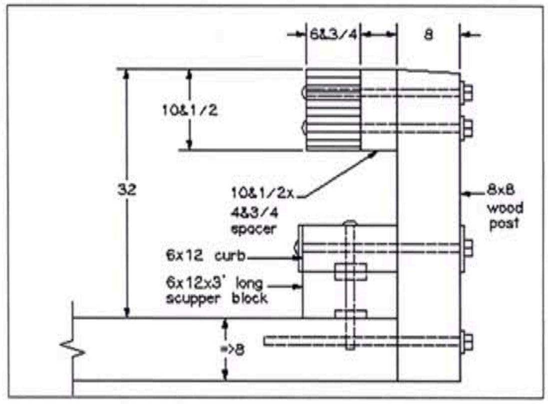
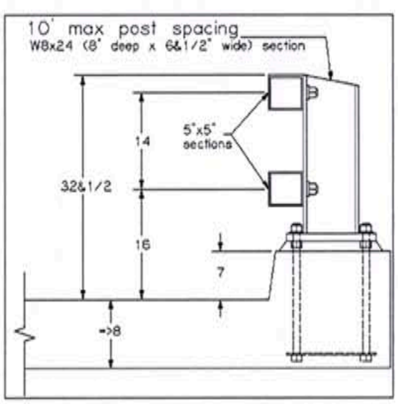
Traffic safety Features Rating Manual

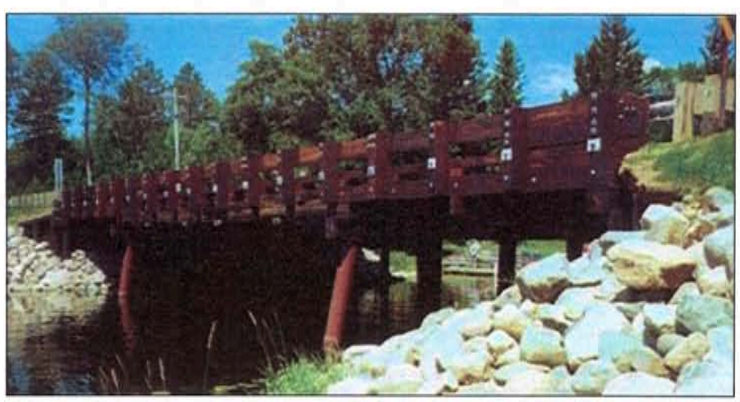


BRIDGE INSPECTOR TRAFFIC SAFETY FEATURES RATING MANUAL

Item 36 of the Structure Inventory & Appraisal Form

Last updated 2007





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INTRODUCTION

Bridge traffic safety features include the rail/parapet, transitions, approach rail/barrier and end treatments. Bridge inspectors must determine whether these features meet current standard in order to code item 36 of the Structure Inventory and Appraisal Form. This manual provides guidance on rating these features.

This manual is presented in two parts. Part One describes the evolution of safety feature performance standards and describes the current AASHTO LRFD Specification standard which is based on the dynamic crash testing and performance requirements presented in NCHRP Research Report 350. This part also outlines the policies of the responsible government agencies. Part Two provides a procedure for inspectors to follow when rating features.

It is important to recognize that when a feature does not meet current standard, it does not mean replacement will be a priority. There will be lower priority for features that have performed functional to date, have low likelihood of being hit or there is limited public risk if the feature is hit or penetrated. However, this determination shall be made by an engineer and shall not influence the inspector's rating.

This manual shall be used for rating in-service features only. It is not intended for design or construction because the manual's methodology and included diagrams have been simplified. This simplification is necessary to provide an efficient field rating approach based on readily available roadway information and visual evaluation of only the exposed components. As well, design shall follow the current policy of owners with respect to required feature type and test level for different roadways. Such policies are intended for replacement and new design and are not directly incorporated into this manual's rating methodology. For instance, if an owner's policy is to use 42 inch F safety shape rail (meets test level 5) on all National Highway System roads, however the national policy is to use any rail that meets test level 3 or higher, by this manual's rating methodology any rail tested to level 3 or higher will be rated as meets standard.

PERFORMANCE STANDARDS FOR TRAFFIC SAFETY FEATURES

Performance standards are established to ensure safety features have sufficient strength and geometry to protect the public. Properly designed features will prevent vehicles from leaving the bridge or roadway by penetration, climbing or rollover. They also safely redirect vehicles without excessive damage to the occupant compartment, without snagging or dramatic deceleration and without redirection into the travel lane or opposing traffic.

For years the AASHTO Standard Specification static force and geometric design criteria have been used in bridge railing design. This specification calls for the application of a 10,000 lb static force and includes some dimensional requirements for the opening between rail components and other geometry. Designs by this outdated criteria sometimes have insufficient strength and geometry. Modern design criteria require full-scale simulated crash testing otherwise termed dynamic crash testing. Dynamic performance standards have evolved over time in response to an improved understanding of safety performance, a changing vehicle fleet, a broader range of feature types and increased interest in matching safety performance to levels of roadway use. The history of standards has included the following;

- 1962 Highway Research Correlation Services Circular 482: Proposed Full-Scale Testing Procedures for Guardrails
- 1974 NCHRP Report 153: Recommended Procedures for Vehicle Crash Testing of Highway Appurtenances
- 1978 Transportation Research Board's Transportation Research Circular 191
- 1980 NCHRP Report 230: Recommended Procedures for the Safety Performance Evaluation of Highway Safety Appurtenances
- 1981 NCHRP Report 239: Multiple-Service-Level Highway Bridge Railing Selection Procedures
- 1989 AASHTO Guide Specifications for Bridge Railings
- 1993 NCHRP Report 350: Recommended Procedures for the Safety Performance Evaluation of Highway Features
- 1994 AASHTO LRFD Bridge Design Specifications, 1st Edition
- 1998 AASHTO LRFD Bridge Design Specifications, 2nd Edition
- 2003 Interims to 1998 AASHTO LRFD Bridge Design Specifications, 2nd Edition

Each of these standards specifies different dynamic crash test criteria. The criteria include parameters such as simulation vehicle types, weight, impact speed and impact angle. The criteria also include the acceptable response to the simulated impact as it relates to structural adequacy, occupant risk and vehicle post-impact trajectory. Typical response criteria are provided in Table 1.

Table 1: Typical Crash Test Response Criteria
Structural Adequacy ⇒ Contain and redirect vehicle, i.e. vehicle cannot penetrate, override or underride the feature. ⇒ Feature shall have a controlled failure mechanism including breakaway or yielding that presents minimal risk to the public.
Occupant Risk ⇒ Detached fragments, elements or debris should not show potential for penetrating occupant compartment or present an undue hazard to other traffic and pedestrians. ⇒ Vehicle should remain upright although moderate roll, pitch and yaw are acceptable. ⇒ Occupant impact velocity limits are prescribed. ⇒ Occupant deceleration limits are prescribed.
Vehicle Trajectory ⇒ After impact the vehicle should not intrude into adjacent traffic lanes. ⇒ Following impact the exit angle should be less than 60 percent of the impact angle.

The 1962 Highway Research Correlation Services Circular 482 was the first widely recognized set of recommendations for performing full-scale crash tests of guardrails. The 1974 NCHRP Report 153 expanded on Circular 482 by including recommendations for crash cushions, breakaway and yielding supports, guardrail transitions and end treatments. The 1978 Transportation Research Board's Circular 191 was an interim modification to NCHRP Report 153. The 1980 NCHRP Report 230 introduced many now-standard test and performance criteria. Like the prior documents it addressed crash cushions, breakaway and yielding supports, end treatments, median barriers and guardrails. The 1989 AASHTO Guide Specifications presented test and performance criteria specifically for bridge railings. It was the first AASHTO specification that adopted crash testing. It included a multiple service level concept for bridge railings which provided variable test levels that could be applied to different roadway types, roadway geometry, traffic types and traffic volumes. The 1993 NCHRP Report 350 expanded on Report 230 by modifying the test and performance requirements and including truck mounted attenuators and work zone traffic control devices.

The 1989 AASHTO Guide Specification has three test levels (PL-1, PL-2 and PL-3) as described in Table 2. It includes tests for cars, pickups, single unit trucks and light tractor trailers. The 1994 AASHTO LRFD Specification adopted the 1989 AASHTO Guide Specification's three test levels and hence was the first AASHTO standard specification to adopt dynamic crash test criteria. The 1998 AASHTO LRFD Specification adopted the six test levels of NCHRP 350 plus one additional for light tractor trailers as described in Table 3. The 2003 interim revisions to the 1998 AASHTO LRFD Specification then adopted the NCHRP 350 tests levels without modification. The 1993 NCHRP Report 350 has six test levels (TL-1 through 6) as described in Table 4. It includes tests for cars, pickups, single unit trucks, heavy tractor trailers and tankers. The NCHRP 350 test levels were developed to provide a broader range of tests which could be applied to different roadway types, roadway geometry, traffic types and traffic volumes. This is the current standard adopted by FHWA and AASHTO.

The 1997 FHWA memo, Crash Testing of Bridge Railings, established correlations between each performance standard as described in Table 5. Therefore, features tested to prior standards do not necessarily have to be tested to NCHRP 350 standard. However, the equivalencies are regarded as conservative and testing could be conducted if particular features are expected to pass a higher NCHRP 350 test level.

Although NCHRP 350 established six test levels, amazingly there is little guidance on selecting the appropriate test level for different roadway types, roadway geometry, traffic types and traffic volumes. The 1989 AASHTO Guide Specification provides a matrix for selecting bridge rail test level as a function of roadway type, travel speed, ADT, ADTT and travel lane offset. The matrix was generated using a cost benefit analysis program. However, the matrix is outdated as it includes just three test levels whereas today's standards include six test levels.

Lastly, it is important to recognize that when a feature does not meet current standard, it does not mean replacement will be a priority. There will be lower priority for features that have performed functional to date, have low likelihood of being hit or there is limited public risk if the feature is hit or penetrated. However, this determination shall be made by an engineer and shall not influence the inspector's rating.

Table 2: AASHTO Guide Specification Test Criteria 1989

Performance Level	Vehicle	Impact Angle	Speed
1	compact (1,800lb)	20	50
	pickup (5,400lb)	20	45
2	compact (1,800lb)	20	60
	pickup (5,400lb)	20	60
	single unit truck (18,000lb)	15	50
3	compact (1,800lb)	20	60
	pickup (5,400lb)	20	60
	light tractor trailer (50,000lb)	15	50

Table 3: AASHTO LRFD Specification Test Criteria 1998			
Test Level	Vehicle	Impact Angle	Speed
1	mini-compact (1,550lb)	20	30
	compact (1,800lb)	20	30
	pickup (4,500lb)	25	30
2	mini-compact (1,550lb)	20	45
	compact (1,800lb)	20	45
	pickup (4,500lb)	25	45
3	mini-compact (1,550lb)	20	60
	compact (1,800lb)	20	60
	pickup (4,500lb)	25	60
4	mini-compact (1,550lb)	20	60
	compact (1,800lb)	20	60
	pickup (4,500lb)	25	60
	single unit truck (18,000lb)	15	50
5A	mini-compact (1,550lb)	20	60
	compact (1,800lb)	20	60
	pickup (4,500lb)	25	60
	light tractor trailer (50,000lb)	15	50
5	mini-compact (1,550lb)	20	60
	compact (1,800lb)	20	60
	pickup (4,500lb)	25	60
	tractor trailer (80,000lb)	15	50
6	mini-compact (1,550lb)	20	60
	compact (1,800lb)	20	60
	pickup (4,500lb)	25	60
	tanker (80,000lb)	15	50

Table 4: NCHRP Report 350 Test Criteria & AASHTO LRFD Specification 2003			
Test Level	Vehicle	Impact Angle	Speed
1	mini-compact (1,550lb)	20	30
	compact (1,800lb)	20	30
	pickup (4,500lb)	25	30
2	mini-compact (1,550lb)	20	45
	compact (1,800lb)	20	45
	pickup (4,500lb)	25	45
3	mini-compact (1,550lb)	20	60
	compact (1,800lb)	20	60
	pickup (4,500lb)	25	60
4	mini-compact (1,550lb)	20	60
	compact (1,800lb)	20	60
	pickup (4,500lb)	25	60
	single unit truck (18,000lb)	15	50
5	mini-compact (1,550lb)	20	60
	compact (1,800lb)	20	60
	pickup (4,500lb)	25	60
	tractor trailer (80,000lb)	15	50
6	mini-compact (1,550lb)	20	60
	compact (1,800lb)	20	60
	pickup (4,500lb)	25	60
	tanker (80,000lb)	15	50

Table 5: Test Criteria Equivalencies						
Rail Test Criteria	Equivalencies					
NCHRP Report 350 & AASHTO LRFD specification 2003	TL-1	TL-2	TL-3	TL-4	TL-5	TL-6
AASHTO Guide Specification 1989 & AASHTO LRFD Specification 1994		PL-1		PL-2	PL-3	
NCHRP Report 230		MSL-1 MSL-2		MSL-3		
TL = test level, PL = performance level, MSL = multiple service level						

POLICY

Owners' policies apply to replacement and new design. Therefore, regardless of the feature type and test level specified by an owner's policy, for rating purposes it is appropriate to rate as meets standard if it has been crash tested to a level appropriate for the roadway type, roadway geometry, traffic type and traffic volume. The following policies are provided for information purposes, not for rating purposes.

i) Federal Highway Administration

Bridge Rail

National Highway System roads, regardless of funding source, shall meet NCHRP 350 test level 3 or higher unless a rational selection procedure is used to select an appropriate test level based on roadway type, roadway geometry, traffic type and traffic volume. On roads other than National Highway System it is strongly encouraged to utilize crash tested features that meet NCHRP 350.

Other Traffic Safety Features

National Highway System roads, regardless of funding source, shall meet NCHRP 350. Minimum test levels are not specified. On roads other than National Highway System it is strongly encouraged to utilize crash tested features that meet NCHRP 350.

ii) Maryland State Highway Administration

Bridge Rail

A policy is under development that requires utilization of crash tested rail on all roads on all MSHA projects regardless of funding source. The rails to be utilized include;

- Divided/Dual Highways
  ⇒ 42" F safety shape (meets NCHRP 350 test level 5)
- Undivided Highways with Future Projected ADT ≥ 2,500
  ⇒ 32" F safety shape (meets NCHRP 350 test level 4)
- Undivided Highways with Future Projected ADT < 2,500
  ⇒ 32" Two Tube Curb Mounted Rail Oregon Type (meets NCHRP 350 test level 4)

- Rails adjacent to Sidewalk
  - ⇒ 42” vertical parapet composed of 27” vertical shape with 14” tall elliptical tube rail (has not been crash tested)

MSHA current standard drawings include;

- 34” and 42” F safety shape
- 27” vertical face 12” wide with 14” tall elliptical tube rail (note 15” elliptical tube rail is required for 42” height despite the standard), 5’ wide sidewalk, 8” curb (note 6” curb is preferred despite the standard)

Transitions

A policy is under development that requires utilization of crash tested transitions on all roads on all MSHA projects regardless of funding source.

MSHA current standard drawings include;

- w-beam (steel posts) and rub rail anchored to Jersey or F safety shape
- thrie-beam (wood posts) anchored to Jersey or F safety shape tapered face

Approach Rail

MSHA utilizes crash tested rails that meet NCHRP 350 standard.

MSHA current standard drawings include;

- w-beam with “strong” posts
- 34” and 42” F safety shapes

End Treatments

MSHA utilizes crash tested end treatments that meet NCHRP 350 standard.

MSHA current standard drawings include;

- Type A (Buried-in-Backslope) Single Rail & Double Rail
- Type B (Modified Flared Breakaway)
- Type C (Parallel Breakaway Extruder)
- Type D (Two-Sided Breakaway Attenuating)
- Type E (Two-Sided Non-Breakaway G.R.E.A.T.)
- Type F (Two-Sided Semi-Breakaway Brakemaster)
- Type G (Turn-Down)
- Type J (Two-Side Non-Breakaway)
- Type K (Downstream Anchorage)
- Type L (Radius Section Anchorage)

- Sand Barrel Crash Cushions

iii) Maryland Local Governments

In the absence of a prescribed policy approved by MSHA, AASHTO specifications apply. The AASHTO LRFD Specification says all bridge rail shall be crashworthy regardless of roadway type, geometry and traffic. AASHTO defines crashworthy as successfully crash tested to a currently acceptable performance standard and test level or can be geometrically and structurally evaluated as equal to a crash tested system.

BASIS OF RATING PROCEDURE

This manual's rating procedure is based on the premise a safety feature meets current standard only if it has been crash tested to an appropriate test level. Selection of test levels for different roadways is problematic given a lack of available guidance.

For bridge rail, the 1989 AASHTO Guide Specification offers a selection matrix however it is based on three crash test levels rather than the six test levels of NCHRP 350 and the AASHTO LRFD Specification. There is need for updated selection guidance that takes advantage of the broader six test levels. Regardless, the AASHTO matrix is used in this manual. For simplification ADTT is assumed equal to 10% whereas AASHTO allows selection from 0 to 40%.

