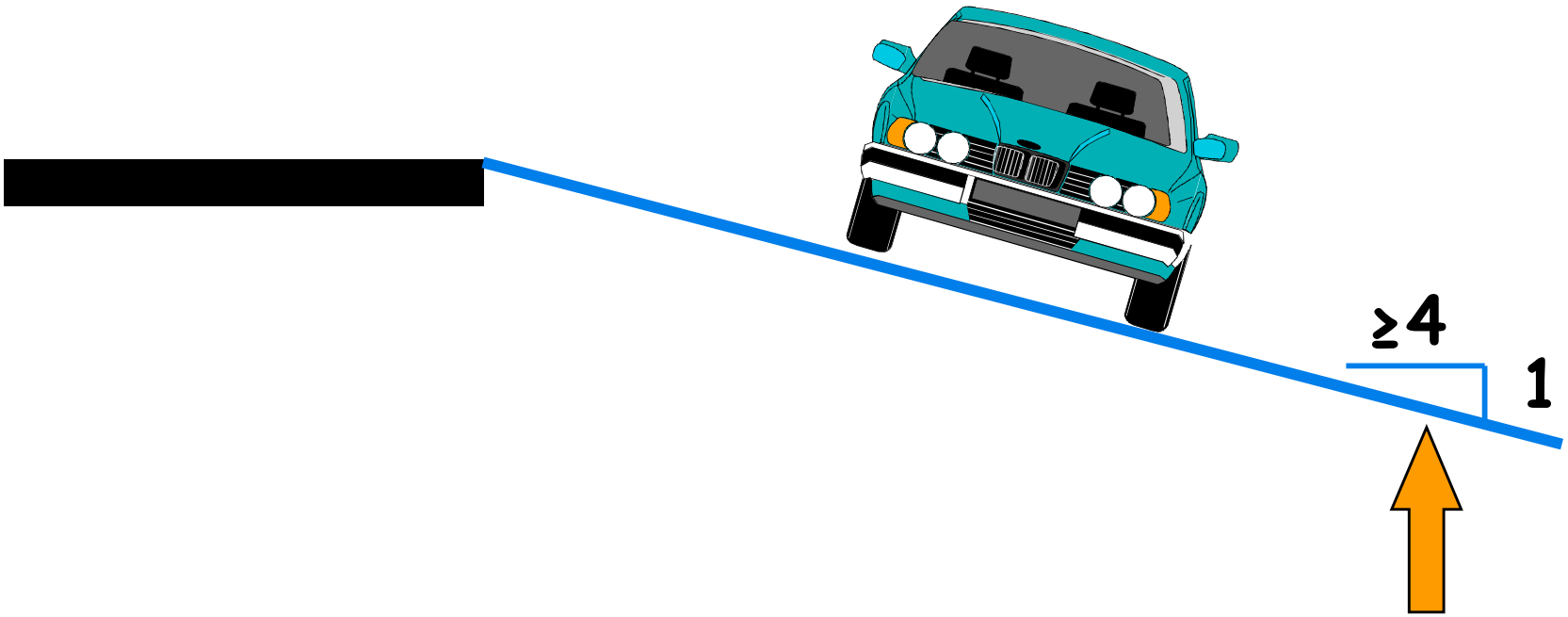
As Wide as Practical

Do not compromise available clear zone

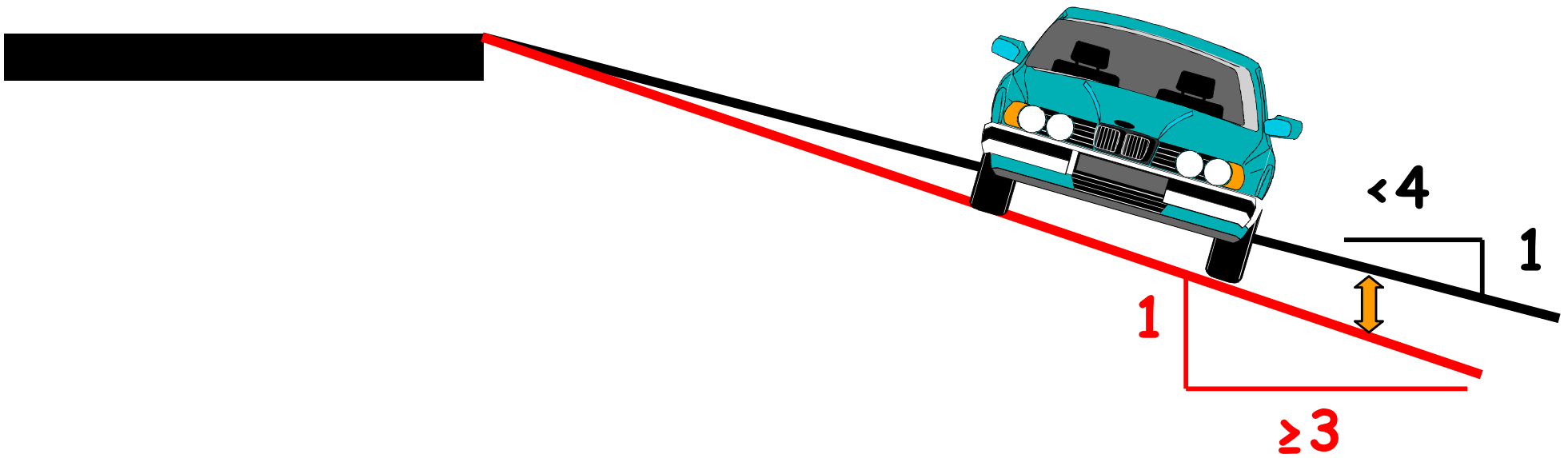
Clear Zone Factors

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

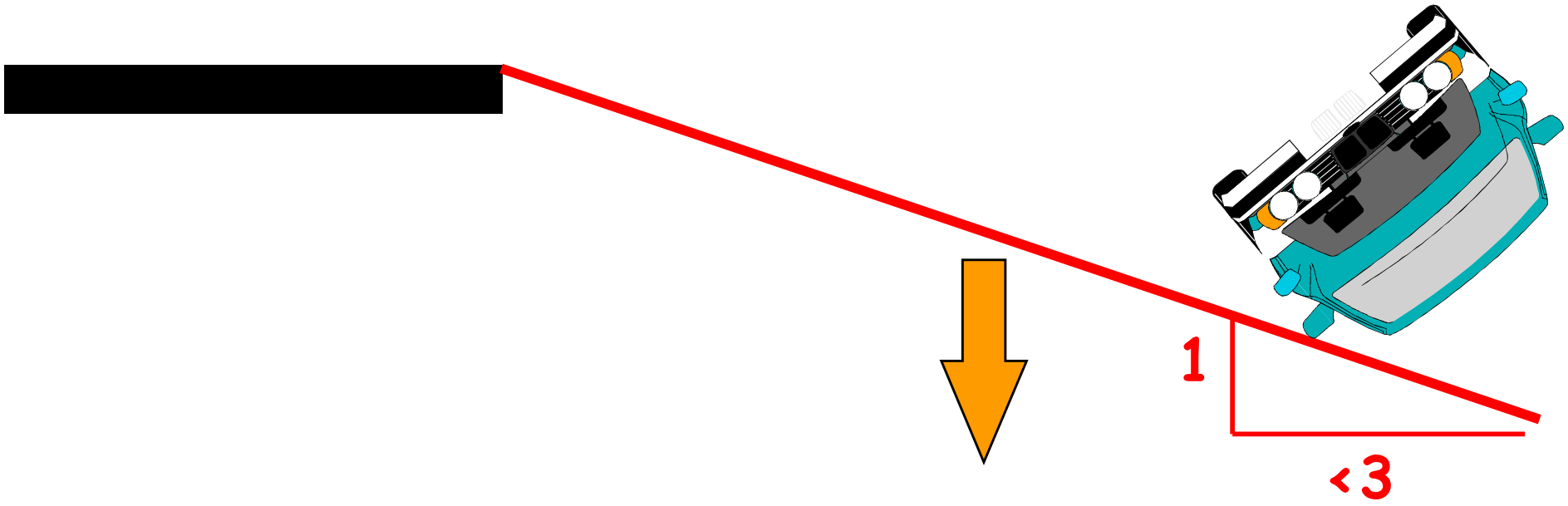
Recoverable



Non-Recoverable (but Traversable)



Critical



Clear Zone

THE "MAGIC"

30 FEET

NCDOT Design Clear Zone Table

Table 4-5 Suggested Clear-Zone Distances from Edge of Through Traveled Lane

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

Order of Preference

4.6 Roadside Design

6.1 General Considerations

- Remove obstacle
- Redesign obstacle to be safely traversed
- Relocate obstacle
- Reduce impact severity with a breakaway device
- Shield obstacle with barrier that will redirect vehicle or use crash cushion
- Delineate obstacle if other options are not appropriate

Barriers Must Be Less of a Hazard

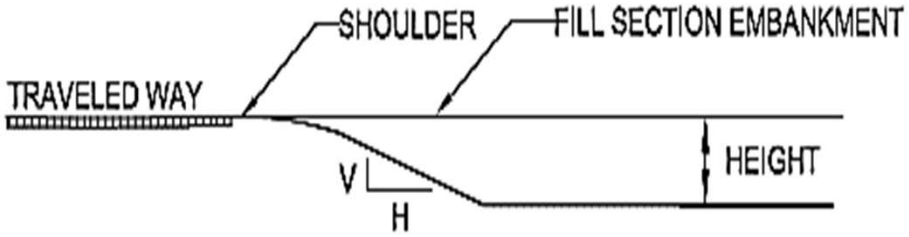
6.2.1 Barrier Warrants

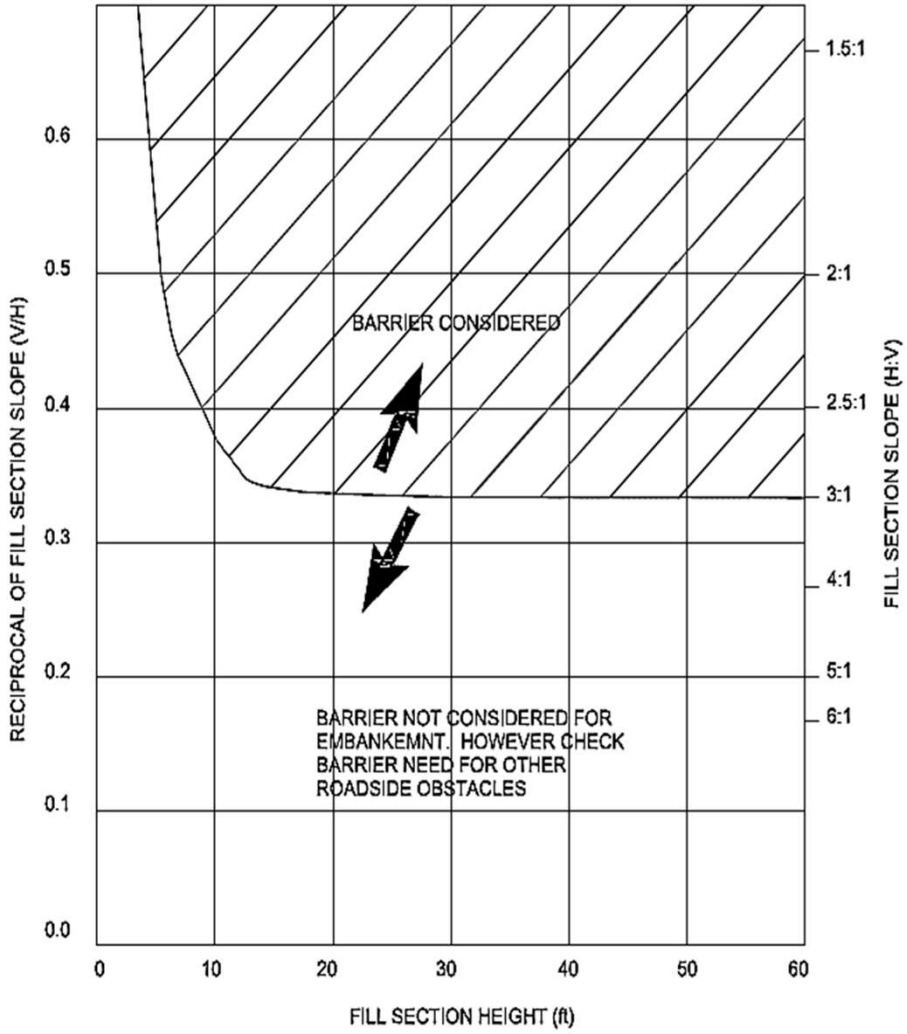
impacts to the protective barrier will be less severe than impact with the roadside hazard.

Potential Hazards

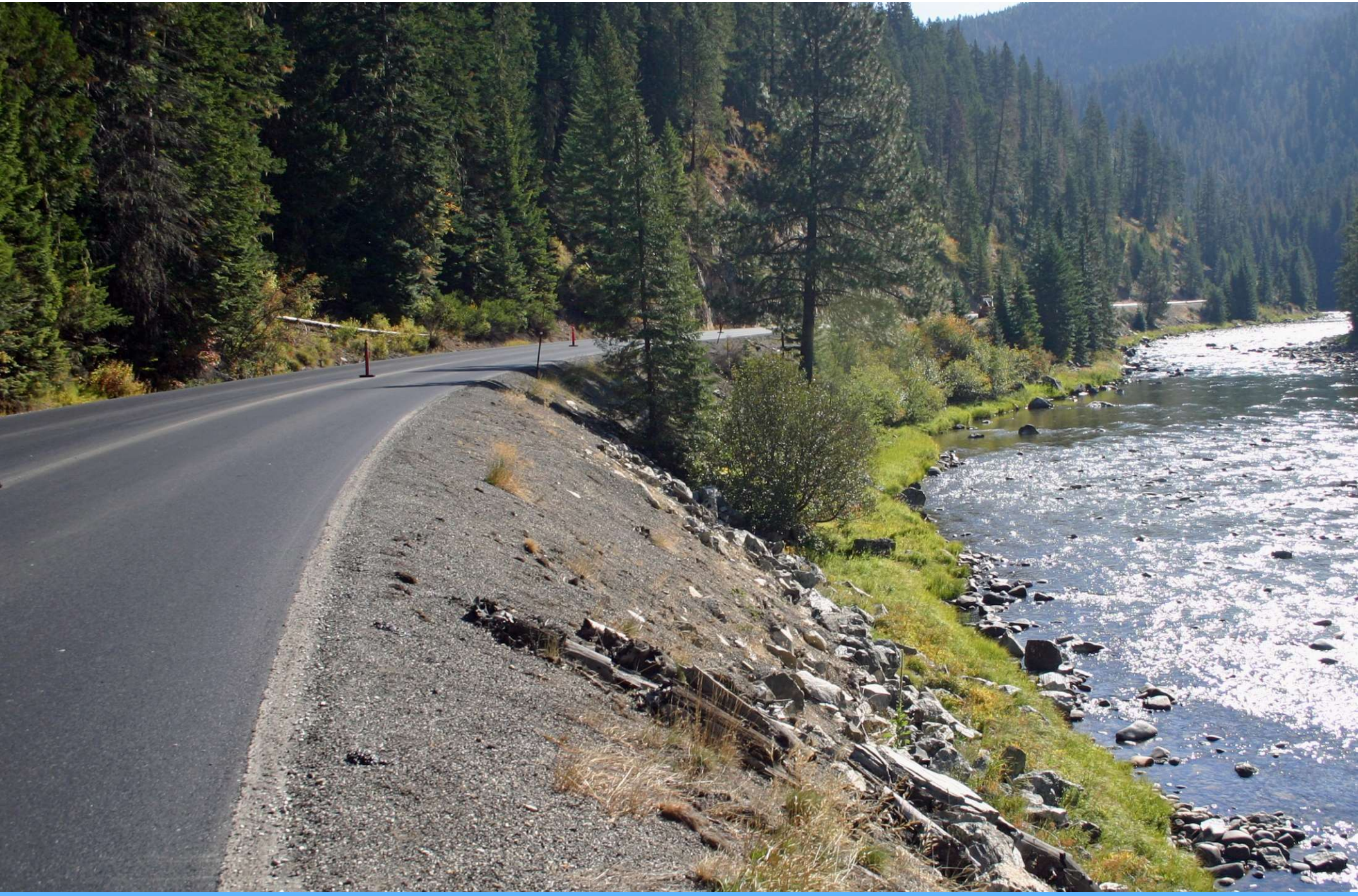
- Bridge Piers / Abutments / Railing Ends
- Drainage Structures / Ditches
- Sign and Luminaire Supports
- Permanent Bodies of Water
- Steep Embankments

Embankment Guidelines





Ref: AASHTO Roadside Design Guide, 4th Edition – Figure 5.1b, Pg. 5-6



Review Learning Outcomes

- Describe the primary Roadside Safety Concerns in North Carolina.
- Identify the need for training.
- Explain clear zone and when a barrier may be warranted.

Session 2:

Testing Requirements and Performance Characteristics of Common Barrier Systems

Session 2 Learning Outcomes

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

- Understand how barriers are tested for crashworthiness
- Identify common barrier systems of NCDOT
- Explain how these barrier systems function
- Define the key components of a transition (Structure Anchor Unit) design

Crash Testing Guidelines

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

MASH Implementation Timeline

(AASHTO/FHWA Joint MASH Implementation Agreement Issued January 7, 2016)

11 years

10 years

9½ years

7 years

2 years

2009

2016

Dec 31

ber 9

ALL DATES HAVE PASSED

MASH

W-Beam Terminals
- Tangent
- ❖ Flared
- ❖ Median

X Crash Cushions
- ❖ Cable Barriers
- ❖ Cable Terminals

Other Terminals & Transitions
- All Other Barriers/Portable
- Bridge Rails
- Sign Supports
- Other Breakaway Hardware

❖ MOVED TO DEC. 31, 2019

X SOME MOVED TO DEC. 31, 2019

MASH Test Conditions

Selection of a performance level is based on speed and traffic mix.

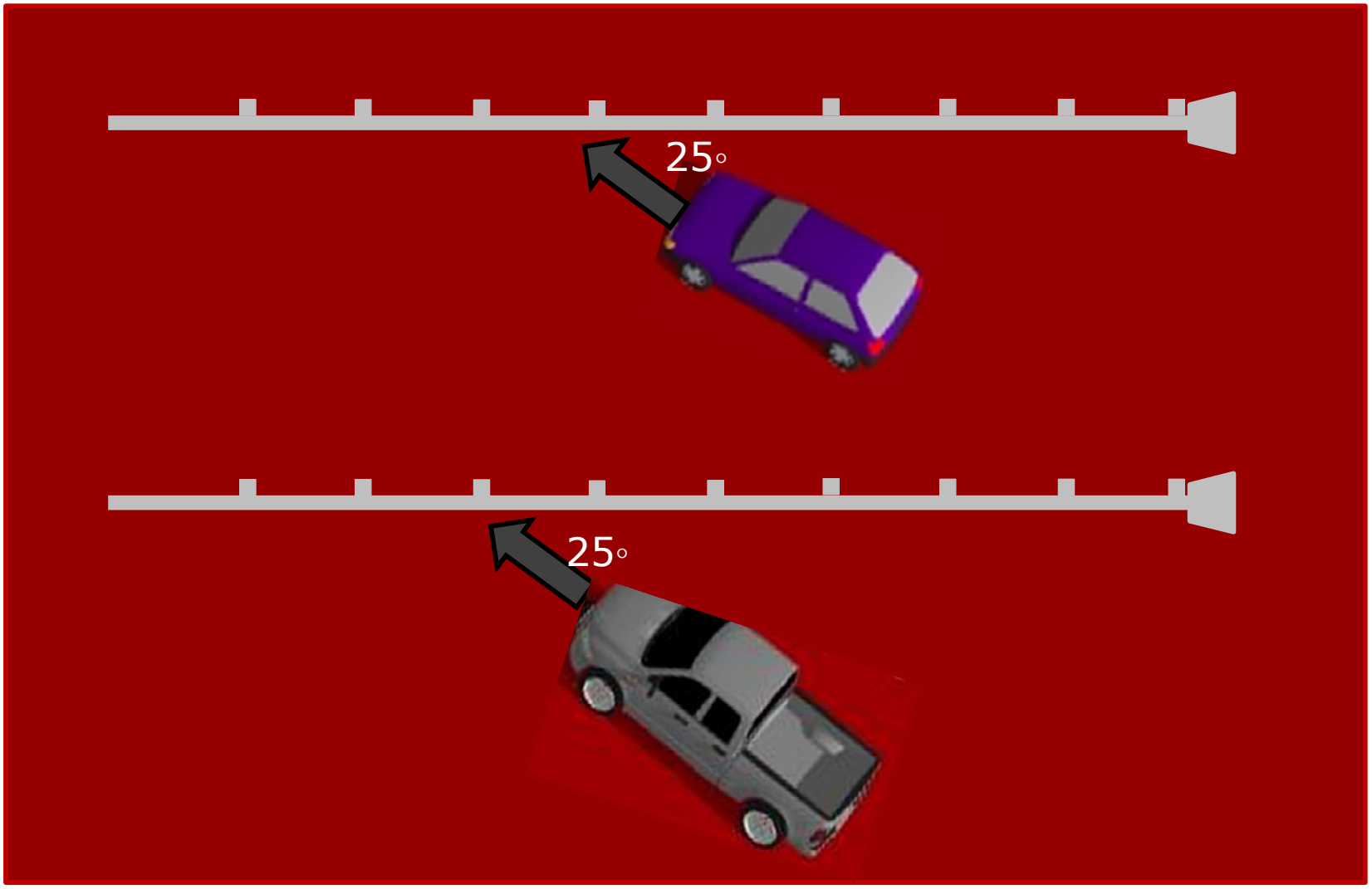
- **TL-1**, **TL-2**, and **TL-3**: crash tests with small car and pickup truck with a 25˚ impact angle at 31, 44, and 62 mph, respectively.

2,420 lbs.
1100C

5,000 lbs.
2270P

NCHRP 350 comparison with MASH Crew Cab Truck

MASH Impact Angles for Barrier Tests



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 degree max)
3. Tolerable Occupant Impact Forces
4. Minimum Occupant Compartment Deformation and no Debris Intrusion

Standard Barrier Systems

- Rigid Systems
- Semi-Rigid Systems
- Flexible Systems
- Median Barrier Systems

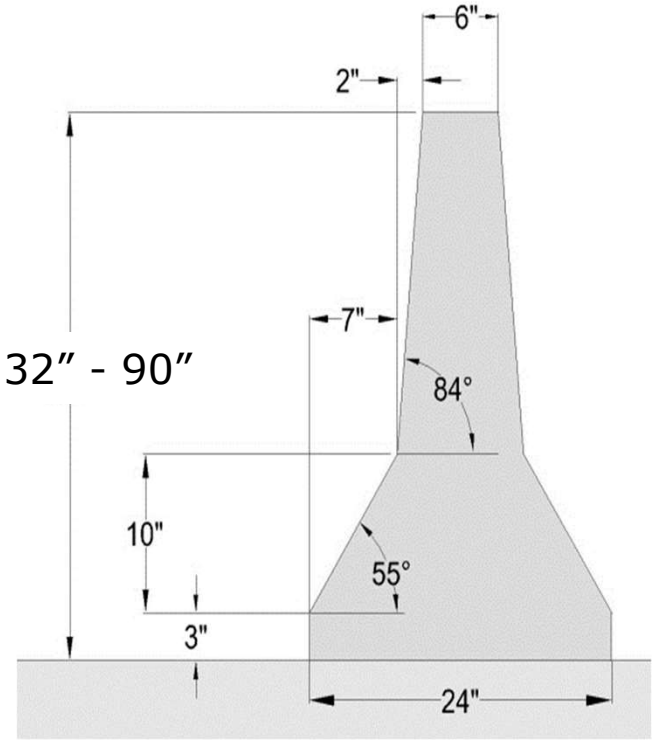
Barrier Systems: Rigid Barriers

Rigid Barrier Systems have little (between 0 to 1 ft.) deflection under the TL-3 pickup impact. They are generally anchored by some acceptable means.

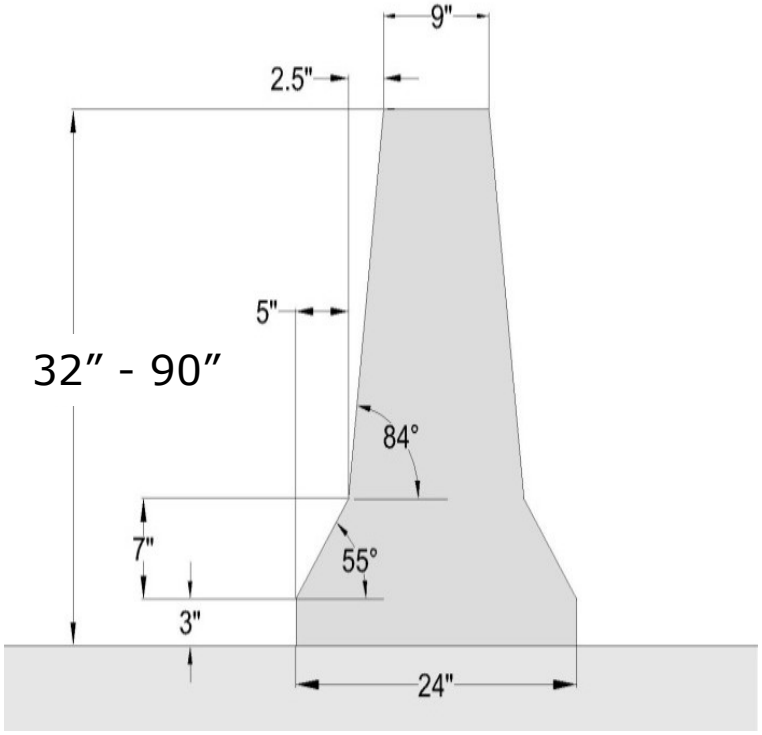
Examples include:

- New Jersey Safety Shape Concrete Barrier
- F-shape Concrete Barrier
- Single or Slope Concrete Barrier
- Vertical Wall

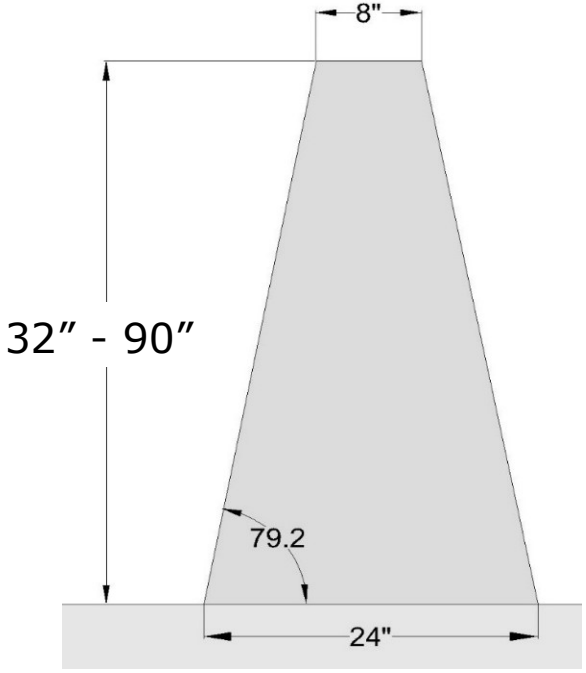
Rigid Barrier



New Jersey Shape



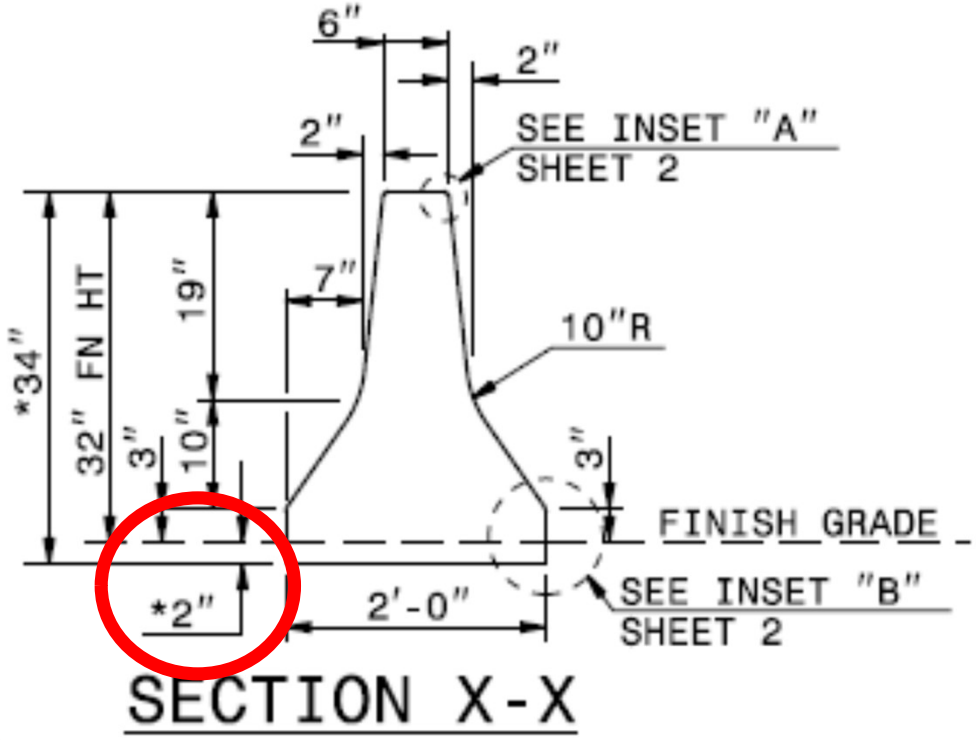
F-Shape



Single Shape

MASH Testing of 32" New Jersey Shaped Concrete Barrier

Rigid Barrier – New Jersey Shape



SECTION X-X

TYPE IV - NO GLARE SCREEN PERMITTED

Type IV typically used

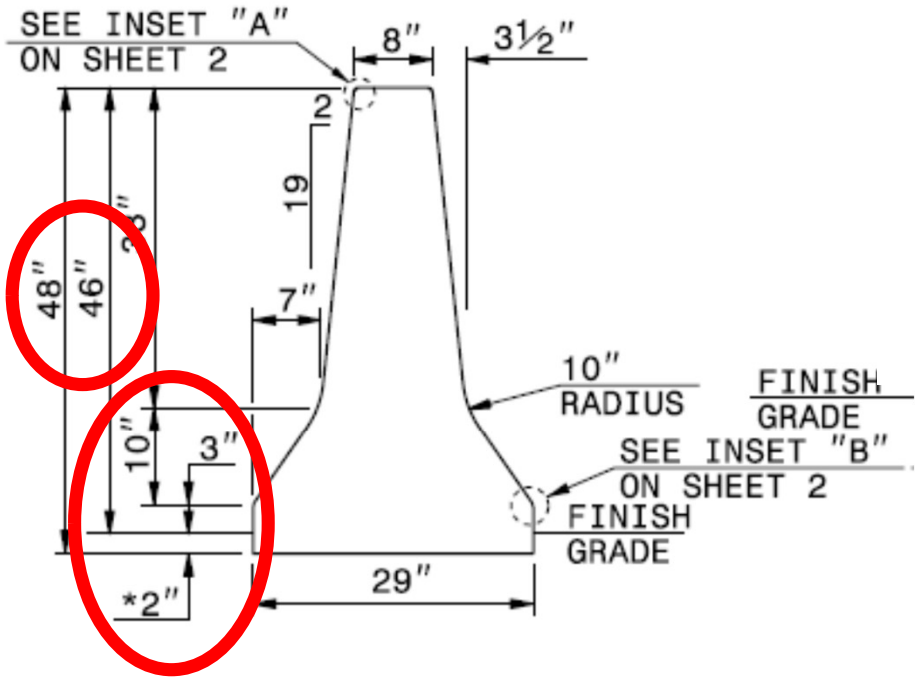
Types II & III for bifurcated cross-sections

2" min Embedment minimizes Deflection

When large trucks are not an issue

854.01 SHEET 1 OF 4	ROADWAY STANDARD DRAWING FOR **DOUBLE FACED CONCRETE BARRIER** TYPES I, II, III & IV	1-24 STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

Rigid Barrier – New Jersey Shape



SECTION X-X

TYPE - T

2" min Embedment minimizes Deflection

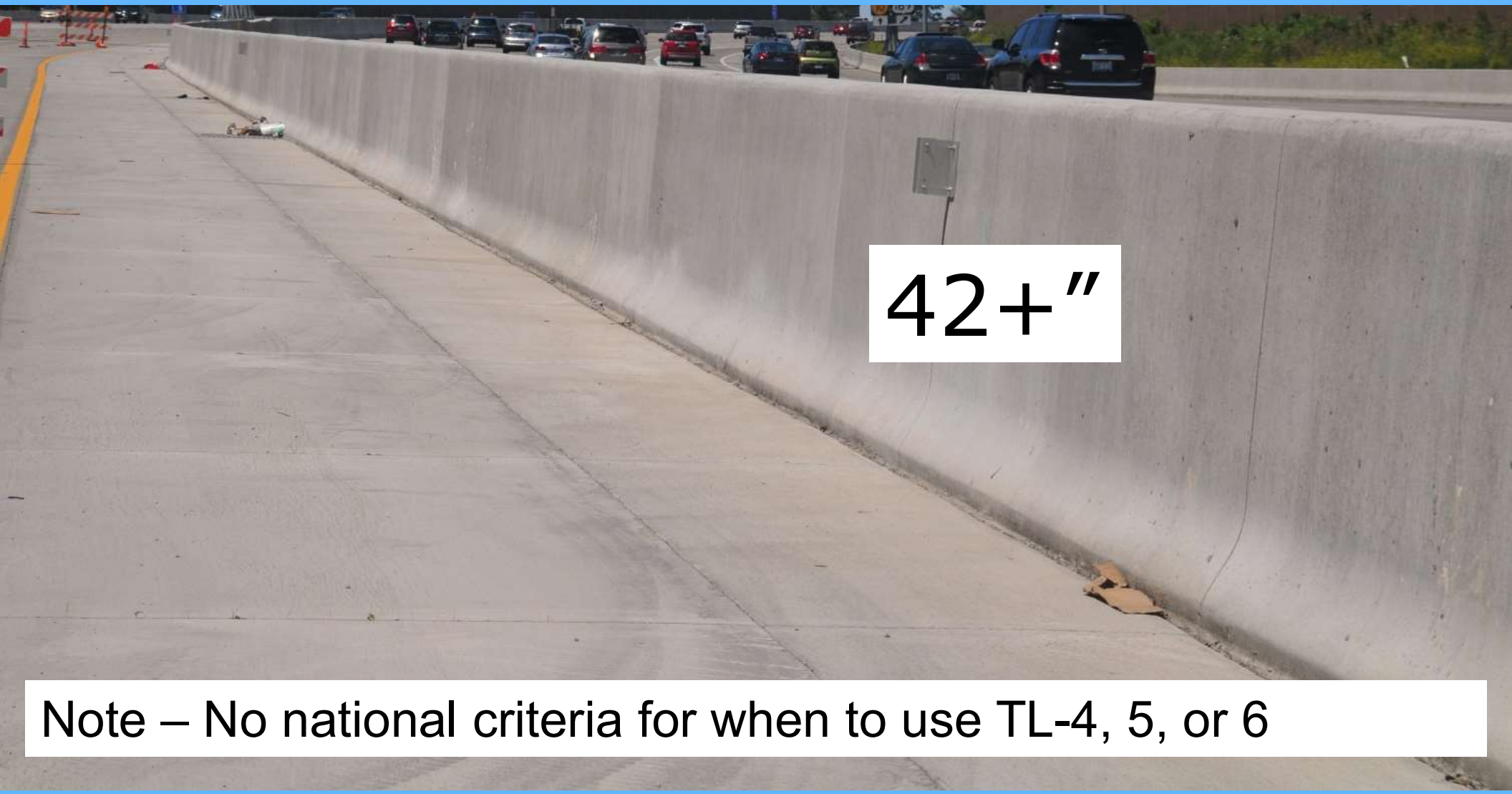
Considered TL- 5

For use when conditions warrant (typical urban, high truck volume

854.02	SHEET 1 OF 4	ROADWAY STANDARD DRAWING FOR **DOUBLE FACED CONCRETE BARRIER** TYPE T, T1 AND T2	1-24	STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

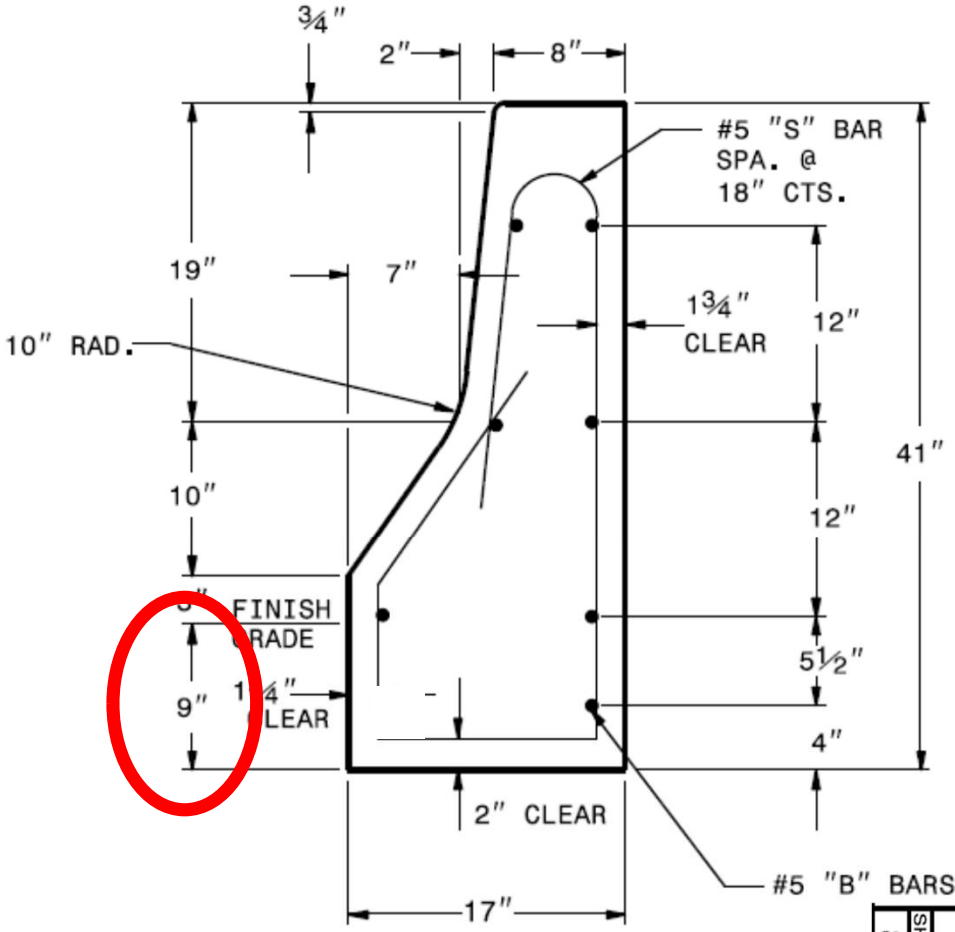
*THE 2" OR 5" DIMENSION FROM FINSIH GRADE TO THE BASE IS A MINIMUM DIMENSION. REFER TO PLAN TYPICAL SECTIONS AND PAVEMENT SCHEDULE TO DETERMINE KEY-IN DEPTH.

Rigid Barrier



Note – No national criteria for when to use TL-4, 5, or 6

Rigid Barrier – New Jersey Shape



DETAIL X-X

CROSS SECTIONAL VIEW

9" min Provides Fixity

857.01	SHEET 5 OF 8	ROADWAY STANDARD DRAWING FOR **PRECAST REINFORCED CONCRETE BARRIER** 41" SINGLE FACED	1-24	STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

Rigid Barrier: TL-5

Concrete Barrier - MASH – Free Standing

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.

TERMINOLOGY: Call new system 31”

Barrier Systems: Semi-Rigid

- W-Beam Steel Guardrail – **350 Guardrail (29”)**
  - 12” wide W-beam rail section (12-gauge thickness).
  - Posts are spaced at 6’-3” centers, and the nominal rail height is 27” – 29”
  - Rail splice at the post.
  - Steel posts: W6 x 8.5/9.0 x 6’-0” long.
  - Offset Block: 6” x 8” recycle plastic or composite.

Although previous practice may have referred to height at mid-rail, all heights used in this training are to top of rail

Guardrail with Steel Post & Steel Offset Block 27 5/8” Height

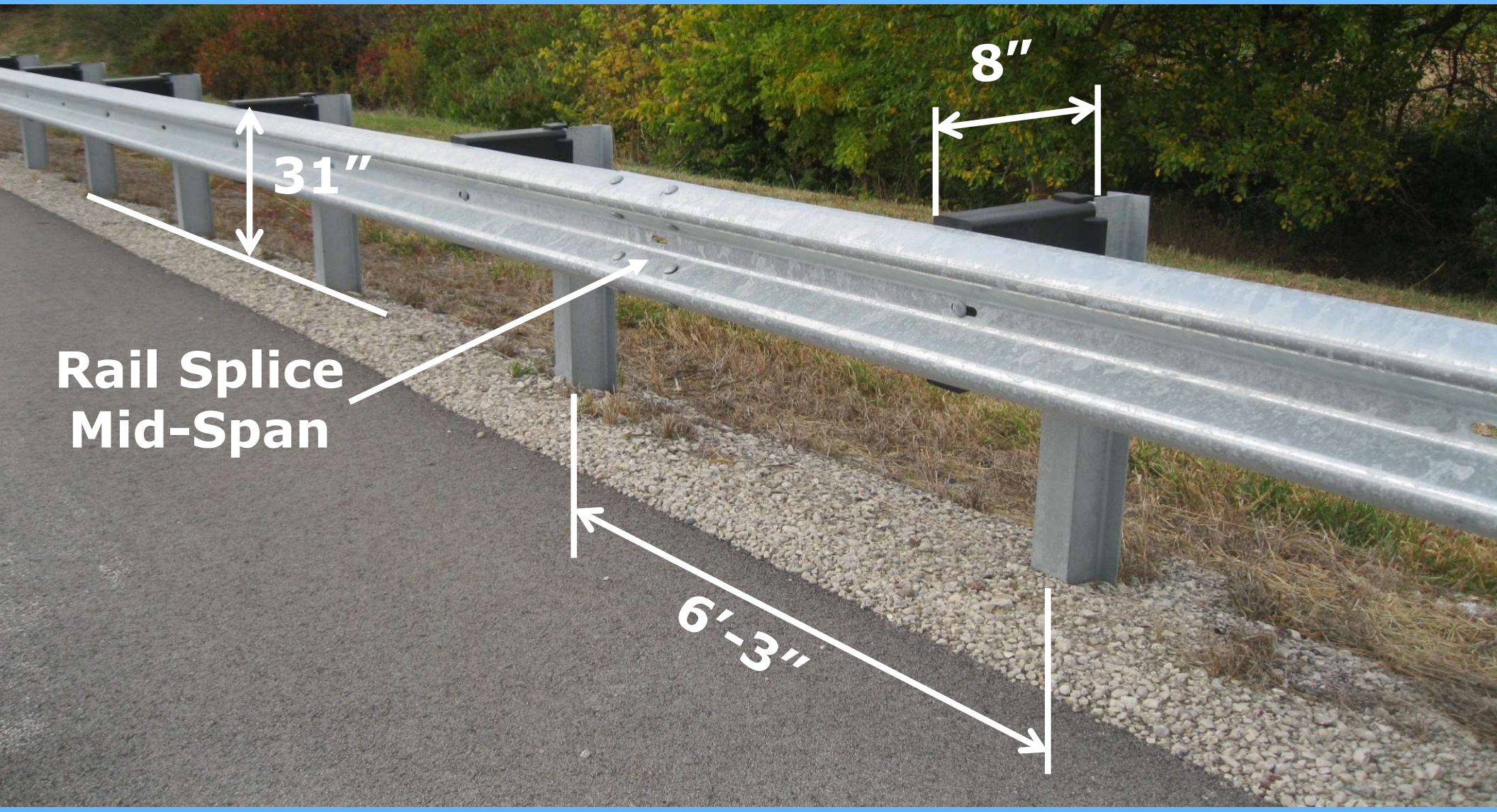
Guardrail with Wood Post & Wood Offset Block 27 5/8” Height

Guardrail with Steel Post & Wood Offset Block 27 5/8” Height

Barrier Systems: Semi-Rigid

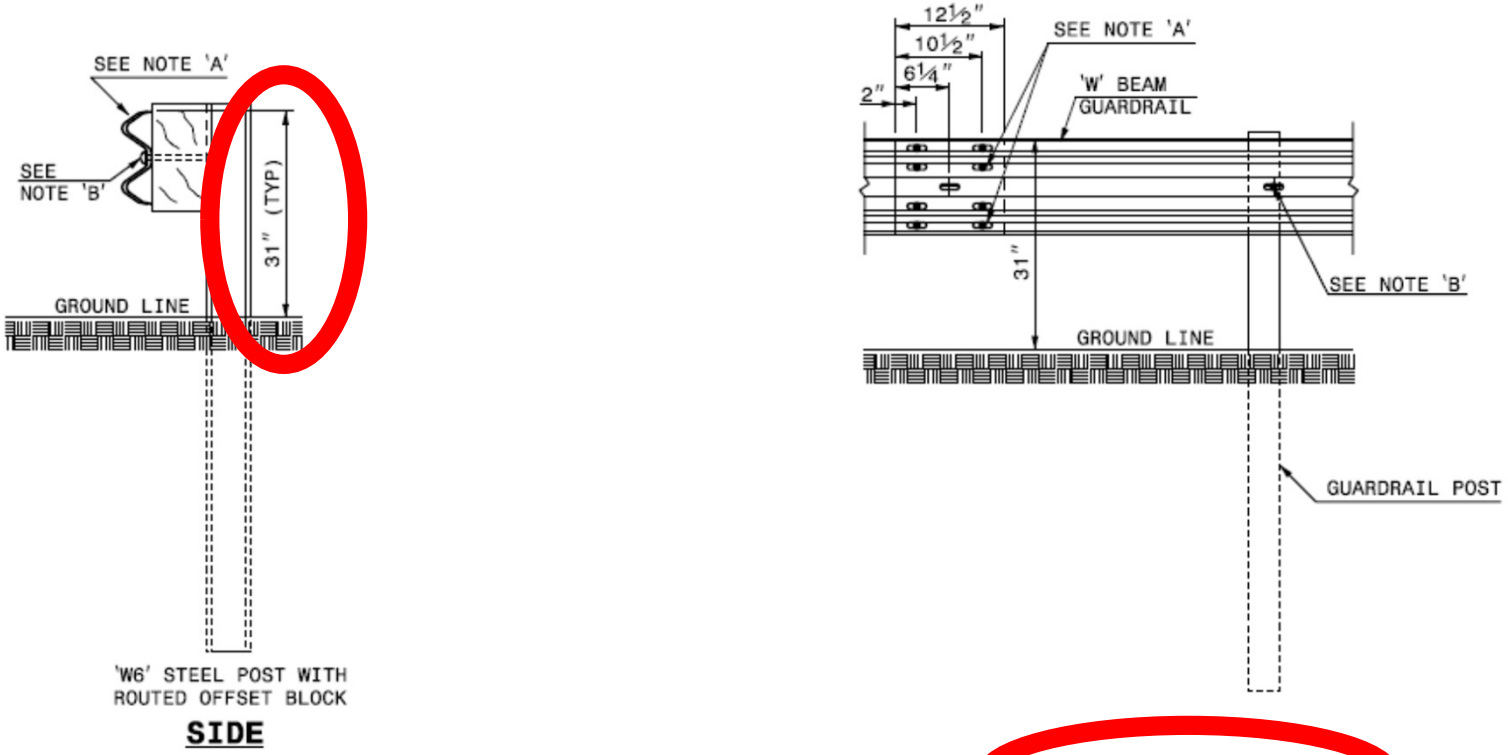
- **31”** (shown in standards as 2’-1”)
  - 31” Height to Top of Rail
  - Rail Splice mid-span.
  - Post spacing 6’-3”
  - Steel posts, W6 x 8.5/9.0 x 6’
  - Offset Block: 8” recycled plastic or composite

31” Guardrail



31” MASH Test 3-11

NCDOT 31” Guardrail



862.02	SHEET 6 OF 9	ROADWAY STANDARD DRAWING FOR **GUARDRAIL INSTALLATION**	1-24	STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

Barrier Systems: Flexible Barriers

Flexible Barrier Systems typically have relatively large deflections

Examples of Flexible Barriers include:

- Weak post W-beam No longer in standards
- Low tension cable Guiderail (LTCG)
- High tension cable Guiderail (HTCG)

Barrier Systems: Flexible Barriers

Advantages of cable systems include:

- Low initial cost
- Lower deceleration forces
- Effective vehicle containment and redirection
- Installation conditions flexibility
- SNOW

Barrier Systems: Flexible Barriers

- High Tension Cable Guiderail (HTCG)
  - Five different proprietary designs developed
  - Each requires a unique proprietary terminal
  - Somewhat reduced deflections
  - Generally easier maintenance
  - Can retain effectiveness after most impacts

High-Tension Cable Guiderail (HTCG)

- Brifen ★ ★
- Safence ★
- CASS (Valtir)
- Nucor
- Gibraltar ★

★ = APL
(Work zone, Type 3)

★ = RDM
(6.8.1.1)

As of 8-1-23

High-Tension Cable Guiderail (HTCG)

6.8.1.1 Types of installations to be used

Use HTCG in areas where lower deflections are needed in the median or on the outside shoulder. HTCG systems are proprietary. HTCG systems must be on the NCDOT Approved Products List and may be used at the approval of Division personnel or the State Roadway Design Engineer. Install all HTCG systems per the manufacturer's instructions. Gibraltar, Safence, and Brifen are MASH approved HTCG systems available for use by NCDOT {as of 8-1-23}.

Need old standard to repair LTCG

Brifen USA

Brifen “O” Post

- Interweaving cables creates a “mini-anchor” at each post due to friction as the tensioned cables weave past each post.
- MASH 09 approved 4 cable level terrain TL-4 and 4:1 TL-3

http://www.brifenusa.com

Safence Gregory Industries

- Posts have slot located in the upper section of the web.
- 3 or 4 cable TL-3 Level and 4:1 (Also tested TL-3 on 2:1 200mm offset from breakpoint) MASH09

http://www.safence.com

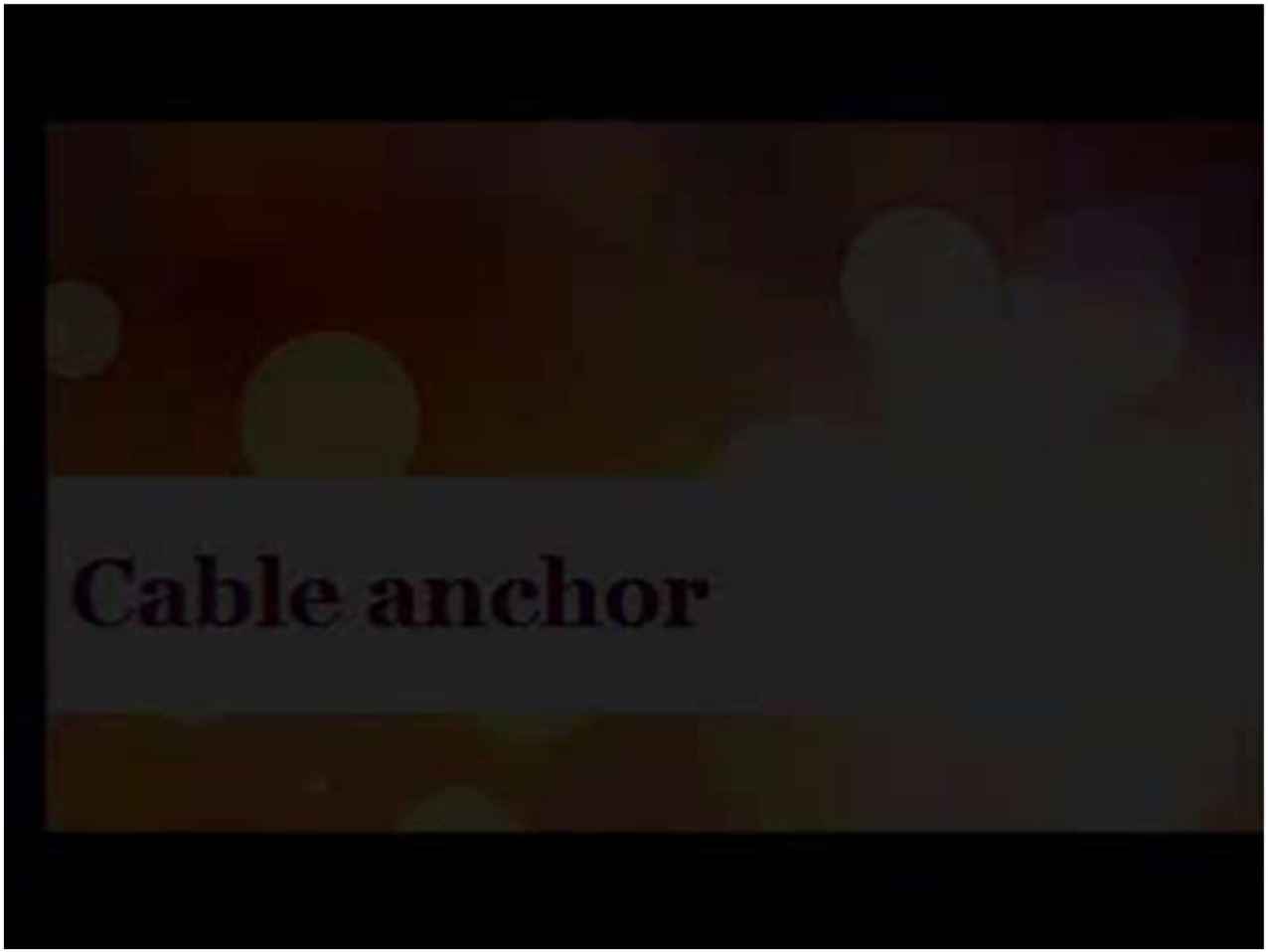
Gibraltar

- Has hairpin type connection to post.
- Posts to cable connection is alternate side-to-side.
- MASH approved 4 cable Level terrain TL-4 and 4:1slope TL-3

https://gibraltarglobal.com

Four Cable System

Post Foundation and Typical Terminal



HTCG On 4:1 Slope

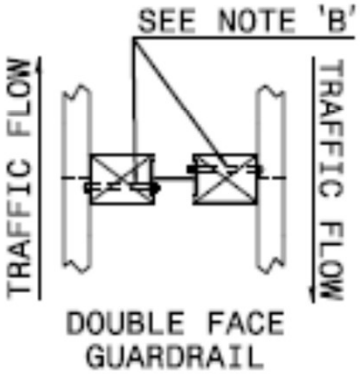
Barriers in the Median

- 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.