After selecting the appropriate test level the inspector then refers to the included diagrams of crash tested bridge rail. The rails selected for inclusion in this manual are those likely to be found in Maryland. All crash tested rails are not included. If a rail is encountered that is believed to have been tested, the FHWA Bridge Rail Guide may be consulted. This manual's diagrams are simplified design/construction drawings. The following simplifications were made;

- The bridge rail diagrams do not show all structural details. Primary member sizes are shown however unexposed connections and reinforcement are not shown given they are not visible in the field. The diagrams show all significant geometry such as height, shape, openings and post setback.
- The bridge rail heights shown have zero tolerance unless a range is noted. Per the AASHTO LRFD Specification 4th Edition, for safety shapes with a bottom lip for future overlays, an encroachment of 2" leaving a 1" lip has been satisfactorily tested. MSHA's standard for 34" F safety shape is 2" higher that the crash tested 32" safety shape to allow future overlays while retaining a height of 32".
- Deck overhang width is not shown. Crash testing is conducted on a representative deck section to evaluate whether the rail anchorage is adequate, whether the deck reinforcement steel is adequate to distribute post anchorage loads without deck localized failures and whether the deck is structurally sufficient. The tested overhang width is not readily available for all rails therefore maximum allowed overhang width is not shown.
- Minimum deck thickness is provided from rules of thumb when not readily available for specific rail. Sufficient deck thickness is required for anchorage.
- Pedestrian and bicycle rail attachments are not shown. Current standard requires 42" height if there is an adjacent sidewalk or bicycle lane. The lack of a pedestrian/bicycle rail should not enter into the rating, however should be noted in the inspection report recommendations.

For informational purposes the following are some general rules of thumb based on observations of bridge rail crash tests;

- Minimum deck overhang mount thickness regardless of test level

  ⇒ Concrete parapet – 8"
  ⇒ Top mounted post system – 8"
  ⇒ Side mounted post system – 12"

- Minimum height to top of structural rail (excludes height of pedestrian rail attachments)

  ⇒ TL-3 ≥ 27"
  ⇒ TL-4 ≥ 32"
  ⇒ TL-5 ≥ 42"
  ⇒ TL-6 ≥ 90"
  ⇒ Pedestrian and bicycle traffic (if sidewalk or bicycle lane present) – 42"

- Transverse load capacity (note these far exceed the 1989 AASHTO Guide Specification 10,000 lb static force criteria)

  ⇒ TL-1 ≥14,000 lb
  ⇒ TL-2 ≥ 27,000 lb
  ⇒ TL-3 ≥ 54,000 lb
  ⇒ TL-4 ≥ 54,000 lb
  ⇒ TL-5 ≥ 124,000 lb
  ⇒ TL-6 ≥ 175,000 lb

CRASH TESTED BRIDGE RAIL LIST

The following is a list of crash tested bridge rails included in the FHWA Bridge Rail Guide. The most current version of the Guide can be found at internet address http://www.fhwa.dot.gov/bridge/bridgerail/. The Guide includes geometric and structural details of crash tested rail. The rail diagrams selected for inclusion in Part 2 of this manual are those likely to be found in Maryland. The diagrams are simplified versions of design/construction drawings.

Type	FHWA Bridge Rail Guide Section	NCHRP 350 Test Level	Agency That Crash Tested & Rail Name	Diagram Source Used In This Manual	Included In This Manual?
Safety Shape Rail					
Single Slope 32"	4.62	TL-4	California Type 732	FHWA Bridge Rail Guide	YES
Jersey Shape 32"	4.1	TL-4	California Type	FHWA Bridge Rail Guide	YES
F Shape 32"	5.21	TL-4	Florida Type	FHWA Bridge Rail Guide	YES
Jersey Shape & One Tube 39"	4.76	TL-4	Nevada Type	FHWA Bridge Rail Guide (not on NVDOT website)	YES
Single Slope 42"	4.66	TL-5	California Type 742	CALTRANS website	YES
F Shape 42"	5.43	TL-5	Florida Type	FHWA Bridge Rail Guide	YES
Jersey Shape & One Tube 50"	4.78	TL-5	Texas Type HT	TXDOT website	YES
Jersey Shape 32"	4.15	TL-4	Georgia type	(not on GDOT website)	
Single Slope 42"	4.33	TL-5	Missouri Type		
Jersey Shape 72"	4.45	TL-4	Texas Type T501SW		
Jersey Shape 90"	4.54	TL-6	Texas Type TT		
Jersey Shape 32"	4.56	TL-4	Missouri Type		
Single Slope 36"	4.64	TL-4	California Type 736		
Jersey Shape & One Tube 39"	4.70	TL-3	California Type 20		
Vertical Shape Rail					
Vertical Face Balustrade 32" to 42"	4.47 & 4.52	TL-2	Texas Type T411 & C411	TXDOT website	YES
Vertical Face & One Tube 32"	3.4	TL-2	North Carolina Type	FHWA Bridge Rail Guide	YES
Vertical Face & Two Tube with Sidewalk 41"	4.19	TL-2	Georgia Type	FHWA Bridge Rail Guide (not on GDOT website)	YES
Vertical Face & One Tube with Sidewalk 42"	4.17	TL-4	Georgia Type	FHWA Bridge Rail Guide (not on GDOT website)	YES
Vertical Face with Sidewalk 34"	4.21	TL-4	Georgia Type	FHWA Bridge Rail Guide (not on GDOT website)	YES
Vertical Face & One Tube with &	4.41	TL-4	Oregon Flush Mounted Type	ORDOT website	YES

without Sidewalk 42"			(w/o 54" pedestrian rail)		
Vertical Face & One Tube 27"	3.26	TL-2	California Type 9		
Vertical Face & Two Tube 42"	3.31	TL-4	Michigan Type BR27D		
Vertical Face & One Tube 36"	3.33	TL-4	Minnesota Type		
Vertical Face & One Tube 54"	3.35	TL-5	Texas Type C202		
Vertical Face Modern Pilaster 32"	4.3	TL-4	California Type 80		
Vertical Face Masonry 32"	4.9	TL-3	Federal Lands Type		
Vertical Face Modern Pilaster 32.5"	4.13	TL-2	Federal Lands Type		
Vertical Face Modern Pilaster 29"	4.24	TL-2	Iowa Type		
Vertical Face Modern Pilaster 27"	4.28	TL-2	Kansas Type Modified Corral		
Vertical Face Modern Pilaster 32"	4.31	TL-4	Kansas Type Corral		
Vertical Face Modern Pilaster 29"	4.35	TL-2	Nebraska Type		
Vertical Face Modern Pilaster 29"	4.37	TL-4	Nebraska Type		
Vertical Face Modern Pilaster 29"	4.39	TL-2	Oklahoma Type TR1 Modified		
Vertical Face Modern Pilaster 27"	4.49	TL-3	Texas Type T203		
Vertical Face & One Tube with Sidewalk 36"	4.60	TL-2	California Type 26		
Metal Tube Rail					
Two Tube Curb Mounted 32"	3.57	TL-4	Oregon Type	ORDOT website (although FHWA Bridge Rail Guide lists as TL-2 ORDOT "Office Practice Manual" contains an updated rail that meets TL-4)	YES
Three Tube Curb Mounted 42"	3.58	TL-4	Oregon Type	ORDOT website	YES
Two Tube Curb Mounted 32"	3.39	TL-4	Illinois Type 2399	FHWA Bridge Rail Guide	
Two Tube Curb Mounted 33" (aluminum)	3.1	TL-2	Federal Lands Type		
Two Tube Bottom	3.5	TL-3	Texas Type		

Mounted 27”					
Two Tube Side Mounted 36”	3.7	TL-2	California Type 18		
Two Tube Side Mounted 30”	3.10	TL-2	California Type 115		
Two Tube Side Mounted 42”	3.12	TL-2	California Type 116		
Two Tube Side Mounted 54”	3.14	TL-2	California Type 117		
Two Tube Side Mounted 32”	3.18	TL-4	Oregon type		
Two Tube Top Mounted 32”	3.20	TL-2	Texas Type 421		
Two Tube Curb Mounted 32”	3.24	TL-4	Alaska Type		
Two Tube Curb Mounted 32”	3.28	TL-4	California Type ST-10		
Three Tube Curb Mounted 42”	3.37	TL-3	Federal Lands Type		
Three Tube Top Mounted 42”	3.42	TL-4	Michigan Type		
Two Tube Curb Mounted 32.5”	3.44	TL-4	Michigan Type		
Two Tube Curb Mounted 34”	3.46	TL-4	New England Type		
Two Tube Curb Mounted 32”	3.48	TL-4	New York Type		
Three Tube Top Mounted 32”	3.50	TL-4	New York Type		
Four Tube Top Mounted 42”	3.52	TL-4	New York Type		
Five Tube Top Mounted 56”	3.54	TL-4	New York Type		
Two Tube Curb Mounted 32”	3.61	TL-4	Wyoming Type		
Two Tube Curb Mounted 29”	3.64	TL-3	Wyoming Type		
Thrie-Beam Rail					
Thrie-Beam Side Mounted 27”	2.9	TL-2	Oregon Type	ORDOT website	YES
Thrie-Beam Top Mounted 34”	N/A	TL-2	New York Type	NYSDOT website	YES
Thrie-Beam Top Mounted 32”	2.1	TL-4	Delaware Type		
Thrie-Beam Top Mounted 30.5”	2.5	TL-3	Missouri Type		
Tubular Thrie-Beam Top Mounted 32”	2.7	TL-3	Nebraska Type		
Thrie-Beam Side Mounted 32”	6.15	TL-2	US Forest Service Type	FHWA Bridge Rail Guide (rail guide insufficient, no drawings on internet)	
Thrie-Beam with Upper Channel Side Mounted 33”	6.17	TL-4	US Forest Service Type TCB8000		

W-Beam Rail					
W-Beam Top & Side Mounted 28"	6.19	TL-1	US Forest Service Type	University of Nebraska-Lincoln published drawings	YES
W-Beam Backed with Box Beam Side Mounted 27"	1.5	TL-2	Ohio Type	OHDOT website	YES
W-Beam Backed with Box Beam Top Mounted 27"	1.1	TL-3	Texas Type T101	TXDOT website (although FHWA Bridge Rail Guide lists as TL-2 TXDOT drawing lists as TL-3)	YES
W-Beam Side Mounted 28"	1.3	TL-2	Michigan Type	MDOT procured drawings (although FHWA Bridge Rail Guide lists as TL-3 MDOT procured drawings are same as Ohio Type TL-2 which is correct)	
Tubular W-Beam Top Mounted 27"	1.7	TL-2	Texas Type T6		
Timber Rail					
Curb Type Glulam Rail 18"	6.5	TL-1	US Forest Service Type	University of Nebraska-Lincoln published drawings	YES
W-Beam with Timber Breakaway Post Side Mounted 28"	6.13	TL-1	US Forest Service Type	University of Nebraska-Lincoln published drawings	YES
Glulam Rail with Shoe Attachment Side Mounted 32"	6.7	TL-2	US Forest Service Type	University of Nebraska-Lincoln published drawing	YES
Glulam Rail with Curb Top & Side Mounted 32"	N/A	TL-2	US Forest Service Type	University of Nebraska-Lincoln published drawings	YES
Glulam Rail with Curb Top & Side Mounted 33"	6.9	TL-4	US Forest Service Type GC8000	University of Nebraska-Lincoln published drawings	YES
Glulam Rail Top & Bottom Mounted 27"	6.1	TL-3	Oklahoma Type Timber Rail 3	FHWA Bridge Rail Guide (not on OKDOT website)	

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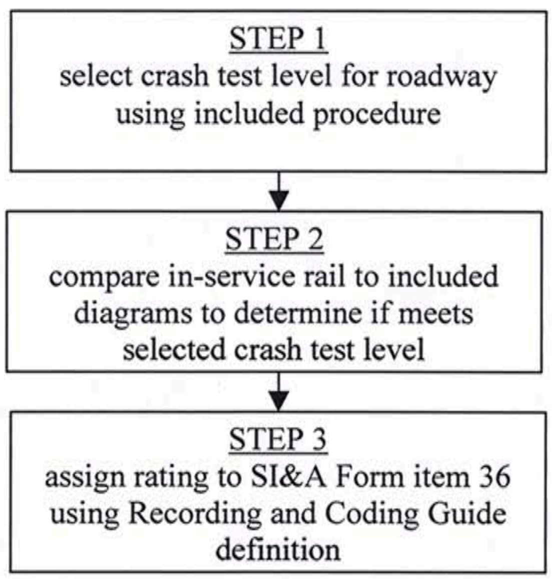
RATING BRIDGE RAIL

Bridge rail must be adequate to prevent vehicles from leaving the bridge by penetration, climbing or rollover. It should also redirect vehicles without excessive damage to the occupant compartment, without snagging or dramatic deceleration and without detached fragments, elements or debris penetrating the occupant compartment. The rail geometry and structural capacity are essential to its proper function. Modern design criteria require full-scale simulated crash testing. There are six different crash test levels a rail may be tested to (TL-1 through TL-6). Each test level includes different vehicle types, weights, impact speed and impact angle. TL-1 includes the lowest vehicle weight (1,550 lb car) and impact speed (30 mph). TL-6 includes the highest vehicle weight (80,000 lb tanker) and impact speed (60 mph). Part 1 of this manual may be referred to for further explanation.

i) Rating Procedure

The rating of rail includes three steps;



STEP 1:

A) National Highway System Roads

Determine if road is a National Highway System (NHS) route by referring to Structure Inventory and Appraisal Form item 104 "Highway System of the Inventory Route". Per the 1995 Recording and Coding Guide if item 104 is coded "1" it is a NHS route. NHS generally includes interstates, other principle arterials and Strategic Highway Network Routes (STRAHNET).

<u>If is National Highway System the test level shall be greater than or equal to 3</u>

B) Roads other than National Highway System

If not NHS the test level shall be selected from Table 1. The following information is needed to use the table;

<u>Travel Speed:</u> Can be estimated from field observation.

<u>Rail Offset:</u> Offset from travel lane can be taken as the distance from painted edge line to the rail's closest component. Typically this is considered the shoulder width.

<u>ADT:</u> Can be taken from Structure Inventory and Appraisal Form item 29 "Average Daily Traffic". Is the combined traffic in both directions unless are parallel structures in which case the ADT is only for the direction carried.

Enter this information in the table to determine the required crash test level.

STEP 2:

Compare in-service rail to included diagrams of crash tested rails. If the in-service rail matches any of the diagrams, compare the selected test level to that on the diagram. If the selected test level is less than or equal to the diagram then the rail may be rated as meets standard.

The rail heights shown have zero tolerance unless a range is noted. For safety shapes with a bottom lip for future overlays, an encroachment of 2" leaving a 1" lip has been satisfactorily tested.

Rail with sidewalk only meets standard if crash testing included the sidewalk. Diagrams with sidewalk were tested with the sidewalk. Sidewalk is generally not recommended for speeds greater than 40 mph. Bridge curb height shall not exceed 6" unless it ties into approach curb that is higher than 6" for a significant length beyond the bridge and is also higher elsewhere on the roadway in nearby vicinities. *How may sidewalk width dimensions vary?*

If the rail has aesthetic surface treatments (reliefs or depressions) the treatments must be evaluated according to the criteria given in this manual's section "Aesthetic Surface Treatments".

Pedestrian and bicycle rail attachments are not shown. Current standard requires 42" height if there is an adjacent sidewalk or bicycle lane. The lack of a pedestrian/bicycle rail should not enter into the rating, however should be noted in the inspection report recommendations.

The rails selected for inclusion in this manual are those likely to be found in Maryland. All crash tested rails are not included. If a rail is encountered that is believed to have been tested, the FHWA Bridge Rail Guide may be consulted to check if has been tested.

STEP 3:

1995 Recording and Coding Guide definition

Code item 36A of the Structure Inventory and Appraisal Form.

0	=	does not meet currently acceptable standard
1	=	meets currently acceptable standard
N	=	safety feature not required

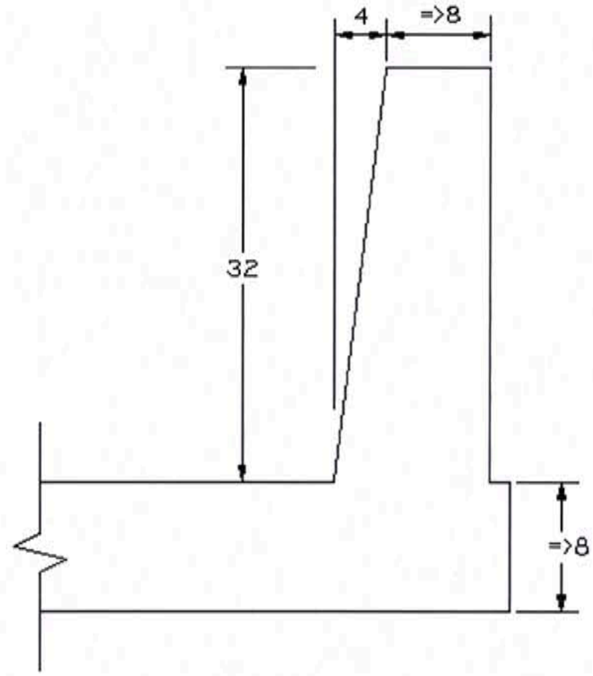
Code N shall seldom be used. An example where N may be used is for box and pipe culverts with side slopes and headwalls far from travel lane such that rail is not required.

Collision damage or deterioration of elements is not considered when coding.

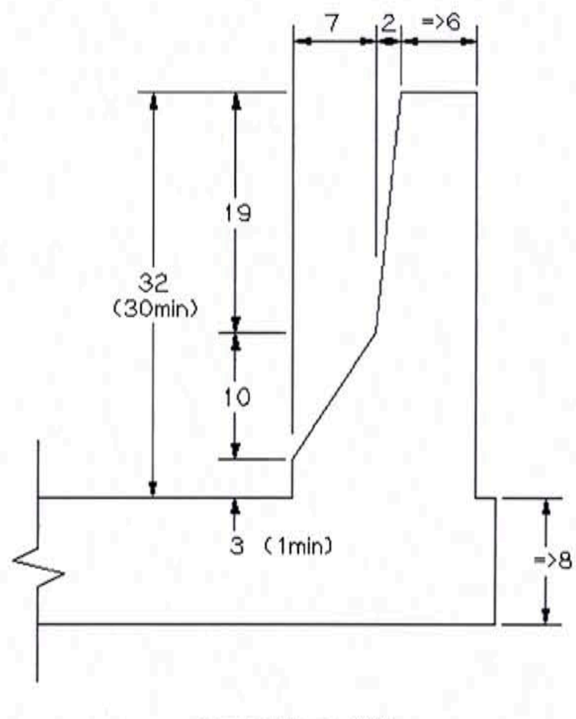
Table 1: Test Level Selection Non-NHS																						
Site Characteristics		ADT (1000 vehicles per day both directions combined total)																				
Travel Speed (mph)	Rail Offset (ft)	All Divided Roadways & Undivided Roadways ≥ 5 Lanes Combined							Undivided Roadways ≤ 4 Lanes Combined							One Direction Roadways (Ramps, One Way Streets, Etc.)						
			TL-2		TL-4		TL-5			TL-2		TL-4		TL-5			TL-2		TL-4		TL-5	
30	0-3	0	to	23.9	to	179.8	to	∞	0	to	19.3	to	147.9	to	∞	0	to	12.0	to	89.9	to	∞
	>3-7	0	to	36.5	to	258.3	to	∞	0	to	28.8	to	228.7	to	∞	0	to	18.3	to	129.2	to	∞
	>7-12	0	to	55.9	to	404.4	to	∞	0	to	46.5	to	364.6	to	∞	0	to	28.0	to	202.2	to	∞
	>12	0	to	100.7	to	∞			0	to	84.6	to	∞			0	to	50.4	to	417.1	to	∞
40	0-3	0	to	9.8	to	79.7	to	∞	0	to	7.1	to	55.6	to	∞	0	to	4.9	to	39.9	to	∞
	>3-7	0	to	12.7	to	89.8	to	∞	0	to	9.2	to	68.6	to	∞	0	to	6.4	to	44.9	to	∞
	>7-12	0	to	16.9	to	132.4	to	∞	0	to	12.8	to	102.3	to	∞	0	to	8.5	to	66.2	to	∞
	>12	0	to	25.8	to	183.6	to	∞	0	to	20.1	to	157.2	to	∞	0	to	12.9	to	91.8	to	∞
50	0-3	0	to	4.7	to	50.0	to	∞	0	to	3.2	to	32.0	to	∞	0	to	2.4	to	25.0	to	∞
	>3-7	0	to	5.4	to	61.4	to	∞	0	to	3.7	to	41.8	to	∞	0	to	2.7	to	30.7	to	∞
	>7-12	0	to	7.2	to	70.6	to	∞	0	to	5.1	to	49.3	to	∞	0	to	3.6	to	35.3	to	∞
	>12	0	to	9.6	to	88.5	to	∞	0	to	6.9	to	67.8	to	∞	0	to	4.8	to	44.3	to	∞
60	0-3	0	to	2.8	to	39.6	to	∞	0	to	1.8	to	25.0	to	∞	0	to	1.4	to	19.8	to	∞
	>3-7	0	to	3.1	to	47.5	to	∞	0	to	2.0	to	29.3	to	∞	0	to	1.6	to	23.8	to	∞
	>7-12	0	to	3.9	to	53.1	to	∞	0	to	2.5	to	33.7	to	∞	0	to	2.0	to	26.6	to	∞
	>12	0	to	4.7	to	67.6	to	∞	0	to	3.1	to	44.1	to	∞	0	to	2.4	to	33.8	to	∞
70	0-3	0	to	2.0	to	32.1	to	∞	0	to	1.2	to	20.0	to	∞	0	to	1.0	to	16.1	to	∞
	>3-7	0	to	2.3	to	38.5	to	∞	0	to	1.4	to	22.9	to	∞	0	to	1.2	to	19.3	to	∞
	>7-12	0	to	2.6	to	42.2	to	∞	0	to	1.6	to	26.7	to	∞	0	to	1.3	to	21.1	to	∞
	>12	0	to	3.0	to	53.0	to	∞	0	to	1.8	to	33.1	to	∞	0	to	1.5	to	26.5	to	∞

NOTES:
This table is a simplification of 1989 AASHTO Guide Specification, 10% ADTT assumed.
A limitation of this matrix is only three of NCHRP 350's six test levels are represented. This is because the matrix is based on the 1989 AASHTO Guide Specification's three performance levels. As a result high speeds will almost always require TL-4 or greater given TL-2 only satisfies for very low ADTs.

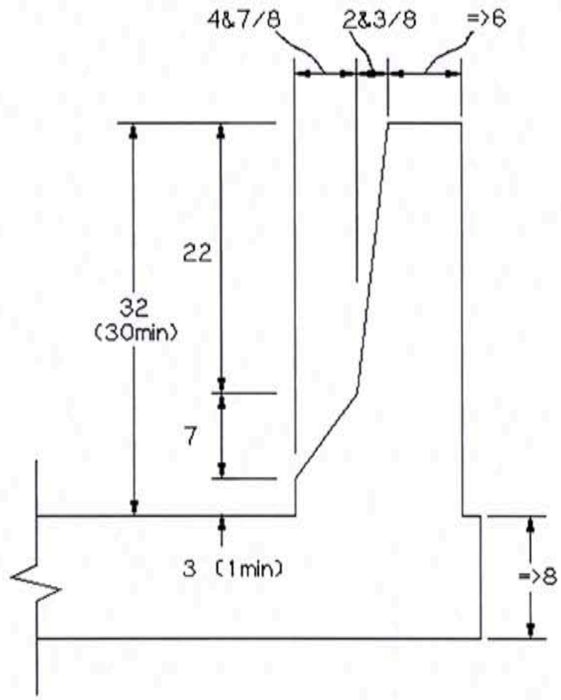
ii) Crash Tested Rail Diagrams



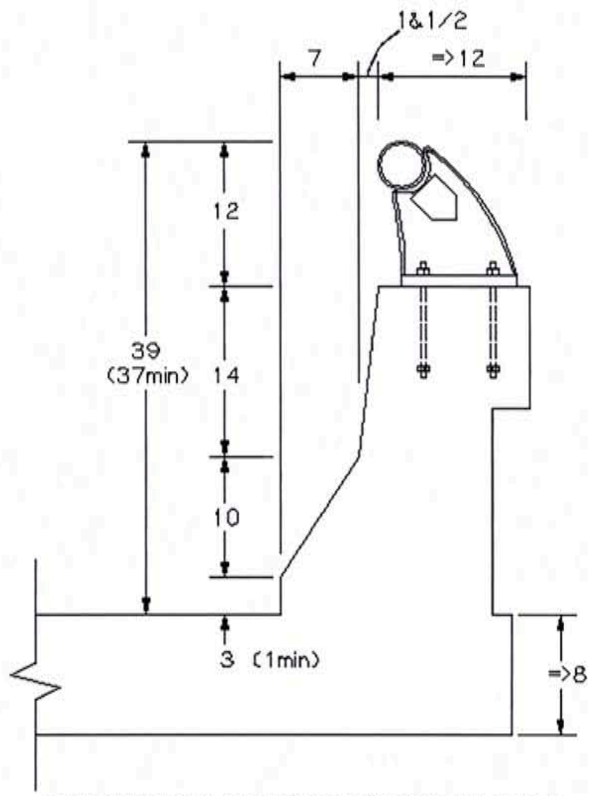
Single Slope 32" (California Type 732)
TL-4



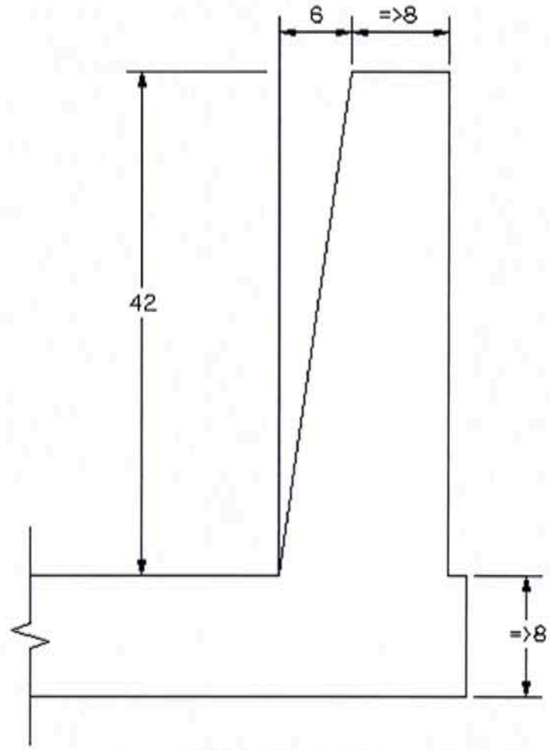
Jersey Shape 32"
TL-4



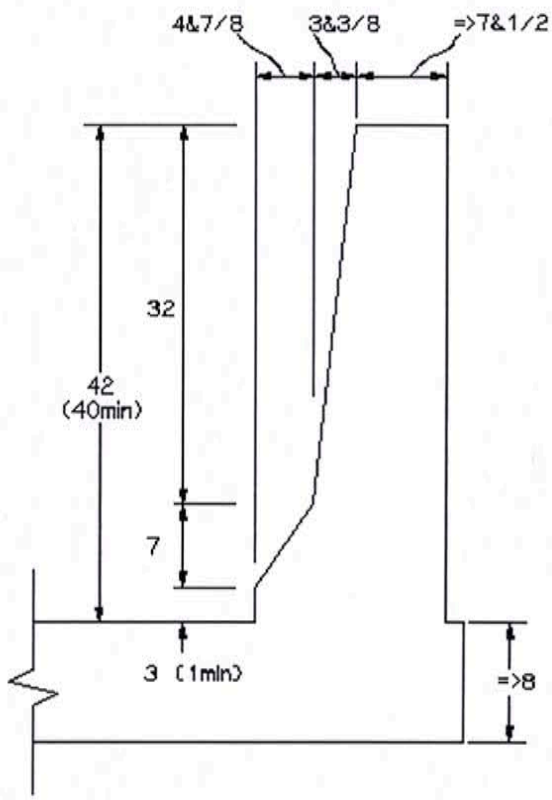
F Shape 32"
TL-4



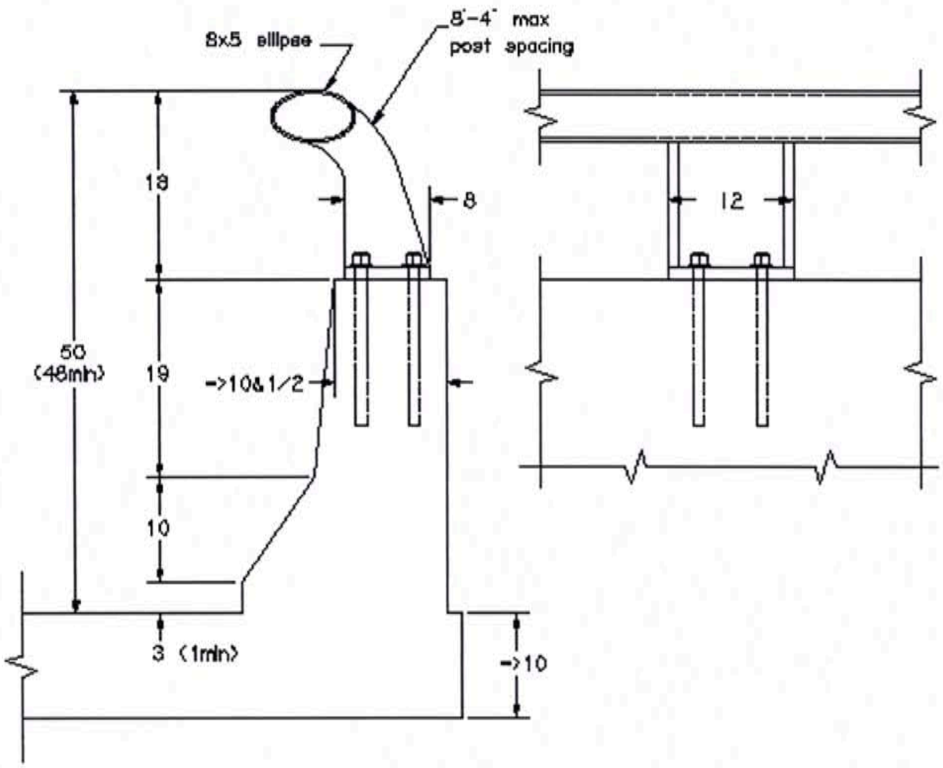
Jersey Shape & One Tube 39" (Nevada Type)
TL-4



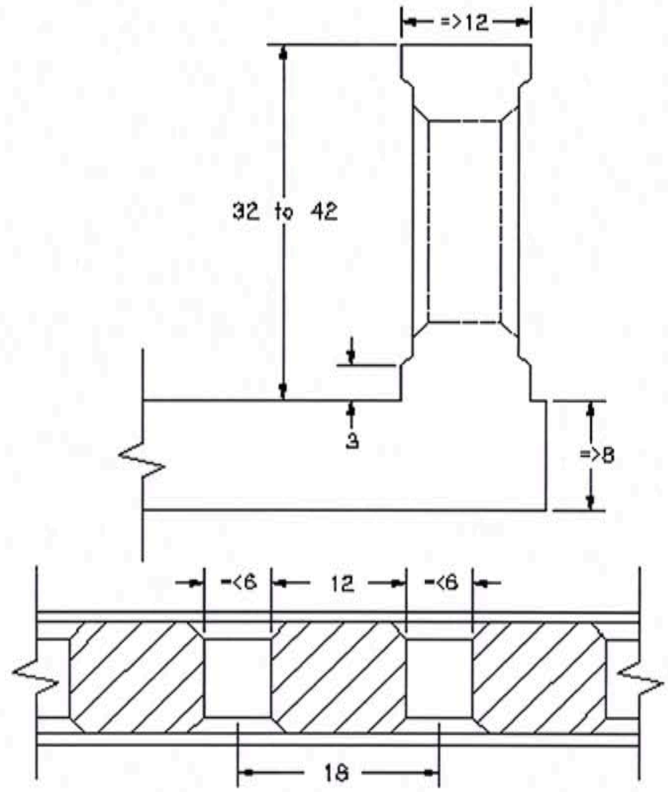
Single Slope 42"
TL-5



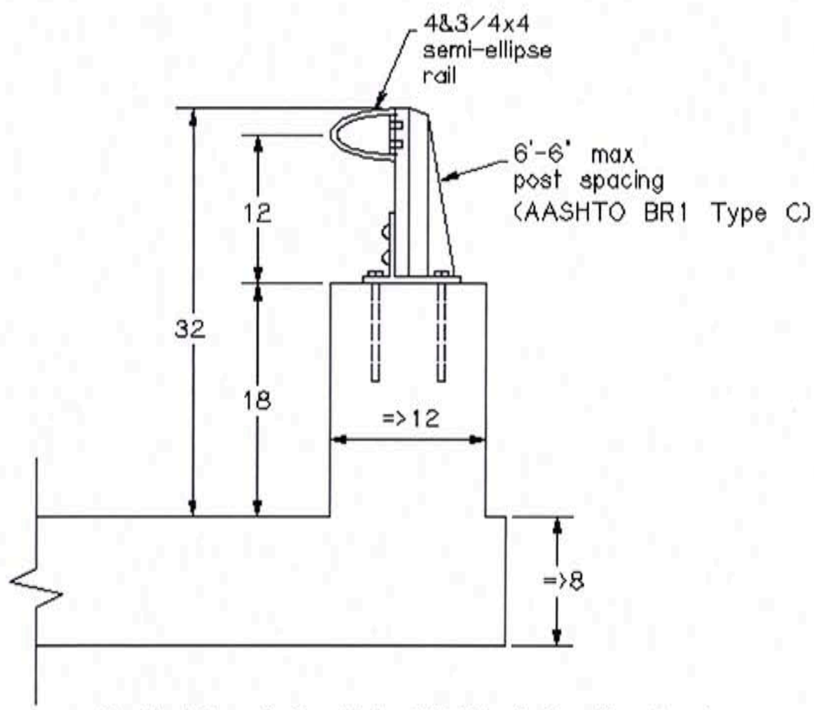
F Shape 42"
TL-5



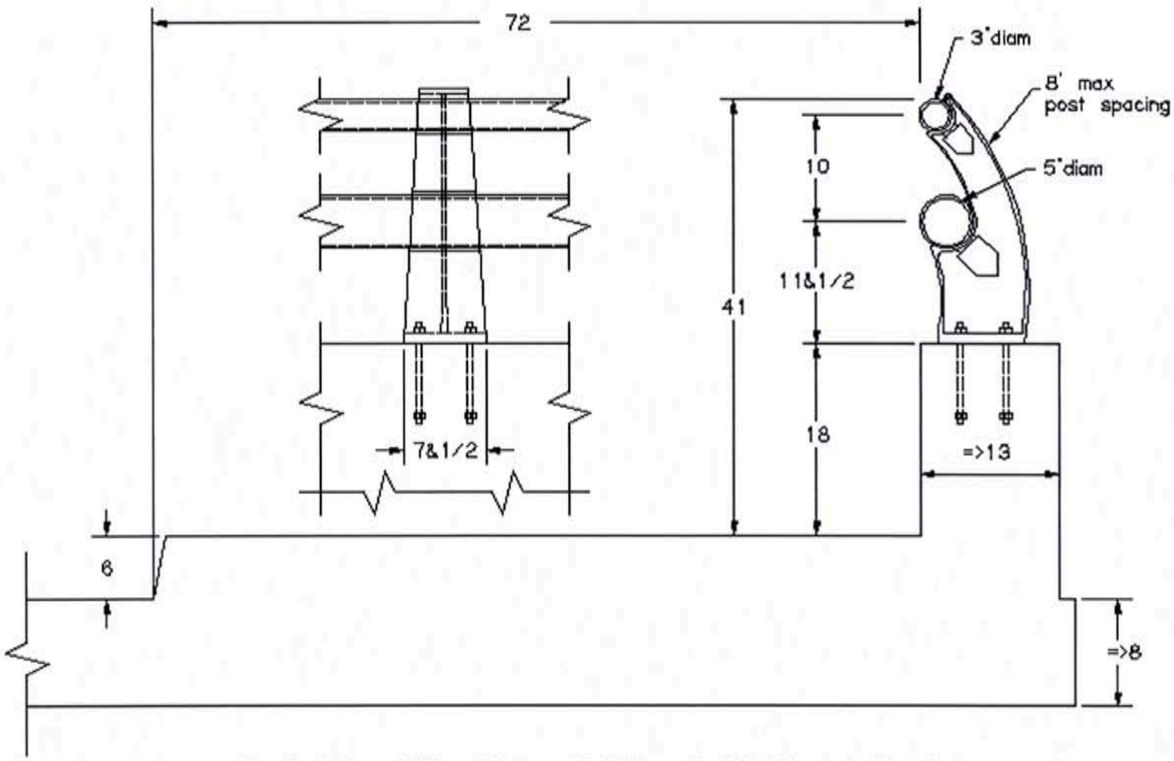
Jersey Shape & One Tube 50" (Texas Type HT)
TL-5