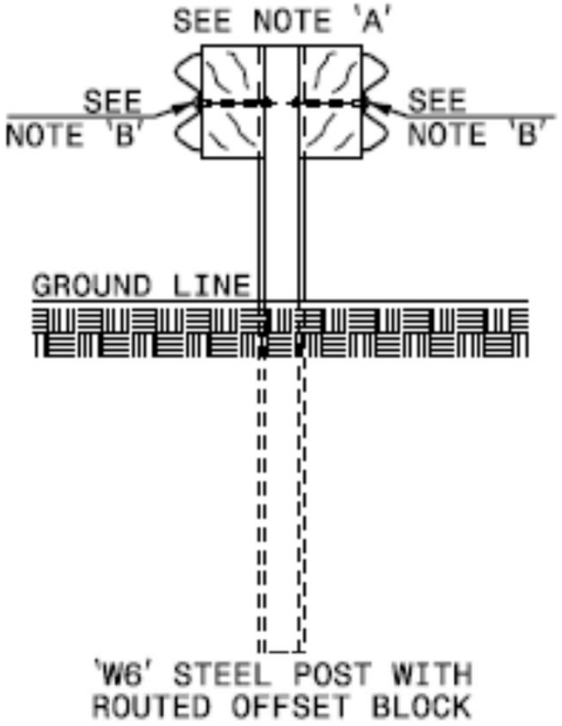
MASH 27” W-Beam Median Barrier Test

MASH 31” Median Barrier Test

MASH 31” Median Barrier



PLAN



SIDE

862.01 SHEET 13 OF 15	ROADWAY STANDARD DRAWING FOR **GUARDRAIL PLACEMENT** DOUBLE FACED W-BEAM	1-24 STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

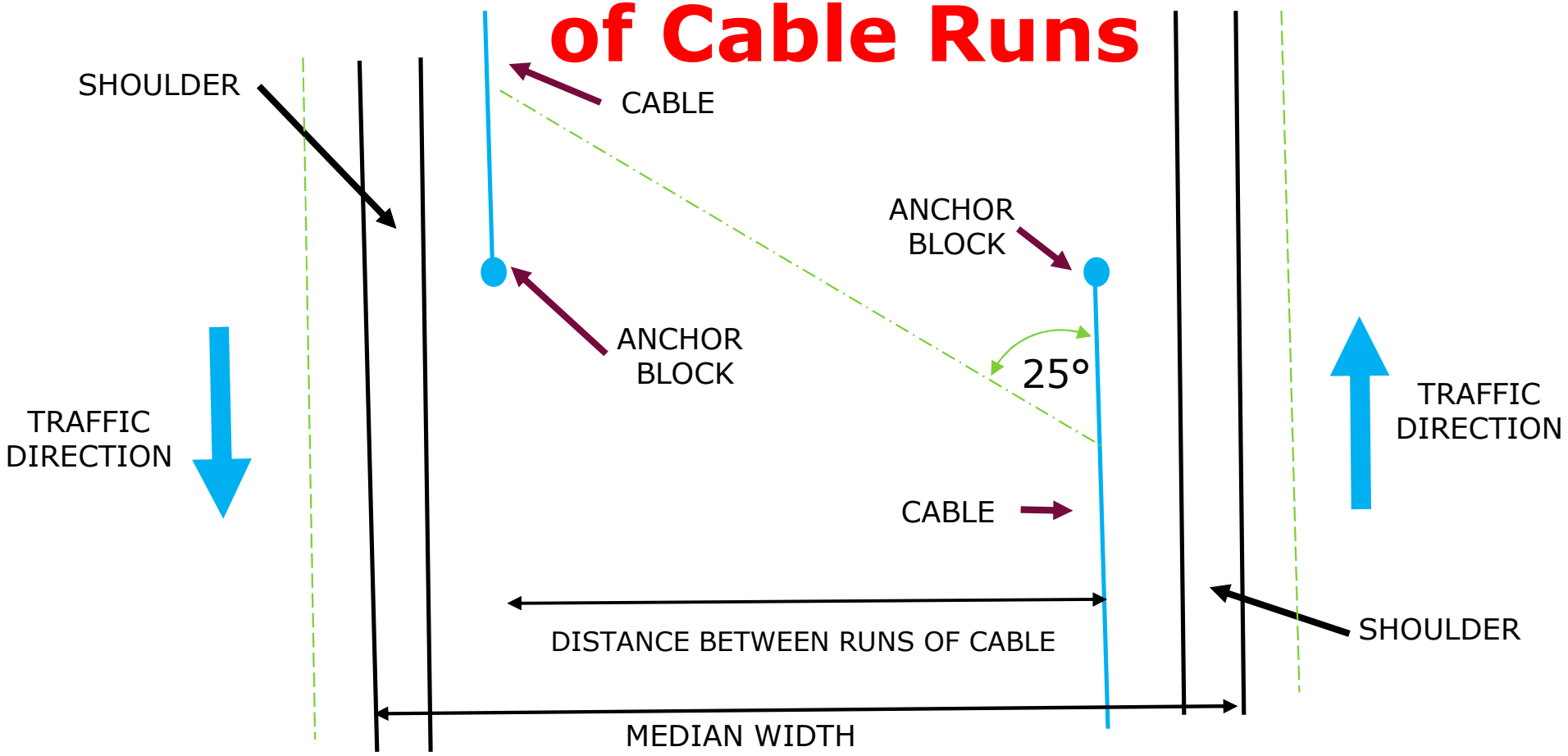
Flexible Median Barriers

Advantage of high tension cable is it may remain effective after impact.

Flexible Median Barriers

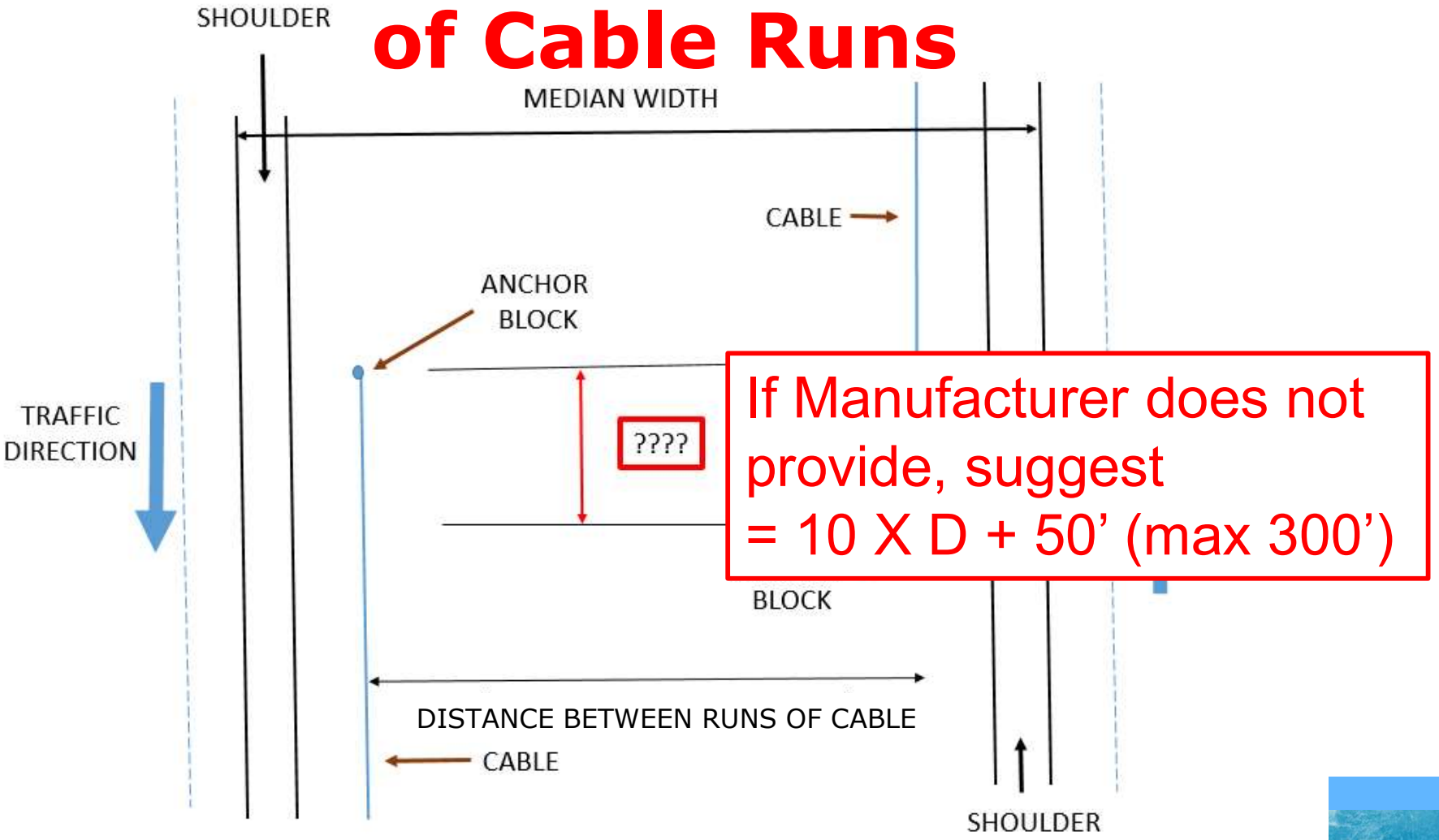
Design Issue
Check in Construction

Near-Side Overlap of Cable Runs



Design Issue
Check in Construction

Far-Side Overlap of Cable Runs



If Manufacturer does not provide, suggest
= 10 X D + 50' (max 300')

Transition Sections

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


SKOOKUMCHUCK
CREEK
Problematic

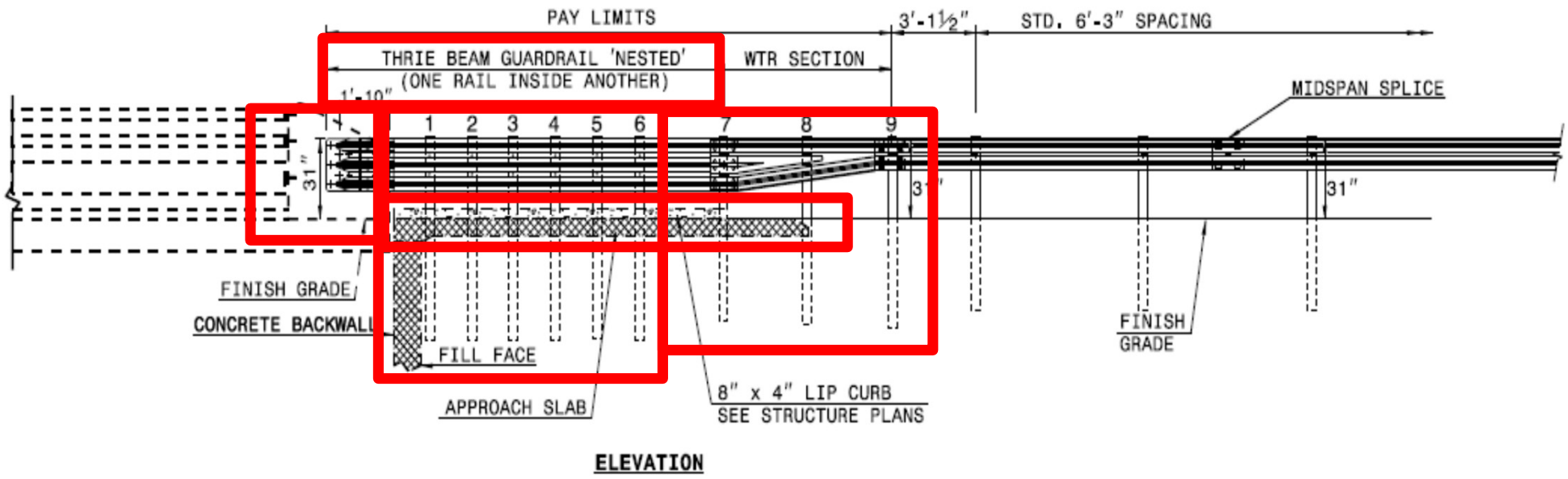
Inadequate Transition

Transition Sections

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

- Additional and/or Larger Posts
- Nested rail (W-beam or Thrie-beam)
- Curbs (only as crash-tested transition unit), Rub Rails, and/or Flared Parapet Wall to Prevent Snagging

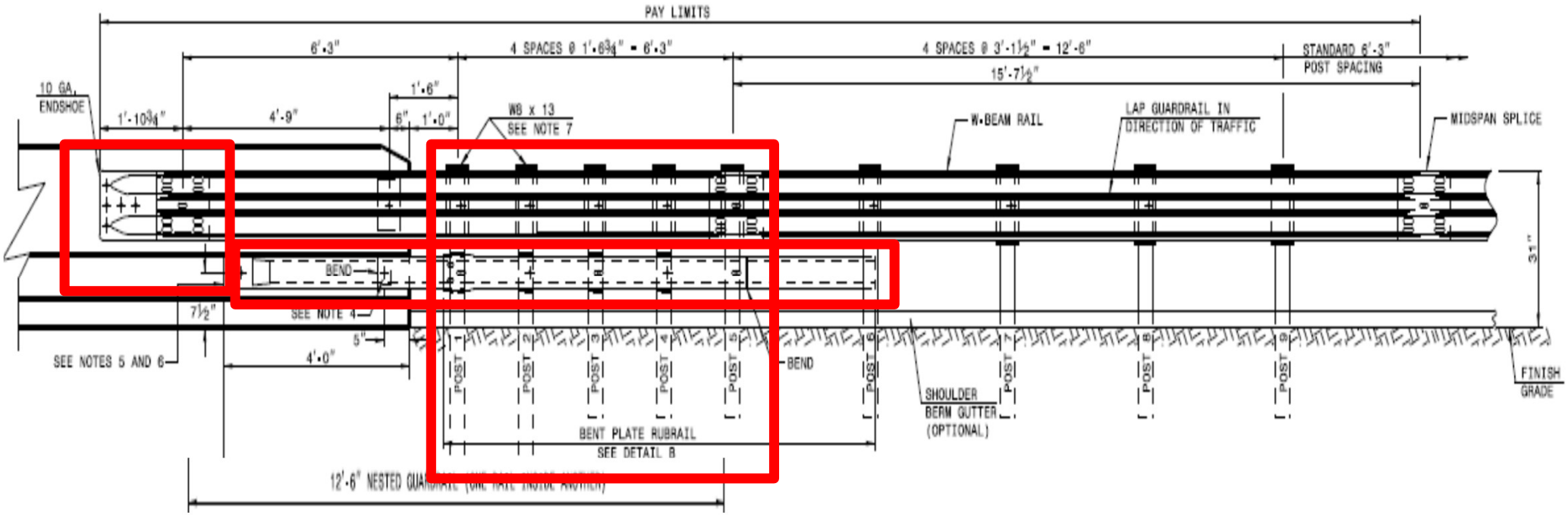
NCDOT Transition – Thrie-beam



862.03 SHEET 1 OF 9	ROADWAY STANDARD DRAWING FOR **STRUCTURE ANCHOR UNITS** GUARDRAIL ANCHOR UNIT, TYPE III FOR ATTACHMENT TO RAIL ON BRIDGE	1-24 STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

NCDOT Transition – Previous Standard

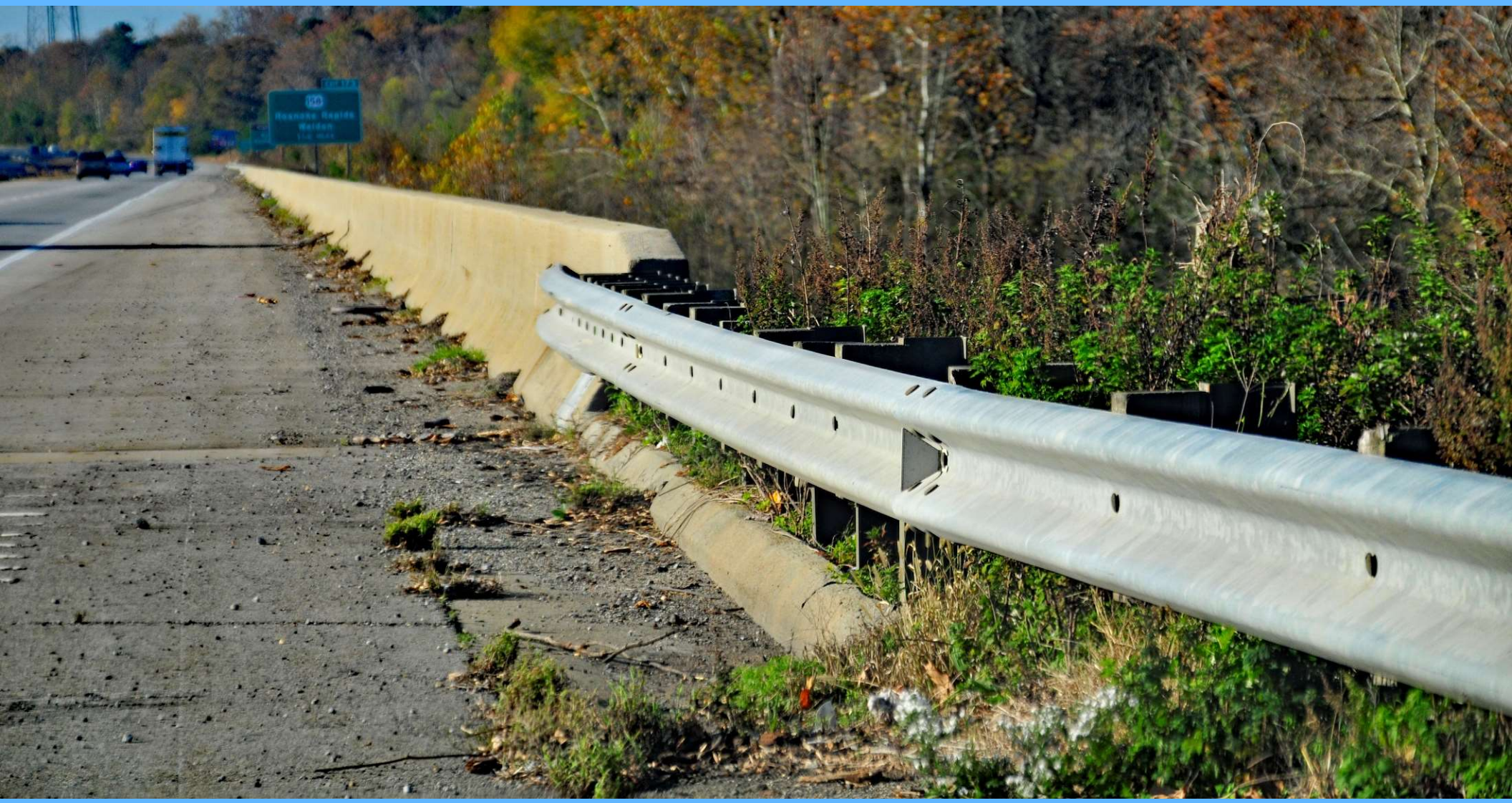
NCDOT Transition – Direct



ELEVATION

862.03 SHEET 4 OF 9	ROADWAY STANDARD DRAWING FOR **STRUCTURE ANCHOR UNITS** GUARDRAIL ANCHOR UNIT TYPE B-77 FOR F-SHAPE BARRIER	1-24 STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

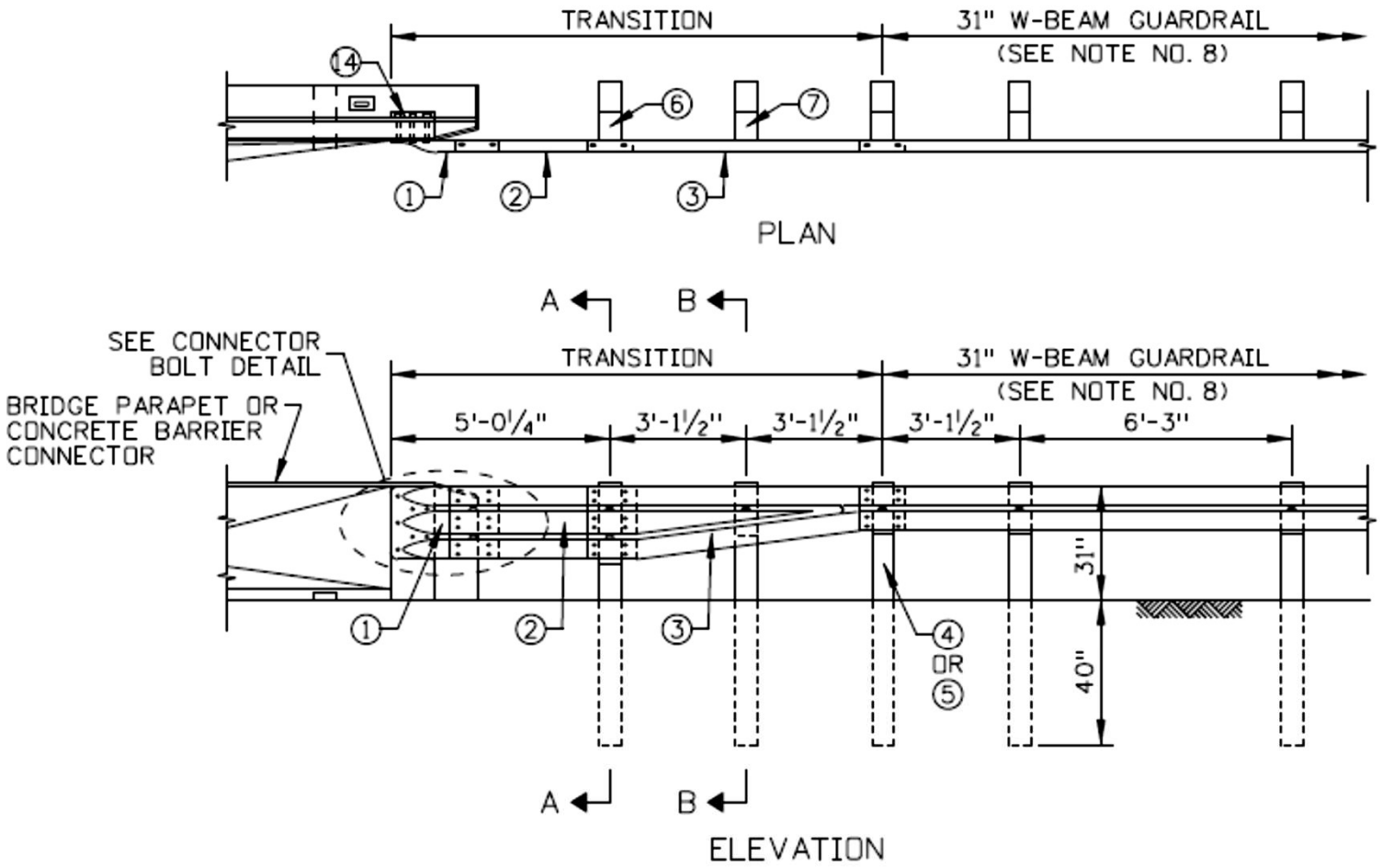
NCDOT Transition – With Curb



NPS Transition

31” Transition - Video

Transition – 31”, TL-2



LOW SPEED GUARDRAIL TRANSITION

Tested – NOT a NCDOT standard

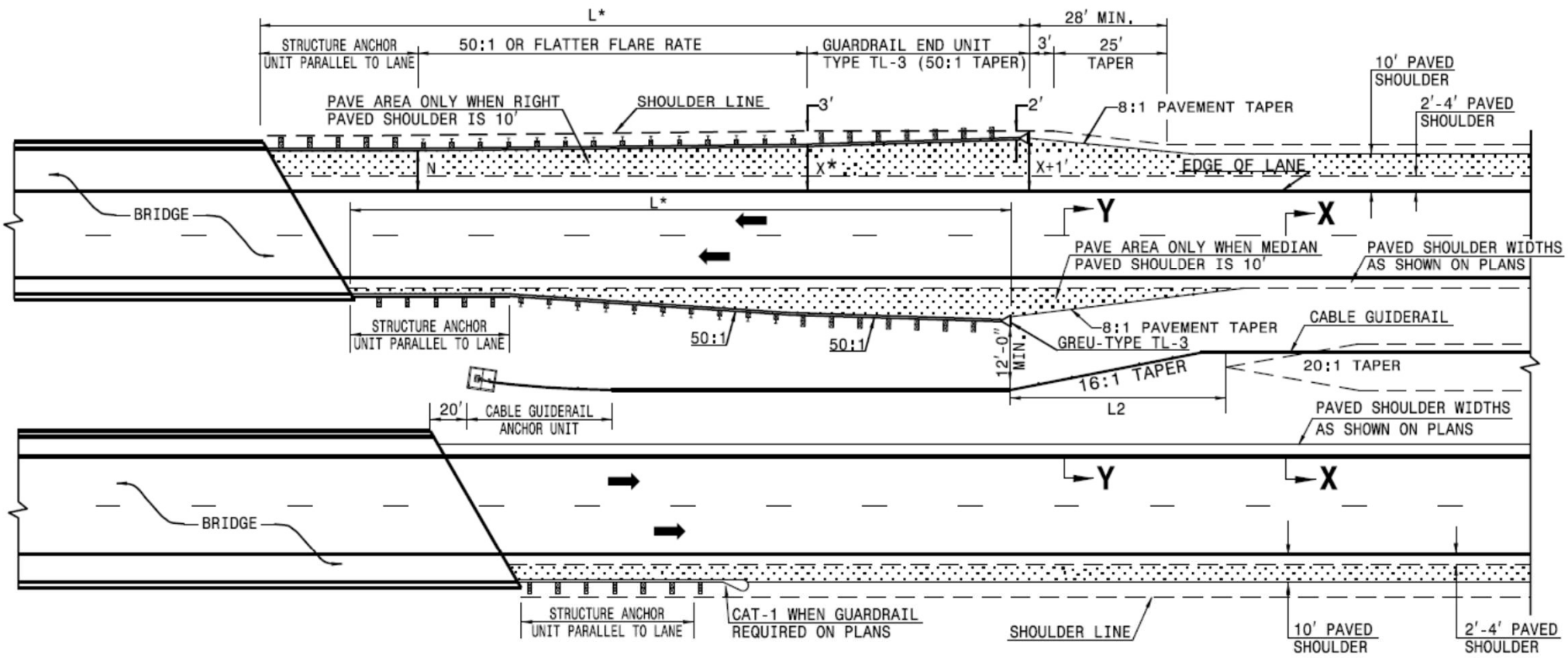
Connections to Low Parapets or Combination Rails

If the concrete parapet or portion of a combination rail is less than the transition height (31”), a steel plate may be applicable to adjust the height.

Not Crash Tested

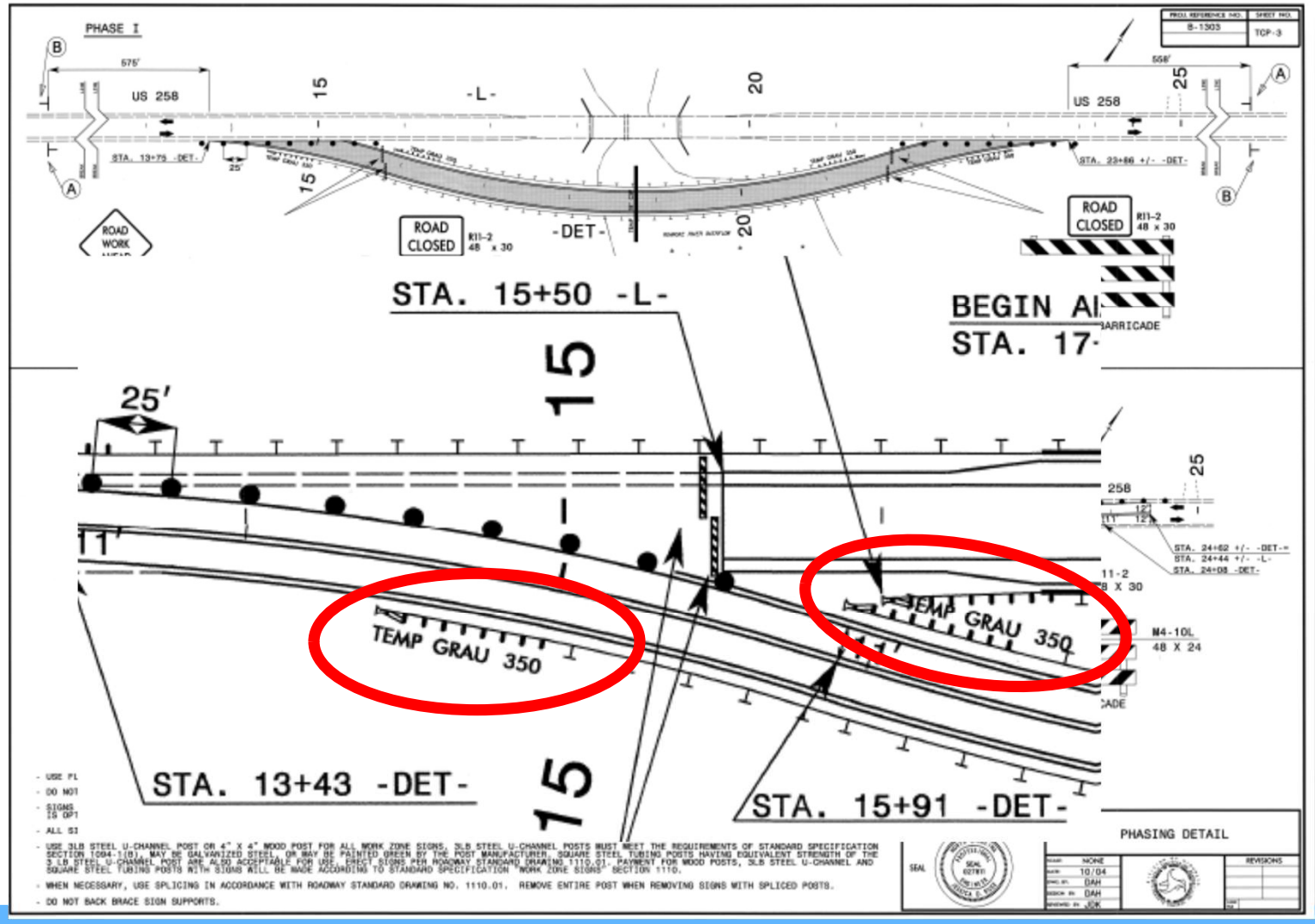
Transition: HTCG to Guardrail (Spatial)

Transition: HTCG to Guardrail (Spatial)



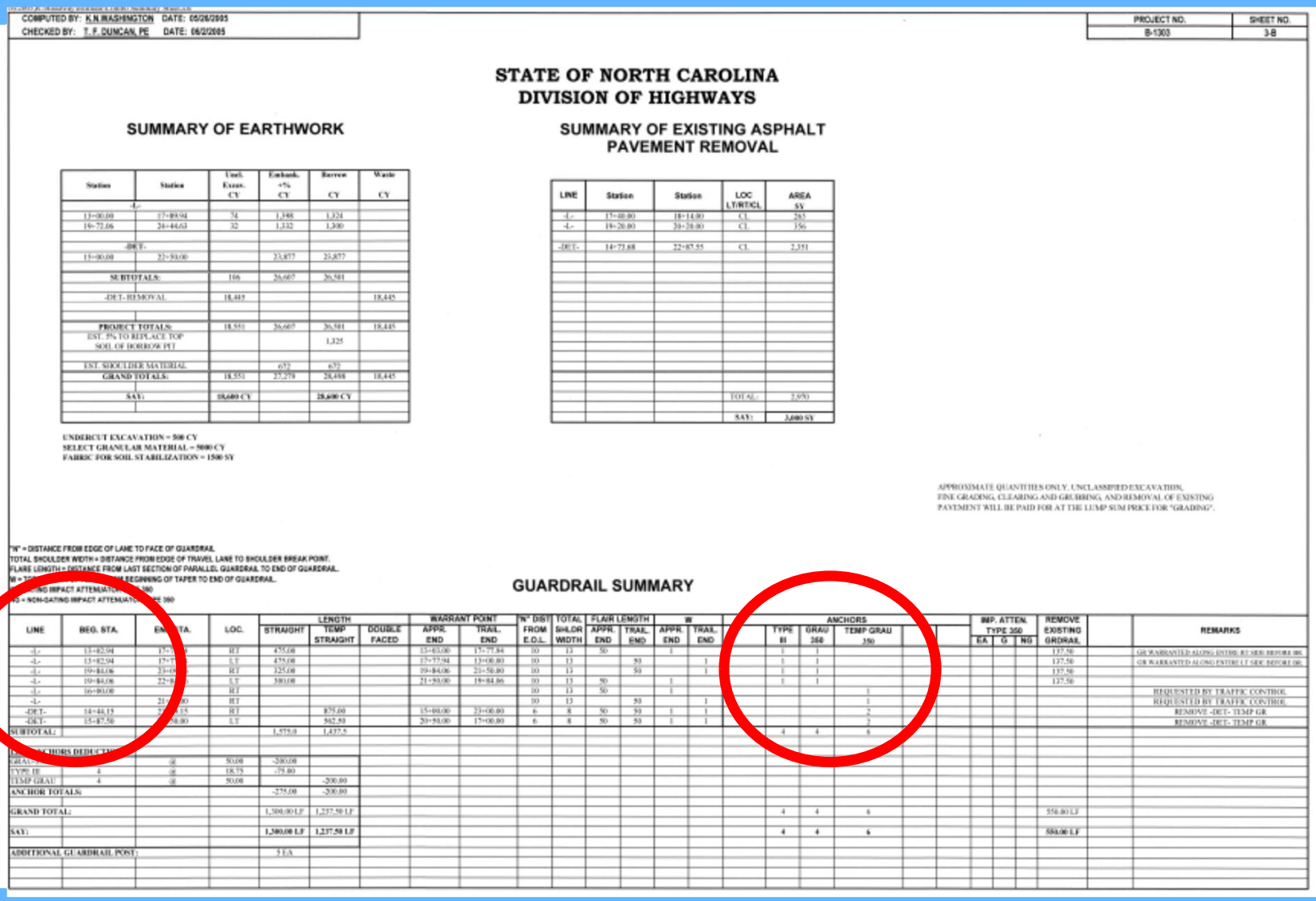
865.01	SHEET 2 OF 12	ROADWAY STANDARD DRAWING FOR **CABLE GUIDERAIL** DUAL LANE BRIDGES GUIDERAIL LAYOUT	1-24	STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

Temporary Barrier – Need for Tension



Traffic Management Plan

Quantity Summary Sheet



COMPUTED BY: K.N.WASHINGTON DATE: 05/26/2005
CHECKED BY: T.F.DUNCAN, PE DATE: 06/2/2005

PROJECT NO.	SHEET NO.
B-1303	3-B

STATE OF NORTH CAROLINA
DIVISION OF HIGHWAYS

SUMMARY OF EARTHWORK

Station	Station	Unclass. Excav. CY	Embank. +% CY	Borrow CY	Waste CY
-L-					
13+00.00	17+89.94	74	1,398	1,324	
19+72.06	24+44.63	32	1,332	1,300	
-DET-					
15+80.00	22+93.00		23,877	23,877	
SUBTOTALS:		106	26,607	26,501	
-DET- REMOVAL		18,445			18,445
PROJECT TOTALS:		18,551	26,607	26,501	18,445
EST. 5% TO REPLACE TOP SOIL OF BORROW PIT				1,325	
EST. SHOULDER MATERIAL			672	672	
GRAND TOTALS:		18,551	27,279	28,498	18,445
SAY:		18,600 CY		28,600 CY	

UNDERCUT EXCAVATION = 500 CY
SELECT GRANULAR MATERIAL = 5000 CY
FABRIC FOR SOIL STABILIZATION = 1500 SY

SUMMARY OF EXISTING ASPHALT PAVEMENT REMOVAL

LINE	Station	Station	LOC LT/RT/CL	AREA SY
-L-	17+40.80	18+14.80	CL	283
-L-	19+20.80	20+28.80	CL	356
-DET-	14+73.68	22+87.55	CL	2,351
			TOTAL:	2,970
			SAY:	3,000 SY

APPROXIMATE QUANTITIES ONLY. UNCLASSIFIED EXCAVATION, FINE GRADING, CLEARING AND GRUBBING, AND REMOVAL OF EXISTING PAVEMENT WILL BE PAID FOR AT THE LUMP SUM PRICE FOR "GRADING".

"W" = DISTANCE FROM EDGE OF LANE TO FACE OF GUARDRAIL
TOTAL SHOULDER WIDTH = DISTANCE FROM EDGE OF TRAVEL LANE TO SHOULDER BREAK POINT.
FLARE LENGTH = DISTANCE FROM LAST SECTION OF PARALLEL GUARDRAIL TO END OF GUARDRAIL.
W = [illegible] BEGINNING OF TAPER TO END OF GUARDRAIL.
[illegible] IMPACT ATTEMUATOR = 350
[illegible] = NON-GATING IMPACT ATTEMUATOR = 350

GUARDRAIL SUMMARY

LINE	BEG. STA.	END STA.	LOC.	LENGTH STRAIGHT	LENGTH TEMP STRAIGHT	LENGTH DOUBLE FACED	WARRANT POINT APPR. END	WARRANT POINT TRAIL. END	"W" DIST FROM E.O.L.	TOTAL SHLDR WIDTH	FLAIR LENGTH APPR. END	FLAIR LENGTH TRAIL. END	W APPR. END	W TRAIL. END	ANCHORS TYPE III	ANCHORS GRAU 350	ANCHORS TEMP GRAU 350	IMP. ATTEN. TYPE 350 EA	IMP. ATTEN. TYPE 350 G	IMP. ATTEN. TYPE 350 NG	REMOVE EXISTING GRDRAIL	REMARKS
-L-	13+82.94	17+	RT	455.00			13+65.00	17+77.84	10	13	50		1		1	1					137.50	GR WARRANTED ALONG ENTIRE RT SIDE BEFORE BR.
-L-	13+82.94	17+	LT	475.00			17+77.94	13+00.80	10	13		50		1	1	1					137.50	GR WARRANTED ALONG ENTIRE LT SIDE BEFORE BR.
-L-	19+84.06	23+	RT	325.00			19+84.06	23+50.80	10	13		50		1	1	1					137.50	
-L-	19+84.06	22+	LT	380.00			21+93.00	18+84.86	10	13	50		1		1	1					137.50	
-L-	16+80.00		RT						10	13	50		1				1					REQUESTED BY TRAFFIC CONTROL
-L-		21+	RT						10	13		50		1			1					REQUESTED BY TRAFFIC CONTROL
-DET-	14+44.15	17+	RT		875.00		15+60.00	23+00.80	6	8	50	50	1	1			2					REMOVE -DET- TEMP GR.
-DET-	15+87.50	17+	LT		562.50		20+50.00	17+00.80	6	8	50	50	1	1			2					REMOVE -DET- TEMP GR.
SUBTOTAL:				1,575.0	1,437.5										4	4	8					
[illegible] ANCHORS DEDUCTED:																						
GRAU				50.00	-200.00																	
TYPE III	4			18.75	-75.00																	
TEMP GRAU	4			50.00		-200.00																
ANCHOR TOTALS:				-275.00	-200.00																	
GRAND TOTAL:				1,300.00 LF	1,237.50 LF										4	4	6				550.00 LF	
SAY:				1,300.00 LF	1,237.50 LF										4	4	6				550.00 LF	
ADDITIONAL GUARDRAIL POST:				5 EA																		

Quantity Summary Sheet – blow-up

LINE	BEG. STA.	END STA.
-L-	13+02.94	17+77.94
-L-	13+02.94	17+77.94
-L-	19+84.06	23+09.06
-L-	19+84.06	22+84.06
-L-	16+00.00	
-L-		21+50.00
-DET-	14+44.15	23+09.15
-DET-	15+87.50	21+50.00
SUBTOTAL:		

W		ANCHORS		
APPR. END	TRAIL. END	TYPE III	GRAU 350	TEMP GRAU 350
1		1	1	
	1	1	1	
	1	1	1	
1		1	1	
1				1
	1			1
1	1			2
1	1			2
		4	4	6

Need to re-establish tension in any altered guardrail – include in plan sheets

★ Placement of GRAU (GREU) must abide by standard application criteria (Deflection and Length of Need {LON})

Review Learning Outcomes

- Understand how barriers are tested for crashworthiness
- Identify common barrier systems of NCDOT
- Explain how these barrier systems function
- Define the key components of a transition (Structure Anchor Unit) design

Session 3:

Testing Requirements and Performance Characteristics of End Treatments and Impact Attenuators

Session 3 Learning Outcomes

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

- Understand how end treatments and impact attenuators are tested for crashworthiness
- Identify common end treatments and impact attenuators
- Understand how these systems function
- Choose the appropriate system for a specific site

Guardrail End Treatments (GREU)

A barrier end treatment must serve two functions:

- Provide the necessary TENSION of the guardrail system for downstream impacts
- Be crashworthy when impacted end-on.

Cable Anchor Terminal – MASH

- 2 Design Tested
- Both have a strut between last 2 posts

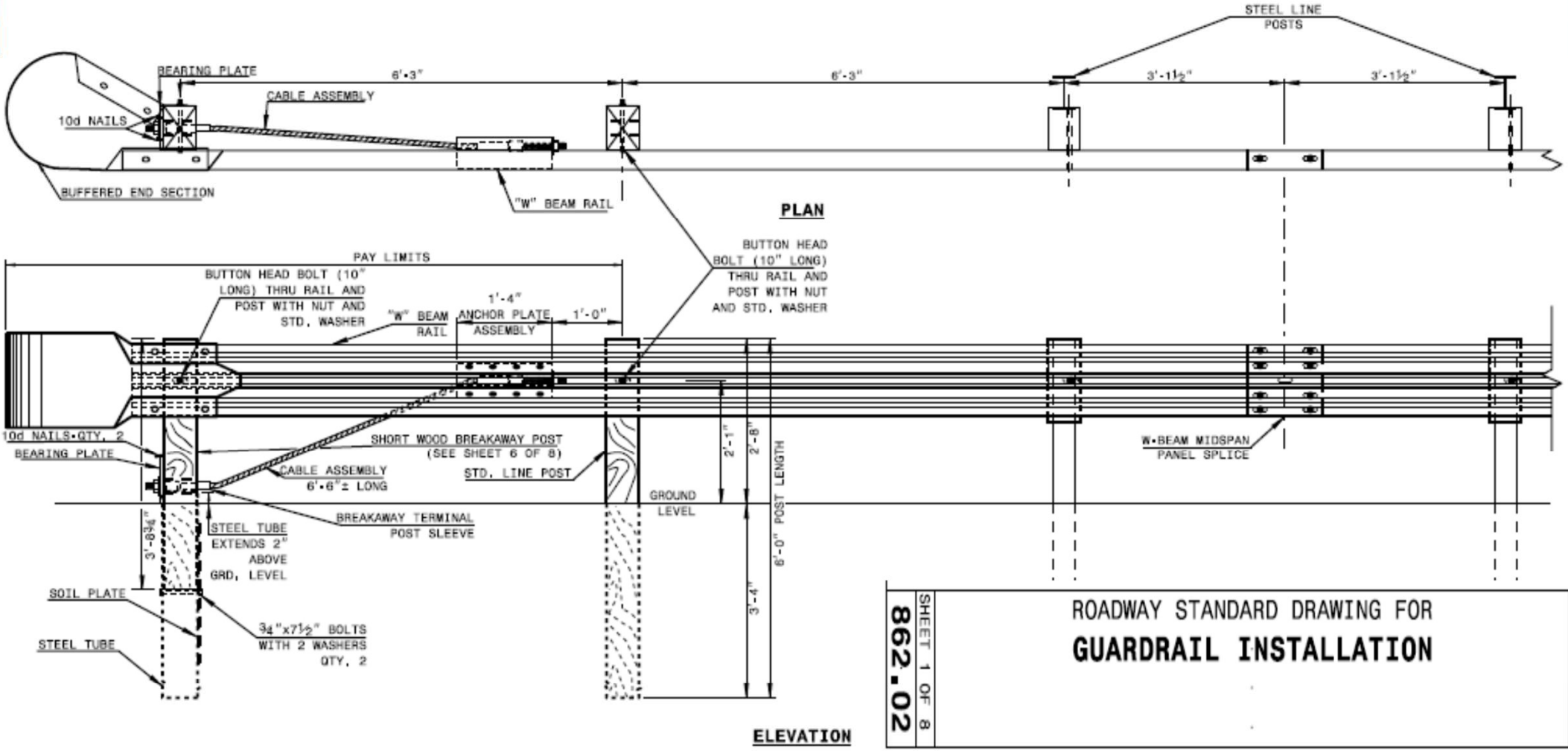
TxDOT Design
9’- 4 ½ “ rail element
Rail ends at last post

Eligibility Letter B-256

MwRSF Design
12’- 6” rail
Rail extends past last post

Cable Anchor Terminal - Tension

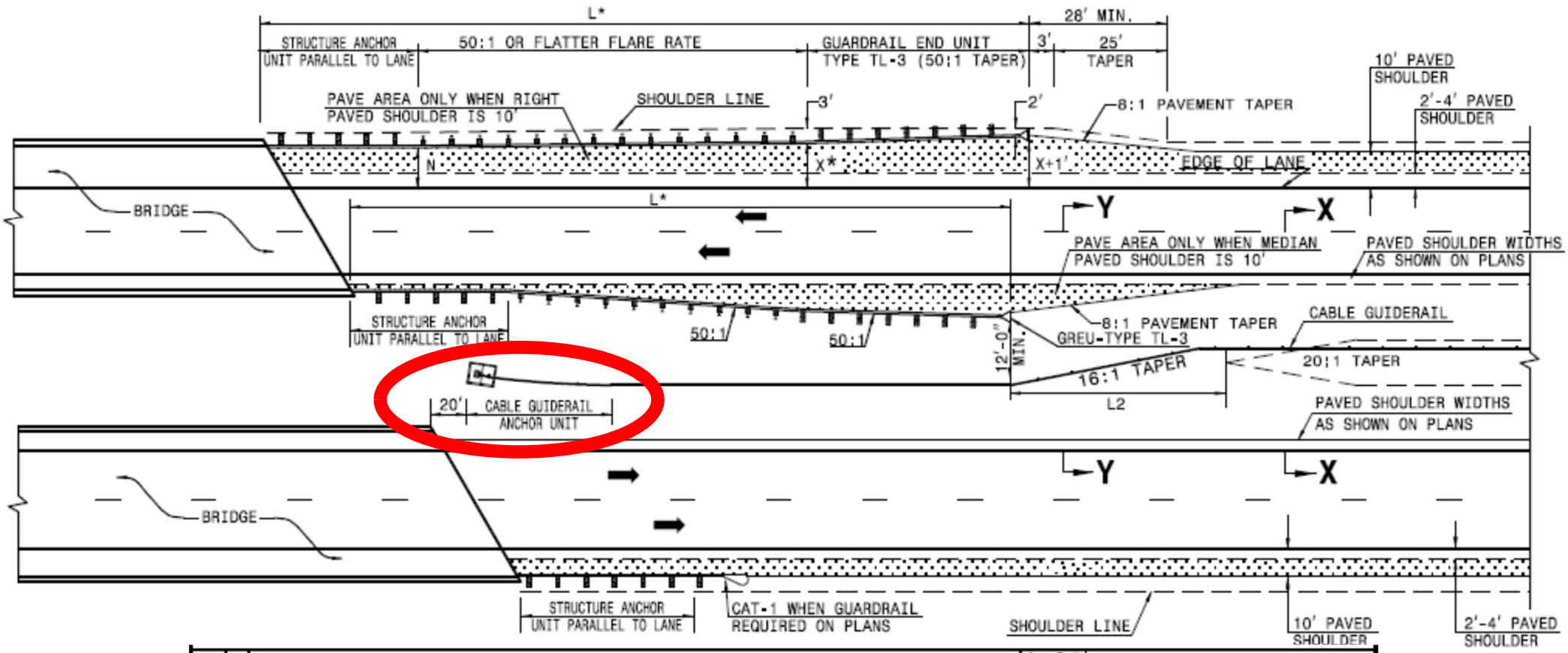
NC Cable Anchor – Not tested



TRAILING END UNIT ASSEMBLY

C.A.T.-1 SYSTEM

Cable Guiderail Anchor Unit Placement



865.01 SHEET 2 OF 12

ROADWAY STANDARD DRAWING FOR

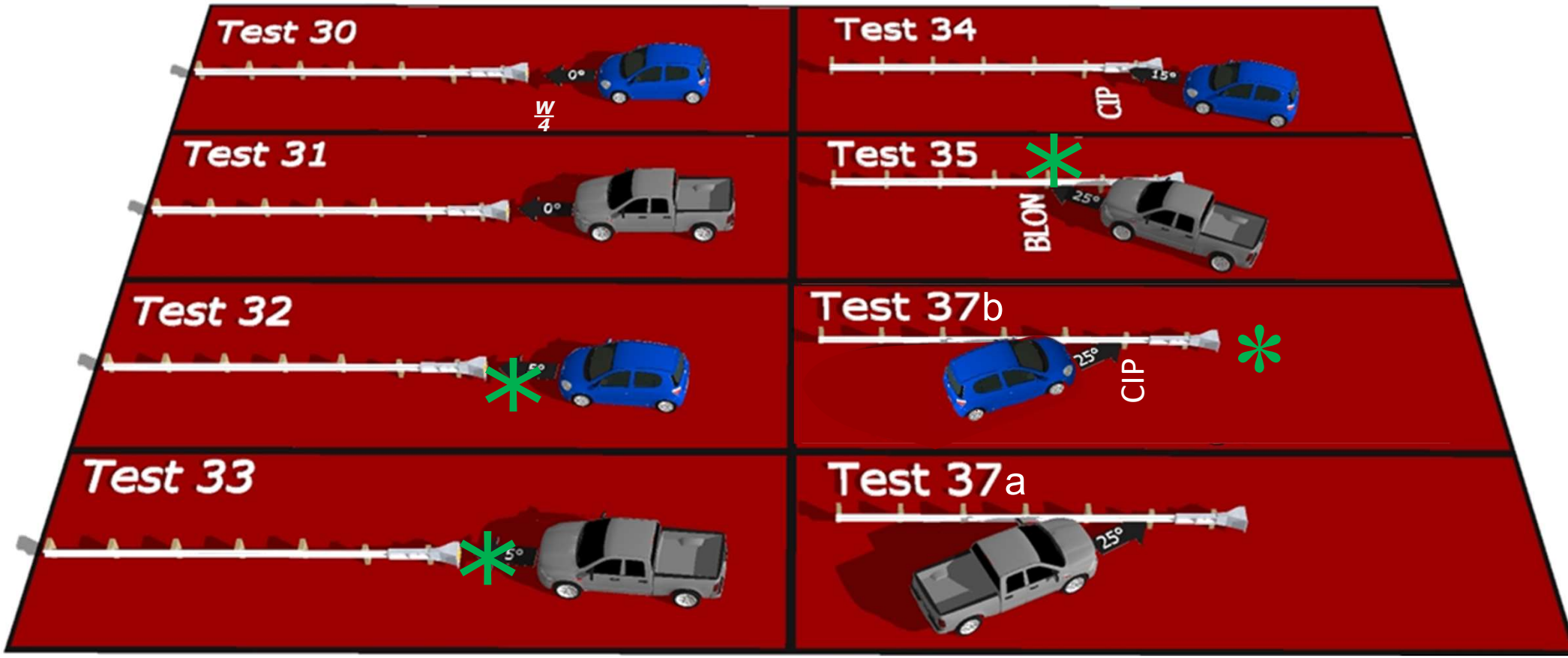
CABLE GUIDERAIL

DUAL LANE BRIDGES GUIDERAIL LAYOUT

1-24

STATE OF NORTH CAROLINA
DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS
RALEIGH, N.C.

End Treatment MASH Test Matrix



* Significant Change

* Small Car 1100C (2420 lbs.)

* Pickup Truck 2270P (5000 lbs.)

BLON – Beginning Length of Need

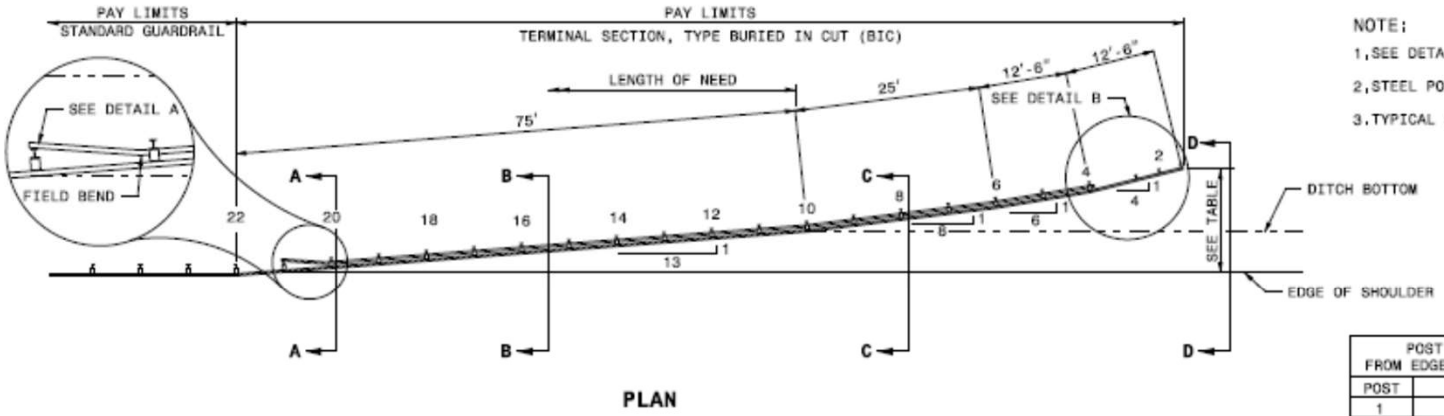
Guardrail End Treatments

Types of End Treatments

- Buried-in-Cut (Detail, not in Standards)
- Tangent terminals – terminal is parallel to the roadway or has a straight flare with a “slight” offset; all are Energy-absorbing
- Flared terminals – terminal is placed on a flare to the roadway typically 3’ or 4’; both non-energy- and energy-absorbing

MASH
Buried in Cut End Treatment

DRAWING NOT TO SCALE

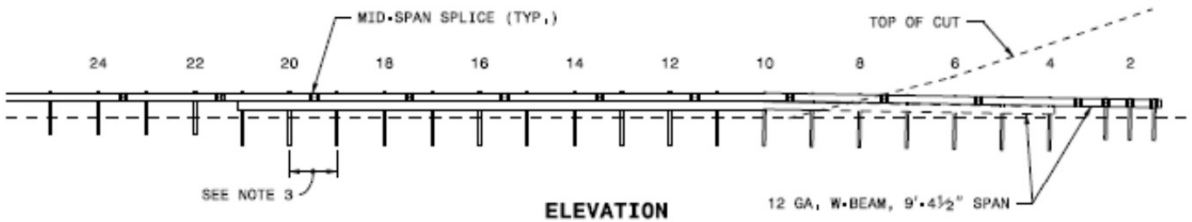


PLAN

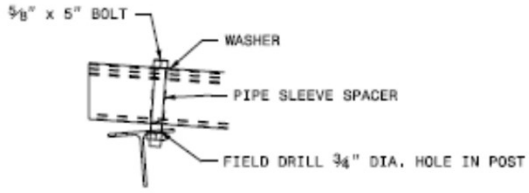
NOTE:

1. SEE DETAIL SHEET 2 OF 2 FOR OTHER DETAILS.
2. STEEL POSTS SHOWN.
3. TYPICAL POST SPACING IS 6'-3" UNLESS OTHERWISE NOTED.