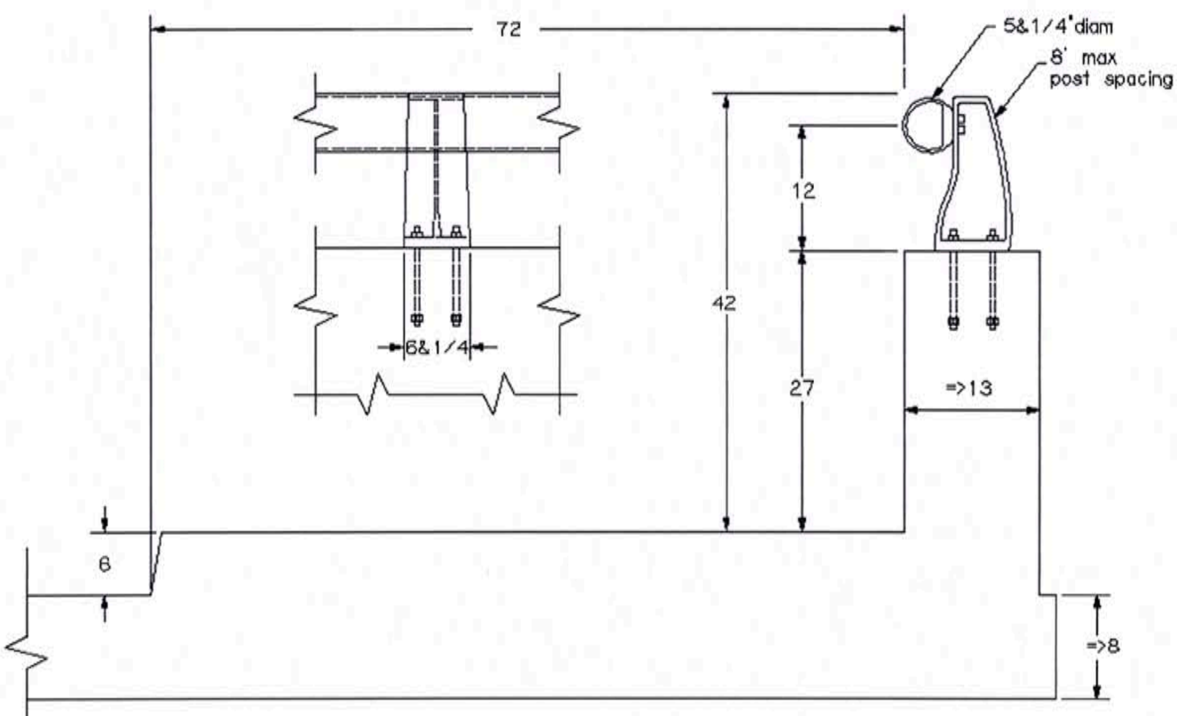
Vertical Face Balustrade 32" to 42" (Texas Type T411 & C411)
TL-2



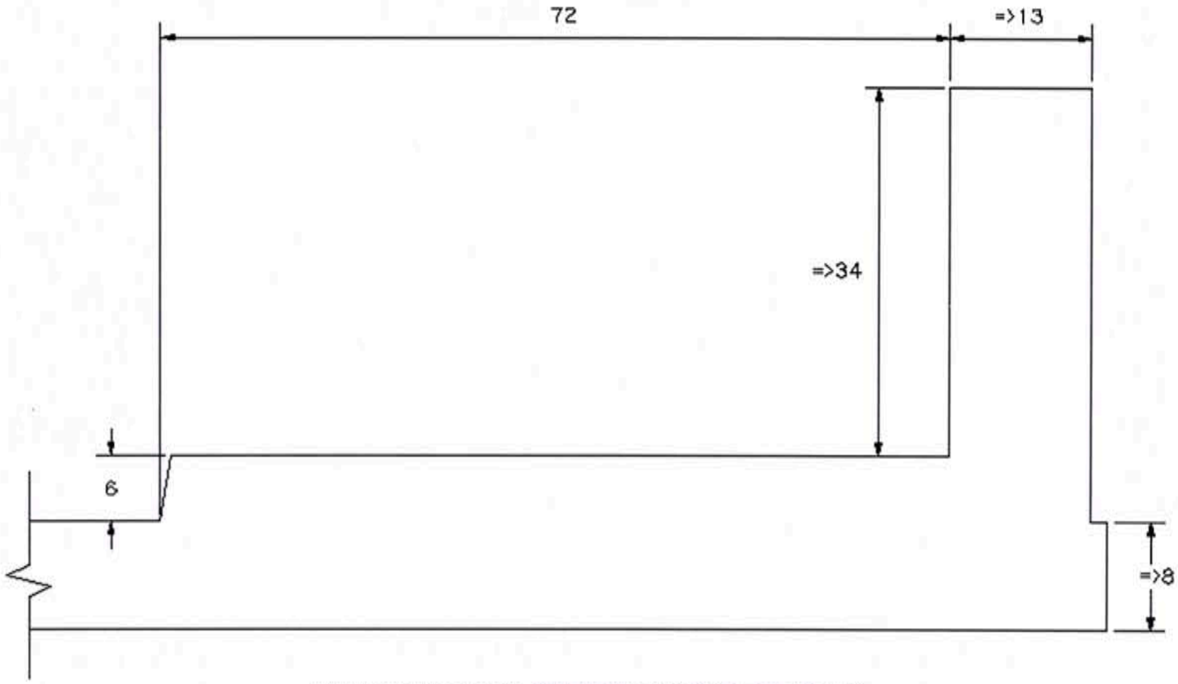
Vertical Face & One Tube 32" (North Carolina Type)
TL-2



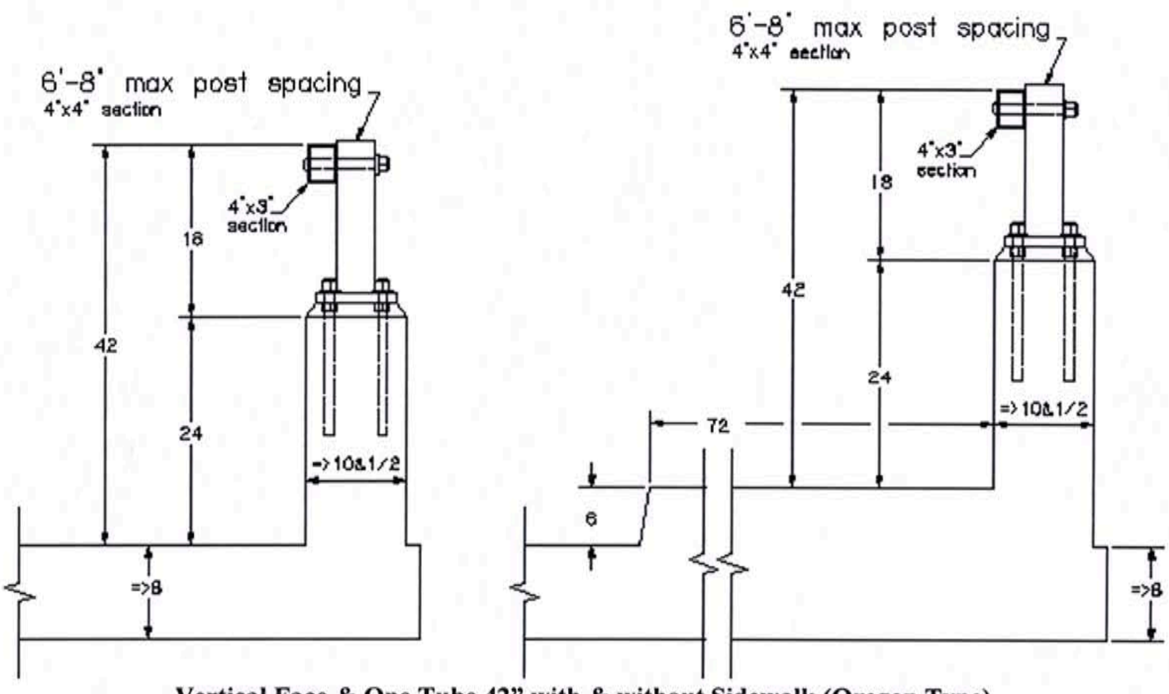
Vertical Face & Two Tube with Sidewalk 41" (Georgia Type)
TL-2



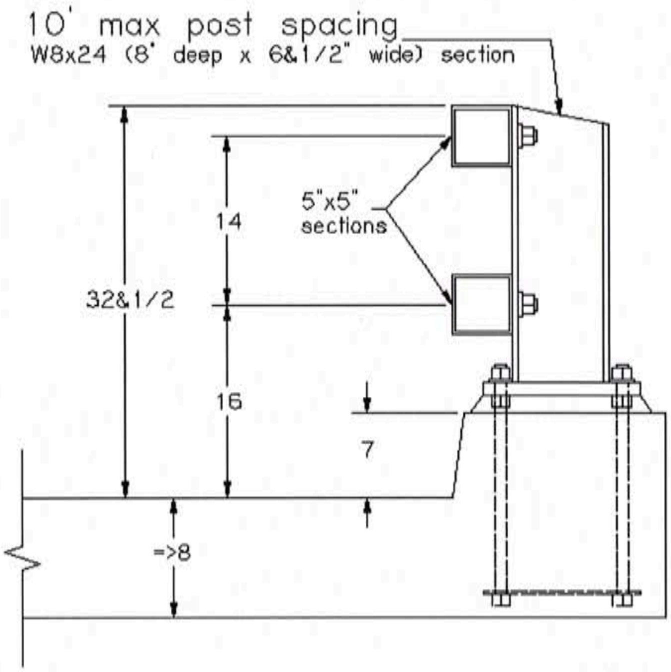
Vertical Face & One Tube with Sidewalk 42" (Georgia Type)
TL-4



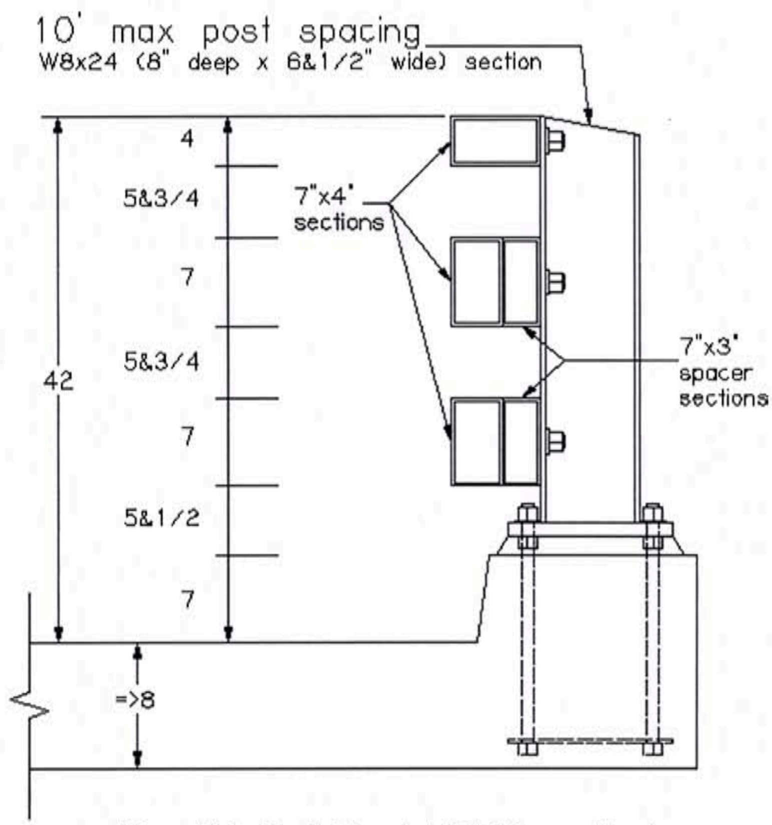
Vertical Face with Sidewalk 34" (Georgia Type)
TL-4



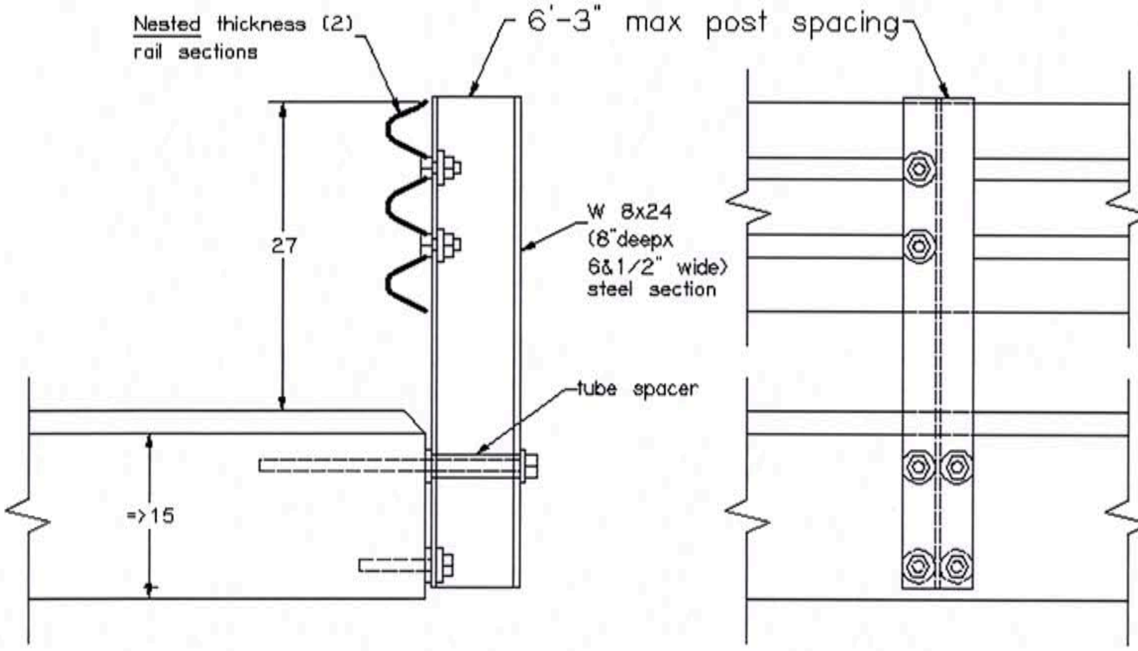
Vertical Face & One Tube 42" with & without Sidewalk (Oregon Type)
TL-4



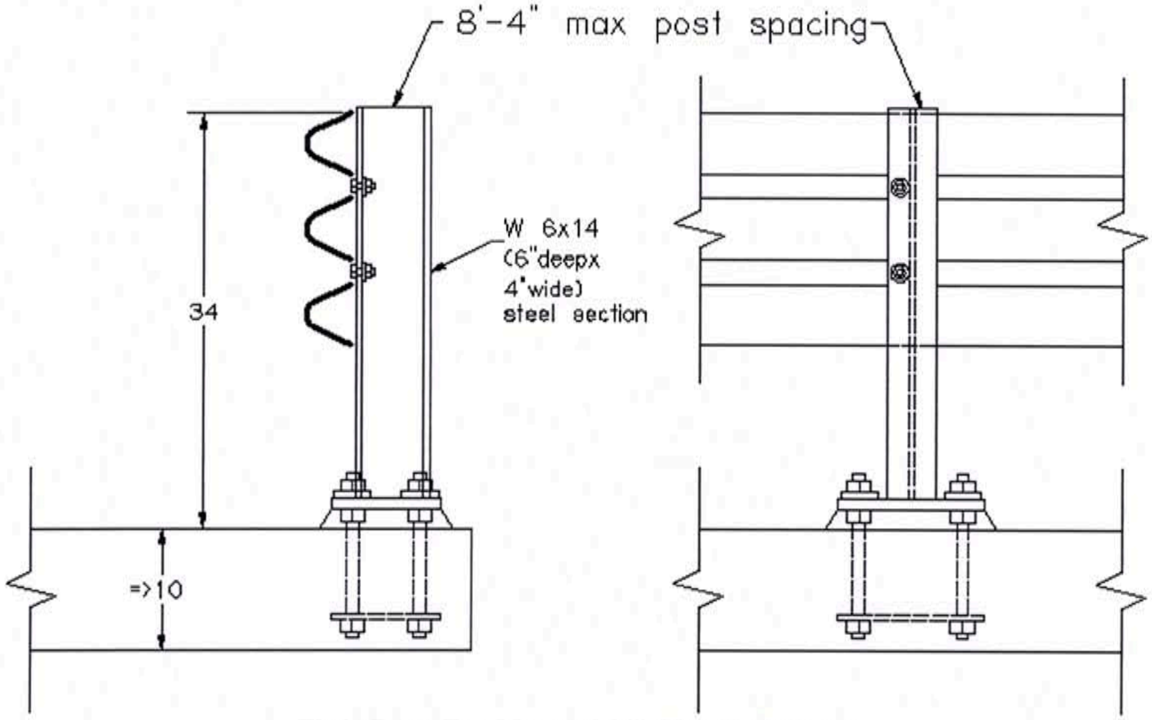
Two Tube Curb Mounted 32" (Oregon Type)
TL-4



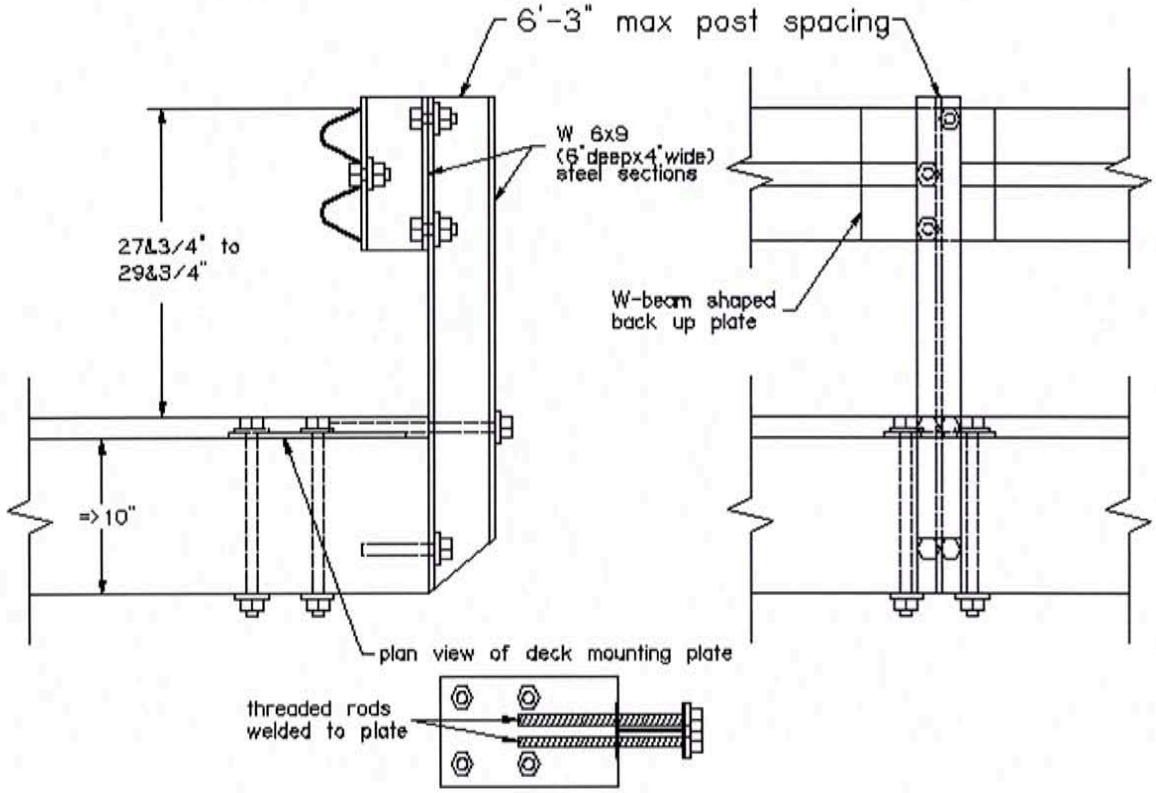
Three Tube Curb Mounted 42" (Oregon Type)
TL-4



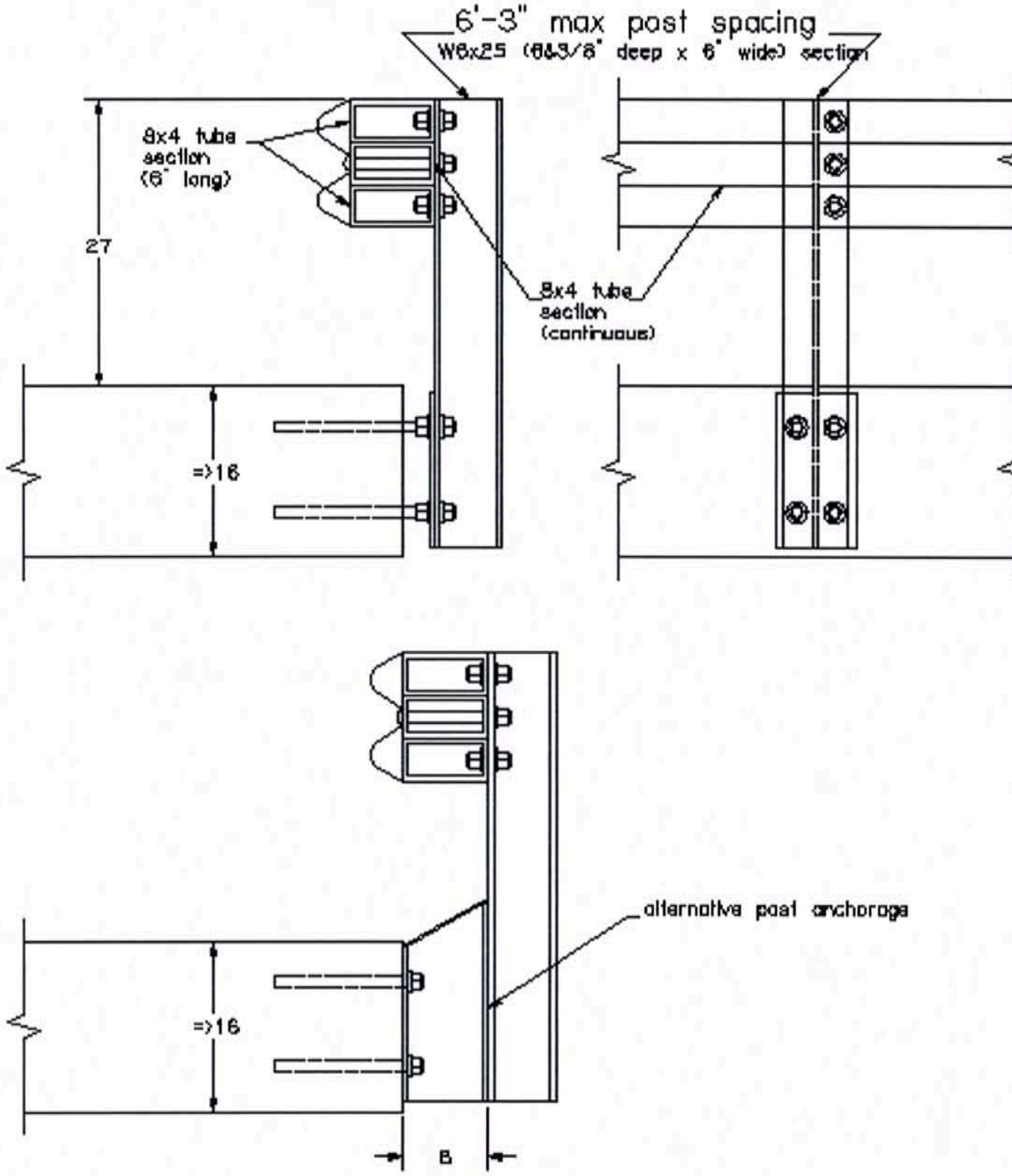
Thrie-Beam Side Mounted 27" (Oregon Type)
TL-2



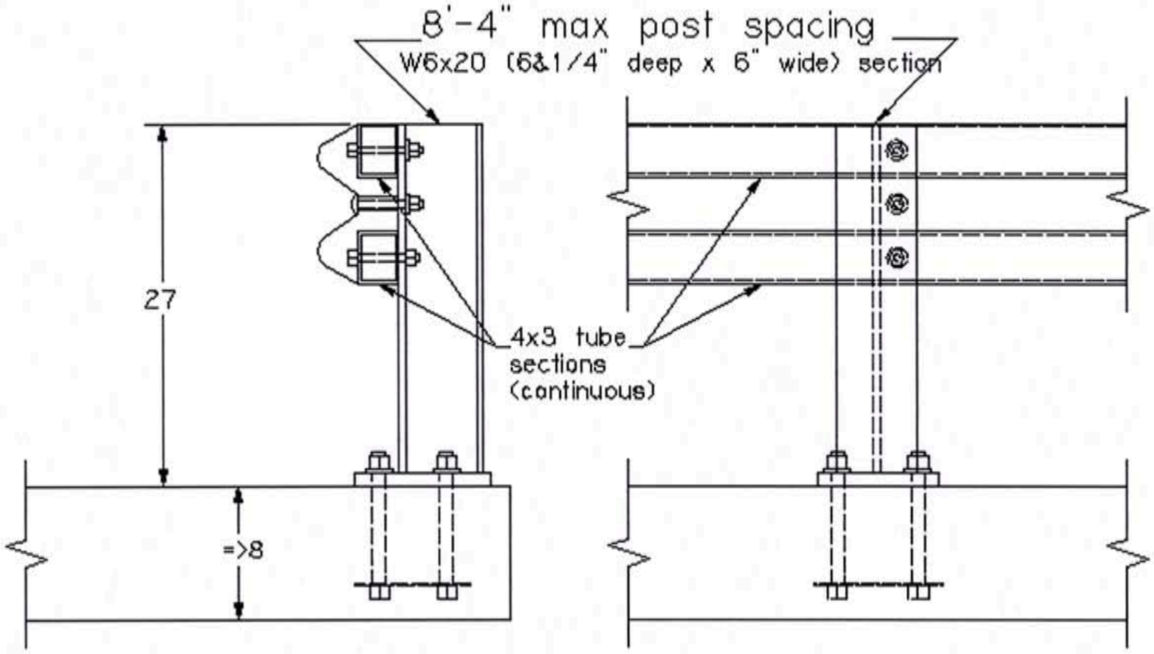
Thrie-Beam Top Mounted 34" (New York Type)
TL-2