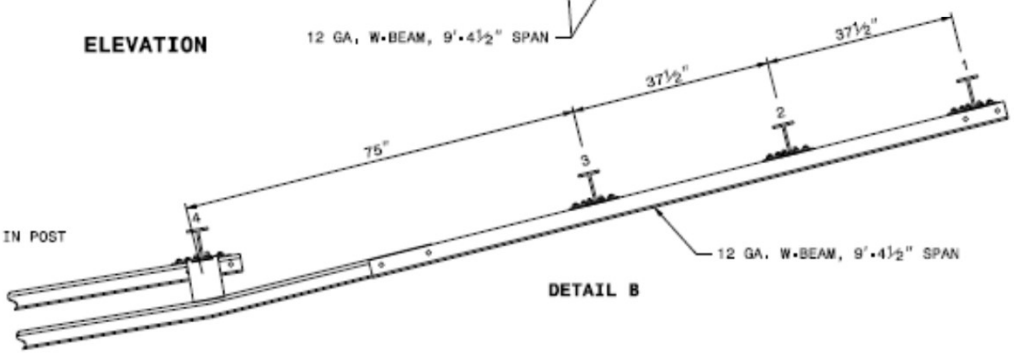
POST OFFSETS FROM EDGE OF SHOULDER	
POST	DISTANCE
1	13'-11¾"
4	10'-11"
6	8'-10¼"
10	69"



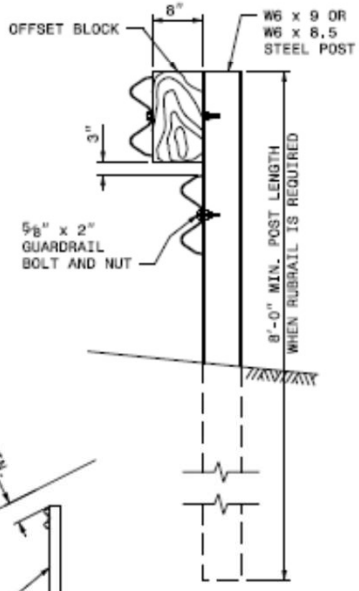
ELEVATION



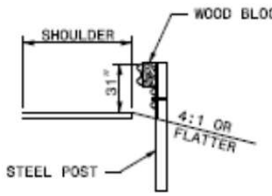
DETAIL A



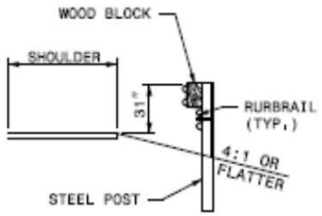
DETAIL B



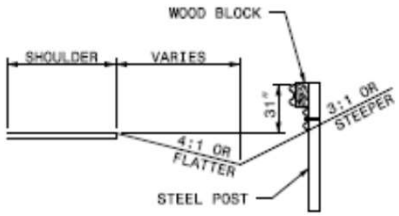
STEEL POST AND BLOCK DETAIL



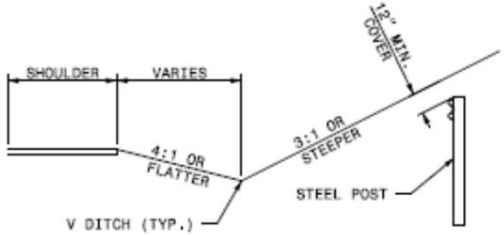
SECTION A-A



SECTION B-B



SECTION C-C



SECTION D-D

STATE OF
NORTH CAROLINA
DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS
RALEIGH, N.C.

1-24

ROADWAY STANDARD DRAWING FOR

GUARDRAIL PLACEMENT

BURIED IN CUT END UNIT

SHEET 14 OF 15

862.01

Buried-in-Cut End Treatment

- 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 (but a max height of ~47”)
  - Use a flare rate of 13:1 or flatter on the foreslope
  - Use an anchor of steel posts capable of developing the full tensile strength of the W-beam rail and buried 1’ below ground

BIC Looking Across Roadway

End Treatments - Terminology

CAT-1 – Cable Anchor Terminal – non-crashworthy device to develop Tension where there is no opportunity for end-on impacts

(AT-1 – Anchor Terminal – no cable)

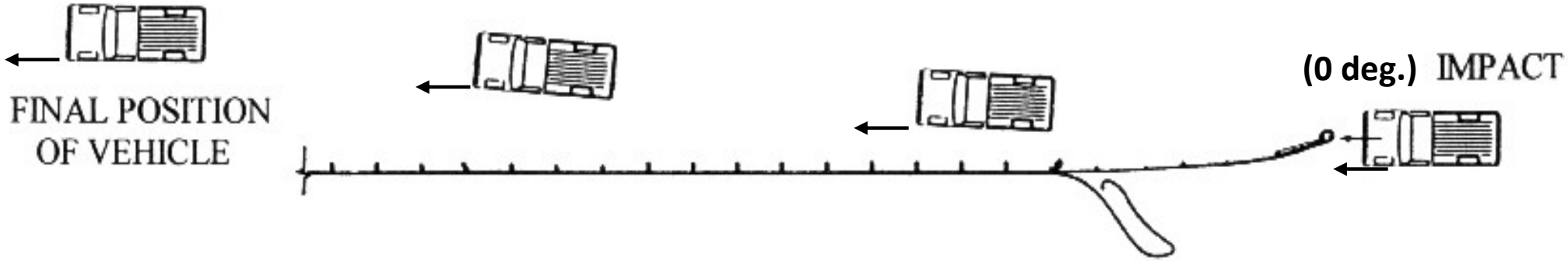
GREA – Guardrail End Anchor – crashworthy Pre-MASH devices

GREU – Guardrail End Unit – crashworthy MASH approved devices

End Treatments

Energy Absorbing Terminal

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



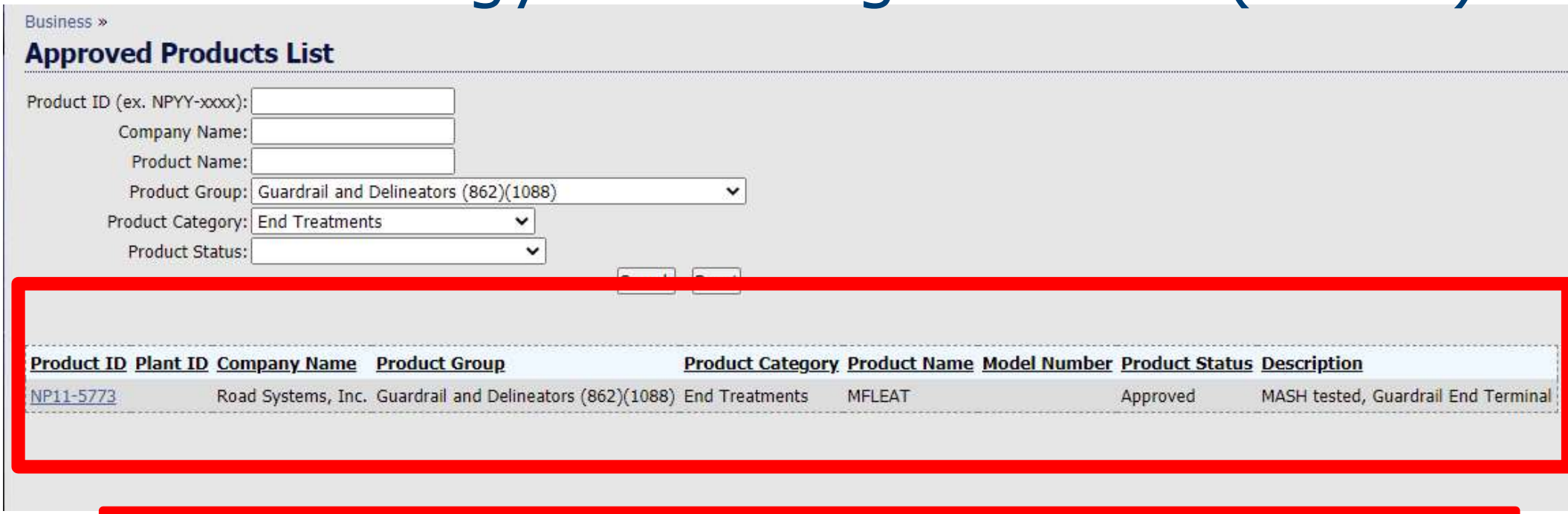
Non-Energy Absorbing Terminal

Controlled Buckling Terminal

(vehicle may travel hundreds of feet before stopping)

Flared End Treatments

Historically used, most recently the Slotted Rail Terminal (SRT) and Flared Energy Absorbing Terminal (FLEAT)



Business »

Approved Products List

Product ID (ex. NPYY-xxxx):
Company Name:
Product Name:
Product Group: Guardrail and Delineators (862)(1088)
Product Category: End Treatments
Product Status:

Product ID	Plant ID	Company Name	Product Group	Product Category	Product Name	Model Number	Product Status	Description
NP11-5773		Road Systems, Inc.	Guardrail and Delineators (862)(1088)	End Treatments	MFLEAT		Approved	MASH tested, Guardrail End Terminal

https://apps.ncdot.gov/vendor/approvedproducts/

Flared End Treatment: Energy Absorbing

- **MFLEAT** *MASH Version of FLEAT*
  - Curls the rail (by kinking) tightly towards the roadway.
  - Steel post system; BLON at 4th Post
  - TL-3 at 39’ 7” straight flared length. 3-ft. offset.
  - Cable-anchored, compression system

BLON – Beginning Length of Need

Ref: FHWA Eligibility Letter CC-143 dated 04/10/19

MASH
MFLEAT

Flared End Treatment: Non-energy-Absorbing

- SRT 350 (Slotted Rail Terminal)
  - W-Beam rails on a parabola or a straight line and horizontal slots in rail
  - Offset - 4’; 31” Height
  - 37’-6” long, BLON at Post 3
  - Cable-anchored system

Correct ONLY if LON and Grading Satisfied

Test 3-31: SRT

Because of the non-energy absorption, no hazard should exist within 150’ downstream of post #1


NOT GOOD!!!!!

Flared End Treatments on Flared Standard Run

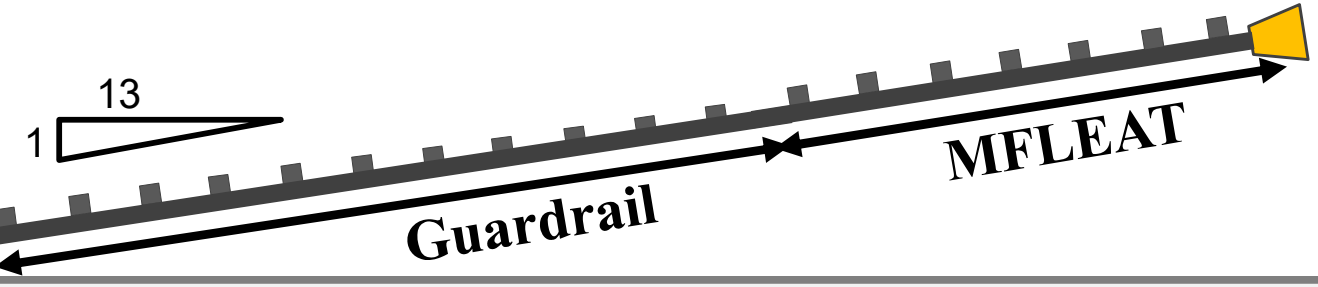
The flare of the end treatment is measured from a line parallel to the ROADWAY:

For Energy Absorbing (MFLEAT) which has a 13:1 flare, there may need to be a “kink” either toward or away from the roadway, depending on the flare of the standard guardrail

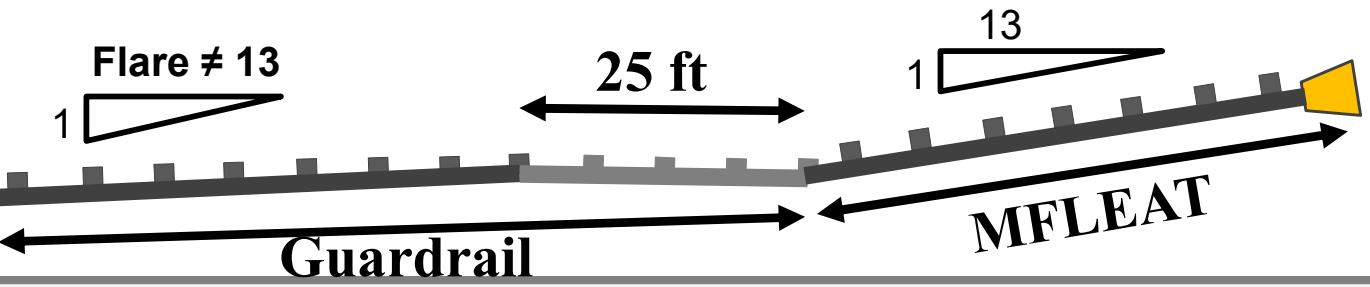
For the SRT 350, the offsets historically were measured from the standard flare extended

NCDOT guidance is to provide 25’ of parallel guardrail in advance of any end treatment requiring a kink.

Flared End Treatment on Flared Standard Run MFLEAT - Schematic

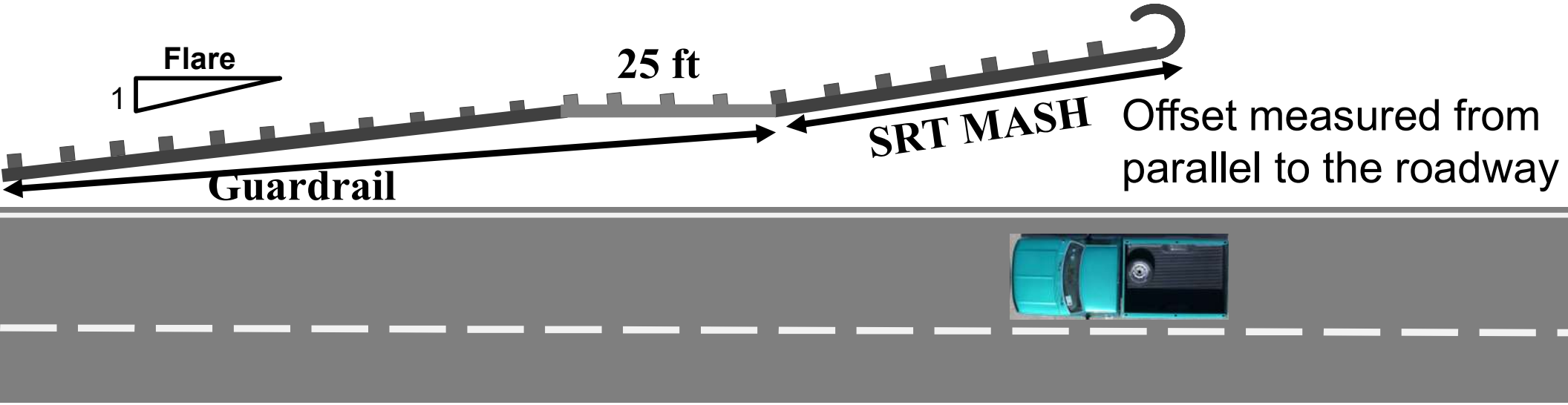


Flare of standard guardrail is 13:1



Flare of standard guardrail is not 13:1

Flared End Treatments on Flared Standard Run
SRT MASH - Schematic



Flared End Treatment Difference

- One is energy absorbing (currently MFLEAT)
- One could be non-energy absorbing (SRT)

What is **important** is to understand how the system works –a **FLARED** system should only be allowed if criteria have been met (LON and grading)

Tangent End Treatment

Approved Products List

Product ID (ex. NPYY-xxxx):
Company Name:
Product Name:
Product Group:
Product Category: End Treatments, Type MASH-16

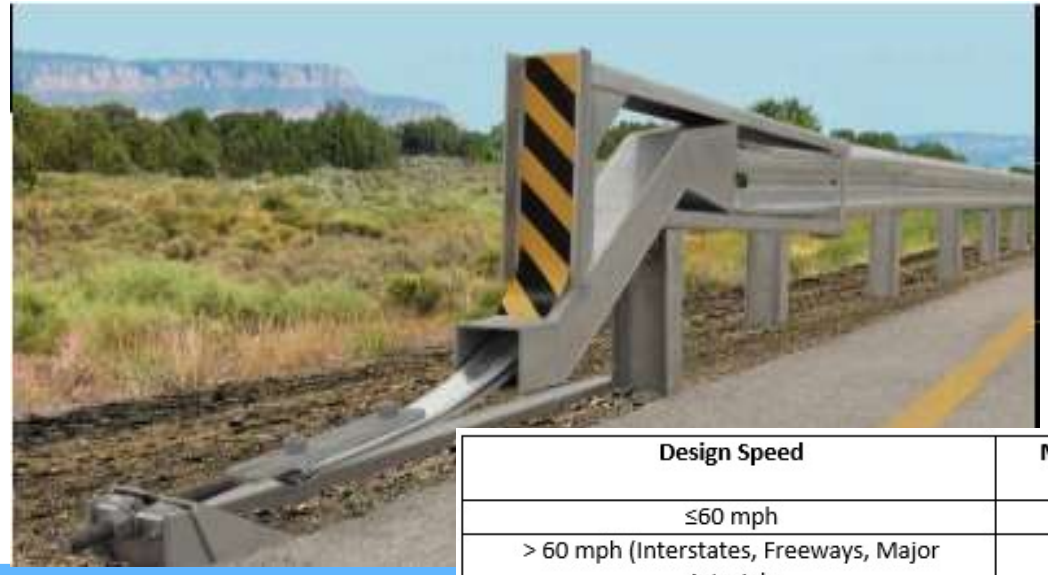
Product ID	Plant ID	Company Name	Product Group	Product Category	Product Name	Model Number	Product Status	Description
NP17-7819		Valtir, LLC	Guardrail and Delineators (862) (1088)	End Treatments, Type MASH-16	SoftStop Mash End Terminal		Approved	MASH tested;All steel galvanized tangent end terminal for use with 31" W-Beam system. Approved for TL-3 & TL-2 applicaitons.
NP17-7851		Road Systems, Inc.	Guardrail and Delineators (862) (1088)	End Treatments, Type MASH-16	MSKT		Approved	MASH tested;Guardrail End Terminal
NP18-8257		SPIG Industry, LLC	Guardrail and Delineators (862) (1088)	End Treatments, Type MASH-16	SGET		Approved	The SGET (SPIG Gating End Terminal) is a gating guardrail end terminal system in which an impact upon the head causes the head to move down the guardrail and dissipate the energy of the impact. The SGET system also deflects vehicles back onto the roadway

Product Category: End Treatments

NP17-7848	GR44	Lindsay Transportation Solutions	Guardrail and Delineators (862) (1088)	End Treatments	Max-Tension End Treatment		Approved	MASH tested;Telescoping, tension-based guardrail end terminal with an energy absorbing coupler that features a cutting tooth design.

Tangent End Treatment: Energy Absorbing

- Soft Stop (MASH)
  - Impact head slides along panels, crushing them vertically, absorbing the energy of the vehicle in shallow angle impacts – **works in tension**
  - TL-3 at 51’ long; BLON at 16’-6”; 31” only

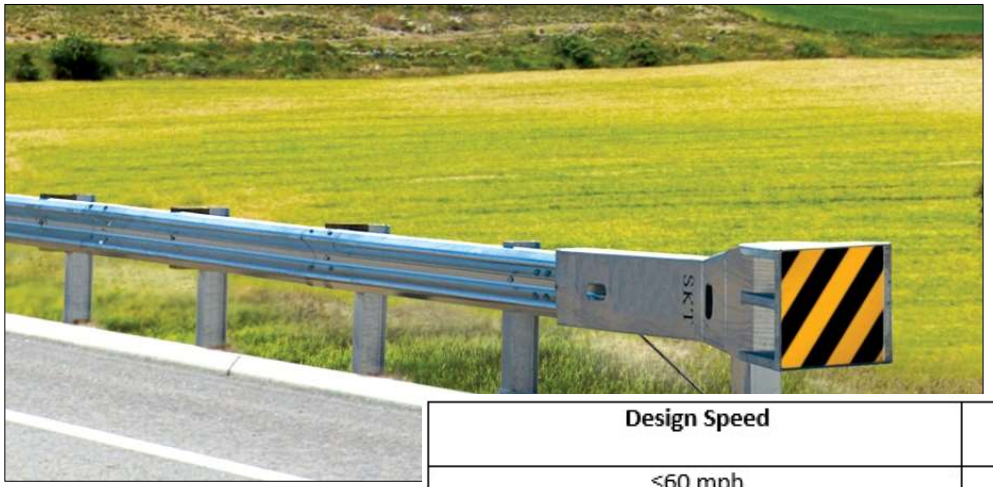


Design Speed	Minimum Length of Steel Beam Guardrail Between Structural Anchor and GREU
≤60 mph	12.5 feet
> 60 mph (Interstates, Freeways, Major Arterials	25 feet

MASH Soft Stop

Tangent End Treatment: Energy Absorbing

- MASH Sequential Kinking Terminal (MSKT)
  MASH Version of SKT
  - Kinks Guardrail when hit head-on or at a shallow angle
  - Steel post system; BLON at 3rd Post
  - TL-3 at 47’ long; attachment to 31” Guardrail
  - Cable-anchored system, Compression system



Design Speed	Minimum Length of Steel Beam Guardrail Between Structural Anchor and GREU
≤60 mph	12.5 feet
> 60 mph (Interstates, Freeways, Major Arterials	25 feet

MASH MSKT

Tangent End Treatment: Energy Absorbing

- SPIG Gating End Terminal (SGET) (MASH)
  - Flattens guardrail when hit head-on or at a shallow angle
  - Steel and wood post system; BLON at 3rd Post
  - TL-3 at 47’ long; attachment to 31” MGS Barrier
  - Cable-anchored system, Compression system

No FHWA Eligibility Letter

MASH SGET – Test 3-31

Tangent End Treatment: Energy Absorbing

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

MASH MAX-Tension

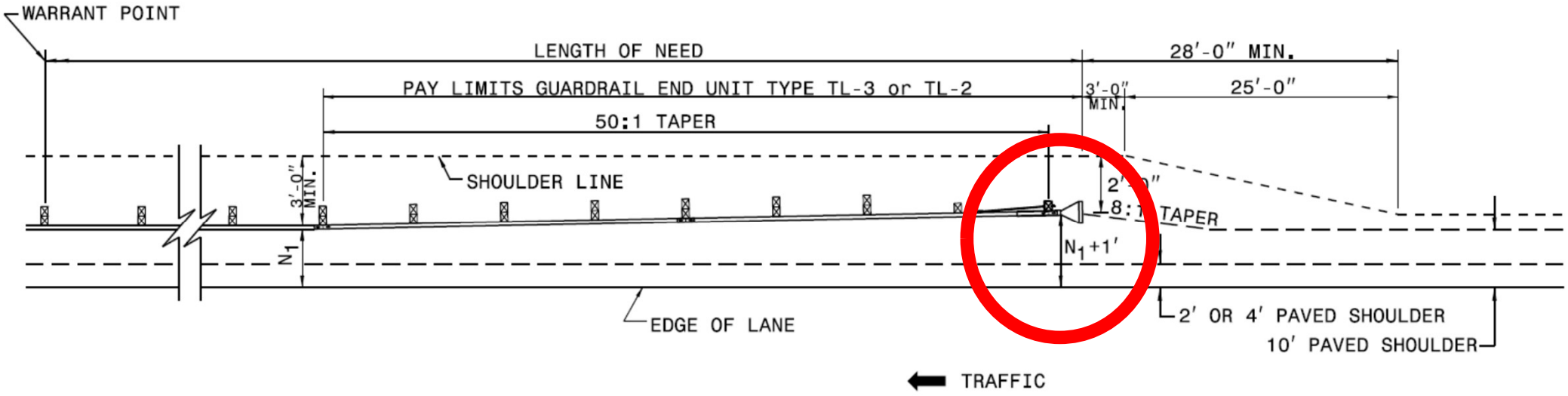
6.9 Guardrail End Units

Guardrail End Unit Test Level 2 and Test Level 3 (GREU-TL-2 and TL-3) – The GREU TL-2 and TL-3 are tangential end units used parallel to the travel way. Flare these units over the last 50 feet to provide a 1 -foot offset. GREU-TL-2 (25 feet long) can be used when design speeds are 44 mph or less. GREU TL-3 (50 feet long) can be used when design speeds are 45 mph or greater.

Tangent End Treatments – End Offset

862.01 SHEET 6 OF 15

ROADWAY STANDARD DRAWING FOR
GUARDRAIL PLACEMENT



FOR POSTED SPEEDS ≥ 45mph USE GREU TYPE TL-3
FOR POSTED SPEEDS < 45mph USE GREU TYPE TL-2

Tangent End Treatments on Flared Standard Run

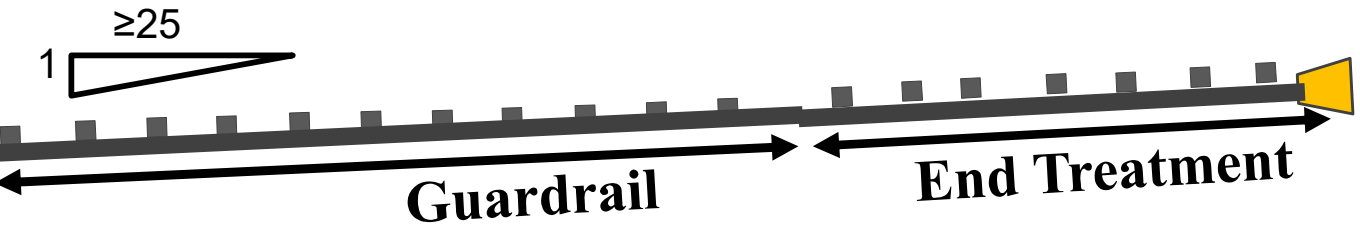
The offset of the end treatment is measured from a line parallel to the ROADWAY:

If the standard flare is 25:1 or flatter, the end treatment may be placed on the standard flare line extended

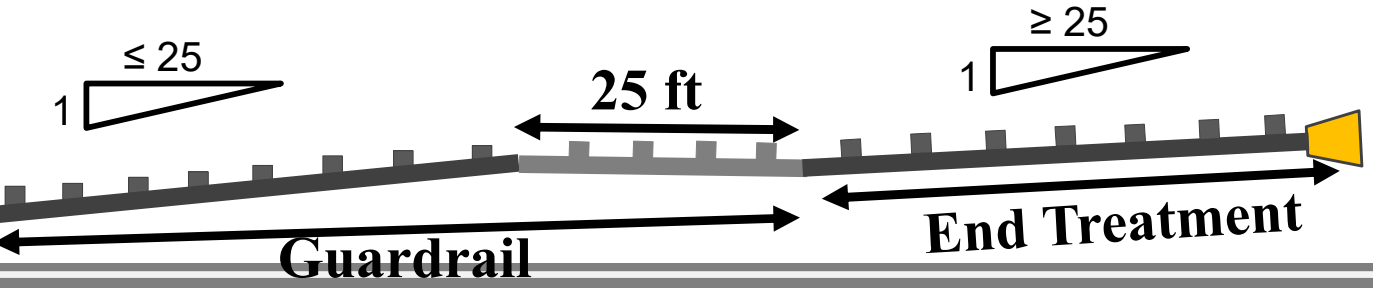
If the standard flare is sharper than 25:1, a kink in the run must be provided so the end treatment is no sharper than 25:1

NCDOT guidance is to provide 25’ of parallel guardrail in advance of any end treatment requiring a kink.

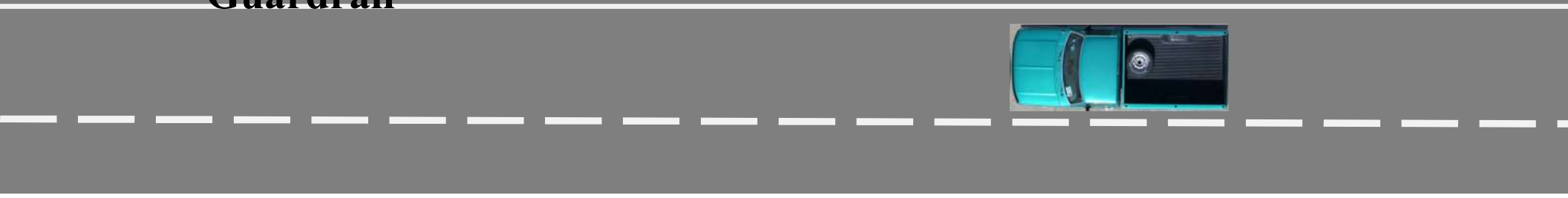
Tangent End Treatments on Flared Standard Run Schematic



Standard Run Flare of 25:1 or flatter



Standard Run Flare is sharper than 25:1



INSTALLATION

MUST HAVE MANUFACTURER'S SHOP DRAWINGS AND INSTALLATION MANUAL TO INSTALL / INSPECT ANY OF THE PROPRIETARY END TREATMENTS

Terminals: Energy Absorbing

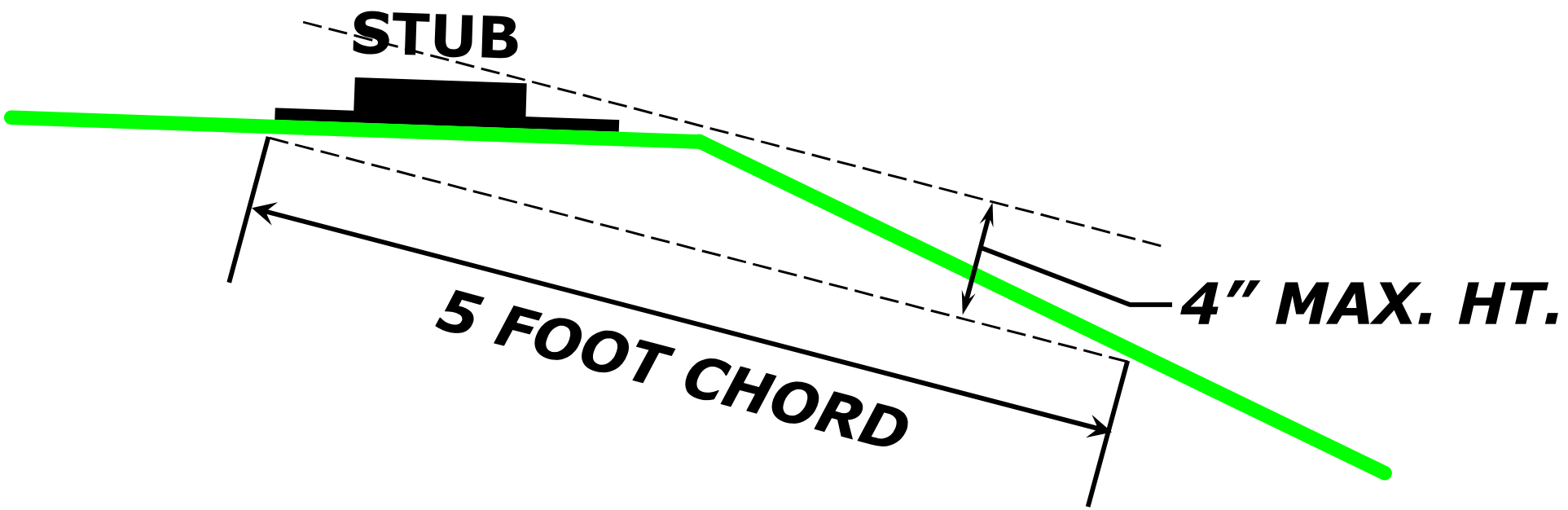
Terminal MUST be installed on a straight line

End Treatment Grading

- Special grading requirements for guardrail end treatments:
  - Flat terrain (10:1 or flatter) is required *in* **ADVANCE** *of all end treatments* so that vehicles are relatively stable on approach
  - Flat grading must extend *behind* post 1 (**ADJACENT**) so vehicle is stable at impact ***and*** stub height criteria is satisfied

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



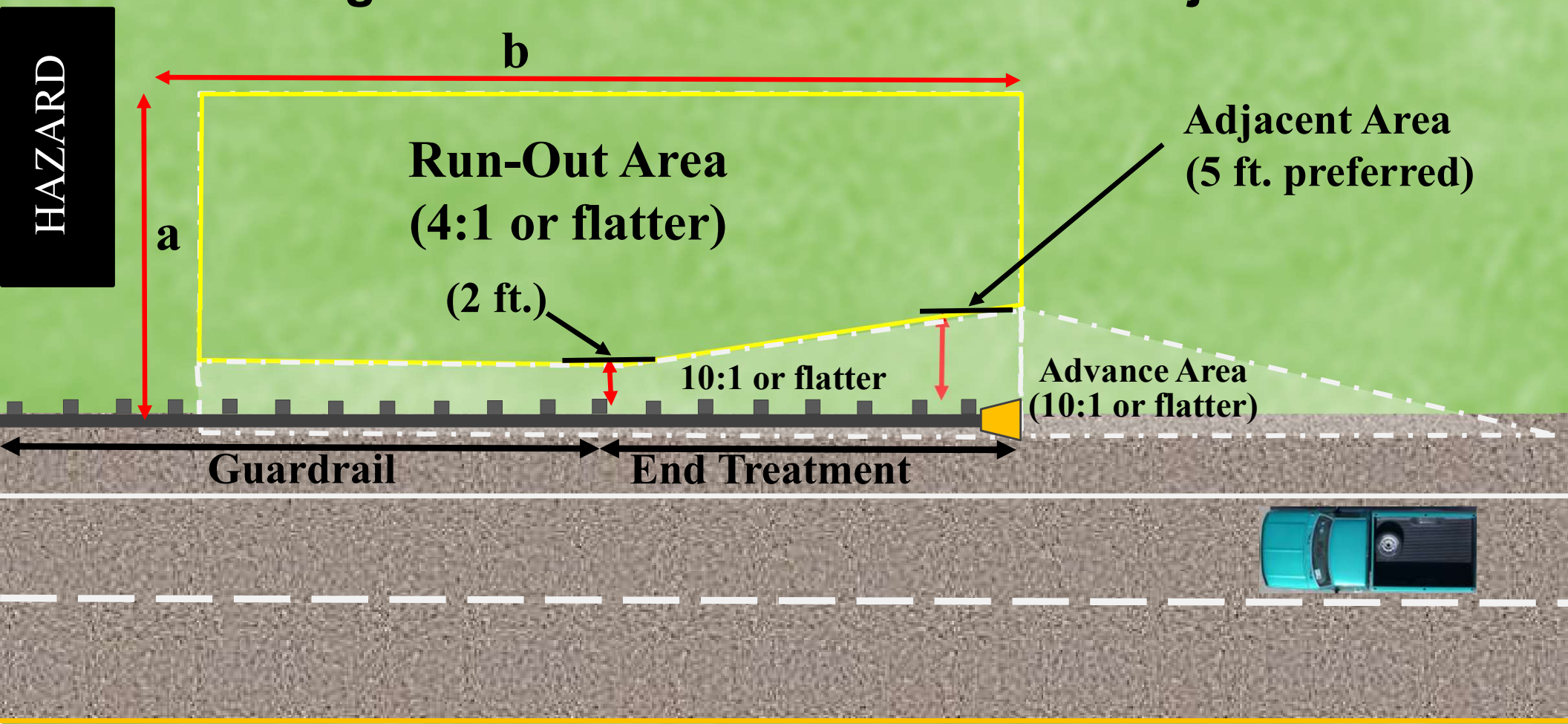
Ref: AASHTO Roadside Design Guide, 4th Edition – Figure 4.1

End Treatment 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 minimum longitudinal recovery obstacle-free area behind and beyond a terminal should be approximately 75 ft. long.

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

Grading for New and Reconstruction Projects



a – Extend out to clear zone when practical; if not, it should be at least as wide as area upstream of the end treatment.

b – Length of Need (LON); when LON cannot be provided due to site conditions, a minimum of 75' from post 1 may be acceptable

Flared End Treatment Grading - AASHTO

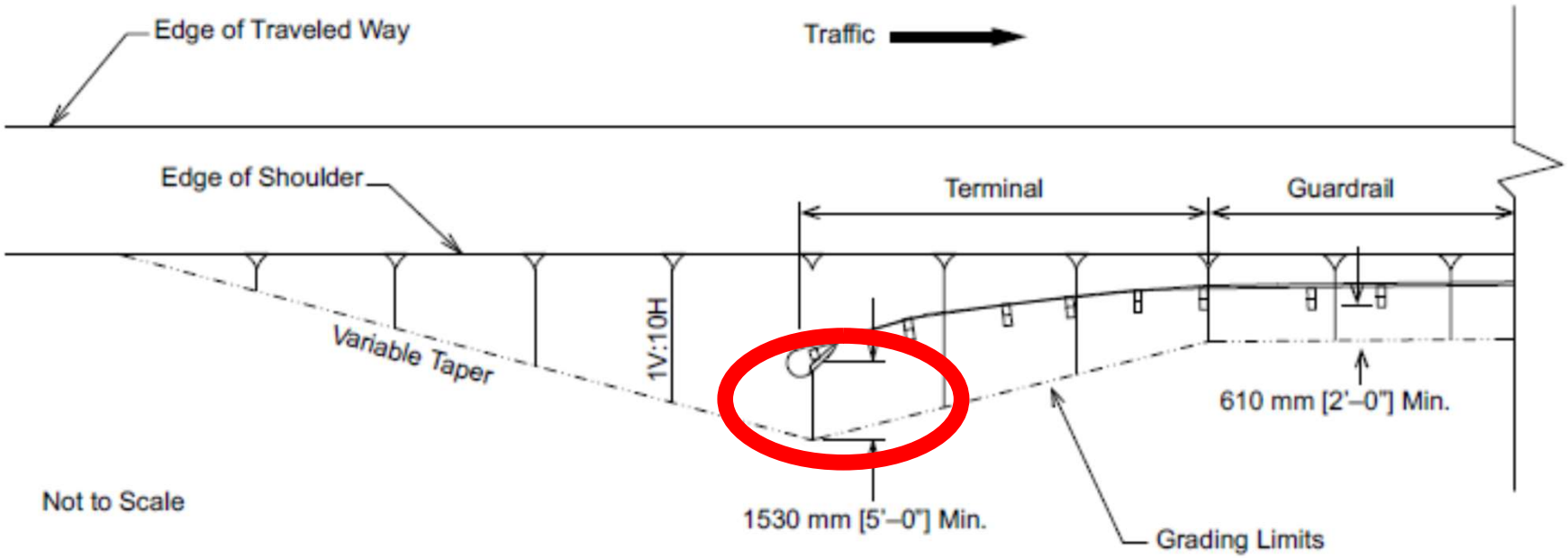
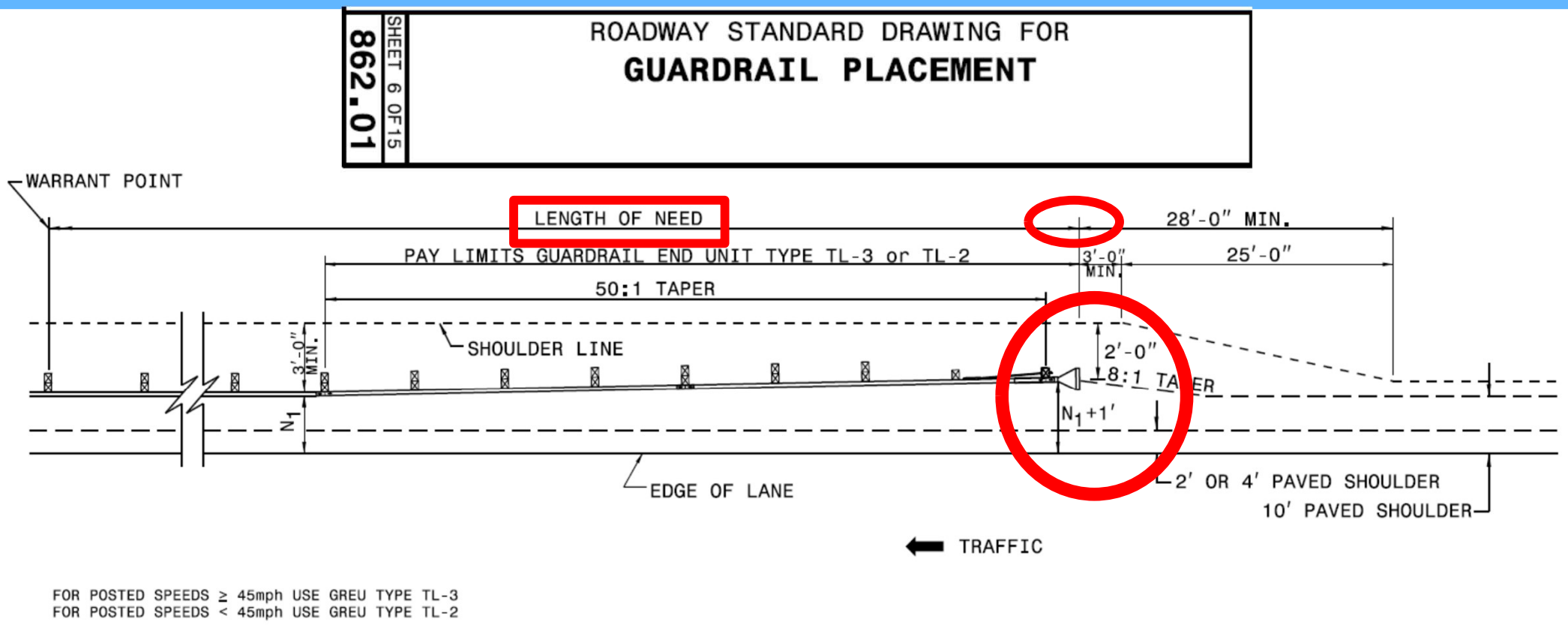


Figure 8-2. Grading for Flared Guardrail Terminal

Must have this full grading if a flared end treatment is used

Tangent End Treatment Grading - NCDOT

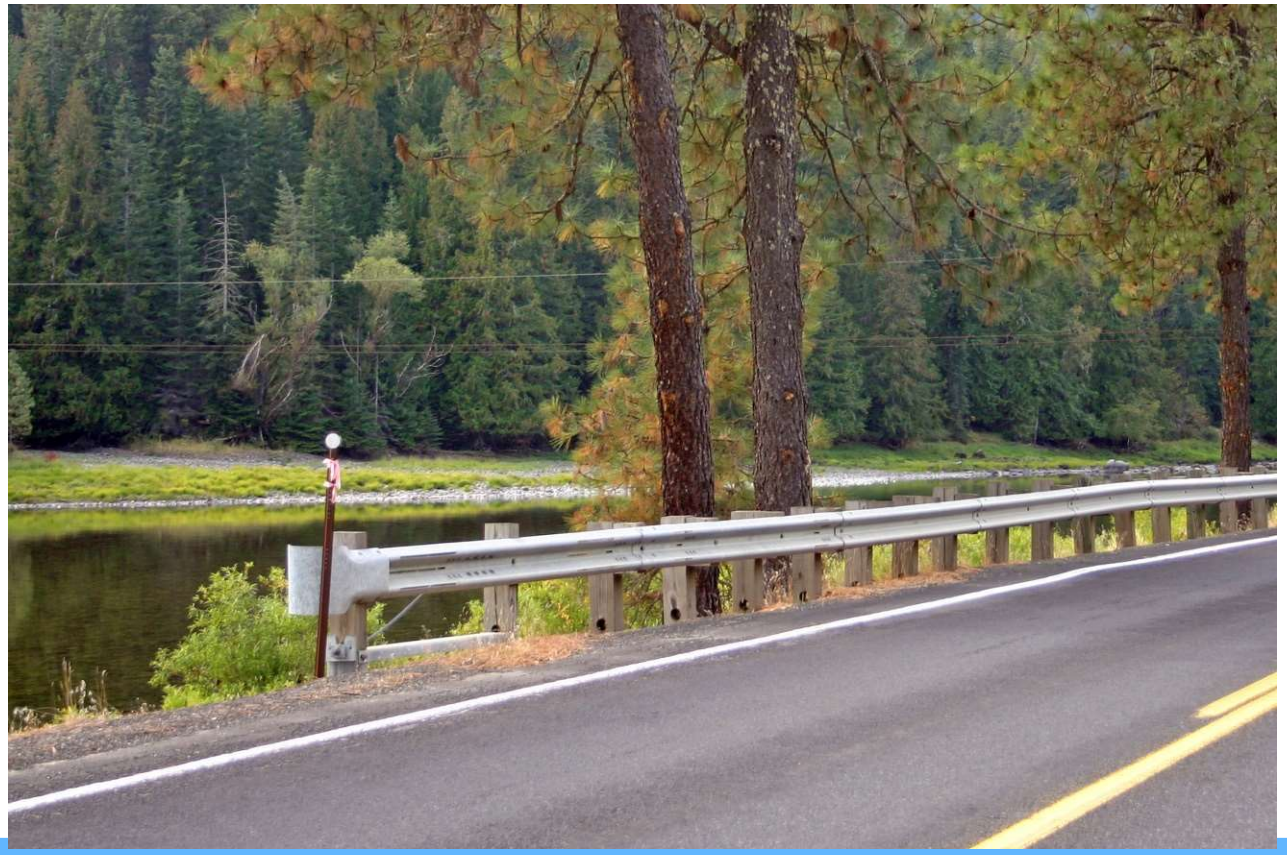


Need special Borrow bid item for 3R projects

Need Special Provision for Density

Thing to Remember about End Treatments

Non-Energy Absorbing End Treatments will not shield objects directly behind and within End Treatment limits



Thing to Remember about End Treatments

Even Energy Absorbing End Treatment will not shield objects directly behind and within End Treatment limits

EXISTING END TREATMENTS (OTHER THAN SRT 350)

Tangent Guardrail End Treatment
Energy Absorbing

- SKT 350 (Sequential Kinking Terminal)(NCHRP 350)
  - Kinks panels when hit head-on or at a shallow angle
  - Wood or Steel post system (many options)
  - TL-3 at 50’ long; BLON at 3rd Post
  - Cable-anchored, Compression system

Ref: FHWA Eligibility Letter CC-88 dated 3/8/05

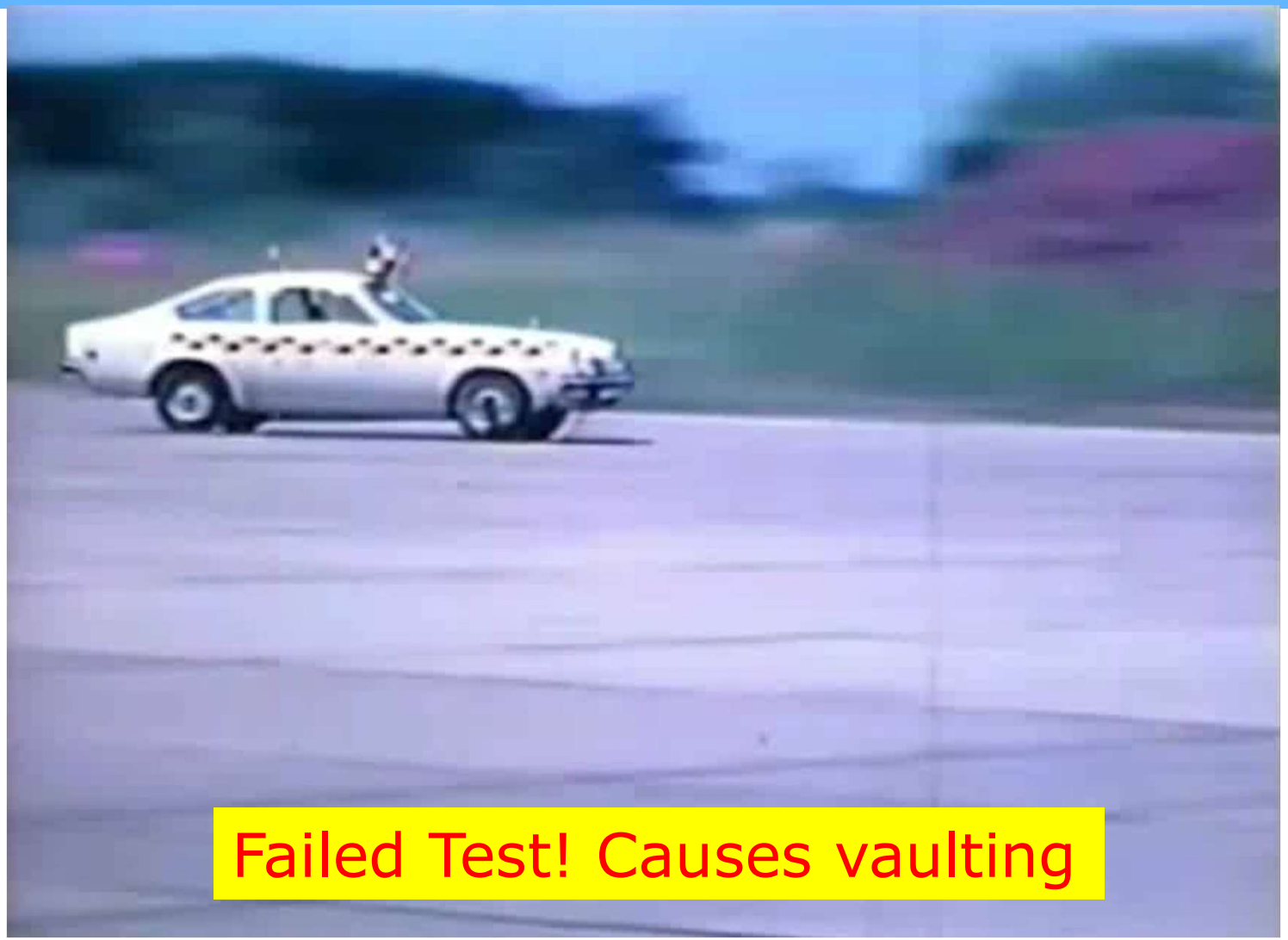
Tangent Guardrail End Treatment
Energy Absorbing

- ET Plus (Guardrail Extruder Terminal)(NCHRP 350)
  - Flattens the rail element when hit head-on
  - Weakened wood or [illegible] (several option[illegible])
  - 50’ long[illegible] either height w[illegible]m
  - [illegible]at 3rd Post
  - Cable-anchored, compression system

PARTS NO LONGER AVAILABLE

Ref: FHWA Eligibility Letter CC-12Q dated 3/15/10

Turndown



Non-crashworthy End Treatment
BCT Terminal

- Breakaway Cable Terminal (BCT) NCHRP 230
  - W-Beam rail with a parabolic curve and 4-ft offset.
  - No impact head or ground strut between the two end posts.
  - Only two breakaway posts.
  - Rail bolted to all posts.

For Identification Only

Non-crashworthy End Treatment
BCT Terminal

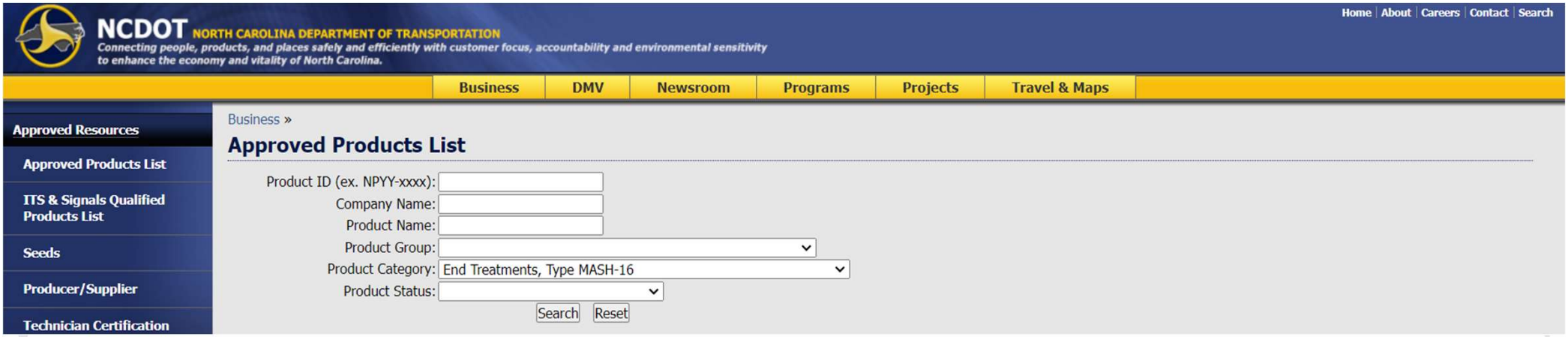
Guardrail End Treatments: Non-energy Absorbing – For Identification Only

- MELT – Modified Eccentric Loader Terminal
  - W-Beam rail with an accentuated parabolic curve and 4-ft offset.
  - Strut between the steel tubes foundation of the two end posts.
  - 37’-6” long with 8 breakaway posts; BLON at Post #3.
  - No rail-to-post bolts except at posts 1 and 8 and beyond.

For Identification Only

(NCHRP 350 TL-2)

Guardrail End Treatments: W-Beam Median



NP22-9059	GR7	Valtir, LLC	Guardrail and Delineators (862) (1088)	End Treatments, Type MASH-16	MATT□	Approved	The MATT□ is a MASH 2016 TL-3, tangent, double-sided, redirective/gating and energy absorbing attenuator/end terminal.

NP18-8095	Lindsay Transportation Solutions	Guardrail and Delineators (862)(1088)	End Treatments	MAX-Tension Median Guardrail Terminal	Approved	MASH Tested, telescoping, tension-based terminal with an energy absorbing coupler that features a cutting tooth design.