W-Beam Top & Side Mounted 28" (University of Nebraska-Lincoln Type)
TL-1

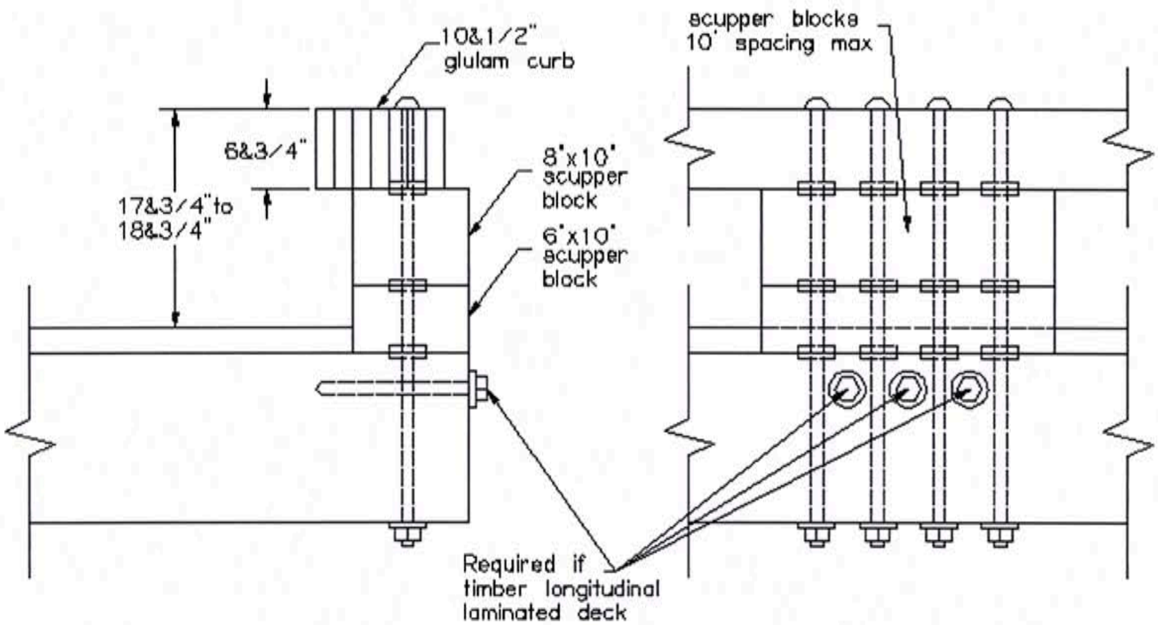


W-Beam Backed with Box Beam Side Mounted 27" (Ohio Type)
TL-2

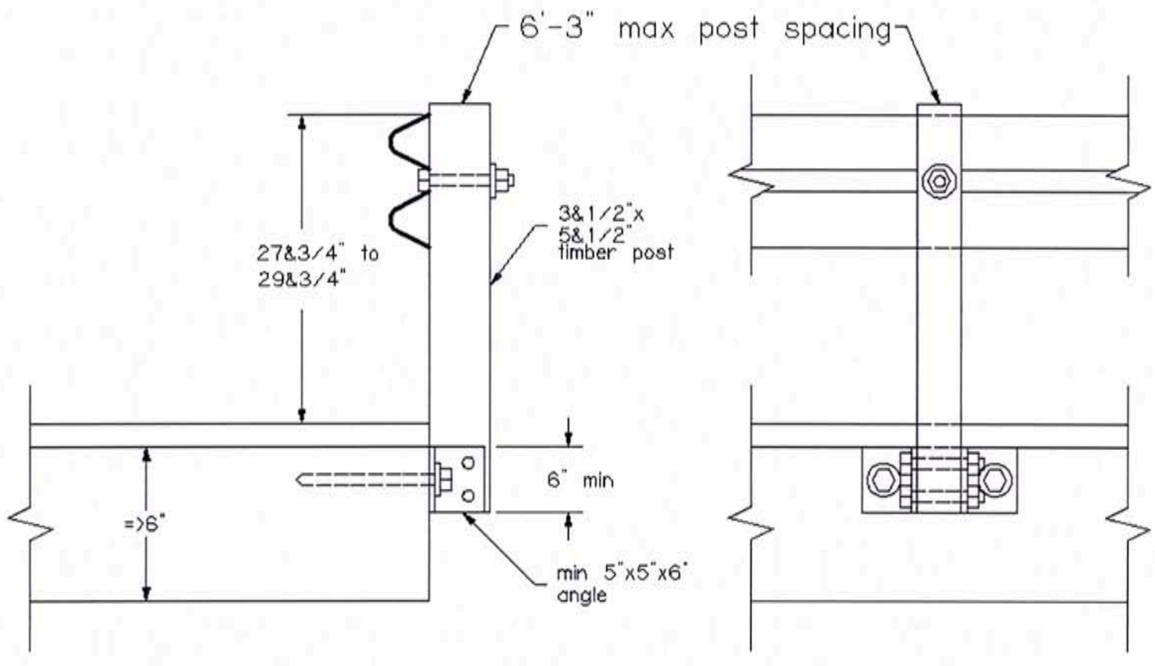


W-Beam Backed with Box Beam Top Mounted 27" (Texas Type T101)
TL-3

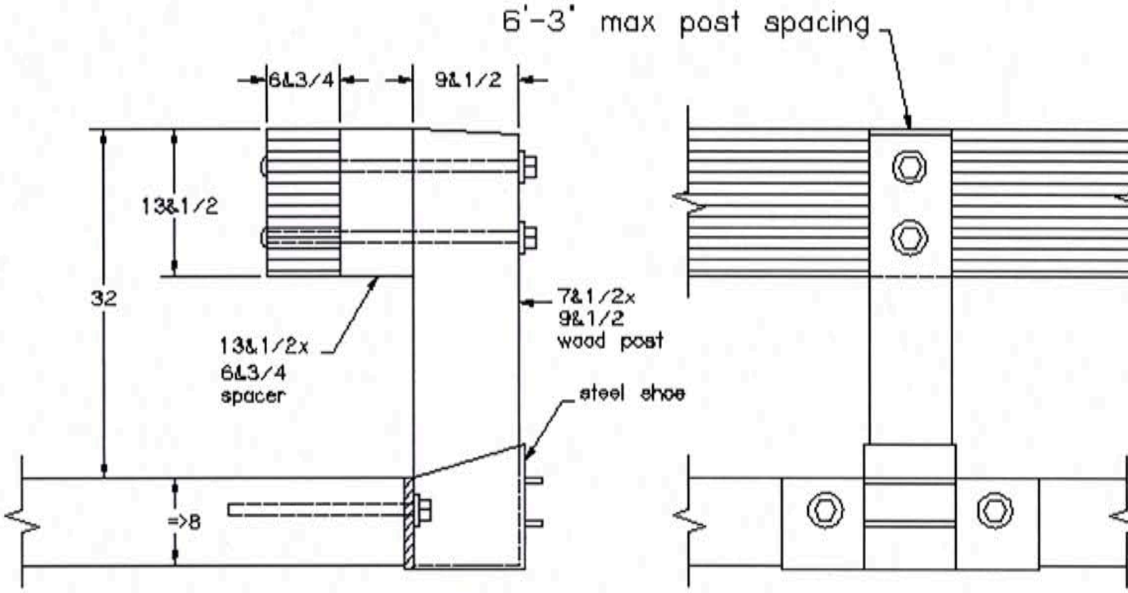
W-BEAM RAILS



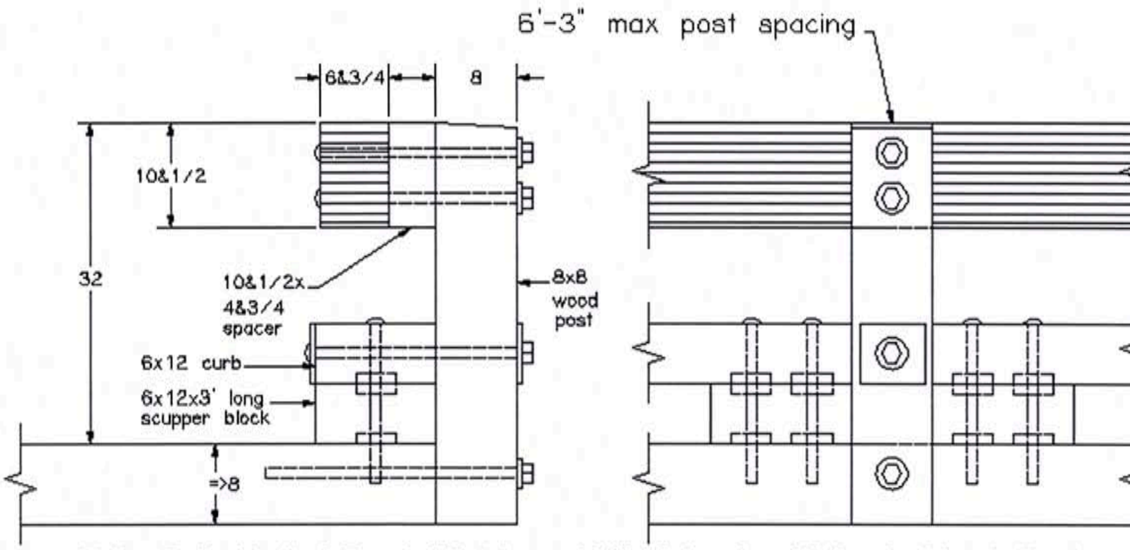
Curb Type Glulam Rail 18"
TL-1



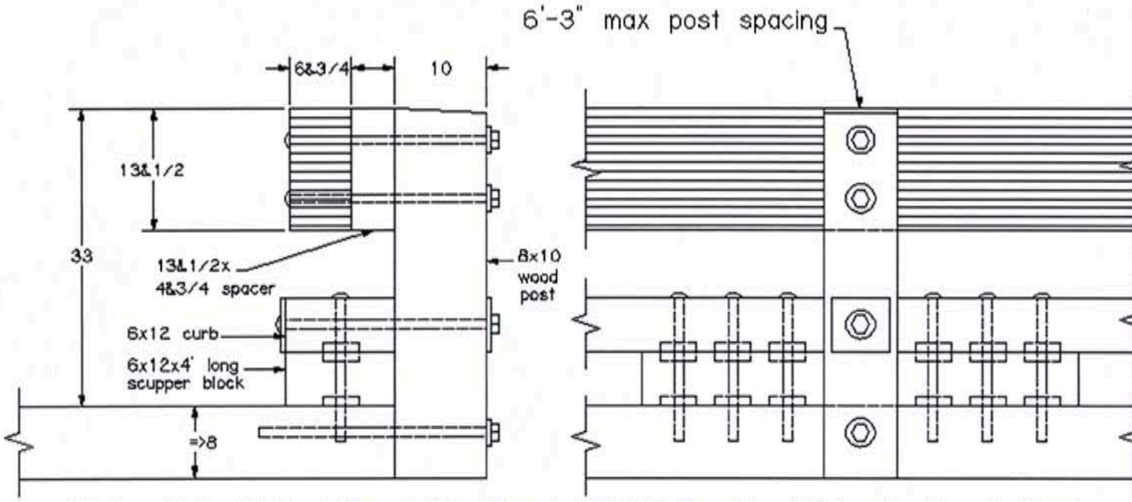
W-Beam with Timber Breakaway Post Side Mounted 28" (University of Nebraska-Lincoln Type)
TL-1



Glulam Rail with Shoe Attachment Side Mounted 32" (University of Nebraska-Lincoln Type)
TL-2



Glulam Rail with Curb Top & Side Mounted 32" (University of Nebraska-Lincoln Type)
TL-2



Glulam Rail with Curb Top & Side Mounted 33" (University of Nebraska-Lincoln Type)
TL-4

iii) Aesthetic Surface Treatments

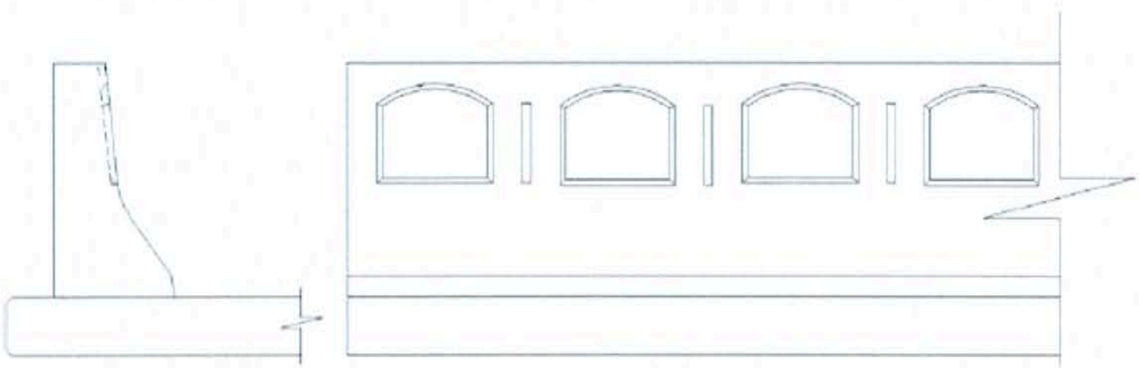
The following criteria are taken from NCHRP Report 554 Aesthetic Concrete Barrier Design.

(a) Jersey and F Safety Shape Rails

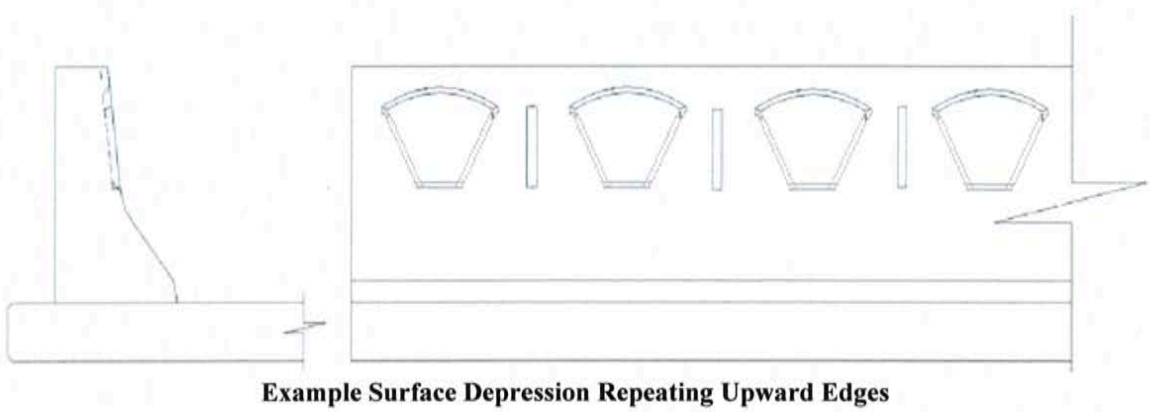
Surface treatments that comply with the following criteria satisfy for all crash test levels (TL-1 through TL-6).

Criteria:

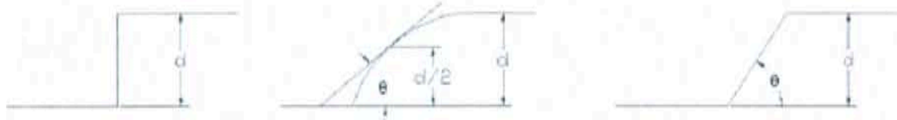
- Only depressions (not relieves) shall be used.
- Depressions shall only be used in the upper flat portion of the rail face (above the break point).
- Depression pattern shall not have repeating upward sloping edges as this can cause vehicle instability and high roll angles on impact that may result in vehicle rollover (see below illustration "Example Surface Depression Repeating Upward Edges").
- The below figures shall be used to determine if the depression depth, edge chamfer angle (90°, 45°or 30°) and pattern width (longitudinal dimension along rail face) meets standard.



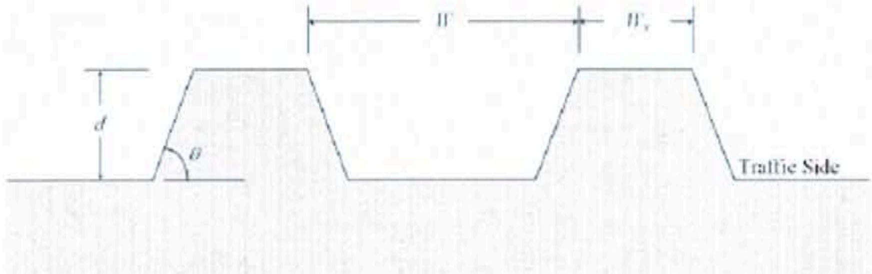
Example Surface Depression Treatment



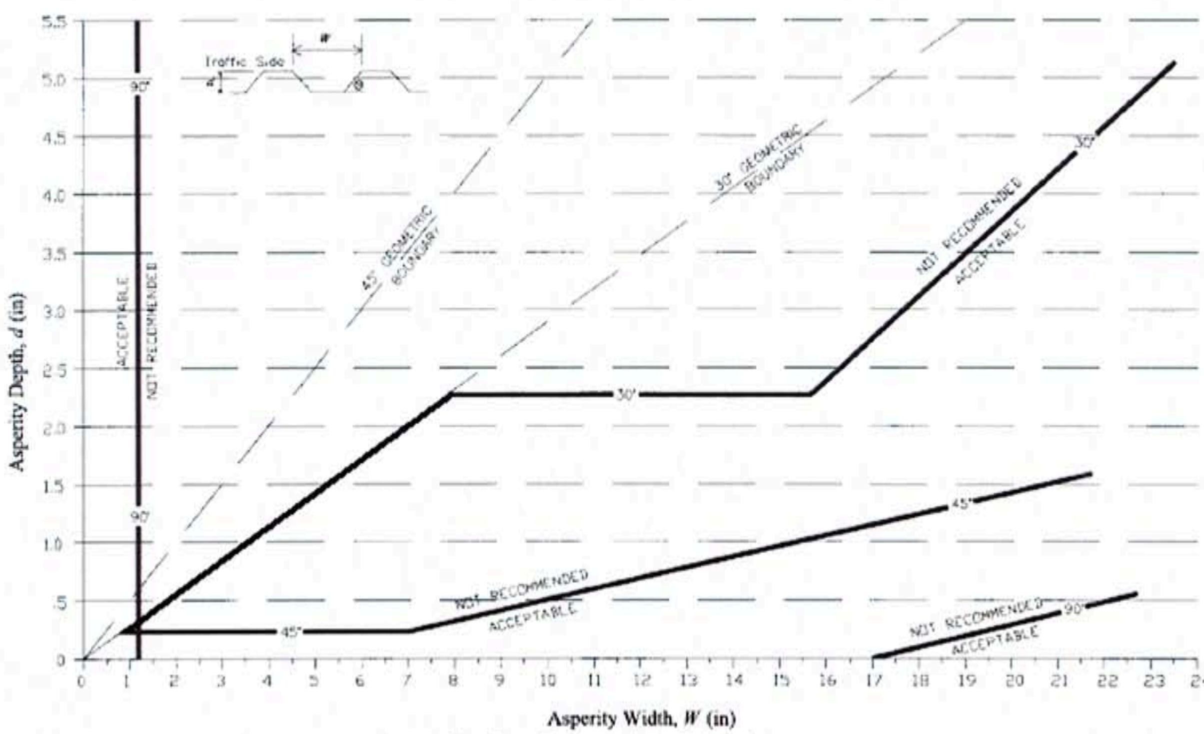
Example Surface Depression Repeating Upward Edges



Types of Depression Chamfer Edges



Surface Depression Variables



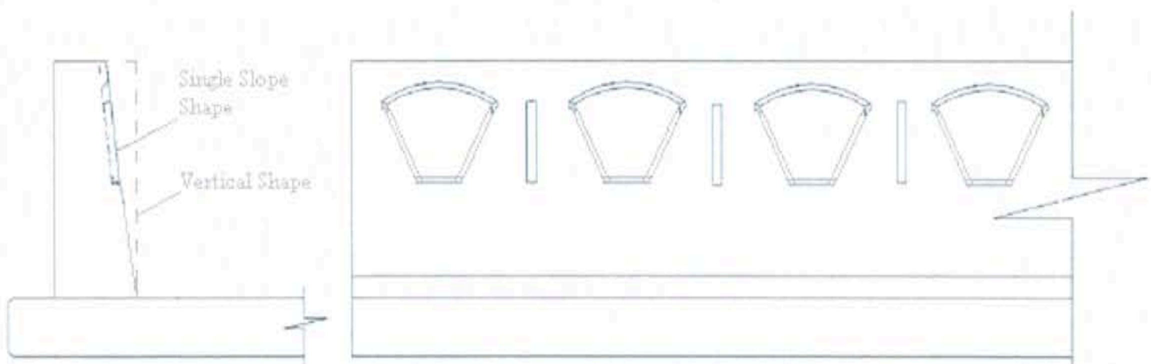
Surface Depression Criteria

(b) Single Slope Safety Shape and Vertical Shape Rails

Surface treatments that comply with the following criteria satisfy for crash test levels TL-1, TL-2 and TL-3.

Criteria:

- Sandblasted and exposed aggregate textures with relieves ≤ 3/8".
- Depression patterns with depths ≤ 1" and chamfer edges 45° or flatter.
- Depression patterns with depths ≤ 1/2", widths ≤ 1" and chamfer edges ≤ 90°.
- Slots, grooves and joints of any depth, width ≤ 3/4", and maximum surface differential of 3/16".
- Patterns with gradual undulations and a maximum relief of 3/4" over 12".
- Patterns with a maximum relief of 2&1/2" if located 24" or higher from the rail bottom and with all chamfer edges rounded or sloped.
- Depression or relief patterns shall not have repeating upward sloping edges as this can cause vehicle instability and high roll angles on impact that may result in vehicle rollover (see below illustration "Example Surface Depression Repeating Upward Edges").



Example Surface Depression Repeating Upward Edges

(c) Masonry Rails

Surface treatments that comply with the following criteria satisfy for crash test levels TL-1, TL-2 and TL-3.

Criteria:

- Stone projections shall be shaped/dressed so are no jagged surfaces or square edges.
- Ends, exposed angles and corners of rail shall have smooth shaped stones.
- No stone shall project more than 1&1/2" from neat line.
- Large projections shall be oriented downstream to prevent vehicle snagging.
- Mortar joint width shall be ≤ 2&1/2".
- Mortar joint depth shall be ≤ 2".

RATING TRANSITIONS

Transitions connect rail of lesser stiffness to rail of greater stiffness. Most transitions consist of;

1. strong rail elements composed of w-beam or thrie-beam nested sections (two rails nested inside each other) strongly anchored to the rigid bridge rail to maintain tension to prevent pocketing and poor redirection
2. reduced post spacing and sometimes stronger posts approaching the rigid rail to maintain tension to prevent pocketing and poor redirection
3. a component such as thrie-beam, rub rail or flared back curb to prevent vehicle snagging on the end of the rigid bridge rail

i) Rating Procedure

1995 Recording and Coding Guide definition

Code item 36B of the Structure Inventory and Appraisal Form.

0	=	does not meet currently acceptable standard
1	=	meets currently acceptable standard
N	=	safety feature not required

Code N shall seldom be used. An example where N may be used is for box and pipe culverts with side slopes and headwalls far from travel lane such that rail is not required.

Collision damage or deterioration of elements is not considered when coding.

When rating approach rail the following should be checked;

Approach versus Trail End: Transitions are required only on the approach ends unless there is two-directional traffic with two lanes or less combined.

Type:

- W-beam nested and rub rail
- Thrie-beam nested
- Other

Height:

- W-beam – 25" min, 30" max, 27" desired
- Thrie-beam – can be higher than maximum allowed for w-beam

Post Spacing: Less than approach rail standard spacing which is typically 6'-3" maxiumum. For travel speeds ≥ 45 mph posts should gradually transition from standard spacing (6'-3") to half spacing (3'-1&1/2") to quarter spacing (1'-6&3/4"). For travel speeds < 45 mph half spacing is adequate.

Post Setback: Timber or plastic offset blocks are required to distance w-beam or thrie-beam from the posts to prevent vehicle snagging on the posts. Steel is not an acceptable offset block.

Post Embedment: 4'-6" nominal embedment required. 5'-6" nominal embedment required in slopes steeper than 4:1 or within 2' from the top of a slope steeper than 4:1. If erosion is affecting the embedment depth it should not enter into the rating, however it should be noted in the inspection report recommendations.