MASH Terminals: W-Beam Median

- MATT (Median Attenuating TREND Terminal) (MASH)
  - The MATT is similar to the CAT, utilizing special HS bolts to tear tabs between multiple slots in 6”-3” rail panels upon head-on impact
  - Cable-anchored, compression system; BLON at Post 3

MATT Terminal Video

MASH Terminals: W-Beam Median

- MAX-Tension Median (MASH) – TL-3
  - The MAX system utilizes cables, telescoping panels, and a cutting tooth to absorb the kinetic energy
  - TL-3 at 50’ long; BLON at 9’-4 ½” from post 1; 31” only
  - Has rail elements on both sides

Ref: FHWA Eligibility Letter CC-141 dated 01/10/2018

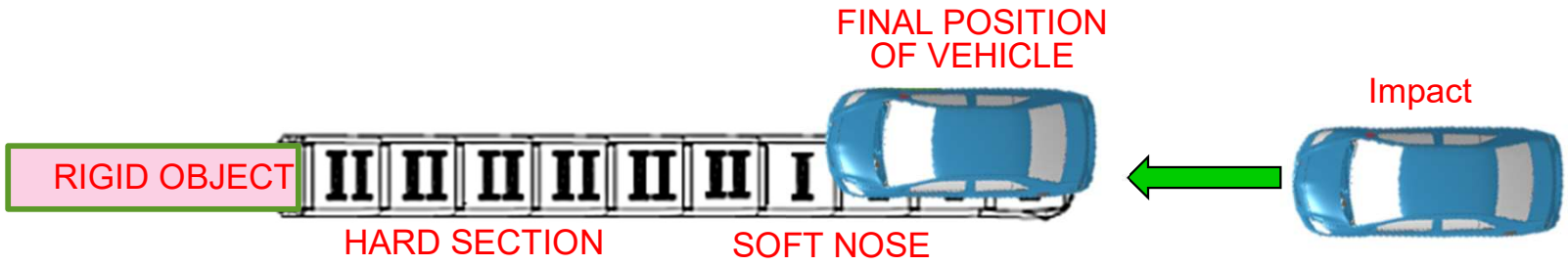
Impact Attenuator

Crash test with blunt end – Video:

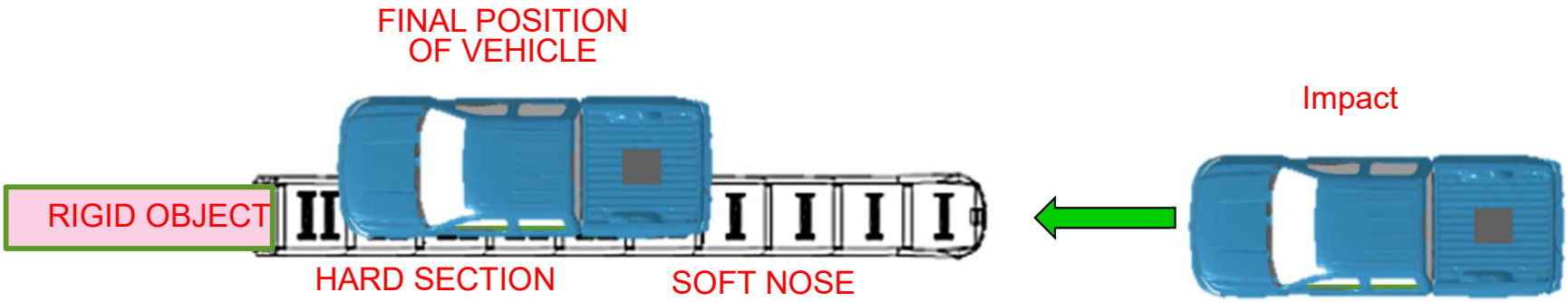
Impact Attenuator

Crash test with ramped end – Video:

Impact Attenuator Theory



Soft nose to bring a small car to a controlled stop



Harder back section to bring a pick-up truck to a controlled stop

Impact Attenuator, Sacrificial - Water Filled

- Water-filled Barriers

  <u>Absorb M (MASH)</u> / <u>Sled(MASH</u>) / ACZ 350 / TRITON CET

  - Individual crash cushion designs vary by manufacturer, but they all function in a similar manner.
  - Vehicles impacting the nose at an angle will **not** be redirected.
  - No appreciable re-directive capability under most impact conditions.
  - Typically used in work zones to shield temporary concrete barrier.

Impact Attenuator, Sacrificial - Water Filled

Approved Products List

Product ID (ex. NPYY-xxxx):
Company Name:
Product Name:
Product Group:
Product Category: WZTC - Category III

NP11-5771		Lindsay Transportation Solutions	Work Zone Traffic Control	WZTC - Category III	Absorb 350		Approved for Provisional Use	*Must be approved by Steve Kite (919-814-4937) prior to use on NCDOT project.* The ABSORB 350 is a non-redirective, gating water filled crash cushion that has been successfully tested to NCHRP Report 350 TL-2&3.
NP11-5884		TrafFix Devices, Inc.	Work Zone Traffic Control	WZTC - Category III	SLED	Series 45044	Approved	PE Water Filled Crash Cushion w/Galvanized Steel Cables molded inside.NCHRP-350 for Test Level 1,2or3.Use as end treatment/crash cushion.
NP16-7335		Trinity Highway Products	Work Zone Traffic Control	WZTC - Category III	ACZ-350 Water Filled Crash Cushion	ACZ-350	Approved for Provisional Use	The ACZ-350 is a narrow, non-redirecting TL-2 and TL-3 impact attenuator
NP99-3106	GR10	Energy Absorption Systems, Inc.	Work Zone Traffic Control	WZTC - Category III	Triton Barrier	Triton Barrier	Approved	The Triton Barrier® is a highly portable, water-filled barrier. Performance meets the FHWA NCHRP 350 TL-2 or TL-3 (with TL-3 kit) standard for longitudinal re-directive barrier. The Triton Barrier is certified as its own end treatment.

Impact Attenuator, Sacrificial - Water Filled

Absorb M (MASH)

ACZ-350

Sled (MASH)

TRITON barrier CET

Water Filled

Impact Attenuator, Sacrificial – Sand Barrel

Non-Redirective and Gating

- 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
- Impacting vehicles will not be redirected.
- Since no re-directive capability, the corner of the hazard must be reasonably shielded.

Impact Attenuator, Sacrificial – Sand Barrel

- Sand Barrels:

Energite

TrafFix Big Sandy (MASH)

Not Normally Used

CrashGard (MASH)

Sand Barrels – Good Application

Sand-Filled Array

NCDOT Impact Attenuator Selection

“For median width less than or equal to 40’ use NON-GATING IAU’s. For median width greater than 40’ may use GATING or NON-GATING IAU’s”

Impact Attenuators, Non-Gating

Non-gating as follows:

- Contains and redirects vehicles impacting along the sides of the device essentially its entire length
- Contains vehicles impacting the nose either head-on or at a 15º angle.
- Approved for TL-2 (350) & TL-3 systems.
- Designed to shield a point hazard; either attached or stand alone.

Use MASH passed Systems if Available

Impact Attenuators, Non-Gating

Approved Products List

Product ID (ex. NPYY-xxxx):

Company Name:

Product Name:

Product Group:

Product Category: Impact Attenuators, Non-Gating

NCHRP 350 - Allowed if Conditions Mandate

NP03-4111	Trinity Highway Products	Guardrail and Delineators (862)(1088)	Impact Attenuators, Non-Gating	WIDE TRACC	N/A	Approved for Provisional Use	the WideTRACC is test level 3 crash cushion and is avaliable in varying lengths and widths. can be configured for any appropriate width application.

Impact Attenuators, Non-Gating - MASH

Approved Products List

Product ID (ex. NPYY-xxxx):
Company Name:
Product Name:
Product Group:
Product Category: Impact Attenuators, Non-Gating

NP19-8389		Lindsay Transportation Solutions	Guardrail and Delineators (862) (1088)	Impact Attenuators, Non-Gating	Universal TAU-M		Approved	MASH compliant re-directive, non-gating anchored, partially reusable compression-based crash cushion
NP19-8510		Valtir, LLC	Guardrail and Delineators (862) (1088)	Impact Attenuators, Non-Gating	QuadGuard® M10 24in Wide	QM10024	Approved	MASH tested, redirective, non-gating crash cushion. Test Level 3, 24in wide.
NP20-8730	GR43	Valtir, LLC	Guardrail and Delineators (862) (1088)	Impact Attenuators, Non-Gating	QuadGuard M10 24in TL-2	QM7024	Approved	MASH tested, redirective, non-gating crash cushion. Test Level 2.
NP20-8836	GR43	Valtir, LLC	Guardrail and Delineators (862) (1088)	Impact Attenuators, Non-Gating	QuadGuard® M Wide	QM10069	Approved	The QuadGuard® M Wide is a MASH 2016, Test Level 3 compliant redirective, non-gating crash cushion used to shield fixed objects up to 69in (1753 mm) wide, and has various transition options.
NP21-8875		SMA Road Safety s.r.l.	Guardrail and Delineators (862) (1088)	Impact Attenuators, Non-Gating	Hercules	Hercules TL3	Approved	All Steel Crash Cushion - Non-Gating, Redirective, Energy Absorbing, Low Maintenace, Double sided - Bidirectional
NP21-8926		TrafFix Devices, Inc	Guardrail and Delineators (862) (1088)	End Treatments, Type MASH-16	Delta□ Cr Cushion			

Under category "End Treatments, Type MASH-16"

Impact Attenuators, Non-Gating

- TAU-M (MASH) 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 (350)
  - Consists of Thrie-beam panels, expendable (MASH) or self-restoring (R) (350) absorbing cartridges, steel diaphragms and two cables at the bottom to provide redirection.

Impact Attenuators, Non-Gating

- QuardGuard M10 (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 if damaged
  - M10 has metal nose, available at 24” & 69” widths
  - (350 available in widths from 24 to 36 inches with parallel sides and 69 or 96 inches with flared sides)

REF: FHWA Eligibility Letters CC-35M dated 3/29/16 350 CC-121 dated 7/30/12 MASH

Crash Cushions– Reusable

- HERCULES (MASH)
  - 23” width, 19’-5” long
  - Comes pre-assembled

FHWA Letter CC-156

Crash Cushions– Reusable

- DELTA (MASH)
  - DELTA is 30” width, 21’ long
  - Attenuates energy evenly for all vehicle types with shear bolts tearing through cut-outs of various sizes and shapes

Pre-Impact Panel

Post-Impact Panel

Impact Attenuators, Non-Gating - Typical

Impact Attenuators, Life Cycle - MASH

Approved Products List

Product ID (ex. NPYY-xxxx):
Company Name:
Product Name:
Product Group:
Product Category: Impact Attenuators, Life Cycle

Product ID	Plant ID	Company Name	Product Group	Product Category	Product Name	Model Number	Product Status	Description
NP16-7403		Valtir, LLC	Guardrail and Delineators (862) (1088)	Impact Attenuators, Life Cycle	Quadguard Elite	N/A	Approved for Provisional Use	**Contact NCDOT Mobility and Safety Field Operations prior to use at 919-773-2800**The QuadGuard Elite System offers the added value of reusable cylinders for applications with above average impact frequency. After a typical design impact, the system is
NP16-7404		Hill and Smith	Guardrail and Delineators (862) (1088)	Impact Attenuators, Life Cycle	Smart Cushion Innovations Crash Cushion	SCI100GM	Approved	Test Level III Crash Attenuator
NP16-7405		Hill and Smith	Guardrail and Delineators (862) (1088)	Impact Attenuators, Life Cycle	Smart Cushion Innovations Crash Cushion	SCI70GM	Approved	Test Level II Crash Attenuator
NP16-7406		TrafFix Devices, Inc.	Guardrail and Delineators (862) (1088)	Impact Attenuators, Life Cycle	Compressor System		Approved	Low Maintenance, Severe-Duty, Self-Restoring, Re-Directive Impact [illegible] approved as TL-3. Designed for repeated impacts with no need for repair. For use in Uni-directional or Bi-Directional applications up to 96 wide
NP20-8607		Valtir, LLC	Guardrail and Delineators (862) (1088)	Impact Attenuators, Life Cycle	QuadGuard® Elite M10 24in	QM10024EY	Approved	Redirective, non-gating crash cushion with flex-belt nose and HDPE cylinders.
NP20-8757	GR43	Valtir, LLC	Guardrail and Delineators (862) (1088)	Impact Attenuators, Life Cycle	QuadGuard® Elite M10 Wide	QM10069EY	Approved	The QuadGuard® Elite M10 Wide is a MASH 2016, Test Level 3 compliant re-directive, non-gating crash cushion used to shield fixed objects up to 69in (1753 mm) wide, and has various transition options.
NP21-8957	GR43	Valtir, LLC	Guardrail and Delineators (862) (1088)	Impact Attenuators, Life Cycle	REACT☐ M	RM62B036	Approved	MASH 2016 Test Level 3 redirective, non-gating crash cushion. Product has been shown to provide self-restoring characteristic from impacts within MASH criteria.

Impact Attenuators, Life Cycle

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

Example – Low Cost

SCI
MASH TL 3

Impact Attenuators, Life Cycle

- QuadGuard Elite (MASH)
  - Uses High Density Polyethylene cylinders to absorb energy
  - Essentially for use in locations where a high number of hits is anticipated
  - 24” Standard and 69” Wide

REF: FHWA Eligibility Letter CC-57E dated 12/18/15

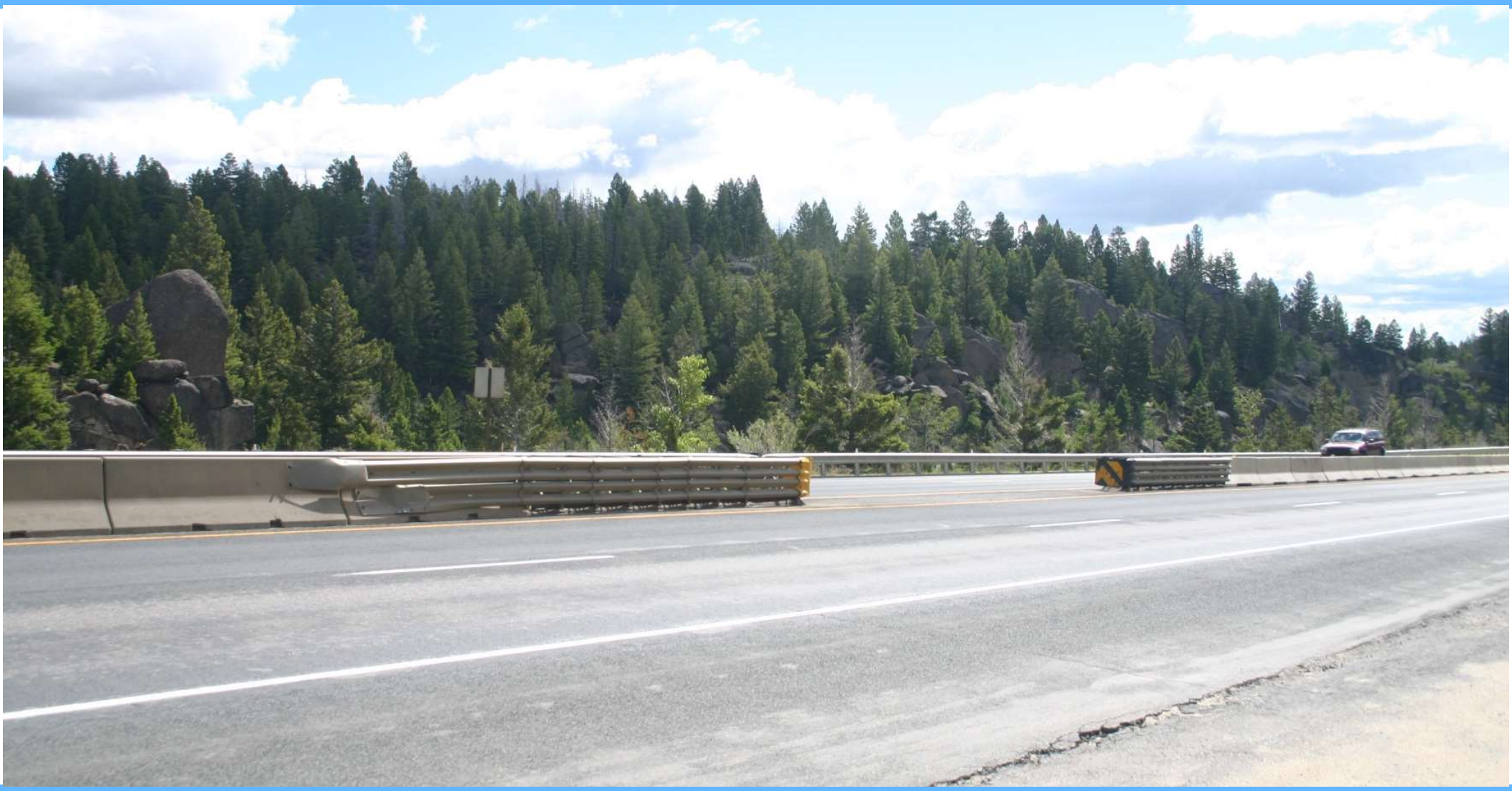
Crash Cushions (Essentially)Self Restoring

- REACT M (MASH)
  - High density Polyethylene cylinders HMW/HDPE
  - “Self-restoring” after design impact
  - Self-contained back-up
  - Side redirection by side cables anchored to foundation
  - Single cylinder width 36 inches

REF: FHWA Eligibility Letter CC-169 dated 6/23/2021

Example - Self Restoring

Very Appropriate Use



Review Learning Outcomes

- Understand how end treatments and impact attenuators are tested for crashworthiness
- Identify common end treatments and impact attenuators
- Understand how these systems function
- Choose the appropriate system for a specific site

Session 4: Design Principles, Length of Need, and Site-specific Installation Considerations

Session 4 Learning Outcomes

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

- Understand the design principles affecting an optimal barrier installation
- Apply a field procedure to check Length of Need
- Be familiar with special designs to address site-specific installation considerations

Guardrail Placement

Place AS FAR AWAY as Possible

without affecting function

Barrier Design Principles

1. Deflection
2. Slope in Front of Barrier
3. Guardrail and Curb
4. Soil Backing for Fill Locations
5. Flare Rate

Principle 1: Deflection

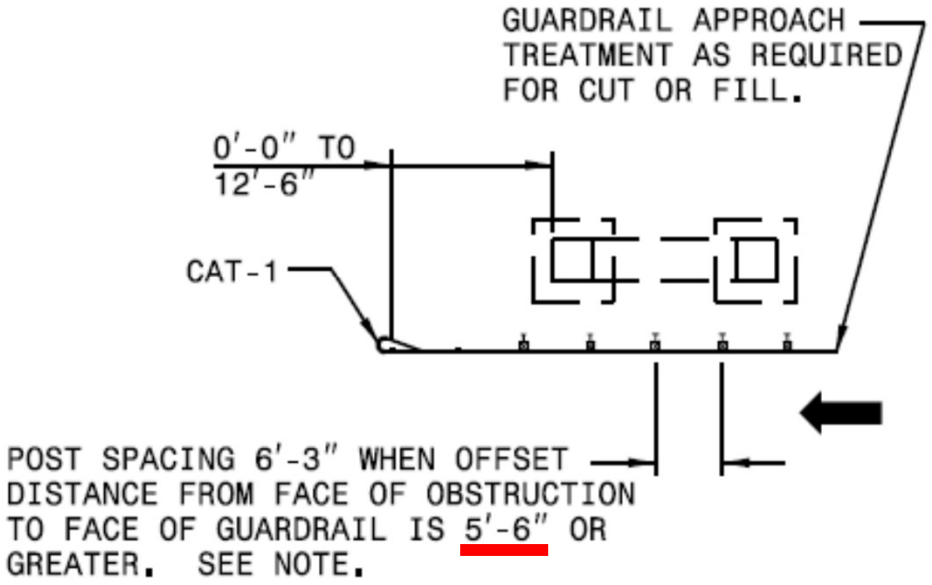
Adequate room must be left behind the barrier to allow for lateral deflection in an impact.

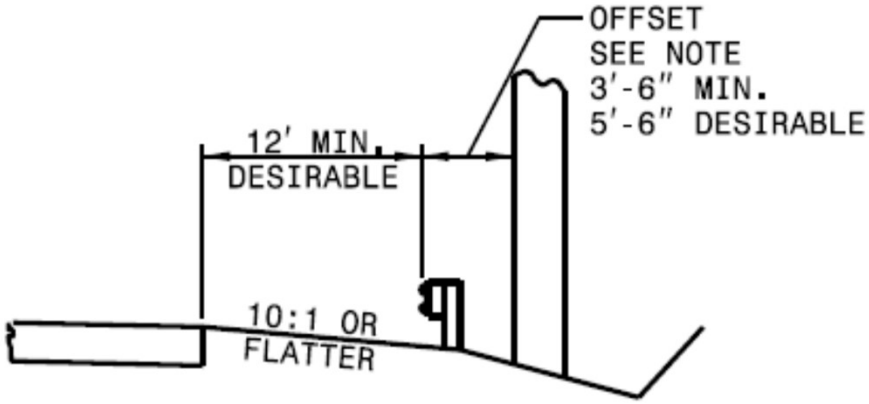
- If the barrier is shielding a vertical rigid object, the distance between the barrier and the object should be sufficient to avoid the vehicle impacting or snagging on the object.
- Note that, even for rigid barriers with no lateral deflection, large vehicles may roll behind the top of the barrier even if the barrier itself does not deflect.

Deflection

Results of Inadequate Deflection Distance

Deflection Distance - NCDOT





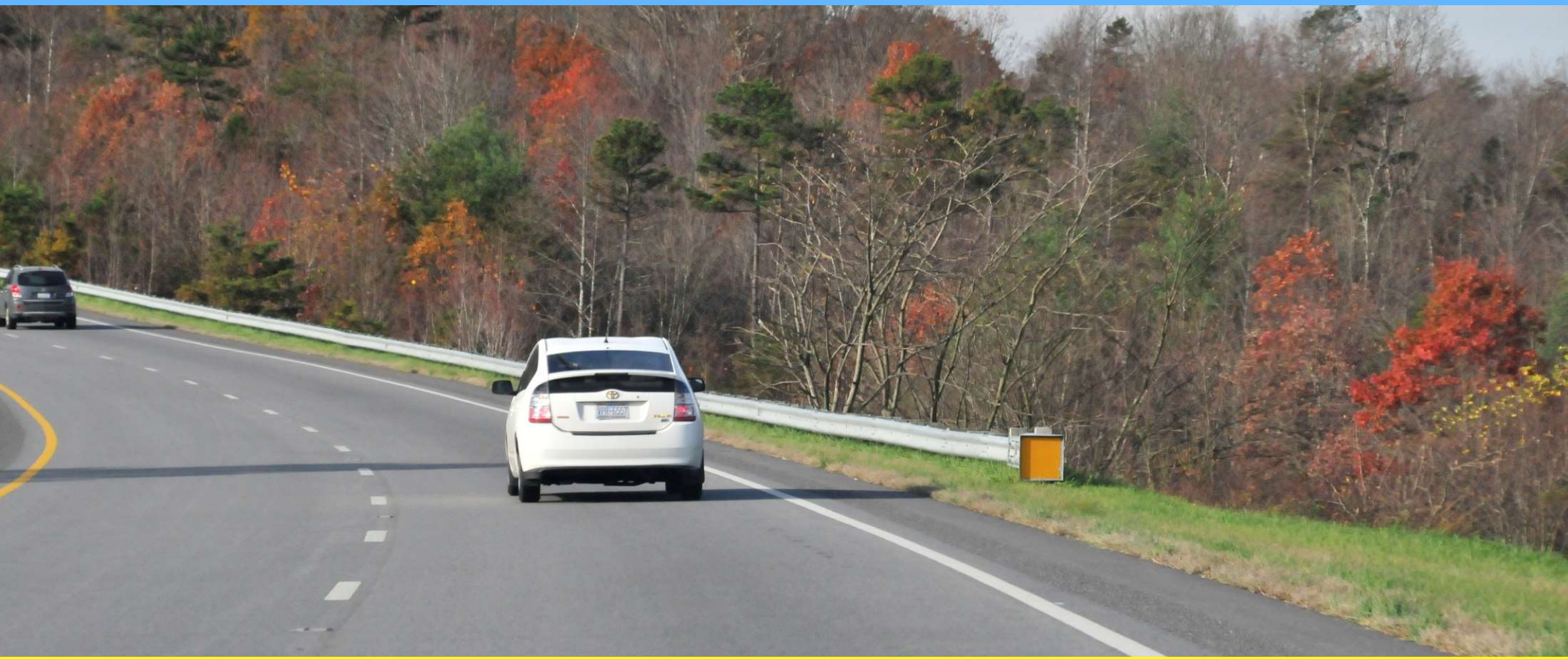
862.01 SHEET 1 OF 15	ROADWAY STANDARD DRAWING FOR **GUARDRAIL PLACEMENT**	1-24 STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

Half Post Spacing

NOTE: WHEN OFFSET DISTANCE FROM FACE OF OBSTRUCTION TO FACE OF GUARDRAIL IS BETWEEN 3′-6″ AND 5′-6″, BEGIN 3′-1½″ POST SPACING AT A POINT 25′ BEFORE REACHING THE OBSTRUCTION AND CARRY THROUGHOUT ITS LENGTH. IF THE OFFSET IS LESS THAN 3′-6″ USE CONCRETE BARRIER.

862.01	SHEET 1 OF 15	ROADWAY STANDARD DRAWING FOR **GUARDRAIL PLACEMENT**	1-24	STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

Principle 2: Slope in Front of Barrier



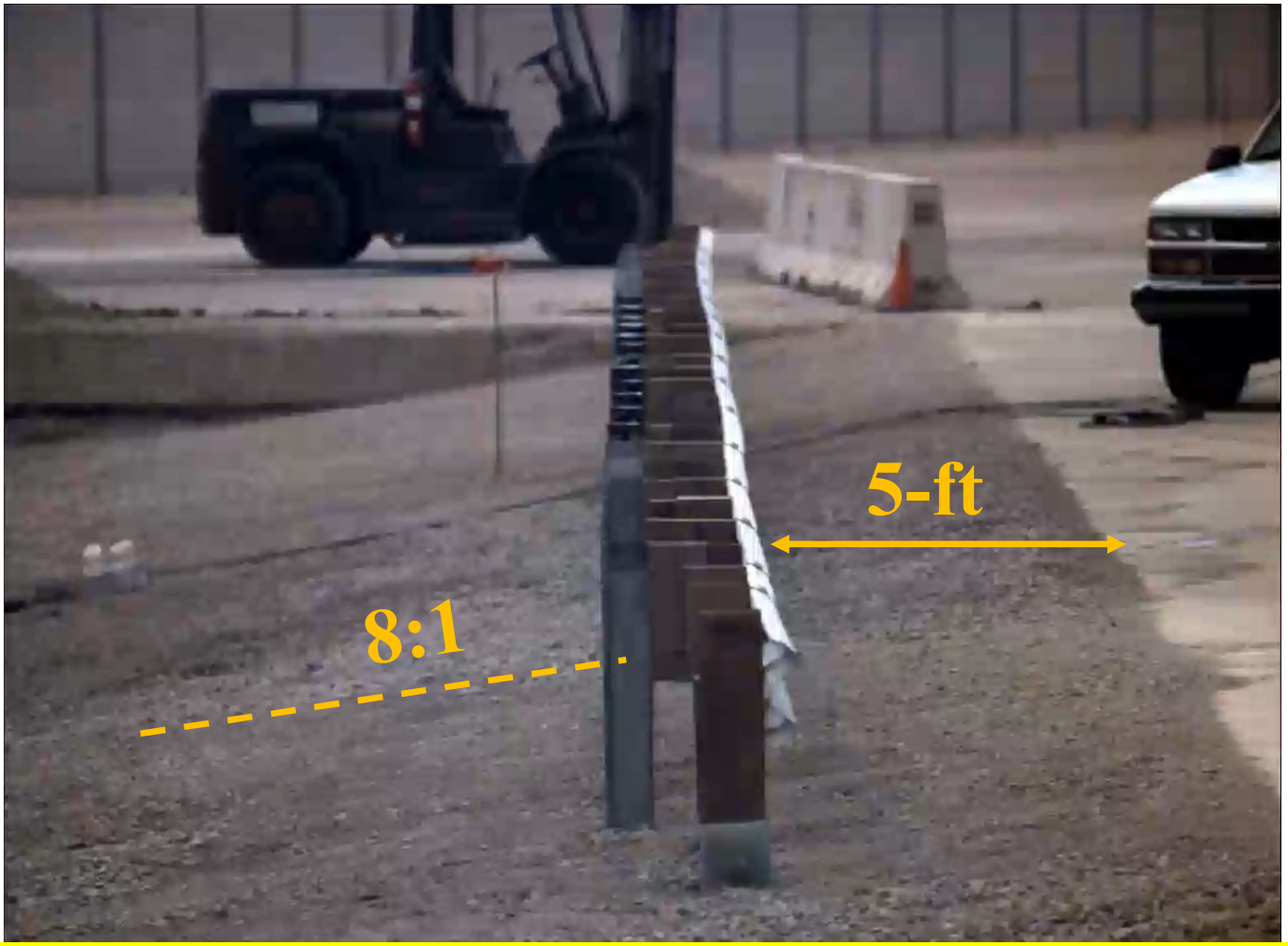
Any barrier may be placed anywhere on a 10H:1V or flatter slope.

Guardrail on Slopes

- Any barrier may be placed anywhere on a 10H:1V or flatter slope.
- Cable barrier may be placed on slopes of 6H:1V or flatter, but restrictions apply when placed in a swale. Special HTCB designs are available for placement on 4:1 slopes.

Principle 2: Slope in Front of Barrier

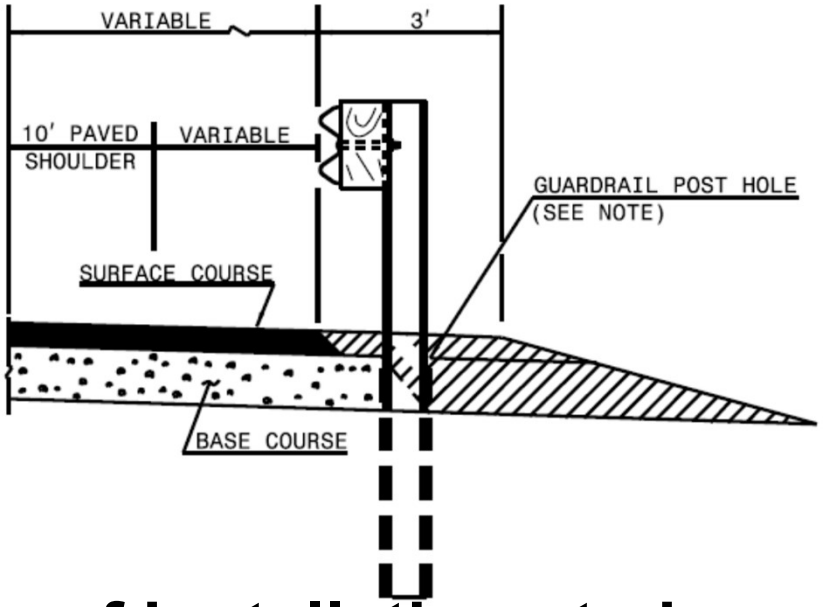
NCHRP 350 TL-3 31” on 8:1 Slope

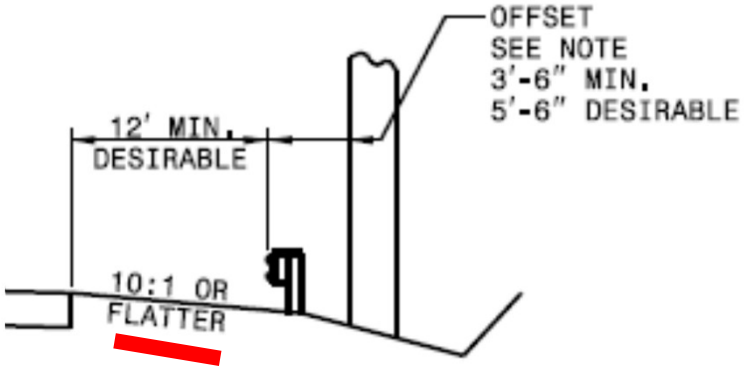


Vehicle is contained and redirected but shows instability

Slope in Front of Barrier

IMPLIED – FLAT





6.8.1.1 Types of installations to be used

Steel beam guardrail must be placed on 10:1 or flatter slopes

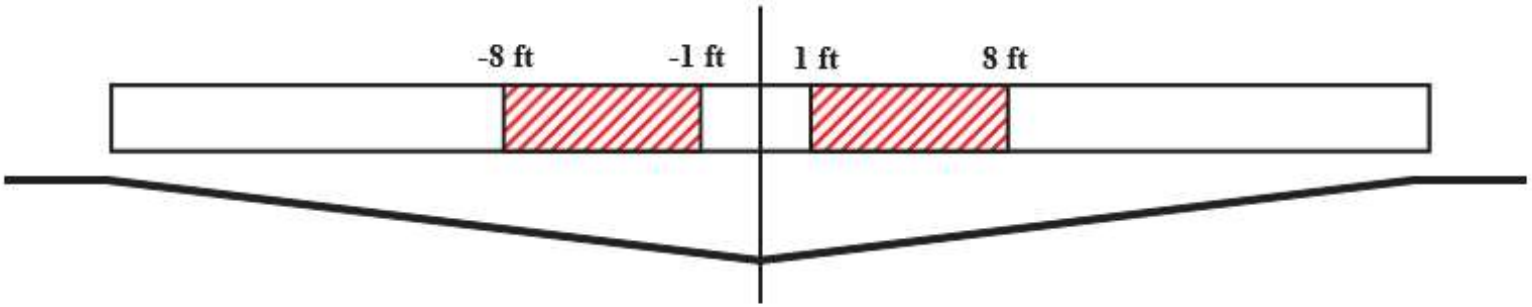
FLEXIBLE PAVED SHOULDER

862.01	SHEET 11 OF 15	ROADWAY STANDARD DRAWING FOR **GUARDRAIL PLACEMENT**	1-24	STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

Barrier in Sloped Median
- Old System (29”) ONLY -

Slope in Front of Cable Barrier

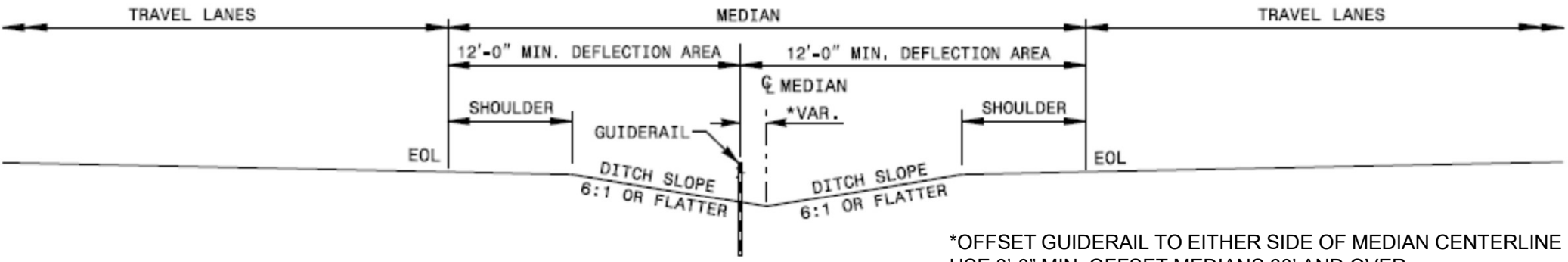
- Cable barrier may be placed anywhere on a 10:1 or flatter slope.
- Cable barrier may be placed on slopes of 6:1, but not in the area from 1 ft. to 8 ft. from the ditch bottom.



(a) Medians shallower than 6H:1V slope (NCHRP Report 711)

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

NCDOT Slope/Swale Guidance - LTCG



*OFFSET GUIDERAIL TO EITHER SIDE OF MEDIAN CENTERLINE
USE 8'-0" MIN. OFFSET MEDIANS 60' AND OVER.
USE 4'-0" MIN. OFFSET FOR MEDIANS LESS THAN 60'

TYPICAL SECTION

(DEFLECTION AREA ON MEDIAN SLOPES)

DOUBLE FACE GUIDERAIL APPLICATION

USE 4'-0" MIN. OFFSET FOR MEDIANS LESS THAN 60'.

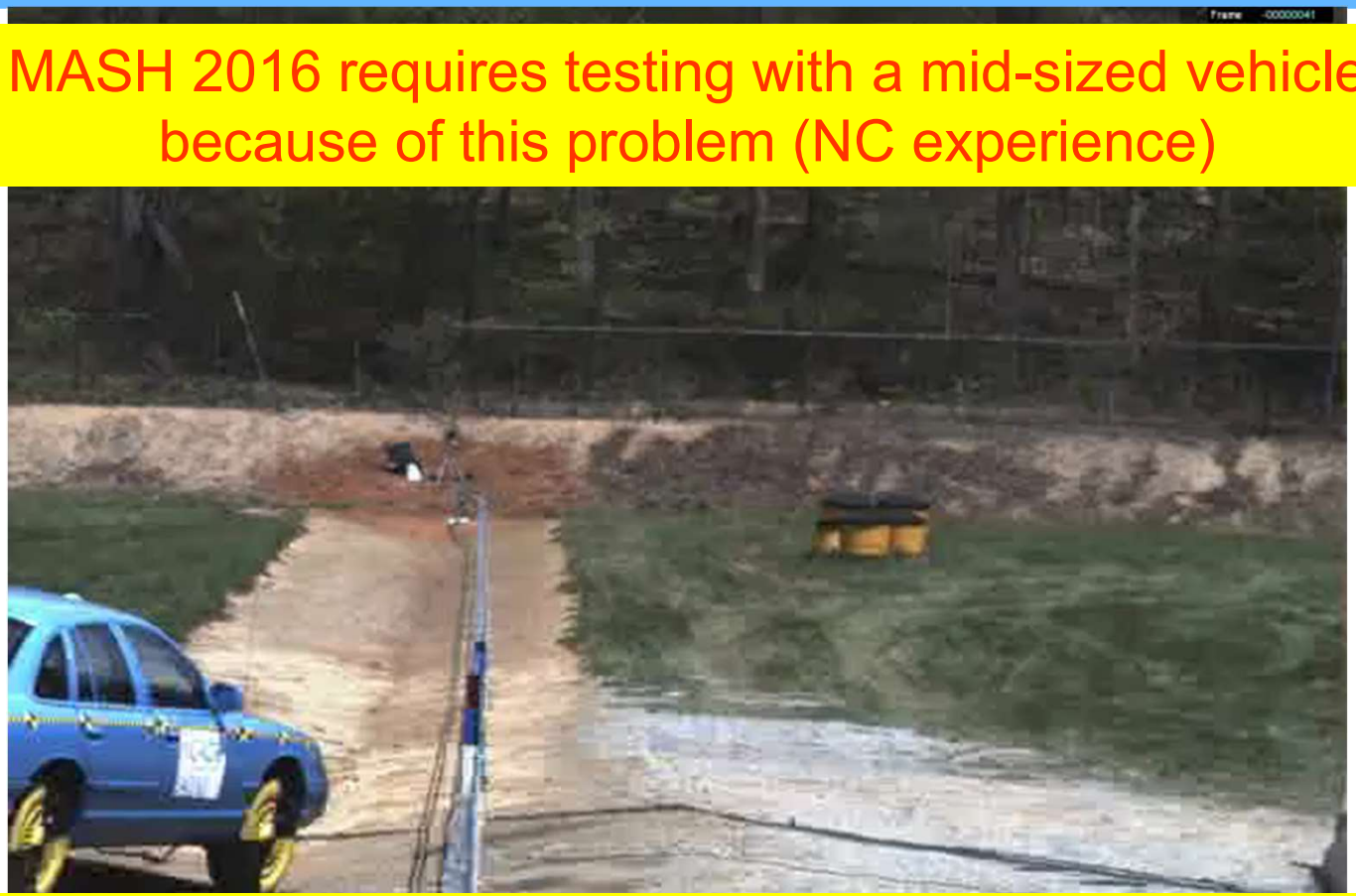
Caution

865.01 SHEET 4 OF 12

ROADWAY STANDARD DRAWING FOR
CABLE GUIDERAIL
DESIGN AND PLACEMENT

Location of Cable in Swales

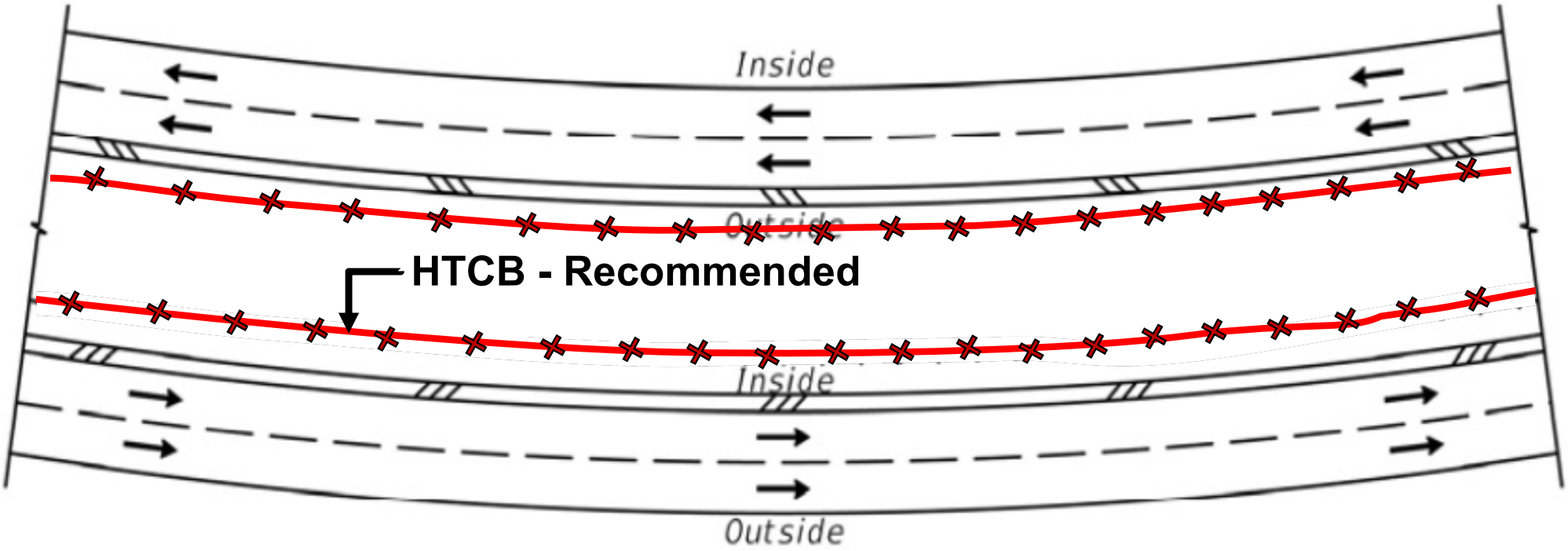
MASH 2016 requires testing with a mid-sized vehicle because of this problem (NC experience)



CABLE SHOULD NOT BE PLACED BETWEEN 1' AND 8' BEYOND THE BOTTOM OF A DITCH

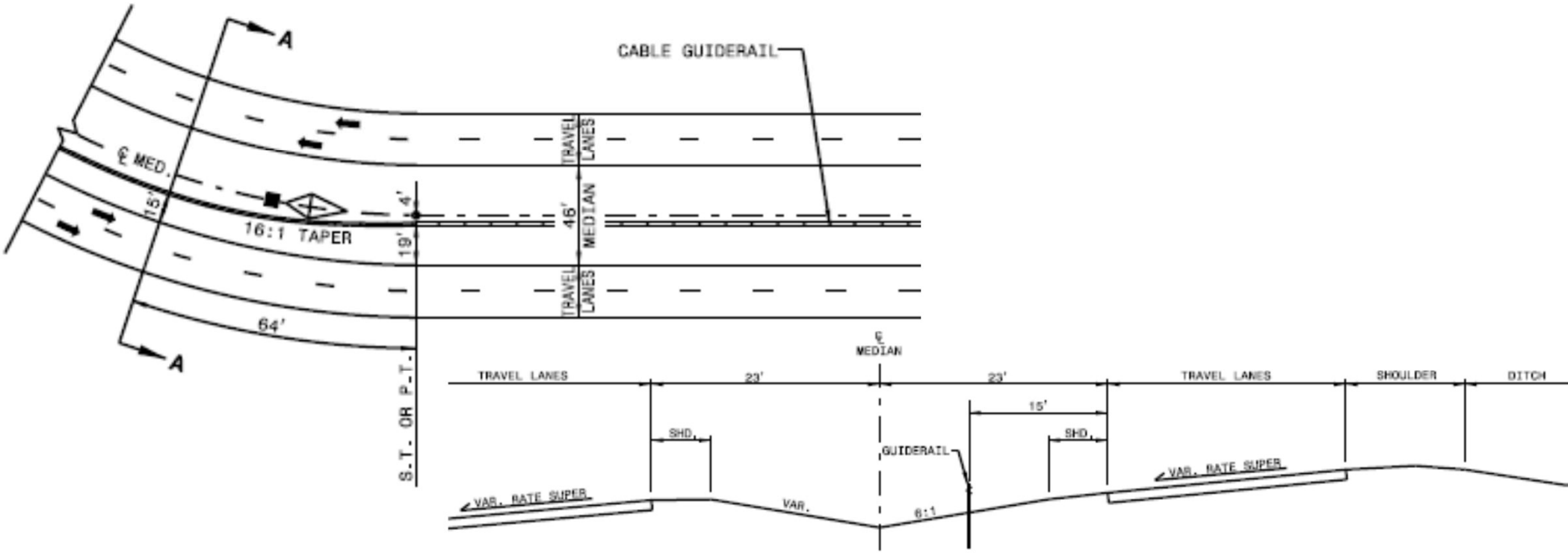
Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – 6.6.1.1, Pg. 6-18

Which Side of the Median Should Cable Barrier be Placed?



HTCB = High-Tension Cable Barrier

Barrier in a Curved Median



SECTION A-A

865.01 SHEET 3 OF 12

ROADWAY STANDARD DRAWING FOR

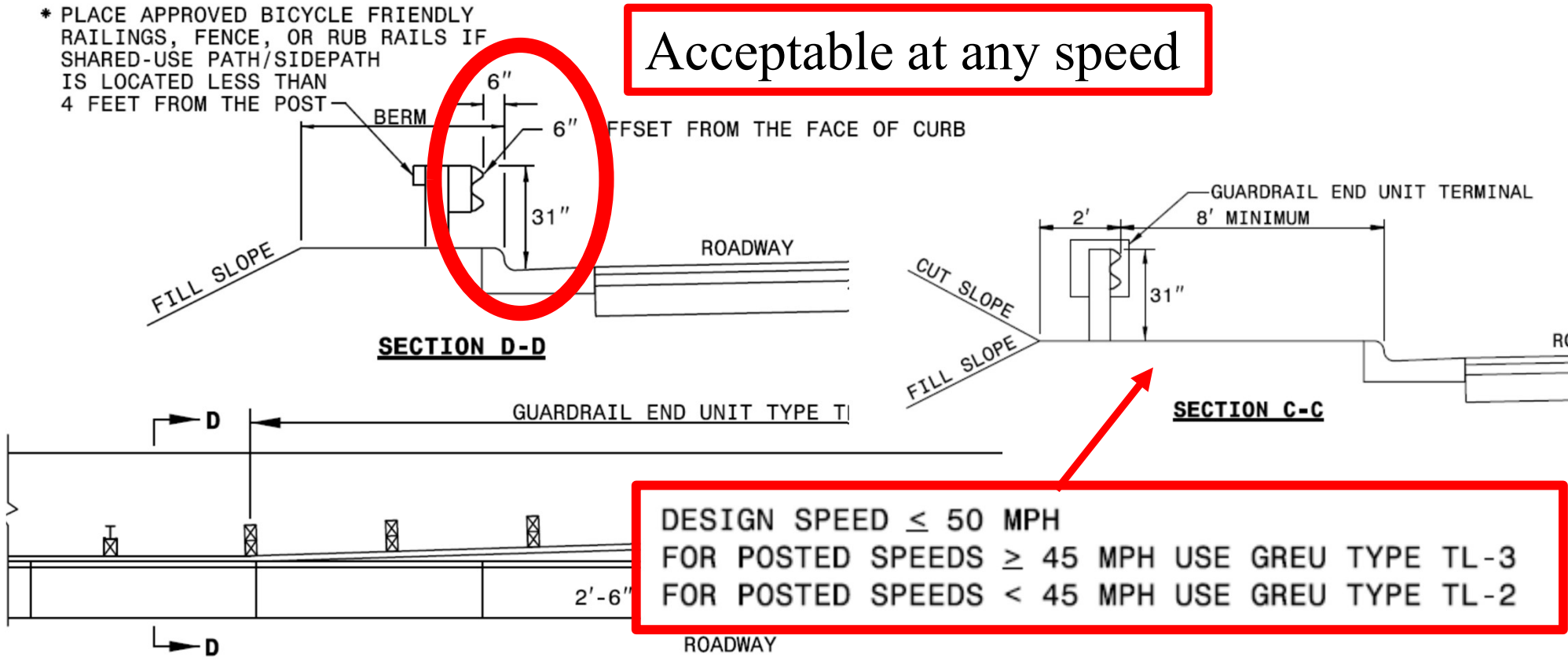
CABLE GUIDERAIL

46′ MEDIAN GUIDERAIL TRANSITIONS WITH SUPERELEVATION AND/OR FALSE SUMPS

Principle 3: Guardrail and Curbs

Guardrail and Curbs – 29”

NCDOT Guardrail and Curbs



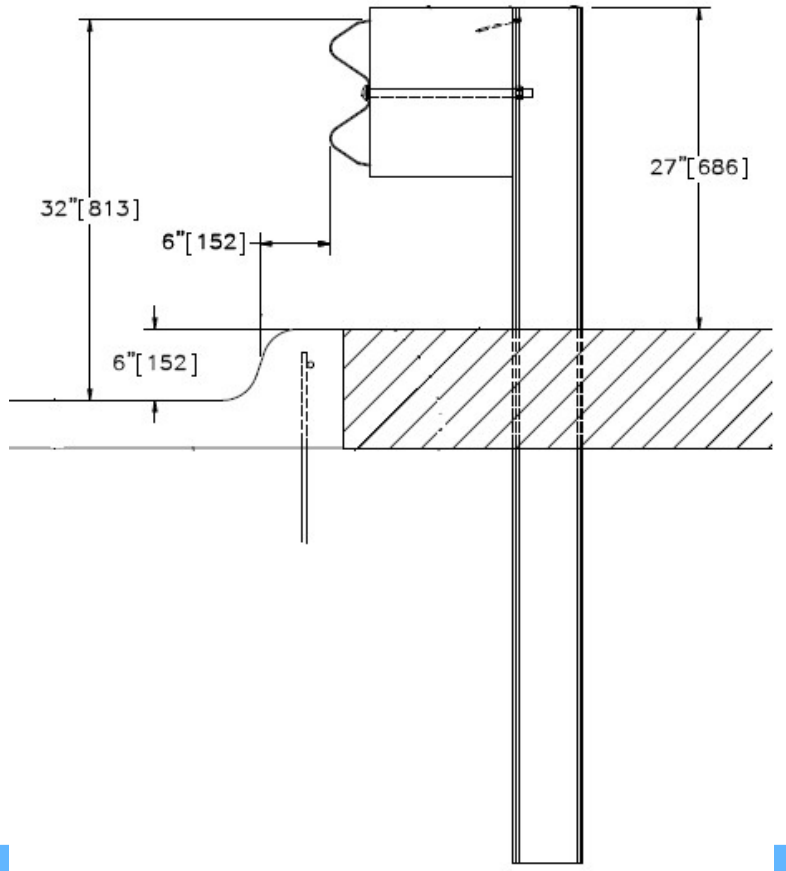
Acceptable at any speed

DESIGN SPEED ≤ 50 MPH
FOR POSTED SPEEDS ≥ 45 MPH USE GREU TYPE TL-3
FOR POSTED SPEEDS < 45 MPH USE GREU TYPE TL-2

862.01	SHEET 12 OF 15	ROADWAY STANDARD DRAWING FOR **GUARDRAIL PLACEMENT** GUARDRAIL TREATMENT AT CURB AND GUTTER	1-24	STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

31” and Curbs

Successfully tested to MASH placed 6” behind a 6” high curb at TL-3



MASH TL-3 31”
Placed 6” behind 6” high Curb

Typical “lower” speed environment

MASH TL-2 31” 6 ft. behind curb

End Treatments and Curbs

Although Standard 862.01, sheet 12 of 15, provides guidance for placing end treatments in combination with 6” curb, unfortunately there is no crash tested design for this common situation.

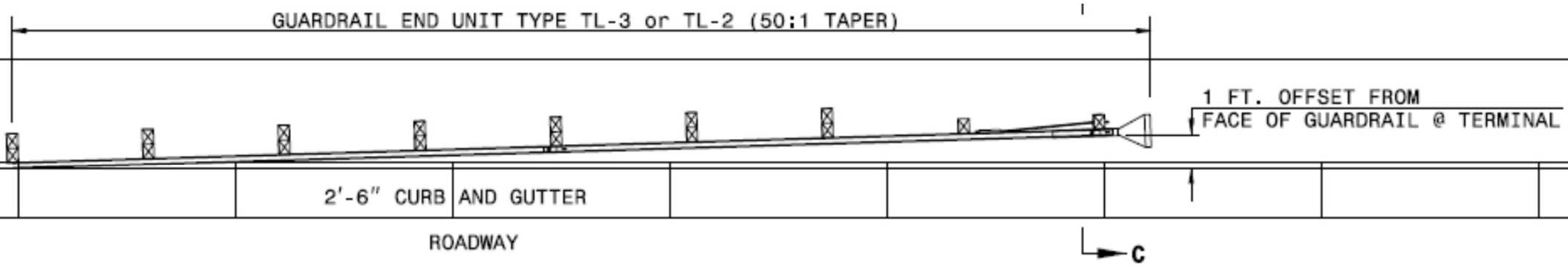
Especially careful with BCA Terminal Anchor – Don’t let Bearing Plate be buried

End Treatments and Curbs

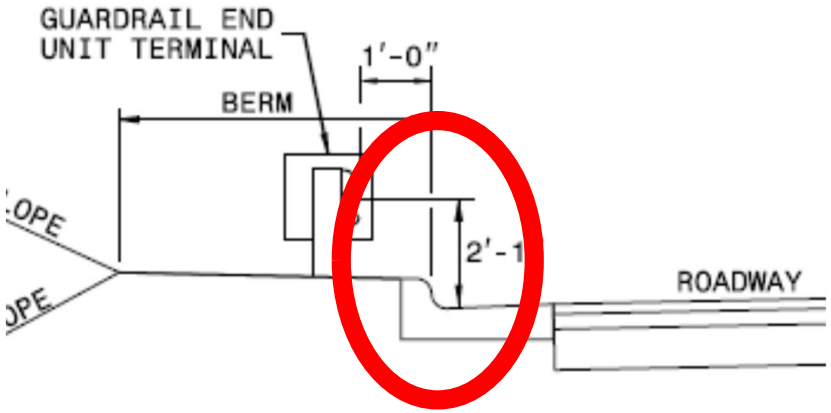
CURRENTLY UNDER STUDY –
DO NOT BURY BEARING PLATE

2” maximum height recommended

End Treatments and Curbs - NCDOT



GUARDRAIL AT FACE OF CURB



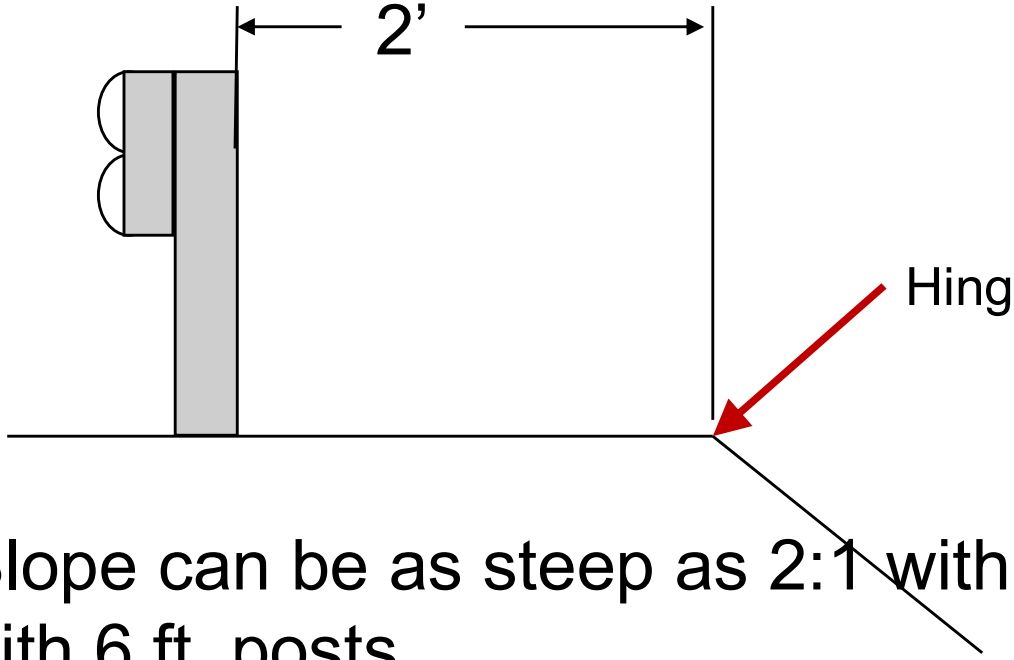
SECTION C-C

Careful with Breakaway Cable Anchorage Terminals – Don't let Bearing Plate be buried

Ref: NCDOT Standard Drawings, 862.01 Sht. 11

Principle 4: Soil Backing For Fill Locations

Soil Backing Recommendation



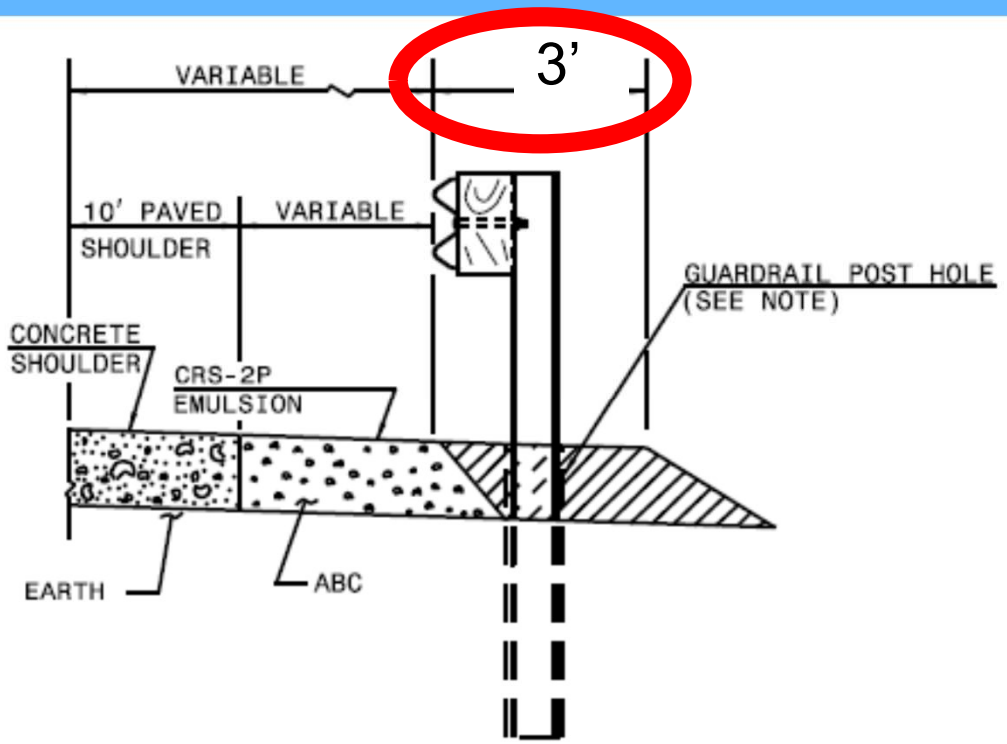
Historical Guidance

1. Slope can be as steep as 2:1 with 2-ft. backing in strong soil with 6 ft. posts.

2. Backing can be less than 2 ft. with 2:1 slope in strong soil with 7 ft. posts. NCHRP 350 requires half post spacing – ONLY applies to 29” system

Ref: AASHTO Roadside Design Guide, 4th Edition – Figure 5.33, Pg. 5-41

Soil Backing – NCDOT



862.01 SHEET 11 OF 15	ROADWAY STANDARD DRAWING FOR **GUARDRAIL PLACEMENT**	1-24 STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

31” with Posts on a 2:1 Slope

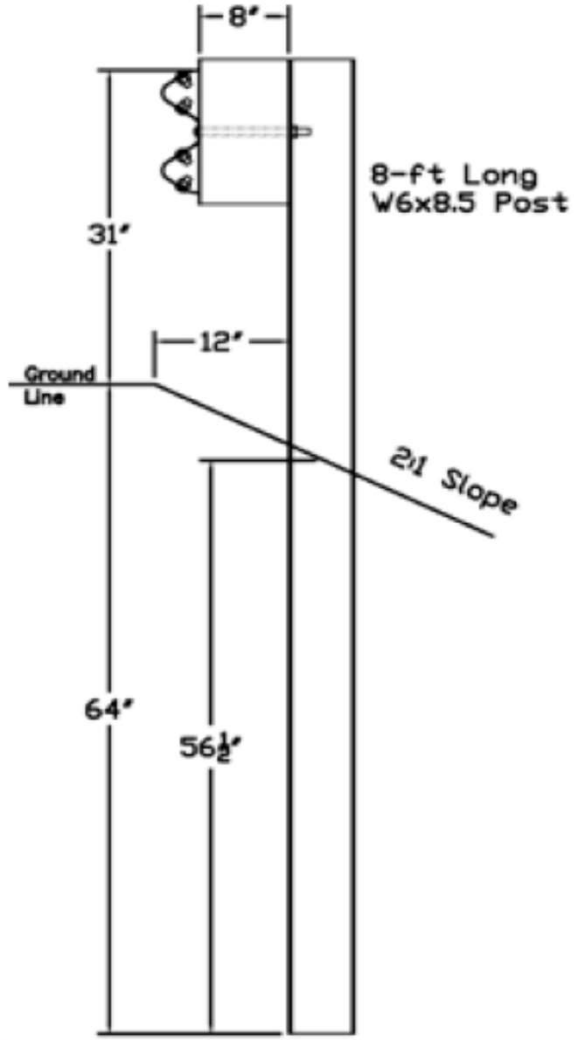
31” with face of rail at slope break point of 2:1 slope

Posts

- 8’ long W6x9 posts tested
- Not recommended with Wood posts at this time
- 6’-3” post spacing

Offset Blocks

- 8” Offset block tested
- Not recommended without offset block at this time

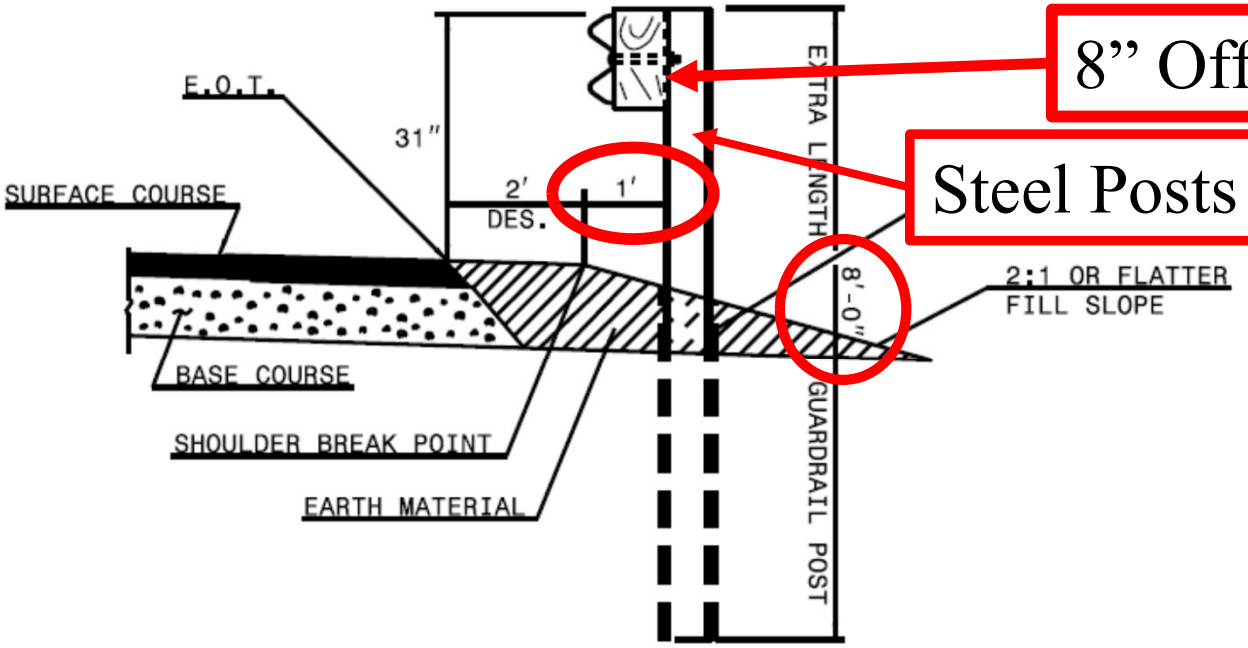


31” with Posts on a 2:1 Slope

MASH Testing of
MGS adjacent to a
2:1 Slope
8" blockout
8' long posts at
6'-3" spacing

Working Width – 55.2”
Eligibility Letter B-261

Soil Backing – NCDOT



8" Offset Block

Steel Posts ONLY

* FOR POSTED SPEEDS ≤ 60 MPH

8' GUARDRAIL POST ON 2:1 SLOPE *

862.01 SHEET 11 OF 15	ROADWAY STANDARD DRAWING FOR **GUARDRAIL PLACEMENT**	1-24 STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

Principle 5: Flare Rate

Flare Rate

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

- Locate end treatments farther from the roadway.
- Lessen driver reaction to a roadside obstacle.
- Reduce total length of rail needed.
- Reduce nuisance hits.
- When tying to a bridge rail from a farther offset (in advance of transition)

Suggested Flare Rates - RDG

Table 5-9. Suggested Flare Rates for Barrier Design

Design Speed		Flare Rate for Barrier Inside Shy Line	Flare Rate for Barrier at or Beyond Shy Line	
km/h	[mph]		Rigid Barrier	Semi -Rigid Barrier
110	[70]	30:1	20:1	15:1
100	[60]	26:1	18:1	14:1
90	[55]	24:1	16:1	12:1
80	[50]	21:1	14:1	11:1
70	[45]	18:1	12:1	10:1
60	[40]	16:1	10:1	8:1
50	[30]	13:1	8:1	7:1

Notes:

A = Suggested maximum flare rate for rigid barrier system.

B = Suggested maximum flare rate for semi-rigid barrier system.

The MGS has been tested in accordance with NCHRP Report 350 TL-3 at 5:1 flare.

Flatter flare rates for the MGS installations also are acceptable. The MGS should be installed using the flare rates shown or flatter for semi-rigid barriers beyond the shy line when installed in rock formations.

Example of Benefit of Flare

Possibly Excessive Flare and Slope Steeper than 10:1

Tangent End Treatments on Flared Standard Run - Repeat

The offset of the end treatment is measured from a line parallel to the ROADWAY:

If the standard flare is 25:1 or flatter, the end treatment may be placed on the standard flare line extended

If the standard flare is sharper than 25:1, a kink in the run must be provided so the end treatment is no sharper than 25:1

NCDOT guidance is to provide 25’ of parallel guardrail in advance of any end treatment requiring a kink.

Length of Need (LON) Definition

AASHTO

The length of effective barrier needed IN ADVANCE OF the hazard to intercept and redirect an encroaching vehicle.

Length of Need (LON)

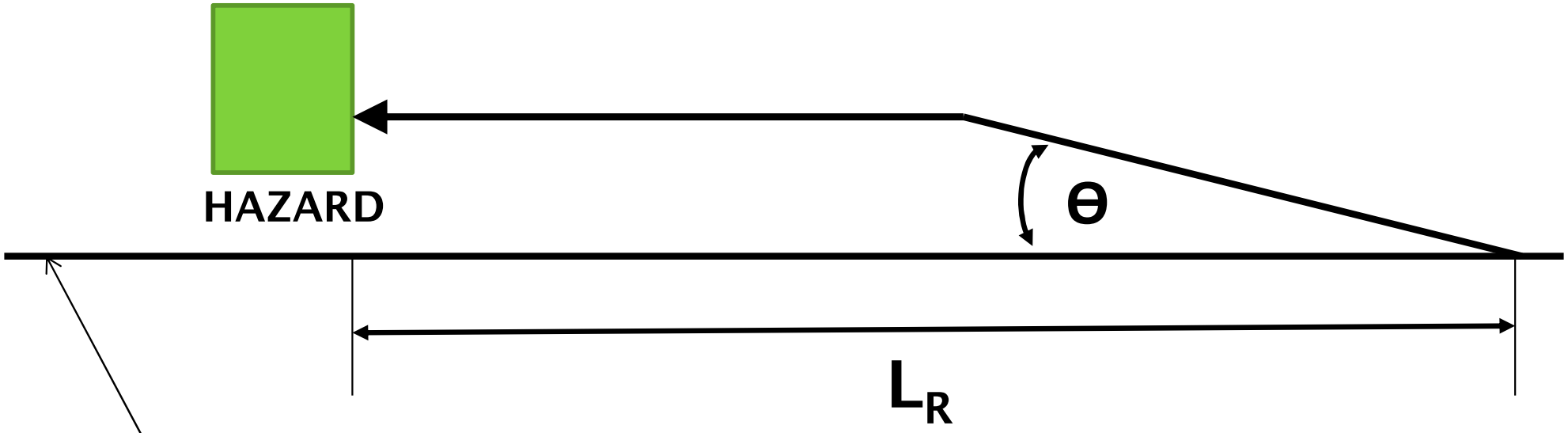
NCDOT

X = Length of need which will be measured from the approach end of the hazard (area of concern) to the guardrail end unit (GREU).

6.3.1 Placement on Approach End of Rigid Obstacle Warrant

Length of Need (LON) Theory

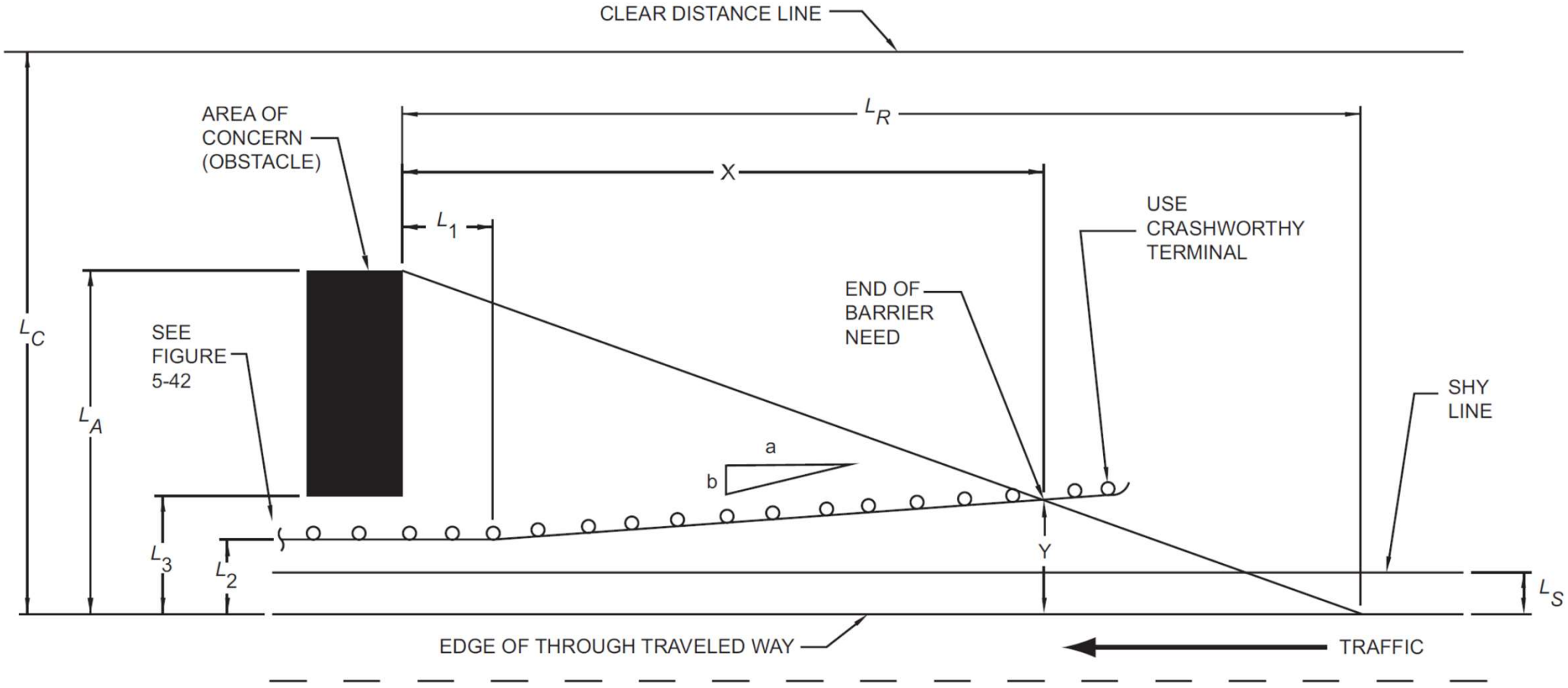
AASHTO



θ = Angle of Departure (Unknown)

L_R = Runout Length

LON Design Procedure for Approach Barrier Layout



Ref: AASHTO Roadside Design Guide, 4th Edition, Figure 5.39, Pg. 5-49

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, Equation 5-1 and 5-2, Pg 5-51

Runout Lengths - AASHTO

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

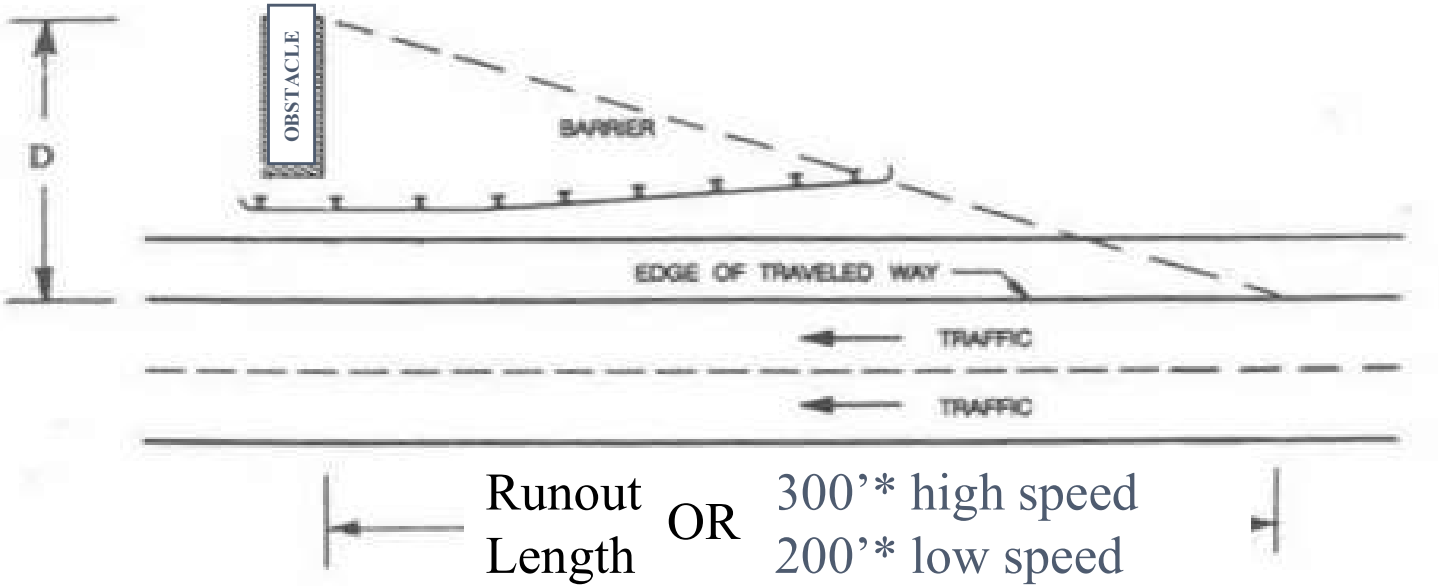
Design Speed (mph)	Runout Length (L_R) Given Traffic Volume (ADT) (ft)			
	Over 10,000	5,000 to 10,000	1,000 to 5,000	Under 1,000
80	470	430	380	330
70	360	330	290	250
60	300	250	210	200
50	230	190	160	150
40	160	130	110	100
30	110	90	80	70

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

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) – use 300'/200' as default value.
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 ALL hazards that should be shielded in this area
6. Check for better terminal location by extending barrier a short distance (especially on curves!!!)

Length of Need Field Check



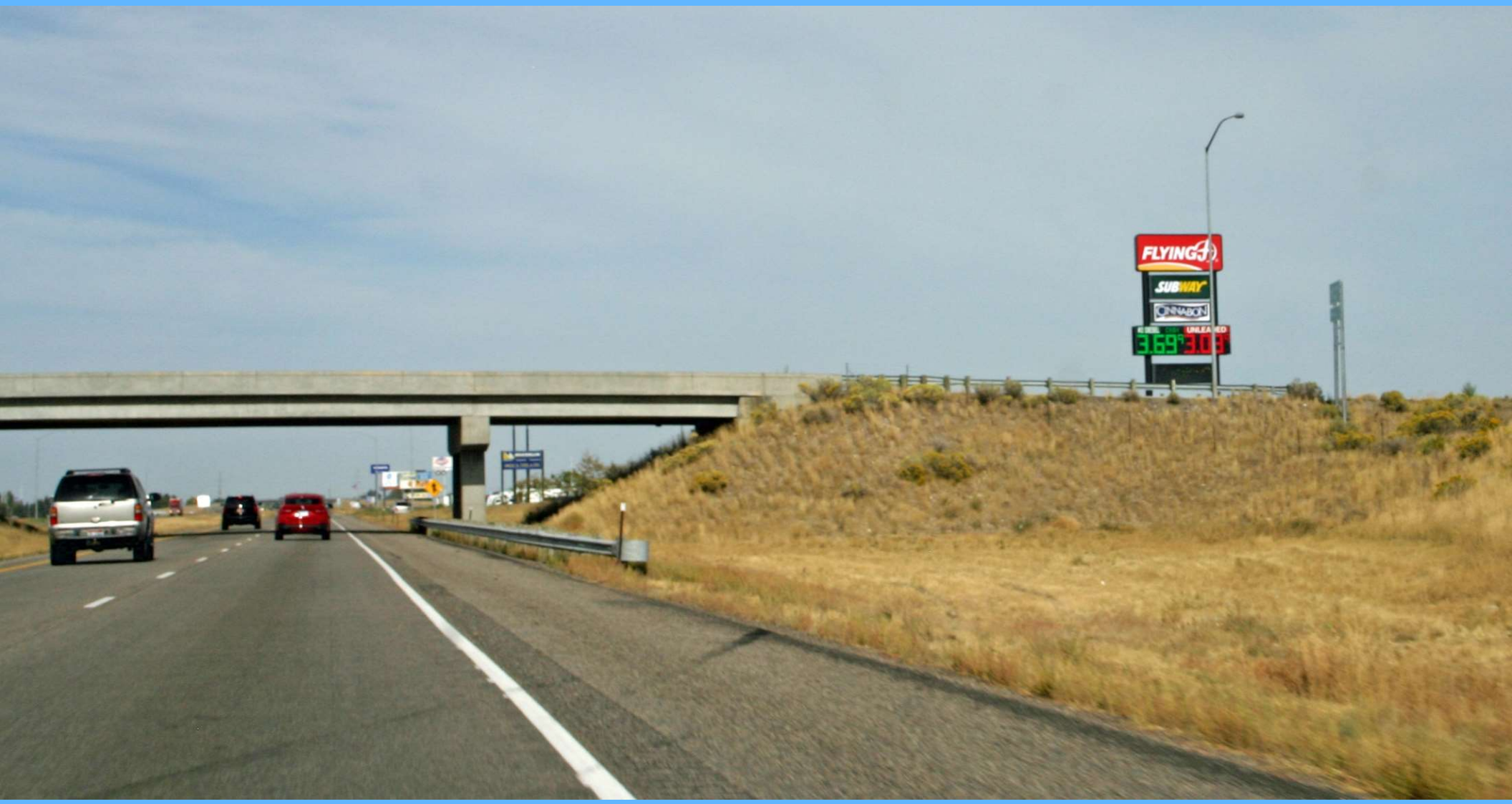
Procedure

- Identify upstream face of hazard
- Identify back of hazard D – limit to 30'
- Walk upstream along the white edge line, beginning at the upstream side of the hazard, (Runout Length if known or) 300'* for high speed, or 200'* for low speed (45 mph or less)
- Sight from this position to the upstream face, back edge of hazard (limited to 30')
- End of terminal should intercept line of sight (± ≈30')

On two-way roadways, check also for opposing traffic

Length of Need – Adequate?

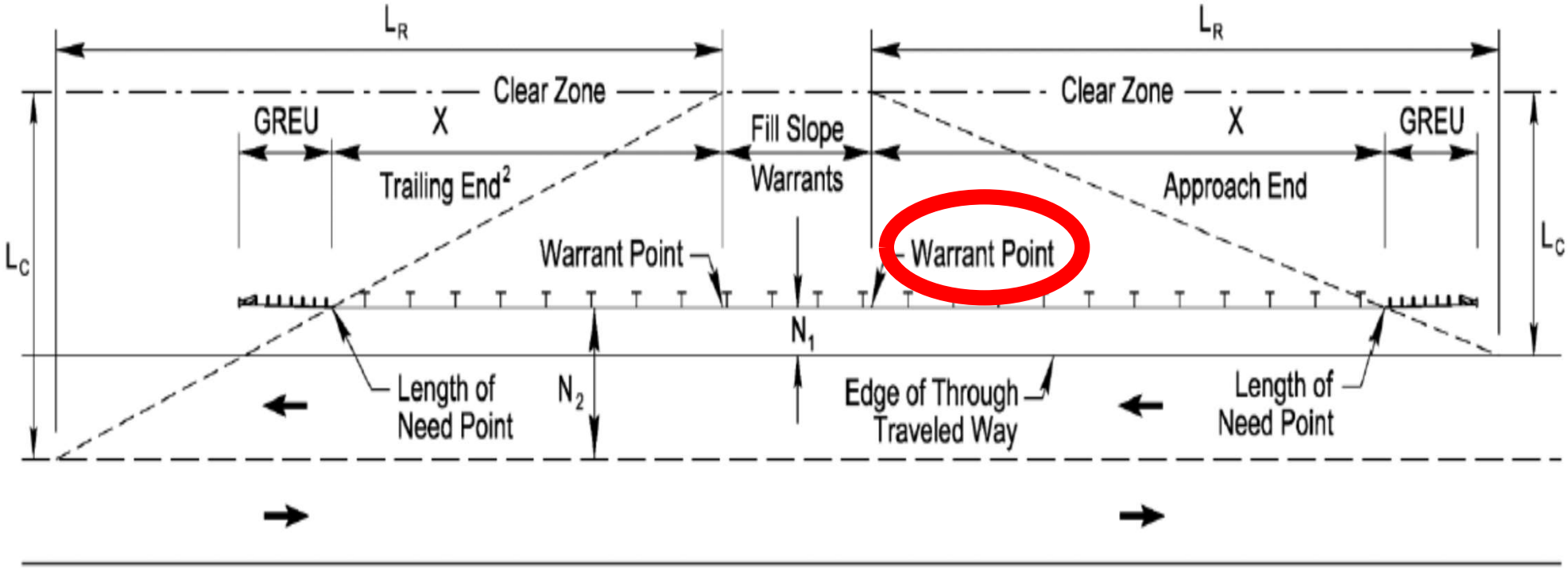
Length of Need – Adequate?



Length of Need – Adequate?

Fill Slope Length of Need

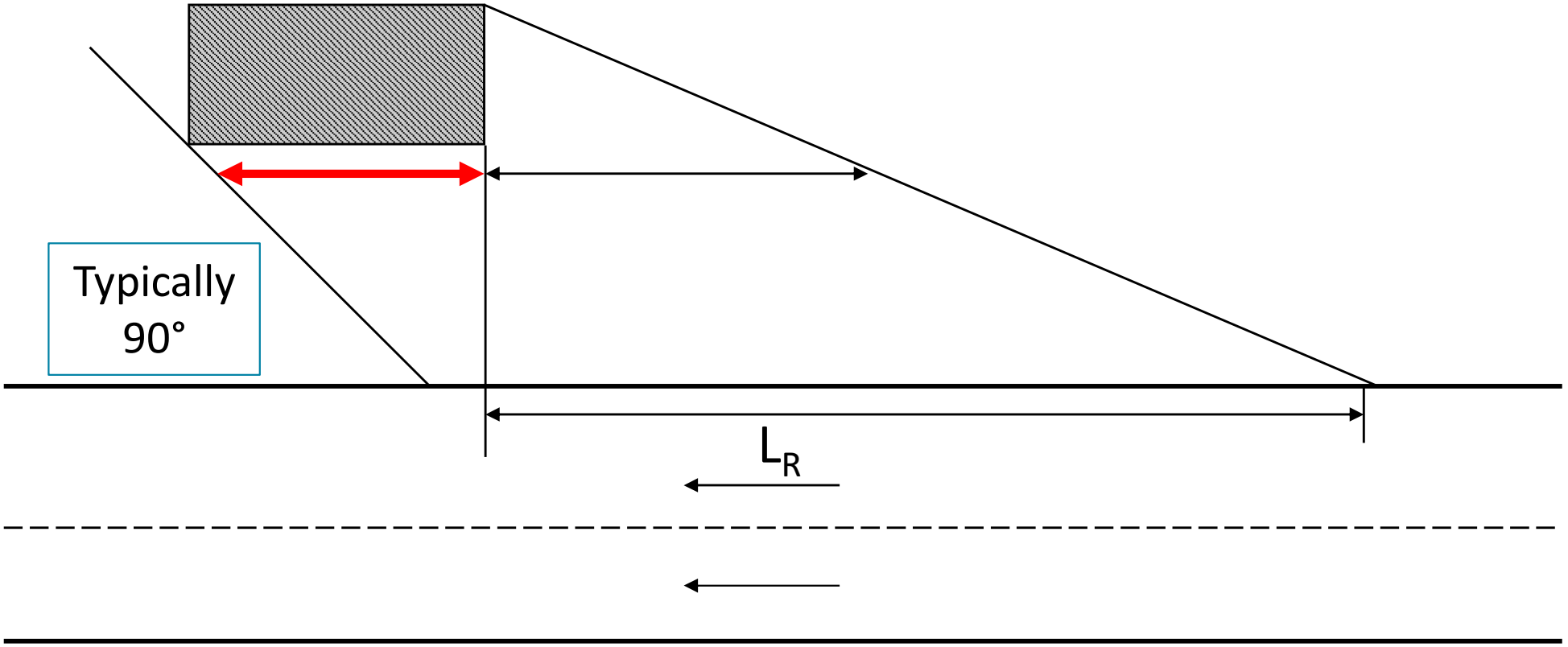
Figure 6-3 Detail of Guardrail Placement on Approach and Trailing End of Fill Slope Warrant



Typically, the fill slope warrant point is at the location where the fill slope becomes steeper than 3:1 (or 4:1 if a hazard is present at the bottom of the slope). Refer to RDG Chapter 5 Section 5.2.1 Figure 5-1b for further detail.

Downstream Termination One Direction Traffic

An anchor (CAT-1) plus 25’ of rail must be ADDED at the end



Minimum Lengths of Guardrail

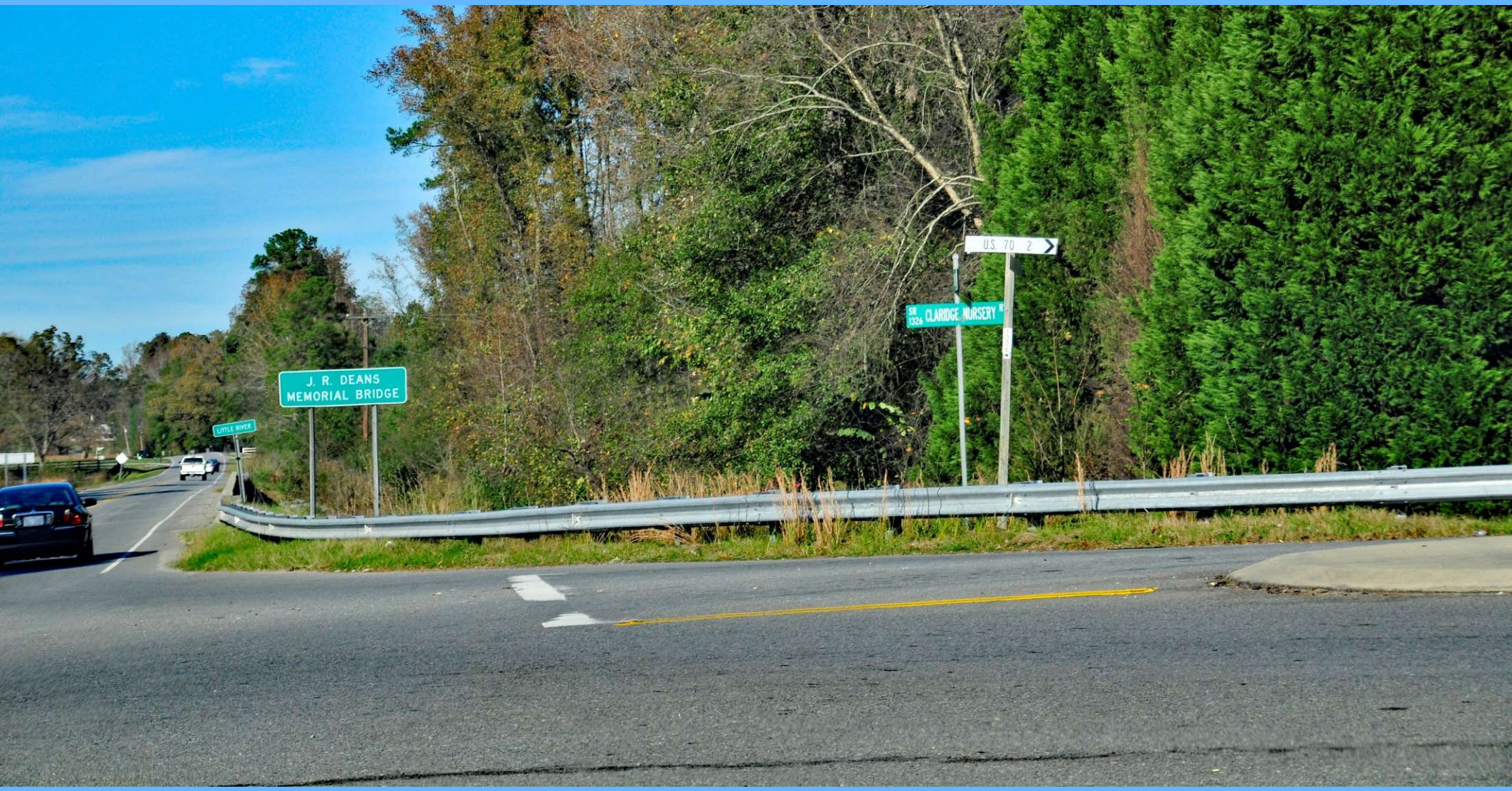
6.2.2 Length of Need

The minimum length of guardrail between end units is 12.5 feet when the design speed is 45 mph or less and 25 feet when the design speed is greater than 45 mph. Guardrail end units and structural anchor units are not designed to connect to each other warranting a section of guardrail between them.

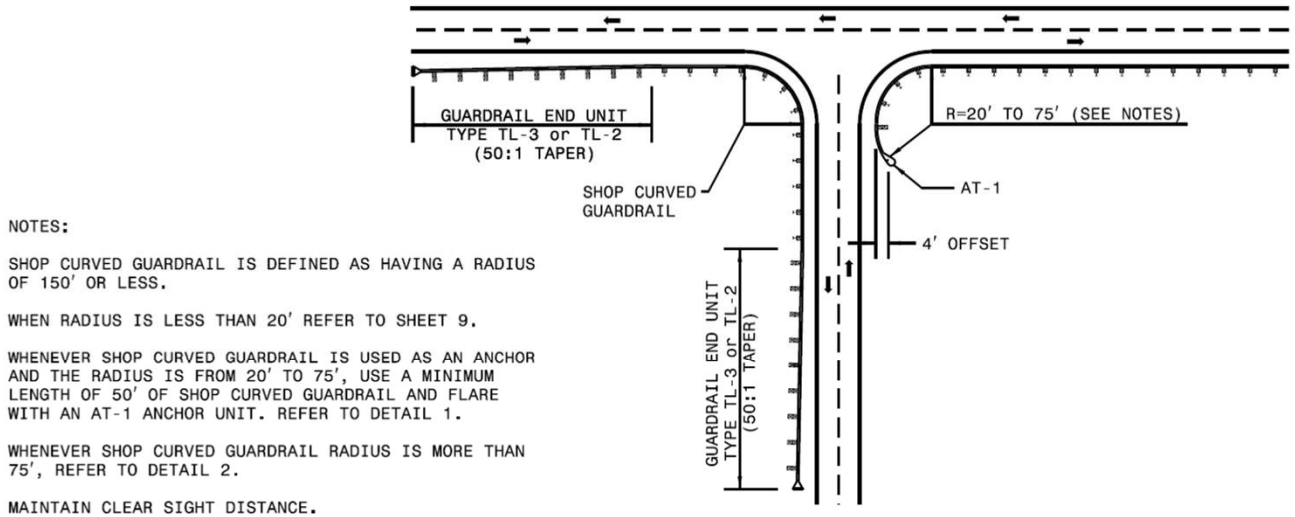
Guardrail Placement in Special Situations

- Guardrail Placement at Intersections
- Long Span (Omitted Post{s})
- Gaps between runs of barrier
- Extra Offset Blocks
- Leaveouts for Posts in Structural Pavement
- Guardrail Post in Rock

Guardrail Placement at Intersections



Guardrail Placement at Intersections



NOTES:

SHOP CURVED GUARDRAIL IS DEFINED AS HAVING A RADIUS OF 150' OR LESS.

WHEN RADIUS IS LESS THAN 20' REFER TO SHEET 9.

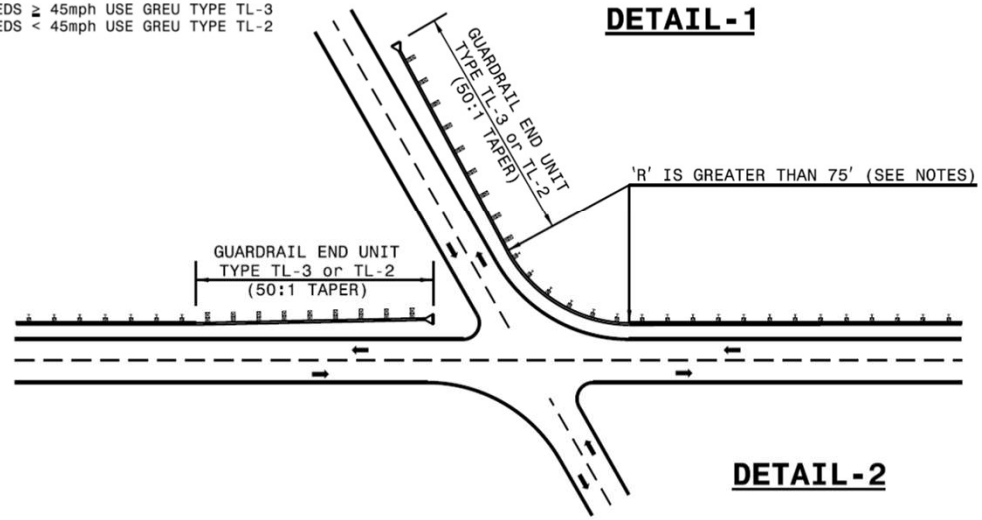
WHENEVER SHOP CURVED GUARDRAIL IS USED AS AN ANCHOR AND THE RADIUS IS FROM 20' TO 75', USE A MINIMUM LENGTH OF 50' OF SHOP CURVED GUARDRAIL AND FLARE WITH AN AT-1 ANCHOR UNIT. REFER TO DETAIL 1.

WHENEVER SHOP CURVED GUARDRAIL RADIUS IS MORE THAN 75', REFER TO DETAIL 2.

MAINTAIN CLEAR SIGHT DISTANCE.

FOR POSTED SPEEDS ≥ 45mph USE GREU TYPE TL-3
FOR POSTED SPEEDS < 45mph USE GREU TYPE TL-2

DETAIL-1



DETAIL-2

GUARDRAIL TREATMENT AT INTERSECTIONS

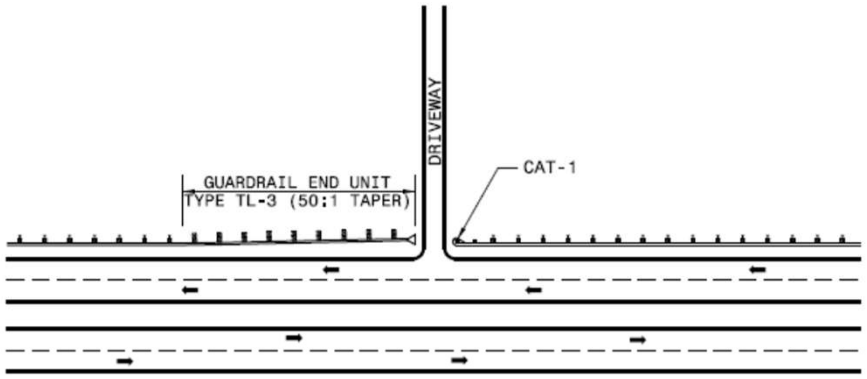
STATE OF NORTH CAROLINA
DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS
RALEIGH, N.C.

1-18

ROADWAY STANDARD DRAWING FOR
GUARDRAIL PLACEMENT

SHEET 8 OF 11
862.01

Guardrail Placement at Driveways

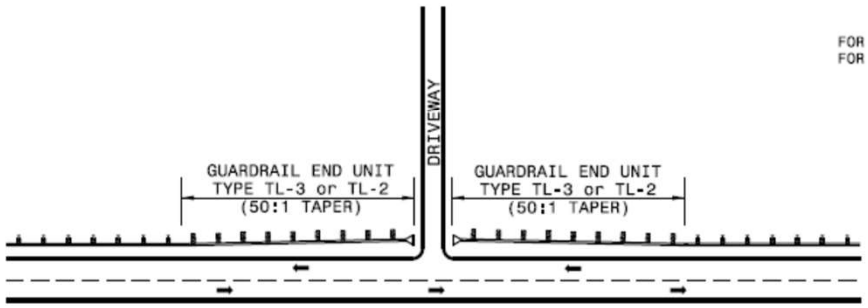


DETAIL-3
DIVIDED HIGHWAY

NOTE: USE DETAIL 3 & 4 WHENEVER 20' OR LARGER RADIUS CANNOT BE UTILIZED.

MAINTAIN CLEAR SIGHT DISTANCE.

FOR POSTED SPEEDS ≥ 45mph USE GREU TYPE TL-3
FOR POSTED SPEEDS < 45mph USE GREU TYPE TL-2



DETAIL-4
UNDIVIDED HIGHWAY

GUARDRAIL TREATMENT AT DRIVEWAYS

1-24
STATE OF NORTH CAROLINA
DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS
RALEIGH, N.C.

ROADWAY STANDARD DRAWING FOR
GUARDRAIL PLACEMENT

SHEET 9 OF15
862.01

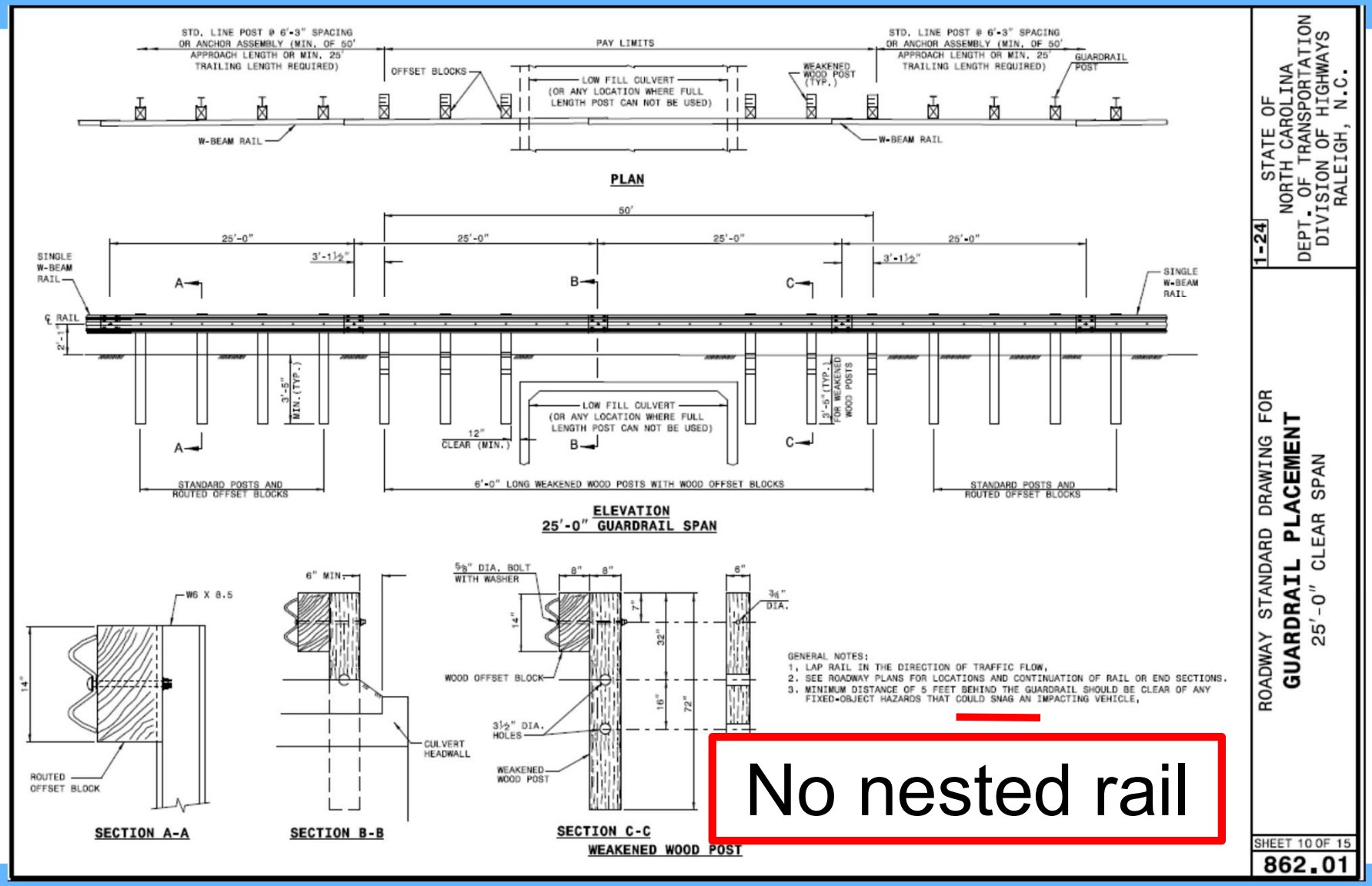
Omitting posts – old 29” guardrail

Required nested rail

31” – Omitting 3 posts

Working Width = 94”
Eligibility Letter B-189

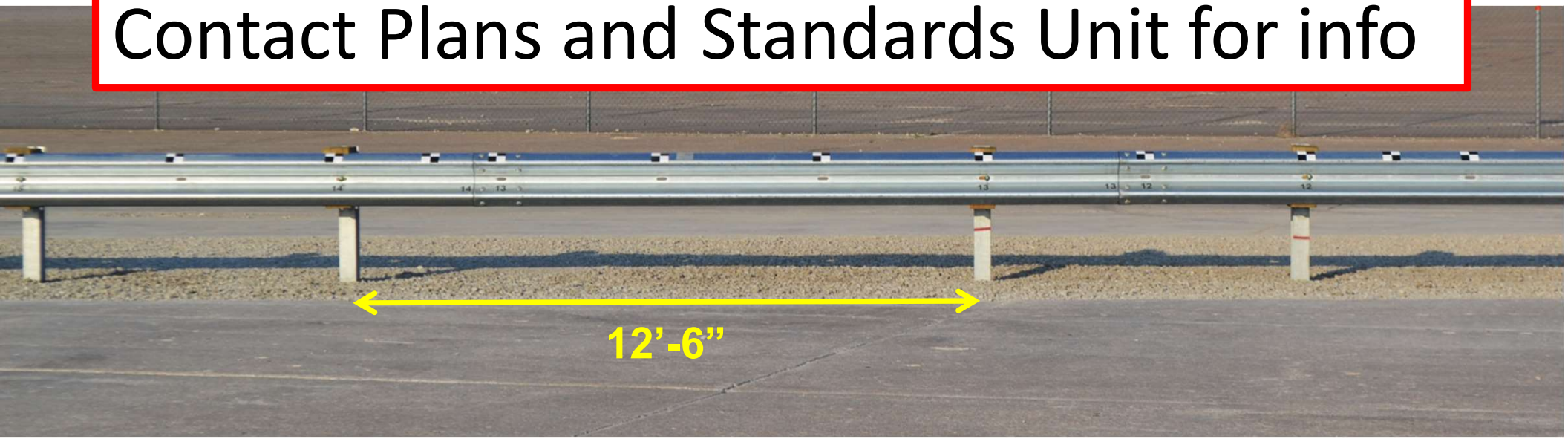
31” – Omitting 3 posts



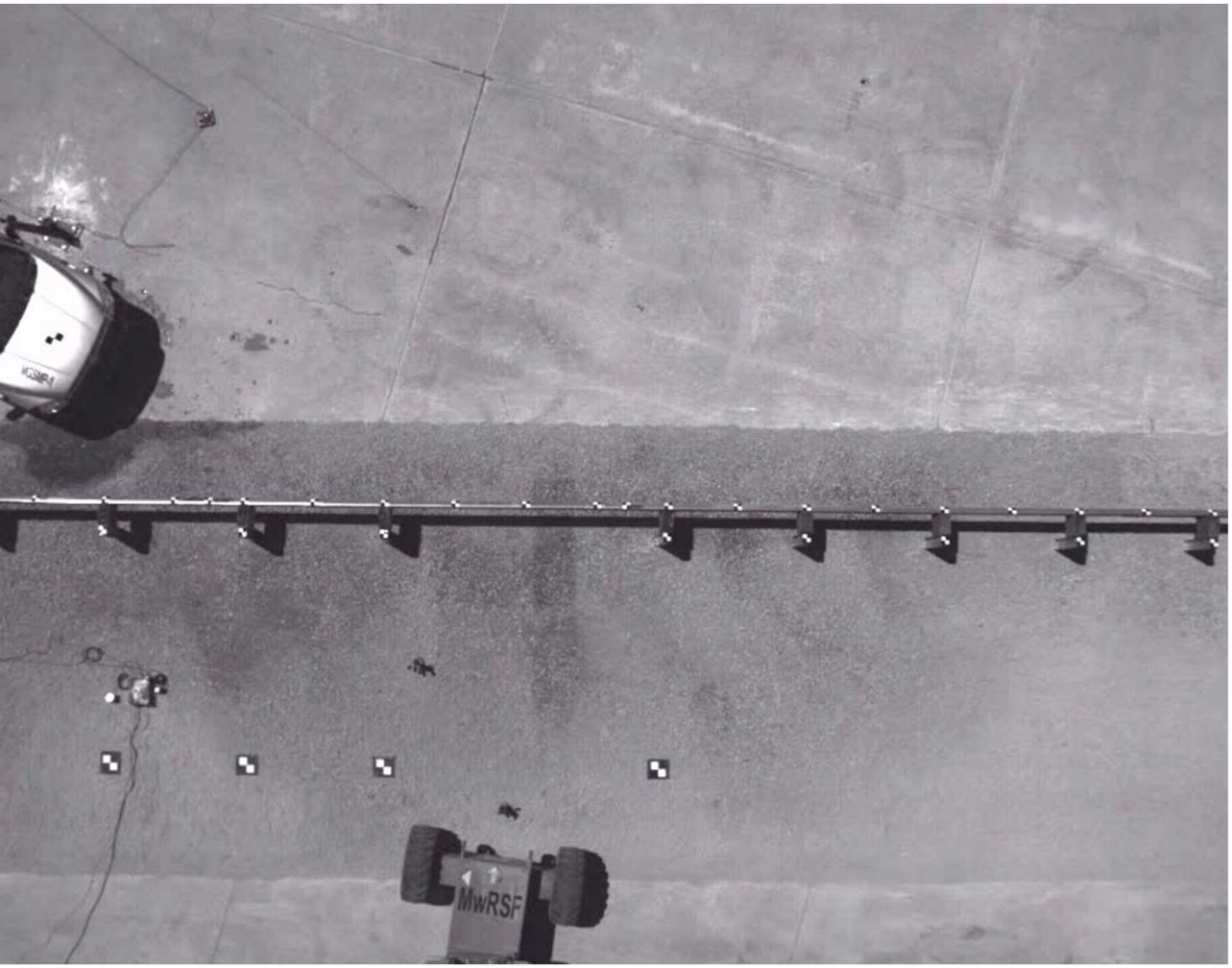
MGS - Omitting 1 post – Future??