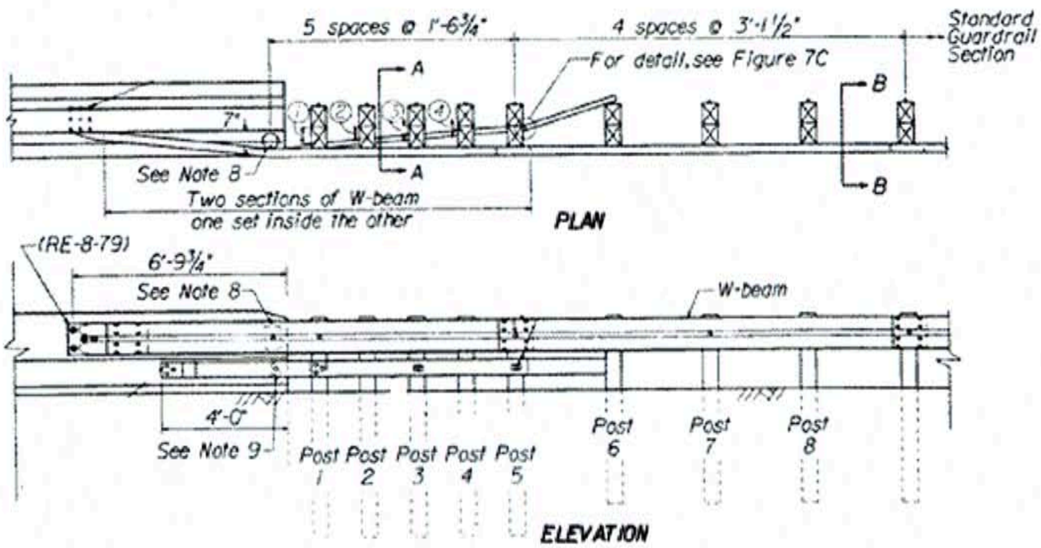
Curb Sections: Ends of bridge curbs should be flared behind transition rail, tapered or made continuous with approach roadway curb.

Horizontal Projection of Bridge Rail: Rigid bridge rail should not have any horizontal projection in front of the transition rail face to prevent vehicle snagging on the end of the rigid bridge rail. Normally the bridge rail safety shape face is gradually tapered to a vertical face.

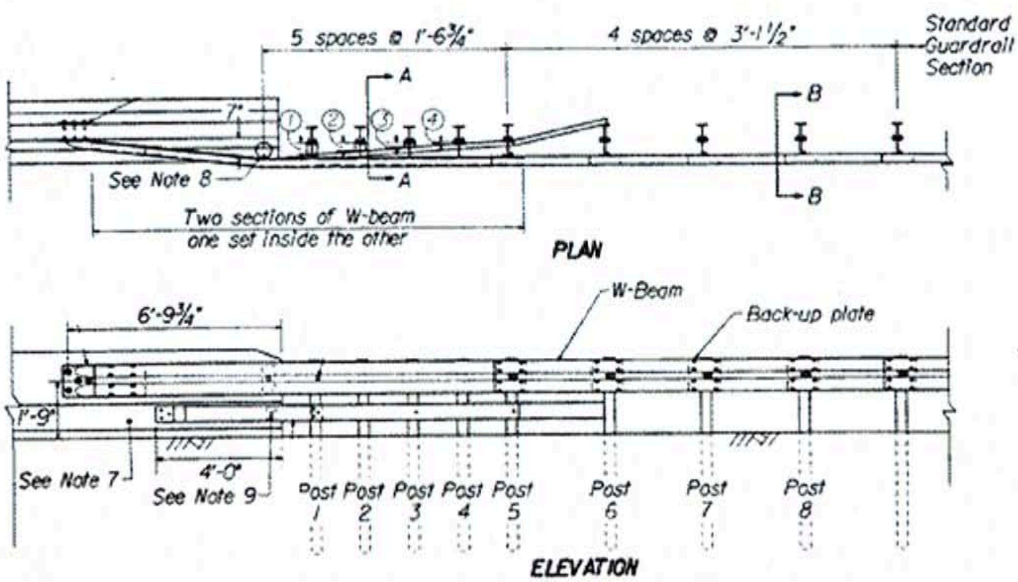
Vertical Projection of Bridge Rail: Top of rigid bridge rail should not be higher than transition rail. When impacted the more flexible transition rail will rotate slightly allowing the vehicle to lean over it. Any vertical projection of the rigid rail will snag the vehicle. Normally the top of rigid rail is gradually tapered down to match the transition height.

ii) Crash Tested Transition Diagrams

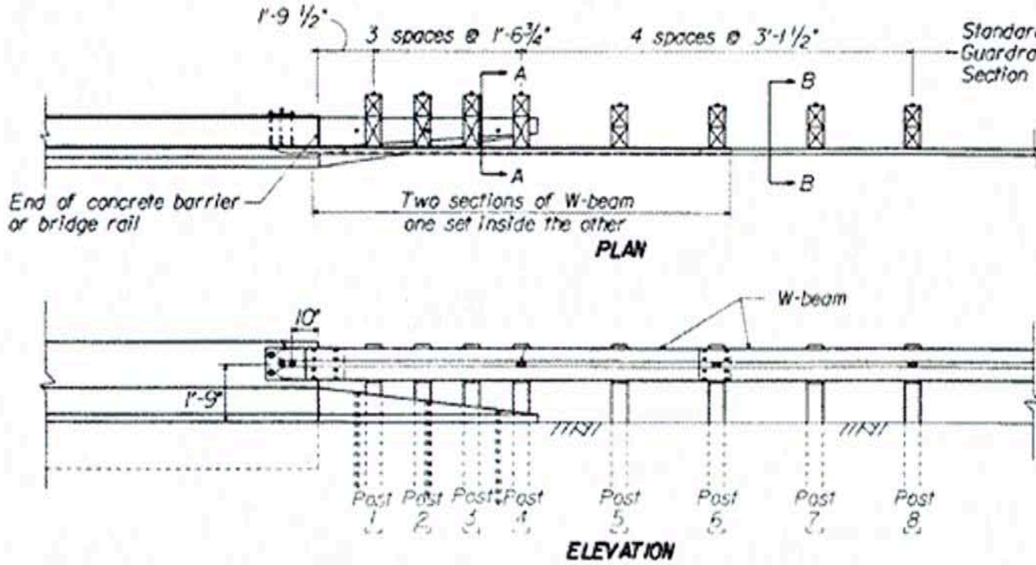
The following diagrams do not include all crash tested transitions. If the in-service transition is not included in the following diagrams evaluate it according to the criteria in part (i).



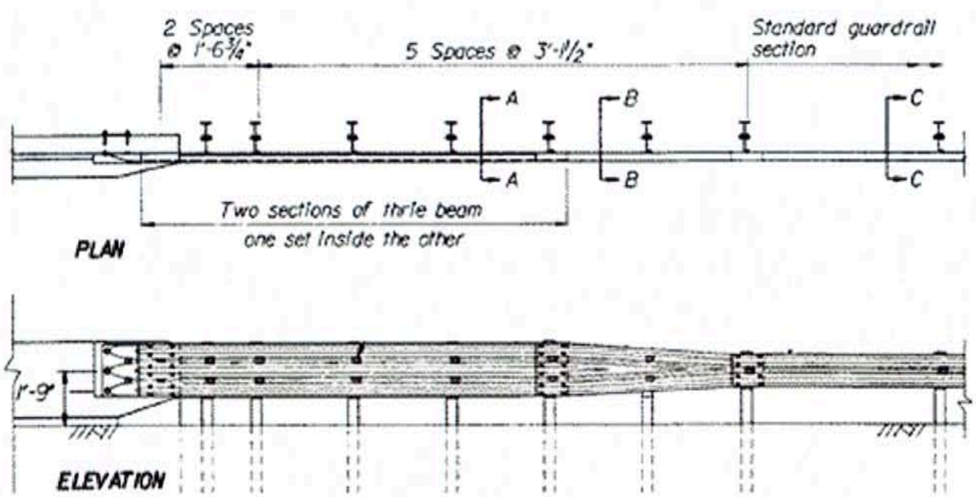
W-Beam Nested and Wood Post with Rub Rail Anchored to Safety Shape



W-Beam Nested and Steel Post with Rub Rail Anchored to Safety Shape



W-Beam Nested and Wood Post Anchored to Flared Back Safety Shape



Thrie-Beam Nested and Steel or Wood Post Anchored to Tapered Safety Shape

RATING APPROACH RAIL

Approach rail/barrier shields vehicles from roadside hazards. Rail may be classified among the three types, flexible, semi-rigid and rigid, based on how much deflection or rotation occurs when impacted. Examples of flexible rail are w-beam and thrie-beam with "weak" posts. Examples of semi-rigid rail are w-beam and thrie-beam with "strong" posts and offset blocks and timber rail that is steel backed. "Strong" posts may be composed of wood or steel. Offset blocks prevent vehicle snagging and climbing and may be composed of timber or plastic blocks – steel I-shapes are not acceptable. Examples of rigid rail are concrete vertical shapes, concrete safety shapes and masonry. Flexible rail is not preferred. W-beam with "strong" posts (semi-rigid system) is the most commonly used.

i) Rating Procedure

1995 Recording and Coding Guide definition

Code item 36C of the Structure Inventory and Appraisal Form.

0	=	does not meet currently acceptable standard
1	=	meets currently acceptable standard
N	=	safety feature not required

Code N shall seldom be used. An example where N may be used is for box and pipe culverts with side slopes and headwalls far from travel lane such that rail is not required.

Collision damage or deterioration of elements is not considered when coding.

When rating approach rail the following should be checked;

Type: Should be semi-rigid or rigid.

- Flexible - w-beam with "weak" posts, thrie-beam with "weak" posts
- Semi-rigid - w-beam with "strong" posts and offset blocks, thrie-beam with "strong" posts and offset blocks, timber rail that is steel backed
- Rigid - concrete vertical shapes, concrete safety shapes, masonry

Height:

- W-beam - 25" min, 30" max, 27" desired
- Thrie-beam - can be higher than maximum allowed for w-beam
- Concrete and masonry vertical faces - 27" min
- Concrete safety shapes - 29" min

Post Spacing: 6'-3" maximum. If a post is missing because of obstructions (drop inlets, storm pipes, etc.) the rail must be stiffened. Up to two posts may be left out if an additional w-beam or thrie-beam rail is nested inside the normal rail. The additional rail must extend to at least the second post on each side of the gap. Stiffening may also be needed when rigid objects (pole, tree, etc.) are located directly behind the rail. Semi-rigid rails have deflections of about 3' when impacted by heavy cars or pickups at 60 mph. For travel speeds ≥ 45 mph, 3' clearance is required. For travel speeds < 45 mph, 2' clearance is required. The rail can be stiffened by decreasing the post spacing or nesting the rail. A single stiffening system will reduce deflection by 1', two systems will reduce deflection by 1'-6" and three systems will reduce deflection by 2'. An example of three systems is half post spacing and three rails nested.

Post Setback: Timber or plastic offset blocks are required to distance w-beam and thrie-beam from the posts to prevent vehicle snagging on the posts. Steel blocking is not acceptable.

Post Embedment: 4'-6" nominal embedment required. 5'-6" nominal embedment required when in slopes steeper than 4:1 or within 2' of the top of a slope steeper than 4:1. If erosion is affecting the embedment depth it should not enter into the rating, however it should be noted in the inspection report recommendations.

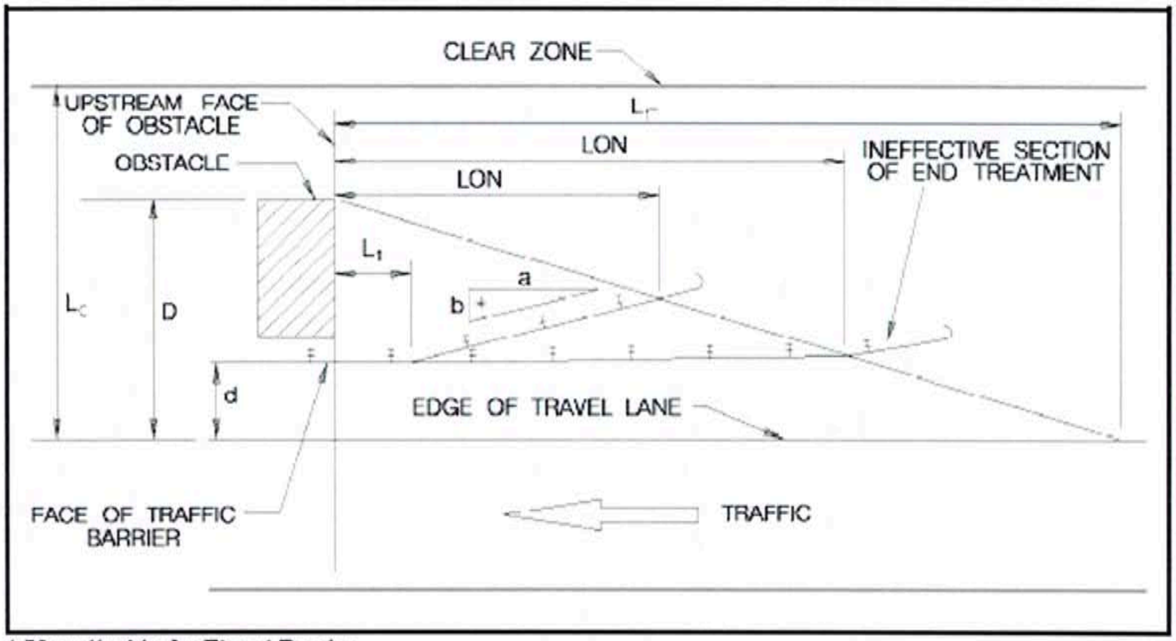
Flare Rate: This is the rate at which a rail is moved away from the roadway. Since rail is crash tested at a specific impact angle, to keep the angle from being more severe than tested, flare rates are limited to the below values.

Maximum Flare Rate		
Travel Speed (mph)	Rigid Rail (concrete)	Semi-Rigid & Flexible Rail (w-beam, thrie-beam, timber)
70	20:1	15:1
60	18:1	14:1
50	14:1	11:1
40	10:1	8:1
30	8:1	7:1

Curb Sections: When curb is used in combination with flexible or semi-rigid rail, if the travel speed is ≥ 35 mph and curb height is > 4" stiffer rail shall be used such as thrie-beam or nested w-beam with rub rail. The face of rail must align with or be in front of the flow line.

Length-of-Need: This is the length of rail needed from the location of the hazard to a required distance upstream. Length is needed in advance of a hazard to develop the full rail strength so a vehicle does not pass through the rail and so vehicles leaving the roadway in advance of the rail which can get behind the rail have adequate distance to stop before the hazard.

The inspector can make a rough determination if the length-of-need does not meet standard by visually checking if it is likely a vehicle can get behind the rail and not come to a stop before reaching the hazard.. For more exact determinations the following guidance can be used.



* If applicable for Flared Barrier.

$$LON = \{L_r * (D - d)\} / D$$

L_r ≡ runout length (refer to below values)
D ≡ distance from edge of travel lane to back of hazard or design clear zone width whichever is less (clear zone values given below)
d ≡ distance from edge of travel lane to face of rail

Runout Length (L_r) in Feet				
Travel Speed (mph)	ADT			
	> 6,000	6,000 – 2,000	2,000 - 800	< 800
70	475	445	395	360
60	425	400	345	330
50	330	300	260	245
40	230	200	180	165
30	165	165	150	130

Travel Speed (mph)	Clear Zone (ft)
≥55	30
54-41	24
≤40	16

RATING END TREATMENTS

End treatments serve two purposes, (1) if hit end-on they minimize injury to vehicle occupants by preventing sudden deceleration and preventing rail/barrier elements from penetrating the occupant compartment and (2) if hit side-on some systems are capable of redirecting a vehicle by developing tension. Systems without sufficient strength (along entire length including the end) to redirect a vehicle are termed breakaway systems. Those with sufficient strength are termed non-breakaway. A breakaway system allows a vehicle to pass through therefore there must be traversable ground behind the treatment and approach rail.

i) Rating Procedure

1995 Recording and Coding Guide definition

Code item 36D of the Structure Inventory and Appraisal Form.

0	=	does not meet currently acceptable standard
1	=	meets currently acceptable standard
N	=	safety feature not required

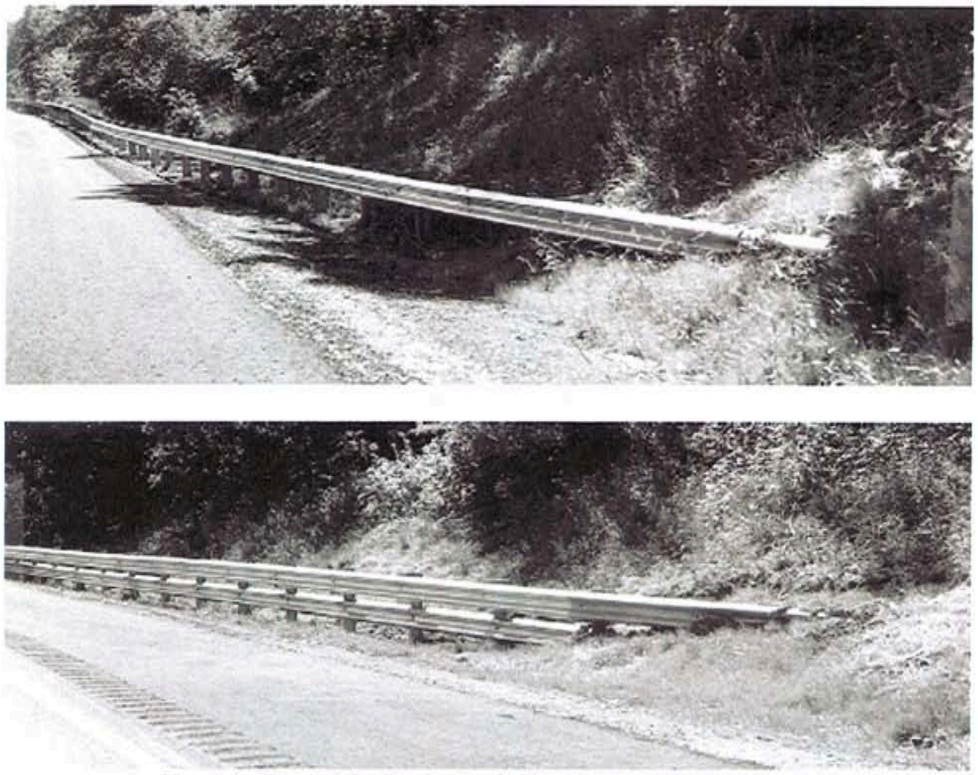
Code N shall seldom be used. Examples where N may be used include;

- When the approach rail is terminated beyond the required clear zone. Clear zone values measured as distance from edge of travel lane may be taken as;
  - -30' for travel speed ≥ 55 mph,
  - -24' for travel speed between 54 and 41 mph
  - -16' for travel speed ≤ 40 mph
- When the length of approach rail exceeds 400' (any additional rail length is normally not required because of the feature that is bridged over).