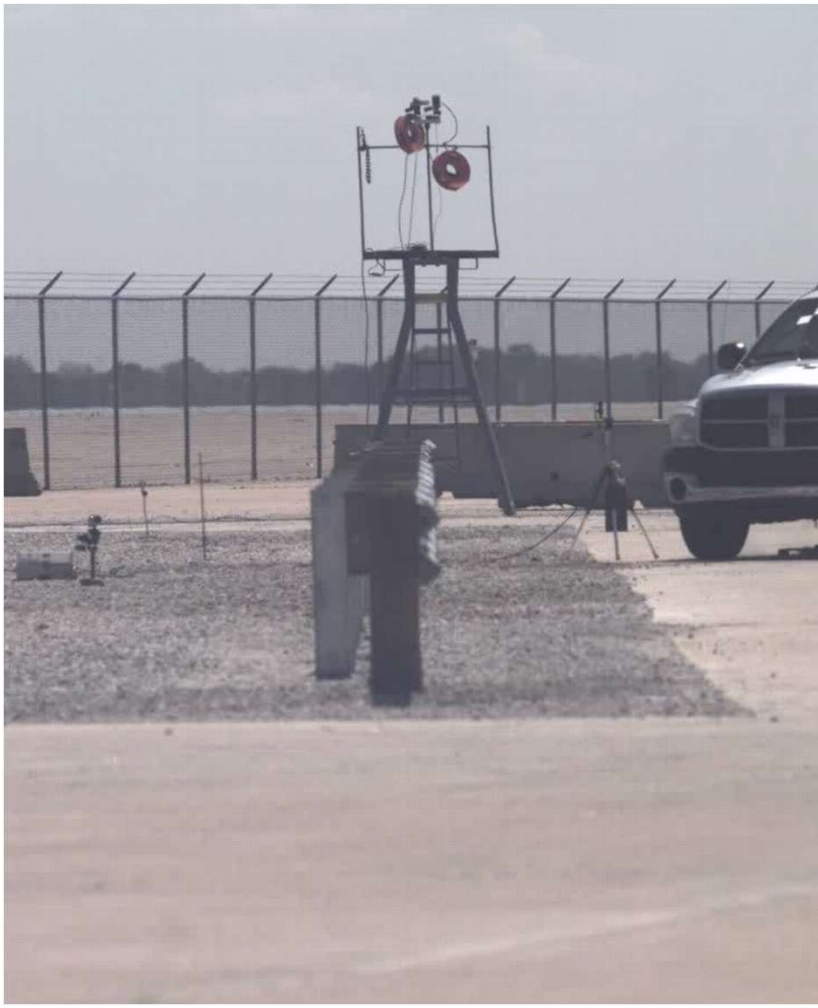
- No post modifications
- Can be used with wood or steel posts
- Can be used with 8” and 12” blockouts but not with the non-blocked system

Contact Plans and Standards Unit for info



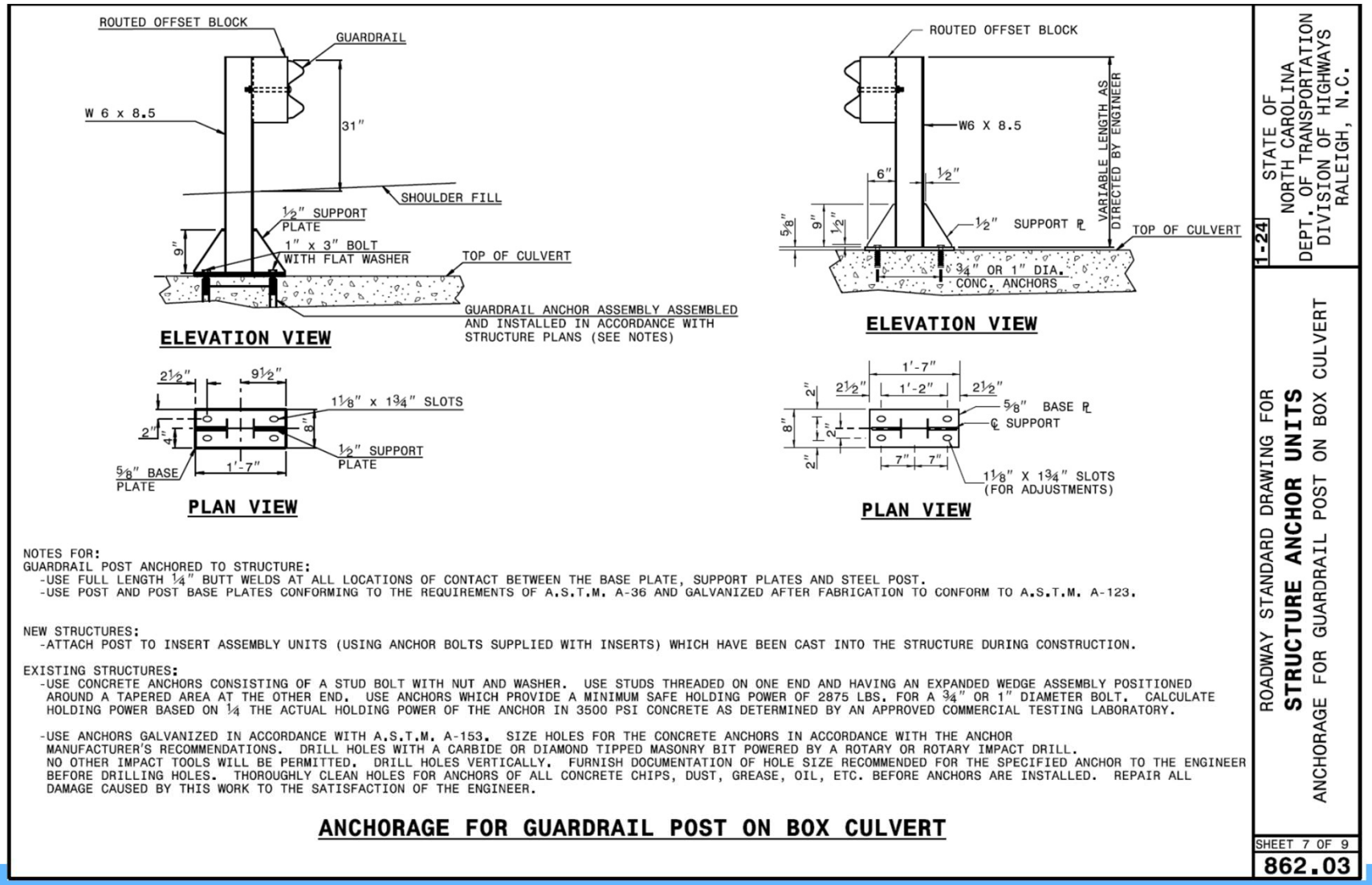
MGS - Omitting 1 post – NCDOT Looking into Developing Guidance





Working Width 50.1”
Limit 1 per 50’

Structure Mounted Guardrail



NOTES FOR:
GUARDRAIL POST ANCHORED TO STRUCTURE:
-USE FULL LENGTH ¼" BUTT WELDS AT ALL LOCATIONS OF CONTACT BETWEEN THE BASE PLATE, SUPPORT PLATES AND STEEL POST.
-USE POST AND POST BASE PLATES CONFORMING TO THE REQUIREMENTS OF A.S.T.M. A-36 AND GALVANIZED AFTER FABRICATION TO CONFORM TO A.S.T.M. A-123.

NEW STRUCTURES:
-ATTACH POST TO INSERT ASSEMBLY UNITS (USING ANCHOR BOLTS SUPPLIED WITH INSERTS) WHICH HAVE BEEN CAST INTO THE STRUCTURE DURING CONSTRUCTION.

EXISTING STRUCTURES:
-USE CONCRETE ANCHORS CONSISTING OF A STUD BOLT WITH NUT AND WASHER. USE STUDS THREADED ON ONE END AND HAVING AN EXPANDED WEDGE ASSEMBLY POSITIONED AROUND A TAPERED AREA AT THE OTHER END. USE ANCHORS WHICH PROVIDE A MINIMUM SAFE HOLDING POWER OF 2875 LBS. FOR A ¾" OR 1" DIAMETER BOLT. CALCULATE HOLDING POWER BASED ON ¼ THE ACTUAL HOLDING POWER OF THE ANCHOR IN 3500 PSI CONCRETE AS DETERMINED BY AN APPROVED COMMERCIAL TESTING LABORATORY.

-USE ANCHORS GALVANIZED IN ACCORDANCE WITH A.S.T.M. A-153. SIZE HOLES FOR THE CONCRETE ANCHORS IN ACCORDANCE WITH THE ANCHOR MANUFACTURER'S RECOMMENDATIONS. DRILL HOLES WITH A CARBIDE OR DIAMOND TIPPED MASONRY BIT POWERED BY A ROTARY OR ROTARY IMPACT DRILL. NO OTHER IMPACT TOOLS WILL BE PERMITTED. DRILL HOLES VERTICALLY. FURNISH DOCUMENTATION OF HOLE SIZE RECOMMENDED FOR THE SPECIFIED ANCHOR TO THE ENGINEER BEFORE DRILLING HOLES. THOROUGHLY CLEAN HOLES FOR ANCHORS OF ALL CONCRETE CHIPS, DUST, GREASE, OIL, ETC. BEFORE ANCHORS ARE INSTALLED. REPAIR ALL DAMAGE CAUSED BY THIS WORK TO THE SATISFACTION OF THE ENGINEER.

ANCHORAGE FOR GUARDRAIL POST ON BOX CULVERT

STATE OF NORTH CAROLINA
DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS
RALEIGH, N.C.

1-24

ROADWAY STANDARD DRAWING FOR
STRUCTURE ANCHOR UNITS
ANCHORAGE FOR GUARDRAIL POST ON BOX CULVERT

SHEET 7 OF 9
862.03

Openings in Barriers

Check with maintenance, ROW, etc

Openings in Barriers - NCDOT

6.2.2 Length of Need

Note: Do not leave a space of less than 300 feet between guardrail installations. Extend the guardrail through the area if less than 300 feet exists between installations.

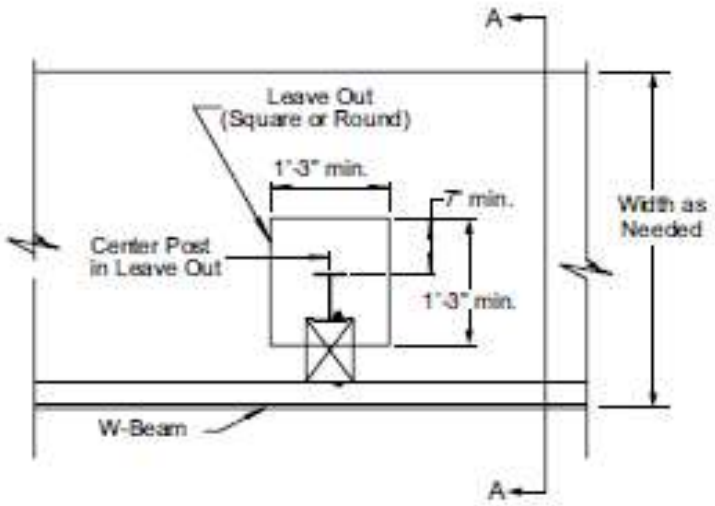
Again, be sure there are no conditions that would preclude closure

Extra Offset Blocks – National Guidance

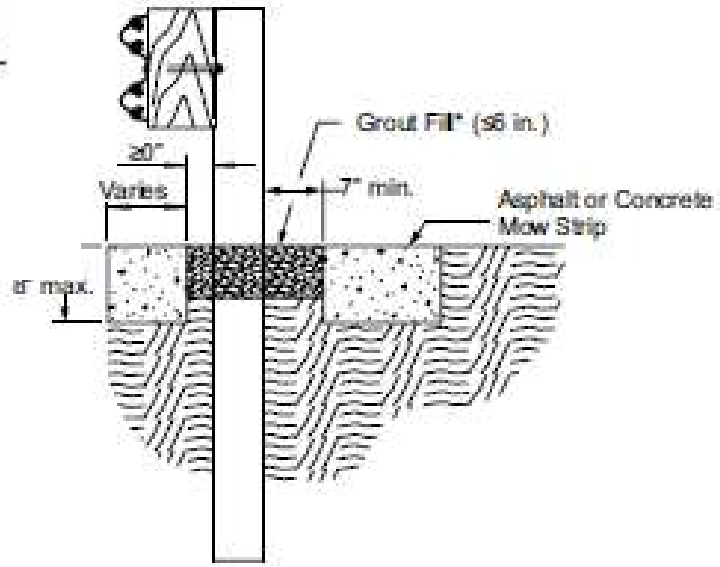
- Two Offset blocks (up to 16” deep) may be used at any time, for any number of posts.
- Three Offset blocks may be used at one or two posts in a section of guardrail.

Ref: AASHTO Roadside Design Guide – 3rd Edition, Section 5.4.1.6

Leaveouts in Structural Pavement



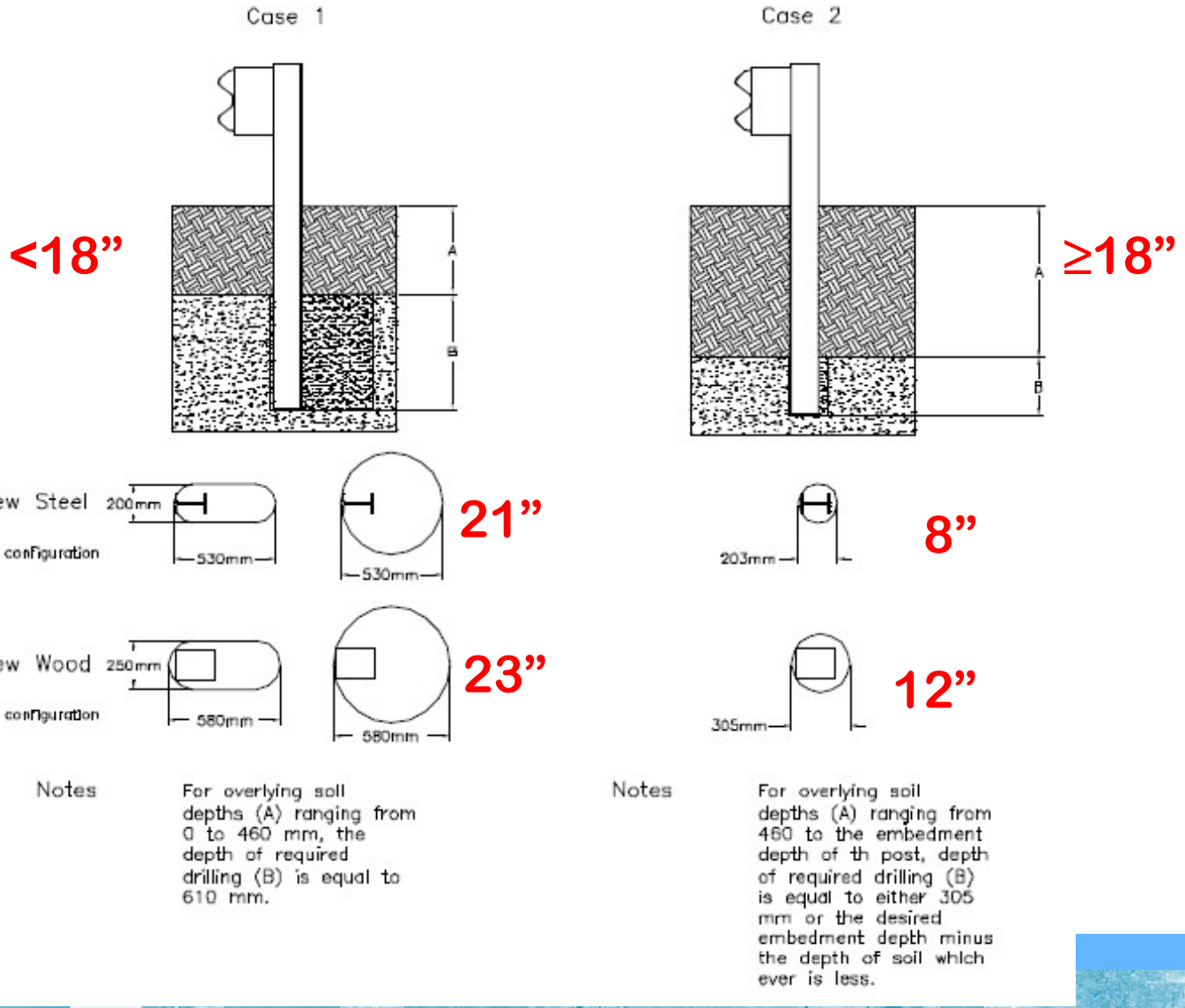
Steel Post Detail



Section A-A

Ref: AASHTO Roadside Design Guide – 4th Edition, Figure 5-52

Guardrail Posts in Rock - AASHTO



Eligibility Letter B-64B

Guardrail Posts in Rock - NCDOT

SECTION 862

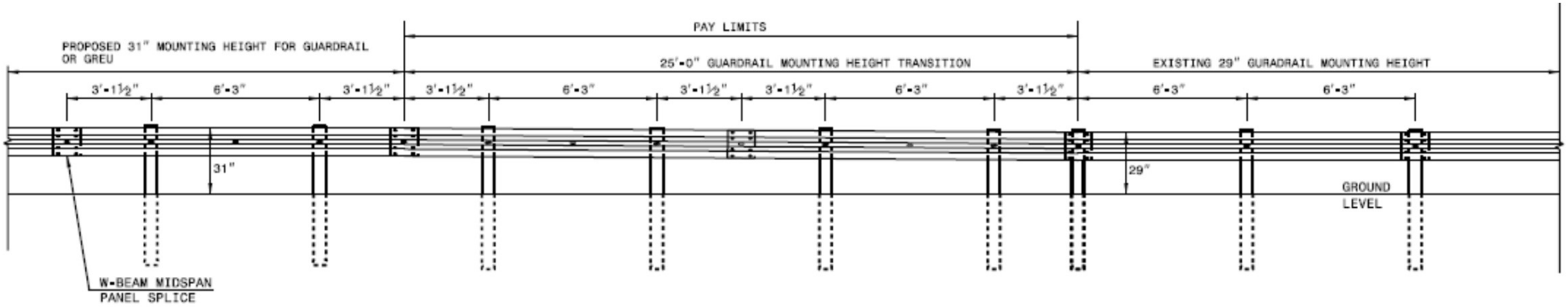
GUARDRAIL

862-3 CONSTRUCTION METHODS

Where rock interferes with the proper installation of the post, excavate a shaft in the rock at least 9 inches wide, parallel to the roadway, by 23 inches long, perpendicular to the roadway and 24 inches deep. Place the post against the roadside edge of the shaft and fill in behind the post with Class VI select material, up to the top elevation of the rock.

Provide bid item if aware of rock

Height Transition – 31” to/from Old Guardrail



ELEVATION VIEW

TRANSITION FROM 29" TO 31" W-BEAM GUARDRAIL MOUNTING HEIGHT

862.02 SHEET 5 OF 9	ROADWAY STANDARD DRAWING FOR **GUARDRAIL INSTALLATION**	1-24 STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

Review Learning Outcomes

- Understand the design principles affecting an optimal barrier installation
- Apply a field procedure to check Length of Need
- Be familiar with special designs to address site-specific installation considerations

Session 5:
Installation/Common Errors of System

Session 5 Learning Outcomes

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

- Describe key components of barrier systems
- Identify common installation errors

Barrier Components

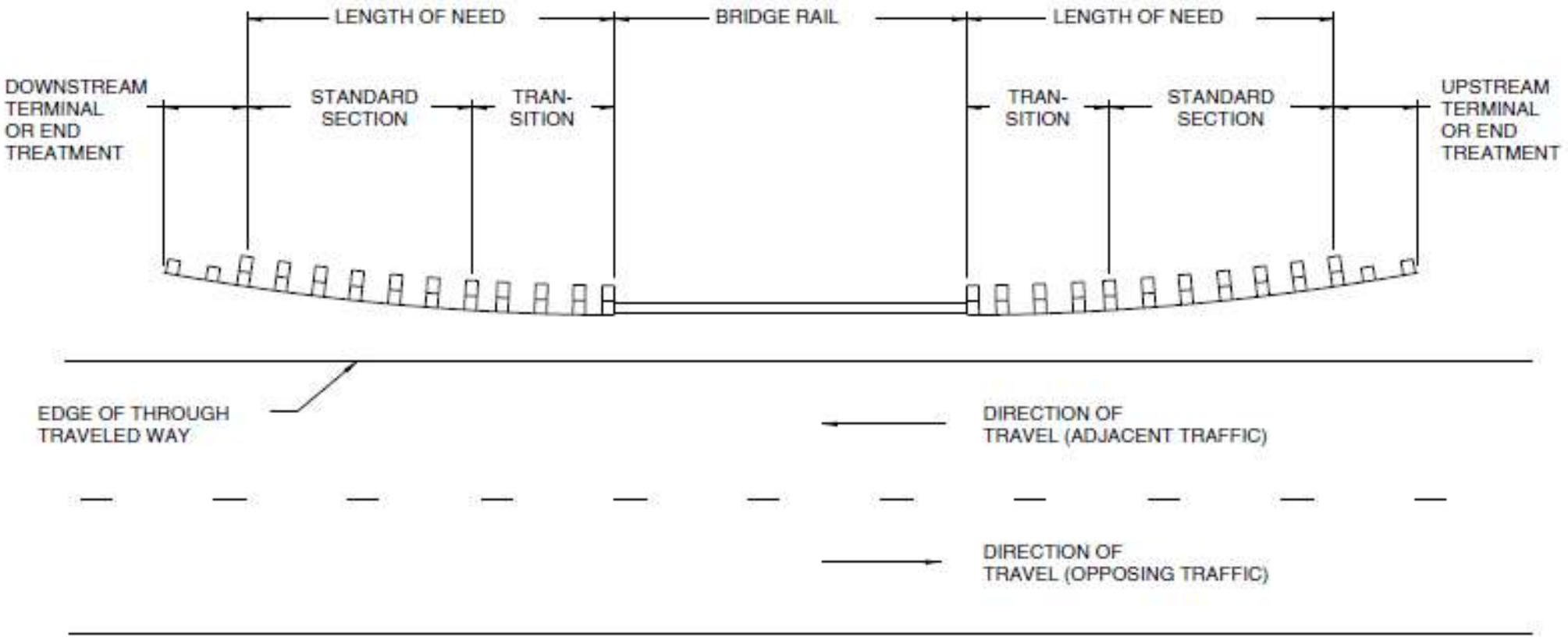


Figure 5-4. Definition of Roadside Barriers

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. End Treatment
4. Impact Attenuator

1. Standard Run of Barrier

a. Barrier Design Principles
b. Height Measurement
c. Tension Continuity
d. Other Considerations
e. Barriers in Work Zones

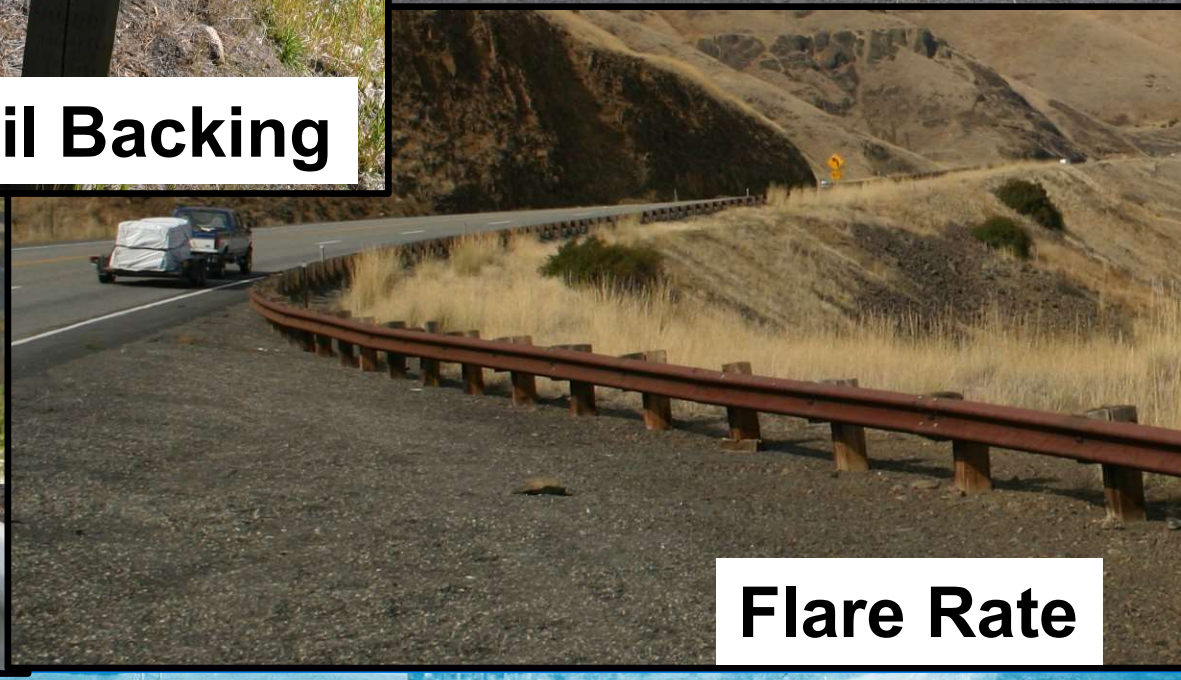
a. Barrier Design Principles

Deflection

Soil Backing

Slope in Front of Barrier

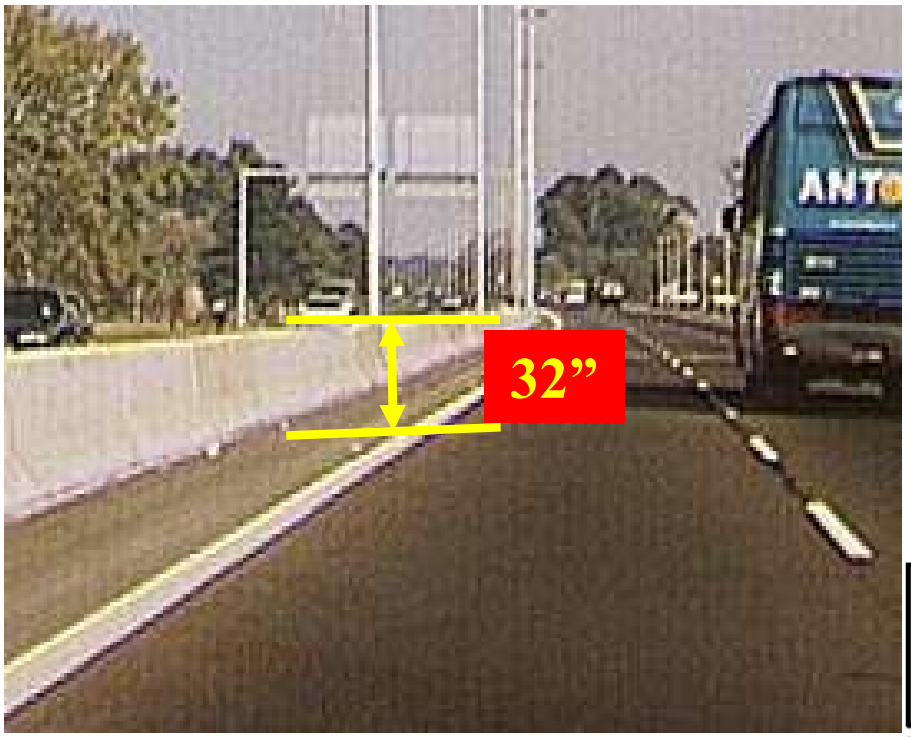
Barriers and Curbs

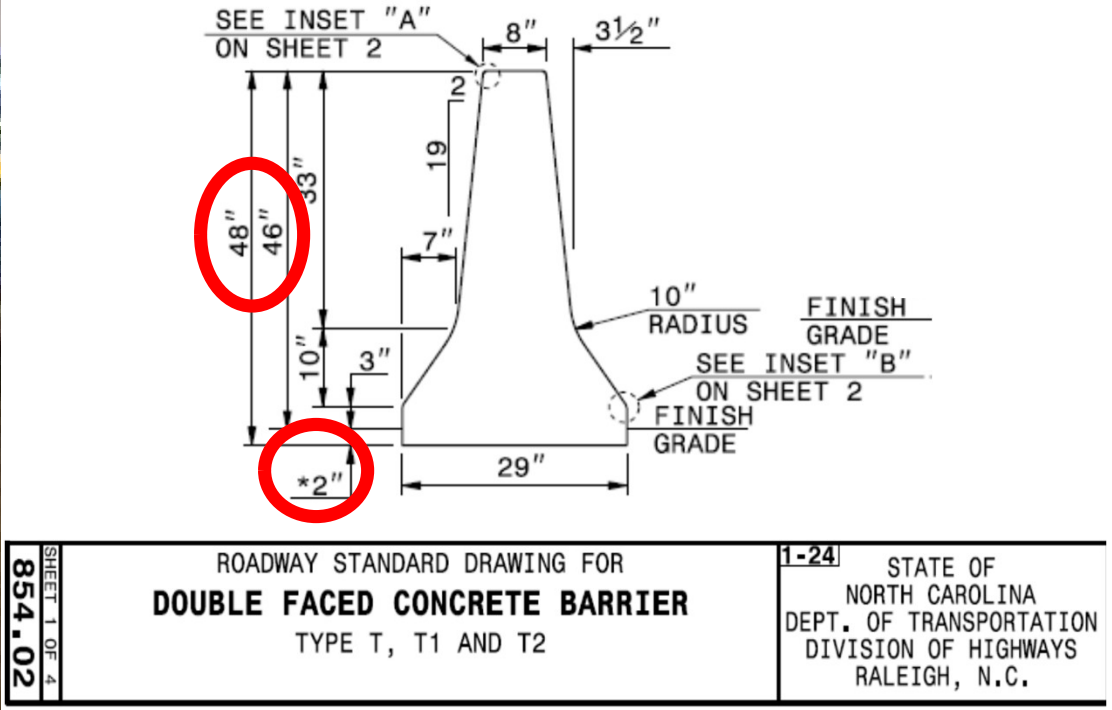


Flare Rate

b. Height Measurement

- Concrete Barrier Standards
  - Roadside & Median Barrier - 32” Jersey shape from Finished Grade (46” for Type T)



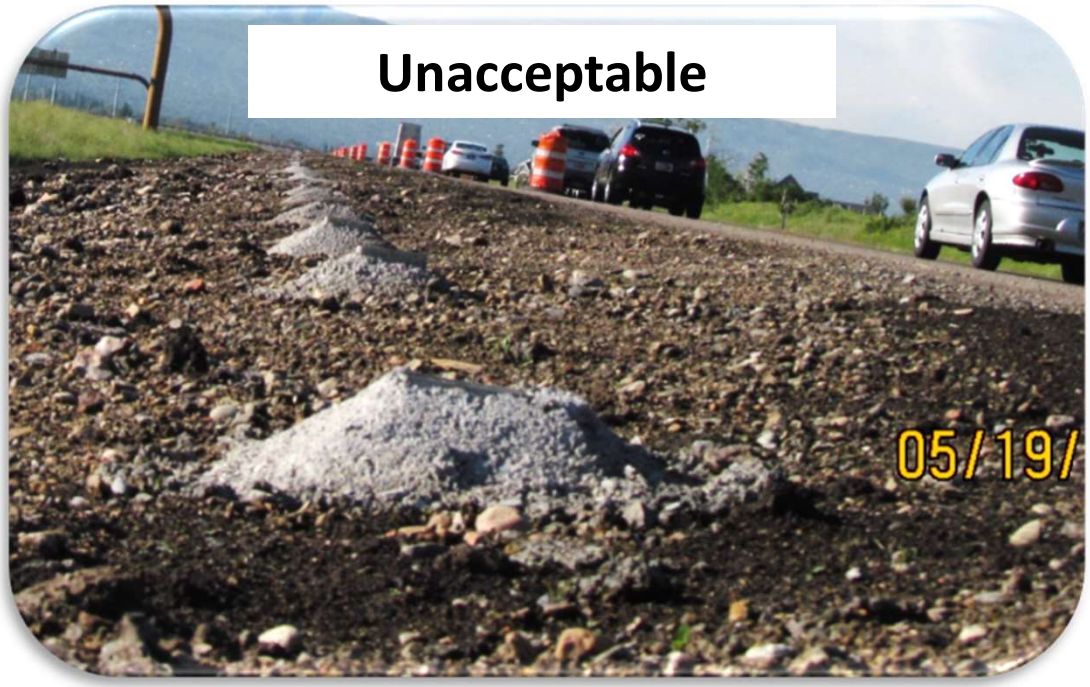


b. Height Measurement

- High Tension Cable Guiderail (HTCG)
  - Dependent on Manufactured System

b. Height Measurement

- High Tension Cable Guiderail (HTCG)
  - If the agency uses foundations, ensure top is at proper height. This will affect the height of the cable.



High Tension Cable Guiderail Systems

- The installation requirements are specific to the manufacturer. Referral to the manufacturer's installation manual is essential.
- The next slide shows an example of a installation checklist from a manufacturer's manual.

INSTALLATION CHECKLISTS

Cable Checklist

- ☐ Is there anything in front of the cable barrier that might cause a vehicle to vault the barrier or make the barrier ineffective? Items to look for include vegetation, rough ground, debris, or hard packed snow. These items should be removed if present.
- ☐ Has the roadside grading been completed correctly?
- ☐ Is there enough clearance between the barrier and the hazard for the expected barrier deflection? Minimum clearance is dependent upon post spacing.
- ☐ Is the cable barrier the correct height?

  Cable heights measured to the middle of the cable are as follows:

	Top	Middle	Bottom
Median & Roadside	29.5 in [750 mm]	25.5 in [650 mm]	21.5 in [545 mm]

- ☐ Are the cables properly tensioned?
- ☐ Are there irregular curves or joints where an errant vehicle might snag? Is there evidence of corrosion or damage to the cable? The cable should be scheduled for repair if either of these circumstances exist.
- ☐ Check to see that nuts are installed on the special locking hook bolts.

Post Checklist

Is there sufficient soil behind the posts to prevent them from being pushed out when the barrier is hit? Eroded or disturbed soil should be replaced and recompacted.

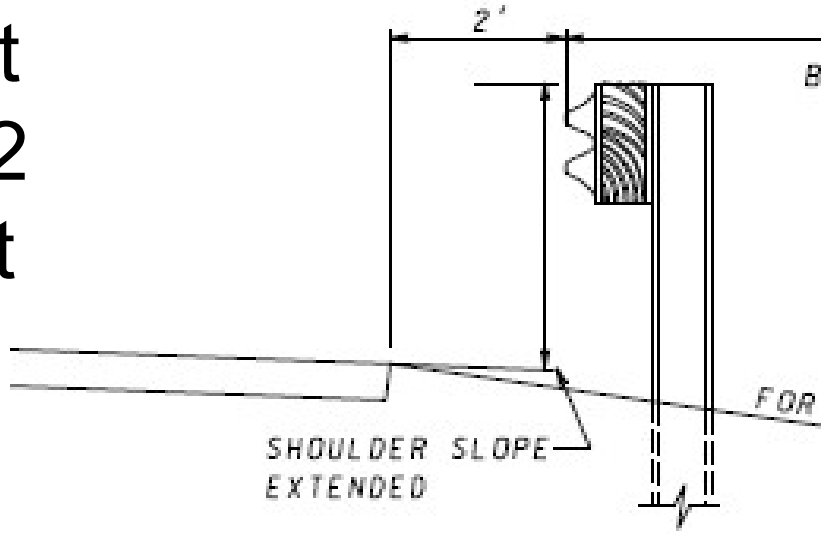
- ☐ Is the post spacing correct?
- ☐ Is there evidence of corrosion or damage to the posts? The posts should be replaced if either of these circumstances exist.

Old 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

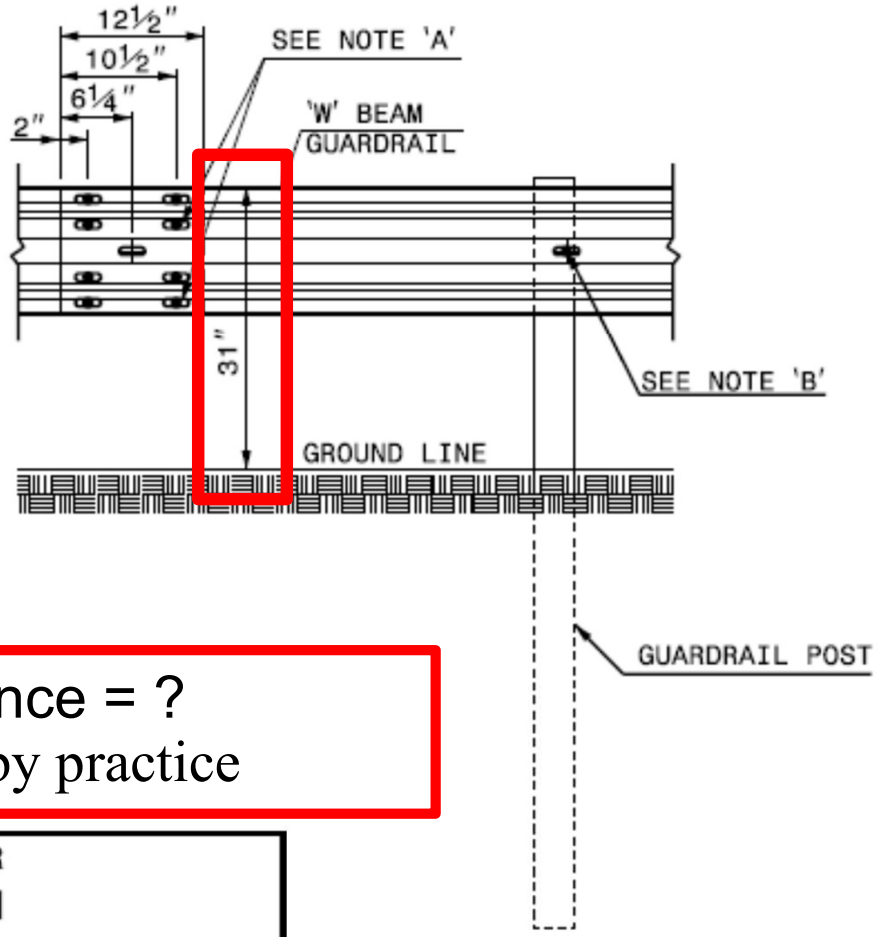
Only for the 27 3/4" Guardrail



PLACEMENT ON SLOPE

31” W-Beam Height Measurement

- 31” W-Beam



Remember: our terminology is referring to TOP of Rail

Ground slope is 10:1 or FLATTER

Tolerance = ?
± 1”, by practice

862.02 SHEET 6 OF 9

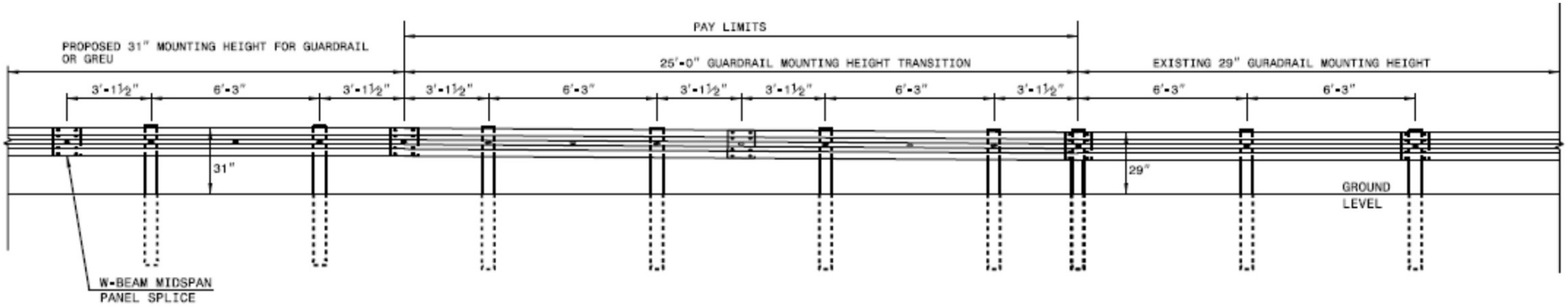
ROADWAY STANDARD DRAWING FOR
GUARDRAIL INSTALLATION

b. Height Measurement

Rail too high

Rail too low

b. Height Transition Measurement



ELEVATION VIEW

NOTE: IF EXISTING GUARDRAIL IS LOWER THAN 29", USE AN ADDITIONAL 12'-6" LONG SECTION OF GUARDRAIL, FOR EVERY 1" OF HEIGHT DIFFERENCE, TO TRANSITION FROM EXISTING GUARDRAIL TO PROPOSED 31" GUARDRAIL

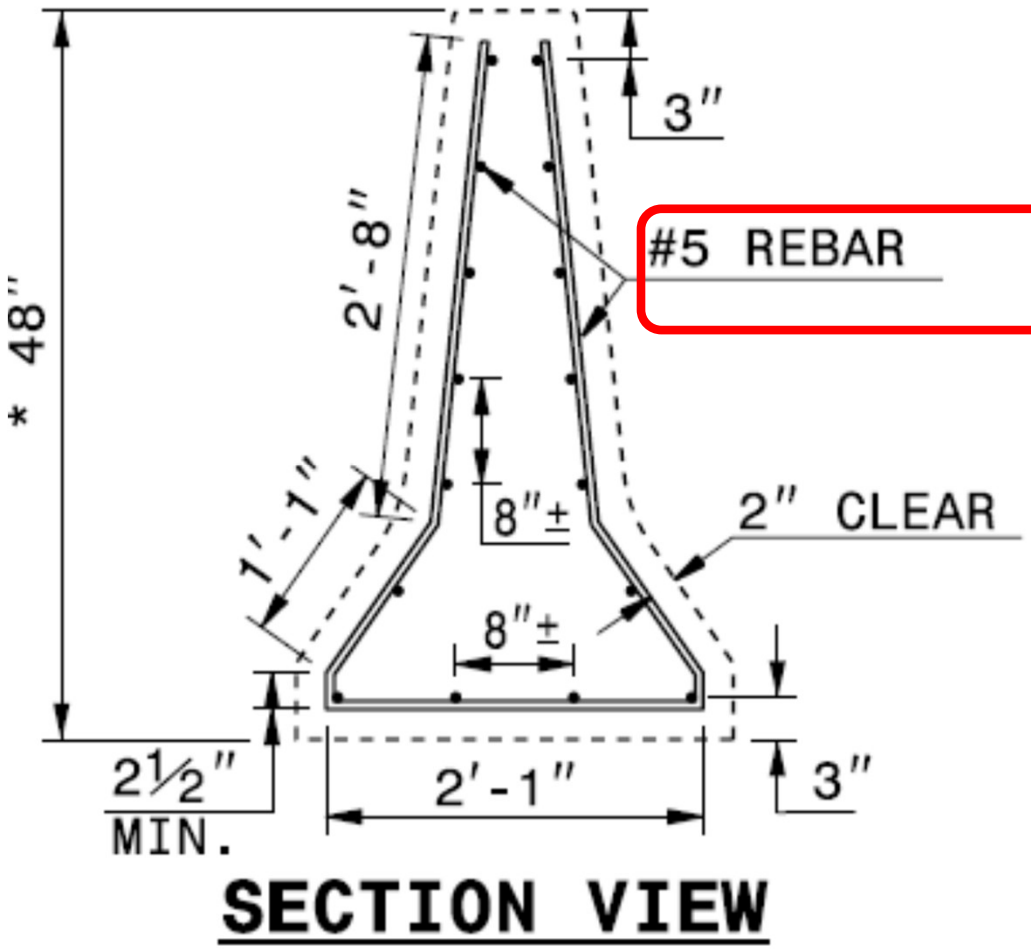
TRANSITION FROM 29" TO 31" W-BEAM GUARDRAIL MOUNTING HEIGHT

862.02 SHEET 5 OF 9	ROADWAY STANDARD DRAWING FOR **GUARDRAIL INSTALLATION**	1-24 STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C.

c. Tension Continuity

- Concrete Barrier
  - Continuous reinforcement and/or anchored to/in the pavement, and for PCB, the connection pin and loops
- 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)
- High Tension Cable Guiderail
  - Proprietary systems typically use a type of turn buckle between successive cables and end terminal anchors.

c. Tension Continuity



SECTION VIEW

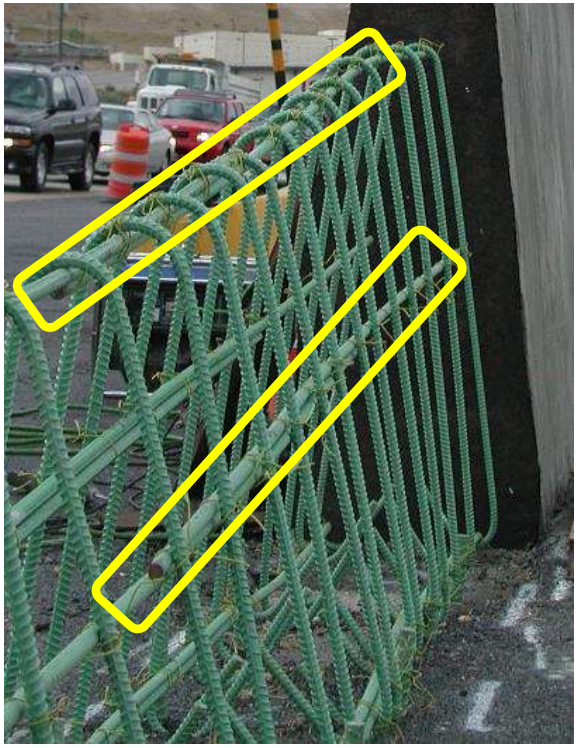
* REFER TO PLAN TYPICAL SECTIONS AND PAVEMENT SCHEDULE TO DETERMINE KEY-IN DEPTH. DIMENSIONS SHOWN ARE BASED ON A MIN. KEY-IN DEPTH.

TYPE T

854.02	SHEET 3 OF 4	ROADWAY STANDARD DRAWING FOR **DOUBLE FACED CONCRETE BARRIER** TYPE T, T1 AND T2

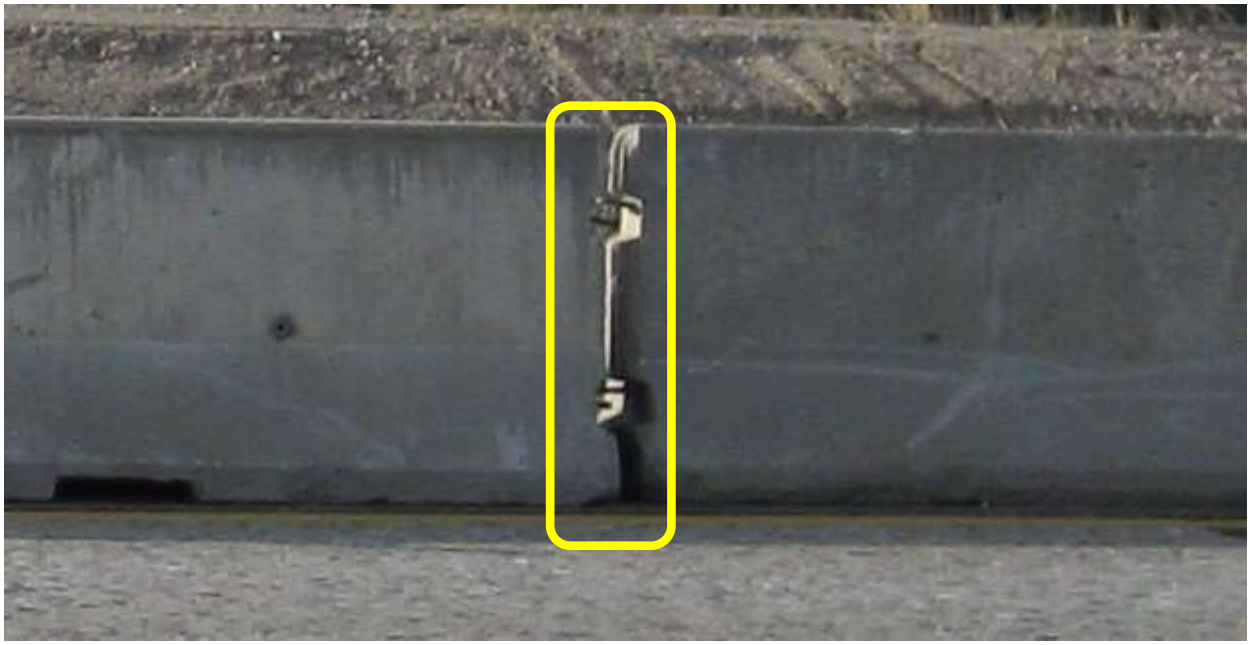
c. Tension Continuity

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
  - 8 bolts tying panels together
  - structural connection to a rigid barrier with 4 (min) thru bolts

c. Tension Continuity

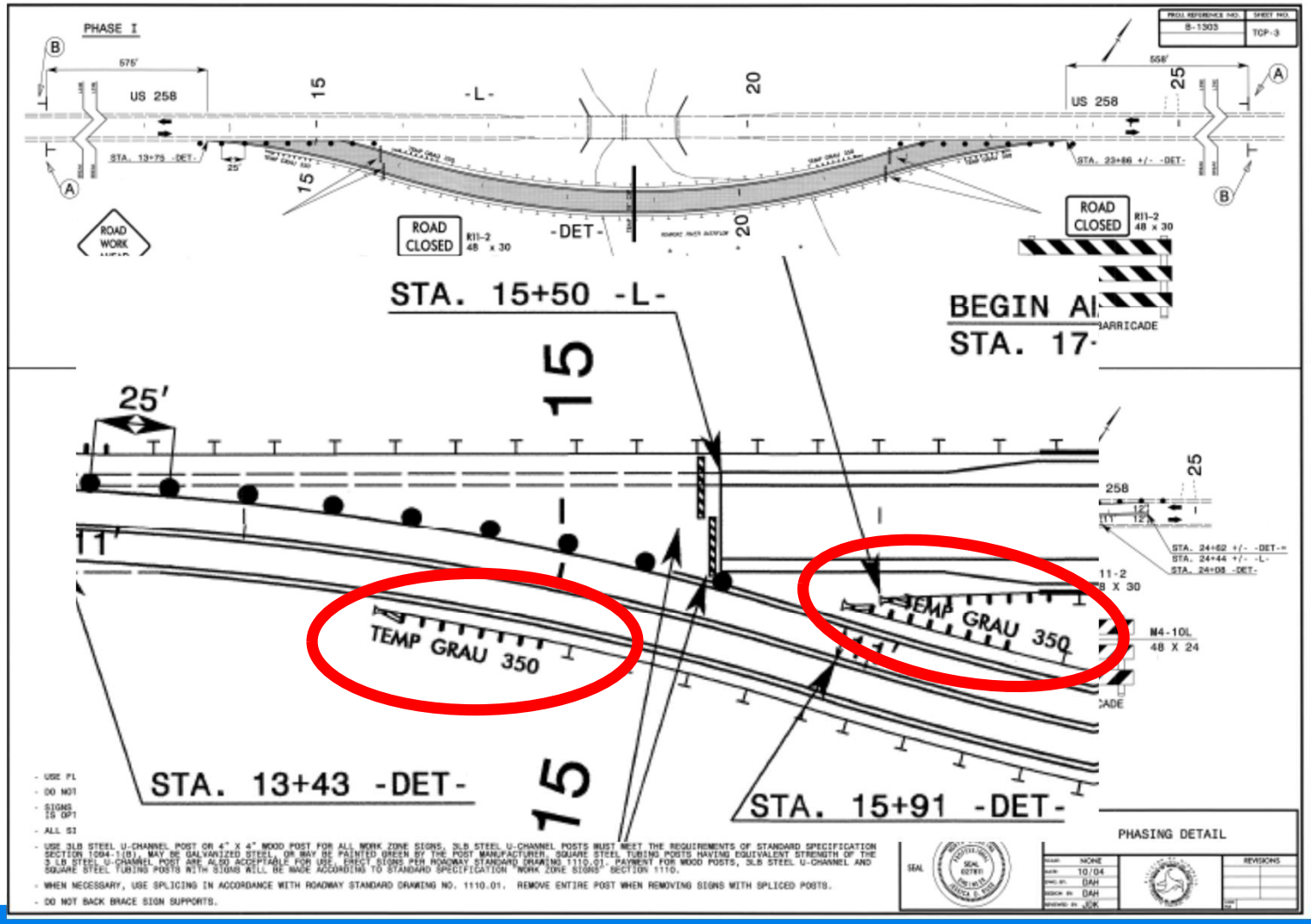
- Thrie Beam Connection
  - 5 bolts required for a structural connection to a rigid barrier
  - Holes cored through concrete preferred, 7/8” high strength hex head bolt with nut

c. Tension Continuity

Missing bolts

No Structural connection

Temporary Barrier – Need for Tension



Traffic Management Plan

Quantity Summary Sheet

COMPUTED BY: K.N.WASHINGTON DATE: 05/26/2005
CHECKED BY: T.F.DUNCAN, PE DATE: 06/2/2005

PROJECT NO.	SHEET NO.
B-1303	3-B

STATE OF NORTH CAROLINA
DIVISION OF HIGHWAYS

SUMMARY OF EARTHWORK

Station	Station	Unclass. Excav. CY	Embank. +% CY	Borrow CY	Waste CY
-L-					
13+00.00	17+89.94	74	1,398	1,324	
19+72.06	24+44.63	32	1,332	1,300	
-DET-					
15+80.00	22+93.00		23,877	23,877	
SUBTOTALS:		106	26,607	26,501	
-DET- REMOVAL		18,445			18,445
PROJECT TOTALS:		18,551	26,607	26,501	18,445
EST. 5% TO REPLACE TOP SOIL OF BORROW PIT				1,325	
EST. SHOULDER MATERIAL			672	672	
GRAND TOTALS:		18,551	27,279	28,498	18,445
SAY:		18,600 CY		28,600 CY	

UNDERCUT EXCAVATION = 500 CY
SELECT GRANULAR MATERIAL = 5000 CY
FABRIC FOR SOIL STABILIZATION = 1500 SY

SUMMARY OF EXISTING ASPHALT PAVEMENT REMOVAL

LINE	Station	Station	LOC LT/RT/CL	AREA SY
-L-	17+40.80	18+14.80	CL	283
-L-	19+20.80	20+28.80	CL	356
-DET-	14+73.68	22+87.55	CL	2,351
			TOTAL:	2,970
			SAY:	3,000 SY

APPROXIMATE QUANTITIES ONLY. UNCLASSIFIED EXCAVATION, FINE GRADING, CLEARING AND GRUBBING, AND REMOVAL OF EXISTING PAVEMENT WILL BE PAID FOR AT THE LUMP SUM PRICE FOR "GRADING".

"W" = DISTANCE FROM EDGE OF LANE TO FACE OF GUARDRAIL
TOTAL SHOULDER WIDTH = DISTANCE FROM EDGE OF TRAVEL LANE TO SHOULDER BREAK POINT.
FLARE LENGTH = DISTANCE FROM LAST SECTION OF PARALLEL GUARDRAIL TO END OF GUARDRAIL.
W = [illegible] BEGINNING OF TAPER TO END OF GUARDRAIL.
[illegible] IMPACT ATTEMUATOR = 350
NG = NON-GATING IMPACT ATTEMUATOR = 350

GUARDRAIL SUMMARY

LINE	BEG. STA.	END STA.	LOC.	LENGTH STRAIGHT	LENGTH TEMP STRAIGHT	LENGTH DOUBLE FACED	WARRANT POINT APPR. END	WARRANT POINT TRAIL. END	"W" DIST FROM E.O.L.	TOTAL SHLDR WIDTH	FLAIR LENGTH APPR. END	FLAIR LENGTH TRAIL. END	W APPR. END	W TRAIL. END	ANCHORS TYPE III	ANCHORS GRAU 350	ANCHORS TEMP GRAU 350	IMP. ATTEN. TYPE 350 EA	IMP. ATTEN. TYPE 350 G	IMP. ATTEN. TYPE 350 NG	REMOVE EXISTING GRDRAIL	REMARKS
-L-	13+82.94	17+	RT	455.00			13+65.00	17+77.84	10	13	50		1		1	1					137.50	GR WARRANTED ALONG ENTIRE RT SIDE BEFORE BR.
-L-	13+82.94	17+	LT	475.00			17+77.94	13+00.80	10	13		50		1	1	1					137.50	GR WARRANTED ALONG ENTIRE LT SIDE BEFORE BR.
-L-	19+84.06	23+	RT	325.00			19+84.06	23+50.80	10	13		50		1	1	1					137.50	
-L-	19+84.06	22+	LT	380.00			21+93.00	18+84.86	10	13	50		1		1	1					137.50	
-L-	16+80.00		RT						10	13	50		1				1					REQUESTED BY TRAFFIC CONTROL
-L-		21+	RT						10	13		50		1			1					REQUESTED BY TRAFFIC CONTROL
-DET-	14+44.15	17+	RT		875.00		15+60.00	23+00.80	6	8	50	50	1	1			2					REMOVE -DET- TEMP GR.
-DET-	15+87.50	17+	LT		562.50		20+50.00	17+00.80	6	8	50	50	1	1			2					REMOVE -DET- TEMP GR.
SUBTOTAL:				1,575.0	1,437.5										4	4	8					
[illegible] ANCHORS DEDUCT:																						
GRAU	4	@	50.00	-200.00																		
TYPE III	4	@	18.75	-75.00																		
TEMP GRAU	4	@	50.00		-200.00																	
ANCHOR TOTALS:				-275.00	-200.00																	
GRAND TOTAL:				1,300.00 LF	1,237.50 LF										4	4	6				550.80 LF	
SAY:				1,300.00 LF	1,237.50 LF										4	4	6				550.00 LF	
ADDITIONAL GUARDRAIL POST:				5 EA																		

Quantity Summary Sheet – blow-up

LINE	BEG. STA.	END STA.
-L-	13+02.94	17+77.94
-L-	13+02.94	17+77.94
-L-	19+84.06	23+09.06
-L-	19+84.06	22+84.06
-L-	16+00.00	
-L-		21+50.00
-DET-	14+44.15	23+09.15
-DET-	15+87.50	21+50.00
SUBTOTAL:		

W		ANCHORS		
APPR. END	TRAIL. END	TYPE III	GRAU 350	TEMP GRAU 350
1		1	1	
	1	1	1	
	1	1	1	
1		1	1	
1				1
	1			1
1	1			2
1	1			2
		4	4	6

Need to re-establish tension in any altered guardrail – include in plan sheets

★ Placement of GREU must abide by standard application criteria (Deflection and Length of Need {LON})

d. Other Considerations

- 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.

Structural Anchor Standards reference “LAP”

d. Other Considerations

Correctly Lapped

d. Other Considerations

Typically NO WASHERS

Unless called for in the plans

d. Other Considerations

Delineators

Placed on the **RAIL to post** bolt – NOT GOOD

Placed on the **SPLICE** bolt – GOOD

d. Other Considerations

Drilling of holes into the rail FOR THE RAIL TO POST CONNECTION is not recommended.

Better to bolt offset block to post, no rail attachment, for one or two consecutive posts.

d. Other Considerations

Cutting a slot, hole or a rail section with a torch is NOT PERMISSIBLE

Using a torch on the rail element may compromise the strength of the rail.

Tests results have shown this becomes a weak point in the rail and can cause ripping and rupturing.

e. Barriers in Work Zones

Barrier should be in GOOD condition

e. Barriers in Work Zones

Flare rate appears to be too excessive here

2. Transition

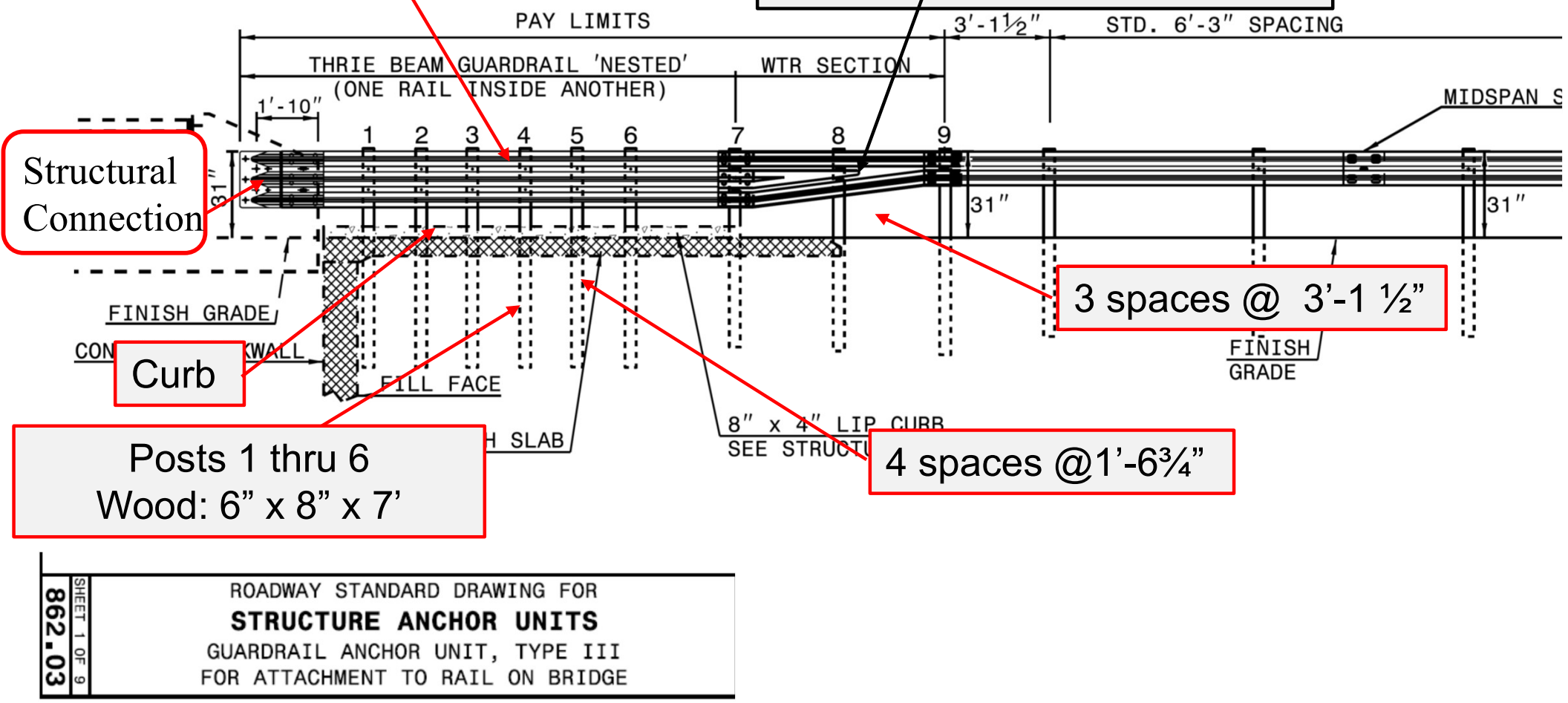
Old 29” Guardrail Standard

31 Inch Transition Design

12’ – 6” Nested Thrie-Beam Panels

6'-3" Asymmetrical transition to W beam (10 gauge)

Structural Connection



Curb

3 spaces @ 3’-1 ½”

Posts 1 thru 6
Wood: 6” x 8” x 7’

4 spaces @1’-6¾”

862.03 SHEET 1 OF 9

ROADWAY STANDARD DRAWING FOR
STRUCTURE ANCHOR UNITS
GUARDRAIL ANCHOR UNIT, TYPE III
FOR ATTACHMENT TO RAIL ON BRIDGE

Transition

Structural Connection

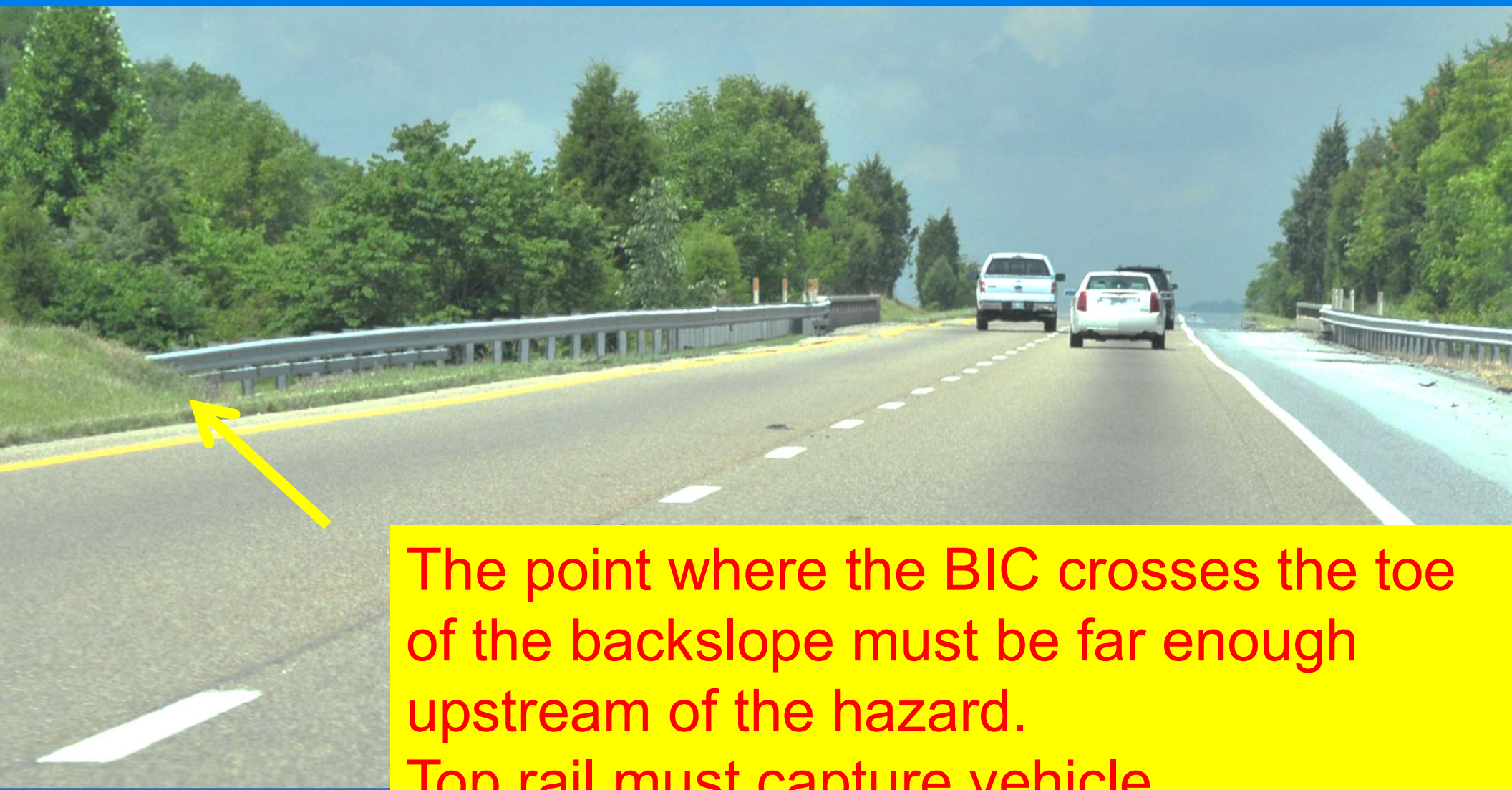
3. End Treatments

a. Manufacturers Manuals
b. Post types
c. Panel requirements
d. Grading
e. Breakaway Cable **Anchorage**
f. Other Common Errors
g. Delineation

3. End Treatment – Non-proprietary

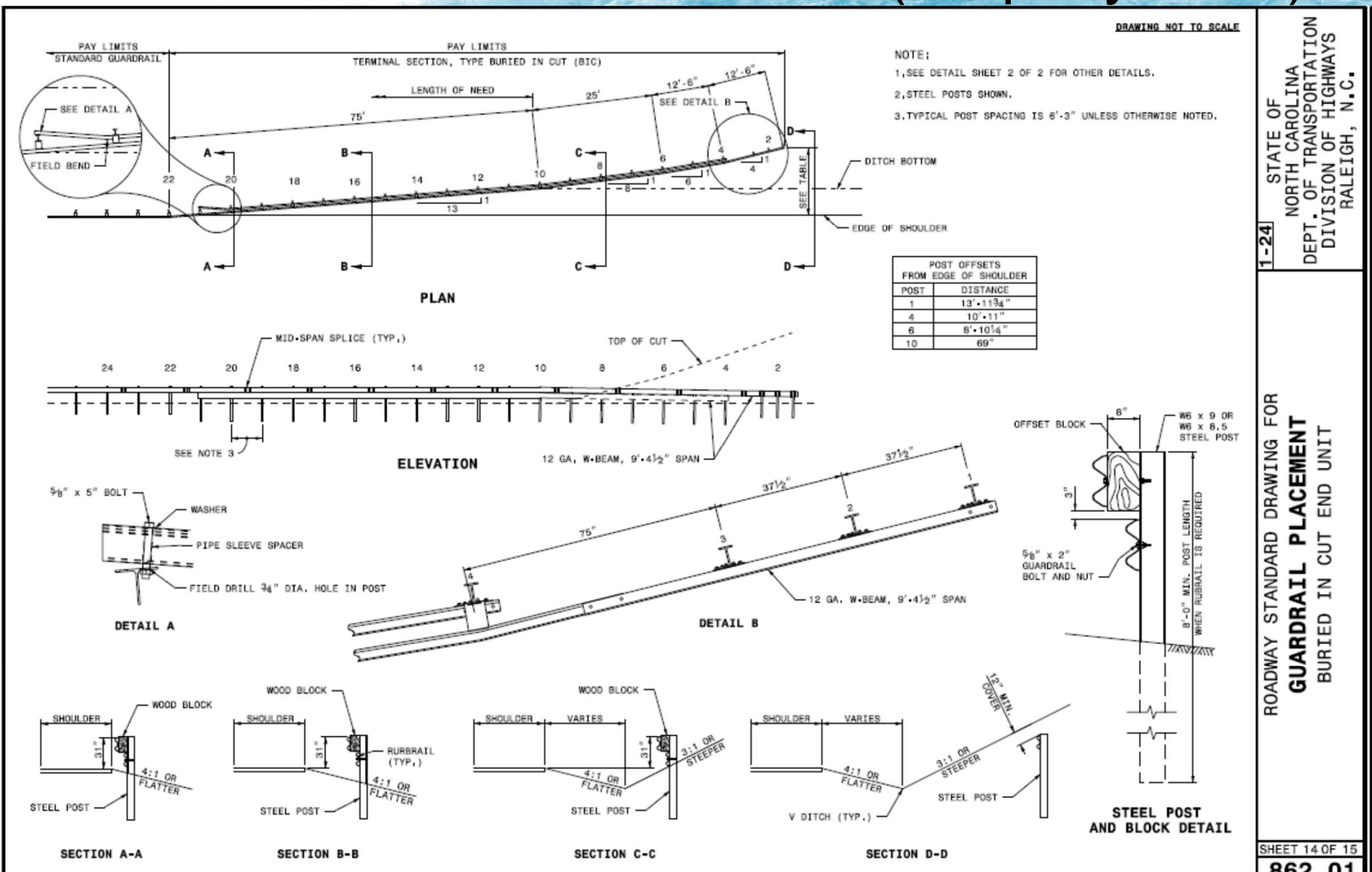
Although the Buried-in-Cut (BIC) is the preferred (and best) end treatment, it can be constructed incorrectly

3. End Treatment – Non-proprietary



The point where the BIC crosses the toe of the backslope must be far enough upstream of the hazard.
Top rail must capture vehicle

Just a reminder – It's the Best (Properly done)



STATE OF NORTH CAROLINA
DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS
RALEIGH, N.C.

1-24

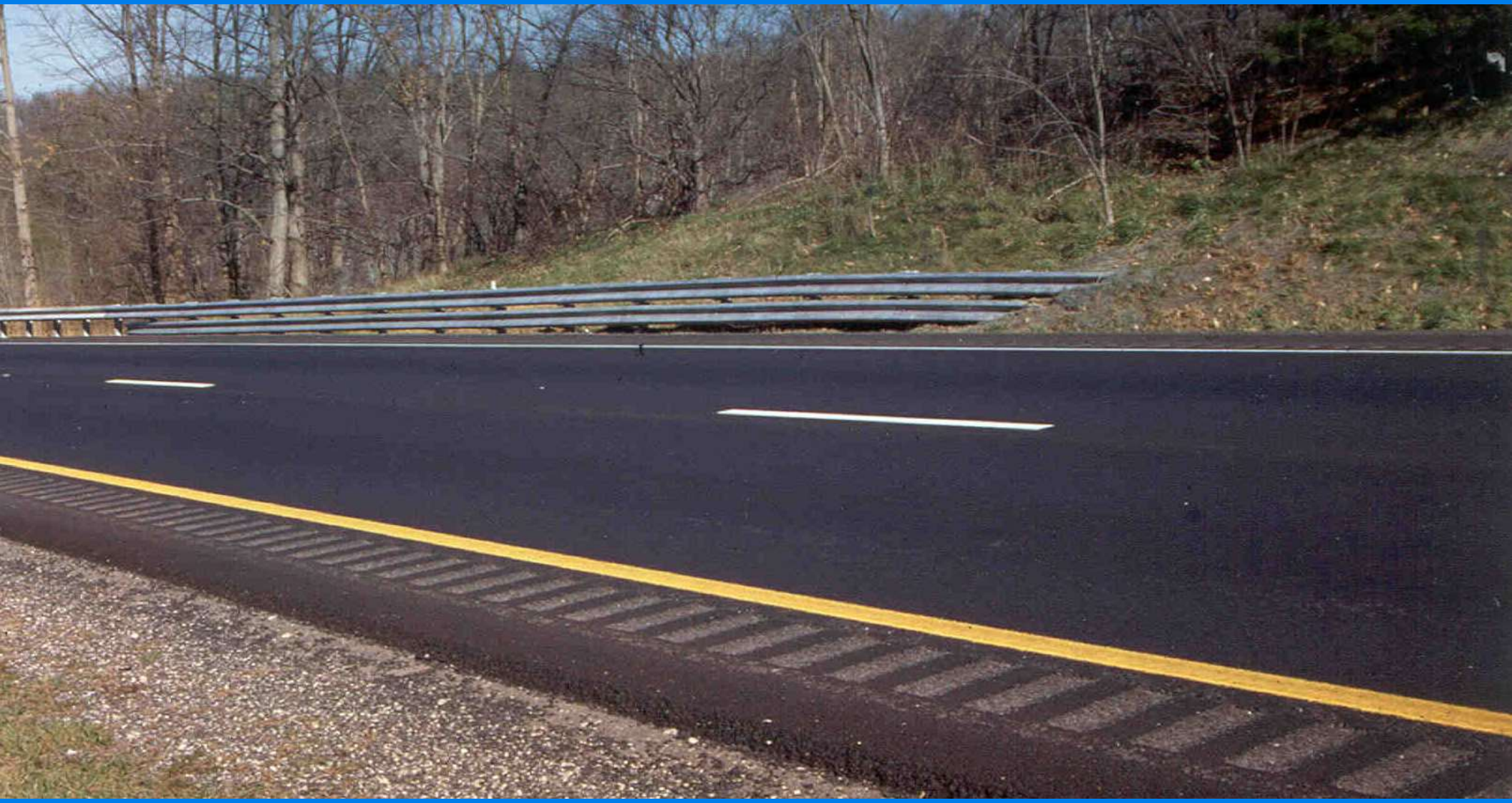
ROADWAY STANDARD DRAWING FOR
GUARDRAIL PLACEMENT
BURIED IN CUT END UNIT

SHEET 14 OF 15
862.01

Buried-in-Cut End Treatment

- 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 (but a max height of ~47”)
  - Use a flare rate of 13:1 or flatter on the foreslope
  - Use an anchor of steel posts capable of developing the full tensile strength of the W-beam rail and buried 1’ below ground

BIC Looking Across Roadway



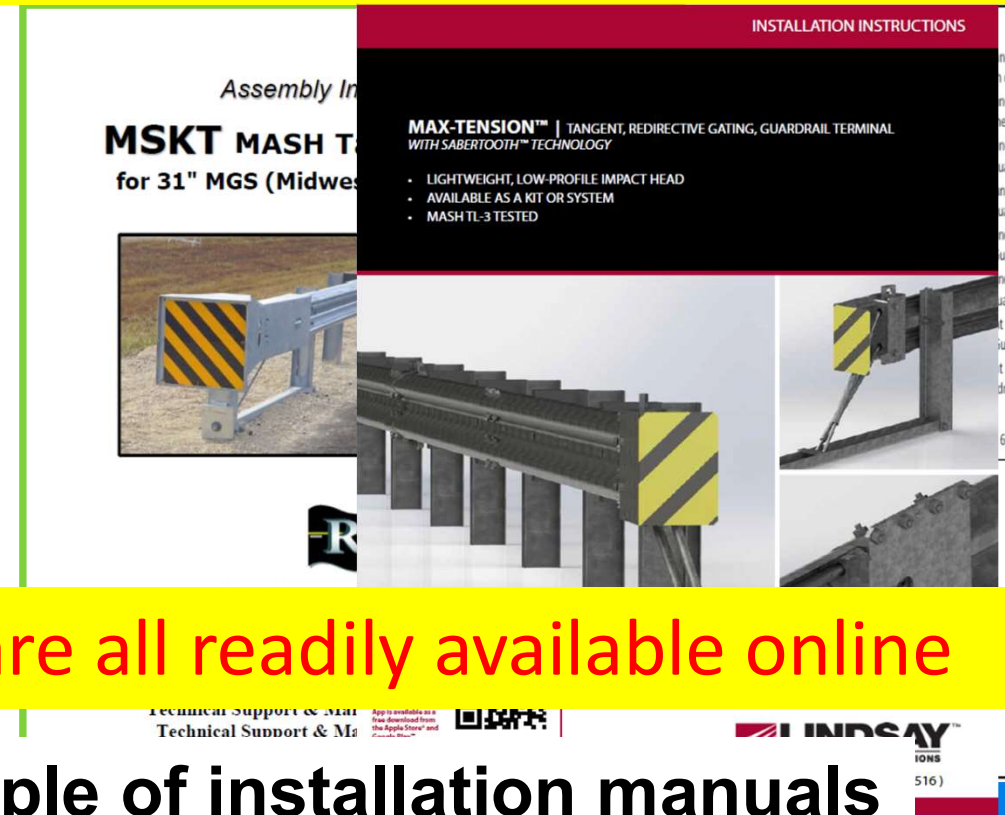
3. End Treatment

RULE #1: Follow manufacturers instructions and NCDOT standard plans.

3. End Treatment

a. Manufacturers Manuals

Must follow manufacturer's installation instructions and State standards.



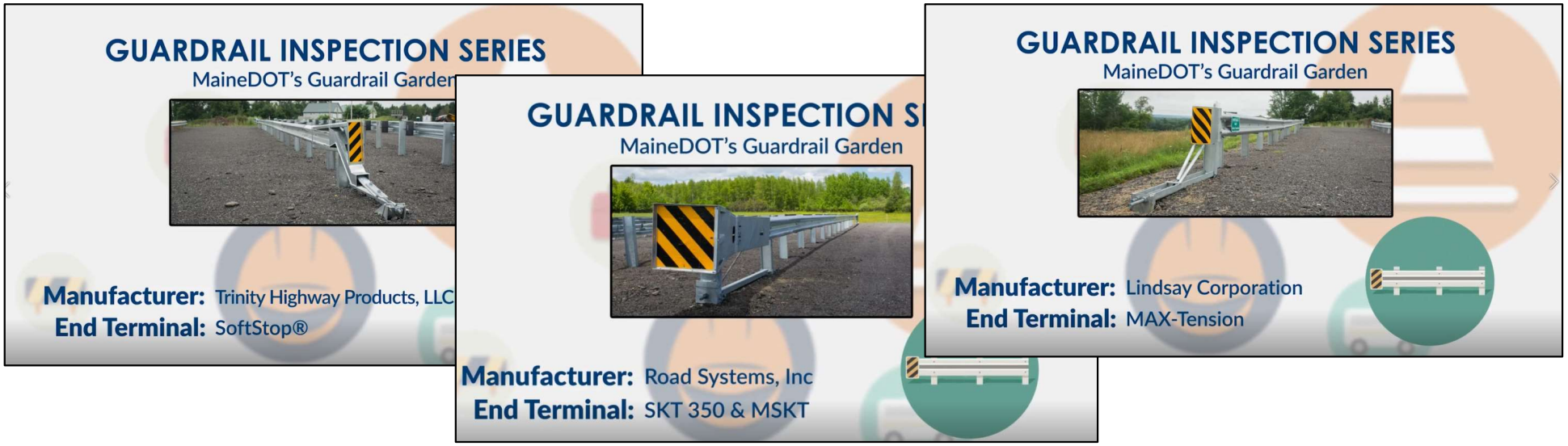
These are all readily available online

Example of installation manuals

TAKE ADVANTAGE OF MANUFACTURER TRAINING FOR DETAILED INSTRUCTION ON INSTALLING ANY OF THE PROPRIETARY END TREATMENTS

Additional Resources

- Manufacturers website – online training, installation manuals, etc.
- Maine DOT's Guardrail Inspection Series videos http://www.dot.state.mn.us/design/roadsidesafety/links.html



FLEAT and SRT videos are also available

BEAT and BEAT-MT Installation Inspection Checklist

State: _____ Date: _____

Project #: _____ Inspection performed by: _____

Location: _____

- ☐ The 6"x 6" end tube section is the special 1/8" thickness tube as supplied by the manufacturer with the corners cut at the approach end where the impact head is placed.
- ☐ Both the **Roadside BEAT** terminal and **Median BEAT-MT** terminal have at least one 18'-0" long 6"x 6" x 3/16" standard tube section joining with the special 12'-0" long end tube section.
- ☐ The end tube section is bolted to the standard tube section with the special rail tie splice.
- ☐ The height of the 6"x 6" box beam tubing is in accordance with the plans:
  --**Roadside BEAT** rail height = 2'-4"
  --**Median BEAT-MT** rail height = 2'-4"
- ☐ The 6"x 6" box beam tubing is attached to rail support brackets with proper hardware:
  --**Roadside BEAT** post bolt = 5/16" x 7 ½" hex bolt
  --**Median BEAT-MT** post bolt = 5/16" x 7 ½" hex bolt
- ☐ The rail support brackets are attached to posts with proper hardware:
  --**Roadside BEAT** posts #1 & #2 support bracket bolts = ½"x 2" hex bolt
  --**Median BEAT-MT** posts #2 through #5 support bracket bolts = ¾"x 1 ½" hex bolt
  --**Median BEAT-MT** post #1 support bracket bolt = ½"x 2" hex bolt
- ☐ The upper and lower sections of post #1 are properly connected with a 5/8"x 8" hex bolt.
- ☐ The 3" weak posts have the soil plate positioned the same direction as the rail.
  --**Roadside BEAT** has a 3" weak post at post location #2 plus at least three more 3" weak posts spaced at 6'-0" within the standard downstream 6"x 6" box beam barrier.
  --**Median BEAT-MT** has a 3" weak post at post locations #2 through #5.
- ☐ The impact head is properly inserted into the end tube section with the large triangular gusset plates facing down. The bottom of the impact head is approx. 12" above ground.
- ☐ The post breaker is installed on the proper side of post #1 and stabilized with two bolts.
- ☐ The 8" x 8" bearing plate at post 1 is correctly positioned with the 5" dimension up & the 3" dimension down. The anchor cable is taut and correctly installed.
- ☐ The **Median BEAT-MT** has a tether cable properly attached to restrain the impact head.
- ☐ If the posts were augered, be sure the backfill material around the posts is compacted.

Additional notes:

_____

INSTALLING THE RAIL PANEL TO THE POST WITHOUT OFFSET BLOCK AT POST 2

Complete the following steps to attach the rail panel to the post without offset block at **Post 2**:

Step	Actions
1.	Select the Option A, Option B, or Option C to install the rail panel without offset block at **Post 2**:

Option A For Wood Post	1. Insert a $^{5}/_{8}$" (16 mm) diameter x 10" (255 mm) HGR Post Bolt (PN-3500G) through the rail and the wood post at **location 2**. 2. Place a $^{5}/_{8}$" (16 mm) Round Washer (PN-3300G) under a $^{5}/_{8}$" (16 mm) HGR Nut (PN-3340G) on the inserted bolt. Tighten the bolts. (There is no torque requirement for these bolts.)
Option B For SYTP™	1. Insert a $^{5}/_{8}$" (16 mm) diameter x $1^{1}/_{4}$" (31 mm) HGR Blot (PN-3360G) through the rail panel and the hole in the SYTP™. **Note:** For SYTP stubs, use the hole in the SYTP™ that will place the rail at the correct height. (If there are two (2) sets of holes in the SYTP™ stub for attaching the rail.) 2. Place a $^{5}/_{8}$" (16 mm) Round Washer (PN-3300G) under a $^{5}/_{8}$" (16 mm) HGR Nut (PN-3340G) on the inserted bolt.
Option C For HBA™ Post	1. Do NOT bolt the rail panel to the HBA™ post at **location 2**. **WARNING:** Do NOT bolt the rail to the HBA™ post at **location 2**. Failure to follow this warning could result in serious injury or death in the event of a collision.

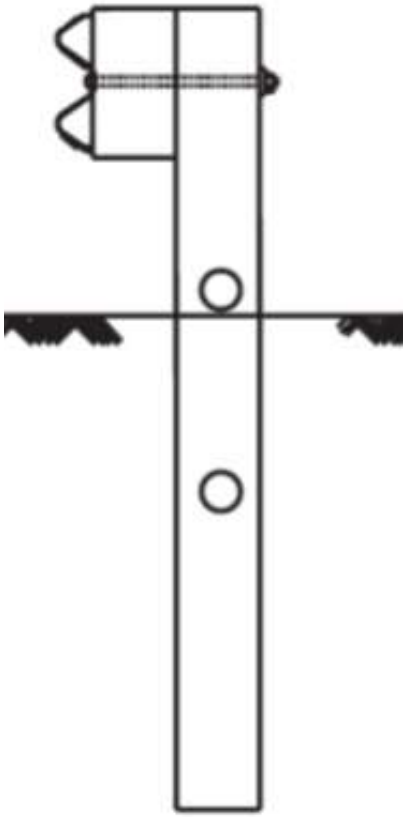
3. End Treatment

b. Post Types

Each manufacturer may have several different types of post, even for the same system - both currently approved and previously used.

Must consult with the installation manual of the specific model being worked with for proper post type.

Only one generic special post for terminals – the CRT post with large holes to weaken it.



Controlled Release Terminal (CRT) Post

3. End Treatment

c. Panel Types

Each system may have one or more different rail panels.

Must consult with the installation manual of the specific system for proper panel type

3. End Treatment

c. Panel Types

SRT Rail with a FLEAT impact head

3. End Treatment

d. Grading

Check grading compliance with Standard Drawing (or plan details).

Ensure the area is properly compacted and is vegetated to a minimum of 80% (or another version of slope stabilization).

EXCELLENT GRADING!!!

GOOD GRADING???

What about BAD stub height?

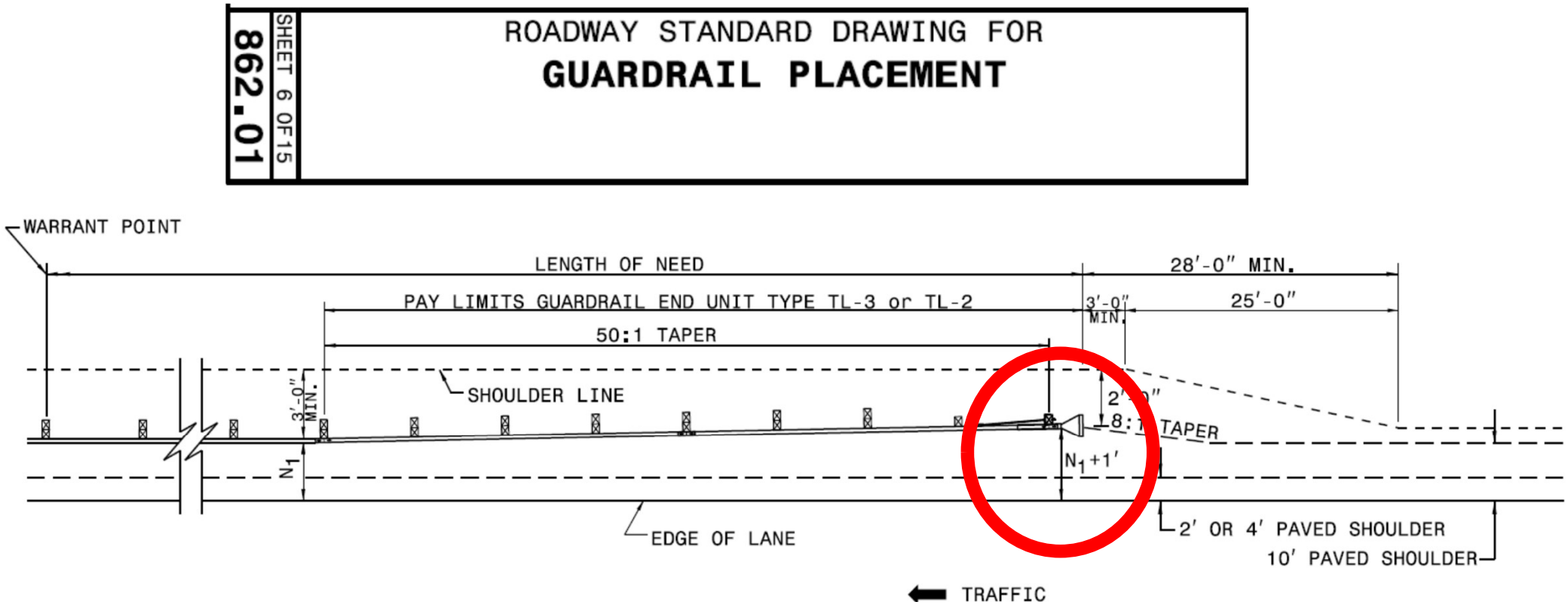
Would have been easily made excellent

ALSO – CLEAN UP!

- Last, load the damaged materials, smooth out the shoulder, check around for tools, then remove the Work Zone Traffic Control.

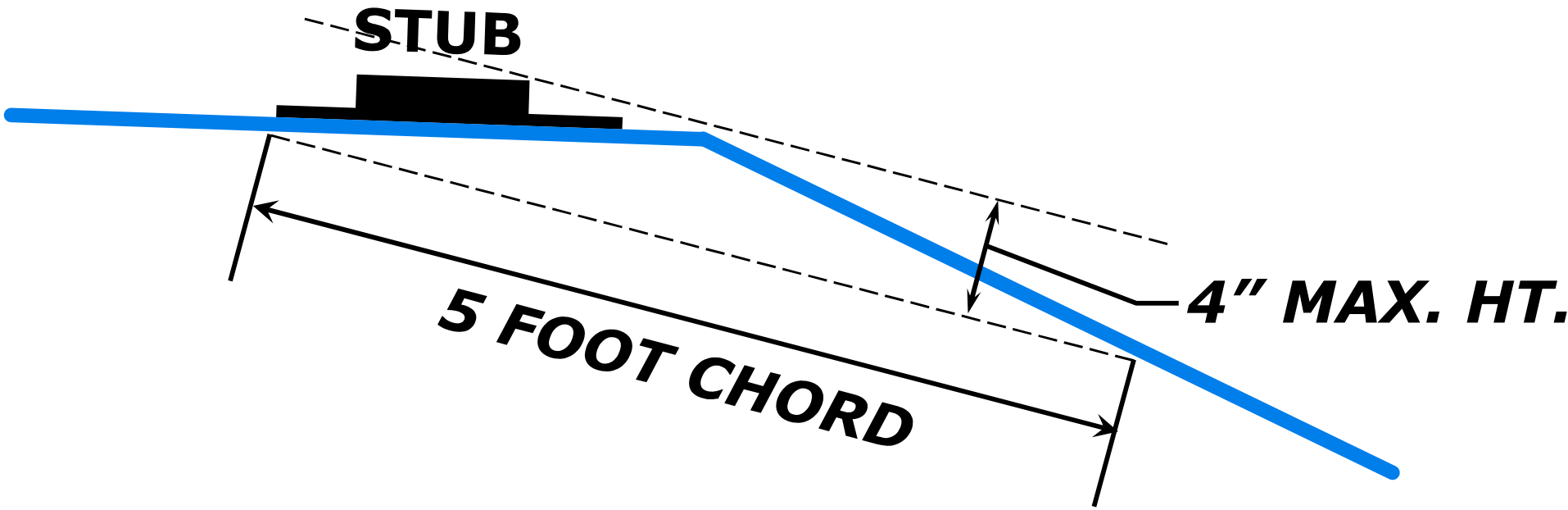
5.5 - SEQUENCE OF REPAIR (CONT.)

Tangent Terminal Grading - NCDOT



- Need special Borrow bid item for 3R projects
- Need Special Provision for Density

Stub Height Criteria



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

3. End Treatment

d. Grading

Improper Grading

A common error with all end treatment types.

3. End Treatment

d. Grading

Telltales of poor grading

- Soil tubes/foundation posts installed too high
- Soil plate showing
- Strut too high

(Also bearing plate misaligned)

Common Error applies to both energy absorbing and non energy absorbing terminals

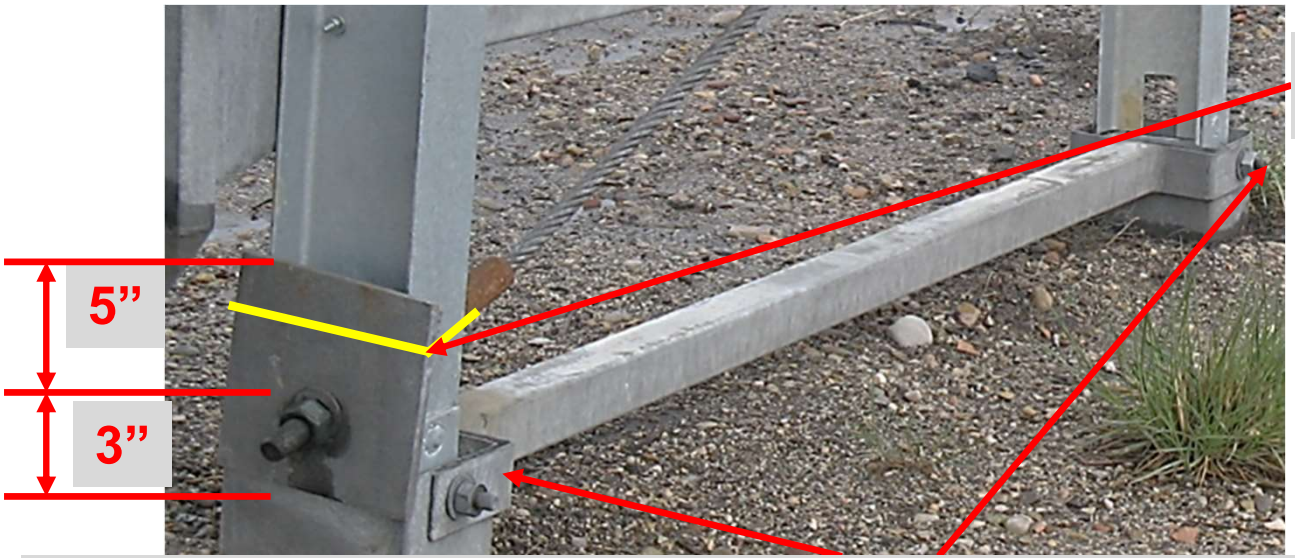
Substandard Grading – DOCUMENT

3. End Treatment

e. Breakaway Cable Anchorage (BCA) Assembly

Bearing Plate & Strut

- Should be in up position and secured to post.
- Strut secured at posts required locations.



Strut secured at breakaway posts 1 & 2

3. End Treatment

e. Breakaway Cable Anchorage Assembly

Wrong Bearing Plate

Missing Bearing Plate

3. End Treatment

e. Breakaway Cable Anchorage Assembly

Buried and upside down bearing plate – won't release

3. End Treatment

e. Breakaway Cable Anchorage Assembly

Upside down bearing plate – may not release

3. End Treatment

e. Breakaway Cable Anchorage Assembly

Most systems require an anchor bracket and anchor cable.

- Anchor block must release from rail if system has impact head
- Non-energy absorbing system does not have to release from rail.

Energy absorbing

Non-energy absorbing

3. End Treatment

e. Breakaway Cable Anchorage Assembly

- 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 offset block.
- Check to see that the correct cable anchor bracket is used and it is properly attached to the rail.

Wrong anchor bracket

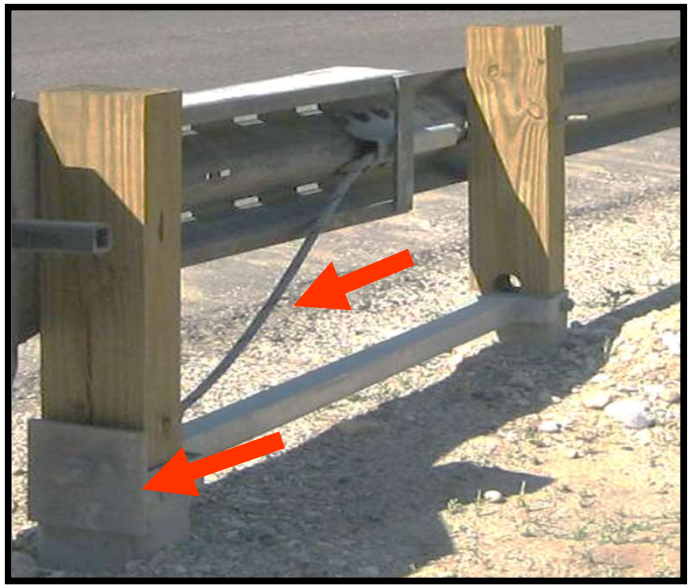
Anchor bracket not attached

3. End Treatment

e. Breakaway Cable Anchorage Assembly

Anchor Cable

- Should be taut, lift up 1” or less
- Tightened by holding cable at bottom, not allowing cable twist.



3. End Treatment

f. Other Common Errors

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.

IMPROPER

3. End Treatment

f. Other Common Errors

Post Installed Backwards

3. End Treatment

f. Other Common Errors

End treatments with an impact head should be parallel* with the top of the rail.

* For Softstop see manufacturers manual

3. End Treatment

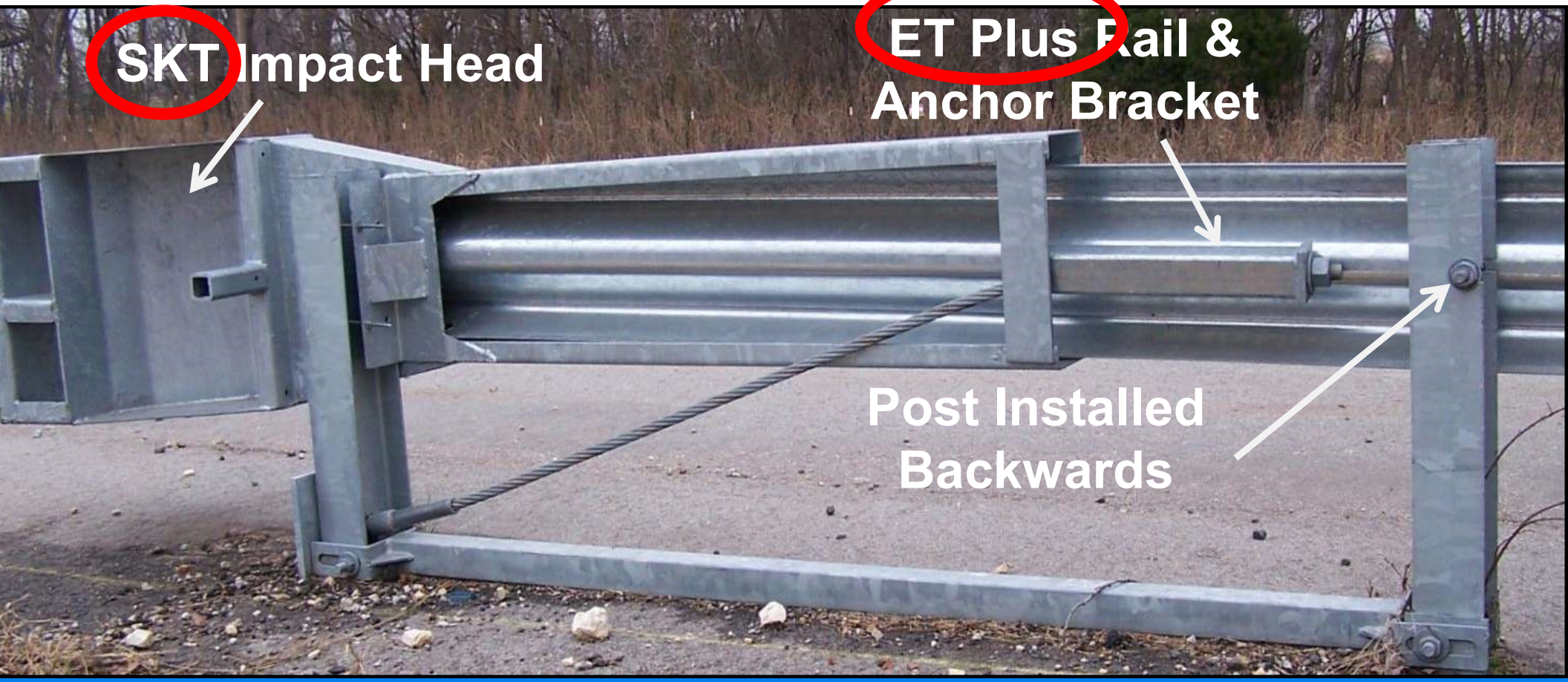
f. Other Common Errors

Energy Absorbing (compression based) Terminals MUST be installed on a straight line

Manufacturers of Tension-based systems also require straight line

3. End Treatment

f. Other Common Errors



HTCG

CO-MINGLING OF PARTS FROM DIFFERENT SYSTEMS (EVEN FROM THE SAME MANUFACTURER) IS UNACCEPTABLE

3. End Treatment

f. Other Common Errors

FLEAT head on SRT rail - HORRIBLE

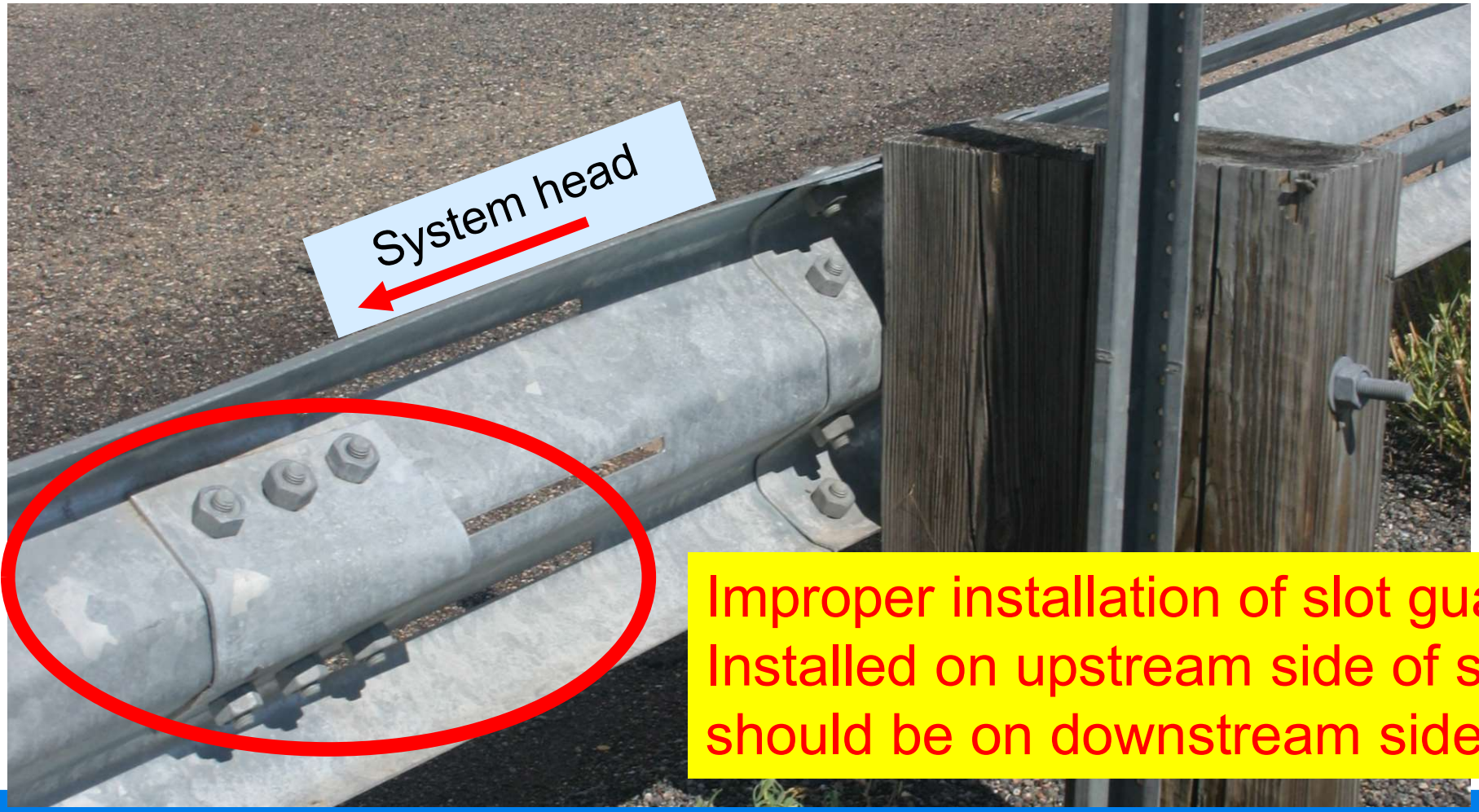
3. End Treatment

f. Other Common Errors

It's easy to tell if it's wrong – the slot guards must be on the same end of the slots for the first (can't get it wrong) and second rail panels

3. End Treatment

f. Other Common Errors



Improper installation of slot guard, Installed on upstream side of slot - should be on downstream side.

3. End Treatment

f. Other Common Errors

Unrestrained bearing plate

3. End Treatment

f. Other Common Errors

Bolt only impact head to post #1, NOT rail panel.

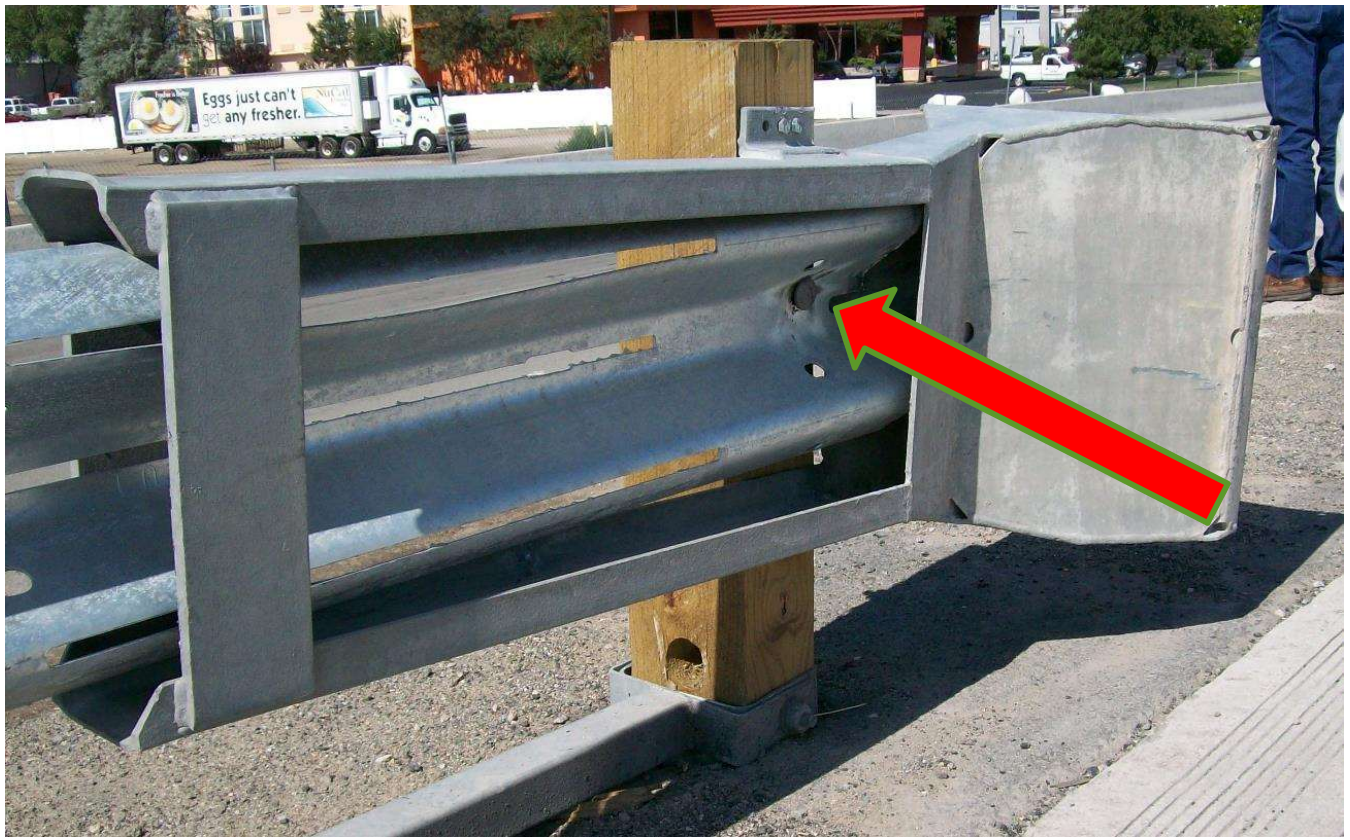
- Wood Post – Lag Screws (screwed in only)
- Steel Post – Hex Bolts

Refer to manufacturer's installation instructions.