Collision damage or deterioration of elements is not considered when coding.

The in-service end treatment should be compared to the included diagrams of crash tested treatments. Each diagram includes requirements regarding the features and roadway types for which it meets standard. Length-of-need requirements may be checked according to the criteria given in this manual's section on approach rail. If the in-service treatment closely matches an included diagram and complies with the stated requirements and appropriate roadway types noted on the diagram, it may be rated as meets standard.

ii) Crash Tested End Treatment Diagrams



Type A (Buried-in-Backslope) Single Rail & Double Rail

How Works: For side-on impacts tensile strength developed by end anchor composed of either a post and plate, concrete block or rock bolts.

Requirements: Rail height shall be constant relative to shoulder until exceeds 45" and then can gradually lower. If grading is steeper than 10:1 utilize double rail or when height exceeds 30" utilize rub rail or double rail. The length-of-need must be provided in advance of the toe of back slope if more gradual than 1:1 because vehicles may climb over the back slope and get behind the rail.

MEETS STANDARD: ALL ROADS

Type B (Modified Flared Breakaway)

How Works: For end-on impacts first two posts fracture allowing rail to bend away (if flare not provided rail too stiff to bend). For side-on impacts tensile strength developed by anchored cable.

Requirements: Grading 10:1 or more gradual in front. 6:1 maximum allowed when located 12 feet or more from outside edge of shoulder. Flared 4 feet from front face of approach rail. Eight wooden breakaway posts. Length-of-need must be provided in advance of the third post from the end. Must be traversable behind rail.

MEETS STANDARD: ALL ROADS

Type C (Parallel Breakaway Extruder)

How Works: For end-on impacts end extruder passes over rail flattening it and bending it into a roll. For side-on impacts tensile strength developed by anchored cable.

Requirements: Grading 10:1 or more gradual in front. 6:1 maximum allowed when located 12 feet or more from outside edge of shoulder. Eight wooden breakaway posts. Length-of-need must be provided in advance of the third post from the end. Must be traversable behind rail.

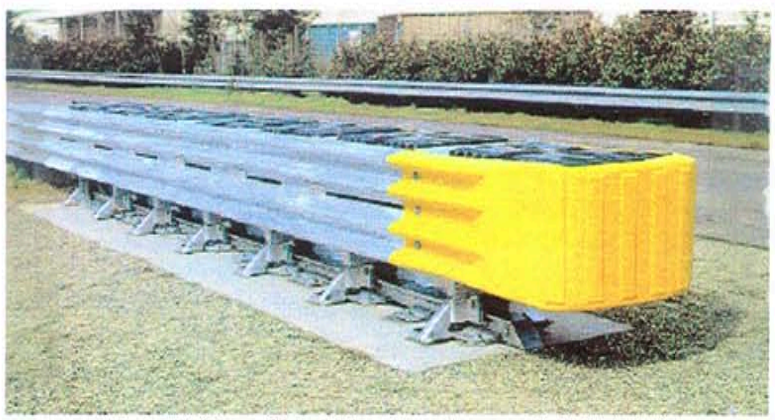
MEETS STANDARD: ALL ROADS

Type D (Two-Sided Breakaway Attenuating)

How Works: For end-on impacts rail telescopes and posts break away. For side-on impacts tensile strength developed by anchored cable.

Requirements: Grading 10:1 or less in front. 6:1 maximum allowed when located 12 feet or more from outside edge of shoulder. Length-of-need must be provided in advance of the fourth post from the end. Must be traversable behind rail.

MEETS STANDARD: ALL ROADS (PARTICULARLY USED AT MEDIANS AND GORES)



Type E (Two-Sided Non-Breakaway G.R.E.A.T.)

How Works: For end-on impacts rail telescopes, foam cartridges compress and posts temporarily collapse. For side-on impacts tensile strength developed by post leg pins and anchored cable.

Requirements: Grading 10:1 or less in front. Length varies between 5'-9" and 32'-9" depending on travel speed. Full length of end treatment can be included in the length-of-need because is non-breakaway.

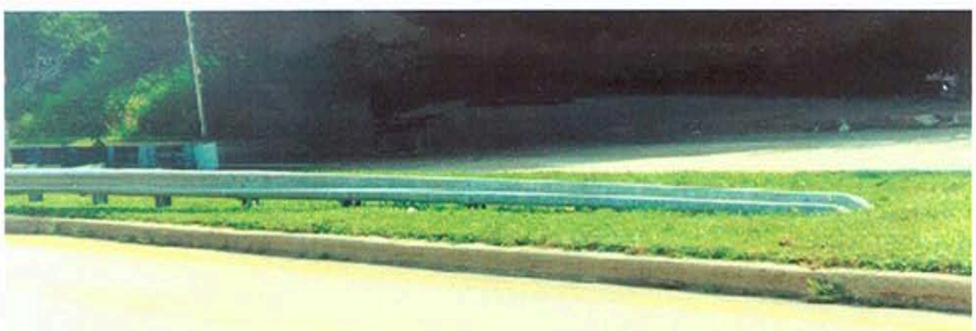
MEETS STANDARD: ALL ROADS (PARTICULARLY USED AT MEDIANS, MEDIAN OPENINGS AND GORES)

Type F (Two-Sided Semi-Breakaway Brakemaster)

How Works: For end-on impacts rail telescopes and friction brake cable assembly dissipates energy. For side-on impacts tensile strength developed by an anchor assembly.

Requirements: Grading 10:1 or less in front. 6:1 maximum allowed when located 12 feet or more from outside edge of shoulder. Length-of-need must be provided in advance of the midpoint of the end treatment.

MEETS STANDARD: ALL ROADS (PARTICULARLY USED AT MEDIANS AND GORES)

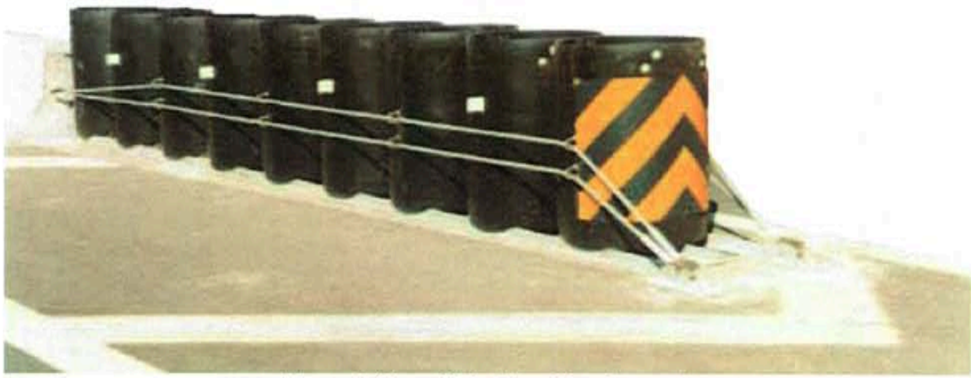


Type G (Turn-Down)

How Works: For end-on impacts vehicle collapses rail and is slowed down as strikes posts.

Requirements: Flared 6 feet from front face of approach rail. Twist from vertical to horizontal occurs within 39' length. Length-of-need must be provided before begins to turn down. Must be traversable behind rail.

MEETS STANDARD: NON-NHS ROADS WITH TRAVEL SPEED < 40 MPH AND < 10,000 ADT



Type J (Two-Side Non-Breakaway)

Requirements: Grading 10:1 or less in front or 8:1 if paved. Number of cylinders vary between 4 and 9 depending on travel speed. Full length of end treatment can be included in the length-of-need because is non-breakaway.

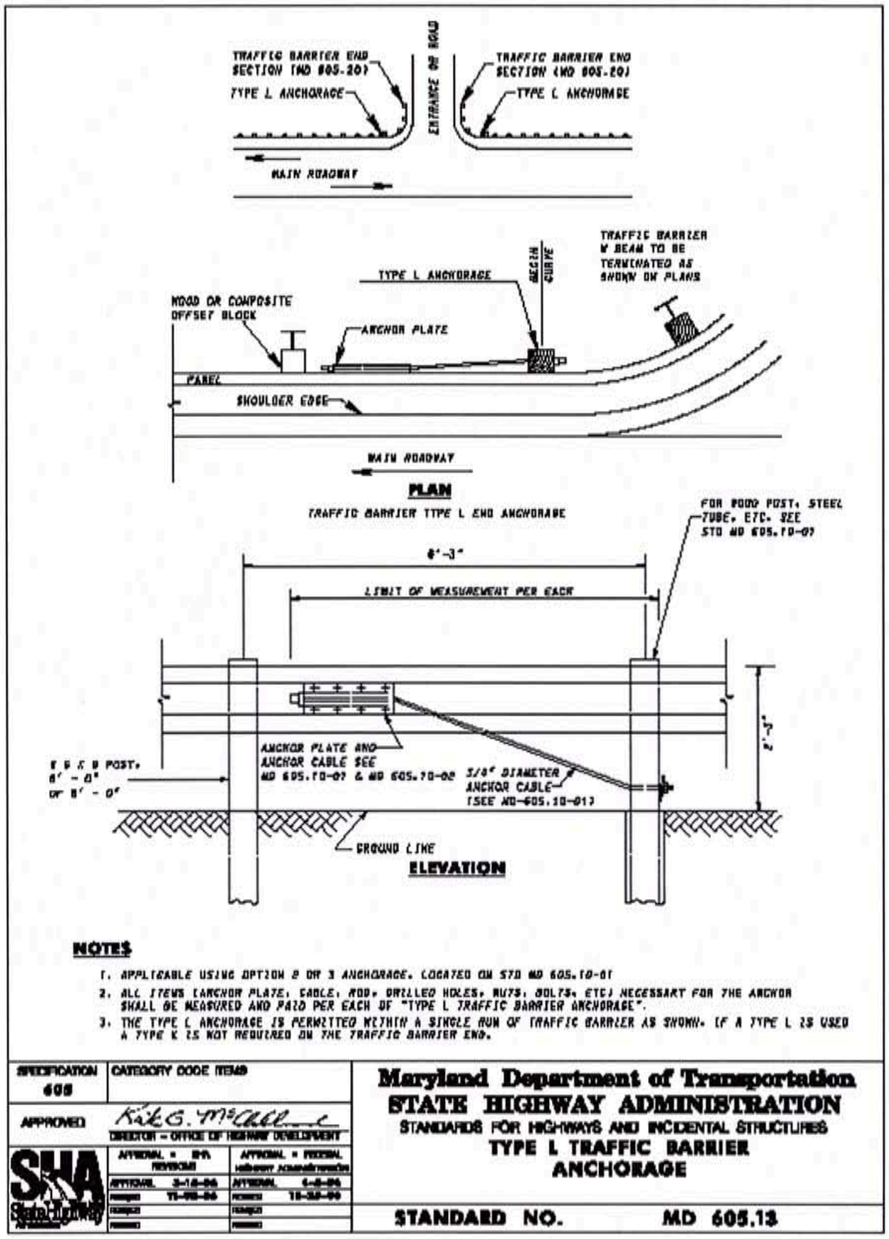
MEETS STANDARD: ALL ROADS (PARTICULARLY USED AT MEDIANS AND GORES)

Type K (Downstream Anchorage)

How Works: Not intended for end-on impacts. For side-on impacts tensile strength developed by anchored cable.

Requirements: Not to be used when opposing traffic within clear zone distance (30' for travel speeds $\geq$ 55 mph, 24' for 54 to 41 mph and 16' for $\leq$ 40 mph) to prevent end-on impacts.

MEETS STANDARD: ALL ROADS DOWNSTREAM END ONLY



Type L (Radius Section Anchorage)

How Works: Improves rail strength at radius section of access breaks. Develops tension immediately down stream of the cable attachment.

Requirements: Rail should be utilized on main road on both sides of access break to minimize opportunity for perpendicular impacts on radius section. When this anchorage is used at radius sections and the rail is terminated at the end of the radius, a Type K end treatment is not required at the very end. When opposing traffic is within 16’ (clear zone value for travel speeds < 40 mph) a Type L should be provided on both radius sections. Length-of-need must be provided in advance of the anchored cable.

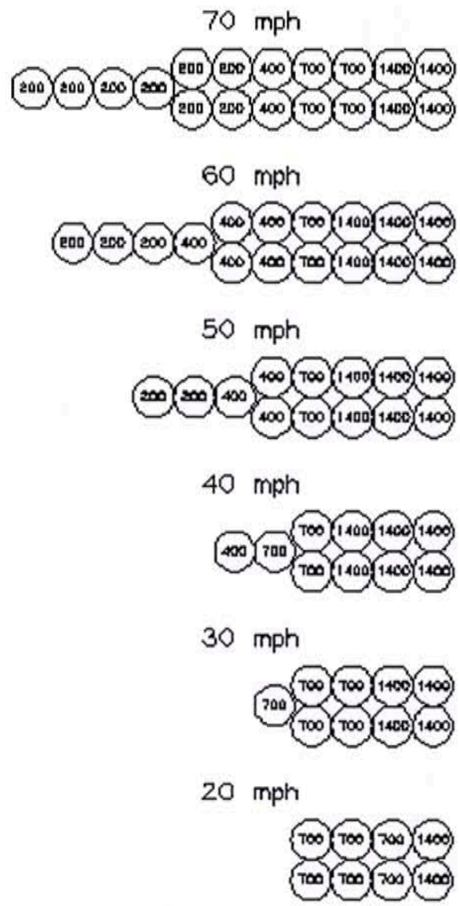
MEETS STANDARD: ALL ROADS WITH TRAVEL SPEEDS < 40 MPH

SAND BARREL CRASH CUSHIONS

Typical Configurations

(minor variations acceptable)

Barrel standard sizes are 200, 400, 700, 1,400 and 2,100 lbs however 2,100 seldom used. Combination barrels may be substituted for single barrels if have equal combined weight, for instance one 1,440 lb barrel may be substituted for two 700 lb barrels.



How Works: For end-on impacts transfers momentum to sand. No side-on impact redirection capability.

Requirements: Must be traversable on both sides of cushions. No side-on impact redirection capability. When opposing traffic is within the required clear zone distance (30' for travel speeds ≥ 55 mph, 24' for 54 to 41 mph and 16' for ≤ 40 mph) the rearmost "heavy" cushions shall not be exposed such that an end-on impact can occur.

MEETS STANDARD: ALL ROADS (PARTICULARLY USED AT MEDIANS AND GORES)

DETERMINING IF ADEQUATE CLEAR ZONE EXISTS

There are bridges that currently do not have any type of traffic safety feature present. The majority of these structures are located on backroads and see a relatively small amount of vehicular traffic. It is important for the inspection team to evaluate whether or not traffic safety features are required at such a location during the inspection. In order to determine this, the amount of clear zone present needs to be measured and compared to the chart below. In addition, the NBI Items #36A-D shall be coded according to the procedure below.

i) Rating Procedure

1995 Recording and Coding Guide definition

Code item 36A, B, C & D of the Structure Inventory and Appraisal Form.

0	=	approved traffic safety features do not exist, but are needed
N	=	traffic safety feature not required

ii) Clear Zone Chart

Roadside Design Guide

TABLE 3.1 (Cont'd)

[U.S. Customary Units]

DESIGN SPEED	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 mph or less	UNDER 750	7 – 10	7 – 10	**	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 mph	UNDER 750	10 – 12	12 – 14	**	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 mph	UNDER 750	12 – 14	14 – 18	**	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 *	**	16 – 18	20 – 22	22 – 24
60 mph	UNDER 750	16 – 18	20 – 24	**	10 – 12	12 – 14	14 – 16
	750 – 1500	20 – 24	26 – 32 *	**	12 – 14	16 – 18	20 – 22
	1500 – 6000	26 – 30	32 – 40 *	**	14 – 18	18 – 22	24 – 26
	OVER 6000	30 – 32 *	36 – 44 *	**	20 – 22	24 – 26	26 – 28
65–70 mph	UNDER 750	18 – 20	20 – 26	**	10 – 12	14 – 16	14 – 16
	750 – 1500	24 – 26	28 – 36 *	**	12 – 16	18 – 20	20 – 22
	1500 – 6000	28 – 32 *	34 – 42 *	**	16 – 20	22 – 24	26 – 28
	OVER 6000	30 – 34 *	38 – 46 *	**	22 – 24	26 – 30	28 – 30

* Where a site specific investigation indicates a high probability of continuing crashes, or such occurrences are indicated by cras history, the designer may provide clear-zone distances greater than the clear-zone shown in Table 3.1. Clear zones may be limited t 30 ft for practicality and to provide a consistent roadway template if previous experience with similar projects or designs indicate satisfactory performance.

** Since recovery is less likely on the unshielded, traversable 1V:3H slopes, fixed objects should not be present in the vicinity of the to of these slopes. Recovery of high-speed vehicles that encroach beyond the edge of the shoulder may be expected to occur beyond th toe of slope. Determination of the width of the recovery area at the toe of slope should take into consideration right-of-wa availability, environmental concerns, economic factors, safety needs, and crash histories. Also, the distance between the edge of th through traveled lane and the beginning of the 1V:3H slope should influence the recovery area provided at the toe of slope. While th application may be limited by several factors, the foreslope parameters which may enter into determining a maximum desirabl recovery area are illustrated in Figure 3.2.