3. End Treatment

f. Other Common Errors

NO rail to post connection at post 1 of systems with impact heads.



Note the WRONG rail for this terminal.

3. End Treatment

f. Other Common Errors

DO NOT place any washers or delineators on the face of a guardrail terminal unless specifically called for or allowed in manufacturer's installation instructions

3. End Treatment

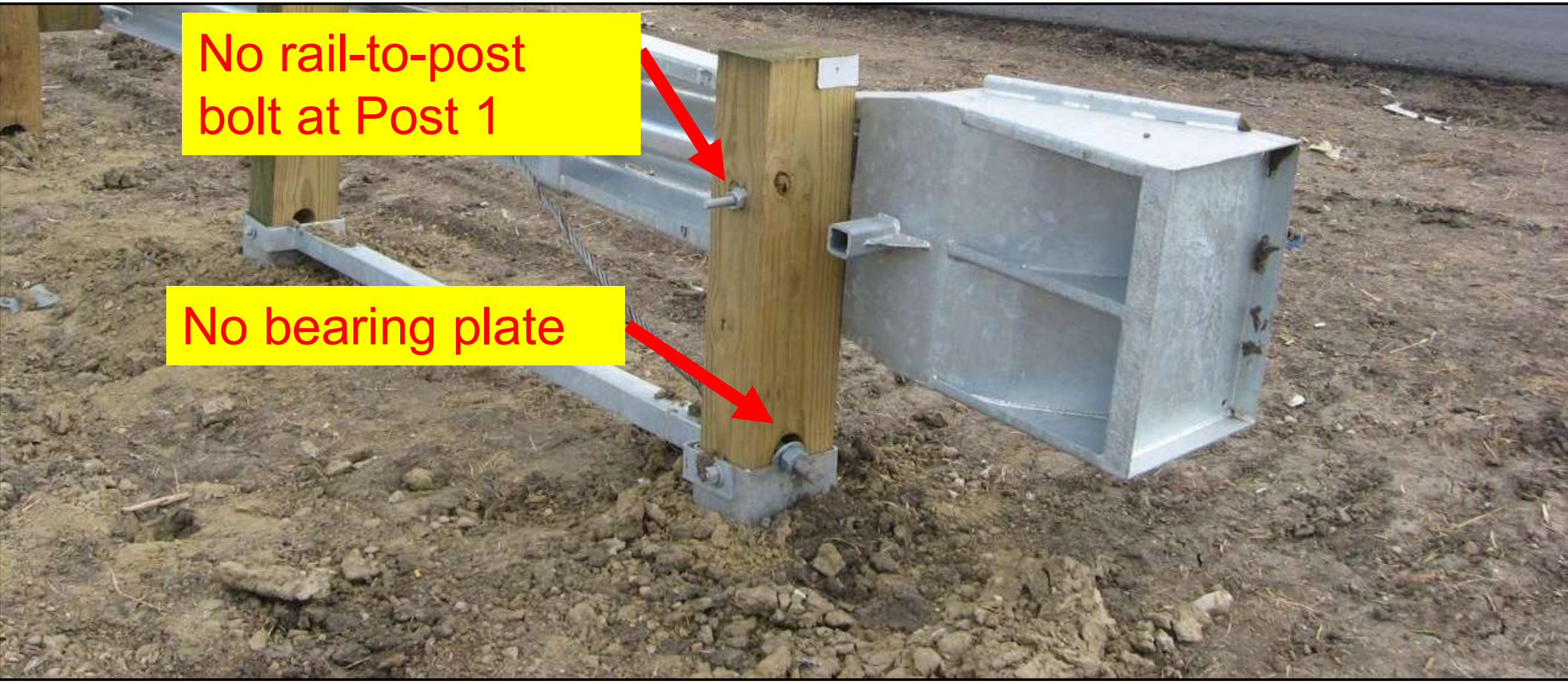
f. Other Common Errors

Improper bolt @ post 2

Refer to manufacturer's installation instructions.

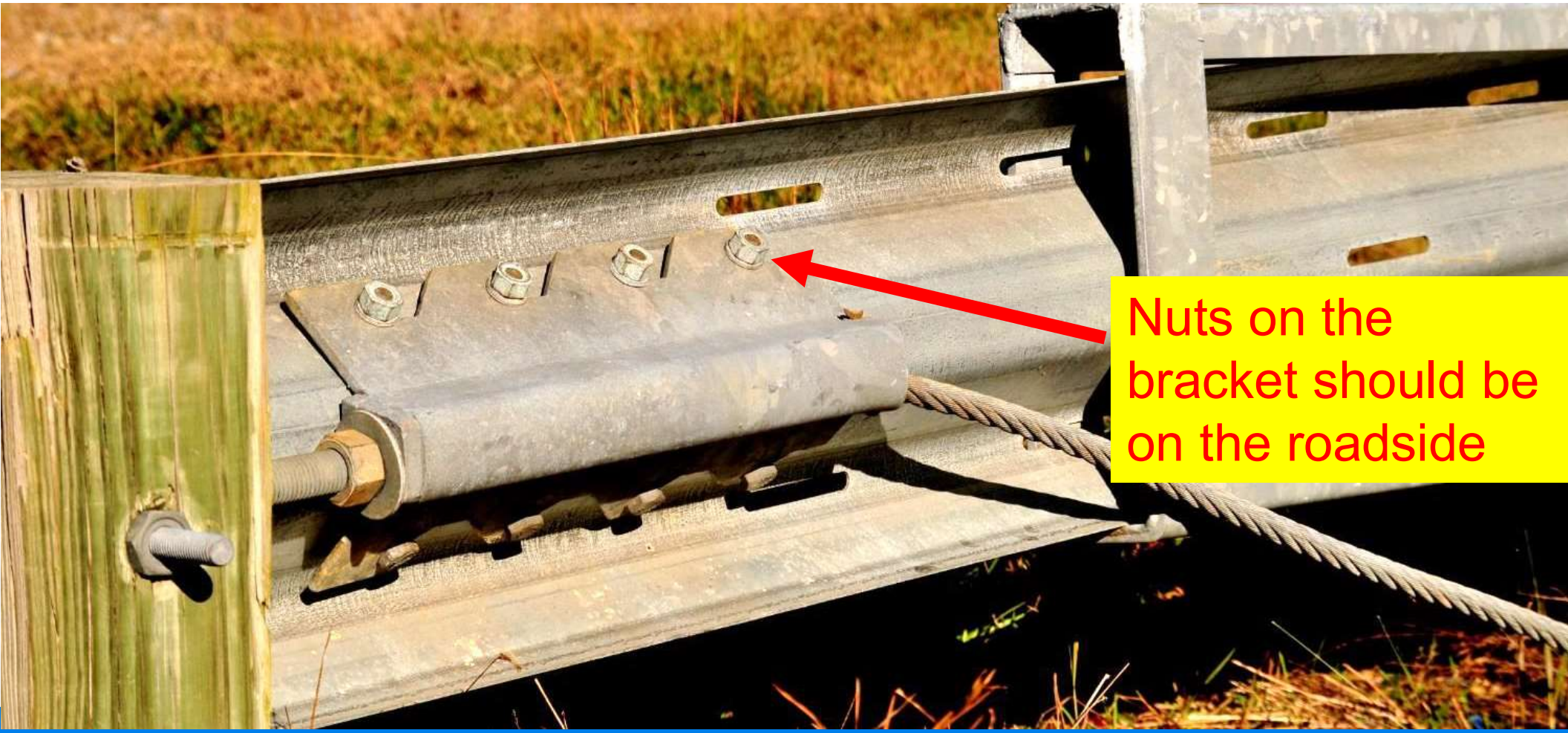
3. End Treatment

f. Other Common Errors



3. End Treatment

f. Other Common Errors



3. End Treatment

f. Other Common Errors

Excessive flare on a end treatment.

3. End Treatment

f. Other Common Errors

Improper Application – Hazard within terminal length

3. End Treatment

f. Other Common Errors

Improper Application – no runout for a non-energy absorbing terminal…LON (as well as grading)

3. End Treatment

f. Other Common Errors

Improper Application – Terminals should have 7’ separation (and the sign should be beyond the terminal system)

3. End Treatment

g. Delineation

General Details for End Treatments

- USE MANUALS
- Stub height (Desirable Grading)
- Straight Line (25:1 Flare max; NCDOT 50:1)
- Rail Lap (Absolutely for Telescoping Devices)
- No Delineators within System
- Anchor Details (ex. – SOFTSTOP strut)

Check Length of Need – Field Procedure

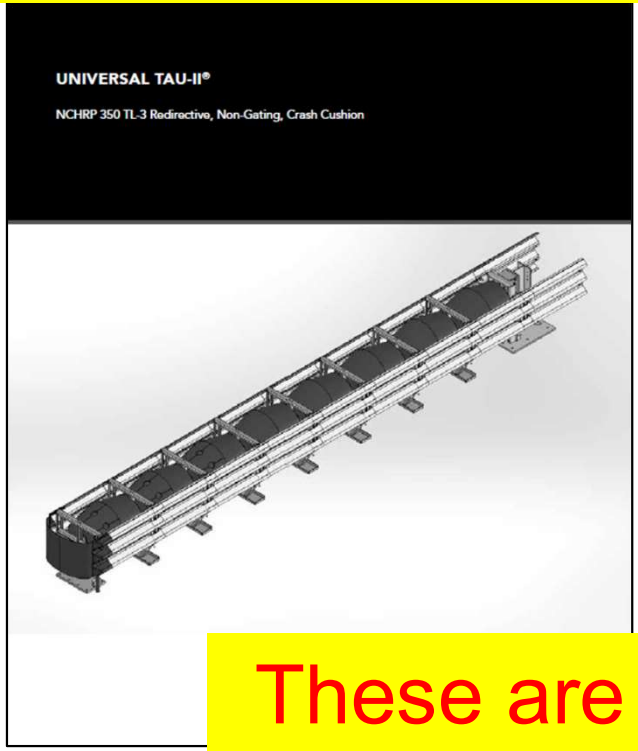
4. Impact Attenuators

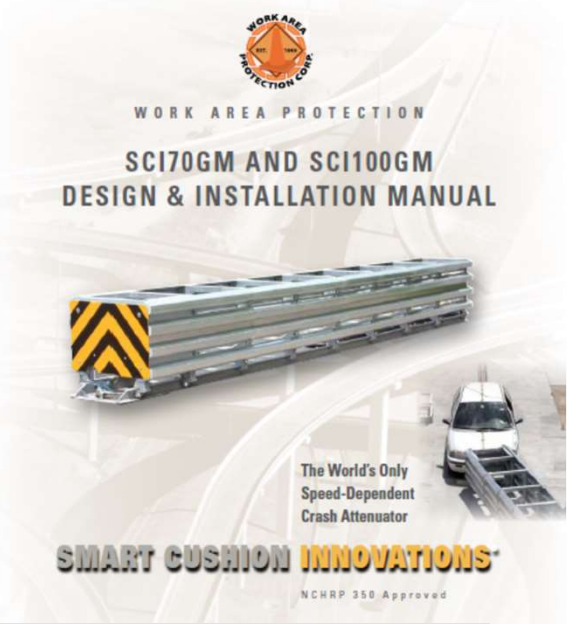
a. Manufacturers Manuals
b. Grading

4. Impact Attenuators

a. Manufacturers Manuals

Must follow manufacturer's installation instructions and State standards.





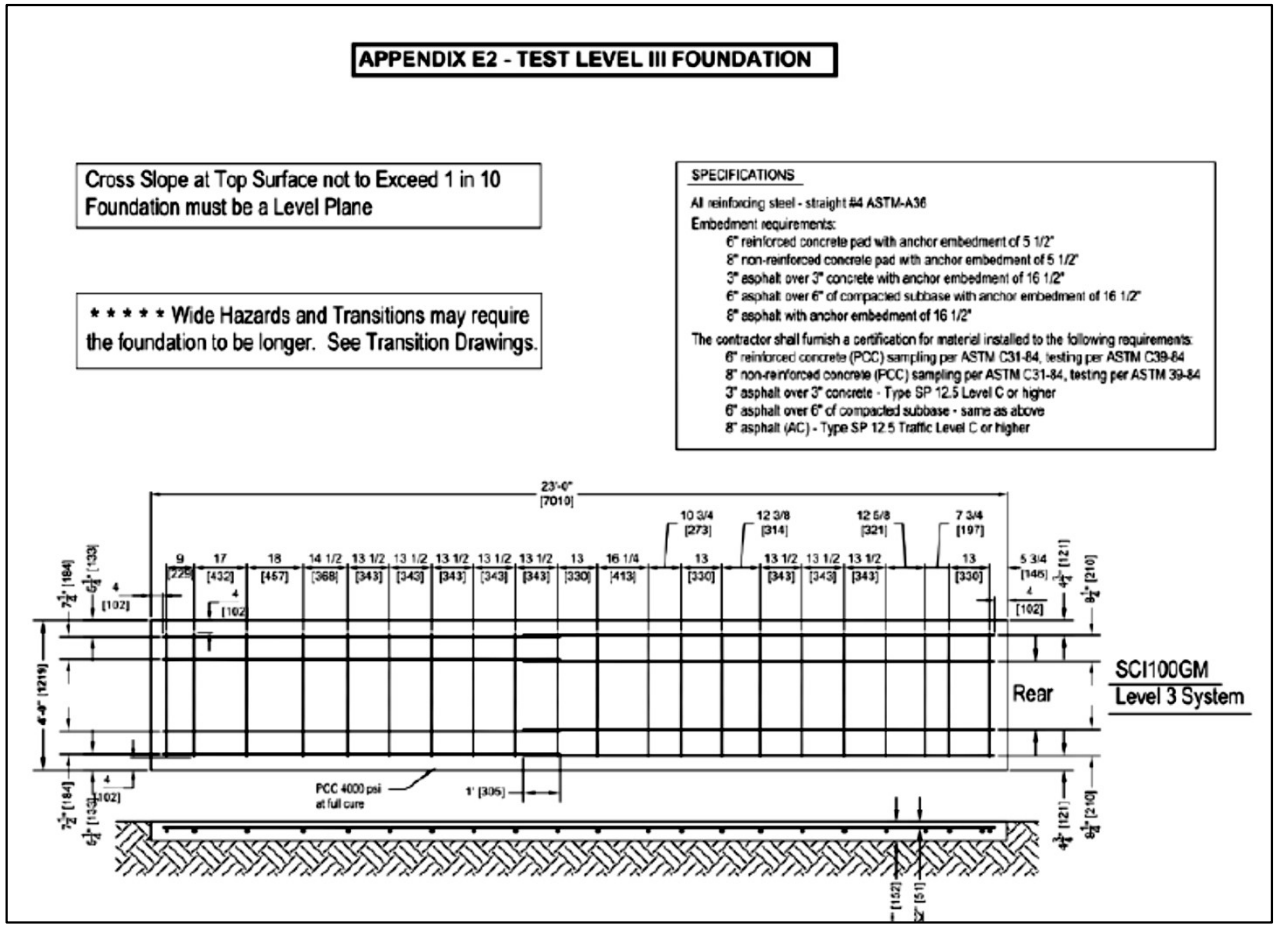
These are all readily available online

4. Impact Attenuators

a. Manufacturers Manuals

Construct concrete pad if called for per manufacturer's requirements or state standards.

Clean out drilled holes WELL!!



4. Impact Attenuators

a. Manufacturers Manuals

- Anchor bolts are required to secure the system to concrete 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.

4. Impact Attenuators

a. Manufacturers Manuals

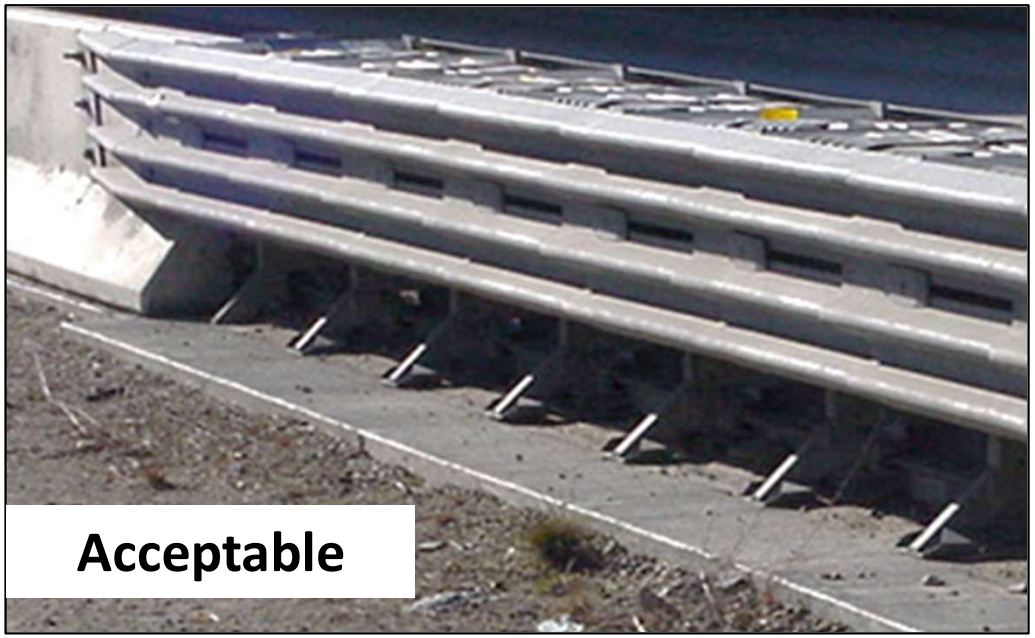
- Backup varies among systems.
- May be connected to a barrier or may be a stand alone

Must follow manufacturer's installation instructions.

4. Impact Attenuators

a. Manufacturers Manuals

- When system is placed in a bidirectional application a transition is required to prevent back side snagging



Acceptable

Unacceptable

Must follow manufacturer's installation instructions.

4. Impact Attenuators

a. Manufacturers Manuals

- Place appropriate delineation on front of system

Must follow manufacturer's installation instructions and state guidance

4. Impact Attenuators

b. Grading

Grading should be so an errant vehicle impacts the system in a stable condition – same as end treatments

Suspect Grading

Must follow manufacturer's installation instructions.

4. Impact Attenuators

Ex: results of improper torque values applied to fender panels.

Must follow manufacturer's installation instructions.

General Details for Impact Attenuators

- **USE MANUALS**
- TRANSITION if necessary
- GRADING – 10:1 or flatter
- Clean out Foundation Holes – Brush
- Lap for Translation
- Rear Panels Must Clear Object
- Torque – per Manual
- Softer Modules in Front

Review Learning Outcomes

- Describe key components of barrier systems
- Identify common installation errors

Session 6:
Maintenance of Systems

Session 6 Learning Outcomes

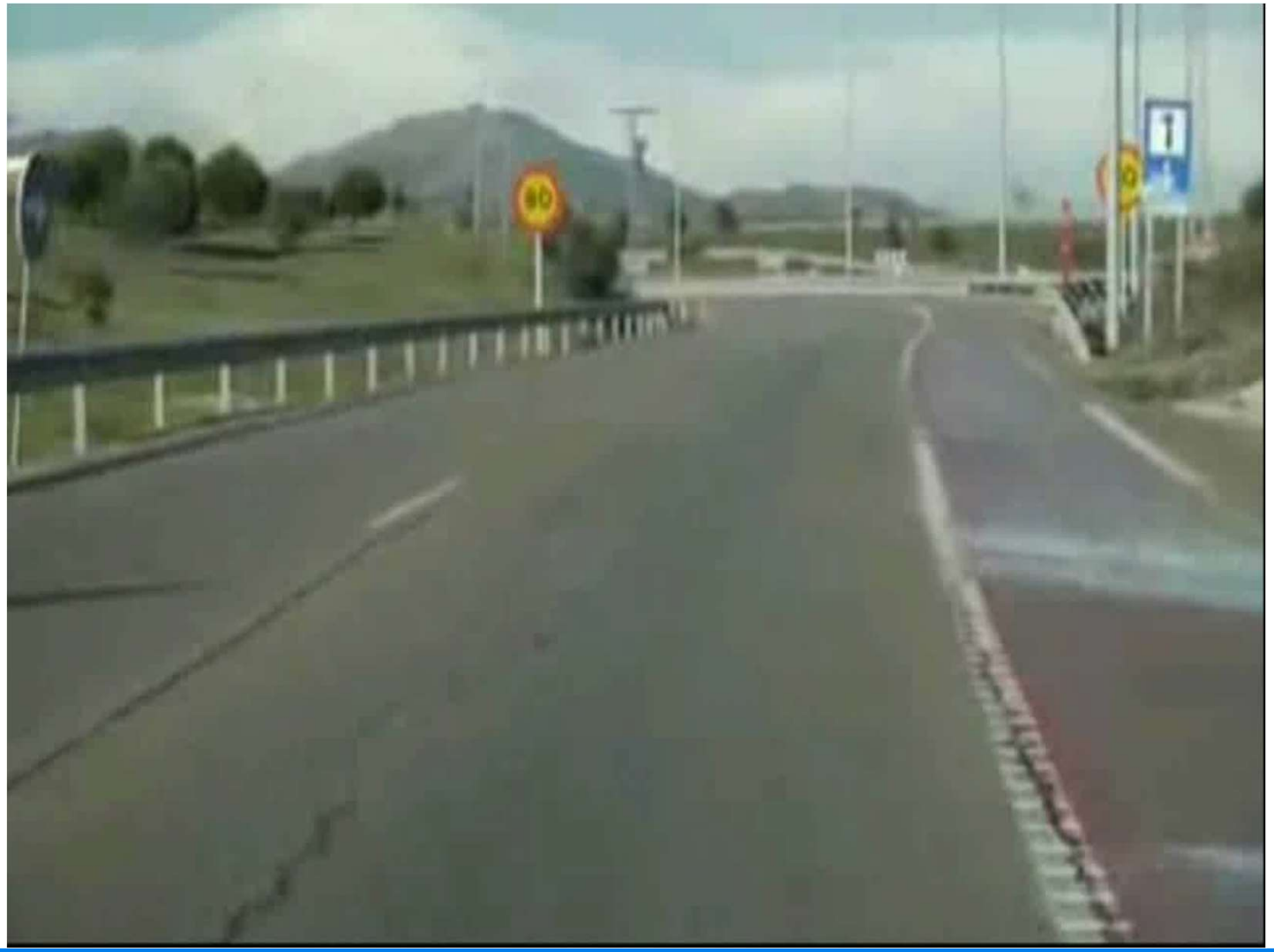
At the end of this session, you should be able to:

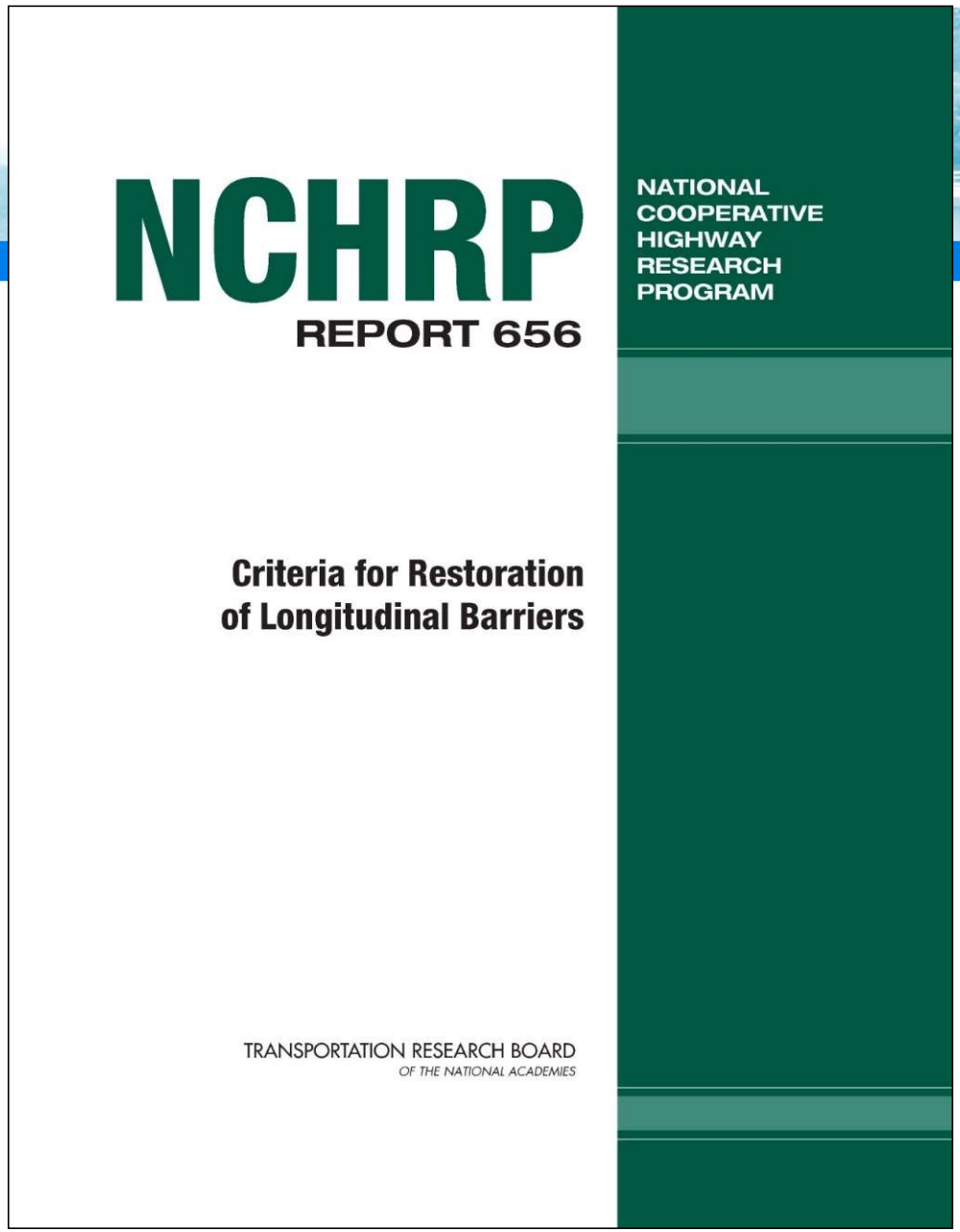
- Recognize how damaged barrier MAY BE assessed for maintenance response.
- Understand when a damaged barrier end treatment MAY no longer function.
- Effectively delineate/treatment of damaged hardware prior to repair.

Introduction

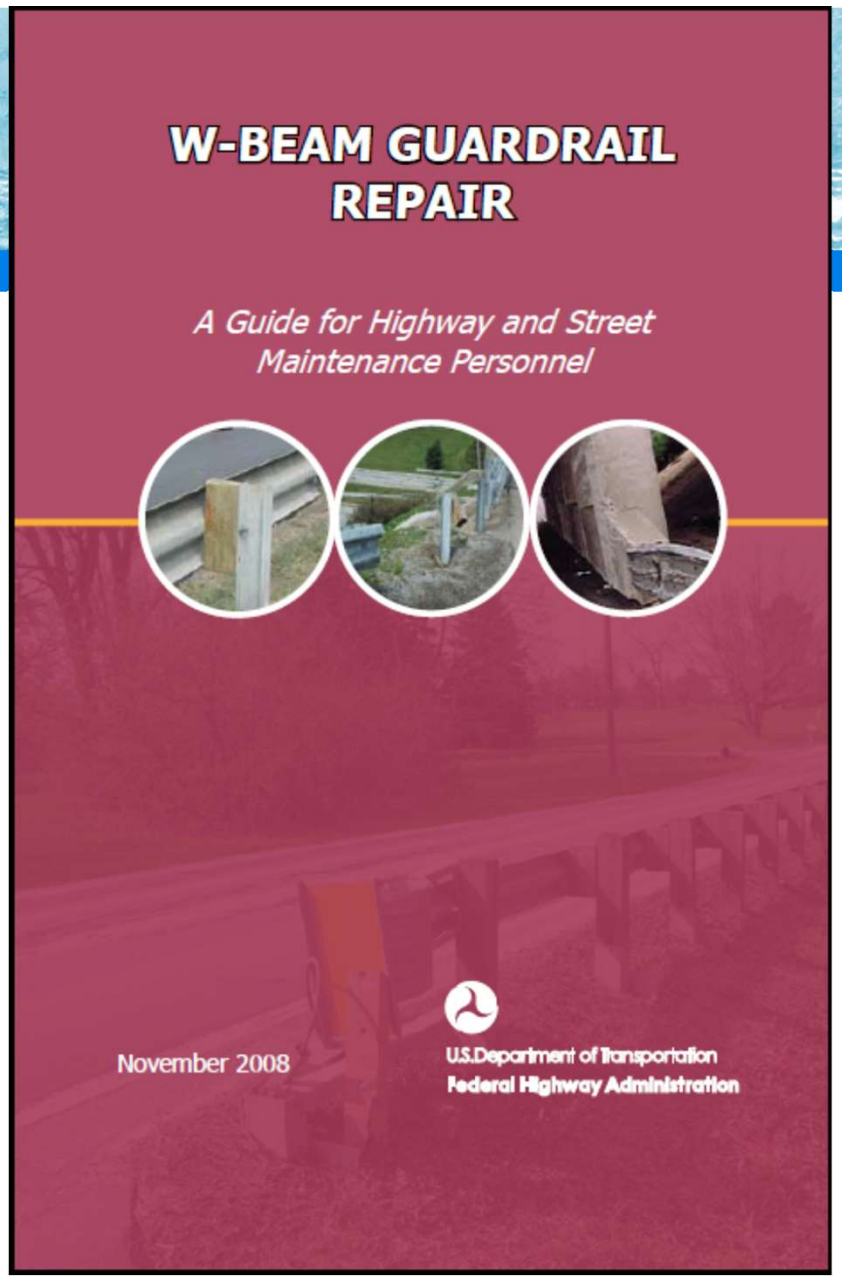
- Barriers need routine inspection and maintenance.
- Barrier may need to be repaired after crashes or long-term exposure.

Need To Repair





Available for purchase



Available online

BEST Guidance

INSTALLATION & REPAIR GUIDELINES

STATE MAINTENANCE
NCDOT
OPERATIONS

JANUARY 2019

NCDOT Policies

J. D. Goins

STATE OF NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
P.O. BOX 25201, RALEIGH, N.C. 27611-5201

JAMES B. HUNT, JR.
GOVERNOR

SAM HUNT
SECRETARY

December 15, 1993

MEMORANDUM TO: Division Engineers

FROM: C. A. Gardner, Jr., P.E.
Deputy Chief Engineer - Construction & Maintenance

SUBJECT: Guardrail/Attenuator Maintenance Policy

Attached for your immediate implementation is the maintenance policy for repairing or replacing accident damaged guardrail and attenuators on the State Highway System. Please insure that all your personnel are made aware of the policy.

This replaces all existing policies for guardrail repairs and maintenance. Revision to the Interstate Maintenance Manual will be sent in the near future.

If additional information is needed, please advise.

CAG/bj

STATE OF NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION

MICHAEL F. EASLEY
GOVERNOR

LYNDO TIPPETT
SECRETARY

Median Barrier Inspection and Maintenance Policy

The median guardrail program in North Carolina has been saving lives since its implementation in the late 1990s. There has been a 90 percent reduction in fatal and severe injuries in across-median crashes. Though the end of 2005, more than 150 lives have been saved and countless injuries have been avoided.

NCDOT is very concerned with the maintenance and operation of its entire transportation system. A recent report to the N.C. General Assembly shows that guardrails statewide are being maintained at an acceptable level.

The recent tragic event where a family was killed by a vehicle that crossed the median has placed an additional emphasis on median barrier maintenance. While our history with the median barrier program shows that a vehicle passing through a damaged section of barrier is very rare, NCDOT will implement a more in-depth review of our median barriers throughout the state.

We will continue to work with the N.C. Highway Patrol, local law enforcement and emergency responders to improve the notification process following crashes into the barriers. Effective immediately, all 14 highway divisions of the North Carolina Department of Transportation will assign appropriate staff to inspect weekly all highway sections with median guardrails. This inspection will include identifying and marking the non-functioning guardrail, and then scheduling it for repair. As soon as the department completes its inspection, the department shall immediately, and in no instance more than 24 hours, notify the appropriate contractor of the damaged guardrail and the contractor will begin repairs as soon as reasonably possible.

NCDOT is a national and international leader in median barrier safety. We have helped other

Timing of Repair

RESPONSE TO NOTIFICATION OF DAMAGE

Attenuator or guardrail damaged by accident is to be scheduled for repair/replacement as soon as possible after the condition is known. If the damaged area is determined by the engineer to present a traffic hazard by nature of the damage itself, or by exposing traffic to some previously protected situation, the area will be properly marked by barricade, warning lights, cones, truck mounted attenuator, etc., as appropriate until such time as repair has been completed.

REF: NCDOT GUARDRAIL/ATTENUATOR MAINTENANCE POLICY. December 1993

Timing of Repair (cont'd)

RESPONSE TO NOTIFICATION OF DAMAGE (cont'd)

Examples would be straight pieces of rail exposed by the destruction of an anchor unit, bridge abutment exposed, sign post protection rail destroyed, or areas where rail has been damaged so badly it has to be removed. If there is any question as to the need for delineating such hazards, then the areas should be properly marked.

REF: NCDOT GUARDRAIL/ATTENUATOR MAINTENANCE POLICY. December 1993

Timing of Repairs

2015 House Bill 97

§ 136-18.05. Establishment of "DOT Report" Program.

problem. Excluding potholes, which shall be repaired within two business days of the date the report is received, the Department of Transportation shall properly address (i) safety-related citizen reports no later than 10 business days after the date the report is received and (ii) non-safety-related citizen reports no later than 15 business days after the date the report is received. The Department shall determine, in its discretion, whether a citizen report is safety-related or non-safety-related. The Department shall transmit

Damaged End Treatments

Spear –worse than no tension –
must be treated (drop rail) immediately- Severe

Damaged End Treatments

Spear –worse than no tension –
Protect spearing end immediately- Severe

Damaged End Treatments

Added end section still leaves blunt end

Temporary Barrier Delineation

Delineate damaged areas while evaluating damage. Make repairs as soon as practical.

Temporary Barrier Delineation

For Cable Guiderail, removal of damaged posts will eliminate a spearing obstacle for opposing traffic.

For HTCG Barrier, Keep the Cable Intact

Alternatives to cutting the cable include:

- Removing the vehicle by towing it in the opposite direction from which it hit the system.
- Loosening the cables at the turnbuckles.
- Release the cables at the anchor.
- Cutting the turnbuckle (preferred method to cutting the cable). The adjacent posts on either side of the turnbuckle need to be removed. Be sure that all personnel are clear of the cable and always cut the center of the turnbuckle, between two undamaged posts away from the impact area.

Evaluate the Site

DECISION TO REPAIR/REPLACE OR ELIMINATE GUARDRAIL

Consideration should be given to eliminating the need for the rail by flattening the slope and/or eliminating the hazard. The warrants in the Roadway Design Manual and the drawings in the Roadway Standard Drawings Manual should be used in this determination. The department that eliminates the hazard is responsible for coordinating the removal of the guardrail by the county road maintenance personnel.

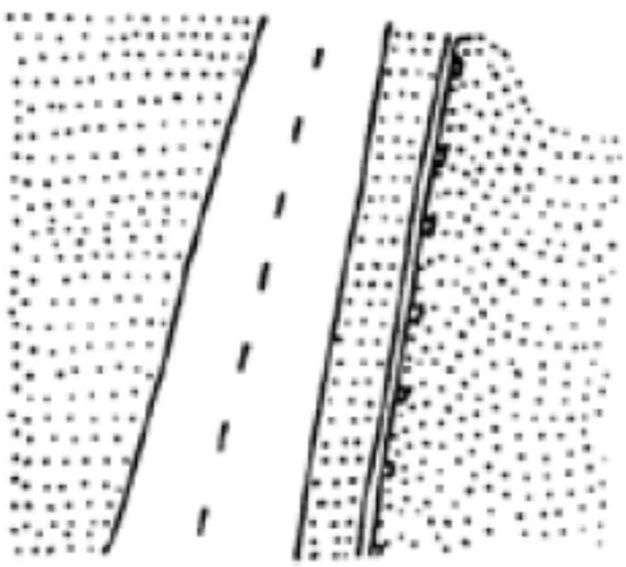
REF: NCDOT GUARDRAIL/ATTENUATOR MAINTENANCE POLICY. December 1993

Evaluate the Site

5.2 - Repair Or Eliminate

- Before repairing the guardrail, consider if it can be eliminated. If the slope can be flattened or the hazard relocated, the barrier is not necessary. If the roadside obstacle is no longer there, the guardrail is itself a hazard and should be removed.

Flatten the slope



REF: NCDOT GUARDRAIL INSTALLATION AND REPAIR GUIDE - 2019

Determine Extent of Damage

SAFETY-RELATED ????

Safety-related DEFINITELY

5.1 - Site Review

- When guardrail has been hit, determine the extent or severity of damage. If the damage is minor or so slight that it will still function to shield the hazard, schedule the repair with other work. If the damage is severe, schedule it for repair as soon as possible. Until then, clear debris from the road and shoulder, then set out barrels or barricades to warn motorists.

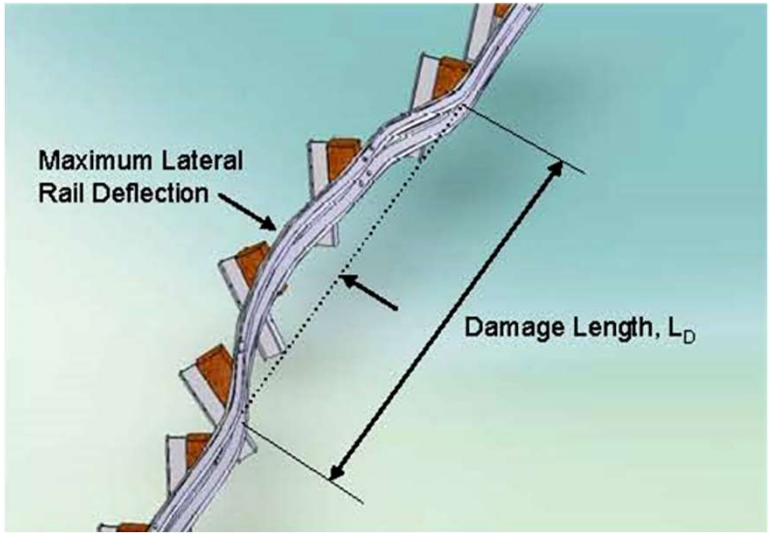
REF: NCDOT GUARDRAIL INSTALLATION AND REPAIR GUIDE - 2019

Guardrail – Damage Modes

Severely Damaged

- Rail beam has been severed
- Beam is crushed more than 18” out of line or
- Three or more posts have been broken

Severe damage needs to be repaired as soon as possible



5.1 - SITE REVIEW

REF: NCDOT GUARDRAIL INSTALLATION AND REPAIR GUIDE - 2019

Guardrail – Damage Modes

Minor Damage. Repair later if the guardrail will still function properly. Schedule with other work.

Supervisor needs to make decision – is moderate "safety-related" or not; this was intent of NCHRP 656

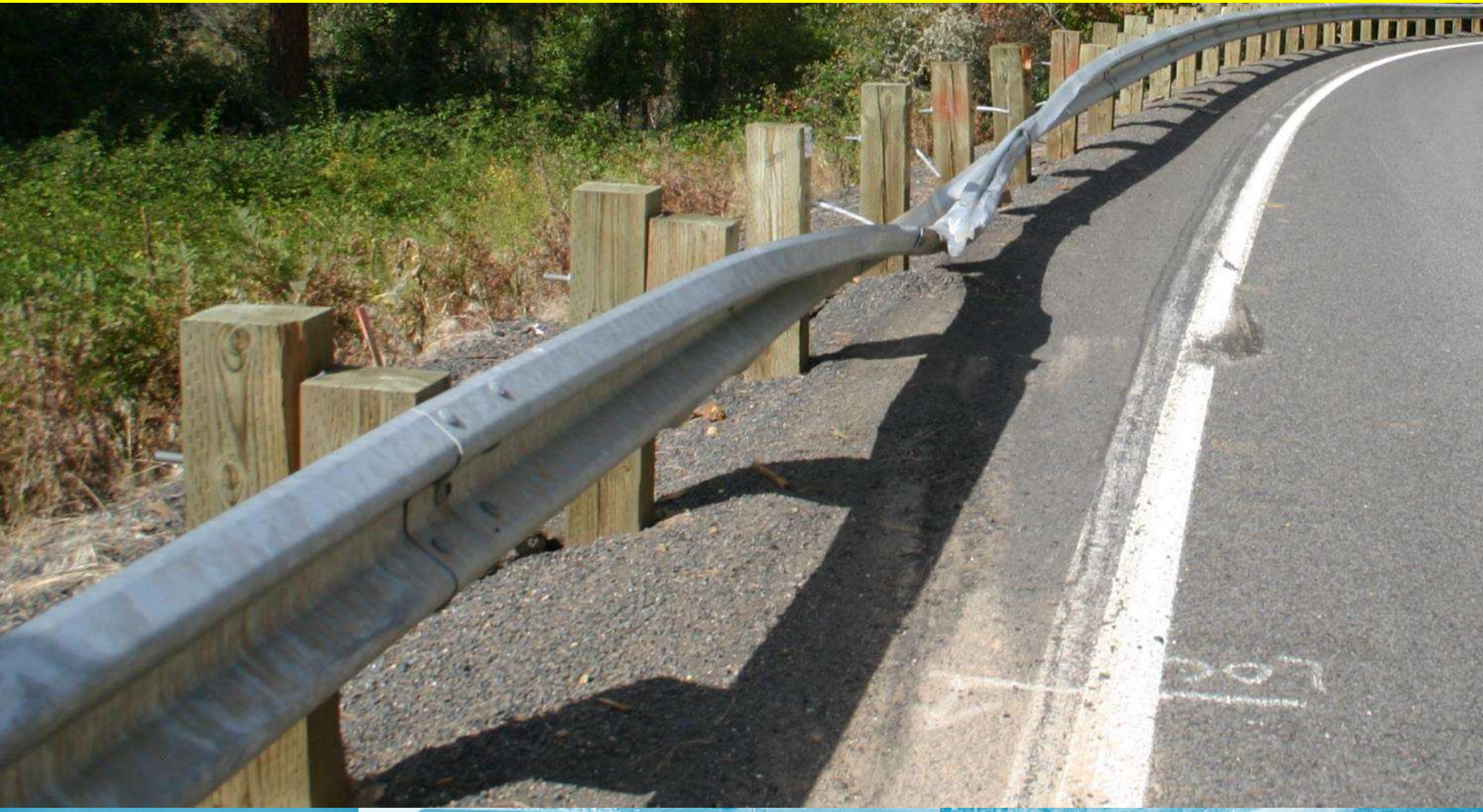
Guardrail

How much deflection (~ 11”) – Not Severe

Bends within compressive terminal may cause unwanted buckling – little energy absorption – Safety-related

Post separation – Severe or moderate?

If height is too low (?”), penetration is likely - Severe



No tension continuity – Severe

Tension discontinuity (half strength and stress concentrator) – Severe

Cable Guiderail – Damage Modes

Severely Damaged

- Any cable is broken or pulled loose from the anchor or
- Cable is sagging to the point that it would not function properly when hit or
- Four or more posts have been knocked down.

Severely damaged needs to be repaired as soon as possible

REF: NCDOT GUARDRAIL INSTALLATION AND REPAIR GUIDE - 2019

Cable Guiderail

End Treatments – Damage Modes

Severely Damaged

- One or more broken posts
- Rail that has been torn loose or
- Damaged cable assembly.

Severe damaged needs to be repaired as soon as possible

REF: NCDOT GUARDRAIL INSTALLATION AND REPAIR GUIDE - 2019

End Treatments

This could act like a spear if not repaired expeditiously - Severe

You need to have the manufacturer's installation manual to repair these systems.

End Treatments

- Check for nuisance hits on end treatments to be sure post #1 is not damaged.
- Even with claims of “reusability” – use best judgment and closely examine all salvageable parts.
- Impact Heads may be re-usable based on state policy and manufacturers recommendations (generally say no).

Sheared end post -No tension capability – Severe

No tension capability and possible spear – Severe

Non-Energy Absorbing Terminal WRONG here – no Runout
Don't know why memorial is here

Foundation tubes too high – Severity depends on how excessive the height is

SRT first rail only – not as tested. Light pole nearby may also be a problem. Severity - ????


Impact head not parallel to rail – don't know how serious –
Doubt Severe; Just POOR workmanship

Cable disconnected - No tension capability – Severe

Existing head is off post – Moderate or Severe ???

When repairing a wood Post 1 holding an impact head, drill pilot holes per Installation Manual

End Treatments

Bearing plate misaligned
Moderate

Buried plate may not release
Severe

Missing bearing plate and cable - No tension capability – (Also the head should be parallel to top of rail) & into throat – Severe

Rail not engaged with head
Severe

Damaged End Treatments

No tension, impact head damaged - Severe

Urgency of Repair ???

Some reserve capacity – Moderate or Severe???
Have manufacturer's Installation Manual available.

Urgency of Repair ???

This is a blunt end until repaired - Severe
Have manufacturer's Installation Manual available.

Impact Attenuators

Ensure all mounting hardware is correct and Repaired per Installation Manual

Impact Attenuators

Typical QuadGuard Cartridges

Typical Universal TAU Cartridges

Place proper cartridges in the correct system & in the proper order

Impact Attenuators

Place sand container in the correct position with the correct amount of sand.

Replace In-Kind vs. Upgrade

REPLACEMENT/REPAIR OF GUARDRAIL COMPONENTS

A. *Rail (Steel)*

The accident damaged section of rail shall be replaced/repaired to the current design standard as practical. It should be noted when only a portion of a rail system is damaged, consideration should be given to replacing the remaining undamaged length to current standards. However, when the undamaged length of remaining rail is less than 100* feet, the entire rail system shall be replaced to current design standards. *Also in 2019 Guidelines **5.3 - REPLACE IN-KIND OR UPGRADE**

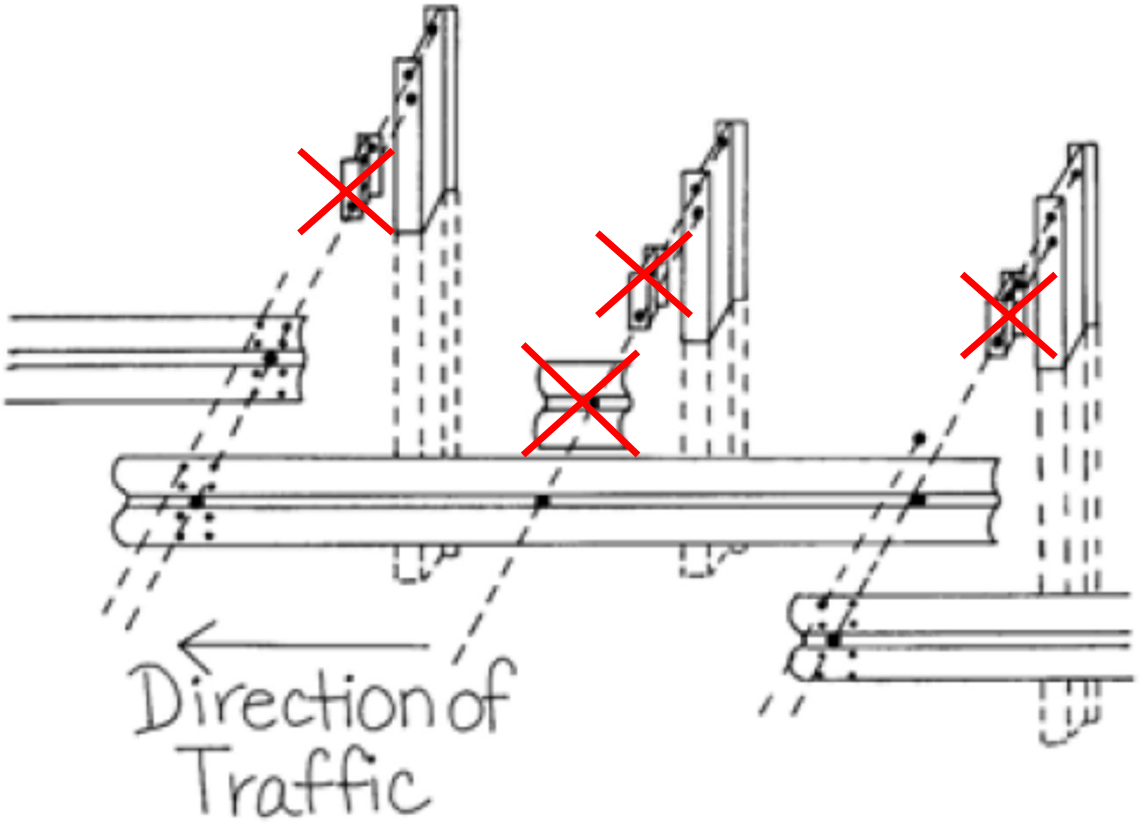
For pre-31” guardrail, it is suggested that the repaired guardrail should be to the latest 29” standard, especially related to height.

REF: NCDOT GUARDRAIL/ATTENUATOR MAINTENANCE POLICY. December 1993

Replace In-Kind – 29” Guardrail

5.0 - Repair Of Guardrail (cont.)

Standard W-beam Guardrail 12'-6" Sections on Steel Posts



Post Snagging Video

Replace In-Kind vs. Upgrade

5.3 - Replace In-Kind Or Upgrade (cont.)

- Damaged sections of rail must be repaired to the current design standard as practical. For example, if an old weak-post guardrail system that is shielding a hazard has been hit, the damaged section should be replace by the standard blocked-out W-beam system. Note that a 50' transition will be needed from the old weak-post rail to the new strong-post rail to minimize pocketing effects.

REF: NCDOT GUARDRAIL INSTALLATION AND REPAIR GUIDE - 2019

Replace In-Kind vs. Upgrade

REPLACEMENT/REPAIR OF GUARDRAIL COMPONENTS

B. *Rail (Cable)*

The damaged section of cable rail shall be replaced/repaired to the current design standard.

It should be noted that periodic inspections of the cable tension is required to insure its proper function. Additionally, large vegetation shall not be allowed to grow within 15 feet of the cable as the system is designed to deflect 15 feet under impact.

REF: NCDOT GUARDRAIL/ATTENUATOR MAINTENANCE POLICY. December 1993

Replace In-Kind vs. Upgrade

REPLACEMENT/REPAIR OF GUARDRAIL COMPONENTS

C. Terminal End Section

The accident damaged end section shall be replaced/repaired to the current design standard except as follows:

Exceptions:

- When only the guardrail end section (buffer or terminal end design) has been damaged (bent), with no post damage, it may be repaired with like kind.
- When adequate shoulder width cannot be obtained economically to meet the current design standard contact Roadway Design for an alternate design.

REF: NCDOT GUARDRAIL/ATTENUATOR MAINTENANCE POLICY. December 1993

Replace In-Kind vs. Upgrade

STATE OF NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION

ROY COOPER
GOVERNOR

JAMES H. TROGDON, III
SECRETARY

DATE: May 26, 2017

MEMORANDUM TO: Division Engineers

FROM: Michael L. Holder, PE
Chief Engineer

SUBJECT: MASH Guardrail Units (GREU)

Reference is made to Glenn Mumford's April 28, 2017 memorandum on the subject Guardrail End Units – AASHTO MASH Compliance. The Department will accelerate the previously planned September 19, 2017 implementation. All contracts advertised on or after July1, 2017 shall include the project special provisions requiring the MASH compliant guardrail end units.

MASH Complaint GREU shall also be installed on all active contracts, including guardrail maintenance or repair contracts, to the extent feasible. Contract administrators shall request a proposal from the prime contractor on active construction projects which would detail the cost associated with changing to the MASH compliant guardrail end units and any associated schedule impacts to the project. Contract administrators should contact their Area Construction Engineer to assist with review of contractor proposals and supplemental agreement development.

Questions concerning the new guardrail end units should be directed to Joel S. Howerton, PE, at (919) 707-6950 or jhowerton@ncdot.gov.

Replace In-Kind vs. Upgrade

REPLACEMENT/REPAIR OF GUARDRAIL COMPONENTS

D. Structure Anchor Unit

The accident damaged guardrail attached to a structure (ex: bridge, concrete barrier, etc.) shall be replaced/repaired in accordance with current design standard. If field conditions prevent the use of standard design and it is structurally sound to attach to the structure, assistance in the design of an acceptable replacement and/or repair is available through the Road Maintenance Unit as needed.

REF: NCDOT GUARDRAIL/ATTENUATOR MAINTENANCE POLICY. December 1993

Replace In-Kind vs. Upgrade

REPLACEMENT/REPAIR OF IMPACT ATTENUATORS

Damaged or malfunctioning attenuators shall be replaced/repaired to the current design standard.

Attenuators should be inventoried by type and location and maintained on a regular schedule (every 6 months) to insure proper function.

REF: NCDOT GUARDRAIL/ATTENUATOR MAINTENANCE POLICY. December 1993

Median Barrier Inspection/Maintenance

- Requires weekly inspection by each NCDOT highway division.
- All non-functioning section of median barrier identified and marked.
- Appropriate contractor notified of damaged section within 24 hours.
- Repair work to begin “as soon as reasonably possible”

Ref: NCDOT Median Barriers Inspection and Maintenance Policy

Inspect Repairs

Inspection once the repairs are completed, as well as periodic inspection.

6.3 – Maintenance Tips

- Before repairing guardrail, consider eliminating it.
- When barrier must be repaired, check the design.
- Keep large vegetation away from the guardrail.
- Watch for material buildup under and in front of the rail.
- Loosen cable turnbuckle in cooler weather, and tighten in warmer weather. ???? – to Spec

REF: NCDOT GUARDRAIL INSTALLATION AND/OR REAIR PROCEDURE TRAINING MANUAL. April 2000P

Review Learning Outcomes

- Recognize how damaged barrier MAY BE assessed for maintenance response.
- Understand when a damaged barrier end treatment MAY no longer function.
- Effectively delineate/treatment of damaged hardware prior to repair.